Economic Commission for Europe
Statistical Division

CONFERENCE OF EUROPEAN STATISTICIANS

READINGS IN INTERNATIONAL ENVIRONMENT STATISTICS

UNITED NATIONS

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READINGS IN INTERNATIONAL ENVIRONMENT STATISTICS

- ECE Standard Statistical Classifications and definitions of terms
- Selected national practices in estimations of air and water emissions
- Materials balance sheets
- Bibliography of methodological papers

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PART ONE:
ECE STANDARD STATISTICAL CLASSIFICATIONS FOR THE ENVIRONMENT

CHAPTER ONE

ECE STANDARD STATISTICAL CLASSIFICATION OF LAND USE
(1989)

CONTENTS

A. INTRODUCTION

Purpose, scope and coverage of the classification

Land information is needed at three levels. At the local level, it is required for the purposes of physical planning and land management. At the national level, the emphasis lies on needs for overall resource policy and management, including the planning of future use of land, and on information requirements of environmental protection activities. At the international level, land information is used for comparative descriptions and analyses of national patterns.

This classification provides a structure into which available national information can be cast to arrive at internationally comparable data. . . In addition, account is taken of the special national characteristics and purposes within which nationally -available information is generated, as well as of possible other roles a land use classification is likely to play.

Four broad substantive concerns require land information, each creating specific needs. The first is the description of existing land-use patterns. It calls for land information in terms of land cover. The second area comprises questions linked to broad demand for land in terms of human activities. Such concerns stipulate the existence of information on the use of land, and its changes over time, in terms of a breakdown by type of human activity. The third area relates to the environmental repercussions of land use. While information on land cover can be used as a starting point in this context, the assessment of environmental impact, for example, necessitates the incorporation of ecological aspects into the classification. The fourth area focuses on the planning for future land use. This implies the need for information on potential or alternative uses of land which can partly be met through capability assessments.

The four areas of concern are not mutually exclusive; their information needs overlap to some extent. Aspects of land cover, while being the easiest to collect statistical information on, are often interwoven to a considerable degree with activity aspects. The ECE Standard Statistical Classification of Land Use is a mixed classification of land cover and activity categories. The classification is dominated by physical characteristics at the one-digit level. In selecting this approach, emphasis was put on practical aspects of actual production of land use statistics. Accordingly, previous versions of this classification were tested wholly or partly (with the help of the Joint FAO/ECE Working Party on Forest Economics and Statistics and of the OECD) before further development was undertaken.

The classification focuses on inventory data of land use. Statistical information on land use changes may be of equal or even greater interest to users of land information. The conceptual development of internationally comparable statistics on land use changes is undertaken by the Conference of European Statisticians in the framework of the development of a set of ECE Environmental Indicators. Statistics of land use changes could be derived from adequate inventory data, but could also be available from other sources.

This classification does not provide for information that would be directly relevant for the consideration of the degree of reversibility of land use changes. Likewise, it does not provide support to investigations into the intensity of “sealing” of land, which is of particular interest in relation to the environmental aspects of human settlements. Exploration of the possibility of developing statistics covering these two areas is left to future work.

Relationship to data collection and processing techniques

Pronounced relationships exist between classifications and particular data collection techniques. For example, the use of remote sensing techniques discloses land information in terms of land cover, while functional chatacteristics can only rarely be recorded by this technique. Thus the classification is not entirely and exclusively tailored towards the capabilities of remote sensing. Modem data processing techniques in most cases, however, permit the linkage and cross-classification of data obtained through various techniques. This is particularly true for data from geographic information systems. Systematic geocoding enhances possibilities for cross-classification.

Conventions

The classification is considered basic at the one- and two-digit levels. The three-digit level is optional.

The concept used in recording agricultural land should be the “gross area” concept as developed by FAO, subject to the adaptations required by the conventions below.

For purposes of actual classification of land, a lower size limit of 0.5 hectare is applied in the categories of the draft classification. Countries for which the application of this minimum size is impossible are invited to indicate their national practices in appropriate footnotes.

This classification should cover the total territory of a country. The sum of the classes 1 to 6 forms the “total land area”. This concept should be used as a basis for other calculations such as density of population, etc.

B. CATEGORIES OF THE CLASSIFICATION

1. *Agricultural land*

   1.1 Arable land

   1.2 Land under permanent crops

   1.3 **Land** under permanent meadows and pastures

   1.4 Other agricultural land, n.e.s. (not elsewhere specified)

   1.5 Total agricultural land
   <u>of which</u>: Fallow agricultural land

2. *Forest and other wooded land*

   2.1 Total land under forest and other wooded land
   <u>of which</u>: - Stands of exotic species
   - Particularly fire-prone stands

      2.1.1 With wood production the recognized major function
      2.1.2 With protection, conservation, and biological use the recognized major functions
      2.1.3 With recreation the recognized major function

   2.2 Land under coniferous forest

      2.2.1 (same as 2.1.1)
      2.2.2 (same as 2.1.2)
      2.2.3 (same as 2.1.3)

   2.3 Land under non-coniferous forest

      2.3.1 (same as 2.1.1)
      2.3.2 (same as 2.1.2)
      2.3.3 (same as 2.1.3)

   2.4 Land under mixed forest

      2.4.1 (same as 2.1.1)
      2.4.2 (same as 2.1.2)
      2.4.3 (same as 2.1.3)

   2.5 Other wooded land

      2.5.1 (same as 2.1.1)
      2.5.2 (same as 2.1.2)
      2.5.3 (same as 2.1.3)

3. *Built-up and related land (excl. scattered farm buildings)*

- 3.1 Residential Land
  - 3.1.1 With mainly one- or two-storey buildings
  - 3.1.2 With mainly three- and more- storey buildings

- 3.2 Industrial land (excl. land classified under 3.3 below)

- 3.3 Land used for quarries, pits, mines and related facilities
  - 3.3.1 For peat cutting
  - 3.3.2 For other open-cast mining and quarrying
  - 3.3.3. Other, n.e.s.

- 3.4 Commercial land

- 3.5 Land used for public services (excluding transport, communication, and technical infrastructure)

- 3.6 Land of mixed use

- 3.7 Land used for transport and communication
  - 3.7.1 Land under roads
  - 3.7.2 Land under railways
  - 3.7.3 Land under airports and related facilities
  - 3.7.4 Other land used for transport and communication, n.e.s.

- 3.8 Land used for technical infrastructure
  - 3.8.1 Land used for the disposal of wastes
  - 3.8.2 Land used for water supply and waste-water treatment
  - 3.8.3 **Land** used for electricity generation and distribution
  - 3.8.4 Other land used for technical infrastructure, n.e.s.

- 3.9 Recreational and other open land
  - 3.9.1 Parks, green areas, hobby gardens, cemeteries, etc.
  - 3.9.2 Recreational land mainly occupied by camping sites, secondary residences, or vacation houses
  - 3.9.3 Land under current construction
  - 3.9.4 Land intended for future construction
  - 3.9.5 Other, n.e.s.

4. *Wet open land*

- 4.1 Mires
  - 4.1.1 Ombrogenous mires (upland moors)
  - 4.1.2 Soligenous mires (lowland bogs)

- 4.2 Wet tundra
- 4.3 Other wet open land, n.e.s.

5. *Dry open land with special vegetation cover*
   - 5.1 Heathland
   - 5.2 Dry tundra
   - 5.3 Mountainous grassland
     - 5.3.1. Used for grazing of domestic animals
     - 5.3.2. Not used for grazing of domestic animals
   - 5.4 Other n.e.s.

6. *Open Land without, or with insignificant, vegetation cover*
   - 6.1 Bare rocks, glaciers, perpetual snow
     - 6.1.1 Bare rocks
     - 6.1.2 Glaciers and perpetual snow
   - 6.2 Sand-beaches, dunes, other sandy land
   - 6.3 Other, n.e.s.

7. *Waters*
   - 7.1 Inland waters
     <u>of which:</u> in harbour areas
     - 7.1.1 Natural watercourses
     - 7.1.2 Artificial watercourses
     - 7.1.3 Inland sea (freshwater or saline), lakes, ponds, coastal land-locked bodies of water
     - 7.1.4 Artificial water impoundments
     - 7.1.5 Other inland waters, n.e.s.
   - 7.2 Tidal waters
     <u>of which:</u> in harbour areas
     - 7.2.1 Coastal lagoons
     - 7.2.2 Estuaries
     - 7.2.3 Other tidal waters, n.e.s.

CHAPTER TWO

ECE STANDARD STATISTICAL CLASSIFICATION OF WATER USE
(1989)

CONTENTS

A. INTRODUCTION

Purpose, scope and coverage of the classification

Water management aims at an optimal water economy within recognized ecological functions of water. Among the bases for water management are quantitative data about aspects of the water cycle. Such aspects relate to both water quantities and water quality. The present classification covers water use only and provides a framework for the systematic compilation and presentation of data on offstream water uses. It is part of the ECE standard environmental statistical classifications being developed by the Conference of European Statisticians. Thus, the classification only covers a fraction of the statistical information needs of water authorities. Another section dealing with the assessment of water quality is the subject of the ECE Standard Statistical Classification of Water Quality.

The classification considered here serves three main purposes. First, it is intended to provide assistance to national statistical offices developing national systems of water use statistics. Second, it provides concepts and definitions for use in international statistical surveys of water use. Third, it contributes to the standardization of terms used in water use statistics at the international level.

It is recognized that these purposes cover but a small fraction of the data requirements for water resource studies or water demand management. A comprehensive data system that would satisfy such information needs would have to be complemented with economic parameters, including information on end-uses and on costs. Any fully fledged development of such a comprehensive system should therefore ensure that the water use data be linked as necessary to economic variables of interest. The inclusion of appropriate linkages to the system of national accounts and balances already in place can replace the need for including economic variables in the system of water use statistics.

In any national development of a water use statistical system, due attention should also be paid to the seasonal patterns of water use. Adequate provisions should be made for access to timely data by all national, regional, and local water-management authorities.

It should be noted that the classification is descriptive in nature, as opposed to normative. In particular, no harmonization of environmental protection standards is attempted.

Use of the classification in international surveys

International surveys of water use should relate to annual data for countries as a whole or for the most important regional river basins. It is recommended that the following criteria be used in selecting such river basins:

(a) The area of the river basin is at least 30,000 km^2; or

(b) at least three countries share in the area.

Detailed arrangements on these matters should be made by the participants in such surveys and should be spelled out in the related publications. Respondents to questionnaires used **in international** surveys should submit, together with the data they supply, information on the methods used in the measurement and compilation of such data, because an adequate interpretation of water use data can often only be made if sufficient methodological information is available.

The data requirements implied by the classification may lead in individual countries to estimation. This is particularly true for the variables in Section 1. In such cases, it is recommended that respondents make information available on the estimation method used.

Further work on related issues

It would be useful to complement this classification with standard recommendations covering related data requirements derived from water resource studies and water demand management. Such work should aim at a full coverage of data needs of water management authorities.

The development of a format for water balances could be a useful step in this direction. Furthermore, statistical development work is required on in-stream uses of water. The development of variables suitable for linking water statistics with other statistics, and of indicators capable of serving as a basis for estimating water use data unobtainable through direct reporting can be mentioned as possibilities for future work.

Finally, some conceptual solutions embodied in this classification require refinement through further consideration once some practical experience is obtained in their application. The statistical coverage of sludge from waste-water treatment in this classification and in that of wastes, and the applicability of the concept of losses of waste-water during transport, are the most prominent cases in point.

B. CATEGORIES OF THE CLASSIFICATION

1. Water resources [Unit: 10^6 or 10^9 m^3/year; per cent where stated]

1.1 Inflow of surface water
  1.1.1. Long-term annual average
  1.1.2 Current year
1.2 Outflow of surface water
  1.2.1 Long-term annual average
  1.2.2 Current year

1.3 Precipitation
    1.3.1 Long-term annual average
    1.3.2 Current year
1.4 Evaporation
    1.4.1 Long-term annual average
    1.4.2 Current year
1.5 Annual change in groundwater resources [volume or per cent]
1.6 Groundwater available for annual abstraction

2. <u>Water abstraction</u> [10^3, 10^6 or 10^9 m^3/year]

2.1 Abstraction from surface water resources
2.2 Abstraction from groundwater resources
2.3 Abstraction from other water resources
2.4 Total abstraction by type of activity (2.1 + 2.2 + 2.3)
2.5 Returned water by type of activity
2.6 Net total abstraction by type of activity (2.4 - 2.5)
<u>of which</u>: Treated prior to first use

The following classification by type of activity (ISIC/Rev.3) is recommended:

(1) Domestic sector
(2) Collection, purification, and distribution of water (ISIC 41)
(3) Agriculture, forestry, hunting, fishing, and related service activities (ISIC 01 to 05)
(4) Mining and quarrying (ISIC 10-14)
(5) Manufacturing (ISIC 15-37)
(6) Production, collection, and distribution of electricity (ISIC 401)
(7) Construction (ISIC 45)
(8) Other activities

3. <u>Water supply</u> [10^3, 10^6 or 10^9 m^3/year]

3.1 Public supply by type of activity
3.2 Self supply by type of activity
3.3 Other supply by type of activity
3.4 Total supply by type of activity
3.5 Losses during transport

The following breakdown by type of activity (ISIC/Rev.3) is recommended:

(1) Domestic sector
(2) Agriculture, forestry, hunting, fishing, and related service activities (ISIC 01 to 05)
(3) Mining of coal and lignite; extraction of peat (ISIC 10)
(4) Other mining and quarrying (ISIC 11 to 14)

Sub-total: Total mining etc. (ISIC 10-14)

(5) Manufacture of basic metals (ISIC 27)
(6) Manufacture of transport equipment (ISIC 35)

(7) Manufacture of textiles, wearing apparel; dressing and dying of fur; tanning and dressing of leather; manufacture of luggage, handbags, saddler-y, harnesses and footwear (ISIC 17-19)
(8) Manufacture of paper and paper products (ISIC 21)
(9) Manufacture of chemicals and chemical products (ISIC 24)
(10) **Manufacture** of coke, refmed petroleum products, and nuclear fuel **(ISIC 23)**
(11) Other manufacturing

Sub-total: Total manufacturing (ISIC 15-37)

(12) Production, collection, and distribution of electricity (ISIC 401)
(13) Other industrial activities

Sub-total: All industrial activities

(14) Other activities

4. Agricultural and industrial use of water [10^3 or 10^6 m^3/year]

4.1 Agricultural and similar use of water
    4.1.1 Spray irrigation
    4.1.2 Flood irrigation
    4.1.3 Offstream fish farming
    4.1.3 Other agricultural or similar use

4.2 Industrial use of water
    4.2.1 Cooling in electricity generation
    4.2.2 Cooling, except in electricity generation
    4.2.3 Consumptive use of water
    4.2.4 Other industrial use
    4.2.5 Recycled water

Categories 4.2.1 to 4.2.5 should be broken down by type of industrial activity. It is recommended to use activities (3) to (13) as appropriate -- of the list of activities specified under section 3 above for this purpose -- including the related sub-totals.

5. Waste-water [10^3, 10^6 or 10^9 m^3/year]

5.1 Collection of waste-water through public sewerage
of which: from industry

5.2 Generation of waste-water in industry by type of activity

5.3 Waste-water treatment
    5.3.1 In public treatment plants
        5.3.1.1 mechanical treatment technology
        5.3.1.2 biological treatment technology
        5.3.1.3 advanced treatment technology

5.3.2 In industrial treatment plants
    5.3.2.1 mechanical treatment technology
    5.3.2.2 biological treatment technology
    5.3.2.3 advanced treatment technology

5.3.3 Total waste- water treated
    of which: treated to national standards

5.4 Discharge of waste- water
  5.4.1 from public sewerage without treatment
  5.4.2 from public sewerage after treatment
  5.4.3 from industry without treatment (by type of activity)
  5.4.4 from industry after treatment (by type of activity)
  5.4.5 total discharge of waste-water
    5.4.5.1 into inland waters
    5.4.5.2 into coastal sea

For information: -- Losses of waste-water during transport
-- Total discharge of cooling water

5.5 Sludge from waste-water treatment
  5.5.1 Generation
    5.5.1 .1 in public treatment plants
    5.5.1.2 in industrial treatment plants

  5.5.2 Use or treatment/disposal of sludge from public treatment plants
    5.5.2.1 Use in agriculture
    5.5.2.2 Other use
    5.5.2.3 Incineration
    5.5.2.4 Dumping at sea
    5.5.2.5 Dumping on land

  5.5.3 Use or treatment/disposal of sludge from industrial treatment plants
    5.5.3.1 Use in agriculture
    5.5.3.2 Other use
    5.5.3.3 Incineration
    5.5.3.4 Dumping at sea
    5.5.3.5 Dumping on land

The activity breakdown recommended for use in relation to section 5 is that specified in section 4.

CHAPTERTHREE

ECE STANDARD STATISTICAL CLASSIFICATION OF AMBIENT AIR QUALITY
(1990)

CONTENTS

A. INTRODUCI'ION

Purpose, scope and coverage of the classification

The purpose of comprehensive air quality statistics is to provide generalized statements about air pollution and the quality of ambient air. Such statements are needed to determine and to quantify factors with harmful effects on air pollution, and to assess possible abatement measures.

Air pollution can be seen in four phases: Emission of pollutants, their concentration in ambient air, their deposition, and the exposure to them of humans, animals, plants, and buildings. At present, statistics on exposure are only rarely available. Instead, exposure is frequently assessed on the basis of concentration data. Thus, for the time being, exposure is not covered as such by this classification.

The inclusion of the remaining three phases can be justified in terms of environmental problems related to air pollution. The contribution of emissions, concentrations, and depositions to acidification, corrosion, eutrophication, climate changes, health risks, accumulation of persistent substances and photochemical oxydants, forest damage, and the economic aspects of these consequences as well as of any remedial action, to name the most prominent of environmental problems attributed to air pollution, can be studied with the help of relevant statistical information. The purposes of such studies determine which pollutants to include and which statistical variables to use.

Air pollution can be caused by natural as well as anthropogenic sources. Generally, however, the emission of pollutants -- primarily chemical elements and compounds -- from socio-economic processes receives most interest. The statistical description of such emissions covers their sources and the quantities emitted. The selected data are used for regulatory purposes as well as for the development of pollution abatement strategies. In addition, emission statistics can be and are widely used in the estimation and modelling of air pollution, for example in environmental, economic, and dispersion models. Deposition statistics, together with available information on critical loads of areas or ecosystems concerned, are increasingly requested for research and management purposes.

Concentration data are primarily used for the monitoring of environmental problems with air quality at various scales. At the global level, large scale changes in atmospheric constituents influencing weather and climate are of special interest. The possibility of rather dramatic effects of the related global air pollution problems add considerably to the urgent need for reliable and adequate information on concentrations of pollutants of global significance in the air. The overall impact of human activities on air quality can be studied in broad terms at the regional level. For the local level, ambient air quality standards are usually cast in terms of concentrations. In general, it should be noted that environment statistics in general and air quality statistics in particular are to a considerable extent intended for the general public. It also appears that environment statistics are increasingly used by decision-makers other than environmental managers. Their data requirements seem to resemble more those of the general public than those of environmental managers. The data needs of the general public differ from those of environmental managers in that statistical generalizations play a larger role than time- and site-specific monitoring data. This circumstance influences both the concepts chosen for this classification and the ways in which air-quality statistics should be presented. At the conceptual level, variables that are representative of widely encountered environmental problems should be selected for international standard classification. In presentation, the focus should be on techniques for recognizing patterns in air quality over time, and that avoid easy misinterpretation of statistical data.

This classification provides conceptual and classificatory guidance. It intends to support national as well as international efforts. It is in principle limited to those pollutants for which international standard recommendations on measurement and analysis of ambient air samples are currently available.

In a few instances, pollutants are also included that are widely measured but for which corresponding international standard recommendations have not (yet) been developed. The classification attempts to reflect current data capabilities in order to promote its wide use in international collection, compilation; and presentation of air quality statistics.

Structure of the classification and principles of application

The classification as set out in Chapter II below is composed of four sections. Each of these sections is briefly ‘reviewed here.

Chemicals for measurement or estimation

This part of the classification should be looked upon as a reference framework for the long-term development of air quality statistics. The framework is primarily derived from the availability of internationally standardized measurement techniques and analytical methods or at least that of widely applied routines. It indicates the purpose for which data should be collected: for emission statistics, for local, for national/regional background and/or for global air pollution statistics. Not all of the compounds listed are proposed for the preparation of statistics in the short run. Those proposed for present data collection are repeated in subsequent sections of the classification.

Emissions

This section relates exclusively to anthropogenic emissions of air polluting substances. Emissions from stationary sources by process, by activity, and by availability of cleaning, and from mobile sources, are distinguished. Emissions by process are devided into emissions from the combustion of fuels and from other processes, as they can differ in composition, volume, and seasonal pattern.

Air emissions can be measured directly, or can be estimated on the basis of fuel and other material consumption data and process-specific emission factors. While some countries prefer measurement to estimation, data are more frequently available from estimations. Estimation procedures are at hand for a number of pollutants, as is relatively sound information on the reliability of the estimates. The classification does not aim at standardizing estimation procedures. Emission data (either measured or estimated) should be reported and presented together with information on the measurement and/or estimation method used.

The estimation of emissions from power plants in accordance with this classification may pose problems, depending on the ease with which relevant basic data can be obtained from the public and private stations covered. In cases where problems arise, these should be clearly stated in any response to international data requests. The statements should include a description of the methods used in estimation and should permit an assessment of the size of the uncovered part of electricity generation.

For international data reporting, the use of annual national totals is recommended. For national purposes, regional and even site-specific emission data may have to be used together with information on seasonal variations.

Concentrations in ambient air

Concentration of pollutants in ambient air can be measured at different distances from their sources of emission. As a rule, a maximum of concentrations caused by the source (or sources) is found in their proximity. The influence of the source on concentration levels decreases generally with growing distance from the source - except for pollutants depending on the existence of synergistic effects. Accordingly, a distinction is made in the classification between “impact” and “background” concentrations. In addition, “regional background” concentrations are separated from “global background” concentrations. The different types of concentrations are measured at like-named stations.

It is recognized that the terms “impact” and “background” are rather vague and suggestive in nature. They are used for want of a better term. The substantive issue concerned relates to the need for exposer data on one hand and for spatially representative data on the other. Both requirements are currently not easily met. Thus, concentration data obtained at impact stations are often used as proxies for exposer statistics. At the same time, statisticians are often forced to provide generalized data that can justifiably be considered representative of impact areas. The understanding for the purpose of this international classification is that the impact stations retained in international reporting should enable justifiable use for both purposes -- estimates of exposer and statements about general levels of air pollution in defined areas.

Statistics based on measurements carried out at impact stations describe local air quality. These measurements are influenced by the type of air polluting activities carried out in the neighbourhood of the measurement station, and by meteorological and physical factors. Attempts are sometimes made to classify different impact stations by the type of area in which they are located. For example, the Global Environment Monitoring System (GEMS) uses a six-fold classification of urban areas for the purpose of urban air pollution statistics. The use of the GEMS classification for urban air quality statistics requires, however, that data presentation should include information on the location of the measurement station. When impact stations exist outside the direct influence of local sources, it should be studied whether these stations could be used as background stations for those stations measuring the direct impact of local air pollution sources.

Ideally, statistics based on measurements carried out at background stations should not be influenced by emission sources of local significance. This requirement imposes restrictions on the location of background stations. If possible, international statistical reporting of background concentrations should be accompanied by minimum information on the location of the measurement sites for which the statistics are computed.

Depositions

The aim of deposition statistics is to cover total deposition, i.e. both wet and dry deposition. Deposition statistics, as recommended in this classification, however, cover wet depositions of acids and acidifying compounds. Statistics on wet acidifying deposition are based on the chemical analysis of precipitation at background stations. The volume of wet acidifying deposition is calculated as the product of the concentration of the given component in precipitation and the volume of precipitation. For the purposes of international data reporting, annual national totals should be reported.

The input of dry deposition into soil, vegetation, surface waters, and materials is also of environmental significance. However, dry deposition is not included in the classification because of the current absence of systematic measurement data and of uncertainties in determining deposition velocities. For some compounds, the relationship between pollutant concentration in air and in the acqueous phase is relatively well-known. For most compounds, however, this relationship is currently unknown.

Information on depositions can also be obtained indirectly, by measuring the accumulation of deposited substances in plants. No recommendations for such measurements are for the time being included in this classification. However, as indirect measurements of deposition are becoming more common, the classification is sufficiently flexible to allow for the inclusion of related recommendations as soon as they are considered appropriate.

Conventions

The following should be applied to all uses of this classification in data collection and presentation:

> Emission statistics should be accompanied by a sufficient description of the procedures used in estimation (including ranges of emission factors), or an

identification of the measurement techniques which were applied.

- Concentration statistics should be accompanied by indications of which sampling and analytical methods were used in basic measurement.

Summary information on the characteristics of measurement sites should be made available to users of concentration statistics.

In addition, the following conventions should be applied to international collection and presentation of air quality statistics:

Emission statistics should relate to countries as a whole and calendar years. Problems arising from reporting data on emissions from public and private power plants should clearly be stated.

Concentration statistics should be presented in such a way that the geographical area to which they relate is clearly visible. Such areas could be urban areas, areas in well-defined natural boundaries, countries as a whole, and regions including more than one country. For the ECE region, the most aggregate sub-regions are Europe and North America, separately.

For the purpose of data reporting of concentrations at impact stations, measurement stations which are used only for monitoring one point source of pollution should not be selected. If the GEMS classification of measurement stations is used for urban air quality statistics, data presentation should include information on location of the measurement station.

For reporting concentrations at background stations, BAPMoN stations should be used for global background measurements, and EMEP stations for regional background measurements in the European region.

The degree of reliability of concentration statistics should be indicated in presentation. In particular, the representativeness of statistics in terms of the time period covered should be observed and stated.

Concentration statistics should be calculated from 24h averages (or lh averages), separately for a “summer” period (1 April to 30 September of reporting year) and a “winter” period (1 October of previous year to 3 1 March of reporting year).

The volume of wet acidifying deposition is to be calculated as the product of the concentration of the given component in precipitation and the volume of precipitation. For the purposes of international data reporting, annual national totals should be reported.

The following statistical variables should be used in presentation:

(i) Tons per year of emissions;

(ii) Measures of central tendency of the underlying frequency distribution of the data from each individual sampling site, e.g./arithmetic means, geometric means and/or medians; and

(iii) Measures of dispersal about the averages, e.g. standard deviations, where applicable, and/or maximum and minimum of high and low percentiles.

Trends of -peaks, upper percentiles, and annual means should be included in statistical presentation whenever this is possible.

The following statistical variable is proposed for national use:

Number of days exceeding national ambient air quality standards (for selected cities, as applicable).

Methodological problems and further work required

Many air quality statistics are usually based on monitoring. This implies that statistical generalization of data is impeded by the site-specificity of monitoring data, the characteristics of measurement sites, sampler design and specification, calibration, and sampling and analytical methods used. The repercussions of these aspects on data reliability and comparability are only known to some extent. Future work should bring about clarifications in this respect. Of special interest appear to be studies of the relationship between site characteristics and levels of measured data. The detailed specification of information needed on site characteristics should be deferred until after knowledge of the relationship has improved. Future methodological studies should shed further light on possibilities for valid generalizations relating monitoring data to air quality statistics.

In the Annex of the classification, a review of analytical methods commonly used in air quality measurements is provided. The aim of the review is not to standardize measurement and analytical practices but to serve as a reference framework for the air quality classification and for the purpose of international data collection. Existing variations in measurement and analytical methods between station practices should give rise to the use of adequate techniques of data presentation. Such techniques include references to measurement techniques and analytical methods used, to site characteristics of the relevant stations, to meteorological conditions etc. The use of more than one statistical measure to describe statistical distributions of variables as well as the use of maps, isopleths and other graphic techniques are also ways of reducing the impression of “spurious accuracy” of air quality statistics. Furthermore, the conditions that have to be met in terms of data completeness before reliable trends can be calculated should be explored. Also, methods used in the correction or adjustment of time series for different types of background conditions should be compared and evaluated.

Further development of emission statistics should include the development of physical measures of pollution abatement facilities. The related work could perhaps best be undertaken in connection with the ongoing conceptual work by the Conference of European Statisticians on economic aspects of environmental protection.

Finally, a systematic conceptual and methodological exploration of the scope and limits of exposure statistics is required. Such statistics could be obtained from direct measurement, but could also be derived from the application of appropriate estimation procedures to concentration and emission data.

B. CATEGORIES OF THE CLASSIFICATION

Chemicals and their relevance in measurement/estimation

(E = emissions; C = concentrations; I = at impact stations; B= at national or regional background stations; G = at global background stations)

		E	CI	CB	CG
1.	Sulnhur comnounds				
1.1	Sulphur oxides (incl. emissions of hydrogen sulphide)	X	X	X	
1.2	Particulate sulphate			X	X
2.	Oxidized nitrogen comnounds and oxidants				
2.1	NOX (excluding nitrous oxide)	X	X	X	
2.2	Nitric acid and particulate nitrate		X	X	X
2.3	Ozone - tropospheric			X	X
	- stratospheric				X
2.4	Nitrous oxide (tropospheric)				X
3.	Reduced nitrogen comnounds				
3.1	Ammonia	X	X	X	
3.2	Particulate ammonium compounds		X	X	X
4.	Inorganic carbon comnounds				
4.1	Carbon monoxide	xx			x
4.2	Carbon dioxide	X			X
5.	Halogens and inorganic halogen compounds	x		x	
6.	Volatile organic comnounds [1] (incl. halogenated compounds)				
6.1	Methane	X			X
6.2	Non-methane compounds				
	6.2.1 Aldehydes	x	x	x	
	6.2.2 CFCs	X			X
	6.2.3 Halons	X			X
	6.2.4 Other halogenated hydrocarbons	X			X

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[1] It may become possible to add relevant dioxins (toxic polychlorinated debenzo dioxins and furans) as a separate group under this heading once sufficiently reliable emission and/or concentration data become available.

		E	CI	CB	G
7.	Heavy metals (to be specified)	X	X	X	
8.	Suspended particulate matter	X	X	X	X
9.	Chemical composition of precipitation water			X	X

Emissions [tons/year]

1. Emissions from stationary sources
    - 1.1 By process
        - 1.1.1 Combustion of fuels
            - 1.1.1.1 In power plants
            - 1.1.1.2 In industrial establishments, excl. power plants
            - 1.1.1.3 In other economic activities and domestic heating
        - 1.1.2 Other processes, incl. evaporation
            - 1.1.2.1 In industrial sources
            - 1.1.2.2 In non-industrial and domestic sources
    - 1.2 By activity
        - 1.2.1 Agricultural etc. (ISIC 01)
        - 1.2.2 Mining and quarrying (ISIC 10- 14)
        - 1.2.3 Manufacture of paper and paper products (ISIC 21)
        - 1.2.4 Manufacture of coke (ISIC 231)
        - 1.2.5 Manufacture of refined petroleum products (ISIC 232)
        - 1.2.6 Manufacture of chemicals and chemical products (ISIC 24)
        - 1.2.7 Manufacture of rubber and plastic products (ISIC 25)
        - 1.2.8 Manufacture of other non-metallic mineral products (ISIC/26)
        - 1.2.9 Manufacture of basic iron and steel (ISIC 271)
        - 1.2.10 Manufacture of basic precious and non-ferrous metal (ISIC/272)
        - 1.2.11 Electricity, gas, steam and hot water supply (ISIC 40)
        - 1.2.12 Other economic activities
        - 1.2.13 Households
    - 1.3 By availability of cleaning
        - 1.3.1 Without cleaning
        - 1.3.2 With cleaning or equivalent device

2. Emission from mobile sources

2.1 From road transport

2.1.1 Using motor spirit (gasoline)
2.1.2 Using gas (diesel) oil
2.1.3 Using other fuels

2.2 From railway transport

2.3 From other transport

2.4 From other mobile sources

Emissions should at this time be reported on the following materials:

- Sulphur oxides, incl. hydrogen sulphide [in units of SO_2]
- NOX, excl. nitrous oxide [in units of NO_2]
- Ammonia
- Carbon monoxide
- Carbon dioxide [in units of CO_2]
- Total volatile organic compounds, incl. halogenated compounds
  Lead
  Mercury
  Cadmium
- Suspended particulate matter

Emission data on items 1 .1. 1.1 to 1.1.1.3 should be broken down by type of fuel as follows:

Coal and coal products
Products obtained from petroleum refineries
Natural gas
Other fuels

Concentrations in ambient air

2.1 Concentrations at impact stations

2.1.1 Sulphur oxides [expressed as SO_2]
2.1.2 Nitrogen oxides [expressed as NO_2]
2.1.3 Carbon monoxide
2.1.4 VOCs (to be specified)
2.1.5 Lead
2.1.6 Mercury
2.1.7 Cadmium
2.1.8 Suspended particulate matter

2.2 Concentrations at national/regional background stations

- 2.2.1 Sulphur oxides [expressed as SO_2]
- 2.2.2 Particulate sulphate
- 2.2.3 Nitrogen oxides [expressed as NO_2]
- 2.2.4 Nitric acid and particulate nitrate
- 2.2.5 Ozone (tropospheric)
- 2.2.6 Ammonia
- 2.2.7 Particulate ammonium compounds
- 2.2.8 VOCs (to be specified)
- 2.2.9 Chemical composition of precipitation (pH/H+ ammonium, nitrate, chloride and sulphate ions, sodium, potassium, magnesium and calcium ions, conductivity)

2.3 Concentrations at global background stations

- 2.3.1 Ozone (stratospheric)
- 2.3.2 Carbon dioxide
- 2.3.3 Methane
- 2.3.4 CFCs
- 2.3.5 Halons
- 2.3.6 Nitrous oxide
- 2.3.7 Suspended particulate matter

Depositions

3.1 Wet acidifying deposition

- 3.1.1 Sulphur dioxide and sulphate expressed in sulphur content
- 3.1.2 Nitrogen dioxide, nitric acid and nitrate expressed in nitrogen content
- 3.1.3 Ammonia and ammonium compounds expressed in nitrogen content
- 3.1.4 pH/H+

Note: Other deposition indicators may be added, once their development is sufficiently advanced.

ANNEX:

EVALUATION OF ANALYTICAL METHODS USED IN MEASURING CONCENTRATIONS OF AIR POLLUTANTS

Table of contents

A. INTRODUCTION

In this Annex, sampling and analytical methods for air pollutants are collected that are standardized or recommended by international organizations, namely the International Organization for Standardization, World Meteorological Organization (WMO), Background Air Pollution Monitoring Program, World Health Organization (WHO), Economic Commission for Europe (ECE), European Monitoring and Evaluation Programme, and Council of Mutual Economical Assistance (CMEA), Programme of Monitoring of Background Pollution of the Atmospheric Environment. In some cases, where international recommendations are lacking, generally used routine sampling and analytical techniques are described which seem to be adequate for standardization.

In addition to the methodological references, a brief description of technical principles of sampling and analytical techniques, together with an evaluation of their reliability and adequacy, is included. Finally, the numerical differences between data obtained from different measurement techniques are briefly evaluated, although the number of intercalibrations and comparisons is very limited.

B. SAMPLING AND ANALYTICAL METHODS OF DIRECTLY MEASURED CHARACTERISTICS

Sulphur compounds

Sulphur dioxide

Hydrogen peroxide/thorin method (CMEA, 1986; ECE/EMEP 1977; ISO, 1979; ISO, 1980; WMO, 1978)

Technical principle:

Air filtered from sulphate particules passes through a bubbler containing hydrogen peroxide. Sulphur dioxide is oxidized by hydrogen peroxide to sulphate. Barium perchlorate reagent added yields insoluble barium sulphate precipitation. Residual barium ion is determined as barium-thorin complex by spectrophotometry at a wavelength of 520 nm. Amount of barium ions measured is inversely proportional with sulphate and sulphur dioxide concentration.

Applicability:

The method is applicable for measurement of up to 24-h-integrated averages of sulphur dioxide concentration in ambient air, both at impact and regional stations above a concentration level of 3 ug/m^3.

Disadvantages:

The method is not selective for sulphur dioxide; reduced sulphur compounds (e.g. hydrogen sulphide) are sampled in parallel. The absorption is pH-dependent (below pH=3.5 or above pH=9.8 negative or positive error). Sulphur dioxide can be oxidized on the surface of the pre-filter; sometimes absorption of sulphur is not complete. Both effects cause negative error.

Tetrachloro mercurate/West-Gaeke method (CMEA, 1986; ISO, 1988; West and Gaeke, 1956; WHO, 1976; WMO, 1978)

Technical principle:

Air filtered from particles passes through a bubbler containing solution of tetrachloro mercurate ion. Sulphur dioxide is fixed as dichloro sulfito mercurate and determined as p-rosaniline methylsulfonic acid after reaction with p-rosaniline and formaldehyde, by spectrophotometry at a wavelength of 550 nm.

Applicability:

The method is applicable for measurement of up to 24-h-integrated averages of sulphur dioxide concentration in ambient air, both at impact and regional stations above a concentration level of 5 ug/m^3. Interferences of nitrogen oxides, ozone, hydrogen sulphide, heavy metals are minimized. Selective method for sulphur dioxide.

Disadvantages:

Sulphur dioxide can be oxidized on the surfaces of the pre-filter, sometimes absorption of sulphur dioxide is not complete. *(see: Hydrogen peroxide/thorin method*).

Hydrogen peroxide/isotope dilution method (ECE/EMEP, 1977)

Technical principle:

Sampling is similar to *Hydrogen peroxide/thorin method.* Analysis is based on isotope dilution analysis of sulphate ion.

Applicability, reliability, adequacy:

Same as for *Hydrogen peroxide/thorin method*

Disadavantages:

Same as for *Hydrogen peroxide/thorin method*

Impregnated filter/thorin (isotope dilution) method (ECE/EMEP, 1977, corrected in 1980)

Technical principle:

Air passes through potassium hydroxide prepared filter, sulphate particles removed by a pre-filter. Sulphate is analysed by thorin or isotope dilution method.

Applicability:

The method is applicable for measurement of 24-h-integrated averages of sulphur dioxide concentration in background air above a concentration level of 0.1 ug/m^3.

Disadvantages:

The method is not selective for sulphur dioxide. Sulphur dioxide can be oxidized on the surfaces of the pre-filter (negative error).

Pulsed fluorescent method

Technical principle:

Pulsating UV light excites sulphur dioxide molecules. Excited species emit characteristic radiation. By means of photomultiplyer tube, the radiation is converted to electronic signal, which is proportional to sulphur dioxide concentration.

Applicability:

The method is applicable for continuous monitoring of sulphur dioxide concentration in ambient air both at impact and regional stations.

Denuder technique

See: Denuder technique on page 32.

Overview of sulphur dioxide methods

For impact and background measurements, the *Tetrachloro mercurate/West-Gaeke method* is generally considered as the reference method. However, for extremely low concentrations, only the impregnated filter method is applicable. In the case of higher concentrations, the *Pulsed fluorescent method* is also recommended.

Particulate sulphate

Membrane filter/x-ray fluorescence (or thorin) method (WMO, 1978)

Technical principle:

Air passes through a membrane filter (sampling train is the same as for the *Hydrogen peroxide/thorin method).* Particles collected are analysed by X-Ray fluorescence method or washed and analysed by thorin method for sulphate.

Applicability:

The method is applicable for measurement of 24-h-integrated averages of sulphate concentration in ambient air both at impact and regional stations above a concentration level of 2 ug/m^3.

Disadvantages:

The method is not selective for sulphate (in the case of x-ray fluorescence). Sulphur dioxide can be oxidized on the surface of filter causing artifact sulphate (positive error).

Filter/thorin (or isotope dilution) method (ECE/EMEP, 1977; CMEA, 1986)

Technical principle:

Air passes through a cellulose or Teflon filter. Particles collected are washed and analysed by thorin or isotope dilution method for sulphate.

Applicability:

The method is applicable for measurement of 24-h-integrated averages of sulphate concentration of ambient air both at impact and regional stations above concentration levels of 0.1 ug/m^3 (medium volume sampling, 15/m^3/day air flow) or 1 ug/m^3 (low volume sampling, 2 m^3/day air flow).

Disadvantages:

Sulphur dioxide can be oxidized on the surface of filter, causing artifact sulphate (positive error). However, the use of a Teflon filter reduces this interference.

Cellulose filter/x-ray fluorescence method (ECE/EMEP, 1977)

Technical principle:

Air passes through cellulose filter. Particles collected are analysed by x-ray fluorescence method.

Applicability:

The method is applicable for measurement of 24-h-integrated averages of sulphate concentration in ambient air both at impact and regional stations above a concentration level of 0.1 ug/m^3.

Disadvantages:

The method is not selective for sulphate. Sulphur dioxide can be oxidized on the surface of filter causing artifact sulphate (positive error).

Denuder technique:

See Denuder technique on page 32.

Overview of sulphate methods

Other filters than Teflon as pre-filter for sulphate are not recommended, because of artifact sulphate formation. Therefore the *Filter/thorin (or isotope dilution)* methodusing a teflon filter seems to be the most reliable method among those with direct filtration. However, only the use of a denuder can entirely avoid artifact sulphate formation on the filters, but the application of denuders is not widespread and is not standardized.

Hydrogen sulphide

Methylene-blue method (ISO, 1983)

Technical principle:

Air passes through a bubbler containing cadmium hydroxide, yielding cadmium sulphide. After separation, cadmium sulphide precipitation reacts with N-N-dimehtyl-p-phenilendiamine hydrochloride in the presence of iron giving methylene blue. Absorption of methylene blue is proportional with hydrogen sulphide concentration and is measured by spectrophotometry at a wavelength off 660 nm.

Applicability:

The method is applicable for short-time (generally 30 min) measurement of ambient concentration of hydrogen sulphide both at impact and regional stations above a concentration level of 0.5 ug/m^3.

Disadvantages:

Cadmium sulphide is unstable, analysis has to be performed within 24 h, above 10 ug/m^3 immediately after sampling. The method is not applicable for the determination of daily integrated averages.

Gas chromatographic/flame photometric method (ISO, *1982)*

Technical principle:

Air sample is injected into a gas chromatograph where hydrogen sulphide is separated from hydrocarbons and from other sulphur compounds. The eluted hydrogen sulphide is passed through a hydrogen flame and converted into S2 molecules with a higher energy state. Excited S2 molecules emit characteristic light radiation, which is measured by photomultiplayer tube. The signal is proportional with hydrogen sulphide concentration.

Applicability:

The method is applicable for semi-continuous monitoring of sulphur dioxide concentration in ambient air mainly at impact stations above a concentration level of 3-5 ug/m^3. Selective method with no interference.

Disadvantages:

The method is not applicable to continuous 24-h-measurement of hydrogen sulphide.

Ovewiew of hydrogen sulphide methods

From the point of view of background monitoring, there is no appropriate international standard or recommendation. The *Methylene-blue method* described on page 27 is not applicable for determination of 24-h-averages because of the instability of the cadmium sulphide generated. The gas chromatographic/flame photometric method is technically complicated for semi-continuous measurement. The detection limit of this method is higher than expected background concentrations, therefore it is appropriate only for impact measurements.

Oxidized nitrogen compounds and oxidants

Nitric oxide and nitrogen dioxide

Modijïed TGS/ANSA method (ECE/EMEP, 1977, corrected in 1985; USA/EPA, 1977)

Technical principle:

Air is drawn through a bubbler containing triethanolamine, o-methoxiphenol (quaiacol) and sodium metabisulfite absorbing solution. The concentration of nitrite ions produced during sampling isdetermined by spectrophotometry at a wavelength of 550 nm, on the basis of a coloured compound developed by the reaction of nitrite ion with sulphanilamide and ANSA (8-anilino- 1 -naphtalenesulphonic acid, ammonium salt).

Applicability:

The method is applicable to the measurement of 24-h-integrated averages of nitrogen dioxide concentration in ambient air both at impact and regional stations above a concentration level of 1-1.5 ug/m^3.

Disadvantages:

Absorption and conversion of nitrogen dioxide is not complete and is not well-defined. Correction factor (sampling efficiency) depends on flow rate and sampling equipment. PAN (=peroxi acetyl nitrate) causes positive error. Other important pollutants do not interfere.

Saltzman method (CMEA, 1986; Saltzman, 1954; WHO, 1976)

Technical principle:

Air passes through a bubbler containing azo-dye forming reagent (sulfanilic acid and NEDA). Coloured product formed with nitrogen dioxide is measured by spectrophotometry at a wavelength of 550 nm.

Applicability:

The method is applicable for measurement of short-ter-m (generally less than 2 h) integrated averages of nitrogen dioxide concentration in ambient air both at background and impact stations above a concentration level of a few ug/m^3.

Disadvantages:

Samples have to be measured immediately after sampling, because of interference of oxidizing and reducing compounds. Therefore it is not applicable for longer (24 h) periods.

Modijïed Griess-Saltzman method (ISO, 1985)

Technical principle:

This procedure differs from the previous one in sampling train and composition of absorption solution (sulfanil amide instead of sulfanilic acid).

Applicability:

The method is applicable to the measurement of short-term (max. 2 h) integrated average concentration of nitrogen dioxide at impact stations above a concentration level of 10 ug/m^3.

Disadvantages:

The time lapsed between the end of sampling and analysis should not exceed 8 h, because of the limited stability of the sample solution. PAN, nitrite and nitrous acid cause a positive error, the effect of other important pollutants is small. It is not applicable for longer (24 h) periods, as the detection limit is not low enough for regional background measurements.

Modified Saltzman method (CMEA, 1986; Meszaros, 1978; Levaggi et al., 1973)

Technical principle:

Air passes through a bubbler containing triethanolamine where nitrogen oxide is fixed. After sampling, a coloured compound is developed with azo-dye forming reagents (sulfanil amide and NEDA). Absorbance of solution is measured by spectrophotometry at a wavelength of 540-550 nm.

Applicability:

The method is applicable to the measurement of 24-h-integrated averages of nitrogen dioxide concentration in ambient air both at impact and regional stations above a concentration level of 1 ug/m^3.

Disadvantages:

Absorption and conversion of nitrogen dioxide are not complete and are not well-defined. Certain nitrogen compounds may cause positive error. Stability of exposed samples is questionable.

Simultaneous measurement of nitric oxide and nitrogen dioxide

Nitric oxide can be measured together with nitrogen dioxide as described in the *Hydogen peroxide/thorin*; *Tetrachloromercurate/West-Gaeke method*; *Hydrogen peroxide/isotope dilution method* and *Impregnated filter/thorin (isotope dilution)* methods (pp 24-26), after the oxidation of nitric oxide to nitrogen dioxide. However, the oxidation procedure is not well-defined, therefore it is not recommended.

Chemiluminescence method (CEC, 1987; CMEA, 1986; ISO, 1985B; WMO, 1978)

Technical principle:

The measurement is based on the photometry of chemiluminescence due to gas phase reaction between nitric oxide and ozone. The air to be analysed is continuously passed through a reaction cell containing ozone. The intensity of light is measured by photomultiplayer tube. The photocurrent is amplified and recorded. Owing to the prior reduction of nitrogen dioxide to nitric oxide in a converter, the concentration of nitrogen dioxide can be measured in parallel.

Applicability:

The method is applicable to the parallel, continuous monitoring of nitric oxide and nitrogen dioxide both at impact and regional stations, above a concentration level of 1 ug/m^3.

Disadvantages:

PAN, nitric acid and all other materials which can be formed to nitric oxide in the converter may interfere with the nitrogen dioxide measurement.

Overview of nitrogen oxide measurements

When 24-h-averages are of interest, the *Modified TGS/ANSA* (page 29), *Modified Saltzman* and *Chemiluminescence* (pp. 31) methods are applicable. Because of the uncertainties of the *Hydrogen peroxide/thorin, Tetrachloro mercurate/West-Gaeke, Hydrogen peroxide/isotope dilution, Impregnated filter/thorin (isotope dilution) and Pulsed fluorescent* methods (pp. 24-26), generally the chemiluminescence method is recommended. However, at very low concentrations (at background sites), the applicability of this method is also questionable. Other new procedures (e.g. luminol, passive diffusion tube technique) may eliminate the disadvantages, but they are not generally used for routine analysis yet.

Nitric acid and particulate nitrate

Note:

Nitric acid vapor and particulate nitrate are generally sampled together. There is no international standard for sampling of nitric acid and particulate nitrate. However, they are routinely measured (e.g. ECE/EMEP, 1988).

Filter pack method (Appel et al., 1980; Forrest et al., 1980; Okita et al., 1976)

Technical principle:

Air passes through a Teflon or a pre-treated quartz filter, collecting particles. Subsequently a cellulose filter, in the same filter holder, prepared with nylon or sodium chloride, adsorbs nitric acid vapor. The flow rate may vary between 20 l/min to high-volume sampling. Filters are washed by bi-distilled water and analysed for nitrate, or, after reduction, for nitrite by spectrophotometry or ion chromatography (pre-filters are analysed for other ions like ammonium and sulphate).

Applicability:

This method is applicable for measuring 24-h-integrated averages of nitric acid and particulate nitrate. Sulphate and ammonium concentrations in ambient air both at impact and regional stations. The detection limit strongly depends on the air volume sampled, but is generally satisfactorily low.

Disadvantages:

Acidic gases like nitric acid, and nitrogen dioxide (or sulphuric acid and sulphur dioxide), especially at high relative humidities, cause error because the particulates collected on the pre-filter react with acidic gases, resulting in overestimates of nitrate (or sulphate) particles. Ammonia captured on the pre-filter transforms to ammonium, causing positive error when ammonium is also analysed. Because of pressure reduction on the filter, the volatile salts (e.g. ammonium nitrate) collected can dissociate, thereby causing negative error for particulate nitrate (and ammonium), and positive error for nitric acid measurement.

Denuder technique (Allegrini et al., 1985; De Santis et al., 1985; Possanzini et al., 1983; Slanina et al., 1981)

Technical principle:

Many types of denuders exist. Generally, acidic gases are sampled in a sodium carbonate or sodium fluoride coated annular (or, for low volume sampling, tubular) diffusion tube. Gaseous ammonia are captured by another tube connected with the first one, coated by citric acid or phosphoric acid. Air is then drawn into a subsequent filter pack, aerosol particles not being adsorbed at the walls of the tubes. Particles are captured on the surface of a Teflon filter. A second, Nylon or sodium chloride prepared filter, and a third, citric acid or phosphoric acid prepared filter, collect nitric acid vapor and ammonia gas, respectively, which are derived from the decomposition of volatile salts collected on the first filter. After sampling the tubes and filters are washed by bi-distilled water and analysed for nitrate, sulphate, ammonium, chloride, fluoride etc., by spectrophotometry or ion chromatography.

Applicability:

The method is applicable to the simultaneous determination of 24-h-(or shorter) integrated averages of nitric acid and particulate nitrate in ambient air both at impact and regional stations. The denuder technique is also suitable for the determination of sulphur dioxide, hydrogen fluoride, hydrogen chloride and ammonia gases and particulate sulphate, ammonium, chloride and fluoride concentrations. The detection limit depends on the type of denuder; it is generally good for low concentrations. There is practically no interference.

No known disadvantages.

Overview of nitric acid particulate nitrate methods

The filter pack method is frequently used because of the simplicity of sampling. However, it is not fully adequate owing to the different disadvantages mentioned. The denuder technique is quite applicable for sampling, but is not widespread in routine investigation. Hence there are no records for long periods, which could be used for a complete evaluation.

Ozone

Chemiluminescence method (CMEA, 1986; WHO, 1978; WMO, 1978)

Technical principle:

The measurement is based on the photometry of chemiluminescence due to gas phase reaction between nitric oxide and ozone (see: *Chemiluminescence method,* page 30).

Applicability:

The method is applicable for continuous monitoring of ozone both at impact and regional stations above a concentration level of 2- 10 ug/m^3. The method is sensitive and specific for ozone. Oxidants other than ozone do not interfere.

Disadvantages:

A precise calibration of the ozone generator of monitors is difficult, as it is generally based on uncertain wet chemical methods *(see* e.g. *Neutral buffered potassium iodide method,* below).

Note Recently, ozone monitors are being based on the UV absorption of ozone molecules. The absorption at the wavelength of 254 nm is proportional with the ozone concentration. The advantage of UV ozone monitors is their simplicity and reliability as compared with the chemiluminescence method described above.

Neutral buffered potassium iodide method (WHO, 1976)

Technical principle:

Air is drawn through a bubbler containing a neutral buffered potassium iodide solution. Iodine is released through oxidation of iodide. The quantity of iodine is measured by spectrophotometry at a wavelength of 352 nm. Absorption is proportional with ozone concentration.

Applicability:

The method is applicable for measuring of 30-min.-integrated averages of ozone concentration of ambient air both at impact and regional stations above a concentration level of 20 ug/m^3.

Disadvantages:

The released iodine deteriorates with time, therefore only short-term sampling can be performed, including immediate analysis. The method is not specific for ozone as total oxidants are measured. Ambient oxidization and reducing species interfere.

Note: A continuous monitor has been developed based on the reaction between ozone and potassium iodide (WMO, 1978). This method has the same disadvantages as mentioned for the *Chemiluminescence* one mentioned above.

Dobson spectrophotometry (total ozone) (WMO, 1978)

Technical principle:

Total ozone is measured in a vertical column by spectrophotometry. The UV absorption of solar radiation by ozone molecules is proportional to the amount of ozone molecules in the vertical column. Two pairs of different wavelengths are used eliminate the influence of aerosol particles.

Applicability:

The method is applicable to the determination of total (mostly stratospheric) ozone in the air at global stations. Discrete measurements are carried out a few times a day during sunshine. Dobson spectrophotometry practically does not suffer from interference.

No known disadvantages.

Overview of ozone measurements

Only continuous monitoring of ozone is applicable *(Chemiluminescence method,* page 33) to the determination of tropospheric surface level concentrations, because of uncertainties about wet chemical methods. The potassium iodide method is not recommended. For stratospheric ozone, Dobson photometry is applicable.

Reduced nitrogen compounds

Ammonia

Sulphuric acid/bubbler method (WMO, 1978)

Technical principle:

Air passes through a membrane pre-filter to remove ammonium particles, and through a bubbler containing diluted sulphuric acid. Ammonia is transformed to ammonium, which is determined by spectrophotometric indophenol-blue technique at a wavelength of 630 nm.

Applicability:

The method is applicable for measuring of 24-h-integrated averages of ammonia concentration both at impact and regional stations above a concentration level of 0.4 ug/m3.

Disadvantages:

Volatile ammonium salts (e.g. ammonium nitrate) collected on the pre-filter may decompose, producing ammonia during sampling because of pressure reduction (positive error). Ammonia gas on the pre-filter can be transformed to ammonium on the collected acidic particles (negative error), and ammonia can be released when ammonium salts react with alkaline particles (positive error).

Diffusion tube method (Ferm, 1979)

Technical principle:

Air is drawn through a diffusion tube coated with oxalic acid at a flow rate of 3 l/min. Ammonia gas is adsorbed on the wall, yielding ammonium salt, while ammonium particles leave the tube without adsorption. After sampling, the tube is washed with bi-distilled water and analysed for ammonium by a gas sensitive electrode, or by spectrophotometry.

Applicability:

The method is applicable for measuring of 24-h-(or less) integrated averages of ammonia concentration in ambient air both at impact and regional stations above a concentration level of 0.01 ug/m3. This technique practically does not suffer from interference, but reproducibility is relatively low (S.D. = 15 per cent).

No known disadvantages.

Note: The diffusion tube may be a part of the denuder described in *Denuder technique* (page 32)

Particulate ammonium/ammonia

Particulate ammonium : Filter pack method (see: *Filter pack method,* page 31).

Ammonia and ammonium (parallel sampling): Denuder technique (see: *Filter pack method,* page 31)

Ovewiew of ammonia/ammonium measurements

Generally, the sulphuric acid and the filter pack methods for ammonia and ammonium particles, respectively, are not recommended, because of the interferences mentioned. The diffusion tube method for ammonia and the denuder technique seem to be adequate sampling methods, but the latter is not generally applied in routine analyses.

Halogens and halogen compounds

Halogens and halogen compounds are primarily of interest for impact stations. While they are important pollutants, international recommendations for their sampling do not seem to exist.

Haloacids (hydrogen fluoride, hydrogen chloride) and particulate haloids (fluoride, chloride) can be sampled by filter pack method or by denuder technique (see: *Filter pack method* and *Denuder Technique,* pp. 31-32). As both positive and negative artifacts appear during the application of the filter pack method the denuder technique is generally preferable. Denuder sampling and subsequent analysis for haloids is described by Matusca et al. (1984) and De Santis et al. (1985).

Inorganic carbon compounds

Carbon monoxide

Non-dispersive infrared method (ISO, 1981; WHO, 1976)

Technical principle:

The method is based on IR absorption by carbon monoxide molecules. Two beams of IR radiation pass through a reference or a sample cell, each followed by detector cells containing carbon monoxide. Infrared absorption in the sample cell reduces the infrared absorption in the following detector cell, resulting in pressure and temperature differences between detector cells. Displacing of diaphragm is caused by pressure difference. It is proportional to the concentration of carbon monoxide in the sampled air and is measured.

Applicability:

The method is applicable to continuous monitoring of carbon monoxide at impact stations above a concentration level of 500-1000 mg/m^3.

Disadvantages:

This technique is not sufficiently sensitive for low concentrations. Hydrocarbons may interfere with measurement.

Gas chromatogrqhic method (ISO, 1986; WHO, 1976; WMO, 1978)

Technical principle:

Carbon monoxide in the air sample is separated from carbon dioxide, methane, non-methane hydrocarbons and water vapor. It is then converted by catalytic reduction to methane. Methane is detected by a flame ionization detector. The signal produced is proportional to carbon monoxide concentration. This technique is suitable for measuring simultaneously methane, non-methane hydrocarbons and carbon monoxide.

Applicability:

Applicable to semi-continuous measurement (4- 12 times per hour) of carbon monoxide concentration in ambient air both at impact and regional stations above a concentration level of l-30 ug/m3. Separation precludes practically all interference.

No known disadvantages.

Mercury oxide method (WMO, 1978)

Technical principle:

The sample air is separated from hydrocarbons, sulphur dioxide, water vapor and other gases which may interfere. Carbon monoxide then reacts with mercury oxide, resulting in mercury vapor. Mercury vapor is measured by the atomic absorption technique.

Applicability:

The method is applicable to continuous monitoring of carbon monoxide concentration both at impact and regional stations above concentration level of 0.1 ug/m3. Separation precludes practically all interferences.

No known disadvantages.

Detector tube method (WHO, 1976)

Technical principle:

Air drawn through a test tube containing silical gel impregnated with a chemical (e.g. with a palladium compound that changes color if exposed to carbon monoxide). The length of the stain developed in the tube after sampling is proportional to carbon monoxide concentration.

Applicability:

The method is applicable to the semi-quantitative non-continuous determination of carbon monoxide concentration on the basis of discrete measurements in impact air above a concentration level of 5 000 ug/m3.

Disadvantages:

The method is not selective for carbon monoxide. Reproducibility and sensitivity are not adequate.

Ovewiew of carbon monoxide measurements

The gas chromatographic and mercury oxide techniques seem to be adequate for monitoring carbon monoxide concentrations both at impact and regional stations. The non-dispersive infrared method is applicable only at impact stations with a high concentration level. The detector tube method is generally unsatisfactory.

Carbon dioxide

Non-dispersive infrared method (Meszaros, 1978; WMO, 1978)

Technical principle:

After filtering and drying, the sampled air passes through an analyser based on IR absorption. The technical principle is identical to the *Non-dispersive infrared method of carbon monoxide* (page 36).

Applicability:

The method is applicable for continuous monitoring of carbon dioxide at global stations in the usual concentration range of 0.6-0.8 ug/m3. Precision of this technique is adequate; practically there are no interferences. It is recommended for routine analysis at global background stations.

No known disadvantages.

Organic compounds

From the point of view of urban and global pollution, the following organic compounds have significance: Methane, non-methane hydrocarbons and oxidation products of these compounds (e.g. aldehydes).

Sampling and analysis of the above organics is not widespread. International standards or recommendations are rare. ISO (1988b) gives a method for C3-C10 hydrocarbons by gas chromatography in the air at workplaces. Ciccioli et al. (1987) describe a liquid chromatographic technique for aldehydes and carbonyl compounds. The gas chromatographic method described on page 36 is the most commonly used procedure to detect methane and non-methane hydrocarbons. Müller and Riedel (1987) propose a method for hydrocarbons and chlorinated hydrocarbons usines headspace chromatography. The evaluation of these procedures remains an open question, as they are not yet widely used.

Halogenated organic compounds

Halogenated organic compounds are important for their global effect (e.g. stratospheric ozone decay, greenhouse effect), while other halogenated hydrocarbons have importance at the regional or impact scales (e.g. vinyl chloride or pesticides).

Freons and other chlorinated "greenhouse" organics of global importance (carbon tetrachloride, methyl chloroform) are measured by gas chromatography (Prinn et al., 1983). It should be mentioned here that the global monitoring of another important greenhouse gas, nitrous oxide, is carried out by the same technique. Chlorinated organic compounds can be measured by headspace chromatography as described by Müller and Riedel (1987).

It seems that gas chromatography is the only existing technique to determine halogenated organics. No other general method is mentioned in the literature. There is no method recommended by international organizations (except for pesticides), though WMO (1978) has stressed the importance of their monitoring.

Heavy metals

Atomic absorption method (CMEA, 1986; ISO, 1987 (only for lead); WMO, 1978)

Technical principle:

Air is filtered by high-volume samplers on a glass fiber filter. Filters are extracted and analysed by atomic absorption spectrophotometry.

Applicability:

The method is applicable for measurement of 24-h-integrated average concentrations of Al, Cr, Fe, Ni, Cu, Zn, Cd, Hg and Pb in aerosol particles in ambient air both at impact and background stations above a concentration level of 0.002-0.4 ug/m3, depending on the element.

Disadvantages:

Several factors may interfere with the atomic absorption analyses but they can be minimized. Detection limit is not adequate for Pb and Fe.

A ctivation methods

There are other possibilities to detect the concentrations of heavy metals, e.g. neutron activation analysis (Rahn et al., 1971), and the proton induced X-ray emission (PIXE) method (Johansson et al., 1975). There are no international standards or recommendations. However, the methods mentioned are quite adequate in spite of their complexity and the cost of activation methods.

Fibres

Asbestos

Transmission electron microscopy (ISO, 1988d)

Technical principle:

Air is drawn through a polycarbonate or cellulose-ester filter. Asbestos fibres are identified and counted on the surface of the filter by transmission electron microscopy.

Applicability:

The method is applicable to the determination of the number/concentration of asbestos fibres in ambient air above a concentration level of 1800 fibres/m3. The resolution is adequate for small fibres.

Disadvantages:

A subjective factor can play a role during identification. The largest potential error may be the variability of filter samples with respect to amount of material sampled.

Light microscopy, membrane filter method (ISO, 1984)

Technical principle:

Air is drawn through a membrane filter. Fibres are identified and counted on the surface of the filter by light microscopy.

Applicability:

The method is applicable to the determination of the number concentration of fibres in air from about 0.25 um diameter and a concentration level above 100,000 fibres/m3.

Disadvantages:

Identification of asbestos fibres is not possible with this technique. Subjective factors can play a role during measurement.

Overview of asbestos measurements

There are other measurement techniques for asbestos in the literature besides the *Transmission electron microscopy* and *Light microscopy membrane filter* methodexplained above, e.g. Cherry (1983), Marconi et al. (1985). They propose a method based on scanning electron microscopy. Another important method is the IR-spectroscopy (see: e.g. Marconi, 1983; Hlavay et al., 1984). The application and standardization of these techniques are as yet unsolved regarding ambient air of the two reviewed techniques. Transmission electron microscopy is more adequate because the light microscopy method has a substantially higher detection limit which makes it unsuitable for ambient air samples.

Particulate matter

Determination of number concentration of particles by condensation nuclei counter (e.g. General Electric condensation nuclei counter) (Meszaros, 1978; WMO, 1978)

Technical principle:

Air is drawn into a humidifed and closed expansion chamber, where water vapor condenses on aerosol particles because of supersaturation. Growing particles can be detected optically.

Applicability:

The method is applicable to the semi-continuous measurement of number concentrations of aerosol particles in ambient air above a concentration level of 300 million nuclei/m3.

Disadvantages:

This technique is a relative method; calibration is difficult. Measurement below 300 million nuclei/m3 is questionable.

Determination of mass concentration of total suspended particulate matter by high-volume sampler (Meszaros, 1978; WHO, 1976; WMO, 1978)

Technical principle:

Air is drawn through a low resistance glass fiber filter by a high-volume aerosol sampler.. The air flow varies between 1-2/m3/min. The weight of exposed and unexposed filters is measured by microbalance at a relative humidity of less than 40 per cent mass concentration can be calculated from the weight difference.

Applicability:

The method is applicable to the measurement of 24-h-integrated averages of mass concentration of aerosol particles above a concentration level of l-5 ug/m3 and up to 1 0- 100 um of diameter.

Disadvantages:

Artifact aerosol generation or loss from volatile salts due to pressure reduction may cause positive or negative error. The error is generally less than a few per cent. The method can also have an indeterminate error due to the exhaust gas recirculation to the sampler inlet.

Chemical composition of aerosol particles

See: Particulate sulphate (page 26); Nitric acid and particulate nitrate (page 31); Particulate ammonium/ammonia (page 35); **Halogen and halogen compounds** (page 36); *Atomic Absorption method* and *Activation methods* (page 39).

Overview of aerosol measurements

Many international standards and recommendations exist for measuring aerosol characteristics including measurement of size distribution, mass concentration, number concentration and dry deposition in different fractions (e.g. WHO, 1976; ISO, 1980b; ISO, 1988c; WMO, 1978). From a statistical point of view, the comparison of data obtained with the help of different methods is rather difficult. However, there are some relatively simple, generally used techniques for the determination of mass and number concentrations of aerosol particles (*Determination of number concentration of particles by condensation nuclei counter* and *Determination of mass concentration of total suspendedparticulate matter by high-volume sampler* (page 41)). The number concentration of particles is practically identical with the number concentration of condensation nuclei, generally with a diameter less than 0.1 um, which are important from a meteorological point of view. In mass concentration, aerosol particles of more than 0.1 um diameter dominate. This is the fraction of particles which are responsible for optical properties of air and also the so-called respirable fraction.

Chemical composition of precipitation water

Sampling of precipitation (ECE/EMEP, 1977; ISO, 1989; WMO, 1978)

Technical principle:

Precipitation (rain, snow) is sampled by wet-only collectors (open only during precipitation fall) or by open tunnel, cleaned every day. Sampling is based on an event, a daily, weekly or monthly basis. The amount of precipitation is measured simultaneously.

Applicability:

The method is applicable to the collection of precipitation samples both at regional and global stations.

Disadvantages:

Open collectors (if used) collect dry deposition, soil dust and other contaminations from air, resulting in positive error in chemical analysis. These effects can be limited with regular cleaning of the collection bottle and tunnel. During collection for weekly or monthly samples, the composition of precipitation water can change. To avoid this effect, event or daily, collection is recommended with immediate chemical analyses.

Analyses

pH, acidity

Potentiometric method **(CMEA, 1986;** ECE/EMEP, **1977; WMO, 1978)**

Technical principle:

The potential difference between a hydrogen ion sensitive and a reference electrode is measured by a pH-meter. Voltage, electronically converted to pH units, is proportional to the hydrogen ion concentration in the sample.

Applicability:

The method is applicable to the determination of free acidity (or alkalinity) of precipitation water in terms of pH with a precision better than 0.05 pH unit.

Disadvantages:

The measurement is unreliable in diluted solutions (of low ionic strength).

Acid/base titration method (WMO, 1978)

Technical principle:

Acidity (or alkalinity) of samples is titrated by diluted sodium hydroxide or hydrochlorid acid to the neutral point of pH= 5.6.

Applicability:

The method is applicable to the determination of total (free and bounded) acidity or alkalinity of precipitation samples above a concentration of 1 uequ./l.

No known disadvantages.

Coulometric titration method (ECE/EMEP. **1977)**

Technical principle:

Acidity is titrated at a constant current with hydroxil ions, liberated at a platinum electrode. The potential difference between a hydrogen ion sensitive and a reference electrode is measured by pH-meter, read at intervals, and the results are used to construct a Gran's plot which gives the end point of the titration by extrapolation of the straight part of the curve.

Applicability:

The method is applicable to the determination of total (free and bounded) acidity of precipitation within a concentration range of 10- 1 000/uequ./l.

No known disadvantages.

Conductivity measurement by conductivity meter (WMO, *1978)*

Technical principle:

Conductivity of a precipitation sample can be directly measured by a conductivity meter with a conductivity cell.

Applicability:

The method is applicable to the precise determination of electrical conductivity, which is approximately proportional to the total ion content of the sample.

No known disadvantages.

Determination of sodium and potassium ions by atomic emission method (CMEA, 1986; ECE/EMEP, 1977)

Technical principle:

Sodium or potassium ions in a solution are transformed to atoms and partly excited in flame. The emission from excited atoms, which is proportional to the sodium or potassium concentration in the sample, is measured by flame photometer at a wavelength of emission.

Applicability:

The method is applicable to the determination of sodium and potassium in precipitation samples above a concentration of 0.05 mg/l.

No known disadvantages.

Determination of sodium, potassium, magnesium and calcium ions by atomic absorption method (CMEA, 1986; WMO, 1978)

Technical principle:

Sodium, potassium, magnesium and calcium ions are atomized in a flame. Excited atoms absorb the light at a given wavelength. Absorption, which is proportional to the ionic concentration of metals, is measured by an atomic absorption spectrophotometer.

Applicability:

The method is applicable to the determination of sodium, potassium, magnesium and calcium ions in precipitation samples above a concentration of 0.03-0.1 mg/l.

No known disadvantages.

Determination of ammonium, nitrate, chloride and sulphate ions by spectrophotometric methods (CMEA, 1986; ECE/EMEP, 1977; WMO, 1978)

Technical principle:

Ammonium, nitrate, chloride and sulphate produce coloured compounds after chemical reaction with selected reagents. The absorption of the coloured solution, which is proportional to the ionic concentration of ions, is measured by a spectrophotometer at a given wavelength.

Applicability:

The methods are applicable to the determination of ammonium, nitrate, chloride and sulphate ions in precipitation above a concentration of 0.05-0.1 mg/l.

No known disadvantages.

Overview of analyses of precipitation

All of the methods described in **Analyses** (page 43) are adequate for the determination of the chemical composition of precipitation water. On the basis of the results of international intercalibrations (see: paragraph 4.), one can say that there is no systematic difference between the different methods. In addition to the techniques included in Analyses, there are a number of other procedures for analysis of precipitation, e.g. ion chromatography. Generally, it can be concluded that all routine methods are applicable which have an appropriate sensitivity (about 0.1 mg/l). However, regular intercomparison of laboratories is necessary in order to eliminate accidental and systematic errors of analysis.

C. DERIVED CHARACTERISTICS

Dry deposition

Generally, dry deposition (expressed in g/m2 per time unit) cannot be measured directly. Usually it can be calculated as a product of surface level concentration (as measured by the methods described in paragraph 2) of the given pollutant ant the so-called deposition velocity (WMO, 1978). Deposition velocity (expressed in m/s) can be measured by different techniques (e.g. gradient method, eddy correlation method, etc.). However, deposition velocities for different places, determined by different methods, may exhibit large variations. Therefore, for the purposes of environment statistics, the measurement of ambient concentrations produces more reliable results. When dry deposition is used in comparisons attention should be paid to use the same mean deposition velocity for a given type of surface (e.g. bare soil, low vegetation, forest, water, etc.).

Wet deposition

Wet deposition (expressed in g/m2 per time unit) can be calculated as the product of the concentration of a given ion in precipitation (expressed in mg/l) and the amount of precipitation (expressed in mm/day; mm/week or mm/month, i,e, l/m2 day; l/m2 week or l/m2 month, respectively).

D. NUMERICAL DIFFERENCES BETWEEN DIFFERENT SAMPLING AND ANALYTICAL METHODS

Sulphur dioxide

In 1973, WMO organized an intercalibration in order to compare sulphur dioxide sampling and analysis in different countries. The following techniques were used and compared (WMO, 1978):

tetrachloro mercurate/West-Gaeke method
tetrachloro mercurate/isotope dilution method
hydrogen peroxide/thorin method
hydrogen peroxide/isotope dilution method
impregnated filter/isotope dilution method.

The results of one week of measurements and analysis showed that there was a difference of one order of magnitude between different laboratories, independently of the method applied.

Sulphur dioxide sulphate

In the winter of 1985/86, an intercalibration was organized by ECE/EMEP. The following sampling and analytical techniques were intercalibrated:

For sulphur dioxide:

impregnated filter/thorin method
impregnated filter/ion chromatographic method
impregnatedfilter/sulfonazo III method

tetrachloromercurate/West-Gaeke method
hydrogen peroxide/thorin method
hydrogen peroxide/ion chromatographic method

For sulphate:

filter/thorin method
filter/sulfonazo III method
filter/ion chromatographic method
filter/X-ray fluorescence method

On the basis of 79 parallel measurements, no systematic differences were found among different techniques, but the actual differences are not negligible. Good agreement was found above concentrations of 5 ug/m3. The differences were caused by differences in sampling equipment and analytical handling rather than by the selection of the method.

Ammonia/ammonium, nitric acid/nitrate, sulphur dioxide/sulphate

In a field intercomparison in Sweden (Ferm et al., 1985) of particulate and gas nitrogen and sulphur species, five laboratories sampled simultaneously by using different impregnated filters. Aerosol and gas phases were sampled by denuders. Results showed unacceptable discrepancies. A second intercalibration, when all the laboratories used similar sampling devices led to better results -- deviations were $^{+}$ 20 per cent.

This suggests again that the difference caused by the use of different sampling equipment is higher than deviation due to the application of different methods.

Three different denuder techniques and one filter pack technique were intercalibrated at a field of low ambient concentrations (CEC, 1985). According to the authors, the overall results were quite encouraging despite some relevant discrepancies. Some of the differences are due to the lack of a gas-particulate separation phase, while the reasons for other differences remained unexplained.

Nitrate/nitric acid and ammonium sampling were intercompared in the field, using among others denuder and filter pack technique (Anlauf et al., 1985). The results of sampling for nitric acid measurement correlated reasonably. However, there were high differences at night between denuder and filter pack methods. Concentrations of particulate nitrate and ammonium correlated well but some differences were observed in nitrate sampling.

Nitrogen dioxide

Field intercomparison of TGS-ANSA and the Saltzman methods (Nodop, 1985) for nitrogen dioxide showed differences. Above concentrations of 2.4 ug/m3, TGS-ANSA gave higher results. Uncertain absorption efficiency and interference of other gases (e.g. ozone) may account for differences. A reference method cannot be selected.

Nitric acid

Ten different sampling and analytical methods were intercalibrated, including chemiluminescence, infrared, denuder and sodium chloride prepared cellulose filter or Nylon filter methods (Spicer et al., 1982). Of the ten methods, five were in excellent agreement on the median. Errors seem to be independent of the applied method. Therefore, one cannot determine numerical differences between different sampling and anlytical techniques.

Precipitation sampling

The choice of both sampling technique (open- or wet-only collectors) and sampling period (event to weekly or monthly) can affect the results. Application of open collectors may cause substantial positive error (e.g. 2-3 S/per cent, Söderlund, 1982; 2-63 per cent, Horvath, 1980). Therefore wet-only collectors should be the reference.

As to the sampling period, it seems that longer sampling time leads to higher concentrations in precipitation water. Concentrations measured in weekly or monthly precipitation were in most cases higher than those calculated from daily data (UAPSP, 1986; Horvath, 1980). The differences vary as a function of sampling site, sample handling, etc., so there is no possibility to determine numerical differences between results of different samplings. Daily, wet-only sampling with immediate analysis seems to be the best approach, eliminating errors due to storage, transport, mixing and dry deposition.

Chemical analysis of precipitation

During the 10th EMEP intercomparison (ECE/EMEP, 1988b), synthetic precipitation samples were prepared and distributed to 29 national laboratories. The results show that the reported values (excluding "outliers") generally are within' 3 per cent, which can be regarded as satisfactory.

Up to now WMO has organized 11 intercalibrations (WMO, 1988). From the results of the fourth through ninth intercalibrations, it is concluded that the average deviation of laboratories (excluding outliers) is generally lower than 10 per cent.

According to a comparison between ion chromatographic and colorimetric methods, the results for different ions agree well (Stray, 1,980). 'At high nitrate concentrations; colorimetry gave lower values but the reason for this discrepancy has not been investigated.

Conclusions of intercalibrations

For the measurement of concentrations in air it seems that the use of different sampling devices may cause a more substantial difference than the application of different sampling methods. For most of the components. we cannot select a unique reference technique. Further theoretical and practical investigations and intercalibrations are needed. At the present state of knowledge, we should disregard the systematic errors between samplings during any statistical evaluation. We have to accept that an ex/post assessment of numerical differences between different technique is impossible. Further unification of sampling and analytical procedures, possible relocation of stations, quality assurance, and control of data are proposed.

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CHAPTER FOUR

ECE STANDARD STATISTICAL CLASSIFICATION OF SURFACE FRESHWATER QUALITY FOR THE MAINTENANCE OF AQUATIC LIFE
(1992)

CONTENTS

A. INTRODUCTION

Purpose, scope,. and coverage of the classification

The classification exclusively deals with surface freshwater. It aims at a statistical description of its quality from the point of view of the suitability of such water for aquatic life. A number of polluting substances that constitute risks to aquatic life are covered. Measurements of these variables are classified in five quality classes. The class limits are primarily derived from ecotoxicological considerations, but also are influenced by measurement practices. As a general rule, the orientation of the classification towards. aquatic life implies that the class limits are more conservative than they would be if targeted at other water uses.

Natural water quality is related to the hydrological regime, which is mostly governed by geological characteristics of soil, soil properties and meteorological factors such as precipitation, variation of temperature, and radiation. Ecosystems are usually adapted to the hydrological variation by natural selection. Anthropogenic discharges of polluting substances and corresponding loadings, on the other hand, are generally determined by the living conditions of the human population. Water quality information therefore needs to be linked both to hydrological conditions as described above and to discharges of polluting effluents. Linkage of water quality assessments based on this classification with hydrological considerations is at this stage left to expert evaluations. Regarding discharges, the Conference of European Statisticians will develop a special classification that is fully consistent with this classification of surface freshwater quality.

A special, related problem concerns the impact of water regulation -- usually by dams and spillways -- on quality classifications. It appears to be widely agreed that water regulation may have a strong impact on natural aquatic life in all its forms and stages. However, not enough seems to be known about how to describe such impacts in statistical terms. This classification makes a modest attempt to stimulate experimental work on the topic. Some variables for possible statistical use are proposed, but these cannot be dealt with in a way that would be analogous to the variables forming the core of the classification.

The water quality assessment on the basis of this classification does not separate natural from anthropogenic levels of pollution. Thus, no distinction is made in the numerical quality assessment between the causes of measured concentration levels of the variables included in the classification. In other words, a given level of concentration entirely due to natural processes is assessed at the same quality class as a given concentration level entirely due to pollution from human activities. The inconvenience of this procedure is that in the first of the two cases, the ecology of the water body concerned may be fully adapted to the concentration level, while in the second, a serious disturbance may exist. On the other hand, the procedure avoids a number of additional data requirements. All told, it underlines the need to complement numerical assessments made on the basis of this classification with expert interpretation of the results.

The use of the classification

The first objective is to provide conceptual and methodological guidance for collecting and compiling water- quality statistics for use in relevant international data collections. The classification also is drafted with national statistical developments in mind. That is, statistical offices needing to make generalized, national statistical statements about the quality of freshwater may undertake work similar in kind to the work pursued in the development of this classification. In such cases, the present classification can be used as a starting point.

However, the difficulties in principle with regard to generalized statistical statements about water quality, as well as various other limitations on the interpretation of actual statistics resulting from measurement practices and insufficiencies in the state of subject-matter knowledge, call for caution in the use of the classification. In general, it will be possible under certain conditions to use the classification for the purpose of describing the evolution of water quality over time for given measurement stations. Depending on the spatial representativeness of the measurement sites selected in a given study, it may also be feasible to derive suggestive presentations of water quality along rivers (or for other freshwater bodies) from an application of the classification. The same may be true for comparisons of trends in quality between different water bodies, if still additional criteria of representativeness of the measurements are met. On the other hand, it is currently clearly impossible to use the classification for comprehensive freshwater quality comparisons inside a given country or for a group of countries. Desirable as they might be, such comparative statements would presuppose the solution of a number of conceptual and methodological problems not yet resolved in this classification.

Limitations on the use of statistics compiled in accordance with this classification may also result from choices made based on principles of statistical methodology. For example, the overall perspective of assessing water quality from the point of view of aquatic life speaks in favour of the selection of some high percentile from the distribution of each water-quality variable (except those describing eutrophication) included in the classification. However, many of the variables included are not frequently measured as yet, so that not enough may be known about the distributions to select adequate percentiles. Furthermore, information on sampling frequency and other relevant methodological aspects could give some indication of the quality and comparability of the data. These and the considerations cited above generate a need to accompany the presentation of statistics with expert evaluations, so as to increase their usability and reduce the risk of misinterpretation.

Structure of the classification

The overall classification relates to two water quality aspects that have considerable impacts on aquatic life: the ecological consequences of the regulation of water bodies -- such as by dams -- and the freshwater quality of surface water bodies. Water regulation can have considerable effects on aquatic life. However, the development of a satisfactory statistical scheme that could describe these effects has not yet been completed, so coverage of this subject in the classification remains tentative. Regarding the second target aspect, water quality, the classification attempts in the first instance to provide a framework for a systematic compilation and presentation of water quality data on water bodies of international importance. They are defined as those whose water basins are shared by several countries and/or substantially contribute to coastal pollution.

Ecological consequences of water regulation

The regulation of water flow through such structures as dams may have a considerable impact on the capability of the water to maintain natural aquatic life in all its stages. However, the ongoing research for satisfactory variables or their proxies, as well as persisting uncertainties as to the interpretation of any such variable in the context of aquatic life, prevents a definitive specification of variables and corresponding class ranges at this time. Further studies of the issues involved are therefore encouraged. Such studies should, if possible, use the tentative variables suggested below. The indicative class ranges accompanying them are suggested as a starting point for the further exploration of the assessment of water quality from the point of view of maintenance of aquatic life. Any study should, however, also develop and test other variables than those proposed below, and might use different class ranges where the suggested indicative ranges are not applicable. Variables describing abundance and diversity of faunistic as well as floristic species, and variations of water regime, were mentioned as potentially interesting parameters of this sort.

The results of any such study should be made available to the ECE secretariat so that it could be taken into account during the next review of the classification, which can be expected around 1997. The aim of the statistical work on the impact of water regulation on aquatic life is to include adequate variables at the same level as the physico-chemical variables included in the classification.

The variables proposed are the following:

(a) Variable: Change of discharge [m^3/sec; percentage change caused by regulation]

(b) Variable: Neighbourhood to unregulated drainage basins [percentage of borderline of the drainage basin that is common to drainage basins of unregulated rivers]

The variable is thought to indicate the potential for genetic exchange with relatively undisturbed land surfaces.

(c) Variable: Harnessed water power [developed water power as a potential of potential capacity at mean flow]

(d) Variable: Presence of higher plants [number of sampled vascular plant, grass and fern species as a percentage of total number expected]

(e) Variable: Presence of attached algae [number of sampled attached algae species as a percentage of the total number expected]

The relevant algae for this variable are those that are attached to the bottom substrate of the river, with a special capacity to resist water pressure and tear off.

(f) Variable: Vegetation cover of littoral zone [area covered with vegetation between high and low water marks on the river embankment as a percentage of related total area]

The littoral zone of undisturbed rivers is covered by clearly stratified vegetation, while the much narrower littoral zone of regulated rivers is barely covered by plants.

(g) Variable: Presence of short-lived plants [number of species of short-lived plants as a percentage of total number of plant species on river banks]

The analysis of any use of the variables - particularly with regard to determining the consequences of water regulation for the purpose of electricity generation - should in particular pay attention to the following issues:

River types, climate, and geological conditions in the drainage area may suggest proceeding with a classification of rivers based on their degree of naturalness before proceeding with assessments based on ecological river quality.

Oxygen regime, river width, depth and slope might have to be included in the evaluation of the effects of regulation.

The type of power plant, particularly whether seasonal or short-term stockage is possible, may be more important for the purpose than variable (c).

Variables (c) and (d) should be accompanied by specification of the sampling methods.

Data availability and practicality of data collection for variables (d) to (g) may be prohibitive.

Variables (d) to (g) may require further refinement, before the could be used for purposes of comparison over time or between rivers.

The inclusion of faunistic indicators parallel to variables (d) to (g) should be considered.

The validity of and basis for the specification of class limits need to be clarified.

The tentative class ranges suggested for the variables are as follows (for definitions of classes see following table):

	I	II	III	IV	V
Variable (a)	<10	10-20	20-30	30-40	>40
Variable (b)	80-100	60-80	40-60	20-40	<20
Variable (c)	<10	10-40	40-60	60-75	>75
Variable (d)	90-100	80-90	70-80	60-70	<60
Variable (e)	>80	75-80	70-75	60-70	<60
Variable (f)	50-100	25-50	10-25	5-10	<5
Variable (g)	0-5	5-10	10-15	15-25	>25

Water quality

Generalized statements or quality descriptions on the basis of data aggregation are meant for a wider audience than raw water-quality data only. The corresponding statistics should facilitate the use of the information. This means that the statistics should be useful for statements about the hazards of freshwater pollution for aquatic life. The use of a broad range of statistical data is attempted through concentration on oxygen regime, eutrophication, acidification, pollution by heavy metals and by chlorinated micropollutants, or by other hazardous substances, or by radioactivity. Information on the characteristics of measurement stations, including hardness of the water at the stations, is added to the classification so that the significance of the measurements can be properly analysed.

The concentration of pollutants in water is strongly, sometimes inversely, correlated with flow rates. Thus standardization of measurements for changes in flow is desirable. At present, no relevant recommendation is included in the classification, such as proposals for the statistical parameter to choose for describing flow or a suggestion on which standardization formula to apply. However, the general orientation of the classification towards the requirements of aquatic life suggests the use of some “minimum flow rate” concept in standardization, rather than an average rate. It could be operationally defined as the 20th percentile of the distribution of the average daily flow rates for a multi-annual reference period. The issue should be further studied during the next international data collection which uses the classification. At that time, data should-be collected not only on the mean annual flow rate as calculated from daily means, but also for the “minimum flow rate” as defined above. Also, respondents should be requested to provide information on other definitions of minimum flow rates that might be used nationally, as well as on national standardization formulae.

Statistical aspects and conventions

Water quality statistics compiled with the help of this classification aim at generalizations on the basis of some more or less extensive volume of basic data. The condensation of the information contained in the basic data passes through the identification of representative variables and indicators at different levels of aggregation, which correspond to substantive questions they are supposed to help in answering. The basic data create awkward problems in this respect, as they may be obtained from a multitude of measurement methods, as they are often extremely time- and site-specific, and as subject-matter knowledge does not usually reflect a consensus over representative variables and indicators. In this situation, statistical generalization has to be sought largely without such “consensual guidance”, and for data that effectively resist generalization. It is therefore necessary to be careful in matters of generalization.

This classification attempts to solve the problem in four steps:

a. Groups of problems are defined that are widely considered to be relevant, but which do, not cover all currently acknowledged water-quality problems.

b. Indicative variables are selected for each group, again on the basis of wide acceptance of their relevance, although they may not all be significant in all individual water bodies.

c. Measurements are aggregated to yield summary statistical variables before their classification.

d. Summary statistical variables are further combined to result in an overall quality assessment for each of the problem areas distinguished.

If measurements are not available for a given measurement station on any of the indicative variables referred to in (b) above, it is assumed that the corresponding water quality concern is irrelevant for the measurement station. Thus, the variable would not be likely to determine the water quality class as assessed with the help of this classification.

It is expected that the use of the classification prior to the next revision, foreseen around 1997, will permit a refinement of this approach during the revision.

The choice of the statistic or statistics to be used for classification depends on both substantive and more technical considerations. The overall perspective of the classification to assess water quality from the point of view of aquatic life speaks in favour of the selection of some high percentile from the distribution of each variable -- except those describing eutrophication. However, many of the relevant variables, in particular in the area of hazardous substances, are at present not frequently measured. As a result, not enough may be known about statistical distributions to allow selection of any percentile. As more extensive measurement programmes may develop in these areas in the future, more insight into this question can be expected. If the issue cannot be resolved through special studies, it should be taken up at the time of the next international data collection. Respondents should then be asked to provide data on number of measurements, arithmetic means, 90th percentiles, and observed maxima for all variables included in the table of quality variables. The most appropriate statistical variables should then be used in the classification. The next revision of the classification should aim at making a definite choice of the statistical variable or variables to be used in the classification.

Information on sampling frequency and other methodological aspects could give some indication of the quality and comparability of data. Such information should therefore be sought in the future when collecting data on the basis of the classification.

Statistical water-quality variables are allocated to one of five classes, I to V. Parameters are grouped according to potential effects upon aquatic life. In broad terms, they are ordered according to growing hazard (such as decreasing diversity of species or toxicity) to aquatic life. The ranges of values for each variable are specified together with the variables. Interactions occur between variables in different circumstances. They need to be taken into account when evaluating ranges of concentrations based on specific concerns. The assessment of synergistic, additive, or antagonistic effects can be expected to benefit from the development of accepted biological indicators of water quality. However, current developments do not seem to be advanced to a level that would warrant the formal inclusion of such variables into the classification at this stage.

The determination of class limits is particularly difficult for metals, chlorinated hydrocarbons, and other hazardous substances. In principle, an attempt is made in this classification to derive the class limits from toxicological criteria. Class V starts at acute toxicity, and class IV begins with chronically toxic levels. While this general 'guideline' is not always easy to interpret -- for example, the extended maintenance of chronically toxic concentrations may impair ecosystems as severely as short exposure to acute levels -- a firm toxicological basis for determining class limits for classes I to III does not exist at all. Two solutions could be applied to this problem. First, as the focus of water-quality management is on anthropogenic pollution, the upper limit of class I could be approximately set at widely found natural levels of concentration. The distance between the upper limit of class I and the chronic toxicity level could then be halved and assigned to classes II and III, respectively. This procedure is selected in this classification for metals. The second approach would be to assign class III to all measures below chronic toxicity levels. This solution is practised for chlorinated micropollutants and other hazardous substances. These conventions need to be taken into account when commenting on and interpreting data compiled in accordance with this classification. It is hoped that more satisfactory solutions appear through advances in ecotoxicology and from experience with the classification.

Concentration levels alone do not always portray the same ecosystem effects because duration and frequency of exposure to toxic substances may be decisive. Moreover, different organisms have different sensitivities to exposure, and bioavailability of the toxic substances present may differ, too. On the whole, therefore, the limits specified in this classification have to be understood as indications which must be accompanied by expert judgement if any exhaustive interpretation of a specific situation is undertaken.

A further major difficulty requiring expert judgement concerns the use of dissolved or total concentrations for toxic substances. The development of criteria for dissolved concentrations is not always easy, as the substances may not be dissolved in the relevant laboratory tests. Furthermore, analytical problems are greater for dissolved measurements. Third, particulate forms might be partly bioavailable. The potential bioavailability of all forms of toxins ought to be evaluated in any water-quality assessment, whether or not the assessment is based on dissolved measurements alone. Here again, the application of this classification is expected to lead to clearer recommendations for the next revision.

The ranges for the statistical variables included in the classification table below were determined in accordance with the following principles:

Oxygen regime

Major criteria:	Oxygen content, together with presence of oxygen-demanding substances, and the impact of oxygen content levels on aquatic life	
Class interpretation:	Class I:	Constant near-saturation of oxygen content. Insignificant presence of oxygen demanding substances from the point of view of aquatic life.
	Class II:	The oxygen saturation of water is good. Oxygen demanding substances do not normally disturb oxygen saturation.
	Class III:	Oxygen deficiencies may occur in the hypolimnion. The presence of oxygen-demanding substances risks sometimes

considerable negative impacts on aquatic life through the reduction of oxygen content.

Class IV: Oversaturation of oxygen or oxygen deficiency occur in the epilimnion and oxygen deficiencies are frequent in the hypolimnion, possibly owing to chronic problems with the presence of oxygen- demanding substances.

Class V: Acute problems occur in oxygen regime, i.e. oversaturation or oxygen deficiency in the epilimnion, and oxygen deficiency leading to anaerobic conditions in the hypolimnion. The high level of presence of oxygen-demanding substances may equally cause acute oxygen deficiencies.

Eutrophication

Major criteria: Trophic state and best available expert judgement regarding the impact of trophic state on aquatic life, maintaining consistency between the three variables

Class interpretation:

Class I: Clear, oligotrophic water with, at most, a very slight, occasional anthropogenic pollution with organic matter. Low nutrient content, provides spawning grounds for salmonids.

Class II: Slightly polluted, mesotrophic water receiving small discharges of organic matter. The loadings may lead to slightly increased primary productivity.

Class III: Moderately eutrophic water receiving considerable amounts of discharges of organic matter and nutrients. The level of primary production is considerable, and some changes in community structure, including fish species, can be observed.

Class IV: Strongly eutrophic, polluted water, receiving discharges of organic matter, nutrients, and harmful substances. Algal blooms are common. Increased decomposition of organic matter together with stratification of water bodies may entail anaerobic conditions and fish kills. Mass occurrences of more tolerant species; populations of fish and benthic organisms are affected.

Class V: Extensively polluted, hypertrophic water. Decomposers dominate over producers. Fish or benthic species do not occur permanently.

Acidification

Major criteria: Toxicological impact of acidity on aquatic life as established in US-EPA practices

Class interpretation:

Class I: The buffering capacity of the water is very good.

Class II: The buffering capacity of the water is good.

Class III: The buffering capacity is weak but keeps the acidity of the water at levels still suitable for most fish.

Class IV: The buffering capacity is exceeded, leading to levels of

acidity which affect the development of spawn.
Class V: The water is without buffering capacity and its acidity is toxic for fish species.

Metals

Major criteria: Toxicological impact on aquatic life as established in US-EPA practices

Class interpretation:
Class I: No anthropogenic pollution with inorganic matter.
Class II: Concentrations are below midpoint between natural and chronically toxic levels.
Class III: Concentrations are above midpoint between natural and chronically toxic levels.
Class IV: Excursions beyond chronic criteria concentrations occur, but do not establish chronically toxic conditions in terms of concentration levels, duration or frequency.
Class V: Excursions beyond chronic criteria concentrations allow acutely toxic conditions in terms of concentration levels, duration or frequency.

Chlorinated micropollutants and other hazardous substances

Major criteria: Toxicological impact on aquatic life as established in US-EPA practices

Class interpretation:
Class I: Not applicable
Class II: Not applicable
Class III: Loadings are evident, but concentrations are below chronic and acute criteria levels.
Class IV: Excursions beyond chronic criteria concentrations occur, but do not establish chronically toxic conditions in terms of concentration levels, duration or frequency.
Class V: Excursions beyond chronic criteria concentrations allow acutely toxic conditions in terms of concentration levels, duration or frequency.

Radioactivity

Major criteria: Toxicological impact on aquatic life

Class interpretation: [To be determined after experience is gained through data collection and interpretation.]

Generally, the statistical variables are reported as annual values for total water masses in lakes or rivers. However, in stratified waters, separate DO(%)-values are required for the epilimnion and the hypolimnion. Regarding dissolved oxygen concentrations, both ranges of oxygen deficiency and of oversaturation are shown in quality classes II to V. Variables proposed to evaluate eutrophication are reported for the growth period.

Data should be obtained for measurement stations which are representative of river stretches or, in the case of lakes, of segments of the surface of lakes. River stretches and lake segments should be determined in such a way that the water concerned can, from a practical point of view, be regarded as being relatively homogeneous in terms of overall quality. If more than one station is representative in the above sense, simple arithmetic averages should be calculated for a given variable across all such stations before a quality class is assigned to the stretch or segment of lake surface concerned.

Measurement values should be reported for individual stations. The following characteristics of measurement stations should accompany the quality data (in addition to information implied in above references to future work on the classification regarding adjustment for flow rate):

- Name, geocode and water body of the measurement station
- Type of station (baseline or impact)
- River stretch or lake segment for which the station is representative (geocoded)
- Water level at the station
- Average depth of river or lake in the measurement area
- River width at measurement station
- Upstream basin area [km^2]
- Area upstream of tidal limit [km^2]
- Surface of lake [km^2]
- Average total water hardness for each period for which data are reported

The quality assigned to any of the six sections of the classification or to overall quality across all variables equals the worst quality class assigned to any one individual variable, respectively. A combination of the section indices into one overall index is not proposed, as it would be impossible to interpret such an index in a meaningful way.

Presentation of statistics

Data should be presented for individual measurement stations. Presentation of statistics should be accompanied by explanatory text. That is needed first of all to help reconcile any discrepancies between national standards (which may not follow the general emphasis here on aquatic life maintenance) and those of this classification scheme. Second, international comparability of the results obtained through this classification entails the need for specification of a standard list of variables, which usually will differ from national lists. Third, as mentioned in the introductory section above, comments are necessary on the relationship between natural and man-made causes of levels of water quality. Finally, conventions will also differ between different classifications. Thus, respondents are strongly encouraged to submit, together with their replies, full explanations of any relevant differences between national water-quality assessments and this international assessment.

Further needs for explanations arise from the necessarily incomplete adaptation of this general classification scheme to the peculiarities of each given water body. Also, interdependencies may exist between quality variables that can best be captured through narrative statements qualifying the statistical measures. Some environmental factors such as water hardness influence the form and toxicity of some compounds; these factors and synergisms between toxins should be taken into account in quality assessments. The effect of variables other than those included in the classification ought to be taken into account in expert statements, too. Expert statements should mention any presence of “seasonal shocks” in the behaviour of quality variables over time, such as any prevalence of very low pH values in spring (“acid shock”).

The forms in which data are presented should be well adapted to the statistical quality aspects of the data. However, little is currently known about the optimal relationships between data quality and presentation.

Further work

Two topics merit specific attention.

In national practice, water quality assessments are usually based on physico-chemical parameters which measure compliance with prescribed standards. However, some countries also use biological variables. Biotic indices monitor the composition of communities and changes in the abundance and diversity of species following water quality changes. Scoring of changes is based on the susceptibility of certain taxonomic groups to pollution; the scales of biotic indices vary between countries. The use of biological indicators for describing water quality is considered a promising complement to assessments based on physico-chemical variables, and is encouraged. At this time, it is believed that the general use of saprobic indices may be one of the possibilities for beginning to include biological indices or indicators in the classification. Future work in this direction could therefore start with a systematic analysis of experiences in using saprobic indices.

The specification of rules concerning the relationship between sampling frequencies and data quality is equally left to further work. It is suggested that any international collection of data in accordance with this classification pay special attention to this question and make information on the results of any related investigation available.

B. CATEGORIES OF THE CLASSIFICATION

The table below contains variables and quality ranges by class. The specification of class ranges for COD-Cr and for free ammonia is left to practical experience with the classification. Values for flowing water are given in parentheses. Unbracketed values refer to both stagnant and flowing water bodies, or, if accompanied by bracketed values, to stagnant water. The abbreviations used in the table are the following:

DO	Dissolved oxygen
COD-Mn	Chemical oxygen demand, assessed by the permanganate method
COD-Cr	Chemical oxygen demand, assessed by the dichromate method
O_2	Oxygen
P	Phosphorus
N	Nitrogen
μg/l	micro-grammes per litre
mBq/l	milli-becquerel per litre
n.a.	not applicable

TABLE: VARIABLES AFFECTING AQUATIC LIFE AND THEIR CONCENTRATION RANGES BY QUALITY CLASS

	I	II	III	IV	V
A. Oxygen regime					
DO (%) epilimnion (stratified waters)	90-110	70-90,110-120	50-70,120-130	30-50,130-150	<30,>150
hypolimnion (stratified waters)	*90-70*	70-50	50-30	30-10	<10
Unstratified waters	90-70	70-50,110-120	50-30,120-130	30-10,130-150	<10,>150
DO (mg/l)	>7	7-6	6-4	4-3	<3
COD-Mn (mg 0_2/l)	<3	3-10	10-20	20-30	>30
COD-Cr (mg 0_2/l)	...	...		...	...
B. Eutrophication”					
Total P (µg P/l)	<10(<15)	10-25(15-40)	25-50(40-75)	50-125(75-190)	>125(>190)
Total N (µg N/l)	<300	300-750	750-1500	1500-2500	>2500
Chlorophyll a (µg/l)	<2.5(<4)	2.5-10(4-15)	10-30(15-45)	30-110(45-165)	>110(>165)
C. Acidification					
pH (values <9.0 only)[b]	9.0-6.5	6.5-6.3	6.3-6.0	6.0-5.3	<5.3
Alkalinity (mg $CaCO_3$/l)	>200	200-100	100-20	20-10	<10
D. Metals					
Aluminium (µg/l;pH:<6.5)	<1.6	1.6-3.2	3.2-5	5-75	>75
Arsenic (µg/l)	<10	10-100	100-190	190-360	>360
Cadmium (µg/l)[d]	co.07	0.07-0.53	0.53-1.1	1.1-3.9	>3.9
Chromium (µg/l)	<1	1-6	6-11	11-16	>16
Copper (µg/l)[d]	<2	2-7	7-12	12-18	>18
Lead (µg/l)[d]	<0.1	0.1-1.6	1.6-3.2	3.2-82	>82
Mercury (µg/l)[d]	co.003	0.003-0.007	0.007-0.012	0.012-2.4	>2.4
Nickel (µg/l)[d]	<15	15-87	87-160	160-1400	>1400
Zinc (µg/l)[d]	<45	45-77	77-110	110-120	>120
E. Chlorinated micropollutants and other hazardous substances					
Dieldrin (µg/l)	n.a.	n.a.	<0.0019	0.0019-2.5	>2.5
DDT and metabolites (µg/l)	n.a.	n.a.	<0.001	0.001-1.1	>1.1
Endrin (µg/l)	n.a.	n.a.	<0.0023	0.0023-0.18	>0.18
Heptachlor (µg/l)	n.a.	n.a.	<0.0038	0.0038-0.52	>0.52
Lindane (µg/l)	n.a.	n.a.	<0.08	0.08-2.0	>2.0
Pentachlorophenol (µg/l)	n.a.	n.a.	<13	13-20	>20
PCBs (µg/l)	n.a.	n.a.	co.014	0.014-2.0	>2.0
Free ammonia (NH,)	n.a.	n.a.		...	...
F. Radioactivity					
Gross a-activity (mBq/l)	<50	50-100	100-500	500-2500	>2500
Gross p-activity (mBq/l)	<200	200-500	500-1000	1000-2500	>2500

Note: Measures falling on the borderline between classes are to be classified in the lower numbered class.

[a] Bracketed data refer to flowing water.

[b] Values >9.0 are disregarded in classification of group C.

[c] Applicable for hardness from about 0.5meq/l to 8meq/l. Arsenic V (chromium III) to be converted to arsenic III (chromium VI).

[d] Applicable for hardness from about 0.5meq/l to 8meq/l.

[Class ranges for As and Cr will have to be aligned in future work on the criteria for the determination of class limits.]

ANNEX:

SURVEY OF WIDELY USED ANALYTICAL METHODS FOR THE MEASUREMENT OF CONCENTRATIONS OF WATER POLLUTANTS

Table of contents

A. INTRODUCTION

This annex covers selected sampling and analytical methods used in measuring freshwater pollutants. The selection is made from recommendations by the International Organization for Standardization (ISO), World Health Organization (WHO), Economic Commission for Europe (ECE), the Standard Methods Committees of the American Water Works Association and the Water Pollution Control Federation, the Subcommittee on Standard Methods for the Examination of Water and Wastewater, and the Commitee on Laboratory Standards and Practices of the American Public Health Association. In some cases, where recommendations are lacking, generally used routine sampling and analytical techniques are described.

B. SAMPLING AND ANALYTICAL METHODS OF DIRECTLY MEASURED CHARACTERISTICS

Oxygen regime and eutrophication

Total nitrogen

If it is required to report the results as total nitrogen, this can be calculated by adding the values of nitrate, nitrite, ammonia, and organic nitrogen. Nitrogen gas dissolved in water is not included. All individual components should be expressed as mg/l N. When the inorganic components are expressed as ions, the following equation should be used:

$$0.23(NO_3^-) + 0.30(NO_2^-) + 0.78(NH_4^+) + \text{organic N} = \text{total nitrogen N (mg/l)}$$

Ammonia

Phenate method (WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of ammonia in water within a concentration range of 10 µg N/l - 500 µg N/l.

Principle:

An intensively blue compound, indophenol, is formed by the reaction of ammonia, hypochlorite, and phenol catalyzed by a manganous salt in an alkaline medium (10.X pH < 11.5). Spectrophotometric measurement of the blue colour obtained at 630 nm.

Sampling:

Residual chlorine should be immediately destroyed after sample collection to prevent its reaction with ammonia. If prompt analysis is impossible, samples should be preserved with 0.8 ml conc H_2SO_4 /l sample and stored at 4°C. The pH of the preserved samples should be between 1.5 and 2.

Interferences:

Over 500 mg/l alkalinity, over 100 mg/l acidity, colour and turbidity interfere. These interferences may be removed by preliminary distillation.

Ammonia

Selective electrode method (Standard Methods, 1989)

Applicability:

Determination of ammonia in water within a concentration range of 0.03 mg NH_3-N/l - 1400 mg NH,-N/l.

Principle:

The ammonia-selective electrode uses a hydrophobic gas-permeable membrane to separate the sample solution from an electrode internal solution of ammonium chloride. Dissolved ammonia ($NH_{3(aq)}$ and NH,‘) is converted to $NH_{3(aq)}$ by raising the pH to above 11 with a strong base. NH,,, diffuses through the membrane and changes the pH of the internal solution which is sensed by a pH electrode. The fixed level of chloride in the internal solution is sensed by a chloride ion-selective electrode that serves as the reference electrode. Potentiometric measurements are made with a pH meter having an expanded millivolt scale or with a specific ion meter.

Sampling:

Sampling is the same as in *Phenate method* (page 66)

Interferences:

Mercury and silver interfere by complexing with ammonia.

Distillation and titration method (ISO, 198 ; WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of ammonia in water with a concentration greater than 5 mg NH_3-N/l.

Principle:

Ammonia can be quantatively recovered from a sample by distillation under alkaline conditions into a solution of boric acid and determination by titration with standard acid.

Sampling:

Sampling is the same as in *Phenate method* (page 66)

Interferences:

Volatile amines interfere with the acid titration.

Distillation and Nesslerization method

Applicability:

The method is applicable to the determination of ammonia in water within a concentration range of 20 µg NH_3-N/l - 5 mg NH_3-N/l.

Principle:

Ammonia is quantitatively recovered by distillation under alkaline conditions and determined colorimetrically after the addition of Nessler's reagent.

Sampling:

Sampling is the same as in *Phenate method* (page 66)

Interferences:

A Nesslerized solution should be clear and yellow or brown. Any substance which produces a colour or turbidity with the reagent clearly interferes with the test, as for example some aliphatic and aromatic amines, organic chloramines, ketones, aldehydes and alcohols.

Kieldahl nitrogen (WHO, 1987; Standard Methods, 1989)

Applicability:

Kjeldahl nitrogen is defined as the sum of ammonia nitrogen and those organic nitrogen compounds converted to ammonium sulfate under the conditions of the digestion procedure described below. The organic Kjeldahl nitrogen is obtained by subtracting the value of ammonia nitrogen from the Kjeldahl nitrogen value; alternatively it may be determined directly by removal of ammonia before digestion.

Principle:

The sample is heated in the presence of sulfuric acid and a catalyst, alcohol also being added to ensure removal of oxidized nitrogen. After digestion, the solution is diluted and made alkaline with sodium hydroxide. The ammonia is distilled from the solution and determined by Nesslerization or, if sufficienly large amounts are present, by titration.

Sampling:

Decomposition of organic nitrogen to ammonia may occur in samples between collection and analysis. This effect may be decreased by the addition of 2 ml of sulfuric acid (d=1.84) per litre of sample and storage at 4°C, but it is prudent to analyse all samples as soon as possible after collection.

Interferences:

Neither this method nor any other single method can guarantee that every organic nitrogen compound will be broken down to ammonia. Nitrate and nitrite should be removed earlier to avoid significant errors.

Nitrate

2,6 - Dimethylphenol spectrometric method (ISO, 1986)

Applicability:

The method is applicable to the determination of nitrate in water with a concentration of up to 25 mg/l.

Principle:

Nitrate reacts with 2,6 - dimethylphenol in the presence of sulfuric and phosphoric acids and produces 4-nitro-2,6-dimethylphenol. The reaction time is about 5 min. Spectrometric measurement of the absorbance of the reaction product should be made at 324 nm. The nitrate concentration should be taken from a calibration graph.

Sampling:

Samples should be collected in glass or polyethylene bottles and should be analysed as soon as possible after collection. Storage of samples between 2 and 5°C may preserve many types of sample, but tests should be made to confirm this for each sample type.

Interferences:

Potential interference from nitrite nitrogen at concentrations of up to 5 mg/l is controlled by the use of amidosulfonic acid. Chloride may seriously interfere, but can be removed by addition of silver sulfate to the test sample and filtration prior to taking the test portions.

Spectrometric method using sulfosalicylic acid (ISO, *1988)*

Applicability:

The method is applicable to the determination of nitrate in water with concentration up to 0.2 mg/l.

Principle:

Spectrometric measurement of the yellow compound formed by reaction of sulfosalicylic acid (formed by addition to the sample of sodium salicylate and sulfuric acid) with nitrate and subsequent treatment with alkali.

Sampling:

Samples should be collected in glass bottles and should be analysed as soon as possible after collection. Storage of samples between 2 and 5°C may preserve many types of sample, but tests should be made to confirm this for each sample type.

Interferences:

The main potential interferents are chlorine, orthophosphate, magnesium and manganese (II).

Cadmium reduction method (WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of nitrate in water within a concentration range of 0.01 mg NO;-N/l - 1 .O mg NO_3^--N/l.It is recommended especially for NO,‘ levels below 0.1 mg N/l.

Principle:

Nitrate is reduced to nitrite when a sample is passed through a column containing either amalgamated cadmium granulate or filings (method A), or a granulated cadmium-copper catalyst (method B). The nitrite produced thus is determined by diazotizing with sulfanilamide and coupling with N-(1 -naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye that is measured colorimetrically at 540 nm.

Sampling:

To prevent any change in the nitrogen balance, the nitrate determination should be started promptly after sampling. If storage is necessary, samples should be kept at a temperature just above the freezing point, with or without preservatives such as H_2SO_4(0.8 ml conc H_2SO_4 per liter of sample).

Interferences:

Low results might be obtained for samples that contain high concentrations of iron, copper, or other metals. EDTA is added to the samples to eliminate this interference. Samples that contains a large concentration of oil and grease will coat the cadmium surface. This interference is eliminated by pre-extracting the sample with an organic solvent.

Nitrite

Sulfanilamide photometric method (WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of nitrite nitrogen in water within the concentration range of 0.01 mg/l- 1.0mg/l. Samples containing higher concentrations must first be diluted.

Principle:

Nitrite reacts with sulfanilamide in a strongly acid medium. The resulting diazo compound is coupled with N-(1-naphthyl)-ethylenediamine dihydrochloride to form an intensely red-coloured azo-compound. The absorbance of the dye is proportional to the concentration of nitrite present.

Sampling:

*The nitrite concentration in collected samples can change very rapidly owing to bacterial oxidation or reductive conversions. Therefore, the determination should be made promptly on fresh samples. Acid preservation should be strictly avoided for samples to be analysed for nitrite. Short-term preservation for l-2 days is possible by deep-freezing at -20°C.

Interferences:

There are very few known interferences at concentrations below 1000 times that of the nitrite. However, the presence of strong oxidants or reductants in the samples will readily affect the nitrite concentrations. High alkalinity (>600 mg/l as $CaCO_3$) will give low results owing to a shift in pH.

Dissolved oxygen (DO)

The Winkler or iodometric method (ISO, 1983; WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of dissolved oxygen in all types of water samples with dissolved oxygen concentrations greater than 0.2 mg/l, up to double saturation of oxygen (approximately 20 mg/l), and free from interfering substances.

Principle:

The method is based on the addition of divalent manganese solution, followed by strong alkali, to the sample in a glass-stoppered bottle. DO rapidly oxidizes an equivalent amount of the dispersed divalent manganous hydroxide precipitate to manganese hydroxides of higher valency states. In the presence of iodide ions in an acidic solution, the oxidized manganese reverts to the divalent state, with the liberation of iodine equivalent to the original DO content.The iodine is then titrated with a standard solution of thiosulfate.

Sampling:

The sample must be carefully collected without changing the concentration of dissolved oxygen. Any contact with air or agitation has to be avoided. After the sample has beentaken, 1 ml of the manganese (II) sulphate solution and 2 ml of the alkaline reagent should be added. The sample may be stored for up to 24 hours, if it is protected from light.

Interferences:

Interference is caused by certain oxidizing agents liberating iodine from iodides (ozone, chlorine dioxide, ferric compounds, manganese in III or higher oxidation states, chromate, nitrates, persulfate, peroxides), by certain agents reducing iodine to iodide (ferrous compounds, thiosulfate, sulfite, and readily oxidizable organic matter), whether in solution or in suspension. Some organic compounds hinder the settling of the precipitate; some obscure the end point of the titration by their colour. Biological floccules such as activited sludge mixtures may have very rapid oxygen utilization rates and thus lower quickly the concentration of dissolved oxygen.

The Winkler or iodometric method / azide modification (ISO, *1983;* WHO, 1987; Standard Methods, 1989)

Applicability:

The azide modification of the method effectively removes interference caused by nitrite with a concentrations above 50 µg/l and by ferrous ions below 1 mg/l. If lml KF solution is added before the sample is acidified and there is no delay in titration, the method is applicable in the presence of 100 to 200 mg ferric ion/l.

Principle:

Similar to the principle described in The *Winkler of iodometric method* (page 71) As a main difference, in this modification of the method, a certain amount of sodium azide (NaN_3) should be added for the reaction. Nitrites up to a concentration of 15 mg/l do not interfere with the determination because they are destroyed by the addition of sodium azide.

Sampling:

Sampling is the same as in The *Winkler of iodometric method* (page 71)

Interferences:

The azide modification is used for samples containing more than 50 µg NO_2^--N/l and not more than 1 mg ferrous iron/l. Other reducing or oxidizing materials should be absent. If 1 ml KF solution is added before the sample is acidified and there is no delay in titration, the method is applicable in the presence of 100 to 200 mg ferric iron/l.

Electrochemical probe method (ISO, 1990; WHO, 1987: Standard Methods, 1989)

Applicability:

The method is applicable to the determination of dissolved oxygen in all types of water samples having dissolved oxygen concentrations greater than 0.2 mg/l.

Principle:

Oxygen-sensitive membrane electrodes of the polarographic or galvanic type are composed of two solid metal electrodes in contact with the supporting electrolyte separated from the test solution by a selective membrane. The basic difference between the galvanic and the polarographic methods is that in the former the electrode reaction is spontaneous (similar to that in a fuel cell), while in the latter an external source of applied voltage is needed to polarize the indicator electrode. Polyethylene and fluorocarbon membranes are used commonly because they are permeable to molecular oxygen and are relatively rugged. In all instruments, the “diffusion current” is directly proportional to the concentration of molecular oxygen.

Sampling:

Sampling is the *same* as in The *Winkler of iodometric method* (page 71)

Interferences:

Organic solvents that attack or dissolve the membrane material will cause misreadings, and there is some evidence that prolonged immersion in certain oils can block the molecular structure of the membrane. Gases such as hydrogen sulfide or prolonged exposure to chlorine tend to lengthen the response time and finally lower the electrode sensitivity.

Phosphorus

Ammonium molybdate spectrometric method (ISO, 1986; WHO, 1987)

Applicability:

Determination of orthophosphate and total phosphorus in water with a concentration more than 5 µg P/l.

Principle:

The soluble orthophosphate is determined by colorimetric tests. Other phosphorus compounds have to be converted to soluble orthophosphate by preliminary hydrolysis or by oxidative destruction (total phosphorus). Orthophosphate (for concentrations greater than 20 µgP/l) reacts with ammonium molybdate to form molybdophosphoric acid, which is transformed by reductants to the intensively coloured complex known as molybdenum blue. The method based on reduction with ascorbic acid is preferable. Addition of potassium antimonyl tartrate increases the coloration and the reaction velocity at room temperature. For concentrations of phosphate below 20 µg/l, recommended procedure involves extraction of the molybdenum blue complex from up to 200 ml of water into a relatively small volume of hexanol in order to obtain a considerable increase in sensitivity.

Sampling:

Samples should be collected in glass bottles rinsed several times with hot diluted HCl and distilled water. Preservation of samples is realised by freezing at/or below - 10°C. Samples containing low concentrations of phosphorus cannot be stored in plastic bottles because phosphorus may be absorbed onto the walls of the bottles.

Interferences:

The method is relatively free from interference. Arsenates produce a blue colour similar to that formed with phosphate. They interfere in concentrations as low as 0.1 mg/l. In most water samples, however, arsenates are not present. If necessary, their concentrations can be subtracted from the result.

Chemical oxygen demand

Dichromate method (ISO,1989; WHO,1987)

Applicability:

This method is applicable to the analysis of surface waters samples having a COD in the range of 5 mg/l - 50 mg/l.

Principle:

The types of organic matter are oxidized with the help of a boiling mixture of chromic and sulfuric acids. A sample is refluxed in strongly acid solution with a known excess of potassium dichromate ($K_2Cr_2O_7$). After digestion the remaining unreduced potassium dichrimate is titrated with ferrous ammonium sulfate (FAS), the amount of potassium dichromate consumed is determined, and the amount is calculated in terms of oxygen equivalent.

Sampling:

Samples should preferably be collected in glass bottles, although polyethylene containers are also suitable, if no organic contaminants are present in the containers. Samples may be preserved with 2 ml of concentrated H_2SO_4 per liter of sample. If samples are to be stored for longer than 24 hours, deep freezing is recommended.

Interferences:

Straight-chain aliphatic compounds, aromatic hydrocarbons, and pyridine are not oxidized to any appreciable extent, although this method gives more complete oxidation than the permanganate method. The straight-chain aliphatic compounds are more effectively oxidized when silver sulfate is added as a catalyst; however, silver sulfate reacts with chlorides, bromides, or iodides to produce precipitates that are only partially oxidized.

There is no advantage in using the catalyst in the oxidation of aromatic hydrocarbons, but it is essential for the oxidation of straight-chain alcohols and acids.

Nitrite nitrogen accounts for a COD of 1.14 mg per mg of nitrite nitrogen. To eliminate a significant interference due to nitrites, sulfamic acid at a rate of 10 mg for every 1 mg of nitrite nitrogen in the refluxing flask may be added. Thus, 120 mg of sulfamic acid per litre of dichromate solution will eliminate the interference of up to 6 mg of nitrite nitrogen per litre in the sample if a 20-ml sample is used.

Ferrous iron and hydrogen sulfide generate CODs of 0.14 mg per mg Fe^{2+} and 0.47 mg per mg H_2S, respectively. Appropriate corrections can be calculated and subtracted from the result or both interferences can be avoided by bubbling air through the sample, if volatile organic compounds are not present.

Permanganate method

Applicability:

The method is applicable to the analysis of surface water samples having a COD in the range of 5mg/l - 50 mg/l.

Principle:

The method is based on the oxidation of organic matter in the sample with potassium permanganate of a given concentration, addition of a prescribed amount of sulfuric acid and boiling. The excess of permanganate at the end of the oxidation is determined after addition of a known amount of standardized oxalic acid solution followed by the retitration with permanganate.

Sampling:

Samples shall be collected preferably in glass bottles, although polyethylene bottles are also suitable, if it is known that no organic contaminants are present in the containers. Samples may be preserved with 2 ml of concentrated H_2SO_4 per liter of sample. If samples are to be stored for longer than 24 hours, deep freezing is recommended.

Interferences:

High concentrations of chlorides. Their effect could be reduced by dilution of the sample, or by performing the oxidation in an alkaline medium.

Metals

Flame atomic absorption spectrometry

Principle:

Atomic absorption spectrometry resembles emission flame photometry in that a sample is aspirated into a flame and atomized. The major difference is that in flame photometry the amount of light emitted is measured, whereas in atomic absorption spectrometry a light beam is directed through the flame, into a monochromator, and onto a detector that measures the amount of light absorbed by the atomized element in the flame. For some metals, atomic absorption exhibits superior sensitivity over flame emission. Because each metal has its own characteristic absorption wavelength, a source lamp composed of that element is used; this makes the method relatively free from spectral or radiation interferences. The amount of energy at the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample over a limited concentration range. In conventional flame atomic absorption spectrometry, the cell is usually a 10- 12 cm air/acetylene flame or a 5 cm nitrous oxide/acetylene flame, though other gas mixtures and burner designs have been employed. However, alternative types of cells have been introduced in order to gain increased sensitivity, and these are now quite widely used in water analyses. They include the cold vapor system (for mercury), the heated tube/hydride system (for hydride-forming elements such as arsenic and selenium) and the various graphite or metal furnaces, rods and filaments (all electrically heated) which have become known collectively as electrothermal atomisers. Because requirements for determining metals by atomic absorption spectrophotometry vary with metal and/or concentration to be determined, the method is divided into several modifications, as follows:

A. Determination of cadmium, chromium, copper, lead, nickel, and zinc by direct aspiration of a sample into an air-acetylene flame.
B. Determination of low concentrations of cadmium, chromium, copper, lead, nickel, and zinc by chelation with ammonium pyrrolidin dithiocarbamate (APDC), extraction into methyl isobutyl ketone (MIBK) for metal concentration, and aspiration of a sample into an air-acetylene flame.
C. Determination of aluminium by direct aspiration of a sample into a nitrous oxide-acetylene flame.
D. Determination of low concentrations of aluminium by chelation with 8-hydroxyquinoline, extraction into MIBK, and aspiration into a nitrous oxide-acetylene flame.
E. Determination of arsenic by conversion to its hydride and aspiration into an argon-hydrogen or nitrogen-hydrogen flame: inorganic arsenic is reduced by sodium borohydride reagent in arsenic hydride (AsH_3), which is passed into the hydrogen flame of an atomic absorption spectrometer using argon as the carrier gas.
F. Determination of mercury by the cold-vapor technique.
G. Determination of micro quantities of aluminium, arsenic, cadmium, chromium, copper, lead, and nickel by electrothermal atomic absorption spectrometry.

This principle applies to all methods reviewed in this section, except where stated otherwise.

Aluminium

Atomic absorption spectrometric method / modifications C, D and G (WHO, 1987; Standard Methods, 1989)

Applicability :

Three modifications of the method are applicable to the determination of aluminium in water with a concentration more than 20 µg/l at a wavelength of 309.3 nm:

Modification C -- direct aspiration of a sample into a nitrous oxide-acetylene flame, when the concentration of aluminium in water is more than 5 mg/l. Detection limit is 0.1 mg/l. Optimum concentration range is 5 - 100 mg/l.

Modification D -- 8-hydroxyquinoline-MIBK extraction procedure with sample concentration, when concentration of aluminium in water is less than 900 µg/l.

Modification G -- electrothermal atomic absorption spectrometry, when concentration of aluminium in water is less than 250 µg/l. Detection limit is 3 µg/l. Optimum concentration range is 20 µg/l - 200 µg/l.

Sampling:

As aluminium may be lost from the solution to the walls of the sample containers, samples should be acidified with 1.5 ml of concentrated HNO_3/litre of sample prior to storage in plastic containers. If the pH is not less than 2 after the addition of acid, more HNO_3 should be added. If analyses are to be made of soluble metal fractions, samples should be filtered through 0.45 µm membrane filters as soon as possible after collection and then the filtrate should be acidified.

Interferences:

In modification C - Aluminium is partly ionized in the nitrous oxide-acetylene flame. This problem may be controlled by the addition of an alkali metal to both sample and standard solutions.

In modification D - Concentrations of Fe greater than 10 mg/l interfere by suppressing Al absorption. Iron interference can be masked by addition of hydroxylamine hydrochloride/l,lO-phenanthroline. Mn concentrations up to 80 mg/l do not interfere if turbidity in the extract is allowed to settle. Mg forms an insoluble chelate with 8-hydroxyquinoline at pH 8.0 but tends to remove the Al complex as a coprecipitate. However, the Mg complex forms slowly over 4 to 6 min; its interference can be avoided if the solution is extracted immediately after buffering.

In modification G - Chemical interaction of the graphite tube with various elements to form refractory carbides occurs at high charring and atomization temperatures. Elements that form carbides are. barium, molybdenum, nickel, titanium, vanadium, and silicon. Carbide 'formation is characterized by broad, tailing atomization peaks and reduced sensitivity. Using pyrolytically coated tubes for these metals minimizes the problem. For the analysis of aluminium, thorium treated L'vov platforms provide sharper peaks at low concentrations and enhanced charring stability.

Eriochrome cyanine R method (WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of aluminium in water. The optimum concentration range lies between 20 µg/l and 300 µg/l, but can be extended upward by sample dilution. The minimum aluminium concentration detectable by this method in the absence of fluorides and complex phosphates is approximately 6 µg/l.

Principle:

With Eriochrome cyanine R dye, dilute aluminium solutions buffered to a pH of 6.0 produce a red to pink complex that exhibits maximum absorption at 535 nm.

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method / modifications* (page 76)

Interferences:

Negative errors are caused by both fluorides and polyphosphates. When the fluoride concentration is constant, the percentage error decreases with increasing amounts of aluminium. Because the fluoride concentration often is known or can be determined readily, fairly accurate results can be obtained by adding a known amount of fluoride to a set of standards. A simpler correction can be determined from the family of given curves. Orthophosphates in concentrations under 10 mg/l do not interfere. The interference caused by even a small alkalinity is removed by acidifying the sample just beyond the neutralization point of methyl orange. Sulfate does not interfere up to a concentration of 2000 mg/l.

Arsenic

Atomic absorption spectrometric method / modification E and G (WHO, 1987; Standard Methods, 1989)

Applicability:

Two modifications of the method are applicable to the determination of arsenic in water within a concentration range of 2 - 100 µg/l and at a wavelength of 193.7 nm.

Modification E - conversion of arsenic to its hydride and aspiration into a nitrogen-hydrogen flame. Detection limit is 0.002 mg/l and the optimum concentration range is 0.002 mg/l - 0.02 mg/l.

Modification G - electrothermal atomic absorption spectrometry, without extraction or sample concentration, when concentration of arsenic in water is greater than 5 µg/l. Detection limit is 1 µg/l. Optimum concentration range is 5 µg/l - 100 µg/l.

Sampling:

Samples should be collected in polyethylene bottles and acidified with concentrated sulfuric acid (2 ml/l of a sample) if they are to be stored.

Interferences:

In modification E interferences are minimized because arsenic hydride is removed from the solution containing most potential interfering substances. Concentrations of copper, lead, and nickel at or greater than 1 mg/l, and concentrations between 0.1 and

1 mg/l of hydride-forming elements (Bi, Sb, Sn, and Te) may suppress the response of arsenic hydride.

Silver diethyldithiocarbamate spectrophotometric method (ISO, *1982;* WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of arsenic in water within a concentration range of 0.001 mg/l - 0.1 mg/l. The minimum detectable quantity of arsenic is 1 µg.

Principle:

Inorganic arsenic is reduced to arsenic hydride (AsH_3, arsin) by zinc in acid solution in a Gutzeit generator. The arsin is then passed through a scrubber containing glass wool impregnated with lead acetate solution and into an absorber tube containing silver diethyldithiocarbamate dissolved in pyridine or chloroform. In the absorber, arsenic hydride reacts with the silver salt, forming a soluble red complex suitable for photometric measurement.

Sampling:

Samples should be collected in polyethylene bottles and acidified with concentrated sulfuric acid (2 ml/l of a sample) if they are to be stored. Nitric acid interferes in the determination.

Interferences:

Although certain metals (chromium, cobalt, copper, mercury, molybdenum, nickel, platinum, and silver) interfere in the generation of arsenic hydride, the concentrations of these metals normally present in water do not interfere significantly. Antimony salts in the sample form antimonious hydride (stibin), which interferes with colour development by yielding a red color with maximum absorbance at 5 10 nm.

Cadmium

A tomic absorption spectrometric method / modifications A, B and G (ISO, 1986; WHO, 1987; Standard Methods, 1989)

Applicability:

Three modifications of the method are applicable to the determination of cadmium in water with a concentration of more than 0,5 µg/l at a wavelength of 228.8 nm:

Modification A - direct aspiration of the sample into an air-acetylene flame when the concentration of cadmium in water is greater than 0.05 mg/l and when there are no known interferences. Detection limit is 2 µg/l. Optimum concentration range is 0.05 mg/l - 2 mg/l.

Modification B - APDC-MIBK extraction procedure with sample concentration, when the concentration of cadmium in water is less than 0.05 mg/l, when samples are of a complex or unknown nature and when they contain high concentration of dissolved solids. Optimum concentration range is 0.5 µg/l - 50 µg/l.

Modification G - electrothermal atomic absorption spectrometry (graphite furnace replaces the standard burner head) without extraction or sample concentration, when the concentration of cadmium in water is less than 0.05 mg/liter.Detection limit is 0.1 µg/l. Optimum concentration range is 0.5 µg/l - 10 µg/l.

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method/modifications* (pp. 76-V)

Interferences:

Modification B is not applicable when the chemical oxygen demand (COD) of the samples is greater than 500 mg/l.

Dithizon method (WHO, 1987; Standard methods, 1989)

Applicability:

The method is applicable to the determination of cadmium in water. The minimum detectable concentration in approximately 15 ml of volume is 0.5 µg Cd.

Principle:

Cadmium ions under suitable conditions react with dithizone to form a pink to red color that can be extracted with chloroform ($CHCl_3$). Chloroform extracts are measured photometrically and the cadmium concentration is obtained from a calibration curve prepared from a standard cadmium solution treated in the same manner as the sample:

Sampling:

Samples shall be treated by the addition of nitric acid immediately after collection in order to obtain a pH between 1 and 2. A polyethylene container should be used for sampling.

Interferences:

Under the specified conditions, concentrations of metal ions normally found in water do not interfere. Lead up to 6 mg, zinc up to 3 mg, and copper up to 1 mg in the portion analyzed do not interfere.

Chromium

Atomic absorption spectrometric method / modifications A, B and G (ISO, 1986; WHO, 1987; Standard Methods, 1989)

Applicability:

Three modifications of the method are applicable to the determination of chromium in water at a wavelength of 357.9 nm.

Modification A - direct aspiration of the sample into an air-acetylene flame when the concentration range of chromium in water is between 0.5mg/l and 20 mg/l. When the concentration is below 0.5 mg/l the determination can be carried out after carefully evaporating an acidified sample to a smaller volume. Detection limit is 0.02 mg/l. Optimum concentration range is 0.2 mg/l - 10 mg/l.

Modification B - APDC-MIBK extraction procedure with sample concentration, when the concentration of chromium is less than 0.5 mg/l.

Modification G - electrothermal atomic absorption spectrometry, without extraction or sample concentration, when the concentration of chromium in water is less than 0.1 mg/l. Detection limit is 2 µg/l. Optimum concentration range is 5 µg/l - 100 µg/l.

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method/modifications* (pp. 76-77)

Interferences:

In the air-acetylene flame, cobalt, iron, and nickel suppress chromium absorbance. TO overcome this suppression, a more oxidizing air-acetylene flame can be used with some loss in sensitivity. Interference from copper, barium, nickel,and calcium can be eliminated by the use of a nitrous oxide-acetylene flame with only a small decrease in sensitivity. When the sample concentrations are not near detection limits, the nitrous oxide-acetylene flame is preferable.

Colorimetric method (WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the determination of chromium in water with a concentration more than 0.05 mg/l.

Principle:

Dissolved hexavalent chromium reacts with diphenylcarbazide in acid solution to form a red-violet colour. For total chromium determination, the sample must be digested with a sulfuric-nitric acid mixture if organic materials are present. In addition, trivalent chromium in the sample must be oxidized to the hexavalent form with potassium permanganate prior to reaction with diphenylcarbazide. The colour intensity is related to the amount of chromium available to react with the diphenylcarbazide. The absorbance of the product is measured at 540 nm.

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method/modifications* (pp. 76-77)

Interferences:

The reaction with diphenylcarbazide is nearly specific for chromium. At the specified pH, the colour from hexavalent molybdenum and mercury salt reaction products is generally much weaker than that from chromium. Up to 200 mg/l of molybdenum and mercury can be tolerated. Vanadium to chromium concentration ratios greater than 10: 1 cause measurement interferences. Coloured products from iron and copper as well as from molybdenum and vanadium can be avoided by extraction of the cupferrates of these metals into chloroform. However, residual cupferrates and chloroform interfere with later oxidation procedures and must be decomposed with fuming nitric acid.

Copper

Atomic absorption spectrometric method/modifications A, B and G (ISO, 1986; WHO, 198'7; Standard Methods, 1989)

Applicability:

Three modifications of the method are applicable to the determination of copper in water at a wavelengths of 324.7 nm

Modification A - direct aspiration of the sample into an air-acetylene flame when the concentration of copper in water is greater than 0.05 mg/l and when there are no known interferences. Detection limit is 0.01 mg/l. Optimum concentration range is 0.2 mg/l - 10 mg/l;

Modification B - APDC-MIBK extraction procedure with sample concentration, when the concentration of cadmium in water is less than 0.05 mg/l, when samples are of a complex or unknown nature and when they contain a high concentration of dissolved solids. Optimum concentration range is 1 µg/l -200 µg/l;

Modification G - electrothermal atomic absorption spectrometry, without extraction or sample concentration, when the concentration of copper in water is less than 0.05 mg/l. Detection limit is 1 µg/l. Optimum concentration range is 5 µg/l - 100 µg/l.

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method/modifications* (pp. 76-77)

Interferences:

Modification B is not applicable when the chemical oxygen demand (COD) of the samples is greater than 500 mg/l.

Lead

Atomic absorption spectrometric method / modifications A, B and G (ISO, 1986; WHO, 1987; Standard Methods, 1989)

Applicability:

Three modifications of the method are applicable to the determination of lead in water within a concentration range of 5 µg/l-10mg/l at a wavelength of 283.3 nm:

Modification A - direct aspiration of the sample into an air-acetylene flame when the concentration of lead in water is greater than 0.2 mg/l and when there are no known interferences. Detection limit is 0.05 mg/l. Optimum concentration range is 1 mg/l - 20 mg/l;

Modification B - APDC-MIBK extraction procedure with sample concentration, when the concentration of lead in water is greater than 0.5 µg/l, when samples are of a complex or unknown nature and when they contain a high concentration of dissolved solids. The optimum concentration range is 5 µg/l -200 µg/l;

Modification G - electrothermal atomic absorption spectrometry, without extraction or sample concentration, when the concentration of lead in water is greater than 5 µg/l. Detection limit is 1 µg/l. Optimum concentration range is 5 µg/l - 100 µg/l.

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method/modifications* (pp. 76-77)

Interferences:

Modification B is not applicable when the chemical oxygen demand (COD) of the samples is greater than 500 mg/l.

Mercury

Atomic absorption spectrometry / modification F (ISO, 1983; WHO, 1987)

Applicability:

The method is applicable to the determination of mercury in water with a concentration of more than 0.5 µg of mercury in the sample.

Principle:

Dissolved mercury in various oxidation states is oxidized to the mercuric, Hg(II), form by potassium permanganate and potassium peroxodisulfate in acid. Excess oxidant is destroyed by the addition of a sodium chloride-hydroxylamine sulfate solution. Mercuric ion in solution is then reduced to elemental mercury by excess stannous chloride and swept from the solution by aeration into an absorption cell where the vapour phase mercury concentration is assayed using the 253.7 nm mercury line from a mercury lamp.

Sampling:

Samples should be preserved immediately after collection by acidification with nitric acid to pH 2 or less. If the determination cannot be carried out immediately after sampling, in addition to the nitric acid 4 ml of potassium permanganate solution per litre of sample should be added and if necessery, further quantities until a persistent pink coloration is obtained. Samples should be stored in borosilicate glass bottles.

Interferences:

Potential interference from sulfides should be eliminated by the addition of permanganate. It is conceivable that volatile organic compounds could absorb at the mercury line if not completely oxidized. The presence of volatile organic interference can be checked by aeration of a sample without reagents. If this test is negative but interference from incomplete oxydation of organics (producing volatile intermediates) is suspected, variation in the amount of oxidant and duration of the oxidation should settle the question. Samples containing high chloride concentrations should be given special attention by the addition of excess hydroxylamine to ensure complete reduction of free chlorine, which will otherwise cause a positive interference as it absorbs at 253.7 nm. The method is not applicable if the concentration of organic matter is such that the quantity of potassium permanganate taken for analysis is insufficient to produce a persistant intense violet coloration.

Nickel

A tomic absorption spectrometric method / modifications A, B and G (ISO, 1986; WHO, 1987; Standard Methods, 1989)

Applicability:

Three modifications of the method are applicable to the determination of nickel in water at a wavelengths of 232.0 mn

Modification A - direct aspiration of the sample into an air-acetylene flame when the concentration of nickel in water is greater than 0.1 mg/l and when there are no known interferences. Detection limit is 0.02 mg/l. Optimum concentration range is 0.3 mg/l - 10 mg/l;

Modification B - APDC-MIBK extraction procedure with sample concentration, when the concentration of nickel in water is greater than 0.5 µg/l, when samples are of a complex or unknown nature and when they contain a high concentration of dissolved solids. Optimum concentration range is 1 µg/l -200 µg/l;

Modification G - electrothermal atomic absorption spectrometry, without extraction or sample concentration, when concentration of nickel in water is greater than 5 µg/l. Detection limit is 1 µg/l. Optimum concentration range is 5 µg/l - 100 µg/l.

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method/modifications* (pp. 76-77)

Interferences:

Modification B is not applicable when the chemical oxygen demand (COD) of the samples is greater than 500 mg/l.

Zinc

Atomic absorption spectrometric method / modifications A, B (ISO, *1986;* WHO, 1987; Standard Methods, 1989)

Applicability:

Two modifications of the method are applicable to the determination of zinc in water at a wavelengs of 232.0 nm.

Modification A - direct aspiration of the sample into an air-acetylene flame when the concentration of zinc in water is greater than 0.05 mg/l and when there are no known interferences. Detection limit is 0.005 mg/l. Optimum concentration range is 0.05 mg/l - *2* mg/l;

Modification B - APDC-MIBK extraction procedure with sample concentration, when the concentration of zinc in water is greater than 0.5 µg/l, when samples are of a complex or unknown nature and when they contain a high concentration of dissolved solids. Optimum concentration range is 0.5 µg/l -50 µg/l;

Sampling:

Sampling is the same as in *Atomic absorption spectrometric method/modifications* (pp. 76-77)

Interferences:

Modification B is not applicable when the chemical oxygen demand (COD) of the samples is greater than 500 mg/l.

Organochlorine pesticides and polychlorinated biphenyls (PCBs)

Organochlorine pesticides (OCs) include a number of chlorinated hydrocarbons and related compounds containing oxygen and/or sulfur functional groups. In some cases, such as DDT, the material may be a single chemical form (i.e. p,p'- DDT), which is transformed into closely related, partial degradation and rearrangement compounds (o,p'-DDT,DDD,DDE and others) in the environment. In other cases, such as toxaphene, the pesticide material is itself a rather complex mixture of molecules (chlorinated camphene). Furthermore, other compounds of similar chemical behaviour and environmental persistence, notably the polychlorinated biphenyls (PCBs), must be accounted for in the analysis of organochlorine pesticides. The identification and determination of individual organic compounds causes particular difficulty. This is mainly a consequence of the many organic substances that may be present in waters and the similarities in the physical and chemical properties of related compounds.

Liquid-liquid extraction gas chromatographic method (WHO, 1987; Standard Methods, 1989)

Applicability:

The method is applicable to the quantitative determination in water of the following organochlorine pesticides: BHC, lindane, heptachlor, aldrine, heptachlor epoxide, dieldrine, endrine, captan, DDE, DDD, DDT, methoxychlor, endosulphan, mirex, pentachloronitrobenzene, and polychlorinated biphenyls (PCBs). The detection limits are variable and depend on a wide range of factors such as: detector sensitivity, extraction and clean-up efficiency, concentrations, detector signal-to-noise level, and column efficiency. Typical lower limits of detection for organochlorine pesticides range from 5 to 100 ng/l.

Principle:

The method consists of a gas chromatographic (GC) procedure following liquid-liquid extraction of water samples. In this procedure the pesticides are extracted with a mixed solvent, diethyl ether/hexane or methylene chloride/hexane. The extract is concentrated by evaporation and, if necessary, is purified by adsorbtion-chromatography. The individual pesticides are then determined by gas chromatography. All chromatographic techniques are based upon the differing distribution coefficients of molecules in a mixture between two immiscible phases when the mobil phase passes over the stationary phase. The sample (usually gas or a liquid) is injected, directly or indirectly, onto or into a column, through which it is swept by the carrier gas - commonly nitrogen or helium. The column is contained in an oven, the temperature being closely controlled at the value necessary for the required chromatographic separations. The carrier gas elutes the compounds from the column, at time intervals which are related to their distribution coefficients between the stationary phase and the gas; the higher the distribution coefficient, the longer it takes for the compound to be eluted. On emerging from the column, the gas passes through a detector unit sensitive to the eluted compounds, the response of which is fed continuously to an amplifier and further to a chart recorder. When a compound is eluted, its presence is revealed as a peak - ideally of Gaussian shape - on the recorder chart.

Sampling:

All water samples should be collected in glass containers that were washed with solvent and closed with Teflon-lined caps. While heavy aluminium foil is an acceptable alternative to Teflon, the latter is preferred. If aluminium foil is used, it should be cleaned with analytical grade acetone followed by pesticide grade ethyl acetate and hexane. At no time should the sample come into contact with plastic materials, nor should any solvent used in the analysis come into contact with plastics, since plasticizing agents may leach out and subsequently interfere with the analysis. Samples should be stored as briefly as possible, at temperatures 3-5°C. Immediate extraction is recommended wherever possible; the organic phase can be stored at -15°C for several months. The stability over longer periods can be verified by control samples.

Interferences:

Some non-chlorinated compounds respond to the electron-capture detector. Among these are oxygenated and unsaturated compounds. Sometimes plant or animal extracts obscure pesticide peaks. These interfering substances often can be removed by auxiliary purifying techniques. A magnesia-silica gel column purification and separation procedure is used for this purpose.

High performance liquid chromatography (HPLC) method (The chemical analysis of water, 1986; Standard Methods, 1989; Analytical Methods in Human Toxicology, 1986)

Applicability:

The method is applicable to the quantitative determination of trace organic compounds. The following compounds can be determined: polynuclear aromatic hydrocarbons, phenols, herbicides, pesticides, ect. It is expected that the range of organic substances to which HPLC is applied will continue to increase rapidly as the technique becomes more widely available to water analysis laboratories. Detection limit vary from 0.02μg/l to 2.0 μg/l.

Principle:

Classical liquid chromatography, using columns under atmospheric pressure only, has found very limited application in water analysis - principally as a "purifying" procedure in determination of organic compounds. Interest in the use of HPLC in water analyses derives, to a great extent, from its applicability to the separation and determination of non-volatile organics not amenable to gas chromatography.It has been estimated that about 70% of all known compounds are "non-volatile".

The most obvious difference between HPLC and classical column chromatography is probably the use of high-pressure pumps.The fundamental difference, however, lies in the much smaller particle size of the column packings used. These have provided greatly increased separation efficiency and, in combination with the use of high pressure and the development of on-line detectors, rapid analysis. The components of a typical HPLC include a reservoir for storing the mobil phase, or eluent, a pump, an injection system, a column, where separation of compounds is carried out, a detector and a chart recorder.

HPLC is an analytical method in which a liquid mobile phase transports a sample through a column containing a liquid stationary phase. The interaction of the sample with the stationary phase selectively retains individual compounds and permits separation of other sample components. Detection of the separated compounds is achieved mainly through the use of absorbance detectors for organic compounds. The detector selected for use will depend upon the properties of compounds to be analysed. The following detectors are used in the method: photodiode array detector (PDAD), post column reactor (PCR), fluorescence detector etc.

Sampling:

Sampling is the same as in *Liquid-Liquid extraction gas chromatographic method* (page 86)

Interferences:

The main subject of interferences is the detector. For PDAD most interferences occur in monitoring the shorter wavelength (200-230nm). In this range, many organic compounds absorb light energy and can be sources of interference. For PCR interferences usually arise from the impurities in the reagents used in the reaction. As to the fluorescence detector, interference from individual compounds is minimal because of the detector specificity (i.e., all interfering compounds must fluoresce).

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CHAPTER FIVE

DRAFT STANDARD STATISTICAL CLASSIFICATION OF MARINE WATER QUALITY (1992)

CONTENTS

A. INTRODUCTION

Purpose, scope and coverage of the classification

The purpose of this classification is to develop a framework for the statistical presentation of marine water quality that focuses on its ability to maintain aquatic life. This first draft of the classification and the ECE Standard Statistical Classification of Surface Freshwater Quality for the Maintenance of Aquatic Life are intended to complement each other. They attempt to satisfy the needs for a coherent statistical evaluation of water quality in marine environments and freshwater environments of international importance. For the time being, however, experience with marine water quality statistics is less widespread than that with freshwater quality statistics. It is therefore expected that the two classifications will develop at different speeds. Furthermore, this classification also bears strong connections with the proposed ECE Standard Statistical Classification of Discharges of Water Pollutants (or of all stresses on aquatic ecosystems). The nature and extent of linkages between the two will become clear once sufficient progress is made in their development.

The classification is primarily meant for use in international work. Thus, the classification should be used in drafting international questionnaires for the collection of harmonized statistics on marine water quality. It is seen to be of particular importance for the collection of data for international compendia of environment statistics. However, the general approach chosen in the classification may also be useful for the development of analogous national classifications, and the detail contained could be adjusted to the conditions of the marine water body and country concerned. Such national developments and applications may be valuable in throwing light on many issues that as yet are not satisfactorily resolved.

The classification attempts to define some generalized statistical measures which can summarize complex information for use in the interpretation of marine water quality and of trends in marine pollution. Marine water quality statistics relate both to natural and anthropogenic variations in the marine environment. In spite of the lack of conclusive evidence, deterioration of marine water quality and marine ecosystems is generally believed to be mainly due to anthropogenic impacts rather than to natural variation. Therefore the classification focuses on those major ecological problems -- oxygen depletion, eutrophication, presence of harmful substances and radioactivity -- commonly attributed to human activities. The systematic evaluation of ecosystem degradation poses serious shortcomings for the moment; measures of biological integrity and data on sediments ought to be added to the classification later.

Further restrictions on the current use of the classification relate to the state of scientific knowledge about the relationships between marine water quality and ecosystem health, to differences between measurement practices, and to data availability and quality. The classification responds to these restrictions in several ways. First, it remains close to existing international monitoring practices when proposing quality variables for reporting. Second, it seeks guidance from subject-matter experts in both the presentation and interpretation of marine water quality statistics, as well as in the solution of those problem areas suggested for future work. Third, future work is aimed at improving the joint use of data obtained from different media (water, biota, sediments), to increase the reliability of specified class ranges, and to enhance the forms of presenting water quality statistics to reduce the risk of misinterpretation.

Structure of the classification

Rationale

Comprehensive statistical assessments of marine water quality would ideally focus on sources, appearances of marine water pollution, and ecosystem effects. They also would make use of all relevant sources of data. The structure of this classification therefore ought to correspond to these requirements.

Regarding sources of marine water pollution, the necessary conceptual and methodological work is expected from the development of an ECE Standard Statistical Classification of Discharges of Water Pollutants. Such a statistical standard would be all the more useful if it could be widened to include the coverage of all stresses on aquatic ecosystems. The classification should be planned in such a way that special reference is made to stresses on marine water, including river discharges, discharges from coastal point sources (such as industrial plants and waste-water treatment installations), discharges from diffused terrestrial sources, and atmospheric deposition of polluting substances. The individual stresses and/or discharges should be classified in accordance with their sources in terms of suitable (economic) activity classifications. In view of plans for the development of the discharge or stress classification, the sources of marine pollution need not be covered here, but the future linkage of the classifications should be kept in mind during their respective developments.

The appearance of marine water pollution and the partial description of effects on marine life are the subjects of the present classification. However, ecosystem effects are only covered in an approximate manner. Their complete recognition is currently impossible owing to the limits of scientific knowledge. They are thus partially covered in a direct and an indirect way. The major concerns with ecosystem dysfunctions are reflected in the concentration on ecosystem effects that governs the specification of the water quality variables retained in the classification. The direct -- but partial -- recognition occurs through the inclusion of biota measures. It is hoped that a more satisfactory coverage of biological indicators will become possible after future work.

In this manner, the draft classification incorporates measures for two of the relevant three media (water and biota). By contrast, sediment data are not covered at this stage. Such data are currently collected and used in a number of countries. However, they are primarily used for the purpose of determining global trends in marine water pollution over long periods of time. Water and biota measures on the other hand cover water pollution and quality with a much shorter time horizon, and in much more quantitative detail. Strong impediments remain to the joint interpretation of marine water quality and biota measures with sediment data. This classification focuses on relatively short-term measures for' estimating water quality trends because the linkage problems referred to remain basically unresolved. At the same time, the investigation of marine water pollution through statistical sediment analysis is not ignored -- further refinement of such analyses will be the focus of further work.

Variables and classes

The classification evaluates marine water quality according to six groups: metals, organochlorines, other contaminants, oxygen regime in bottom waters, eutrophication in surface waters, and radioactivity. As the comprehensiveness (with respect to community composition, species variety or richness, trophic organization, impact of toxins, absence of species, etc.) of biotic indices remains largely undemonstrated, the inclusion of ecosystem degradation has been left for the future work. The main criteria used when selecting the five quality classes are adverse effects on biota that result in changes of interspecific factors, biomass productivity, species diversity, or species abundance. This allows a framework in which determinands of greatly differing impact can be compared.

Within each of the six groups, individual statistical variables are listed. They were obtained from a review of international monitoring programmes, in conjunction with the above criteria. These variable lists are tentative in nature. This means that during the period when the classification is jointly evaluated and tested by marine water quality experts, other variables can be included or proposed in addition to -- or in place of -- the variables listed. This flexibility corresponds to current uncertainties over data significance and availability. A more definite recommendation is expected after consultation with national and international experts.

For each of the thus determined variables, the classification allows for the reporting of concentration measures in marine water as well as in biota. Measures obtained are allocated to one of five quality classes. The class limits for concentration measures are to be determined in accordance with explicit principles (see section 'I.3 Conventions' below). Classes are determined according to worst-case situations for each problem area. Class limits for the ecotoxicological effects of harmful substances (metals, organochlorines, and others) are based on the EPA recommendations for salt water quality (EPA "Quality Criteria for Water 1986", 440/5-86-001). Class limits for biota measures are derived from those for concentration measures, by multiplication with species-specific bioaccumulation or bioconcentration factors. In interpreting the quality classification of biota measures as they relate to harmful substances, it should be borne in mind that these values do not necessarily correspond to species-specific chronic or acute toxicities because selected indicator species can be more tolerant of toxic effects than other species taken into account in the EPA water quality recommendations. Implicitly, the use of acute and chronic toxicity data for the classification of contaminant levels in species would describe the status of species but not to a full extent the capacity of marine waters to maintain aquatic life.

The selection of indicator species for purposes of this classification should therefore be made during the developmental period of the classification from those indicator species used in international programmes for which bioaccumulation factors can be obtained. The matrix for contaminant measurements in fish refers to liver wet weight. The shellfish measurements, on the other hand, refer to whole soft tissue expressed as dry weight.

Items for future work

Future work should take three broad directions. First and most important is the further development and completion of the draft classification. The Conference of European Statisticians will consider proposals for this work.

Second, discussions of methodological issues should be organized in support of the development of the classification. Here again, relevant proposals are sought.

Third, conceptual work on the further development of marine water quality statistics after the conclusion of the developmental period mentioned above are required in the following areas:

- Incorporation of sedimentation data into the classification
- Development of measures of the biological integrity of ecosystems -- and/or ecosystem degradation -- such as changes in biodiversity, bioproductivity, and abundance of species, for use in the assessement of marine water quality
- Development of international practices for the normalisation of contaminant measures focusing on age, sex, length, fat content, and other relevant characteristics of marine life.

Conventions

Data collection

Data should be collected from individual marine-measurement sites representative of the parts of the sea area concerned. Respondents should be asked to make information available on the following site characteristics:

- Geographic coordinates of the site
- Criteria used in selecting the site
- Expert explanation that the site is representative (by group of measure; preferrably in the form of a map), or reasons for the lack of representativeness of the selected site, whichever is applicable
- Short description of the sampling programme and sampling methods for the site
- Methods used, by variable covered, in preparing and analysing samples
- Frequency of measurements, by variable

During the developmental period for the classification, water quality and biota measures (either for the variables included in the following table, or for equivalent variables) should be collected in terms of the following statistical parameters:

- Annual means
- Extrema (minima or maxima, as the case may be)

Data classification and aggregation

The water quality and biota statistics obtained in accordance with the above procedure should be classified in one of the five quality classes as stated in the following table. The principles followed in the determination of class limits are given below. They should be adhered to also for the determination of class limits for variables on which data are obtained in addition to or in replacement of variables included in the table.

Aggregate quality classes are determined for each of the six variable groups. The worst quality class for any one variable included in the group determines its aggregate quality level.

Concentration measures for phosphorus and nitrogen should be used for the calculation and publication of N:P ratios.

Principles followed in the determination of class limits

Oxygen regime:

Major criteria: Oxygen content in marine bottom waters

Class interpretation:

Class I:	Excellent oxygen conditions for the maintenance of aquatic life.
Class II:	Good oxygen conditions for the maintenance of aquatic life
Class III:	Slight oxygen deficiencies cause occasional formation of hydrogen sulphide.
Class IV:	Chronic deficiencies of oxygen and frequent occurrence of hydrogen sulphide impair reproduction and cause other sublethal chronic impacts to aquatic life.
Class V:	Frequent oxygen depletion leads to toxic levels of hydrogen sulphide with acute sublethal or lethal effects for aquatic life.

Eutrophication:

Major criteria: Trophic state of marine surface water and the best available expert judgement regarding the impact of trophic state on aquatic life.

Class interpretation:

Class I:	Oligotrophic
Class II:	Mesothrophic
Class III:	Slightly eutrophic
Class IV:	Strongly eutrophic
Class V:	Hypertrophic

Pollution by harmful substances (metals, organochlorines, and other):

Major criteria: Toxicological impact on aquatic life as established by US-EPA.

Class interpretation:

Class I:	Approximate natural level or very low background contamination.
Class II:	[To be determined in accordance with the absence of observable effects (‘no observable effects’) on aquatic life.]
Class **III:**	[To be determined in acccordance with occurrence of lowest observable effects on aquatic life, not exceeding threshold levels in species.]
Class IV:	Chronic toxicity
Class V:	Acute toxicity

Pollution by radioactivity:

Major criteria: [To be determined]

Class interpretation: [To be determined]

Presentation of data,

Data on marine water quality should be presented for the areas surrounding measurement stations, and for which the station is considered representative. The data and/or conclusions based on the data should be accompanied with information on measurement methods and expert conclusions on comparability of data, etc.

B. CATEGORIES OF THE CLASSIFICATION

Variables and concentration ranges by quality class

	I	II	III	IV	V
A. OXYGEN REGIME IN MARINE BOTTOM WATERS					
	water (mg/l)	water (mg/l)	water (mg/l)	water (mg/l)	water (mg/l)
Dissolved oxygen	>7	7-6	6-4	4-3	<3
Hydrogen sulfide* µg/l	0'	0*	0-0.2'	0.2-2.0*	>2.0*
B. EUTROPHICATION IN **MARINE** SURFACE WATERS					
	water (µg/l)	water (µg/l)	water (µg/l)	water (µg/l)	water (µg/l)
Total P: annual mean	<10	10-25	25-50	50-125	>125
Total N: annual mean	<160	160-400	400-800	800-2000	>2000
Total P: winter maximum					
Total N: winter maximum					
Chlorophyll a • mg/l	<2.5*	2.5-10*	10-30*	30-110*	>110*

C. METALS' [levels in animal tissues = $BAF_{indicator\ species}$* concentration in water]

	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish
Arsenic III										36-69			>69		
Cadmium										9.3-43.0			>43.0		
Chromium VI										50-1100			>1100		
Copper										0.9-2.9			>2.9		
Lead										5.6-140.0			>140.0		
Mercury										0.025-2.1			>2.1		
Nickel										8.3-75.0			>75.0		
Zinc		>95								86-95					

D. **ORGANOCHLORINES** [levels in animal tissues = $BAF_{indicator\ species}$* concentration in water]

	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish
Aldrin															
a-BHC (henzene hexachlnride)															
Beta-BHC															

	I			II			III			IV			V		
Chlordane										4-90			>90		
Chlorinated benzenes										129-160			>160		
DDT and its metabolites										10-130			>130		
Dieldrin										1.9-710			>710		
Endrin										2.3-37			>37		
Gamma-BHC															
Heptachlor										3.6-53			>53		
Heptachlor epoxide															
Hexachlorobenzene (HCB)															
Hexachlorocyclohexane (HCH)													>340		
Lindane (g-HCH)													>160		
PCBs										30-1 0000			>1 0000		
Pentachlorophenol *µg/l										7.9-13.0*			>13.0*		
Toxaphene										0.2-210			>210		

E. OTHER **CONTAMINANTS** [levels in animal tissues = BAF$_{\text{indicator species}}$ * concentration in water]

	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish
Dinitrotoluene										370-590			>590		
Oil and grease										10-100			>100		
Polycyclic hydrocarbons (PAH)															

F. RADIOACTIVITY [levels in animal tissues = BAF$_{\text{indicator species}}$ * concentration in water]

	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish	water	shellfish	fish
Cesium 137															
Strontium 90															
Tritium															

1. Arsenic and chromium specifications possibly to be aligned on the practices of the freswater quality classification.

CHAPTER SIX

DRAFT ECE STANDARD STATISTICAL CLASSIFICATION OF WASTES
(1989)

CONTENTS

A. INTRODUCTION

Some basic terminological issues and related questions of data collection

The term “waste” appears to be both well-established and potentially misleading. It is well-established in the sense that a majority of countries use it, or its equivalent, in order to designate the subject of this classification. It is potentially misleading as it is employed in conjunction with refuse which could also continue to serve a useful purpose -- that is, whose “wastage” may be the result of a particular structure of relative prices, of lack of information about possible uses, of relatively expensive transport costs, etc. This circumstance might suggest using the term “residual” rather than “waste”. Nevertheless, it is retained in view of its wide acceptance. It has to be read with the convention in mind that the use of the term “waste” does not preclude reuse, recycling, or recovery of such materials for subsequent use.

This description implies important conceptual conventions. Wastes as understood here can in principle be recycled or reused. In other words, reused and recycled materials are, in a first instance considered -- and, thus, reported -- as waste. Consequently, reuse and recycling, to the extent that they occur, reduce directly the amount of waste left for treatment and disposal. This convention therefore reflects very clearly one option of waste management, namely the relief of treatment and disposal installations through reuse and recycling of wastes.

However, reused and recycled wastes are (re)introduced into economic processes because they are of value. Thus, the borderline between “usual” economic products and wastes becomes blurred, and no convention is proposed that could completely avoid all ambiguities. In exchange, it is suggested not to consider as waste those products -- irrespective of their material content -- intentionally produced for the market (“prime products”). This understanding is necessary, as it renders possible the distinction between such substances as acids that are produced for sale and acids that enter waste-treatment installations. The understanding also enables an intuitive distinction to be made between reuse and recycling on one hand and second-hand markets on the other, as it basically implies that reused/recycled materials at some time during their lifetimes, have been considered wastes. Some of such materials may enter second-hand markets, but second-hand articles per se are different from reused/recycled materials.

Reuse and recycling, therefore, are understood as economic notions. Alternatively, they could also be used in a wider context of natural recycling processes. The convention used here is applied for pragmatic reasons.

Hazardous wastes constitute a special case in the context of this classification. Coverage is primarily focused on those waste streams or wastes that are the subject of the Base1 Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. In addition, radioactive wastes are also included. Consequently, only a fraction of the problems with which hazardous waste managers are concerned are covered by this classification. In particular, no provisions are made for information on the location of activities generating hazardous wastes, or places in which such wastes are stocked and/or treated. Likewise, hazardous-waste managers may require information related to transport methods for such wastes, another matter not dealt with in this classification.

In conclusion, it can be said that the notion of "waste" as understood in this classification, relates to those materials that at some stage fall into the area of competence of waste managers. Waste management deals with the generation of wastes, their stockage, collection and transport, and, eventually treatment and disposal. These are also the steps at which data collection usually takes place. National practices certainly differ regarding the most suitable units of statistical observation when gathering waste data. However, some common patterns exist. For example, information on municipal waste usually is obtained from collectors of such waste; data on industrial wastes appear to be most easily obtainable from generators of such materials; and generators as well as treatment and disposal facilities seem to be the most commonly used sources for statistics on hazardous wastes.

Objectives of the classification

A statistical classification of wastes aims at conceptual harmonization so that data collected in accordance with the standard concepts become comparable over time and/or space. Any statistical classification thus has its ultimate justification in a need for quantitative information.

Two main. issues or concerns can be distinguished within this broad perspective. The first gravitates around the question of what should be done with waste materials so that their elimination from the economic sphere does not endanger, or pose undesirable risks to, the health of human beings, species, environmental media, structures or landscapes. Waste management authorities usually try to answer this question and to solve related problems by considering the entire process from the generation of wastes to treatment and final disposal.

The second main concern that creates a need for information arises from resource management. In particular, wastes "consume" raw materials, and a reduction in wastage produces a concomitant reduction in the demand for raw materials. Similarly, economies in the use of raw materials can also be obtained through the recovery, reuse, and recycling of initially wasted materials. Recovery, reuse and recycling may thus reduce the amounts of waste requiring treatment and final disposal.

The objectives of the present classification therefore are to lay the ground so that quantitative statistical information can be made available on the potential for recycling and reuse, the tracing of wastes from generation to treatment and disposal, the identification of uneconomical use of raw materials, and the monitoring of adequate waste treatment and disposal.

General orientation of the classification

The main concerns listed in the preceding section give rise to two perspectives. The physical and chemical properties of the waste materials determine related health risks, may require certain specific treatment procedures, and may inform on the whereabouts of particular, scarce raw materials. This priority aspect under which waste information is developed can conveniently be called the "material aspect".

At the same time, information is required on how and where solid wastes are produced and, eventually, treated or disposed of. Identification of the producers and the ways in which these wastes occur are essential to many aspects of waste and resource management. In general, producers of waste are held responsible for the adequate treatment and disposal of their wastes, and the contribution of resource management at all levels to conservation of scarce raw materials largely depends on the full understanding of the ways in which raw materials are used. This second aspect under which solid waste information is developed can conveniently be called the "activity aspect".

The present classification recognizes both the material aspect and the activity aspect. It tries to strike a balance between these two aspects in such a way that it is acceptable to proponents of each. The balance is achieved in two steps. First, waste categories -- particularly industrial wastes -- are defined in terms of materials that are characteristic for the waste. Second, the amounts of industrial wastes are cross-classified with the economic activities in which they are generated. Summary categories are also included in the classification for the benefit of those respondents who cannot adopt any material-oriented breakdowns.

In theory, a materials balance approach could be used within this compromise solution. Such an approach would be very ambitious in terms of resources required for its implementation and is therefore not retained in its entirety. However, the sequence of generation, treatment, and final disposal can be retained, although the precise path which a particular material takes between these steps is not statistically described in full.

The generation of wastes constitutes the starting point for the classification. Under this broad heading, particular detail is applied to the classification of industrial wastes. Generation of wastes covers all types of wastes, whether hazardous or not. The definitions of waste and of generation of waste used in this classification (see also the related comments in section I.1 above) leans heavily on an intuitive understanding of what should be included in statistics of waste generated. It implies broadly that all those materials ought to be covered that at some time have fallen into a waste-management concern. Obviously, this rather loose description gives rise to problems. Products intentionally produced for the market should not be included -- but in practice they cannot always be distinguished from wastes. The same is true for products entering the second-hand market which may or may not have been considered waste previously. The third major area of delineation difficulties regards finished products that, although intentionally produced for the market, may perish for various -- including economic -- reasons, and may be "wasted" before being recycled. In all these senses, it is to be hoped that more insight will be obtained -- that methods will be found for establishing more accurate statistical conventions through future use of the classification.

The fourth section, D, deals with treatment and disposal of wastes. Hazardous wastes are not covered in this section, but referred to section E. The breakdown used in this section attempts to capture the most widely used treatment and disposal techniques. The main problem with data in this field is double-counting, which probably cannot be fully avoided.

Reuse and recycling are to be seen as an alternative to treatment and disposal of wastes. This is the main reason for including reused and recycled materials in the generation of waste in the first place (see also section I. 1 above). However, as the preceding paragraph indicates, this convention does not avoid practical problems of conceptual delineation, and it may have to be revised once sufficient experience is obtained with the use of the classification.

The fifth major section of the classification deals with the production, trade, treatment, and disposal of selected hazardous wastes, including radioactive wastes. The special coverage of hazardous wastes is justified by its topical interest. International, fully comparable data cannot be obtained for this part of the classification. Here again, experience is needed for a statistically more exhaustive coverage of the field.

Conventions for the use of the classification

An industrial waste is classified in accordance with both the material that determines its character and the economic activity (at ISIC two-digit level) that has generated the waste. If this is impossible -- either because the characteristic material is unknown or because it is not identified in this classification -- the concerned waste is only included under the adequate category of section B.

Cases of double reporting may be intended. For example, the generation of paper and paperboard wastes would be reported under A. 12. That fraction of this amount which is reused or recycled would be reported again under C.6. Similarly, the production of solvent wastes could appear under A. 14.4, partly under C.8 (to the extent that recycling takes place) and under E.7 (regarding the treatment of the hazardous fraction of such wastes).

If a waste cannot be uniquely classified in one of the categories of this classification because it also contains significant amounts of groups of material products classified in at least one other category, the total amount of the waste concerned should be allocated to only one of the possible categories. Respondents to international data collections should in such cases give additional information on the amounts concerned and potential alternative classifications through appropriate footnotes.

This classification does not specify concentrations of the characteristic substances of given volumes of wastes. In international data collections, respondents should indicate through appropriate footnotes the average concentration in the total amount shown as well as the range of concentration (that is, both minimum and maximum concentrations occurring). This recommendation applies also to submission of data on the production of hazardous wastes.

Data on the material composition of household wastes can be obtained in various ways. Most commonly, such data are estimated, using the ratios of given materials found in total household wastes during ad hoc analyses of the composition of household wastes and applying them to current volumes of household wastes. However, some or all of these data can be obtained, partly or wholly, from direct observation. If both these sources are combined for purposes of compiling overall data, special care has to be applied in order to avoid double-counting. Regarding the residual categories of treatment and disposal of wastes, respondents to international data collections should specify which treatment/disposal method is involved.

As a rule, international requests for statistics of wastes should relate to national data and to calendar years.

B. CATEGORIES OF THE DRAFT CLASSIFICATION

Generation of all wastes, including hazardous wastes

a. Primarily material-oriented breakdown

- a.1 Manure
  - a.1.1 Solid
  - a.1.2 Liquid
- a.2 Animal carcasses
- a.3 Crop and gardening residues
- a.4 Forestry wastes
- a.5 Mining and quarrying extraction wastes
- a.6 Mining and quarrying dressing and beneficiating wastes
- a.7 Foodstuff wastes
- a.8 Textile wastes
- a.9 Natural fibre wastes
- a.10 Synthetic fibre wastes
- a.11 Wood wastes, excluding forestry wastes
- a.12 Paper and paperboard wastes
- a.13 Oil wastes
- a.14 Chemical transformation wastes
  - a.14.1 Acids or lyes [as monohydrides]
  - a.1.4.2 Inorganic salts [as dry matter]
  - a.14.3 Organic salts [as dry matter]
  - a.14.4 Solvents [as pure equivalent]
  - a.14.5 Plastics and polymerides
  - a.14.6 Other
- a.15 Rubber wastes (including tyres)
- a.16 Glass wastes
- a.17 Ferrous metal wastes, except from mining and quarrying
- a.18 Non-ferrous metal wastes, except from mining and quarrying
- a.19 Car wrecks, shredding residues and similar wastes
- a.20 Sludges from waste-water treatment
  - a.20.1 From industrial waste-water treatment
  - a.20.2 From public waste-water treatment
- a.21 Construction and demolition wastes
  - a.21.1 From the destruction of furnaces
  - a.21.2 Other
- a.22 Ashes, slack, fly-ash (including materials from the filtering of air emissions)
- a.23 Contaminated soils
- a.24 Dredging sludges
- a.25 Household and similar wastes, including bulky wastes
  - a.25.1 Foodstuffs, garden wastes and similar materials
  - a.25.2 Textiles
  - a.25.3 Paper and paperboard
  - a.25.4 Plastics
  - a.25.5 Glass
  - a.25.6 Metals
  - a.25.7 Other

a.26 Radioactive wastes
a.27 Other wastes, n.e.s. (not elswewhere specified)

The amounts of waste shown under each of the above categories (except categories ‘car wrecks, shredding residues and similar wastes’ and ‘household and similar wastes, including bulky wastes’) should be broken down by sector of origin in terms of two-digit activities of ISIC. The category ‘household and similar wastes, including bulky wastes’ includes all amounts of such waste, irrespective of their material content.

Primarily activity-oriented breakdown

b.1 Wastes from economic activities (by 2-digit categories of ISIC/Rev.3)
b.2 Household and similar wastes, including bulky wastes
b.3 Other wastes, n.e.s.

Recycling and reuse of materials

c.1 Manure
c.2 Crop and gardening residues
c.3 Food materials
c.4 Textiles
c.5 Wood materials
c.6 Paper and paperboard
c.7 Oils
c.8 Solvents
c.9 Plastic materials
c.10 Rubber, excluding tyres
c.11 Tyres
c.12 Glass bottles (incl. crushed glass for the manufacture of bottles)
c.13 Other glass
c.14 Other mineral materials
c.15 Ferrous metals, excluding tins
c.16 Non-ferrous metals, excluding tins
c.17 Tins
c.18 Sludges from biological waste-water treatment
c.19 Sludges from advanced (chemical) waste-water treatment
c.20 Demolition residues
c.21 Ashes, slack, fly-ash (including materials from the filtering of air emissions)
c.22 Other, n.e.s.

Treatment and disposal of wastes other than hazardous wastes

d.1 Incineration of municipal wastes
    Of which: With recovery of energy
d.2 Incineration of industrial wastes
    Of which: With recovery of energy
d.3 Biological treatment

d.4 Landfill
of which: from incineration of wastes
d.4.1 Controlled
d.4.2 Uncontrolled
d.5 Dumping at sea
d.6 Other treatment/disposal method

Selected aspects regarding hazardous wastes

Generation, trade and stocks of selected hazardous wastes

e.1 Generation of hazardous wastes to be controlled regarding their transboundary movements

Waste streams

e.1.1 Clinical wastes from medical care in hospitals, medical centers and clinics
e.1.2 Wastes from the production and preparation of pharmaceutical products
e.1.3 Waste pharmaceuticals, drugs and medicines
e.1.4 Wastes from the production, formulation and use of biocides and phytopharmaceuticals
e.1.5 Wastes from the manufacture, formulation and use of wood preserving chemicals
e.1.6 Wastes from the production, formulation and use of organic solvents
e.1.7 Wastes from heat treatment and tempering operations containing cyanides
e.1.8 Waste mineral oils unfit for their originally intended use
e.1.9 Waste oils/water, hydrocarbons/water mixtures, emulsions
e.1.10 Waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs) and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs)
e.1.11 Waste tarry residues arising from refining, distillation and any pyrolytic treatment
e.1.12 Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish
e.1.13 Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives
e.1.14 Waste chemical substances arising from research and development or teaching activities which are not identified and/or are new and whose effects on man and/or the environment are not known
e.1.15 Wastes of an explosive nature not subject to other legislation
e.1.16 Wastes from production, formulation and use of photographic chemicals and processing materials
e.1.17 Wastes resulting from surface treatment of metals and plastics
e.1.18 Residues arising from industrial waste disposal operations

Wastes having as constituents

e.1.19 Metal carbonyls
e.1.20 Beryllium; beryllium compounds

e.1.21 Hexavalent chromium compounds
e.1.22 Copper compounds
e.1.23 Zinc compounds
e.1.24 Arsenic; arsenic compounds
e.1.25 Selenium; selenium compounds
e.1.26 Cadmium; cadmium compounds
e.1.27 Antimony; antimony compounds
e.1.28 Tellurium; tellurium compounds
e.1.29 Mercury; mercury compounds
e.1.30 Thallium; thallium compounds
e.1.31 Lead; lead compounds
e.1.32 Inorganic fluorine compounds excluding calcium fluoride
e.1.33 Inorganic cyanides
e.1.34 Acidic solutions or acids in solid form
e.1.35 Basic solutions or bases in solid form
e.1.36 Asbestos (dust and fibres)
e.1.37 Organic phosphorous compounds
e.1.38 Organic cyanides
e.1.39 Phenols; phenol compounds including chlorophenols
e.1.40 Ethers
e.1.41 Halogenated organic solvents
e.1.42 Organic solvents excluding halogenated solvents
e.1.43 Any congenor of polychlorinated dibenzo-furan
e.1.44 Any congenor of polychlorinated dibenzo-p-dioxin
e.1.45 Organohalogen compounds, n.e.s.

The waste streams and wastes listed above should be broken down, whenever possible, by 2-digit categories of ISIC/Rev.3.

e.2 Generation of radioactive wastes
    e.2.1 Low-level
    e.2.2 Intermediate-level
    e.2.3 High-level
e.3 Exports of selected hazardous wastes
e.4 Imports of selected hazardous wastes
e.5 Stocks at the end of year of selected hazardous wastes
e.6 Recycling and reuse of hazardous materials [To be developed in further work.]

Treatment and disposal of hazardous wastes

e.7.1 Physical/chemical treatment
e.7.2 Thermal treatment
    of which: With recovery of energy
e.7.3 Biological treatment
e.7.4 Conditioning of radioactive wastes
e.7.5 Other treatment method
e.7.6 Landfill

e.7.7 Containment/underground disposal
e.7.8 Dumping at sea
e.7.9 Other disposal method

CHAPTER SEVEN

DRAFT ECE STANDARD INTERNATIONAL FRAMEWORK FOR THE DEVELOPMENT OF FAUNA, FLORA AND HABITAT STATISTICS
(1985)

CONTENTS

A. INTRODUCTION

Information on fauna, flora, and habitats is usually gathered for administrations, institutions, and associations dealing with the scientific observation and management of nature. Elements of the available information are used by statistical offices in their own data reporting, but normally on an *ad hoc* basis and not in any systematic fashion.

The Conference of European Statisticians, when deciding to develop the field of environment statistics as a whole, also decided that concepts, definitions and a statistical classification of flora and fauna were to be developed. Work on this project started in 1984. It became apparent in the course of this work that a comprehensive statistical coverage of fauna, flora, and their habitats at a level commensurate with other sub-areas of environment statistics was not an easy task, as certain important elements yet have to be developed, and as subject-matter experts do not always agree on the most suitable approach to be followed in the solution of individual questions. However, a general consensus emerged concerning the broad building blocks which can be seen to constitute this area of statistics. Most of these building blocks can at the present stage be filled with concepts and statistical nomenclatures of varying levels of sophistication. Future work will be directed at the further elaboration and refinement of these building blocks.

The framework for the development of fauna, flora and habitat statistics as presented in this paper is intended to serve the following purposes:

(a) To assist in the elaboration of comprehensive national schemes of fauna, flora, and habitat statistics within the field of environment statistics as a whole;

(b) to promote and facilitate the development of international fauna, flora, and habitat statistics; and

(c) to provide a reference for the selection of variables in international collections of fauna, flora, and habitat data. Such data collection may not include all variables listed in this framework.

The science of biology provides for a number of classification systems of species which are satisfactory as a starting point. While such systems are also changing over time, they appear on the whole to be more developed than classifications of habitats. In this second area, it can be hoped that ongoing work will in due course provide an improved basis for statistical development. Until such time, statistics requiring habitat and ecosystem classifications will remain tentative.

At the most general level, this framework relates to two types of information -- species statistics and area statistics. Two kinds of recommendations are made in each. They first relate to the themes on which statistics should be compiled. Second, the statistical variables which could be used in reporting on the themes are listed. Each section and sub-section is accompanied by text explaining its statistical scope and coverage.

Countries participating in international collections of habitat, fauna and flora statistics are invited to submit, together with their data, concise descriptions of the methods used in collecting these data. These methods follow established national practices, and no standardization is attempted. However, to the extent that data collection methods influence both reliability and international comparability, the description of these methods helps with comparative analyses.

Furthermore, data submitted for international purposes should be accompanied by some assessment of their reliability. Finally, information on data sources often helps in understanding the context in which the provided information was obtained.

B. SPECIES STATISTICS

Species statistics as understood here relate to all wild species -- that is, excluding in particular those grown or raised in agricultural activities. Species living in the wild, but whose population is sustained by constant supply of escaped individuals, are excluded. Wild species raised in captivity or cultivation should be covered in separate categories, where appropriate, and be excluded from coverage elsewhere.

The number of species -- as distinct from the number of individuals of which a species population is composed -- for a given territory is the basic statistical variable. The assessment of species populations is difficult. Owing to their costs, population counts or analogous assessments will only be available in exceptional circumstances. In their absence, less ambitious statistics are satisfactory in many, circumstances. They involve expert judgement of population numbers and trends regarding population growth or geographical distributions of species. Also mentioned in this context could be information on the mere presence or absence of certain (threatened) species. Regarding fauna species, the information available could be confined to known stands of the taxa under study.

The presentation of species statistics might have to be complemented with a brief explanation of the variable under study and the inferences that can be drawn from the data. Narrative supplements to species data are recommended as a suitable - and sometimes even necessary -- complement to statistics, when the chosen level of aggregation of data hides important information on individual species, sub-species or races.

In conclusion, the kind of statistics needed for the description of fauna and flora species follows the purpose for which these statistics are needed. Six such purposes are dealt with in this framework.

Status of species

Status categories are recommended as defined by the International Union for Conservation of Nature and Natural Resources (IUCN) for purposes of Red Data Books.

The use of status categories yields different results, depending on the extension of the geographic area to which they are applied. Consequently, the geographic range for which information is sought should be specified in any collection of status statistics. Collections could involve some or all of the status categories.

Existing data on extinct species often are not fully compatible with the definition of the concept in this framework. For example, individual species may be known to be extinct, although less than fifty years may have passed since they were last observed. Information on this and possible other deviations from the recommended concept should be provided together with any data.

Further problems may arise in the recording of species that were believed to be extinct in earlier surveys, but have been observed since. It should also be specified in the instructions accompanying data collection whether (and if so, how) species that have disappeared from the wild but survive in captivity or cultivation are to be covered. In this connection, the reintroduction of previously extinct species may be worthy of a separate category in data collection.

All data reported on extinct species should be accompanied by information on the effort that has gone into attempts to locate the species. Such information should at least cover the number of such efforts and the importance of the searched habitats in relation to the total number of known habitats of the species.

The statistical variables should permit assessment of the size or development over time of species populations, particularly those of threatened species. Under exceptional circumstances, and where such information is unavailable or lacking in sufficient reliability, qualitative information on the most likely current trend in species populations could replace the respective quantitative data.

Causes of threats to species

[The contents of this section is to be developed in future work.]

Unusual rates of change of population and/or range

Unusually high rates of population change, both positive and negative, if they are sustained for a long period of time, may indicate the need for special measures of species management. The same requirement may arise regarding species whose populations, while growing only slowly over time, progressively extend their range. However, species used for purposes of ecological monitoring and management should not be included here.

Time series of the size of species populations can be used to calculate rates of change, if the time series are available in the required geographic detail. In the absence of regular, reliable population counts or estimates, rates of change can also be obtained from expert judgement. It is recommended that reported data be complemented with verbal descriptions of the methods used in obtaining them. In all cases, expert judgement is required to determine which level of change is to be considered unusual. These levels may fluctuate between species and between the circumstances in which a given species is studied. However, by definition, all newly introduced species should be included here. Likewise, species that have disappeared should be so covered if they are not treated adequately in the context of extinct species.

Data on unusual rates of change should first of all relate to areas defined by natural boundaries -- coastal zones, mountain areas, major ecosystems, etc. Additionally, they may also be compiled for countries as a whole.

Use of species in ecological monitoring and management

This section of the framework is devoted to species that are capable of indicating in some way the status of habitats, ecosystems or environmental media, or changes in such qualities.

It is recommended that experiences obtained with the use of species for such purposes be reported in a free format. The information should primarily be presented in a narrative form, but data should be included to the extent possible, appropriately referenced with the analytical methods used.

Information covered by this section normally relates to small areas.

Economic use of wild species

Wild species are associated with a great number of activities that have economic implications. This framework only deals with hunting and trade of wild species. It should be extended to other aspects of economic use of fauna and flora, once the related concepts can be adequately defined and generally accepted.

Hunting should include both commercial hunting and hunting on own account. Killing of animals raised in captivity but belonging to wild species should be reported and appropriately identified, if such killing is seen to alleviate potential stress on animals of that species living in the wild. Killing of animals for reasons of pest control should be included in hunting data but should be shown in separate categories when it occurs.

Trade data relate to market transactions regarding wild animals and wild animal products. Trade data should be split into statistics on internal trade and statistics on foreign trade. Regarding data on foreign trade, special attention should be paid to trade in such species to which the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) applies. If quantitative information of sufficient reliability is not available, sometimes expert estimates of the order of magnitude of such trade can be obtained. Whenever possible, imports and exports should be subdivided by country of origin and destination, respectively.

The quality and reliability of statistics falling into the present section may vary widely. It is therefore suggested that brief assessments of quality be included with any reported data.

Legal protection of species

Systems of legal protection of species vary between countries, as do the status and effectiveness of such protection. Consequently, the purpose of this section is not to ensure international comparability but to make information available on the protection situation in each individual country. Information should be broken down by the degree of protection afforded. It should cover all species included in national protection lists, irrespective of the geographical range in which protection is afforded.

It is recommended that information on the protection of threatened species be presented in narrative form, by species or groups of species. Information should include the estimated effect of such protection, as well as the techniques used in evaluating these effects.

C. AREA STATISTICS

Area statistics are approached with three concerns in mind. Protected areas and ecosystems are of first importance. Statistics of land-use changes may lose their importance once habitat statistics become fully developed.

Degree of area protection

Data reported internationally on the degree of area protection should be appropriately footnoted if the terminology used in this framework is inapplicable to the circumstances prevailing in individual countries. Reporting should include both number of protected areas by type, and related surface.

In presenting statistics of protected areas, it may be appropriate to show them as a percentage of total national area.

Ecosystem types

[The contents of this section is to be developed in future work.]

Land use changes

It is recommended that the draft ECE Standard International Classification of Land Use be used for statistical description of land-use changes. The one-digit level of that classification is of particular relevance, as it reflects land cover aspects. However, arable land and permanent meadows, pastures, and rough grazing areas may be identified separately in view of their special habitat and/or stress characteristics. More detailed categories may have to be chosen in a given study.

The minimum recommendation for statistical reporting of changes in land use is to report transfers of land between one-digit categories of the draft land-use classification, as well as changes over time in each of the categories identified separately.

D. CATEGORIES OF THE DRAFT ECE STANDARD INTERNATIONAL FRAMEWORK FOR THE DEVELOPMENT OF FAUNA, FLORA, AND HABITAT STATISTICS

a. Species

The following list of species groups is recommended:

a.1 Mammals
a.2 Birds
a.3 Reptiles
a.4 Amphibians
a.5 Freshwater fish
a.6 Invertebrates
a.7 Vascular plants
a.8 Mosses and liverworts
a.9 Fungi
a.10 Lichens
a.11 Algae
a.12 Other

It is suggested -- depending on the scope and purpose of the study in question -- that status categories and statistical variables be selected from the following list:

Extinct species: Number, name

All living species: Number

Endangered: Number; current trends in population dynamics for individual species; population assessments where available

Vulnerable: Number; current trends in population dynamics for individual species; population assessments where available

Rare: Number; current trends in population dynamics

Indeterminate: Number

Out of danger: Number; name

Insufficiently known: Number

In any collection of data, the categories of status as well as the statistical variables selected may differ from one species group to another.

b. Causes of threat to species

[The contents of this category is to be developed in future work.]

c. Unusual rates of change of population and/or range

(Rates of change of population considered conspicuous; name of species concerned; important changes in the geographical range of species; narrative comments on the significance of the rates of change and their effects; for newly introduced and other individual species as appropriate; for species groups mentioned under a.)

d. Species used in ecological monitoring

(Scientific name of species, sub-species or race, as applicable; brief free format presentation of their use in monitoring of media/habitat quality; evaluation of the success of the use of species for the intended purpose; for individual species.)

e. Economic use of wild species

e.1 Internal trade (in terms of physical units of measurement, as well as in terms of national currency; for species groups a.1 to a.9 and a.12, as appropriate; distinction between animals and animal products where possible).

e.2 Foreign trade (in terms of physical units of measurement, as well as in terms of national currency; for species groups a.1 to a.9 and a.12, as appropriate; by country of origin/destination; separate data on foreign trade in species on CITES, where applicable; distinction between animals and animal products where possible).

e.3 Hunting (numbers of specimens; for the minimum lists stated below; additional species could be added; data collection can also be organized in terms of importance of hunted species in regions or countries).

e.3.1 Species hunted in the European subregion:

e.3.1.1 European deer (Cervus elaphus)
e.3.1.2 Roe (Capreolus capreolus)
e.3.1.3 Wild boar (Sus scrofa)
e.3.1.4 Brown hare (Lepus europaeus)
e.3.1.5 Pheasant (Phasianus colchicus)
e.3.1.6 ‘Partridge (Perdix perdix)

e.3.2 Species hunted in the North-American subregion:

e.3.2.1 Moose
e.3.2.2 Deer
e.3.2.3 Bear (black, grizzly, polar)
e.3.2.4 Wolf
e.3.2.5 Fox
e.3.2.6 Otter

f. Legal protection of species

Number and name of species or species groups protected by law; short free format presentation of special protection measures regarding species and degree of protection; effect of the protection measures, including information on criteria used in evaluating effectiveness of protection; for individual species or species groups, as applicable.

g. Degree of area protection

(Number of protected areas and total surface by category)

g.1 National parks
g.2 Nature reserves
g.3 Reserved areas
g.4 Other protected areas

h. Ecosystem types

[The contents of this category is to be developed in future work]

i. Land use changes

Transfers between appropriate categories of the draft ECE Standard International Classification of Land Use; changes over time in each of such categories.

CHAPTER EIGHT

DRAFT ECE STANDARD STATISTICAL CLASSIFICATION
OF ENVIRONMENTAL PROTECTION FACILITIES AND EXPENDITURES
(1992)

CONTENTS

A. INTRODUCTION

Purpose, scope, and coverage of the classification

Special data requirements are needed to consider environmental issues in economic contexts. These requirements are currently being tackled in a systematic manner in ongoing work, be it in the form of satellite relationships to national accounts or in other forms. However, the full development of environmental accounting is time- and resource-consuming. Consequently, it is necessary to bridge the time that will elapse before the implementation of fully elaborated accounting systems with more limited, ad hoc solutions for the collection and compilation of data. The current draft classification falls into this category. Once the fully developed environmental accounting system is in place, the need for maintaining the current draft classification -- or its successor -- will have to be re-assessed.

This draft classification is meant to be a contribution by the Conference of European Statisticians to the development of a single international standard classification in this field. It is hoped that international institutions having either special expertise to offer to the development of such a single classification, or institutions having particular needs for internationally harmonized statistics in the area of work covered by thk classification, will join the development of the envisaged single classification.

The classification covers installations and expenditures made for purposes of environmental protection, whether they are decided or effected by governmental institutions at any level, or by private, industrial, or other non-governmental bodies. In general, available data are not being collected in a current manner that is both comprehensive and systematic. Thus, the classification can also be seen as providing assistance in the coordination and compilation of statistics obtained from different sources and which otherwise would not be available in a coordinated framework. This role of the classification appears to be of particular importance for statistics on environmental protection expenditures, which do not only seem to be fairly dispersed in general, but which also are of increased relevance, especially for environmental managers.

Conventions and presentation of internationally collected data

The classification is primarily meant for use in the collection, compilation and presentation of data for countries. However, it is also possible to use it for other administrative units.

Environmental Protection facilities

The collection, compilation and presentation of the data should relate to all equipment, relevant material or installations of the country concerned. Thus, differences in ownership or management authority should not be taken into account when preparing the statistics.

In reporting capacities of treatment installations in response to international requests for data, the definitions included in this classification should be observed. If other capacity concepts are used nationally, the respondents should provide for approximate conversion factors between the nationally used and the internationally recommended concepts.

Reporting on monitoring facilities should at this time, and in waiting for a more satisfactory handling of the related statistics, cover all sites from which monitoring (except sites for the exclusive use of weather monitoring stations) is regularly carried out. Thus, these sites may not be permanently equipped with technical monitoring installations. Sites used for more than one monitoring activity in terms of the breakdown shown in this classification should be counted under each applicable category -- that is, one site may be counted several times. Respondents to international requests for data are encouraged to indicate the parameters monitored, so that more adequate comparative statistics between countries can be provided. When reporting number of measurements (per parameter and site), the number of sites with continuous measurement (by parameter) should be shown separately.

The presentation of international statistics on monitoring facilities is best done in the form of facilities per square kilometre of built-up and of open lands, respectively. In addition, experience should be gained with the use of ratios between numbers of facilities and urban and rural population numbers. However, any use of such ratios should not only depend on the availability of internationally comparable population numbers, but should also clarify the interpretation of the ratios.

Environmental protection expenditures

In cases of doubt, the conventions for the compilation of statistics on environmental protection expenditures should be those of the United Nations System of National Accounts (SNA). If the national data submitted in accordance with international requests do not comply with SNA rules, respondents to the international request should clearly state the differences and, if possible, assess their quantitative importance.

Expenditure data should be collected in terms of national currency and in constant prices. Any necessary deflation of the data should be undertaken with the help of the best available price index for the expenditure category concerned.

Expenditures for environmental training, environmental education and general administration for purposes of environmental protection should be shown in the most appropriate residual categories. Respondents to international data requests should be asked to provide more detailed information on their national practices in this respect, so that a more satisfactory convention can be developed in future work.

The international presentation of statistics on environmental protection expenditures would ideally include indicators on the effectiveness of the expenditures. It is realized, however, that at present such indicators are not readily available. Thus, respondents to international requests for data should be encouraged to provide, together with such data, any statistical information they consider relevant on the effects of the expenditures.

Further work

Future work should first of all be seen as evolving towards the envisaged single international standard classification. Once the satellite accounts to the SNA become available, the need for the maintenance of a separate classification on environmental protection facilities and expenditures can be reassessed.

Subject to the above developments, the greater priority for future work appears to relate to the part of the draft classification dealing with protection expenditures. This seems to be of greater interest to environmental managers.

The following specific issues should be addressed:

> The possible use of expenditure aggregates (such as total expenditures, or expenditure for gross fixed capital formation by manufacturing industries) in relation to their effects in physical units of measure, or in relation to broader economic aggregates (such as total GDP or total gross fixed capital formation in manufacturing industries) needs to be explored, so that respective indicators can be included in the draft classification at an early time.
>
> The scope of expenditures for the protection of nature and landscape requires particular attention. First, it needs to be clarified whether protection against natural hazards should include protection of human settlements. Second, protection against floods and storm overflows can be classified under protection of ambient water (corresponding to practices in a number of countries), or under protection against natural hazards (for reasons of systematic convenience). This question should be looked into on the occasion of the next collection of data for the draft classification. Third, it also is not clear whether the built-up heritage should be included under preservation of legally protected objects.
>
> A more adequate classification should be developed of expenditures for environmental training, environmental education, and general administration for purposes of environmental protection.
>
> The treatment of all R&D expenditures should further be detailed by type of protection activity, if the provisions of the Frascati manual and other relevant international developments enable such further classification.
>
> The possibility of splitting the residual category under total expenditures into more specific sub-headings should be explored.
>
> The significance of indicators showing relationships between monitoring facilities and land area (or, possibly, population) needs to be established before it can be recommended that indicators be compiled and presented.

The most adequate scope of monitoring facilities for inclusion in the draft classification should be determined in further work, together with the most appropriate breakdown of the facilities. For the time being, weather monitoring stations are excluded, but all other types of monitoring facilities remain included.

Future work should include the specification of installations for the treatment of exhaust gases.

B.. CATEGORIES OF THE CLASSIFICATION

Facilities for environmental protection

1. Industrial establishments equipped for the treatment of exhaust gases [percentage for ISIC two-digit categories 15-37; percentage of thermal electricity generation plants]

2. Waste-water treatment installations [number; capacity in terms of population equivalents]
   - 2.1 Mechanical treatment technology
   - 2.2 Biological treatment technology (excluding septic tanks)
   - 2.3 Advanced treatment technology
   - 2.4 Septic tanks

Information: Population connected to public waste-water treatment installations [per cent of total population]

3. Installations for the treatment of hazardous waste [number; capacity in terms of weight that can be treated per year (by type of waste as applicable)]
   - 3.1 Physical/chemical treatment
   - 3.2 Thermal treatment
   - 3.3 Biological treatment
   - 3.4 Conditioning of radioactive wastes
   - 3.5 Other treatment methods

4. Installations for the treatment of other than hazardous wastes [number; capacity in terms of weight that can be treated per year (by type of waste as applicable)]
   - 4.1 Incineration of municipal wastes
   - 4.2 Incineration of industrial wastes
   - 4.3 Biological treatment
   - 4.4 Other treatment methods

5. Installations for the disposal of hazardous and other than hazardous waste [number]
   - 5.1 Landfill for all types of waste
   - 5.2 Landfill exclusively for hazardous waste
   - 5.3 Biological treatment
   - 5.4 Containment/underground disposal
   - 5.5 Other disposal installations

6. Monitoring facilities [number of measurement sites; number of measurements per year]
   - 6.1 Air monitoring
     of which:
     - In built-up areas
     - In open lands

6.2 Water monitoring
  of which: - In built-up areas
  - In open lands
6.3 Other monitoring (excluding weather monitoring facilities)
  of which: - In built-up areas
  - In open lands

Expenditure for environmental protection

(a) *Gross fixed capital formation*

1. For the protection of ambient air
   - 1.1 For the treatment of exhaust gases and ventilation air
     of which: In thermal electricity generation
   - 1.2 For measurement, control, laboratories, and the like
   - 1.3 Other purposes

2. For thc'protection of ambient water (excluding groundwater)
   - 2.1 Mechanical treatment technology
   - 2.2 Biological treatment technology (excluding septic tanks)
   - 2.3 Advanced treatment technology
   - 2.4 Treatment of cooling water
     of which: In thermal electricity generation
   - 2.5 For measurement, control, laboratories, and the like
   - 2.6 Other purposes, such as for restoring polluted surface waters

3. For the protection of soil and groundwater
   - 3.1 For the decontamination of soils and cleaning of groundwater
   - 3.2 For measurement, control, laboratories, and the like
   - 3.3 Other purposes

4. For the collection, transport, treatment, and disposal of wastes
   - 4.1 Collection and transport of wastes
   - 4.2 Treatment of hazardous waste
   - 4.3 Treatment of other than hazardous waste
   - 4.4 Disposal installations
   - 4.5 For measurement, control, laboratories, and the like
   - 4.6 Other purposes

5. For the protection of nature and landscape
   - 5.1 Protection against natural hazards, excluding protection of human settlements
   - 5.2 Preservation of legally protected (excluding built-up) objects
   - 5.3 Protection of species
   - 5.4 For measurement, control, laboratories, and the like
   - 5.4 Other protection

6. For noise abatement
   - 6.1 Airport noise
   - 6.2 Industrial process noise, excluding workplace protection
   - 6.3 Noise from road and rail traffic

6.4 For measurement, control, laboratories, and the like
6.5 Other

7. For other protective activities

(b) *Current expenditure*

1. For the protection of ambient air

2. For the protection of ambient water (excluding groundwater)

3. For the protection of soil and groundwater

4. For the collection, transport, treatment, and disposal of wastes

5. For the protection of nature and landscape

6. For noise abatement

7. For research and development

8. For other protective activities

(c) *Total expenditure*

1. By central, state, and local government
2. By manufacturing industries
3. Households
4. Other

CHAPTER NINE

DRAFT SET OF ECE ENVIRONMENTAL INDICATORS
(1985)

CONTENTS

A. INTRODUCTION

Environment statistics versus environmental indicators

The terms environment statistics and environmental indicators have many different meanings, and no readily agreeable definition of either exists to date. However, some perception of which environmental indicators are required and what their relationship should be to other types of statistical information is needed before a viable set of such indicators can be established. These clarifications are certainly necessary for national work, and they are an indispensable prerequisite for international statistical cooperation, as the consensus on what to place under the term "environment" still appears to be relatively weak.

Any statistical information, be it termed statistics, indicators, or otherwise, can be characterized in terms of the subject matter to which it is related, in terms of the production process through which it is generated, and in terms of the uses (in the meaning of both user groups and purposes) to which it is put. As the first of these three viewpoints does not help to distinguish the two terms, the borderline between them has to be sought from the other two. In doing so, use will be made of the principles that have emerged over the years from the relevant work undertaken by the Conference of European Statisticians.

The Conference pursues the development of environmental indicators as part of a broader programme devoted to the development of environment statistics. In other words, environmental indicators are seen as a sub-area of a land-use classification, an air pollution classification, etc. However, a classification might be seen as an instrument that ensures consistency in the production of data covering a vast field, while indicators might be seen to be selective measures of individual, particularly interesting phenomena.

The situation is more complicated when it comes to defining purposes and user groups. Environment statistics in general are employed by user groups of various kinds , ranging from decision-making administrations and research institutions to educational establishments, the information media and the general public. However, the type of information required changes between user groups, although such differences are only generally true and may not occur in individual cases. It could be argued that the general public, the information media, educational establishments, and executive-level decision-makers exhibit some preference for aggregated statistical measures.

Furthermore, there is reason to believe that at least one main purpose to which such aggregated statistical measures are put is common to these various user groups: to assess the current state and development over time of environmental conditions of broad environmental concern.

Consequently, the label "environmental indicator" is attached in the set of ECE environmental indicators to aggregated statistical measures which can be used to characterize the state and development over time of a situation corresponding to a broad environmental concern. To "round off' this rather intuitive description with an example, the average concentration of sulphur dioxide in a given location on a given day obtained from hourly sampling would be termed air pollution statistics, while the total annual emissions of SO, from all stationary and mobile sources into the air could be seen as an air pollution indicator.

Environmental indicators in this sense can be obtained in two ways. First, they can be generated through standard procedures of statistical aggregation from basic environmental data. Second, they can be obtained through the selection statistical variables for measurement and reporting which satisfy the conditions of environmental indicators *per se*. The set of ECE environmental indicators is being developed in accordance with this second possibility.

A special but important conceptual problem with environmental indicators relates to their predictive capacity. In fact, environmental managers appear to be keenly interested in indicators which leave them with time to react to emerging crises. It seems at present that requests for such indicators remain largely unsatisfied. The indicators included in this set are only of limited predictive value, although there may in future be scope for the elaboration of suitable predictors from them.

It is readily apparent that environmental indicators in the sense in which the term is used here are extremely difficult to use with confidence and precision -- "intelligently" -- and the remainder of this introductory text as well as the description of the individual indicators will have to provide further guidance for such use. It should be kept in mind throughout the text that the above meaning of environmental indicators is essential for understanding the set of ECE indicators, but this intepretation is not intended to preclude the use of other concepts of the term "environmental indicator" elsewhere.

Characteristics and presentation of environmental indicators

Some characteristics are of a conceptual nature and can be derived from the concept of environmental indicators as used in this set. Other conceptual and computational references or conventions have to be added. The characteristics in their entirety lead to the particular form of presentation of indicators in chapter II below.

The first characteristic of environmental indicators is that they have to be related to environmental concerns. The following list is used for the purposes of the set of ECE Environmental Indicators:

List of environmental concerns for the develonment of ECE indicators

I. NATURE

1. Climate and meteorology (includes indicators of marine environments)
2. Land and subsoil
3. Wildlife
4. Vegetation
5. Natural hazards

II. RESOURCES

6. Land resources (includes information on agricultural production processes -- useo f machinery, fertilizers, etc.)
7. Energy and mineral resources
8. Water resources
9. Forest and other biological resources

III. HUMAN ACTIVITIES AFFECTING ENVIRONMENT QUALITY

10. Emission of pollutants to air, water and soil
11. Generation of solid and hazardous (toxic, radiating, etc.) wastes
12. Noise
13. Development of human settlements

IV. QUALITY OF MEDIA, SPECIES AND HABITATS

14. Air quality
15. Water quality
16. Soil quality
17. Species and habitat quality
18. Quality of human settlements

V. ENVIRONMENTAL MANAGEMENT

Indicators can be significant for one or more of these concerns. The ECE set, once it is fully developed, may list several indicators under individual concerns. In principle, an indicator or indicators are sought for each of the concerns in the list, although initially indicators might not be available to satisfy all requirements and characterists mentioned below.

Indicators, which are intended to be adequate information relating to broad environmental concerns, ought to have a significance which stretches beyond the phenomenon measured. For example, the emissions of a small number of specified air pollutants might be looked upon as an indicator of general air pollution and will be a “good” environmental indicator if that interpretation can be well justified.

Accordingly, suitable environmental indicators are those whose significance for a particular environmental concern is widely agreed upon.

Environmental indicators should be capable of reflecting developments over time. The need to construct time series of environmental indicators suggests that environmental indicators should not undergo important conceptual or computational changes over time.

Individual indicators do not necessarily have to be single statistical variables. Short classifications can also be used as indicators.

The description below is thus in each instance composed of (a) a clear statement of significance of the indicator for the above list of concerns; (b) conceptual references; and (c) conventions adopted for measurement and computation of the indicator. The third part of the presentation format of indicators includes in particular recommendations for spatial units to which the indicator should relate (if different from the country as a whole) and, where applicable, instructions on the preferred way in which the indicator should be presented.

Use of the tentative ECE System of Environmental Indicators

The main intended use is clearly international statistical cooperation, particularly international comparison through the collection of comparable data. This means concentrating on environmental concerns of international importance..

It is clear that great care has to be exercised in the use and interpretation of data. Often the national significance of the indicator does not coincide completely with the intended significance. Frequently, the environmental concern that is the focus has to be considered on the basis of more information than just the indicator or indicators, but such information need not be available on an international level. Conceptual, computational, and measurement conventions specified here cannot always be met, or they may lead to estimates of varying accuracy.

To cope with these many practical difficulties, it is recommended that any submission of data be accompanied with interpretive text, as needed. The final publication of environmental indicators should always, and for each indicator separately, be supplemented with text evaluating the comparability between countries. Other text should be included as needed to enable proper interpretation of the indicators.

Further development of the tentative system

The criteria used in the establishment of the draft Set of ECE Environmental indicators are selective. As a result, a relatively limited number of indicators is recognized. Future work should be undertaken with three broad objectives in mind. First, the underlying concept should be clarified and developed. Second, shortcomings should be eliminated from the existing indicators. Third, indicators should be developed for priority concerns that remain at present uncovered.

B. INDIVIDUAL INDICATORS, SIGNIFICANCE, AND CONVENTIONS FOR MEASUREMENT AND COMPUTATION

Land use changes

Significance: The indicator describes net changes in broad classes of land use. Such changes are usually the result of human activities. They may influence environmental quality and habitats. Changes in the direction of built-up land are seen as being close to irreversible, and thus create special conditions for land-resource management.

Conceptual references: Draft ECE Standard International Classification of Land Use.

Conventions for measurement and comnutation: The indicator is built upon the following categories: agricultural land; forest and other wooded land; built-up and related land; other land. Measured or estimated changes in land use for each of these categories are calculated for the most recent five-year and 30-year periods. Net additions of land (positive in the case of increases in surface area and negative in the case of decreases) are expressed as a percentage of the initial land surface in each category.

Production of primary forms of energy

Significance: Energy resources are used extensively in a wide variety of human activities. The use of the resource base is one of the concerns of resource management. The production of primary energy contributes to the depletion of indigenous resources of non-renewable forms of energy. Environmental concerns with media, media quality, and creation of harzardous wastes are related to the generation of electricity from nuclear and hydro sources.

Concentual reference: Concepts and definitions used in the Annual Bulletin of General Energy Statistics for Europe.

Conventions for measurement and comnutation: For any given year, production of primary energy (joule) is reported separately for

-- fossil fuels
-- nuclear electricity
-- hydro electricity
-- total primary energy

Total abstraction of water per head of population

Significance: Growing needs for water for agricultural, industrial, and domestic uses may seriously stress available resources. The indicator provides basic information on the use of water resources.

Concentual reference: Draft ECE Standard International Classification of Water Use and Quality.

Conventions for measurement and comnutation: For any given year, total abstractions of water (item 1.5.1 of the reference classification) are divided by the mid-year population estimate. The indicator may be computed for countries as a whole and for water management areas as they may be established in any country -- watershed areas, river basins, etc.

Forest damage

Significance: The indicator demonstrates the results of damaging influences on the forest, such as air pollution, insects, and diseases, as well as fires and storms, etc. However, it is not possible in all cases to determine the precise cause or causes of forest damage. The indicator contributes to the assessment of forest resources and of related habitat quality.

Conceptual references: Forest damage is assessed in terms of the number of trees affected or destroyed by damaging factors. If possible, data should be reported separately for coniferous and non-coniferous species.

Data should be broken down into the following categories of cause of damage:

- Fire
- Storms, avalanches, snow break, floods, frost, and similar natural causes of mechanical destruction of trees
- Other causes.

Regarding "other causes", data should be further subdivided by degree of damage as follows:

- Light damage
- Moderate damage
- Heavy damage.

Conventions for measurement and computation: Data should be reported as percentages of the respective national totals. If data are reported by degree of damage, they should be accompanied by the criteria used in assessing forest damage as being light, moderate, or heavy. If possible, damage should be considered light if canopy loss is below 25 per cent. Canopy loss between 25 and 60 per cent should be classified as moderate and canopy loss of 60 per cent and more should be considered heavy damage.

Emissions of selected air pollutants

Significance: The air pollutants selected are sulphur dioxide,* nitrogen oxides, and particulate (suspended) matter. These are pollutants'usually emitted in large quantities and well-documented in most countries. However, other air pollutants exist which also may be dangerous from many points of view. Sulphur dioxide is mainly emitted from stationary sources and emission is often statistically correlated with the emission of other pollutants. Nitrogen oxides are mainly discharged from mobile sources into the air. Particulate matter in the air creates risks which are partly different from the risks created by sulphur and nitrogen oxides. Emission of air pollutants influences air quality and emission data help to evaluate data about quality of other media, of species, and of habitats.

Conceptual references: Draft ECE Standard International Clasification of Ambient Air Pollution for definition of "emissions", "particulate (suspended) matter", and descriptions of analytical methods.

Conventions for measurement and computation: Annual (calendar year) totals are computed. Submissions of national data for purposes of international comparisons should be accompanied by descriptions of the analytical methods used in compiling the indicators. This recommendation is particularly important where the draft ECE Standard International Classification of Air Pollution lacks appropriate analytical methods, or where an entirely different estimation procedure is used (such estimation based on fuel consumption). Emissions for each pollutant should be presented as total per capita (of population), or as total per unit of total energy consumption, or as total per unit of total land area.

Generation of solid wastes

Significance: Solid wastes need to be treated and/or disposed of. The problems of solid waste management depend on weight, volume, and composition of waste. This indicator relates to weight of waste and can be used to describe trends in the generation of solid waste over time.

Conceptual reference: Draft ECE Standard International Classification of Solid Wastes.

Conventions for measurement and commutation: For any given year, tonnages of waste generated are calculated for the following categories:

- Agricultural and forestry wastes (category A.1 of the reference classification)
- Industrial wastes (A.2)
- Mining and quarrying wastes (A.4)
- Household and similar wastes (A.9)
- Total of remaining categories of the reference classification (A.3; A.5 - A.8; A.10)

The tonnage of each category is divided by the mid-year population estimate or by total area.

Wet acidifying deposition

Significance: Acidifying deposition, both wet and dry, is known to constitute a major threat to aquatic and terrestrial ecosystems. It also can damage buildings and similar structures. Acidifying deposition to a large extent originates from emission of sulphur dioxide and nitrogen oxides into the air. Although dry deposition is generally not measured, wet and dry deposition are correlated, their relative importance changing with the distance from the source. The indicator is used in evaluating air quality and the quality of other media. It is of particular relevance to the assessment of background levels.

Conceptual references: Wet acidifying deposition is measured as total monthly precipitation, accompanied by its average monthly pH. Definitions of terms and the descriptions of analytical methods are included in the draft ECE Standard International' Classification of Ambient Air Pollution. The sampling of precipitation is to be carried out in accordance with the WMO International Operations Handbook for Measurement of Background Atmospheric Pollution, Chapter 3.

Conventions for measurement and computation: Daily amounts of precipitation are measured and their pH is determined. 'The corresponding hydrogen ion (H+) concentration is determined. For a given month, the weighted average of such concentrations is computed, using the amounts of precipitation as weights. The average hydrogen ion concentration is subsequently transformed to yield average monthly pH. Total monthly precipitation is measured from the samples used for the calculation of average pH. Monthly data are averaged over the year to eliminate seasonal fluctuations. The presence of further variations may require averaging over longer time periods before data on this indicator are presented.

Concentrations of selected substances in urban air

Significance: The substances selected for the purposes of this indicator are sulphur dioxide, nitrogen oxides and particulate (suspended) matter. These three substances are often used to provide a broad picture of air quality in human settlements, although other pollutants may also generate considerable exposure risks. While ambient air quality information as such does not permit the determination of risk levels for the exposed population (exposure data would be required together with reliable knowledge about effects), it can be assumed for all practical purposes that an increase in average concentration levels over time is likely to imply an increase in risks. The indicator is valuable in assessing the quality of human settlements.

Conceptual references: Draft ECE Standard International Classification of Ambient Air Pollution.

Conventions for measurement and computation: Three to five major human settlements are selected, depending on the size of the country and on the existence of monitoring stations in settlements. Simple monthly averages are computed for each of the selected substances, separately. The unit of measurement for all substances is g/m^3. The averaging method is to be adapted to the frequency of recordings (continuous or discrete). Averaging takes place over the measurement sites of the settlement. If samples are not analysed in accordance with the methods recommended by the draft ECE Standard International Classification of Ambient Air Pollution, any submission of data should be accompanied by a description of the analytical methods used. In presenting data on this indicator, the median, the arithmetic mean, and the 98th percentile of the (cumulative) frequency distribution should be used for each of the selected substances.

Protected areas

Significance: The indicator describes protected areas by category. It represents past decisions by environmental management authorities to conserve natural habitats or other areas in order to protect species, habitats, landscapes, or similar items considered worthy of protection. The indicator can be seen to reflect the natural endowment of a country as well as the degree of risk to which items worthy of protection would be exposed in its absence.

Conceptual references: Draft ECE Standard International Classification of Fauna, Flora and their Habitats.

Conventions for measurement and computation: For each category of protection, total national area is calculated in multiples of km^2, as of 1 January of the year concerned. Data on this indicator should be presented as percentage of total area of the country concerned.

PART TWO:
DEFINITIONS OF TERMS USED IN ECE STANDARD STATISTICAL CLASSIFICATIONS FOR THE ENVIRONMENT

CONTENTS

ACIDIFICATION

An increase of hydrogen ions, usually expressed as pH, in a media.

ACIDIFYING DEPOSITION

The dry or wet fallout of substances from the atmosphere which have the potential to increase the acidity of the receptor medium.

ACUTE TOXICITY

Half of the lethal concentration (LC) of a toxicant, present in a given water volume, at which fifty percent (LC_{50}) of a sensitive species of organism die in acute toxicity tests.

ACUTE TOXICITY TEST

A test of 96 hours or less in duration in which lethality is the measured endpoint.

AQUATIC LIFE

All faunistic and floristic micro-, meso- and macroorganisms, carrying on life processes in water.

ADVANCED TREATMENT TECHNOLOGY

Process capable of reducing specific constituents in waste-water not normally achieved by other treatment options. Covers all unit operations which are not considered to be mechanical or biological: includes, for example, chemical coagulation, flocculation and precipitation; break-point chlorination; stripping; mixed media filtration; micro- screening; selective ion exchange; activated carbon absorption; reverse osmosis; ultra-filtration; electro flotation. Advanced treatment processes may be used in combination and/or in conjunction with mechanical and biological unit operations.

AEROSOL (IS0 4225- 1980)

A suspension in a gaseous medium of solid particles, liquid particles, or solid and liquid particles having a negligible falling velocity.

AGRICULTURAL LAND

This referes to the major classes of land use on agricultural holdings. For classification the “gross area” is surveyed for each class. Agricultural land includes land under scattered farm buildings, yards and their annexes, and permanently uncultivated land, such as uncultivated patches, banks footpaths, ditches, headlands, and shoulders.

AGRICULTURAL AND SIMILAR USE OF WATER

Input of water into the operation of agricultural establishments and as water for irrigation, livestock raising, fish farming or other use.

AIR POLLUTANT (IS0 4225- 1980)

Any material emitted into the atmosphere either by human activity or natural processes and adversely affecting man or the environment.

AIR POLLUTION (IS0 4225-1980)

Usually the presence of substances in the atmosphere resulting either from human activity or natural processes, present in sufficient concentration, for a sufficient time and under circumstances such as to interfere with comfort, health, or welfare of persons or the environment.

ALGAL BLOOM

A rapid and strong increase in one or a few species of planktonic algae.

ALKALINITY

The quantitative capacity of aqueous media to react with hydroxyl ions. The equivalent sum of the bases that are titrable with strong acid. Alkalinity is a factor that represents the acid-neutralizing capacity of an aqueous system.

ALL OTHER AGRICULTURAL LAND N.E.S.

This includes all agricultural land, which is not specified previously. Such land may be potentially productive or not. Included are scattered farm buildings -- that is, isolated buildings not belonging to closed villages or similar rural localities.

ANIMAL CARCASSES

Obtained primarily from agricultural activities, food industries, and relevant laboratories. Included are parts of animal carcasses.

ANNUAL CHANGE IN GROUNDWATER RESOURCES

Estimate of the percentage or volume change of the national total groundwater resources over recent years which can be regarded as being representative of the current trend.

ARABLE LAND

This refers to all land generally under rotation whether for temporary crops or meadows, or left fallow.

ARTIFICIAL WATERCOURSE

Fully artificially constructed watercourse which serves in-stream uses, purposes of water management, irrigation, and the like. The mean tidal level determines the borderline between an artificial watercourse and the sea. The (imaginary) shoreline of the natural watercourse determines the borderline between an artificial and a natural watercourse, where applicable.

ARTIFICIAL WATER IMPOUNDMENT

A water body impounded by a dam, which is used for the supply of drinking water, electricity generation, irrigation or animal husbandry. Watercourses serving as part of a reservoir system are included.

ASHES, SLACK,. FLY-ASH

Residuals from the burning of fossil fuels and from the processing of ferrous and non-ferrous metals, excluding residues from the incineration of wastes. Included are all carbon-containing wastes, but direct discharges into air or water are excluded. However, materials from the filtering of air emissions are included.

BACKGROUND STATION

A station to monitor background concentration levels of air-polluting substances significant for a given region. Regional stations are to be located sufficiently far away from built-up areas and important sources of pollution. The main task of these stations is to monitor long-term changes in the composition of the atmosphere in the region concerned.

BANK FILTRATION

Induced infiltration of river water through bankside gravel strata (by pumping from wells sunk into the gravel strata to create a hydraulic gradient) with the intention of improving water quality. For purpose of this classification, bank filtration is covered under surface water.

BARE ROCKS

Part of open land covered by bare rocks.

BASIN

Catchment (drainage) area of a river or lake.

BIOACCUMULATION

General term describing a process by which chemical substances are accumulated by aquatic organisms from water directly or through consumption of food containing the bioaccumulative chemicals.

BIOACCUMULATION FACTOR (BAF)

Bioaccumulation factor is a ratio of the concentration of a material in one or more tissues of an aquatic organism divided by the average concentration in the solution and food in which the organism had been living. [Reference: US-EPA]

BIOCHEMICAL OXYGEN DEMAND (BOD)

The dissolved oxygen required by organisms for the aerobic decomposition of organic matter present in water. Data used for the purposes of this classification should be measured at 20 degrees Celsius and for a period of five days (BOD5).

BIOCONCENTRATION

Process by which a substance is accumulated by an aquatic organism directly from water containing the bioaccumulative chemicals.

BIOCONCENTRATION FACTOR (BCF)

Bioconcentration factor is a ratio of the concentration of a material in one or more tissues of an aquatic organism divided by the average concentration in the solution in which the organism had been living. [Reference: US-EPA]

BIOLOGICAL TREATMENT TECHNOLOGY

Processes which employ aerobic or anaerobic micro-organisms and result in decanted effluents and separate sludge containing microbial mass together with pollutants. Biological treatment processes are also used in combination and/or in conjunction with mechanical and advanced unit operations.

BIOLOGICAL TREATMENT (of all types of waste)

The treatment of waste in specialized treatment facilities for the removal of organic matter with the assistance of living micro-organisms.

BIOLOGICAL TREATMENT TECHNOLOGY

Processes which employ aerobic or anaerobic micro-organisms and result in decanted effluents and separate sludge containing microbial mass together with pollutants. Biological treatment processes are also used in combination and/or in conjunction with mechanical and advanced unit operations.

BUFFERING CAPACITY

A capacity of a solution of a weak acid and its conjugate weak base to resist changes in acidity and alkalinity.

BUILT-UP AND **RELATED** LAND (**excl.** scattered farm buildings)

Land under houses, roads, mines, and quarries and any other facilities, including their auxiliary spaces, deliberately installed for the pursuit of human activities. Included are also certain types of open land (non-built-up land), which are closely related to these activities, such as waste tips, derelict land in built-up areas, junk yards, city parks and gardens, etc. Land occupied by scattered farm buildings, yards and their annexes (classified in category I .4) is excluded. ‘Land under closed villages or similar rural localities is included.

CAR WRECKS, SHREDDING RESIDUES, AND SIMILAR WASTE

Wastes from car wrecks and shredding residues. In determining the total weight of the waste included in this category, attention should be paid that used tyres and shredding residues are not included twice. Examples of similar wastes are wasted refrigerators, washing machines, dishwashers, etc.

CENTRAL, STATE AND LOCAL GOVERNMENT

All departments, offices, establishments and other bodies classified under general government which are agencies or instruments of the central, state, or provincial, district or county, municipal, town or village, or another organ of government. These bodies may be covered in ordinary or extraordinary budgets, or in extra-budgetary funds. Included are non-profit institutions which, while not an official part of an organ of central, state or local government, are wholly, or mainly, financed and controlled by it. Excluded are the social security funds.

CHEMICAL OXYGEN DEMAND (COD)

The mass concentration of oxygen consumed by the chemical breakdown of organic and inorganic matter. Data used for the purposes of this classification should be measured through sodiumpermanganate (COD- Mn) consumption.

CHEMICAL TRANSFORMATION WASTES (excl. rubber and oil wastes)

Includes solutions jettisoned as waste; plant and timber protecting agents that are unfit for use; pharmaceutical wastes; wasted solvents, pigments, etc., and other chemical refining wastes.

CHEMICAL, TREATMENT OF HAZARDOUS WASTES

Chemical treatment methods are used to effect the complete breakdown of hazardous wastes into nontoxic gases, or, more usually, to modify the chemical properties of the wastes, such as by reducing their water solubility or neutralizing their acidity or alkalinity.

CHLOROPHYLL A

The green, photosynthetic pigment of plants. Chlorophyll A content is used to indicate the biomass and primary production of phytoplankton and periphyton in a water body (ug/l, mg/m2).

CATCHMENT (DRAINAGE) AREA

Contiguous land area surrounding a given water body, from which both surface runoff and groundwater drain to the water body concerned.

CHRONIC TOXICITY

Highest concentration of a toxicant, present in a given water volume, to which the test organisms are exposed that causes no observable adverse effect on the test organism in chronic toxicity tests.

CEIRONIC TOXICITY TEST

Test in which sub-lethal effects, such as on fertilization, growth, and reproduction, are usually measured, in addition to lethality. Traditionally, chronic tests are full life-cycle tests or a shortened test of about 30 days known as an early life-stage test. However, the duration of most EPA chronic-toxicity tests have been shortened to 7 days by focusing on the most sensitive life-cycle stages.

CLEANING OF AIR EMISSIONS

Removal of materials from the exhausts of industrial processes to prevent or reduce emissions of pollutants into ambient air.

CLEANING OF EXHAUST GASES

End-of-line equipment for the removal/reduction of particulate matter and/or other air-polluting substances from/in the emissions into the air from buildings.

COASTAL LAGOONS

Seawater bodies at the coast, but separated from the sea by land spits or similar land features. Coastal lagoons are open to the sea in restricted spaces.

COMMERCIAL LAND

Land mainly used for commerce, trade, and related services, such as shopping centres, banks, commercial garages, repair shops, commercial storage facilities, related office buildings, etc. Also included are private roads and other auxiliary spaces located in the areas concerned. In terms of ISIC/Rev.3, the activities included in this category can be described by divisions 50-55, 65-74, 91 and 93.

COMMUNITY OF SPECIES

An assemblage of organisms characterized by a distinctive combination of species occupying a common environment and interfacing with one and another.

COMPOSTING

Mainly aerobic biochemical treatment of waste, during which the enzyme systems of micro-organisms break down organic waste with biological oxidation, and as a result stable organic matters and inorganic mineral matters are generated. The final product of the process is an earthy material with about 40-50% humidity (compost), which, due to its humic and nutrient content, can be used for the increase of soil fertility. Incompostible residuals are usually disposed of or incinerated.

CONDITIONING OF RADIOACTIVE WASTES

Operations that transform radioactive waste into a proper and fit condition for transport and/or storage and/or disposal.

CONSTRUCTION AND DEMOLITION WASTE

Rubble and other waste material arising from the construction, demolition, renovation, or reconstruction of buildings or parts thereof, whether on the surface or underground. Consists mainly of building material and soil.

CONSUMPTIVE USE OF WATER IN INDUSTRY

Water abstracted and no longer available for use because it has evaporated, transpired, or was incorporated into industrial products. Water losses during the transport of water between the point or points of abstraction and the point or points of use are excluded.

CONTAINMENT

The retention of hazardous material in such a way that it is effectively prevented from dispersing into the environment, or is released only at an acceptable level. Containment may occur in specially built containment spaces.

CONTAMINATED SOIL

Soils which are mixed with biological or chemical substances and must be treated in order to render them fit for handling and normal use.

COOLING WATER

Water which is used to absorb and remove heat.

CROP AND GARDENING RESIDUES

Wastes from harvesting (straw, tops, etc.) and cultivation of kitchen or hobby gardens, and similar activities.

CURRENT EXPENDITURE (for environmental protection)

Sum of expenditure for intermediate consumption and compensation of employees. Also included is any application of indirect taxes (less subsidies). The consumption of fixed assets is excluded.

DEMOLITION WASTE OF FURNACES

Mineral materials obtained in the repair or destruction of industrial furnaces and chambers of metallurgic or non-metallurgic processes.

DETRITUS

Unconsolidated sediments composed both of inorganic and of dead, decaying organic material.

DISCHARGE OF POLLUTING SUBSTANCE

The amount of substances added/leached to a water body from a point or non-point source (t/a).

DISPOSAL OF WASTE

Final placement of waste for which no further use is foreseen, although it may occur in practice (such as extraction of biogas).

DISPOSAL OF HAZARDOUS WASTE

Comprises landfill, containment, underground disposal, dumping at sea, and any other relevant disposal method.

DISPOSAL OF OTHER THAN HAZARDOUS WASTE

Comprises landfill, dumping at sea, and any other disposal method.

DISSOLVED OXYGEN (DO)

The amount of gaseous oxygen actually present in water expressed as a share of water volume (mg O2/1) or of the amount of oxygen in saturated water (%). The dilution of oxygen depends significantly on temperature and salinity of the water.

DREDGING SLUDGE

Sludges obtained from the dredging of rivers, river mouths, harbours, or coastal areas.

DRY OPEN LAND WITH SPECIAL VEGETATION COVER

Non-wooded land which is covered by low vegetation (less than 2 metres).

DRY TUNDRA

Dry, treeless flat regions with arctic climate and vegetation. May or may not be grazed by domestic animals.

DUMPING

Covers both dumping on land and at sea.

DUMPING AT SEA

Licensed disposal of hazardous or non-hazardous substances in the open sea.

EMISSION (into air, IS0 42251980)

The discharge of substances into the atmosphere. The point or area from which the discharge takes place is called the “source”. The term is used to describe the discharge and the rate of discharge. The term can also be applied to noise, heat,etc. Note: For the purposes of this classification the term “emission” covers anthropogenic emission only.

ENDANGERED SPECIES (IUCN Red Data Book)

Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. Included are taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction. Also included are taxa that are possibly already extinct but have definitely been seen in the wild in the past 50 years.

ENVIRONMENTAL PROTECTION

Any activity to maintain or restore the cleanliness of environmental media through preventing the emission of polluting substances or noise etc., recycling of materials that would become waste in the absence of recycling, reduction of the presence of polluting substances in environmental media. Also included are activities aimed at the preservation of designated valuable objects of natural or built-up heritage, the preservation of landscape, and the conservation of wild species. Also included are all related activities for R&D purposes, for monitoring and analysis of environmental conditions.

EPILIMNION

The uppermost layer of water in a lake, characterized by an essentially uniform temperature and mixing by wind and wave action.

EQUIVALENT DEVICE (as compared with cleaning operation)

Modification of either industrial processes or characteristics of input materials that reduces the need for cleansing of emissions or renders cleansing redundant.

ESTUARIES

Consist of those generally broad portions of a river, stream, brook, or torrent near its outlet, and which are influenced by the marine water body into which it flows. The demarcation line is generally the mean tidal level.

EUTROPHIC

Abundant in nutrients and having high rates of bioproduction, resulting frequently in oxygen deficiencies or depletion in the hypolimnion either due to stratification of a water body or increased amount of detritus to be decomposed.

EXHAUST GAS

Emissions into the air from buildings, usually through stacks or chimneys, which are the result of the combustion of fossil fuels.

EXPENDITURE FOR ENVIRONMENTAL PROTECTION

Gross fixed capital formation and current expenditure related to the technical operations or activities as specified in this classification.

EXTINCT SPECIES (IUCN Red Data Book)

Species not definitely located in the wild during the past 50 years (criterion as used by CITES).

FACILITIES FOR ENVIRONMENTAL PROTECTION

Technical installations designed for use in the context of environmental protection. The installations can be of the ‘end-of-pipe’ type or they can be part of a larger production process. Installations exclusively meant for the implementation of industrial safety standards are excluded.

FALLOW AGRICULTURAL LAND

Arable land not under rotation that is set at rest for a period of time ranging from one to five years before it is cultivated again, or land usually under permanent crops, meadows or pastures, which is not being used for that purpose for a period of at least one year. Arable land which is normally used for the cultivation of temporary crops but which is temporarily used for grazing is included.

FERROUS METAL WASTE

Wastes whose characteristics are determined by ferrous metals.

FOODSTUFF WASTE

Wastes whose characteristics are determined by foodstuffs.

FOREST AND OTHER WOODED LAND

Classification of forest and other wooded land should be undertaken irrespective of the charateristics of the soil (for example, wet forest should be shown under forest and not under wetlands). Forest and other wooded land used primarily for agricultural purposes, such as grazing, should not be included under this category but under agricultural land. Excluded is land under timber classified elsewhere, such as city parks and gardens (included in category 3), etc. The following descriptions are proposed under this heading:

Forest: All land with crown cover (stand density) usually more than 20 per cent of the area and in any case more than 10 per cent. Included are:
(a) All plantations, including one-rotation plantations, primarily used for forestry purposes;
(b) Areas normally forming part of the forest area which are unstocked as a result of human intervention or natural causes but which are expected to revert sooner or later to forest;
(c) Young natural stands and all plantations established for forestry purposes which have not yet reached a crown density of more than about 20 per cent;
(d) Forest roads, cleared tracks, firebreaks and other small open areas, as well as forest nurseries, that constitute an integral part of the forest;
(e) Forest in national parks and nature reserves;
(f) Areas of windbreak and shelterbelt trees larger than 0.5 ha in extent.

Excluded are:
(a) Trees in hedgerows and bounderies; scattered trees, tree crops such as fruit tree orchards, etc.; trees in city parks and gardens, etc.
(b) Areas not meeting the conditions of forest as described above, even if administered by a Forest Authority.
Other wooded land: Land which has some forestry characteristics but is not forest as defined above. It includes:
(c) Open woodland: Land with trees whose crowns cover about 5-20 per cent of the area (or with a stand density of less than 20 per cent);
(d) Scrub, shrub, and brushland: Land with shrubs or stunted trees where the main woody elements are shrubs (usually more than about 50 cm or less than 7 m in height), with crown cover usually more than 20 per cent and in any case more than 5 per cent. It excludes trees mentioned also as being excluded from forest above.

FOREST LAND WITH PROTECTION, CONSERVATION AND BIOLOGICAL USE THE RECOGNIZED **MAJOR** FUNCTIONS

Forest or other wooded land, the predominant function of which is whether individually or in combination the protection of soil against erosion, protection of watershed, water flow control, air purification, wind shelter, noise abatement, etc., the preservation of habitats, the protection of fauna and flora species, the preservation of wildlife forage grounds, and other biological uses.

FOREST LAN-D WITH RECREATION THE RECOGNIZED MAJOR FUNCTION

Forest or other wooded land which is predominantly used for recreational activities by the general public.

FOREST LAND WITH WOOD PRODUCTION THE RECOGNIZED MAJOR FUNCTION

Forest or other wooded land predominantly used for the production of timber or other forestry products.

FORESTRY WASTE

Consists mainly of tree-felling wastes and losses in timber floating and transport.

GENERAL GOVERNMENT

All agencies of the public authorities included in the System of National Accounts (SNA) of the United Nations under this term: (i) government departments, offices and other bodies engaged in administration, defence and regulation of the public order, promotion of economic growth and welfare and technological development, provision of education, health, cultural, recreational and other social and community services free of charge or at sales prices which do not fully cover their costs of production; (ii) other non-profit institutions serving households or business enterprises which are wholly, or mainly, financed and controlled by the public authorities or which primarily serve government bodies; (iii) social security arrangements for large sections of the community imposed, controlled or financed by the governmentl; (iv) government enterprises (unincorporated public units) which mainly produce goods and services for government itself or which primarily sell goods and services to the public, but do not operate on a large scale; and (v) public saving and lending bodies which are financially integrated with a government or which lack the authority to acquire financial assets or incur liabilities, respectively, in the capital market.

GENERATION OF WASTE

For the purposes of this classification, generation of waste includes hazardous wastes as well as wastes that are recycled and reused at places other than that at which they were generated. While prime products in principle are not covered (see definition of “waste” above), finished products may turn into waste, if and when they become non-marketable.

GLACIERS AND PERPETUAL SNOW

Part of open land covered by glaciers (measured at their maximum seasonal extension) or perpetual snow.

GLASS WASTE

Wastes whose characteristics are determined by glass.

GLOBAL BACKGROUND STATION (baseline station)

A station to obtain background concentration levels of air polluting materials that are significant for the globe as a whole. Baseline stations measure global background pollution at a distance from continental sources of at least 3000 kilometres. The main task of these stations is to monitor large-scale changes in atmospheric constituents influencing weather and climate.

GROSS FIXED CAPITAL **FORMATION** (FOR ENVIRONMENTAL PROTECTION)

The outlays (purchase and own-account production) on additions of new durable goods (commodities) to stocks of fixed assets less net sales of similar second-hand and scrapped goods. Included are acquisitions of reproducible and non-reproducible durable goods, except land, mineral deposits, timber tracts and the like, for civilian use; work-in-progress on construction projects; capital repairs; outlays on the improvement of land; and the transfer costs in connection with purchases and sales of land, etc. For the purposes of this structure, this definition is only applicable to the items distinguished.

GROUNDWATER

Water which is being held in, and can usually be recovered from, or via, an underground formation. All permanent and temporary deposits of water, both artificially charged and naturally in the subsoil, must be of sufficient quality for at least seasonal use. This category includes phreatic water-bearing strata, as well as deep strata under pressure or not, contained in porous or fracture soils. For purposes of this classification, groundwater includes injected water and springs, both concentrated and diffused, which may be subaqueous. Excluded from groundwater is bank filtration (covered under surface water).

GROUNDWATER AVAILABLE FOR ANNUAL ABSTRACTION

Estimate of the maximum volume of water that can be withdrawn annually from the national groundwater resources under prevailing economic and technical conditions without leading to the depletion of the resource base in the long-term.

HARDNESS

The concentration of metallic cations (ions with a positive charge), except those of alkali metals, present in water. In general, hardness is a measure of the concentration of calcium and magnesium ions in water and is frequently expressed as (mgCaCO3/1).

HAZARDOUS WASTE

Wastes which due to their toxic, infectious, radioactive, flammable etc. character, pose a substantial actual or potential hazard to human health or living organisms. Hazardous waste is potentially damaging to the environment and must therefore be controlled. Hazardous waste can present either short-term acute hazards or long-term environmental hazards. Waste with these properties may arise as by-products, process residues, spent reaction media, contaminated plant or equipment from either manufacturing operations or the treatment of toxic substances, or from the discarding of manufactured products. For the purposes of this definition, “hazardous wastes” comprise for each country all those materials and products which are considered to be hazardous in accordance with that country’s practices.

HEATHLAND

Uncultivated open land covered with vegetation often consisting to a considerable degree (25 per cent or more) of ligneous and semi-ligneous plants (fern, heather, furze, genista, etc.) as well as of herbaceous plants of generally low pastoral value.

HIGH-LEVEL RADIOACTIVE WASTE

This sub-category comprises:

(i) the highly radioactive liquid, containing mainly fission products, as well as some actinides, which is separated during chemical reprocessing of irradiated fuel (aqueous) waste from the first solvent extraction cycle, and those waste streams combined with it.

(ii) Spent reactor fuel, if it is declared a waste.

(iii) Any other waste with a radioactivity level comparable to (i) or (ii).

HOUSEHOLD AND SIMILAR WASTE, INCL. BULKY WASTE

Waste materials usually arising from the residential environment, although they may be generated in any economic activity, if their composition and character is similar to household waste and can thus be treated and disposed of together with household waste. Also included are wastes which, owing to their bulky character, cannot be collected together with household and similar wastes, but require special removal (bulky waste). Excluded are all those wastes requiring treatment other than household wastes. Data on these wastes are usually obtained through surveys of collection and/or treatment or disposal. Data on the material composition of such wastes are usually based on special benchmark surveys.

HUNTING

Shooting and trapping.

HYPERTROPHIC

Excessively loaded with nutrients.

HYPOLIMNION

The region of a water body extending from the thermo- or chemocline to the bottom of the lake. Water masses of remarkably different temperature or concentrations of compounds separate the hypolimnion from the productive epilimnion.

IMPACT STATION

Impact stations are to monitor concentration levels of air polluting substances in the neighbourhood of important sources of pollution. Impact stations selected for the purposes of this classification are usually fixed stations which are located in areas with several sources of pollution. Stations operating for the sole purpose of monitoring one point source of pollution should not be selected for the purposes of this classification.

INCINERATION

Thermal treatment of waste during which chemically fixed energy of combusted matters is transformed into thermal energy. Combustible compounds are transformed into combustion gases leaving the system as flue gases. Incombustible inorganic matters remain in the form of slag and fly ash.

INCINERATION WITH RECOVERY OF ENERGY

Incineration in which evolving thermal energy is used for the production of steam, hot water or electric energy.

INDETERMINATE SPECIES (IUCN Red Data Book)

Taxa known to be ‘Endangered’, ‘Vulnerable,’ or ‘Rare’ but where there is not enough information to say which of the three categories is appropriate.

INDUSTRIAL LAND, EXCLUDING LAND USED FOR QUARRIES, PITS, MINES AND RELATED FACILITIES

Land on which mainly manufacturing activities (ISIC/Rev.3 divisions/l 5-37) are pursued, including all auxiliary grounds, such as private roads, parking areas, storage grounds, office grounds, etc. Included is land used by enterprises primarily engaged in construction work (ISIC/Rev.3 division 45). However, actual construction sites, harbour areas and their storage facilities, although possibly extending to industrial premises, are excluded from this category. Also excluded is land used for quarries, mines, pits, and related facilities.

INDUSTRIAL USE OF WATER

Input of water into the operation of industrial establishments, including any makeup water for closed circuits.

INLAND SEA (FRESHWATER OR SALINE), LAKES, PONDS, COASTAL LAND-LOCKED BODIES OF WATER

A natural water body (freshwater or saline) located in a depression in the earth's surface and surrounded more or less completely by land. The land could form part of one or more countries. The water body could have one or more inlets or outlets in the form of natural or artificial drainage channels (rivers, streams, brooks or channels). Bodies of water included in this category are always separated from the open sea.

INLAND WATERS

All waters on the landward side of the line of the mean tidal level.

INSTALLATION FOR THE TREATMENT OR DISPOSAL OF WASTE

Establishment or part of an establishment that is wholly or partly destined to treat or dispose of wastes, such as treatment plants of wastes of various kinds and technical equipment that is fit for treatment of hazardous or non-hazardous waste which is part of any other production process. For the purposes of this definition, contiguous areas either on land or at sea used for the dumping of wastes are included, such landfill sites and sea areas used for dumping.

INSUFFICIENTLY KNOWN SPECIES (IUCN Red Data Book)

Taxa that are suspected but not definitely known to belong to any other IUCN Red Data Book category, because of lack of information.

N.B. In practice, 'Endangered' and 'Vulnerable' categories may include, temporarily, taxa whose populations are beginning to recover as a result of remedial action, but whose recovery is insufficient to justify their transfer to another category.

INTERMEDIATE-LEVEL RADIOACTIVE WASTE

This subcategory comprises waste of lower activity level and heat output than high-level radioactive waste, but which still requires shielding during handling and transportation. The term is used generally to refer to all wastes which are neither classified under high-level nor under low-level radioactive waste.

IRRIGATION USE

Artificial application of water on lands to assist in the growing of crops and pastures. Can be done by spraying of water under pressure on the lands concerned ("spray irrigation"), or by pumping of water onto the lands concerned ("flood irrigation").

LAND INTENDED FOR FUTURE CONSTRUCTION

Land areas designated in public land development plans as land for construction, but where construction works have not yet started.

LAND OF MIXED USE

This category is reserved for land to which no single main use in accordance with other two-digit items under this category can be ascribed.

LAND UNDER PERMANENT CROPS

This signifies land used for a long period of time for crops which do not have to be planted for several years after each harvest. Land under trees and shrubs producing flowers, such as roses and jasmine, is so classified, as are nurseries (except those for forest trees, which should be classified under "forests and other wooded land"). Permanent meadows and pastures are excluded.

LAND UNDER PERMANENT MEADOWS AND PASTURES

This means land used permanently (that is, for five consecutive years and more) for herbaceous forage crops. Permanent meadows and pastures on which trees and shrubs are grown should be recorded under this heading only if the growing of forage crops is the most important use of the area. Measures may be taken to keep or increase productivity of the land (use of fertilizers, mowing or systematic grazing by domestic animals).

LAND UNDER CONIFEROUS FOREST

This relates to land covered by forest as defined above, in which around 70-75 per cent or more of the volume of growing stock is of coniferous species (Gymnospermae).

LAND UNDER NON-CONIFEROUS FOREST

This relates to land covered by forest as defined above in which around 70-75 per cent or more of the volume of growing stock is of non-coniferous species (Angiospermae).

LAND UNDER MIXED FOREST

Land covered by forest that cannot be classified as either coniferous or non-coniferous forest - - that is, the volume of growing stock of each of coniferous and non-coniferous species is between 25-30 and 70-75 per cent of the total growing stock.

LAND UNDER ROADS

Part of total land under transport and communication facilities which is used by public roads, including motorways, and their auxiliary services. Included are pavements, public parking lots along roads, and similar spaces.

LAND UNDER RAILWAYS

Part of total land for transport and communication facilities which is used by public railways as well as by private rail systems operating on a commercial basis. Included is land used for their auxiliary services, such as stations, related administrative buildings, storage yards, installations for repair and maintenance of equipment, and the like.

LAND UNDER AIRPORTS AND RELATED FACILITIES

Part of total land for transport and communication facilities which is used by airports and airfields of all kinds and their related buildings or installations.

LAND UNDER CURRENT CONSTRUCTION

Open land on which construction is currently in progress.

LAND USED FOR GRAZING OF DOMESTIC ANIMALS

Land on which domestic animals are periodically grazed, usually seasonally.

LAND USED FOR OTHER OPEN-CAST MINING AND QUARRYING

Land area used in connection with all mining and quarrying activities in open pits and quarries, except the cutting of peat.

LAND USED FOR PEAT CUTTING

Land area on which cutting of peat actually takes place.

LAND USED FOR QUARRIES, PITS, MINES AND RELATED FACILITIES

Land which is used in connection with mining and quarrying activities (ISIC/Rev.3 division 1 0-14), including abandoned mines and quarries not put to a different use.

LAND USED FOR PUBLIC SERVICES (EXCLUDING TRANSPORT, COMMUNICATION AND TECHNICAL INFRASTRUCTURE)

This category comprises land mainly used for public administration at the national, provincial, or local levels, schools, hospitals, churches, and other social and cultural facilities, irrespective of whether these functions are provided by government, institutions or private persons. Included is land used for auxiliary purposes. In terms of ISIC/Rev.3, the activities included in this category can be described by divisions 75-85 and 99. Excluded is land used for purposes specified elsewhere, in particular land under technical infrastructures and land used for public transport and communication facilities.

LAND USED FOR TRANSPORT AND COMMUNICATION

Land used for public and private railways, operating on a commercial basis, public roads, land used for surface pipelines for the transport of fuels and other products, airports, land used for installations of the telecommunications system, etc. Also included is the land used for transport-related offices and other service buildings and installations, such as stations, airport buildings, storage facilities for equipment and repair workshops, space used for sidewalks, grass slopes along railways, windshelter belts along roads, open noise abatement areas round airports, and any other space needed, according to national practices, for the provision of the related infrastructure. In terms of ISIC/Rev.3, the activities included in this category can be described by divisions 60-64. However, waterways are not classified here.

LAND USED FOR TECHNICAL INFRASTRUCTURE

This item covers land used for technical installations that serve the generation and transmission of electricity, the treatment and disposal of wastes, supply and distribution of water, collection and treatment of waste-water and related activities. Included also is land used for related offices and other service buildings and installations, as well as any space needed, according to national practices, for the operation of such technical infrastructure. In terms of ISIC, the infrastructure covered by this item is related to activities of major divisions 40, 41 and 90.

LAND USED FOR THE DISPOSAL OF WASTES

Land used for waste-treatment installations and their auxiliary grounds and waste dumps of all kinds (including junk yards), except installations for the collection and treatment of waste-water.

LAND USED FOR WATER SUPPLY AND WASTE-WATER TREATMENT

Land used for technical infrastructure that is devoted to water supply, sewerage, and waste-water treatment installations.

LAND USED FOR ELECTRICITY GENERATION AND DISTRIBUTION

Land used for technical infrastructure that is devoted to the generation of electricity and to the exclusive use of high-voltage transmission of electricity.

LANDFILL

Final placement of waste in or on the land in a controlled or uncontrolled way according to different sanitary, environment protection and other security requirements.

LETHAL TOXICITY

Toxic action resulting in the death of an organism.

LONG-TERM ANNUAL AVERAGE INFLOW

Inflow of surface waters into a country averaged over annual data for a period of at least 20 consecutive years.

LONG-TERM ANNUAL AVERAGE OUTFLOW

Runoff of surface waters from a country averaged over annual data for a period of at least 20 consecutive years.

LONG-TERM ANNUAL AVERAGE PRECIPITATION

Total atmospheric precipitation averaged over a period of normally 20 years or more.

LONG-TERM ANNUAL AVERAGE EVAPORATION

Total evaporation from all man-made and natural lakes and reservoirs, averaged over a period of normally 20 years or more.

LOSSES OF WATER DURING TRANSPORT

Volume of water lost during transport between a point of abstraction and a point of use, or between points of use and re-use.

LOW-LEVEL RADIOACTIVE WASTE

This sub-category comprises waste which, because of its low radionuclide content, does not require shielding during normal handling and transportation.

MANUFACTURING INDUSTRIES

Activities classified in ISIC,Rev.3 categories 15 to 37.

MANURE

Primarily the excreta of animals; may contain some spilled feed and bedding. It can be solid or liquid.

MATERIALS FROM THE FILTERING OF AIR EMISSIONS

Used filters, whether dry or wet, and related materials containing wastes removed from the exhausts of industrial processes in order to prevent or reduce emission of pollutants into the ambient air.

MECHANICAL TREATMENT TECHNOLOGY

Processes of a physical and mechanical nature which result in decanted effluents and separate sludge. Mechanical processes are also used in combination and/or in conjunction with biological and advanced unit operations. Mechanical treatment is understood to include at least such processes as sedimentation, flotation, etc.

MESOTROPHIC

Waters slightly loaded with nutrients.

MINING AND QUARRYING EXTRACTION WASTE

Barren soils which are removed from mining or quarrying sites in preparation of mining or quarrying, and which do not enter dressing or beneficiating processes.

MINING AND QUARRYING DRESSING AND BENEFICIATING WASTE

Wastes obtained in the process of separating minerals from ores or other materials extracted during mining and quarrying activities.

MIRES

Transitional phase between land and water, including blanket or raised peatlands. Depending on elevation, mires may be more or less regularly flooded. In the non-flooded state, the ground is wet and spongy. Vegetation consists chiefly of decayed moss and other vegetal matter.

MONITORING

The programmed process of sampling, measurement, and subsequent recording or signalling, or both, of various characteristics of environmental media, often with the aim of assessing conformity to specified objectives.

MONITORING FACILITIES

Technical installations used in the pursuit of monitoring. They may or may not be operating in networks, and they may or may not be covering one particular environmental medium only (air, water, soil etc.).

MOUNTAINOUS GRASSLAND

Natural grassland in mountainous areas, which may or may not be used for the grazing of domestic animals.

NATURAL FIBRE WASTE

Wastes obtained during production activities whose characteristics are determined by natural fibres.

NATURAL WATERCOURSE

Watercourse, either natural or to some extent artificially constructed, including the (generally broad) portions near its outlets. The mean tidal level in estuaries determines the borderline between a watercourse and the sea into which it flows. The (imaginary) shoreline of a natural watercourse determines its borderline with an artificial watercourse, where applicable.

NET ABSTRACTION OF WATER

Calculated as the difference between water abstraction and returned water. When analysing the relationship between water supply and water abstractions, this item disregards water abstracted primarily during mining or construction activities.

NOISE ABATEMENT

Activity to reduce the emission of noise or vibrations from a source, or to protect persons and built-up structures from exposure to noise and vibrations. For the purposes of this classification, noise abatement for the protection of workplaces is excluded.

NON-FERROUS METAL WASTE

Wastes whose characteristics are determined by non-ferrous metals.

NON-POINT SOURCE OF POLLUTION

A source of emission which cannot be located at an identifiable point in space. The term is used in relation to pollution processes such as leaching from agricultural, forest, and built-up areas, or in relation to atmospheric fallout.

NUTRIENTS

Elements required for growth. The most essential nutrients for aquatic ecosystems are phosphorus, nitrogen, and silica.

OFFSTREAM FISH FARMING

Breeding, rearing, and farming of fish, as well as the cultivation of oysters for pearls or food in offstream freshwater, brackish water, or saline water. Included are related service activities.

OFFSTREAM USE OF WATER

Water withdrawn or diverted from a ground- or surface water sources for public water supply, industry, irrigation, livestock, thermoelectric power generation, or other uses.

OIL WASTE

Wastes whose characteristics are determined by petroleum or its derivatives. Contaminated soils are excluded from this category.

OLIGOTROPHIC

Waters with small supplies of nutrients and low bioproduction.

OMBROGENOUS MIRES (upland moors)

Mires obtaining water from precipitation and comprising acid, raised and blanket bogs, often rich in spaghnum.

OPEN LAND WITHOUT, OR WITH INSIGNIFICANT, VEGETATION COVER

Non-built-up land the surface of which either is not covered at all by vegetation or scarcely covered by some vegetation, which precludes its inclusion in other categories of the classification.

OTHER ECONOMIC ACTMTIES

Covers ISIC divisions 02, 05, 15-20, 22, 28-37, 41, 45, and 50-67.

OTHER FUELS

Includes all renewable forms of energy, such as firewood, biomass, waste used in incineration etc., which are burned when used for energy purposes.

OTHER INDUSTRIAL USE OF WATER

All industrial use of water except consumptive use and use for cooling water.

OTHER LAND USED FOR TRANSPORT AND COMMUNICATION, N.E.S.

Included is land under (surface) pipelines for the transport of fuels and other products. Also included is land officially designated as harbour area even if used for industrial or commercial premises.

OTHER LAND N.E.S.

Includes Prairie Grasslands, Savannah/Portland and Chepperal/Mediterranean Crops.

OTHER PROCESSES

All production and consumption processes except those involving the combustion of fuels for energy purposes. Included are in particular the application of any fertilizer and pesticides in agriculture and forestry, stubble burning, excavations in mining and quarrying, any industrial process giving rise to relevant emission of air pollutants, burning of waste without recovery of energy, evaporation from the filling of fuel reservoirs, etc.

OTHER SUPPLY OF WATER

Any supply of water not elsewhere specified. In particular, supplies from commercial and industrial establishments, whether marketed or not, are covered under this item.

OTHER TREATMENT/DISPOSAL METHOD

Any procedure modifying the characteristics of waste and/or permitting its long-term storage that is not specified elsewhere in this classification.

OTHER WATER

Includes atmospheric precipitation, sea-water, permanent bodies of stagnant water both natural and artificial, mine water, drainage water (reclamations), and transitional water, such as brackish swamps, lagoons, and estuarine areas. Resources can be assessed statistically for individual components of other water, but not for the item as a whole. Other water resources may be of great importance locally, although in a national context they are usually of lesser importance as compared to surface and groundwater resources.

OXYGEN DEFICIENCY

A lack or complete depletion of oxygen leading to anaerobic decomposition and easy formation of toxic hydrogen sulphide gas.

PAPER AND PAPERBOARD WASTE

Wastes whose characteristics are determined by paper and paperboard.

PARKS, GREEN AREAS, HOBBY GARDENS, CEMETERIES, ETC.

Land used for the facilities mentioned and similar purposes (major playgrounds, sportsfields, etc.), including auxiliary spaces.

PERIPHYTON

The organisms attached to submerged plants.

PH

The negative logarithm of the hydrogen ion concentration in a solution. pH values from O-7 are considered to describe acidity and values from 7- 14 alkalinity, respectively. The natural pH of a water body depends on the geochemical characteristics of the catchment area. The pH of a media influences the form of its component substances and thus plays an important role in the circulation of materials.

PHYSICAL TREATMENT OF HAZARDOUS WASTE

Includes various methods of phase separation and solidification whereby the hazardous waste is fixed in an inert, impervious matrix. Phase separation encompasses the widely used techniques of lagooning, sludge drying in beds, and prolonged storage in tanks, air flotation and various filtration and centrifugation techniques, adsorption/desorption, vacuum, extractive and azeotropic distillation. Solidification or fixation processes, which convert the waste into an insluable, rock-hard material, are generally used as pretreatment prior to landfill disposal. These techniques employ blending the waste with various reactants or organic polymerization reactions or the mixing of the waste with organic binders.

POINT SOURCE OF POLLUTION

An anthropogenic source of emission which from a practical point of view is located at an identificable point in space. The term covers sources such as sewage treatment plants, power plants, other industrial establishments, and similar buildings or premises of small spatial extension.

POWER PLANTS

Undertakings producing electricity and/or steam and hot water. For the purposes of this classifications, all power stations should be included, irrespective of their legal form (that is, whether private or public; whether legally independent or not)

PRESERVATION OF LEGALLY PROTECTED OBJECTS

Environmental protection activity to protect individual objects, identified by law or equivalent legal instruments, from damage by environmental pollutants, noise, vibration, and the like. For the purpose of this classification, built-up objects are excluded.

PRIMARY PRODUCTION

The production of organic from inorganic matter by photosynthesis.

PROTECTION OF HUMAN SETTLEMENTS

Activity designed-to safeguard the normal functioning of infrastructure installations in cities or villages.

PROTECTION OF NATURE AND LANDSCAPE

Environmental protection activity in relation to natural hazards (excluding protection of human settlements), the preservation of legally protected objects (excluding built-up objects, and the protection of faunistic or floristic species.

PROTECTION OF SOIL AND GROUNDWATER

Environmental protection activity involving the construction, maintenance, and operation of installations for the decontamination of polluted soils and the cleansing of groundwater.

PROTECTION OF SPECIES

Environmental protection activity for the purpose of the conservation of threatened species of fauna and flora.

PROTECTIVE ACTIVITY

Any process primarily intended to prevent or cure environmental damage, or to abate or reduce environmental pollution. Includes changes in processes undertaken for the same purposes.

PUBLIC SEWERAGE

Sewer networks operated by governmental, federal, or local authorities, by communities, water authorities or sewage/waste-water collection, discharge, and treatment associations.

PUBLIC SUPPLY OF WATER

Water supply by waterworks. Deliveries of water from one public-supply undertaking to another are excluded.

RADIOACTIVE WASTE

Any material that contains or is contaminated with radionuclides at concentrations or radioactivity levels greater than the "exempt quantities" established by the competent authorities, and for which no use is foreseen. Radioactive wastes are produced at nuclear power plants and at associated nuclear fuel cycle facilities as well as through other uses of radioactive material, for example, the use of radio-nuclides in hospitals and research establishments. At nuclear power plants the wastes arise from various operations including coolant cleanup, maintenance, repair and decommissioning; other important wastes are those from mining and milling of uranium and from the reprocessing of spent fuel. Radioactive wastes are commonly classified as low-level, intermediate-level, or high-level.

RARE SPECIES (IUCN Red Data Book)

Taxa with small world populations that are not at present "Endangered" or "Vulnerable", but are at risk. These taxa are usually localized within restricted geographic areas or habitats or are thinly scattered over a more extensive range.

RECREATIONAL AND OTHER OPEN LAND

This item relates to land used for purposes of recreation, such as sports fields, gymnasia, major playgrounds, major public parks and green areas, public beaches and swimming pools, camping sites, areas mainly occupied by facilities for tourism, secondary residences or vacation houses, hobby gardening, cemeteries, open land currently under construction or destined for future construction, etc.

RECREATIONAL LAND MAINLY OCCUPIED BY CAMPING SITES, SECONDARY RESIDENCES OR VACATION HOMES

Part of total residential land which is mainly used in an identifiable way for camping sites, secondary residences, or vacation homes.

RECYCLED WATER

Amount of water that would have been needed in the place of semi-closed and closed industrial circuits, excluding central heating systems.

RECYCLING AND REUSE

The use of materials obtained from wastes as inputs into economic processes. Recycling and reuse can also occur with regard to finished products that temporarily considered waste.

RESIDENTIAL LAND

Land mainly covered by residential or mainly residential buildings, irrespective of whether they are actually occupied or temporarily vacant. Included in residential land are attached private gardens and small green areas mainly used by the inhabitants of the buildings to which they are attached. Residential areas also comprise parking facilities and small playgrounds essentially reserved for use by the local population. Excluded is land used for purposes specified elsewhere, even if it is mainly used by the local population. In replies to international data collections, respondents should specify the criteria used as a basis for determining whether a building is mainly residential or mainly non-residential.

RETURNED WATER

Water abstracted from any source and discharged without use. Occurs primarily during mining or construction activities.

RIVER BASIN

Area having a common outlet for its surface runoff.

RIVER FLOW

Volume of water per unit of time passing through a cross-section of a river.

RUBBER WASTE

Wastes whose characteristics are determined by rubber materials. Used tyres are included.

SAND BEACHES, DUNES, OTHER SANDY LAND

Part of open land covered by beaches, dunes, crude deserts, and desertified areas, etc.

SELF-SUPPLY OF WATER

Net abstraction of water for own final use.

SEPTIC TANK

A settling tank in which settled sludge is in immediate contact with the waste-water flowing through the tank, and the organic solids are decomposed by anaerobic bacterial action.

SLUDGE FROM WASTE-WATER TREATMENT

The accumulated settled solids separated from various types of water, either moist or mixed with a liquid component as a result of natural or artificial processes. For purposes of this classification, only sludges generated in waste-water treatment plants are considered.

SOLIGENOUS MIRES (lowland bogs)

Mires which are influenced by groundwater as well as by precipitation. They produce various forms of peat of low organic content.

SOURCE OF EMISSION

The point or area from which substances are discharged into the atmosphere. In the classification a distinction is made between stationary and mobile sources; and between combustion and other process sources.

SPECIES OUT OF DANGER (IUCN Red Data Book)

Taxa formerly included in one of the IUCN Red Data Book categories, but which are now considered relatively secure because effective conservation measures have been taken or previous threats to their survival have been removed.

SURFACE FRESHWATER BODY

Water which flows over, or rests on, the surface of a land mass. For purposes of this classification, the term covers rivers, lakes, artificial watercourses, and reservoirs. Sea-water and transitional waters such as brackish swamps, lagoons, and estuarine areas are not considered surface freshwater.

SURFACE WATER

Water which flows over, or rests on, the surface of a land mass: natural watercourses such as rivers, streams, brooks, lakes, etc. as well. as artificial watercourses, such as irrigation, industrial and navigation canals, drainage systems and artificial reservoirs. For purposes of this classification, bank filtration is covered under surface water. Sea water, permanent bodies of stagnant water both natural and artificial, and transitional waters, such as brackish swamps, lagoons, and estuarine areas, are not considered surface water and are included under "other water".

SYNTHETIC FIBRE WASTE

Wastes obtained during production activities focusing on synthetic fibres.

TEXTILE WASTE

Wastes produced during final consumption, whose characteristics relate to textiles.

THERMAL ELECTRICITY GENERATION

Activities classified in ISIC, Rev.3 category 401.

THERMAL TREATMENT OF HAZARDOUS WASTES

Process for the high-temperature oxidation of gaseous, liquid, or solid hazardous wastes, converting them into gases and incombustible solid residues. The flue gases are released into the atmosphere (with or without recovery of heat and with or without cleaning) and any slag or ash produced is deposited in the landfill. The main technologies used in the incineration of hazardous waste are the rotary kiln, liquid injection, incinerator grates, multiple chamber incinerators, and fluidized bed incinerators. Residues from hazardous waste incineration may themselves sometimes be regarded as hazardous waste. Incineration of hazardous waste can be carried out on land or at sea. Evolving thermal energy may or may not be used for the production of steam, hot water, or electric energy.

THERMO-TOLERANT COLIFORMS

Organisms capable of aerobic growth at either 44/+/0.25/C or 44.5/+/0.25/C in a liquid lactose culture medium, and producing acid and gas within 24 h.

TIDAL WATERS

All waters (other than inland waters), brackish or marine, lying on the landward side of the "normal base-line" (LOS) along the coast, and in estuaries between this low-water mark baseline and the seaward side of the line at the mean tidal level. (Additional criteria may have to be applied in special cases, where this definition would lead to inappropriate results).

TOTAL EXPENDITURE (FOR ENVIRONMENTAL PROTECTION)

Sum of gross fixed capital formation and current expenditure related to the technical operations or activities as specified in this structure.

TREATMENT OF WATER PRIOR TO FIRST USE

Process to render water withdrawn from any source suitable for first use. Simple screening of water is not considered a treatment.

TREATMENT PLANT

Installation to render waste-water, storm water, or cooling water fit to meet applicable environmental standards.

TREATMENT OF WASTE

Process designed to change the physical, chemical, or biological character or composition of any waste to neutralize it, render it non-hazardous, safer for transport, amenable for recovery or storage, or to reduce it in volume. A particular waste may undergo more than one treatment process.

TREATMENT OF HAZARDOUS WASTE

Comprises the processes of physical/chemical treatment, thermal treatment, biological treatment, conditioning of radioactive wastes, and any other relevant treatment method.

TREATMENT OF OTHER THAN HAZARDOUS WASTE

Comprises incineration of waste, biological treatment, and any other treatment method.

UNDERGROUND DISPOSAL

Temporary storage or final disposal of hazardous wastes in underground mines that meet specific geological and technical criteria.

LAN-D USED FOR GRAZING OF DOMESTIC ANIMALS

Land on which domestic animals are periodically grazed, usually during seasons.

VULNERABLE SPECIES (IUCN Red Data Book)

Taxa believed likely to move into the "Endangered" category in the near future if the causal factors continue operating. Included are taxa of which most or all the populations are decreasing because of over-exploitation, extensive destruction of habitat, or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security has not yet been assured; and taxa with populations that are still abundant but are under threat from severe adverse factors throughout their range.

WASTE

Materials that are not prime products (that is, products produced for the market) for which the generator has no further use for own purposes of production, transformation, or consumption, and which he wants to dispose of. Wastes may be generated during the extraction of raw materials, during the processing of raw materials to intermediate and final products, during the consumption of final products, and during any other human activity. Residuals recycled or reused at the place of generation are excluded. Also excluded are waste materials that are directly discharged into ambient water or air.

WASTE-WATER

Water which is of no further immediate value for the purpose for which it was used or in the pursuit of which it was produced because of quality, quantity, or time of its occurrence. However, waste-water from one user can be a potential supplyof water to a user at a different location. Cooling water is not considered to be waste-water for purposes of this classification.

WASTE-WATER TREATMENT

Process to render waste-water fit to meet applicable environmental standards or other quality norms. Three broad types of treatment are distinguished in the classification: mechanical, biological, and advanced treatment. For purposes of calculating the total amount of treated waste-water, volumes reported should be shown only under the highest type of treatment to which it was subjected. Thus, waste-water treated mechanically as well as biologically should be shown under biological treatment, and waste-water treated in accordance with all three types should be reported under advanced treatment.

WASTE-WATER

Water which is of no further immediate value to the purpose for which it was used or in the pursuit of which it was produced because of quality, quantity, or time of its occurrence. Cooling water is not considered to be waste-water for purposes of this classification.

WASTE-WATER TREATMENT PLANT

Installation to render waste-water fit to meet applicable environmental standards.

WATER ABSTRACTION

Removal of water from any source, either permanently or temporarily. Mine water and drainage water are included. Water abstractions from groundwater resources in any given time period are defined as the difference between the total amount of water withdrawn from aquifers and the total amount charged artificially or injected into aquifers. The amounts of water artificially charged or injected are attributed to abstractions from that water resource from which they were originally withdrawn.

WATER BODY OF INTERNATIONAL IMPORTANCE

A water body fulfilling one or more of the following criteria:

a) The area of the river basin is at least 30,000 km^2; or
b) the area is shared by at least two countries; or
c) the watercourse affects significantly the quality of coastal and/or seawaters at the mouth of the watercourse.

WATER REGULATION

Man-made modification of the location, width, or depth of the bed of a water body, as well as modification of its water regime.

WATER SUPPLY

Delivery of water to final users plus net abstraction of water for own final use (“self-supply”).

WATERS IN LAND USE CLASSIFICATIONS

This relates to the part of the national territory to be reported which is covered by surface waters. The national territory to be reported is defined as the surface enclosed by all inland borders and, if applicable, the normal base-line (low-water mark) on the seaward side.

WET OPEN LAND

Non-wooded sites either partially, temporarily, or permanently water-logged, the water of which may be fresh, brackish, or saline, or on blanket or raised peatlands. The water may be either stagnant or running, and is usually shallow, especially if it is saline.

WET TUNDRA

Temporarily inundated, treeless flood region with arctic climate and vegetation.

WOOD WASTE, EXCLUDING FORESTRY WASTE

Wastes whose characteristics are determined by wood and cellulose. Includes waste consisting of wood panels.

PART THREE:
ESTIMATION OF EMISSIONS TO AIR
(selected national practices)

CHAPTER ONE

AMBIENT AIR POLLUTING EMISSIONS IN THE NETHERLANDS
(February 1991)

CONTENTS

Glossary of terms and acronyms

Note: Tables and figures mentioned in the text are included at the end of the Chapter.

Glossary of terms and acronyms

CBR	Central Business Register of the CBS
CBS	Netherlands Central Bureau of Statistics
CFC	Chlorofluorocarboncompounds, including Bromocompounds
CO	Carbon monoxide
CO_2	Carbon dioxide
EC	European (Economic) Community
ECE	United Nations Economic Commission for Europe
GJ	Gigajoule
EPA	U.S. Environmental Protection Agency

ER	Emission Registration (Netherlands)
F	Fluor
ISIC	International Standard Industrial Classification of all Economic Activity (UN)
LPG	Liquefied petroleum gas
MJ	Megajoule
N	Nitrogen
NACE	General Industrial Classification of Economic Activities within the European Communities
NH_3	Ammonia and ammonium compounds; expressed in NH3
NL	The (Kingdom of the) Netherlands
NO_2	Nitrogen dioxide
NO_x	Nitrogen (nitrous) oxides; expressed in NO, equivalents
O	Oxygen
S	Sulphur
SI	Système International des Poids et Mesures
SIC	Standard Industrial Classification of all economic activities; CBS version (1974) of the EC-NACE (compatible with ISIC)
SO_2	Sulphur dioxide
TA	Technische Anleitung (DE)
TNO	Netherlands Organisation for Applied Scientific Research
TSP	Total in ambient air suspended particles; elsewhere used equivalents: SPM (suspended particulate matter), particulates, fine dust, aerosols
TÜV	Technischer Überwachungs-Verein (DE)
voc	Volatile organic compounds, methane (CH4) excluded

A. INTRODUCTION

The aim of these statistics is to estimate the quantities of major air pollutants. This is done through periodic national and regional surveys. The pollution-causing activities monitored include:

1) combustion of fossil fuels in furnaces and ovens (so-called stationary sources) in economic activities and in private households to generate power and/or heat;

2) industrial and other stationary processes other than fuel combustion;

3) use and combustion of fuels by traffic and other mobile equipment.

Major air pollutants are those groups of compounds that, once released into ambient air, are either in themselves harmful to human and animal life and/or vegetation, and/or are precursors for ozone, smog, and acidification. Included are emissions of carbon dioxide (CO_2), as they contribute to a steady increase in the concentration of this gas in the atmosphere, which may lead to global climate changes (the “greenhouse effect”). Excluded are anthropogenic fugitive emissions and emissions from nature. Also excluded is the emission of ammonia from animal manure, a typically Dutch problem. In the next section, current CBS surveys for the Netherlands are described. In the description of the methodology applied, some items have been generalized somewhat to make them more accessible to the reader. Methodological consistency over time is important in order to achieve comparable time series.

For practical reasons, in the Netherlands the air-pollution survey has been split up into combustion emissions from furnaces, for which estimates are made every three months to show seasonal variations, and once per year on a more detailed level, and process emissions, which are presented biannually. The mobile source emissions are estimated separately on an annual basis which copes reasonably with variations.

Inventory methods are discussed below in section B for combustion emissions, section C for process emissions, section D for road traffic emissions, and section E for emissions from other mobile sources. As will be shown, the statistics dealt with in B, D, and E are so-called derived statistics, calculated on the basis of other CBS statistics (fuel and traffic). Process emissions (C) are so-called secondary statistics, based on a non-CBS third party database. None are primary statistics, the type resulting from direct inquiry into the population in census. Each section can be read more or less independently.

Units

Statistical surveys on environmental pollution concentrate on physical aspects, basically quantities of substances measured in units as prescribed by the Système International des Poids et Mesures (SI). A special and important aspect is that the quantities of the different pollutants released are not only described by origin, but also by destination and region, where applicable and possible. Such statistics concern emissions released on the territory of the Netherlands, which often do not coincide with the emissions of the Dutch economy. Financial aspects of environmental pollution are covered by separate CBS statistics which describe the cost and financing of environmental control. Such statistics are not dealt with in this report.

Statistical coordination

CBS classifies all Dutch enterprises (companies) and their local activity units according to SIC codes (the Dutch version of the International Standard Industrial Classification, or ISIC) and enters permanent company data in its central database, the Central Business Register (CBR). Surveys for most economic statistics, including environmental statistics, make use of population data from the CBR so that statistical results will be mutually and internationally comparable and compatible (NACE; ISIC).

Automation

In the experience of CBS, most operations in gathering, processing, editing, and disseminating data, including calculations, can be automated relatively easily on advanced PC-AT computers (with 80286/386 processors and PC-DOS or MS-DOS operating systems) and adequate IO-features, using standard software such as Lotus l-2-3, DBase, Word-Perfect, and Ventura for publishing (registered tradenames).

B. FURNACES

CONCEPT

The major (groups of) air pollutants caused by the combustion of fossil fuels in furnaces are SO,, NO,, TSP, CO, and VOC. In the statistics, the emission of CO, is also accounted for.

The emission of SO_2 is due to the sulphur present in fuels. The emissions of CO, VOC, and TSP are caused by incomplete combustion of fossil fuels. TSP also is generated in large part through the presence of incombustibles in fuels. Conditions of combustion are themselves paramount factors in the level of NO, generation.

CO_2 emissions depend on the carbon content of fuels. The amounts of the pollutants leaving chimneys and stacks depend on the quality of combustion and on treatment or abatement of flue gases.

Raw data collection through a classical statistical (sample) survey did not prove feasible, as types and uses of furnaces and ovens vary widely. Furnaces range from household stoves, central and space heaters and ovens in industry, to furnaces in refineries and electric power stations. Also, most operators do not keep regular records of emissions. An efficient and dependable method has been to compute emission data on the basis of fuel consumption by economic activity, multiplied by a set of emission factors. The data on fuel consumption could be derived from surveys on the use and storage of energy carriers. Such data are often available from organizations which deal with or control energy production and consumption patterns in the country. Emission factors can be collected as illustrated below.

METHOD (Reference is made to flow chart B1)

Emission factors

- *Introduction*

An emission factor stands for the amount of a specific air pollutant released when a unit quantity of a specific fuel is combusted under certain conditions in a certain type of furnace. Emission factors are preferably expressed as gram (g) pollutant/GJ (gigajoule) net heat of combustion. (Net heat means combustion without condensation of the water vapour fonned.) CBS obtains the emission factors, which vary per year for each compound, as follows:

- *Emission factors of [illegible] VOC, TSP, NO_x and CO_2*

All fossil fuels contain the element carbon. In complete combustion, all carbon reacts with atmospheric oxygen (from the air participating in the combustion) to become CO,. However, in actual practice combustion is never complete. Some carbon is only partly converted, into carbon monoxide

(CO) and VOCs. The better the furnace from a combustion point of view, the better the degree of conversion into CO_2. Large, professionally operated furnaces, such as those in electric power stations, tend to have much lower emission factors for CO and VOC than simple furnaces such as those used for central heating in homes.

Carbon that is not combusted at all produces soot, visible as black smoke, which falls into the category of TSP. Another major source of TSP is the incombustibles in fuel. Major products from incombustibles are bottom slag and fly ash from coal combustion, and fly ash from the incineration of heavy fuel oils. The amount of TSP ultimately released depends on the technologies -- such as electrostatic filter systems -- used for cleaning flue gas.

Most NO, produced in furnaces results from a reaction between N_2 and O_2 in the combustion air introduced in burner flames because of high temperatures. Smaller amounts of NO, result from reactions of nitrogen compounds in fuel, especially in coal, with the combustion oxygen. Large furnaces in steady-state conditions with high flame temperatures and relatively long residence times produce far more NO, than low-temperature equipment (household appliances) and varying combustion loads. The introduction of modem, multi-stage low-NO, burners, catalytic combustion, and catalytic flue-gas cleansing (will) lead to lower emission factors. NO, is expressed in NO_2 equivalents.

In summary, the emission factors for CO, VOC, TSP, and NO, depend on the type of fuel and the type of furnace, with its characteristic conditions of combustion.

Thus, when a survey is conducted, for each of the pollutants an array of emission factors is produced valid for the statistical year under consideration. The array columns show the solid, liquid, and gaseous fuels. The rows show the economic activities according to SIC. The relation between SIC activity and furnace type is that in each of the SIC categories similar types of furnaces are used, so that the determination of average emission factors is possible. Tables B1 through B4 illustrate the emission factors used in the Netherlands in 1989. The emission factors are mostly based on measurements by research institutes, and obtained from literature and from contacts with experts in the field. Each year the factors are carefully scrutinized and adapted, but in general they remain reasonably constant.

The emission factors for CO_2 are derived from the percentage of carbon in the average molecular formula of the fuel, either taken from literature or estimated. This is to a large extent independent of the SIC activity for which the fuel is combusted. As an example, the calculation of the CO,-emission factor for heavy fuel oil is given. The estimated carbon percentage of heavy fuel oil = 86; hence 860 grams of carbon per kg of oil. In case of 100 per cent combustion of the carbon, 44/12 x 860 = 3 160 grams CO_2 is formed and emitted per kg of oil. Via the net heat of combustion for heavy fuel oil (100 kg = 41 GJ), the emission factor can be expressed in gigajoules and becomes 3 160 kg CO_2 per 41 GJ, or 77 kg CO_2/GJ. Table B.5 shows the average CO_2 emission factors now used in the Netherlands.

- *Emission factors of SO,*

The emission of SO_2 is caused entirely by the fact that fuels contain sulphur (S) compounds by nature, and emissions are proportionate with that content. Obviously, SO, emission is independent of the SIC activity for which the fuel is being used. S compounds are usually expressed by fuel suppliers in per cent of S by mass (weight), or w%. The SO, emission factor in grams/gigajoule equals: 20 000 X w% S divided by the net heat of combustion in MJ/kg fuel. A multiplication factor of 0.95 is used with solid fuels because part of the $S0_2$ will not be emitted, as it is captured by the (basic) bottom ashes.

The S content of the fuels is obtained through an inquiry of fuel suppliers, such as the oil and coal companies, who usually keep records of S content for commercial reasons. The periodically weighed average content of S, and thus the SO_2 emission factors, may vary considerably for some fuels. This holds especially true for hard coal and for fuel oil. (In the Netherlands, natural gas for distribution to households and small industries is odorized by adding traces of certain S compounds.) Table D4 shows an S-content time series for heavy fuel oil used in the Netherlands. A good check is that in most countries legal maximum standards apply for sulphur in fuels. Table B6 illustrates the SO, emission factors used in the Netherlands in 1989.

Fuel consumption data

Data on the domestic consumption of each fossil fuel per SIC activity are derived every three months or every year from whatever energy statistics are available. These fuels are:

- solids, such as hard coal, cokes, petroleum cokes and brown coal;

- liquids, such as kerosene, gasoil, (heavy) fuel oil, and the gases LPG (butane and propane), natural gas, coking plant gas, blast-furnace gas, refinery gas, and chemical residue gas.

In the Netherlands the Energy Statistics Department of the CBS collects energy data every month from an inquiry covering all of SIC activities. All enterprises of activity units such as refineries, power plants, etc., are included in the inquiry. For other categories, consisting of relatively smaller enterprises, the inquiry is based on random samples. Totals per SIC activity are estimated from the samples. The fuel-consumption data are fitted into an array similar to that for the emission factors.

- *Data processing*

To enable emission calculations, data on non-fuel energy consumption are removed, such as the use of energy carriers as feedstock for chemicals (or natural gas for ammonia production, or naphta for petrochemicals, or coke for blast furnaces). Also removed are data on fuels used for transport, since they are covered under the category of mobile emission sources. Often a part of the national electricity delivery is generated within the manufacturing industry in so-called total-energy systems. This should be borne in mind when considering pollution due to electricity generation by fossil fuels.

Table B7 illustrates the results for the Netherlands in 1989 --the array of six fuels cornbusted in final use by SIC activity.

Calculation of emissions

Furnace emission data per pollutant are computed by multiplying two arrays, one containing the fuel-consumption data (Table B7) and the other containing the emission factors (Tables Bl-B6). To illustrate the method for the Netherlands, Table B8 shows the aggregated results for pollutants in 1989. Regularly disseminated are detailed tables with the emissions of 18 SIC-activity groups (including 14 industrial) plus private households, and 13 kinds of fuels, similar to the array in Table B7.

- *Limitations*

Until now, no regional data on furnace emissions have been gathered. This is due to the fact that regional data on fuel consumption are not yet available for all major energy carriers (the regional supply of oil products is not recorded by the major respondents).

The accuracy of the results varies considerably, depending on the accuracy of the basic data. The emission factors are less accurate than the fuel-consumption figures. The standard deviations of the emission data are roughly estimated at 10 per cent for SO_2, 10 to 20 per cent for NO,, 25 per cent for TSP, and 25 to 100 per cent for CO and VOC.

C. PROCESS EMISSIONS

CONCEPT

For process emissions, some 500 polluting substances are considered. For practical statistical reasons, these are aggregated into some 20 compound classes based on chemical/environmental similarity. Major classes are SO_2, NO,, F, TSP, CO, VOC, NH,, heavy metals, and CFCs. In the statistics, the emission of CO_2 is also accounted for.

Gathering raw data through a classical statistical (sample) survey did not prove feasible in the Netherlands, as process emissions are widespread and often casual. Also, most operators do not keep regular records on such emissions.

The solution found is based on an agreement between the CBS and the Ministry of the Environment. The agreement permits the CBS to use the database of the periodic Emission Registration (ER) of the ministry as a source of computerized basic data. To convert these basic data into statistics, it is assumed that approximately 20 per cent of the industrial emitters cause about 80 per cent of the process emissions. The assumption was verified for the Netherlands through an exhaustive emission inventory made by the ER covering the past 15 years. For the CBS computation, there are good technical reasons to assume furthermore that emissions are directly proportional to production, as long as no major changes in the processes of the (individual) companies have been reported since the last ER cycle.

When an emission registration is not available as a source of data, process emission data may be calculated with the aid of emission factors for similar processes. In the Netherlands, only ER has practical experience with this method for minor cases.

METHOD

Emission registration

The ER collects process emission data from local units of enterprises with 10 or more employees, enabling regionalized figures. Smaller enterprises are only taken into account if substantial emissions are expected. Registration is carried out by teams of specialists (hired from TNO) who visit sites and plants, or through actual measurements, or via material balances. The emissions of about 1100 major companies (of the 6300 in the ER) are registered in detail. This implies that approximately once every three years, data on individual companies are collected. About four of the 12 provinces/regions are covered every year. The smaller companies are investigated less frequently and through more general methods (calculation using emission factors).

Every two years, the CBS extrapolates the ER data to a common statistical year by using CBS production data per enterprise for the 20 per cent who are the major emitters -- that is, cause 80 per cent of process emissions -- and by applying production activity indices per SIC activity for the remaining 80 per cent of emitters (who cause 20 per cent of the emissions). The major emitters selected are the companies in the SIC activities as indicated with an arrow in the SIC list (see

Table Cl). This assumed 20-80 relationship is checked afterwards for each compound class via the results of the statistics. If air pollution abatement measures or major changes in production processes are known to have occurred, extrapolations are replaced by direct estimation of emissions.

The results are disseminated per compound class for 15 SIC activities, including 11 industrial, for each of the 12 Dutch provinces. Table C2 shows the aggregated results for the year 1984 and 1986 for the Netherlands as a whole. Data on process **CO,** will be available in 1992.

Emission factors

An emission factor is the amount of a specific air pollutant group released per activity unit, for example per tonne of specific product (raw materials input, intermediate, or output), per unit of time, or per man-hour.

Emission factors can be found in the following manual: Handbook of Emission factors (Ministry of the Environment), especially in Part II: “Industrial sources,” which also contains many references. This publication is available in English from SDU Publishers, The Hague. See Appendix I for the contents and a list of background literature. Many emission factors refer to the situation in the Netherlands in the early’eighties and may therefore be different for other countries and years. An update of this publication is under consideration.

Other sources of emission factors are the handbooks of the Environmental Protection Agency (EPA) of the United States, and the German TA-Luft (Technische Anleitung).

Data about variables determining emissions such as input, intermediate consumption or output, and manpower can be found in SIC production and labour statistics. These are available from statistical offices and/or economic institutions. However, many emission factors are given for specific production processes, as may be observed in Appendix I. Hence process data for specific industries or processes should be known.

D. ROAD TRAFFIC

CONCEPT

The major groups of air pollutants from road traffic are the tailpipe emissions of CO, VOC, NO,, TSP, SO,, lead compounds from combustion of fossil fuels in engines, and the VOC emissions due to evaporation of fossil fuels from the fuel systems of road vehicles. In the statistics, emissions of CO_2 are also accounted for.

The emissions of CO, VOC, and TSP are caused by incomplete combustion of motor fuel due to varying motorload conditions while driving. They depend on driving mode, engine type, engine size and condition, and emission abatement measures (for example, exhaust converters). TSP is also caused by incombustibles in fuels and by the reaction products of tailpipe catalyst treatment. TSP (as used in statistics) excludes lead. High internal engine combustion temperatures cause the formation of NO,. Such emissions also depend on engine load.

The emissions of SO_2 and lead are caused entirely by the presence of sulphur compounds and/or lead compounds in motor fuels. The sulphur compounds come from crude petroleum and the lead compounds have been added as anti-knock agents. CO, emissions depend on a fuel’s carbon content.

Data about such emissions generally cannot be obtained through a classical statistical sample survey, such as an inquiry (questionnaire or polling) of the population involved (vehicle owners or garages). The phenomenon is too widespread and nonhomogeneous. A well-proven method for gathering annual statistical data on traffic air pollution is through calculation.

The emissions of CO, VOC, TSP, and NO, are estimated by multiplying traffic-performance data (annual mileage = driven distance) and emission factors (average emission per driven kilometer -- or mile -- in tailpipe exhaust gases after treatment). The emissions of SO,, lead, and CO_2 are estimated on the basis of fuel consumption and emission factors (average emission per kg of combusted fuel). The emission factors are derived from the sulphur, lead, and carbon contents of the fuels.

Emissions due to evaporation are estimated according to the number of vehicles by employing the emission factors (average emissions per vehicle per day). Emissions from the handling and storing of motor fuels, including the filling of vehicle fuel tanks, are considered process emissions (section C).

The data on traffic performance and fuel consumption should be obtained from inquiries into the use of road vehicles. Such data often can be obtained from organizations which produce traffic statistics. The ECE Bulletin of Statistics of Road Traffic Accidents in Europe provides numbers of vehicles and estimated vehicle-kilometre figures for participating countries. If data on fuel consumption by traffic are lacking, they can be obtained by calculating traffic-performance and fuel-consumption factors (average fuel consumption per kilometer driven). Emission factors can be collected as indicated below.

METHOD (Reference is made to flow chart DI)

Emission factors

- *Introduction*

Emission-factor levels for road traffic depend largely on the type of internal combustion engine, the type of fuel used, and on engine power, or output. Normally two types of engines are used --the spark-ignited, 4-stroke Otto engine, which runs on petrol or LPG, and the compression-ignited diesel engine, which runs on automotive gasoil. Since the Sixties in the Netherlands, 2-stroke Otto engines have not been used in cars but only in motorcycles and mopeds.

Motor petrol, or gasoline, consists mainly of a mixture of C6-C9 hydrocarbons, including 30 to 40 per cent aromatic hydrocarbons. In many countries, petrol is supplied in the grades premium, regular, and Euro. A number of dopes are added to the fuel to improve combustion in the engine cylinders. Organic lead compounds, added as an anti-knock agent, are one of these. A maximum lead content is often set by legislation -- see table D4. Petrol exhaust gases contain uncombusted hydrocarbons and reaction products from incomplete combustion, such as CO and very small amounts of ethane, acetylene, aldehydes, and polycyclic hydrocarbons. Because of the high temperature in the engine cylinders, NO, is formed from a reaction between N_2 and O_2 in the combustion air.

Of the lead present in petrol, about 75 per cent escapes through the exhaust as TSP and the remainder ends up as deposit in the engine and in the lube oil. Although the sulphur content of petrol is very low, typically 0.02 w. per cent on average, the resulting SO, emissions cannot be neglected because of the huge quantities of petrol consumed.

LPG, liquid petroleum gas, consists of C3-C4 hydrocarbons and is lead- and sulphur-free. LPG as motor fuel emits much less CO and less VOC than petrol, and no lead or SO,.

Gasoil, or diesel fuel, is a heavier oil product than petrol and has a high percentage of little branched alkanes (approx. C17-C34). It contains sulphur compounds by origin, and a maximum S content is often set by legislation. See Table D4.

In principle, a diesel engine has complete combustion because of the large amount of air used, resulting in low levels of hydrocarbons and CO in the exhaust. The emission of NO, is also lower than with petrol engines. Because gasoil does not contain lead compounds, diesel vehicles do not emit lead. However, diesels emit other substances, such as soot, aldehydes (the main origin of the bad exhaust smell), and polycyclic hydrocarbons. The S content of gasoil is considerably higher than that of petrol, typically 0.2 to 0.3 w%, leading to a higher emission of SO,. It is assumed that 95 per cent of the sulphur in the fuel is converted into SO,.

In modem Otto engines, emission abatement is accomplished through modified engines (such as lean-bum engines) or through exhaust-gas conversion in the tailpipes. Nowadays there are two types of conversion: pure afterburning and catalytic conversion. The so-called three-way catalytic converter changes CO and VOC into CO_2, simultaneously changing NO, into N,. Unfortunately, some sulphuric acid is produced from the SO, in the exhaust gas. Catalyst vehicles need lead-free petrol, which is now often available in each grade.

- *Emission factors of CO, VOC, NO,, and TSP*

The magnitude of the emissions of CO, VOC, and NO, is not only determined by the type of engine and the kind of fuel, but, as mentioned above, also by the engine load (power, or output), which in turn depends on vehicle speed and the driving patterns. Acceleration, deceleration, and idling result in an increase in emissions of CO and VOC. The emissions of CO and VOC decrease if the average speed increases (up to about 100 km/h). In contrast, the emission of NO, increases slowly with speed until about 60 km/h. If the speed grows higher, the increase of the emission of NO, accelerates. At 100 km/h the NO, emission per km is double that of 60 km/h. At speeds over 100 km/h, NO, emission increases still more disproportionately, and so does fuel consumption, so that emissions of CO and VOC increase in similar fashion.

This means that different emission factors apply for each trip a vehicle makes. To enable a reasonable estimate of emissions, traffic experts modelled several driving cycles, each representing the average driving pattern in a particular traffic condition. These driving cycles are converted into basic driving test cycles, enabling simulation of each driving cycle on a chassis dynamometer. The CBS combines six basic cycles into three cycles used in practice, as shown in the following table.

PRACTICALLY USED AND BASIC DRIVING CYCLES USED BY CBS

		Speed km/h average	
	{stagnant traffic		13.5
URBANAREAS	{EC standard town drive	19	
	{ freeflowing traffic		26
RURAL ROADS	{tertiary & other roads	42.5	
	{highways & secondary roads		60
MOTORWAYS	constant 85 km/h goods vehicles & 100 km/h for cars		

A number of research and development organizations in Germany and the Netherlands have measured and determined the different emissions in dynamometer tests of many types of vehicles, using the simulated driving cycles. These emission data are used to determine the emission factors for the three driving cycles CBS uses in practice.

ORIGIN OF THE BASIC DATA OF CBS EMISSION FACTORS

Vehicle category	Reference
Petrol vehicles < 3500 kg maximum weight	EC-type certification air pollution
Diesel vehicles	TÜV (Germany)
Other vehicles	TNO (the Netherlands)

The EC type-certification requirements for new cars, which are used to determine the emission factors of petrol cars, are valid for a standard town drive. This EC town test cycle has an average speed of 19 km/h. The maximum emissions set in the EC Directive for the standard town drive depend on the mass (empty weight) of the car to be certified. The Directive came into force in 1971 and has been made more stringent several times; various degrees of catalytic emission abatement were taken into account. The directive applies to passenger cars and to light duty-vehicles of under 3500 kg.

Based on data from the road traffic authority which performs the EC type certification in the Netherlands, the average emission certification test results were estimated by CBS at 70 to 75 per cent of the limits set by the EC. These EC emission limits per car weight class and model year, and valid for a 19 km/h standard town drive, are converted with the aid of NV-data through calculation into petrol emission factors for each of the three driving cycles used by CBS -- urban areas, rural roads, and motorways.

CBS applies correction coefficients for deterioration of engine tuning (engines getting older), the use of three-way catalytic converters, cold starts, warm-up driving, and the average ambient temperature in the Netherlands. Because the country is flat and at sea level, no corrections are introduced for pressure variations at altitude or for driving on slopes.

Thus an array of emission factors is produced, valid for the statistical year under consideration. The rows of the array show the four air pollutants subdivided into the three driving cycles. The columns of the array contain the following entries: vehicle category (passenger cars, delivery vans, lorries, road tractors, buses) of which propelled by: petrol, diesel fuel, LPG. These vehicles are subdivided into year of construction and weight class. For all these points, the emission factors differ, since new cars are “cleaner” than old cars and, as light vehicles have generally lighter engines than heavy ones, they emit fewer pollutants. The array may change for each statistical year, not only due to the appearance of a new model year, but also because of changes in the basic emission factor data as the result of new knowledge. This is especially true for passenger cars and light-duty vehicles. Heavy-duty vehicles last longer, and their characteristics change more slowly. Table D1 shows the array as used by CBS for 1988, valid for the categories and qualities of vehicles used in the

Netherlands in that year. For easy use this table is somewhat aggregated, not providing the weight classes and years of construction. The detailed background array is available from CBS on request. For other countries the values in the array may be different because of different composition of the vehicle fleet.

The array is recalculated into emission factors valid for the Netherlands vehicle fleet in the statistical year under consideration. Table D2 illustrates the results and contains the weighted averages of the 1988 fleet emission factors for each of the four air pollutants, the driving cycles (roads within built-up areas, motorways, and other -- rural -- roads). Vehicle types not used in the Netherlands, such as road tractors and buses fuelled with petrol, are omitted. Lorries, tractors, special-purpose vehicles (fire trucks, ambulances, etc.) and buses are aggregated into the category heavy-duty vehicles.

<u>Important</u>: the weighing to average values of emission factors is done on the basis of the annual mileage per cell of the array and not through the number of cars per cell. Where mileage data are not available, educated guesses have been used.

- *Emission factors of VOC from evaporation*

Because of the high volatility of petrol, evaporation from vehicle fuel systems causes substantial VOC emissions. Most comes from hot carburetors after driving, the remainder from fuel-tank aeration. The emissions from petrol evaporation are thought to be independent of mileage and fuel consumption. The VOC emissions are estimated by experts at 13 grams per petrol car per day. For motorcycles and mopeds it is estimated at 5 grams per day (Table D1). Furthermore, it is assumed that 95 per cent of the evaporation emissions take place within urban areas because most vehicles stay there most of the time. Emissions from diesel vehicles are set at zero because of the relatively low volatility of gasoil. Set at zero too are the VOC emissions of LPG cars, as the LPG fuel system is virtually closed.

- *Emission factors of CO,, SO, and lead*

The emission factors for CO, are derived from the percentage of carbon in the average molecular formula of the fuel. Obviously this is independent of the vehicle type in which the fuel is combusted. Table D3 shows the averaged CO, emission factors currently in use in the Netherlands for motor fuels. A calculation example of a CO, emission factor is shown in section B on furnace emissions.

The emission factors for SO_2 and lead, shown for the year 1988 in Table D1, are calculated as follows:

Sulphur compounds in fuels are usually expressed by the oil companies as a percentage of sulphur by mass, or w%. The SO_2 emission factor in grams/kg equals 20 X w per cent S X 0.95 (X specific weight to get SO, in grams/liter). The origin of the 0.95 factor stems from the 95 per cent of the sulphur in the fuel being converted into SO_2.

Lead compounds added to petrol are usually expressed by the oil companies in grams/liter of lead. The lead emission factor in grams/liter equals 0.75 X lead (divided by specific weight to get lead in grams/kg.) The factor 0.75 originates from the fact that only 75 per cent of the lead leaves the exhaust.

A common specific weight (in kg/liter) of diesel fuel is 0.84 and of petrol on average, 0.74. LPG is free of sulphur and lead.

The sulphur and lead contents of the fuels are obtained through a CBS inquiry, usually by telephone, among the 10 oil companies which supply the motor-fuel market in the Netherlands. Each month the companies indicate last month's averages of the sulphur and lead contents for each fuel, weighted with the amounts they supplied that month.

From its energy statistics, CBS knows the Dutch market shares of each company each year. These shares are used to compute weighted annual averages of the sulphur and lead contents of the motor gasoil and of the various grades of petrol. Table D4 illustrates the results for the Netherlands over a number of years.

Traffic performance

To compute the emissions of CO, VOC, NO,, and TSP, and to calculate fuel consumption (see below), traffic-performance figures are required. These are fitted into an array similar to that for the population emission factors. Data are needed on mileage in urban areas, on motorways, and on other roads per vehicle category and type of fuel. The data can be compiled from available traffic surveys. A good method is to start from statistical data on the annual average number of motor vehicles -- obtainable from the national vehicle license registration -- and to multiply that data by the average annual mileage per vehicle category (passenger cars, lorries, buses, etc.). Such annual mileages may be available from polls among drivers, from statistical inquiries among transport enterprises, etc. In the Netherlands these data are taken from the CBS Transport Statistics Department. The traffic performance figures have to be split up into urban and non-urban (motorways and rural roads) categories. Performance figures for motorways and other roads might be obtained through traffic counts from road or traffic-control authorities. Estimates by experts and statisticians should complete the picture to the extent feasible. It is necessary to include military traffic. If possible, corrections should be made for inland mileage of foreign vehicles (+) and for mileage abroad of domestic cars (-).

Road traffic fuel consumption

It is important to use motor-fuel road-consumption data for emission estimates, and not sales figures, as these may be quite different from the consumption data for the same year. That may be because of statistical and storage differences, and consumption by engines not engaged in road traffic, such as civil construction and agricultural equipment, military equipment, and boats.

In the Netherlands, road-traffic fuel consumption is estimated on the basis of the average fuel consumption per vehicle type from a regular CBS poll among a panel of drivers, and on the annual traffic performance (in kilometres). Data on average fuel consumption are often available from the same sources that supply data on annual mileage. To divide the emissions of SO_2 and lead into emissions within and outside urban areas, an estimate is needed of the respective fuel consumption. The average consumption per kilometre in urban areas is estimated to be 30 per cent higher than that outside urban areas. Table D5 provides aggregated data about road-traffic fuel consumption in the Netherlands over a number of years.

Calculation of emissions

Road traffic emissions of CO, VOC, NO,, and TSP are computed by multiplying two arrays, one containing traffic performance data and the other containing weighted average vehicle fleet emission factors (Table D2).

The emission of VOC by evaporation from vehicle fuel systems is computed by multiplying the number of vehicles (per type) with the pertaining emission factors (See table D1).

The emissions of CO,, SO,, and lead are obtained by multiplying the array of motor-fuel consumption data (Table D5) by the relevant emission factors (Table D3 for CO, and Table D1 for SO_2 and lead).

Table D.6 shows a time series for the Netherlands with the aggregated results for the pollutants, excluding lead,

For quick, rough estimation purposes, Table D2 (average emission factors, including SO, and lead) may be used.

- *Limitations*

CBS does not yet have regional data on traffic emissions, only data for the Netherlands as a whole. So far, insufficient regional data on road traffic performances are available. The accuracy of the results varies considerably, depending on the accuracy of the basic data. In the Netherlands, traffic data and emission factors on passenger cars and light-duty vehicles are of better quality than those on other types of road vehicles. The standard deviations of the emission data are estimated at 10 per cent for SO,, 10 to 20 per cent for NO,, 25 per cent for TSP, and 25 to 100 per cent for CO and VOC.

E. OTHER MOBILE SOURCES

CONCEPT

Other ambient air-polluting mobile emission sources due to fossil fuel consumption include:

Land-based

- Rail traffic, including trolleybuses;
- agricultural equipment;
- equipment in civil engineering, etc.;

Navigation

- inland shipping;
- recreational boating;
- seagoing vessels;

Aviation

- civil aircraft;
- military aircraft.

The major air pollutants from these mobile sources are essentially the same as those from road traffic (see section D), because most of these sources use internal-combustion engines that consume petroleum products. Adequate raw pollution data for these sources cannot be obtained through classical statistical survey methods, since the populations cannot always be traced. Therefore such emission data are obtained through rough estimates only, and for the Netherlands as a whole. Normally, emissions falling within the category "other mobile sources" are small compared with emissions from road traffic. However, there is reason for caution, because in the Netherlands that generalization does not apply to TSP (12 per cent of road-traffic TSP), CO, (15 per cent), NO, (17 per cent) and SO_2 (> 100 per cent). Important sources in the Netherlands of the additional NO, and SO_2 are seagoing vessels (using fuel oil with high sulphur content) and inland shipping, means of transport which are not significant in all countries.

METHOD

The general method for estimating emissions falling within the category of "other mobile sources" is to multiply a matrix on fuel consumption data and/or performances with a set of emission factors.

Each year, the emission factors in grams/kg fuel for SO_2 are calculated as follows: 20 X 0.95 X weight percentage of sulphur in fuel. See Table E2. In many countries, the sulphur content of fuels is limited by legislation.

The emission factors for CO_2 are derived from the percentage of carbon in the average molecular formula of the fuel. The formula is taken from literature or is estimated. Obviously this method is to a large extent independent of the type of emission source in which the fuel is cornbusted. Table E2 shows the average emission factors currently in use in the Netherlands for "other mobile sources." An sample calculation of a CO_2 emission factor is shown in section B, on furnace emissions.

The emission factors for CO, VOC, NO,, and TSP can be obtained from several sources, including literature and expert opinions. Data about fuel consumption and/or performance of the other mobile sources should be obtained from wherever they are or can be made available. The methods for estimating these emissions in the Netherlands are discussed below for each of the sources mentioned.

1. Rail traffic

Rail traffic in the Netherlands consists of railways (Nederlandse Spoorwegen), metros or subways (in Amsterdam and Rotterdam), trams or streetcars, and trolleybuses. Metros, trams, and trolleybuses have electric propulsion with power obtained from the national electricity network. This is also true of most trains.

Information on the annual electricitv_consumption of rail traffic is obtained from the companies which provide this transportation via the Transport Statistics Department of CBS. The total production of electricity in the Netherlands also is known from the CBS Energy Statistics Department. The national emissions data per pollutant for electric rail traffic are calculated from the emissions of the public power plants (dealt with in section B on furnace emissions) multiplied by the level of the rail traffic electricity consumption, divided by the total effective national electricity delivery. Table El illustrates this in a time series for the Netherlands.

All non-electric trains in the Netherlands have diesel traction as their source of power. This includes locomotives and self-propelled passenger cars. (Steam traction is obsolete.) Emission data are calculated using emission factors and information provided by the railways on diesel-traction fuel consumption. The emission factors applied in the Netherlands are shown in Table E2, and fuel-consumption data are presented in Table D5.

2. Agricultural machinery

Agricultural equipment consists of tractors and of harvesting and other machines with their own engines, usually diesel. Agricultural machinery is not licensed for road use. In countries with industrialized agriculture, the population of such vehicles can cause considerable **air** pollution.

The quick method for computing such emissions is to multiply fuel-consumption data (for the Netherlands given in Table D5) by emission factors from Table E2. In the Netherlands, fuel data are collected through agricultural census by the Agricultural Statistics Department of CBS.

- A more thorough method for computing emission data is through number and horsepower of each type of equipment, annual hours of use, resulting in million kilowatt-hours (or horsepower-hours) per year, and suitable emission factors (available from CBS on request).

In the Netherlands, the number and main types of equipment, and operating times, can be obtained from the annual agricultural census. Similar censuses occur in many countries.

3. Equipment in civil engineering

Civil engineering equipment consists of vehicles with their own engines used in road, rail, or waterway construction, building and demolition, public works, etc. Included are such vehicles as bulldozers, cranes, excavators, graders, etc., which do not have licenses for road use. The air pollution caused by such equipment can be substantial.

An estimate can be made by multiplying generalized emission factors for heavy diesel engines with the number and operating times of the various types of equipment or with fuel consumption data, whichever is available. These types of equipment are hidden under the row heading “other” in tables D5 and E2.

4. Inland shipping

Inland shipping includes the professional transport of goods and passengers in ships and barges along rivers, lakes, and canals. The engines used are nearly always diesels, but sometimes are gas turbines. In the Netherlands, the fuel employed is usually gasoil, but heavy fuel oil is also used. In both cases there is a statutory maximum sulphur content.

Inland shipping in the Netherlands is a substantial emitter of NO, -- it produces amounts equal to 8 per cent of that of road traffic. Air-pollution emission data can be calculated in two ways:

- The first and simplest method is through the fuel consumption of inland shipping, combined with generalized emission factors. In the Netherlands, the annual quantities of fuel delivered are obtained from the suppliers of naval gasoil in the Netherlands -- the oil companies -- by the CBS Energy Statistics Department. They are shown in Table D5. It is important to remove data on oil supplied for use abroad, also called bunker oil. For the Netherlands, average emission factors are given in Table E2.

- The second and more sophisticated method for calculating emissions from inland shipping is on the basis of traffic performance -- mileage navigated per type of vessel available -- and on the basis of emission factors for each type of vessel, in g/km. The process is similar to that for the computation of road-traffic emissions. CBS is currently investigating the use of this method.

5. Recreational boating

In the Netherlands, with its large expanses of shallow surface water and estuaries, recreational boating is popular. Air pollution originates mainly from motor yachts and from outboard engines. Most yachts have diesel engines. Outboard motors use petrol, and are nearly always two-stroke engines, which are quite polluting.

In the Netherlands, emissions data are estimated by multiplying the number of boats per type (approximately known from CBS enquiries on recreational facilities and activities) with emission factors per type of engine per year, assuming an average annual number of running hours. Figures also can be reached via estimated fuel-consumption data.

6. Seagoing vessels

In the Netherlands, with its two major seaports (Rotterdam and Amsterdam) and numerous smaller harbours, the quantities of pollutants emitted by seagoing vessels and coasters cannot be neglected. Such emissions come from vessels in ports and from those navigating in the Dutch estuary of the rivers Rhine, Meuse, and Scheldt (the entrance to the port of Antwerp in Belgium). The emissions of vessels on the high (North) Sea or even in Dutch coastal waters are excluded.

Seagoing vessels almost always use heavy oil; coasters frequently use gasoil. As this bunker oil (for use on high seas) does not have to fulfill requirements limiting sulphur content, the per cent by weight of sulphur may be 3 to 4 per cent, meaning that the emission factor for SO, should be put at least at 70 g/kg. The emission data are estimated based on the inland consumption of bunker oil (see Table D5) and emission factors as indicated in Table E2. The quantity of bunker oil delivered can be obtained from the CBS Energy Statistics Department. The amount of this oil consumed inland, in ports and estuaries, is estimated using traffic data from harbour authorities.

7. Aviation

In the Netherlands, only "life-level" emissions from aviation are considered, meaning emissions up to 1100 feet in altitude resulting from landing, manoeuvring, and takeoff of aircraft. This is usually called the "complete LTO cycle."

Larger aircraft are almost always equipped with gas-turbine propulsion -- two or more jets or turboprops burning jet fuel, a petroleum product. Smaller aircraft are often propulsed by one or two piston engines using aviation petrol.

- 👍♓❖♓● *aircraft*

In the Netherlands each year, the landing and takeoff data for each type of aircraft are obtained from all airport authorities in the country. (This survey is carried out by CBS Transport Statistics Department.) As the emission factors are only available per complete LTO cycle for each type of engine (jet or piston), the landing plus the takeoff data per aircraft type divided by two (to get complete LTO cycles) are multiplied by the number of engines per type of aircraft, resulting in the number of motor LTO cycles. The motor LTO cycles are combined for each type of engine and multiplied by the pertaining emission factors. The emission factors for the mid-Eighties are shown in Table E3. Note that at an international airport such as Schiphol/Amsterdam more manoeuvring takes place than at smaller airports, and that results in larger emission factors. The allocation of specific aircraft types (such as Boeing 747 or Airbus A300) among the categories in the table is available from CBS on request.

- *Military aircraft*

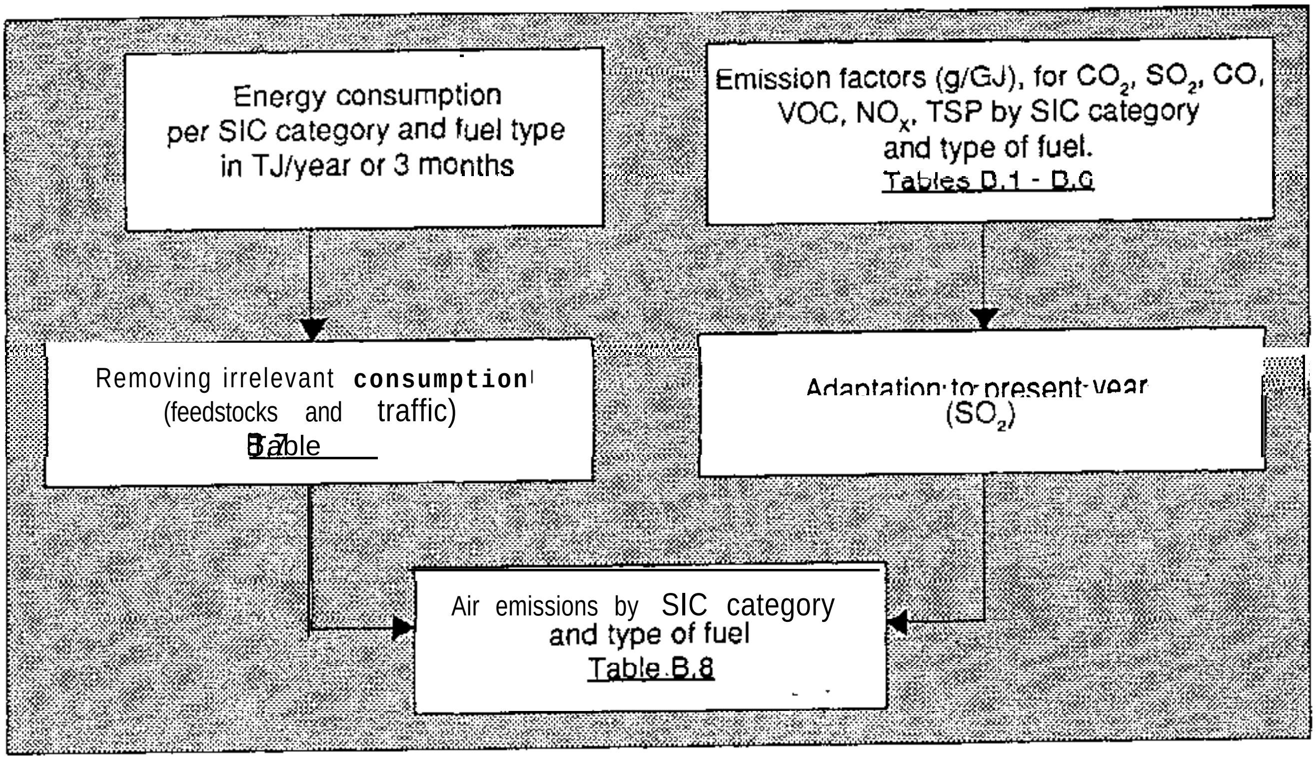
Ground-level emissions are computed in a way similar to that for civil aircraft. However, motor LTO cycles are a military secret. Hence the emissions are calculated by military authorities using emission factors (per engine type) made available by CBS. (Approximate emission factors for military aircraft engines are available from open data sources -- see Table E3.) In the Netherlands, the emission data are published as totals for the entire country only, meaning that LTO data per aircraft type or per air force base cannot be reconstructed.

Results

Table E4 shows a time series for the Netherlands of the emission of air pollutants and CO, by mobile sources, excluding road traffic.

FLOW CHART 8.1

CALCULATION OF PERIODICAL FURNACE EMISSIONS



Codes used in Tables B1 - B8 for fuels and SIC activities (rows)

a. Hard coal
b. Coke
c. Petroleum coke
d. Brown coal
e. Petroleum
f. Domestic fuel oil/gasoil
g. Heavy fuel oil
h. Natural gas
i. Coking-plant gas
j. Blast-furnace gas
k. Refinery gas
l. Chemical residue gas
m. Liquid Petroleum Gas (LPG)
n. Total

1. Agriculture (SIC 01)
2. Mining and quarrying (SIC 12)
3. Gas distribution (natural gas) (SIC 402)
4. Coking plants (SIC 2821 + 3321 partial)
5. Refineries (crude petroleum) (SIC 281)
6. Manufacture of food, beverages, and tobacco products (SIC 20/21)
7. Manufacture of textiles (SIC 22)
8. Manufacture of paper and paper products (SIC 26)
9. Manufacture of synthetic fertilizers (SIC 291)
10. Other chemical industry (manufacture of synthetic fibers included) (SIC 292 - 300)
11. Manufacture of building materials, earthenware, and glass (SIC 32)
12. Basic metal industries (SIC 33 minus 3311 partial)
13. Other metal industries (SIC 34 - 37)
14. Other industries (remaining SIC 34 - 37)
15. (Public) Power plants (electricity) (SIC 401)
16. Other (public) power plants (SIC 404 + 405)
17. Civil construction (SIC 5)
18. Private households
19. Other activities using fossil fuels (SIC 02/03/6/7/8/9)
20. Total

Table B.l
Emission factor carbon monoxide 1989

	A	B	C	D	E	F	G	H	I	J	K	L	M
	g/GJ												
1	100				10	10	10	10					10
2	100				10	10	10	1.0			0.8		10
3					10	10		280					10
4					10	2.0			60	700			10
5	100		72		10	10	11	52			8.0		10
6	480		72	6.8	10	10	100	52				14	10
7	100		72		10	10	0.7	1.0				14	10
8	100				10	10	11	1.0					10
9	100				10	100	9.0	9.0	13		0.8	14	10
10	15		72		10	10	25	13		31		100	10
11	100		72	6.8	10	100	0.5	6.0	13	31			10
12	100		72	6.8	10	10	10	140	13	2950			10
13	100	17000	72	6.8	10	30	200	110			0.8		10
14	100			6.8	10	60	7.4	10					10
15	4.0				10	180	4.0	2.0	13	10			10
16		100			10	10	10	10		10			10
17	100				10	10	10	10					10
18	1500				10	60		80					10
19	100			6.8	10	10	10	10					10

CBS/NL

Table B.2
Emission factor volatile organic compounds 1) 1989

	A	B	C	D	E	F	G	H	I	J	K	L	M
	g/GJ												
1	35				10	10	10	30					2.0
2					10	10		1.0			1.0		2.0
3					10	6.0		250					2.0
4					10	10			130	175			2.0
5	30				10	10	5.0	23			6.0		2.0
6	60			30	10	10	14	6.4				1.0	2.0
7	30				10	10	4.0	1.0					2.0
8	30				10	10	6.0	1.0					2.0
9	30				10	13	6.0	4.0				0.1	2.0
10	5.0				10	10	8.0	2.0			1.0	1.0	2.0
11	5.0			30	10	10	5.0	4.0					2.0
12	30			30	10	10	5.0	4.0	0.2	25			2.0
13	30	200			10	20	4.0	12			1.0		2.0
14	30			30	10	10	5.0	4.0					2.0
15	0.5				10	22	0.5	0.5		4.5			2.0
16	35				10	10	10	4.0					2.0
17	35				10	10	10	30					2.0
18	60				10	15		30					2.0
19	35			140	10	10	10	30					2.0

1) methane excluded

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Table B.3
Emission factor aerosols 1989

	A	B	C	D	E	F	G	H	I	J	K	L	M
	g/GJ												
1	100				2.0	5.0	50	0.3					10
2					2.0	5.0		0.3					10
3					2.0	5.0		0.3					10
4					2.0	5.0			20	50			10
5	30		14		2.0	5.0	56	0.5			21		10
6	180				2.0	5.0	21	0.3					10
7	100				2.0	5.0	9.8	0.3					10
8	100				2.0	5.0	34	0.3					10
9					2.0	5.0	9.7	0.03					10
10	30				2.0	44	31	0.03			0.1		10
11	100				2.0	5.0	3.7	0.3					10
12				40	2.0	5.0	8.5	0.3					10
13	100	12			2.0	5.0	7.0	0.3			0.3		10
14	100			40	2.0	6.0	50	0.3					10
15	9.1		14		2.0	8.0	24	0.3					10
16	100				2.0	5.0	24	0.3					10
17					2.0	5.0	50	0.3					10
18	200				2.0	2.0		0.3					10
19	100			40	2.0	2.0	50	0.3					10

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Table B.4

Emission factor nitrogen oxides 1) 1989

	A	B	C	D	E	F	G	H	I	J	K	L	M
	g/GJ												
1	300				50	50	125	65					40
2	290				50	50		100			100		40
3					50	50		1300					40
4					50	80			100	280			40
5	70		200		50	50	180	140			100		40
6	130		250	300	50	50	130	60				84	40
7	330		250		50	50	160	40					40
8	330				50	50	100	40					40
9	330				50	40	90	90	64			84	40
10	240		250		50	100	100	80			60	120	40
11	330		250	300	50	50	330	140	64	52			40
12	330		250	300	50	50	200	110	320	20			40
13	330	540	250	300	50	50	1000	50			60		40
14	330			300	50	50	120	40					40
15	217		250		50	150	175	120	100	10			40
16	100				50	50	120	50		10			40
17	100				50	50	120	50					40
18	75				50	50		55					40
19	100			300	50	50	120	50					40

1) calculated as nitrogen dioxide

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Table B.5
Emission factor carbon dioxide 1989

	A	B	C	D	E	F	G	H	I	J	K	L	M
	kg/GJ												
1	94				73	73	77	56					66
2	94				73	73	77	56			46		66
3	94				73	73	77	56					66
4	94				73	73	77	56	44	200			66
5	94		103		73	73	77	56			46		66
6	94		103	101	73	73	77	56				46	66
7	94		103		73	73	77	56				46	66
8	94				73	73	77	56					66
9	94				73	73	77	56	44		46	46	66
10	94		103		73	73	77	56		200		46	66
11	94		103	101	73	73	77	56	44	200			66
12	101		103	101	73	73	77	56	44	200			66
13	94	108	103	101	73	73	77	56			46		66
14	94			101	73	73	77	56					66
15	90				73	73	77	56	44	200			66
16	94				73	73	77	56		200			66
17	94				73	73	77	56					66
18	103				73	73	77	56					66
19	94			101	73	73	77	56					66

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Table B.6
Emission factor sulfur dioxide 1989

	A	B	C	D	E	F	G	H	I	J	K	L	M
	g/GJ												
1	460				4.6	90	575	0.6					0.3
2					4.6	90		260					0.3
3					4.6	90		0.6					0.3
4					4.6	90			210	13			0.3
5	80		600		4.6	90	1250	0.6			125		0.3
6	450				4.6	90	520	0.6				6.0	0.3
7	740				4.6	90	605	0.6					0.3
8	740				4.6	90	605	0.6					0.3
9					4.6	90	605	0.1	380			6.0	0.3
10	660				4.6	90	600	5.0			0.3	140	0.3
11	740		600		4.6	90	525	0.6	100	4.5			0.3
12					4.6	90	605	0.1	100	40			0.3
13	660	450			4.6	90	605	0.6			0.3		0.3
14	660			113	4.6	90	605	0.6					0.3
15	205		600		4.6	90	365	0.0	10	4.5			0.3
16	585				4.6	90	575	0.6					0.3
17					4.6	90	575	0.6					0.3
18	420				4.6	90	575	0.6					0.3
19	585			113	4.6	90	575	0.6					0.3

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Table B.7
Consumption of fossil fuels in 1989

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	TJ													
1	100	0	0	0	770	3100	550	107200	0	0	0	0	1035	112755
2	0	0	0	0	0	18	0	26946	0	0	0	0	0	26964
3	0	0	0	0	0	2	0	625	0	0	0	0	3	630
4	0	0	0	0	0	64	0	0	8594	1516	0	0	0	10174
5	0	0	13120	0	0	174	45733	16523	0	0	83937	0	947	160434
6	1958	0	0	0	19	988	1992	60659	0	0	0	171	78	65865
7	66	0	0	0	2	61	58	4451	0	0	0	0	1	4639
8	78	0	0	0	0	31	24	26319	0	0	0	0	72	26524
9	0	0	0	0	5	23	596	43372	2372	0	0	0	0	46368
10	10025	0	0	0	30	241	7884	105231	0	0	6777	44766	400	175354
11	1007	0	780	949	30	510	3533	25829	0	0	0	0	26	32664
12	0	6085	0	0	0	2489	75	15788	10196	10724	0	0	25	45382
13	0	0	0	0	8	958	317	18258	0	0	0	0	168	19709
14	61	0	0	30	9	508	267	8010	0	0	0	0	21	8906
15	204329	0	0	0	0	331	3143	276369	3317	16667	0	0	1	504157
16	0	0	0	0	0	17	410	1155	0	0	0	0	0	1582
17	0	0	0	0	0	2109	53	3400	0	0	0	0	0	5562
18	797	0	0	0	1138	7259	0	329160	0	0	0	0	2168	340522
19	1166	0	0	268	2764	28515	1245	144216	0	0	0	0	1340	179514
20	219587	6085	13900	1247	4775	47398	65880	1E+06	24479	28907	90714	44937	6285	2E+06

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Table B.8
Emissions of fossil fuels 1989

	CO	NO	SO2	A	V.O.C	CO
	mln kg					
1	1.1	7.3	0.69	0.10	3.3	6404
2	0.03	2.7	7.0	0.01	0.03	1510
3	0.18	0.81	0.00	0.00	0.16	35
4	1.6	1.3	1.8	0.25	1.4	686
5	3.0	22	76	4.5	1.1	9734
6	4.3	4.2	2.1	0.42	0.54	3820
7	0.01	0.21	0.09	0.01	0.01	263
8	0.04	1.1	0.09	0.02	0.03	1490
9	0.43	4.1	1.2	0.01	0.18	2581
10	6.2	17	18	0.56	0.38	9859
11	0.37	5.6	3.1	0.16	0.16	2030
12	137	8.6	4.5	0.09	1.6	4325
13	2.1	1.3	0.28	0.01	0.24	1128
14	0.12	0.41	0.24	0.03	0.04	518
15	1.7	76	43	2.0	0.32	38429
16	0.02	0.11	0.22	0.01	0.01	98
17	0.06	0.28	0.22	0.02	0.12	348
18	28	19	1.2	0.30	10	19271
19	1.9	9.2	4.1	0.31	4.7	10681
20	189	1 181	163	[illegible]	[illegible]	[illegible]

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Table C.l Classification of enterprises according to Dutch Standard Industrial Classification of economic activities (SIC 1984)

1			MINING AND QUARRYING
	12*		Crude petroleum and natural gas production and exploration
	19		Other mining and quarrying
2			MANUFACTURING, EXCEPT CONSTRUCTION
	20/21		Manufacture of food, beverages, and tobacco products
	22		Manufacture of textiles
	23		Manufacture of wearing apparel, except footwear
	24		Manufacture of leather, footware, and other leather products
	25		Manufacture of wood products, including furniture
	26		Manufacture of paper and paper products
	27		Printing, publishing, and allied industries
	28*		Oil industry
	29*		Chemical industry
		29.1	Manufacture of synthetic fertilizers
		29.2	Manufacture of synthetic resins and primary plastics
		29.3	Manufacture of pigments and dyes
		29.4	Manufacture of other basic industrial chemicals
		29.5	Manufacture of paints, lacquers, varnishes, and ink
		29.6	Manufacture of drugs, medicines, and antiseptic dressings
		29.7	Manufacture of soap and detergents, perfumes and cosmetics
		29.8	Manufacture of chemical pesticides and similar products
		29.9	Manufacture of other chemical products
	30*		Manufacture of artificial and synthetic filaments and staple fibres (except glass)
	31		Manufacture of rubber and plastic products
	32		Manufacture of building materials, earthenware, glass, and glass products
	33*		Basic metal industries
	34		Manufacture of fabricated metal products, except machinery and transport equipment
	35		Mechanical engineering
	36		Electrical engineering
	37		Manufacture of transport equipment
	38		Instrument engineering
	39		Other manufacturing industries
4*			PUBLIC UTILITIES
	40		Public utilities (electricity, gas, and water)
5			CONSTRUCTION AND INSTALLATION ON CONSTRUCTION PROJECTS
6			TRADE, HOTELS, CAFES, RESTAURANTS, AND REPAIR OF CONSUMER GOODS

7* TRANSPORT, STORAGE, AND COMMUNICATION

72 Road transport
73 Sea transport
74 Inland water transport
75 Air transport
76 Supporting services to transport

8 BANKING, INSURANCE, AND BUSINESS SERVICES

9 OTHER SERVICES

98 Other services

98.13* Waste incineration

90-97 and remainder of 98: Other services n.e.c.

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* Extrapolated per company/local activity unit

Table C.2

Air polluting process emissions, per economic activity, 1984 and 1986

	(1)		(2)		(3)		(4)		(5)		(6)	
	1984	1986	1984	1986	1984	1986	1984	1986	1984	1986	1984	1986
	mln kg											
Industry	66	52	9.0	7.0	21	22	113	128	47	39	1.8	1.3
o.w.												
Refineries (13)	27'	18			0.06	0.03	2.0	2.0	1.2	1.3	0.01	0.01
Chemical industries	28	21	7.5	5.1	21	22	23	18	14	11	0.66	0.13
Basic metal industrie	8.7	0.5	0.25	0.24	0.21	0.28	81	81	12	9.3	0.36	0.36
Other industries	3.1	3.9	1.3	1.6	0.19	0.26	6.6	27	19	17	0.82	0.79
Construction									0.35	0.29		
Handling and storing	0.00	0.00	0.01	0.00					17	10		
Waste incineration	1.6	1.7			3.5	3.5	1.4	1.7	3.3	3.4	0.04	0.05
Other activities	0.02	0.01	0.00	0.00	0.32	0.45	0.00	0.00	0.47	0.39	0.01	0.01
Total	68	53	9.0	7.0	25	26	114	129	68	54	1.9	1.3

	(7)		(8)		(9)		(10)		(11)		(12)	
	1984	1986	1984	1986	1984	1986	1984	1986	1984	1986	1984	1986
	mln kg											
Industry	0.11	0.05	114	99	1.4	1.3	2.7	2.7	12	11	18	16
o.w.												
Refineries (13)	0.00	0.00	15	14	0.00	0.00					1.3	1.3
Chemical industries	0.05	0.01	38	31	1.2	0.96	1.3	1.4	5.5	6.3	5.2	3.9
Basic metal industrie	0.06	0.04	2.9	2.5	0.00	0.00	0.01	0.01	0.39	0.33	0.56	0.60
Other industries	0.01	0.01	58	52	0.22	0.34	1.4	1.3	5.9	3.9	11	9.8
Construction			0.12	0.13					0.01	0.01	0.02	0.02
Handling and storing			14	12			0.01	0.01	0.13	0.11	1.9	1.7
Waste incineration	0.08	0.08	1.6	1.2			0.01	0.01	0.97	0.60	0.00	0.00
Other activities	0.00	0.00	7.1	4.2	0.04	0.04	0.01	0.02	0.24	0.21	1.2	0.70
Total	0.19	0.13	137	117	1.5	1.3	2.7	2.8	13	11	21	18

(1) Sulphur oxides and hydrogen sulphide calculated as sulphur dioxide
(2) Ammonia and ammonium compounds calculated as ammonia
(3) Nitrogen oxides calculated as nitrogen dioxide
(4) Carbon monoxide
(5) Total suspended matter
(6) Fluorocompounds (inorganic) calculated as fluorine
(7) Mercury, Cadmiun and Lead compounds calculated as metal alone
(8) Volatile organic compounds (=VOC), methane excluded. (9)--(12) are included.
(9) Aldehydes
(10) Chlorofluoro compounds (=CFC's), bromochloro(fluoro) compounds included
(11) Other halogens (chloro-, bromo-, iodo-, or fluoro compounds)
(12) Aromatic compounds
(13) Mining and quarrying included

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FLOW CHART D.1

CALCULATION OF ANNUAL ROAD TRAFFIC EMISSIONS

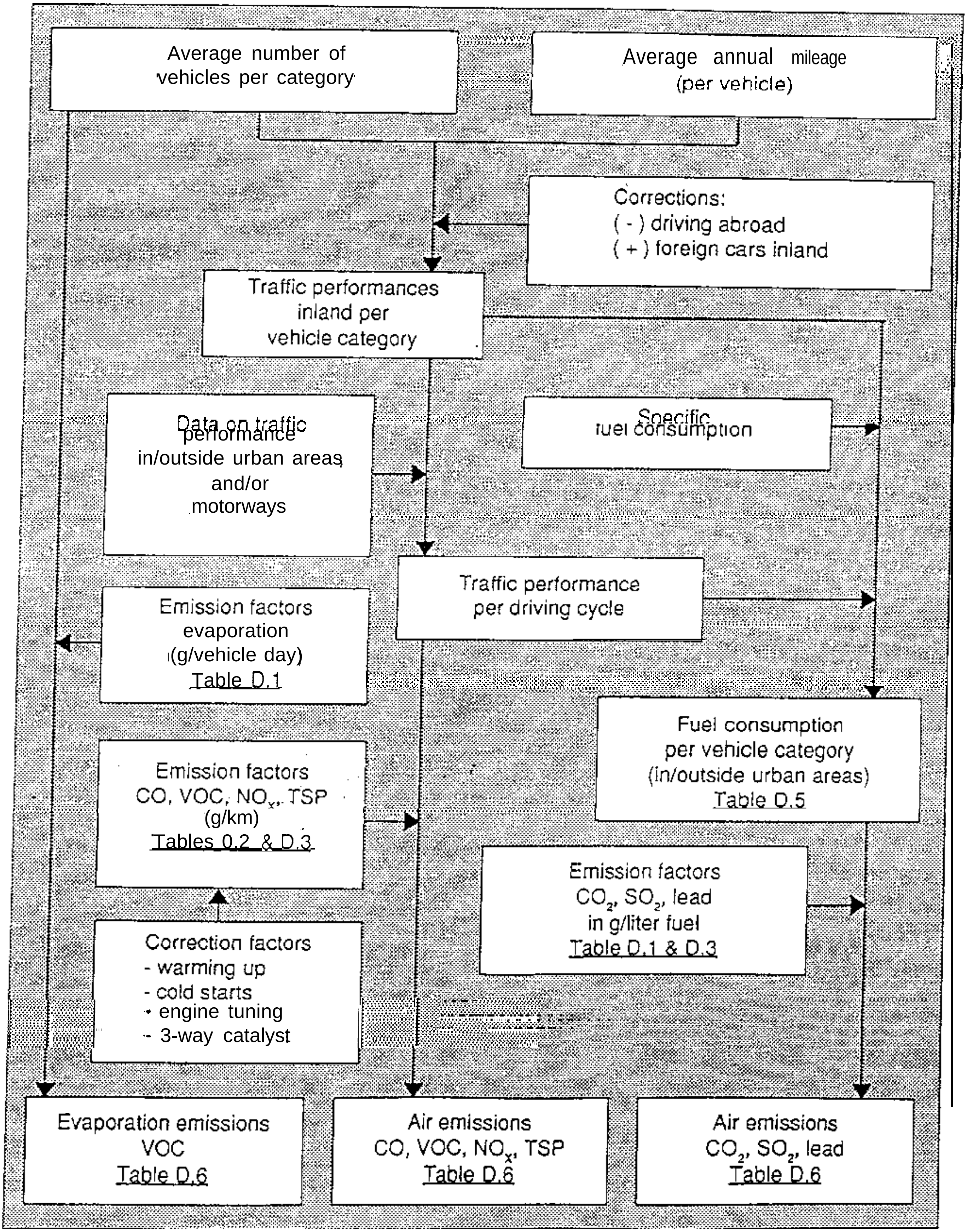

Table D.1

Fleet emission factors for road traffic, 1988

	Passenger cars				Delivery vans				Lorries			Road tractors	Busses			Motor-cycles	Mopeds	TOTAL
	gasoline	diesel	LPC	total	gasoline	diesel	LPC	total	gasoline	diesel	total	1)	gasoline	diesel	total			
	grams/km																	
CO	10.1	2.6	1.5	7.4	20.0	2.8	2.3	7.6	51.0	6.1	6.2	6.5		8.9	8.9	4,0	9	7.7
urban areas	18.0	3.9	1.9	12.9	23.5	3.2	2.5	8.9	84.9	14.0	14.0	20.5	97.6	14.3	14.3	40	9	12.7
motor ways	6.0	2.8	1.2	4.6	7.3	0.9	1.4	2.7	36.0	2.1	2.2	1.8	36.0	1.4	1.4	40	0	4.4
rural roads	8.1	1.4	1.4	5.8	9.7	1.8	1.6	4.0	42.0	4.7	4.8	4.9	43.0	4.3	4.3	40	9	5.9
VOC **(excl.** evaporation)	1.8	0.5	1.1	1.5	3.6	1.4	1.7	2.0	4.5	4.7	4.7	5.4		6.5	6.5	6	5	1.9
urban areas	3.3	1.1	1.5	2.6	4.2	1.7	1.9	2.4	7.4	9.6	9.6	13.9	8.4	10.1	10.1	6	5	3.3
motor ways	1.0	0.3	0.9	0.8	1.1	0.1	1.1	0.5	3.2	2.6	2.6	2.7	3.2	1.8	1.8	6	5	1.0
rural roads	, 1.5	0.3	1.1	1.2	1.7	0.7	1.3	1.0	3.9	3.5	3.5	4.1	3.9	3.3	3.3	6	5	1.4
NOx (as NO2)	2.5	1.1	1.7	2.1	2.8	1.4	1.8	1.8	10.6	14.3	14.3	26.7		15.4	15.4	0.11	0.05	3.2
urban areas	1.7	1.2	1.3	1.6	2.5	1.4	1.6	1.7	6.5	14.2	14.2	31.7	6.2	15.8	15.8	0.10	0.05	2.6
motor ways	3.9	1.3	2.5	3.2	5.4	1.4	3.2	2.6	14.0	15.4	15.4	25.6	14.0	17.2	17.2	0.25	0.05	4.7
rural roads	1.8	0.8	1.3	1.6	2.6	1.3	1.6	1.6	9.7	12.9	12.9	24.9	9.5	13.5	13.5	0.10	0.05	2.4
TSP	0.05	0.67	0.04	0.16	0.10	1.03	0.05	0.71	0.4	2.5	2.5	3.0		3.5	3.5	0.12	0.04	0.38
urban areas	0.07	1.06	0.04	0.23	0.11	1.20	0.05	0.82	0.4	5.0	4.9	7.4	0.4	5.4	5.4	0.12	0.04	0.66
motor ways	0.05	0.50	0.03	0.12	0.05	0.40	0.04	0.28	0.4	1.4	1.4	1.6	0.4	1.0	1.0	0.12	0.04	0.25
rural roads	0.05	0.55	0.04	0.13	0.07	0.55	0.04	0.38	0.4	1.9	1.9	2.3	0.4	1.8	1.8	0.12	0.04	0.25
	grams/liter fuel																	
so2	0.34	3.67	0.00		0.34	3.67	0.00		0.34	3.67		3.67	0.34	3.67		0.34	0.34	
Lead	0.07	0.00	0.00		0.07	0.00	0.00		0.07	0.00		0.00	0.07	0.00		0.07	0.07	
	grams/vehicle.day																	
voc	13				13				13				13			5	5	

Sulphur content of gasoline: 0.18 grams/liter
Sulphur content of diesel fuel: 0.23 weight %
Lead content of gasoline: 0.10 grams/liter

1) For hauling trailers, diesel only.
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Table D.2

Fleet emission factors for road traffic, 1988

	CO				VOC					NOx				TSP				Sulphur dioxide	Lead
	urban areas	motor ways	rural roads	total	urban areas	motor ways	rural roads	total 1)	total 2)	urban areas	motor ways	rural roads	total	urban areas	motor ways	rural roads	total		
	grams/km																		
Passenger cars	13	4.6	5.8	7.4	2.6	0.84	1.2	1.5	1.7	1.6	3.2	1.6	2.1	0.23	0.12	0.13	0.16	0.06	0.004
o.w.																			
gasoline	18	6.0	8.1	10.1	3.3	1.0	1.5	1.8	2.2	1.7	3.9	1.8	2.5	0.07	0.05	0.05	0.05	0.03	0.006
diesel	3.9	2.8	1.4	2.6	1.1	0.25	0.28	0.50	0.50	1.2	1.3	0.83	1.1	1.1	0.50	0.55	0.67	0.25	0.000
LPG	1.9	1.2	1.4	1.5	1.5	0.90	1.1	1.1	1.1	1.3	2.5	1.3	1.7	0.04	0.03	0.04	0.04	0.00	0.000
Light duty vehicles	9	2.7	4.0	7.9	2.6	0.46	1.0	2.2	2.3	1.8	2.6	1.6	1.8	0.83	0.28	0.38	0.72	0.29	0.002
Heavy duty vehicles	16	2.0	4.8	7.1	10.0	2.6	3.6	5.1	5.1	17	19	16	18	5.3	1.4	2.0	2.8	1.3	0.000
Motor cycles	40	40	40	40	6	6	6	6	6.3	0.10	0.25	0.10	0.11	0.12	0.12	0.12	0.12	0.02	0.005
Mopeds	9		9	9	5		5	5	5.6	0.05		0.05	0.05	0.04		0.04	0.04	0.01	0.002
Total	13	4.4	5.9	7.7	3.3	1.0	1.4	1.9	2.1	2.6	4.7	2.4	3.2	0.66	0.25	0.25	0.38	0.16	0.004

1) Excl. evaporation
2) Incl. evaporation

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Table 0.3

Emission of carbon dioxide by mobile sources

	unit	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989*
FUEL **CONSUMPTION**												
Road traffic	mio kgs											
gasoline	"	3766	3658	3481	3431.	3441	3413	3274	3313	3378	3474	3461
diesel	"	1404	2166	2187	2194	2231	2376	2529	2719	2859	3126	3298
LPG	"	119	508	616	699	767	790	778	771	826	840	861
Rail traffic (diesel)	"	42	42	42	36	34	33	34	32	30	28	28
Inland shipping (diesel)	"	460	460	440	440	441	441	443	453	459	465	465
Agicultural machinery 1)	"	190	190	190	190	187	187	187	164	164	164	164
Sea-going vessels 2)	"	200	200	200	200	200	200	200	200	200	200	200
Aviation	"	.										
Other 3)	"	.	.	.	.							
EMISSION FACTORS												
gasoline	grams/kg	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180
Diesel	"	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130
LPG	"	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
EMISSION												
Total 4)	mio kgs	19620	22831	22592	22685	23027	23458	23470	24111	24940	26135	26698
O.W. road traffic	"	16728	19938	19764	19875	20228	20662	20663	21355	22171	23351	23914
O.W. other mobile sources 4)	"	2892	2893	2828	2810	2799	2796	2807	2756	2769	2784	2784
O.W. rail traffic (diesel)	"	132	133	130	112	106	103	108	W	93	89	89
inland shipping	"	1440	1440	1377	1377	1380	1380	1387	1418	1437	1455	1455
agicultural machinery	"	595	595	595	595	586	586	586	513	513	513	513
sea-going vessels 2)	"	626	626	626	626	626	626	626	626	626	626	626
aviation	"	.	.	.	.	.	.		.	.	.	.
other 3) 5)	"	100	100	100	100	100	100	100	100	100	100	100

1) Rough estimation: 8 PJ in 1983, 1984 and 1985; 7 PJ in 1986 and 1987.
2) Rough estimation; within Dutch borders.
3) Internal transport en mobile machinery (e.g. for road construction).
4) Excluding aviation.
5) Rough estimation.

N.B. * = provisional figure.
. = data not available.

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Table 0.4
Lead in petrol and sulphur in petroleum products (1)

	unit	1980	1985	1986	1987	1988
Petrol						
Lead content (2)						
Premium	g/l	0.37	0.37	0.28	0.13	0.13
Regular	g/l	0.30	0.30	0.08		
Eurograde	g/l					
Market share						
Premium	%	82.90	78.70	80.30	79.70	74.00
Regular	%	17.10	21.30	19.30	18.50	8.30
Eurograde	%			0.40	1.80	17.70
Gas oil						
Sulphur content (3)						
Automotive diesel oil	wgt %	0.33	0.20	0.23	0.24	0.23
Other	wgt %	0.35	0.22	0.22	0.22	0.23
Market share						
Automotive diesel oil	%	41.90	59.50	61.00	64.80	64.80
Other	%	58.10	40.50	39.00	35.20	35.20
Heavy fuel oil						
Sulphur content (4)						
<1% sulphur	wgt %	0.94	0.86	0.90	0.94	0.95
>= 1% sulphur	wgt %	1.93	1.91	1.91	1.89	1.95
Market share						
<1% sulphur	%	37.00	48.70	44.00	52.20	80.30
>= 1% sulphur	%	63.00	51.30	56.00	47.80	19.7

(1) Weighted yearly averages, domestic sales

(2) From 1 October 1986, legal maximum: 0.15 gram of lead per litre.

(3) From 1 October 1980, legal maximum in gas oil: 0.3% sulphur.

(4) From 1 September 1979, legal maximum in fuel oil: 2% sulphur.

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Table D.5
Fuel Consumption by Mobile Sources

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989*	1990*
	mio kgs														
NON-ROAD TRAFFIC															
Rail traffic (diesel)			55	42	42	42	36	34	33	34	32	30	28	28	
Inland shipping (diesel)	.		460	460	460	440	440	441	441	443	453	459	465	465	
Agricultural machinery 1)	.		190	190	190	190	190	187	187	187	164	164	164	164	
Sea-going vessels 1)	.		200	200	200	200	200	200	200	200	200	200	200	200	
Aviation	.														
Other 1) 2)	.		280'	280'	280	280	280	280	280	280	280	280	280	280	
ROAD TRAFFIC															
Total															
gasoline	.		3088	3766	3658	3481	3431	3441	3413	3274	3313	3378	3474	3461	3516
diesel fuel	.		1086	1404	2166	2187	2194	2231	2376	2530	2719	2859	3126	3298	3629
LPG	.		39	119	508	616	699	767	790	778	771	826	840	861	900
Passenger cars															
gasoline			2652	3403	3380	3207	3165	3183	3174	3040	3083	3149	3252	3254	
diesel fuel			101	152	299	338	381	440	518	607	674	700	777	868	
LPG			38	114	484	585	664	731	754	744	737	794	808	831	
Goods vehicles															
gasoline	.		326	271	191	185	172	163	156	157	154	154	150	141	
diesel fuel	.		831	1071	1587	1544	1528	1514	1591	1674	1799	1912	2102	2179	
LPG	.		1	5	24	31	35	37	36	34	33	32	32	30	

1) Rough estimation.
2) Internal transport and mobile machinery (e.g. for road construction).

Source: CBS/NL

Table D.6

Air Polluting Emissions by Mobile Sources

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989”	1990*
	mln kg														
CARBON DIOXIDE															
Total 1)	6000	10000	17047	20397	23608	23368	23461	23803	24235	24247	24888	25716	26911	27475	28798
Traffic 1)			15576	18926	22137	21897	21990	22341	22772	22784	23499	24326	25522	26085	27408
road traffic	3500’	7000’	13338	16728	19938	19764	19875	20228	20662	20663	21355	22171	23351	23914	25238
o.w. passenger cars	.	.	8862	11639	13134	13010	13250	13693	13976	13799	14125	14588	15196	15556	
goods vehicles 2)		.	3639	4229	5649	5513	5433	5367	5584	5841	6220	6574	7153	7361	
other traffic		.	2238	2198	2199	2133	2115	2113	2110	2120	2143	2156	2171	2171	
Other mobile sources		.	1471	1471	1471	1471	1471	1463	1463	1463	1390	1390	1390	1390	
CARBON MONOXIDE															
Total	550	900	1485	1489	1038	932	914	890	853	799	773	757	759	727	
Traffic			1470	1475	1023	918	899	876	839	785	759	744	746	713	
road traffic	500’	850’	1448	1452	1001	896	878	854	818	763	737	722	723	691	
o.w. passenger cars	.	.	1217	1236	820	731	717	704	674	627	597	580	581	.	
goods vehicles 2)	.	.	189	157	110	99	91	82	79	79	83	83	85		
other traffic	.	.	23	22	22	22	22	22	22	22	22	22	22	22’	
Other mobile sources			14	14	14	14	14	14	14	14	13	13	13	13	
VOLATILE ORGANIC COMPOUNDS															
Total	150	250	289	288	235	218	216	215	211	202	201	201	206	203	

Table D.6 (Continued)
Air Polluting Emissions by Mobile Sources

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989"	1990"
Traffic			284	284	230	213	212	210	206	197	197	197	202	199	
road traffic	140'	240'	280	280	226	209	208	206	202	194	193	193	198	195	
o.w. passenger cars			206	215	159	146	147	147	145	138	134	133	135		
goods vehicles 2)			40	38	40	38	37	34	34	35	38	40	43		
other traffic			4.1	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9'	
Other mobile sources			4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.2	4.2	4.2	4.2	
NITROGEN OXIDES															
Total	100	150	207	253	336	331	329	329	336	329	339	343	357	362	
Traffic			183	230	312	308	305	305	312	306	316	320	334	339	
road traffic	60'	100'	147	194	277	273	271	271	278	271	281	285	299	304	
0. w. passenger cars			79	116	162	159	159	162	164	158	162	163	165		
goods vehicles 2)			60	69	102	100	97	95	100	99	107	109	121		
other traffic			36	36	36	35	34	34	34	35	35	35	35	35'	
Other mobile sources			24	24	24	24	24	23	23	23	22	22	22	22	
PARTICULATES															
Total	9	12	17.6	20.4	29.8	30.0	30.4	30.4	31.9	33.0	35.9	37.3	40.5	42.7	
Traffic			15.2	18.1	27.4	27.6	28.1	28.1	29.5	30.7	33.6	35.1	38.3	40.5	
road traffic	5'	8'	12.7	15.6	24.9	25.2	25.6	25.7	27.1	28.3	31.2	32.6	35.8	38.0	

Table D.6 (Continued)
Air Polluting Emissions by Mobile Sources

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989*	1990*
o.w. passenger cars	-	-	3.0	3.9	5.7	6.1	6.6	7.6	8.5	9.5	10.5	11.1	12.2		
goods vehicles 2)	-	-	7.8	9.5	15.6	14.9	14.9	14.0	14.8	15.1	17.2	18.1	20.2	.	
other traffic	-	-	2.6	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.5	2.5	2.5	.	
Other mobile sources	-	-	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.2	2.2	2.2	2.5	
														2.2	
SULPHUR DIOXIDE															
Total	30	40	45	40	38	33	34	33	31	31	34	35	36	32	33
Traffic	.	.	39.2	36.0	34.9	30.8	31.2	30.4	29.4	29.4	32.0	33.3	33.9	30.3	31.4
road traffic	10	15	16.2	15.2	15.7	12.4	12.8	12.1	11.4	11.5	13.8	15.0	15.6	12.6	13.7
o.w. passenger cars	.	.	2.9	3.4	3.8	3.4	3.7	3.8	3.9	4.0	4.7	5.0	5.2	4.7	
goods vehicles 2)	.	.	11.2	10.1	10.1	7.4	7.6	7.0	6.4	6.5	7.9	8.8	9.3	7.1	
other traffic	.	.	22.9	20.8	19.3	18.4	18.4	18.3	18.0	17.9	18.2	18.3	18.3	17.7	
Other mobile sources	.	.	6.3	4.4	2.9	2.2	2.3	2.1	1.9	1.8	1.9	2.0	1.9	1.4	

1) Excluding aviation.
2) Delivery vans, lorries and road tractors.

* = provisional figure
. = data not available

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Table E.1
Estimation of Air Polluting Emissions by Power Plants due to Traffic (Electric Traction)

A. Energy consumption by electric traction

	Effective delivery of electricity by public power plants 1)	Electricity consumption by transport 2)	o.w. NL Railways 3) 4)	o.w. tram/ subway/ trolleybus	Share in electricity production: Transport total	o.w. NL Railways	o.w. tram/subway trolley bus
	mio kWh				% of effective delivery of electricity		
1980	55806	978	834	144	1.8	1.5	0.3
1981	55307	1013	860	153	1.8	1.6	0.3
1982	50899	1051	901	150	2.1	1.8	0.3
1983	50456	1059	905	154	2.1	1.8	0.3
1984	52985	1086	919	167	2.0	1.7	0.3
1985	52730	1106	951	155	2.1	1.8	0.3
1986	56331	1142	964	178	2.0	1.7	0.3
1987	56506	1172	990	182	2.1	1.8	0.3
1988	56495	1161	992	169	2.1	1.8	0.3

1) Sources: CBS, Statistics on electricity-supply in the Netherlands.
2) Source: CBS, Energy-supply in the Netherlands.
3) Source: Netherlands Railways.
4) Of which 85 to 90% for passenger transport.

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Table E.1 (Continued)
Estimation of Air Polluting Emissions by Power Plants due to Traffic (Electric Traction)

B. Emissions by (public) power plants (electricity)

	Carbon monoxide	Volatile organic compounds	Nitrogen oxides	Particulates	Sulphur dioxide	Carbon dioxide
	mio kgs					
1980	1.72	0.297	80.3	10.82	195.3	35600
1981	1.78	0.301	83.4	11.65	197.6	36600
1982	1.52	0.265	81.5	8.56	131.5	32800
1983	1.38	0.268	79.7	3.21	85.7	31400
1984	1.39	0.290	83.3	2.68	70.2	33100
1985	1.38	0.287	81.5	1.97	65.3	32700
1986	1.48	0.302	88.6	1.69	65.1	35000
1987	1.53	0.303	84.0	2.20	64.0	35600
1988	1.63	0.310	87.9	4.15	65.0	37200

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Estimation of Air Polluting Emissions by Power Plants due to Traffic (Electric Traction)

C. Estimation of emissions due to electric traction

		Carbon monoxide	Volatile organic compounds	Nitrogen oxides	Particulates	Sulphur dioxide	Carbon dioxide
		mln kg					
Railways							
	1980	0.026	0.0044	1.20	0.16	2.9	532
	1981	0.028	0.0047	1.30	0.18	3.1	569
	1982	0.027	0.0047	1.44	0.15	2.3	581
	1983	0.025	0.0048	1.43	0.06	1.5	563
	1984	0.024	0.0050	1.44	0.05	1.2	574
	1985	0.025	0.0052	1.47	0.04	1.2	590
	1986	0.025	0.0052	1.52	0.03	1.1	599
	1987	0.027	0.0053	1.47	0.04	1.1	624
	1988	0.029	0.0054	1.54	0.07	1.1	653
Tram/subway/trolleybus							
	1980	0.0044	0.0008	0.21	0.03	0.5	92
	1981	0.0049	0.0008	0.23	0.03	0.5	101
	1982	0.0045	0.0008	0.24	0.03	0.4	97
	1983	0.0042	0.0008	0.24	0.01	0.3	96
	1984	0.0044	0.0009	0.26	0.01	0.2	104
	1985	0.0041	0.0008	0.24	0.01	0.2	96
	1986	0.0047	0.0010	0.28	0.01	0.2	111
	1987	0.0049	0.0010	0.27	0.01	0.2	115
	1988	0.0049	0.0009	0.26	0.01	0.2	111

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Table E.2

Emission factors of mobile sources excluding road traffic

grams/kg fuel	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
CARBON DIOXIDE															
Gasoline	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180	3180
Diesel fuel	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130	3130
LPG	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Aviation fuel	3190	3190	3190	3190	3190	3190	3190	3190	3190	3190	3190	3190	3190	3190	3190
CARBON MONOXIDE															
Rail traffic (diesel)	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Inland shipping (diesel)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Agicultural machinery	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Sea-going vessels			10	10	10	10	10	10	10	10	10	10	10	10	10
Aviation															
Other	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
VOLATILE ORGANIC COMPOUNDS															
Rail traffic (diesel)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Inland shipping (diesel)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Agicultural machinery	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Sea-going vessels			6	6	6	6	6	6	6	6	6	6	6	6	6
Aviation															
Other	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Table E.2 (Continued)
Emission factors of mobile sources excluding road traffic

grams/kg fuel	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NITROGEN OXIDES															
Rail traffic (diesel)	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Inland shipping (diesel)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Agricultural machinery	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Sea-going vessels	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Aviation															
Other			50	50	50	50	50	50	50	50	50	50	50	50	50
PARTICULATES															
Rail traffic (diesel)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Inland shipping (diesel)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Agricultural machinery	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Sea-going vessels			4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Aviation															
Other	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
SULPHUR DIOXIDE															
Gasoline	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Diesel fuel	20.9	19.0	13.3	9.3	6.3	4.8	4.9	4.6	4.0	3.8	4.4	4.6	4.4	3.2	3.2
LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aviation fuel															

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Table E.3
Emission factors per engine per LTO cycle in kg

Aircraft type	co		NOx		so2		voc		Aerosols	
Airport type --->	1	2	1	2	1	2	1	2	1	2
Jumbo jet	31.18	18.18	13.43	13.11	0.76	0.64	6.38	3.78	0.27	0.20
Long-range jet	29.83	18.13	2.91	2.73	0.51	0.38	24.78	14.38	0.52	0.48
Medium-range jet	15.07	7.45	7.05	6.56	0.60	0.47	4.92	2.36	0.25	0.16
Turbo prop	8.22	3.67	0.21	0.18	0.14	0.08	5.98	2.00	0.45	0.25
Business jet	6.08	5.14	1.03	0.98	0.05	0.04	0.88	0.69	0.05	0.01
Piston engine	11.09	9.55	0.01	0.01	0.00	0.00	0.17	0.10		
Helicopter	0.78	0.78	0.39	0.39	0.06	0.06	0.26	0.26		
Military jet	12.37	12.37	6.76	6.76	0.53	0.53	0.61	0.61	0.11	0.11
Military transport	9.25	9.25	2.49	2.49	0.69	0.69	5.66	5.66	1.39	1.39

Airport type: 1= Schiphol Airport; 2 = Other Dutch airports.

Table E.4
Mobile Sources, excluding road traffic

mio kgs	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
CARBON DIOXIDE												
Rail traffic (diesel)	172	132	133	130	112	106	103	108	99	93	89	89
Inland shipping (diesel)	1440	1440	1440	1377	1377	1380	1380	1387	1418	1437	1455	1455
Agricultural machinery [1]	595	595	595	595	595	586	586	586	513	513	513	513
Sea-going vessels [3]	626	626	626	626	626	626	626	626	626	626	626	626
Aviation												
Other [1] [2]	876	876	876	876	876	876	876	876	876	876	876	876
CARBON MONOXIDE												
Rail traffic (diesel)	1	1	1	1	1	1	1	1	1	0	0	0
Inland shipping (diesel)	14	14	14	13	13	13	13	13	14	14	14	14
Agricultural machinery [1]	6	6	6	6	6	6	6	6	5	5	5	5
Sea-going vessels [3]	2	2	2	2	2	2	2	2	2	2	2	2
Aviation	6	6	6	6	6	6	6	6	6	6	6	6
Other [1] [2]	8	8	8	8	8	8	8	8	8	8	8	8
VOLATILE ORGANIC COMPOUNDS												
Rail traffic (diesel)	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Inland shipping (diesel)	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4
Agricultural machinery [1]	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.6	1.6	1.6	1.6
Sea-going vessels [3]	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Aviation	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Other [1] [2]	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
NITROGEN OXIDES												
Rail traffic (diesel)	1.9	1.5	1.5	1.5	1.2	1.2	1.2	1.2	1.1	1.0	1.0	1.0
Inland shipping (diesel)	23	23	23	22	22	22	22	22	23	23	23	23

Table E.4 (Continued)
Mobile Sources, excluding road traffic

	mio kgs 1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Agricultural machinery [1]	10	10	10	10	10	9	9	9	8	8	8	8
Sea-going vessels [3]	10	10	10	10	10	10	10	10	10	10	10	10
Aviation	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Other [1 2]	14	14	14	14	14	14	14	14	14	14	14	14
PARTICULATES												
Rail traffic (diesel)	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Inland shipping (diesel)	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4
Agricultural machinery [1]	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.8
Sea-going vessels [3]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Aviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other [1 2]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
SULPHUR DIOXIDE												
Rail traffic (diesel)	0.7	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Inland shipping (diesel)	6.1	4.3	2.9	2.1	2.2	2.0	1.8	1.7	2.0	2.1	2.0	1.5
Agricultural machinery [1]	2.5	1.8	1.2	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.5
Sea-going vessels [3]	16	16	16	16	16	16	16	16	16	16	16	16
Aviation	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other [1 2]	3.7	2.6	1.8	1.3	1.4	1.3	1.1	1.1	1.2	1.3	1.2	0.9

[1] Rough estimation

[2] Internal transport and mobile machinery (e.g. for road constructions)

[3] Estimated by the Dutch Emission registration

CBS/NL

APPENDIX I

HANDBOOK OF EMISSION FACTORS

Part One: Non industrial sources
Part Two: Industrial sources

In order to realize an effective policy planning for the systematic reduction of air and water pollution, a thorough knowledge of the emissions of pollutants is generally considered to be essential. For this reason, a systematic inventory was started in the Netherlands in 1974; it comprises emissions into air and surface water. All known sources, such as space heating, households, traffic, industry and natural sources, are taken into account. Since an enormous quantity of emissions has to be dealt with, it is clear that it is not possible to determine all emissions by measurements. In many cases, the data may be calculated with the help of emission factors.

What is an emission factor?

An emission factor gives the emission into air, or water for a unit considered: this may be a tonne of product, or square kilometre for natural emissions, or, for a motor vehicle, a driven kilometre.

The data given in these handbooks are especially useful to government authorities dealing with environmental problems, to toxicologists, industrial scientists, and others who are interested in the environment.

You can order Part One of the Handbook of Emission Factors and subscribe to Part Two by contacting:

Staatsuitgeverij
P. 0. Box 20014
2500 EA ‘s-Gravenhage
NETHERLANDS

Contents of Part One of the handbook:

Chapter 1
Emissions from domestic activities

- Sanitary installations
- Use of spray cans
- Solvents from paints, wood stains, etc.
- Cooking with gas, water heating in gas-fired boilers and geysers
- Laundering
- Cigarette smoking
- Various sources of heavy metals

Chapter 2
Emissions from small enterprises

- The cleaning of new automobiles
- ML-treatment of new automobiles
- Filling stations
- Car finish repair shop
- Anti-rust and corrosion treatment stations
- Bakeries
- Butcheries
- Preparation of meat in the retail trade
- Preparation of meat products
- Compound feed mills
- Smithies and small engineering workshops
- Painting and decorating trade
- Dry-cleaning establishments
- Wood-working enterprises

Chapter 3
Emissions from heating of various spaces

- Space heating for private houses
- Space heating for other buildings
- Greenhouse heating

Chapter 4
Emissions from road traffic

- Exhaust gases
- Wear in automobile break-lining

Contents of Part Two of the Handbook:

Chapter 1
Combustion equipment and boilers

Chapter 2
Dust collection
Dust collection by means of cyclone
Dust collection by means of a fabric filter
Dust collection by means of an electrostatic precipitator
Dust collection by means of a wet scrubber

Chapter 3
Storage and handling of solid materials
.... storage and handling
Iron-ore storage and handling
Elevator for grain and compound-feed raw materials
Storage and handling of granular fertilizer
Storage and handling of metals and scrap

Chapter 4
Equipment in use in the Chemical Industry
Flanges
Valves
Pumps and compressors
Relief valves
Flares
Cooling water system
Oil-water separators

Chapter 5
Storage and handling of organic liquids
Storage of organic liquids in tanks
Small tankers, barges, tank lorries and railway tank cars
Marine vessel loading and ballasting

Chapter 6
Oil refinery
Hydroskimming refinery
Medium complex or conversion refinery
Complex refinery

Chapter 7
Manufacture of inorganic basic materials
Coke plant
Ammonia plant
Sulphuric-acid plant
Hydrochloric-acid plant
Nitric-acid plant
Phosphoric-acid plant
Chlor-alkali plant
Carbon-black plant

Chapter 8
Fertilizer production
Normal-superphosphate plant
Triple-superphosphate plant
N.P.P. fertilizer plant
Ammonium-nitrate plant

Chapter 9
Manufacture of alcohols. aldehydes and ketones
Methanol plant
Ethanol plant
Formaldehyde plant
Acetone plant
Cyclohexanone plant

Chapter 10
Manufacture of organic acids and anhydrides
Formic-acid plant
Acetic-acid plant
Phatic-anhydride plant

Chapter 11
Manufacture of esters
Dimethyl-terephthalate plant
Ethyl-acetate plant

Chapter 12
Manufacture of organic nitrogen
Urea plant
Melamine plant
Di-isocyanates plant
Caprolactam plant
Acrylonitrile plant

Chapter 13
Manufacture of other organic compounds
Thermal cracker for the manufacture of ethene
Vinyl-chloride plant
Cyclohexane plant
Ethyl-benzene plant
Styrene plant
1.3-Butadiene plant
Rayon plant
Chloro-fluoro hydrocarbons plant
Paint factory

Chapter 14
Manufacture of thermoplastic and thermosetting resins

- Polyvinyl-chloride plant
- Polythene plant
- Polypropene plant
- Polystyrene plant
- Polyether plant
- Alkyd resin plant
- Epoxy resin plant
- Urea-formaldehyde plant
- Melamine-formaldehyde plant
- Phenolformaldehyde plant
- acrylonitrile-1.3-butadiene-styrene (ABS plant)
- Polyacetal plant
- Polyester plant
- Polyurethane resin plant

Chapter 15
Manufacture of elastomers

- Butadiene-styrene rubber plant
- Polybutadiene plant
- Butadiene-nitrile rubber plant
- Polyurethane-rubber plant

Chapter 16
Production of foodstuffs

- Slaughterhouse
- Cutting room
- Meat processing plant
- Rendering plants
- Poultry slaughter house
- Dairy and milk products factory
- Flour-mill
- Beet-sugar factory
- Edible-oil mill
- Vegetables and fruit preserving factory
- Bread factory, rusks factory, pastry factory, paste factory
- Potato-flour factory
- Compound-feed mill
- Malthouse and brewery

Chapter 17
Manufacture of primary and secondary metals

- Blast furnace
- Steel works
- Aluminium plant
- zinc plant
- Secondary aluminium melting plant
- Secondary lead melting plant
- Secondary copper melting plant

Chapter 18
Foundry

- Grey iron foundry
- Non-ferrous alloys foundry

Chapter 19
Surface treatment of metal

- Blast cleaning installations
- Grinding and debuting equipment
- Cutting fluids for metalworking
- Metal spraying (metallizing)
- Hot-dipped zinc coating plant
- Electroplating plant

Chapter 20
Welding, cutting and gouging

- Welding with basic electrodes for mild steel
- Welding mild steel, using rutile electrodes
- Welding low-alloy steel, using coated electrodes
- Welding high-alloy steel, using coated electrodes
- Tungsten Inert Gas (TIG) welding with argon
- Metal Active Gas (MAG) welding with CO, and filler wire
- Metal Active Gas (MAG) welding with CO, and flux cored wire
- Submerged arc welding
- Plasma cutting
- Electric gouging
- Gas-oxygen welding, cutting and gouging of steel

Chapter 21
Manufacture of building materials

- Brickyard
- Wood-working factory
- Stationary asphaltic materials mixing plant
- Concrete batching plant and concrete-products factory
- Cement plant
- Glass works, fibre-glass works, glass wool works

Chapter 22
Other companies

- Fine ceramics factory
- Incinerator for municipal waste
- Paper mill, cardboard mill
- Printing industry
- Textile mill, textile finishing plant
- Dry-cleaning plant

APPENDIX II

LIST OF TABLES IN PART TWO OF EMISSION-FACTOR HANDBOOK

CHAPTER TWO

ESTIMATING PROCEDURES USED AT STATISTICS SWEDEN FOR DETERMINATION OF AIR EMISSIONS

(December 1990)

CONTENTS

Glossary of terms and acronyms

CO_2	Carbon dioxide
MJ	Megajoule
NO_x	Nitrogen oxides
OECD	Organization for Economic Cooperation and Development
SNV	Swedish National Environmental Protection Agency
SO_2	Sulphur dioxide
VOC	Volatile organic compounds

A. INTRODUCTION

In Sweden, statistical data on emissions to air are presented annually. The statistics are produced in close cooperation with the National Environmental Protection Agency (SNV). Statistical data on carbon dioxide emissions to air are also computed and presented together with SO, and NO, estimates. Corresponding data for 1980 and the year proceeding the actual year are presented for comparison purposes. A total in 1 000 tonne is given for various sources of emissions.

The main sources of information are:

1. Energy statistics and factors of emission.

2. Maximum amount of process emissions set by the National Franchise Board for major sources.
3. Transportation statistics and emission factors.

Because estimates are used for some sectors, the model calculations are not clearly defined. In addition to model calculations, judgements have to be made.

B. DATA

The population covered by the study consists of various sources of emission -- that is, units releasing different kinds of polluting emissions.

They are divided into three main categories:

1. Combustion
2. Industrial processes
3. Traffic

The estimates differ by kind of emission. Further, for each kind of emission the population is subdivided by industry, groups of fuels, etc. (see below), to permit higher precision in the calculations.

Usually, the calculations are not based on data for individual units, but on data aggregated in the original statistics programmes on vehicles, consumption, and deliveries of fuel. For a few combustion plants with special types of purification processes, however, the emissions are computed by unit.

B.1 COMBUSTION

Combustion is broken down by:

- Source of emission (electricity and heat production).
- Economic activity (electricity, gas, and heating plants, manufacturing, other).
- Type of combustion plant (condensing steam power, thermal power, etc.).
- Fuel types (heating oil, gasoline, etc.).
- Place of consumption (manufacture of cement, etc.).

Calculations concerning combustion are based on the following sorts of data:

B.1.1 Electricity, gas, and heating plants

(a) Data on consumption of all kinds of fuel.

B.1.2 Manufacturing

(a) Data on consumption of purchased fuels, oil, and coal.
(b) Data on consumption of other (own) fuels.

B.1.3 Other -- housing, agriculture, services, etc.

(a) Data on deliveries of oil products.
(b) Data on consumption; residual items in energy-supply statistics.

B.2 INDUSTRIAL PROCESSES

Industrial processes are broken down by:

- Economic activity (mining, food processing, etc.)

The estimates of emissions of SO, and NO, from different kinds of industrial production refer mainly to licenced maximum amounts set by the National Franchise Board for Environmental Protection (Koncessionsn mnden), which determines permitted amounts of all kinds of emissions. The calculations concerning industrial processes are mainly based on Board decisions taken over the previous year.

B.3 TRANSPORT

Transport is broken down by:

- Source of emission (road transport, other transport)
- Vehicle category (cars, lorries, etc.)
- Fuel types (gasoline, diesel, etc.)

The calculations concerning transport are based on the following kinds of data:

B.3.1 Road transport

(a) Deliveries of fuels (for calculating SO_2).
(b) Numbers and models of vehicles, transported goods, and distances, etc. (for calculating NO,).

B.3.2 Transport other than road transport

(a) Deliveries of fuels (for SO_2).
(b) The calculations concerning NO, are based mainly on an estimate made in 1982 of the number of vehicles. Revised data will be used for the 1989 statistics.

C. VARIABLES

The data collected for each subdivision are: quantity of consumed/delivered fuel; heat value; and factors of emission for sulphur dioxide and nitrogen oxide.

D. COLLECTED DATA

There are various kinds of sources for the emission calculations. One kind is the statistical information collected (available from Statistics Sweden) from different surveys, and of varying quality. Another is factors of emission, estimated with varying degrees of accuracy. A factor of emission is a pollution-specific factor which relates consumed amount of fuel to released amount of pollution -- for example, grams NO, per ton of diesel.

The factors of emission (available from Statistics Sweden) used in this survey for SO, and NO,, respectively, are mainly produced by the National Environmental Protection Agency (SNV). They are partly Swedish factors based on the sulphur content in different kinds of fuels and on measurements carried out on exhaust and flue gas, and partly on international factors recommended by such agencies as OECD. The emission factors are updated annually.

E. ESTIMATING PROCEDURES

E.1 COMBUSTION

The amounts of SO_2 and NO, from combustion are principally computed as products of consumed fuel times the appropriate emission factors. The consumption must first be converted to energy, MJ. This is done by multiplying the consumed amount of fuel by the heat value specific for the fuel in question. The calculations primarily are carried out by type of fuel and by economic activity. The figures are then aggregated to the different levels of presentation. Special consideration is given to the emission conditions at certain combustion plants fired with coal for production of electricity, gas, heat, manufacturing, and cement production; and gas turbine and diesel operations fired with oil. Special consideration is also given to the conditions of SO_2 emissions at lime kilns in some sulphate mills.

E.2 INDUSTRIAL PROCESSES

The emissions from industrial processes are computed from the conditions set by the National Franchise Board for Environmental Protection (Koncessionsnämnden). The calculations are done by adding data for the different economic activities available from the National Environmental Protection Agency.

E.3 TRANSPORT

The total emissions of SO_2 from transport are primarily computed as the products of delivered amounts of fuel and the primary emission factors for each type of fuel. The delivered amount is first converted to energy, MJ, by multiplying the delivered amount of fuel by the heat value specific for that fuel. An estimate of fuel use by different kinds of vehicles in road transport and by various other forms of transport is done on the basis of data on driving distance and fuel consumption. A differentiation of the emissions by types of transport is then possible. NO, emissions by road transport are calculated by projecting data from 1980 according to the percentage change in transport development. Total NO, emissions from transport other than road transport has been assumed to be unchanged since 1982. This is due to a lack of statistical information, but currently a major revision is under way. The model used comprises data on a number of different types of vehicles, distribution of year models, and transport of goods. Also, traffic conditions and driving distances are included.

Below is a sample presentation of emission figures.

SUPHUR DIOXIDE, NITROGEN OXIDE, AND CARBON DIOXIDE EMISSIONS
TO AIR IN 1988, PER 1,000 Tonne

	SO_2			NO_x			CO_2		
	1980	1987	1988	1980	1987	1988	1980	1987	1988
COMBUSTION									
Total	327	123	98	97	73	65	58 810	39 370	35 580
Relative figure	100	37	30	100	75	67	100	67	60
TRANSPORT									
Total	24	18	20	201*	234’	232’	19 350	22 370	23 780
Relative figure	100	77	82	100	116	115	100	116	123
INDUSTRIAL									
Total	151	84	82	34	19	19	2800	3 740	3 390
Relative figure	100	56	54	100	56	56	100	134	121
TOTAL									
Sum	502	225	199	332’	325’	3 16’	80 960	65 480	62 750
Relative figure	100	45	45	100	98	95	100	81	78

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*/ Figures under revision

F. VOC EMISSIONS

Demand for the mapping of volatile organic compound (VOC) emissions is based on their role in the formation of atmospheric oxidants and on the negative health aspects of the emissions.

No annual or continuously published statistical information is available on Swedish VOC emissions. However, several estimates on emissions of hydrocarbons from such sources as traffic have been presented. In 1990, a comprehensive study of total emissions of VOC in Sweden was reported by the National Environmental Protection Agency. It showed that about 460 000 tonne of VOC are emitted yearly and that road traffic is the principal source. The distribution by different sectors and chemical groups is shown below. Figures are in 1 000 tonnes.

Road traffic	200	Alkanes	145
Other transport	55	Alkenes	43
Energy production	48	Alcohols	34
Petrol distribution	22	Ethers and esters	14
Industrial solvents	59	Aldehydes and ketones	8
Industrial processes	30	Aromatics	64
Nonindustrial solvents	46	Chlorinated hydrocarbons	10
		Combined solvents	18
		Unspecified	124
	—		—
Total:	460	Total:	460

Different estimating procedures were used to reach these results. For example, emission factors (g/km), corrected for Swedish conditions, were used in combination with traffic-density data to obtain traffic emissions.

In another example, a selected chemical group belonging to VOC, the amount of chlorinated solvents emitted, was taken to account for about 90 per cent of the total consumption of these compounds in Swedish society.

GUIDELINES FOR FUTURE WORK

International conventions as well as national and regional demands require continuous statistical information on VOC emissions. To achieve this, Statistics Sweden has recently proposed annual publication of VOC emissions based on other available statistical sources. This information includes emission from selected larger point sources, statistics regarding fuel consumption, and the production of different chemicals. Estimates of traffic emissions of VOC will be included. Emission factors, measurements, and expert judgements will be combined in estimating total VOC emissions.

Estimates of certain compounds, such as CFC, chlorinated hydrocarbons, and methane, may be published separately. The results should also reveal regional differences.

It has been suggested that a more detailed study be made every five years or so. Reactive groups of VOC, such as alkenes, isoprene, aldehydes, aromatic compounds, and chlorinated hydrocarbons, should receive special consideration and trend analyses, since they include phytochemically active compounds, and compounds hazardous to health.

CHAPTER THREE

CALCULATION OF EMISSIONS TO AIR IN THE UNITED KINGDOM

(February 1992)

CONTENTS

Note: Tables mentioned in the text are included at the end of the Chapter.

Glossary of terms and acronyms

CO	Carbon monoxide
CO_2	Carbon dioxide
DE	UK Digest of Energy Statistics
DoE	UK Department of the Environment
DT	UK Department of Transport
ECE	United Nations Economic Commission for Europe
HC	Hydrocarbons
M	Methane
MIRA	Motor Industry Research Association
NO_x	Nitrogen oxides
SO_2	Sulphur dioxide
UK	United Kingdom
US	United States of America

VOC	Volatile organic compounds
WSL	Warren Spring Laboratory

A. VEHICLE EXHAUST EMISSIONS

Introduction

Motor vehicles are major emitters of nitrogen oxides and volatile organic compounds (VOC) (about 40 percent of the total UK emissions) and carbon monoxide (about 80 percent) (Table 4). Most of these emissions come from petrol-burning vehicles. This section illustrates methods for calculating emissions from petrol-engine motor vehicles and explores past and future trends in these emissions.

Estimation of emissions for 1981 to 1985

The estimates were made using speed-related emission factors and information about road use and speeds travelled in the UK. The method has been described fully elsewhere. The method is based on in-service measurements of vehicle emissions made by Warren Spring Laboratory (WSL)[3,4].

Speed-related emission factors

From a series of in-service measurements, emissions for a range of average speeds were determined, and the results were graphed. There was no obvious trend between types of vehicles and emissions. Therefore the 'best estimate" was chosen as the midpoint of plotted emissions. The vehicles tested were tuned. Since "as-received" and tuned vehicles had different emissions, the differences between the two were measured. This was necessary so that emission measurements on tuned vehicles could be translated into emissions from as-received vehicles.[2]

Traffic activity statistics

To calculate the total emissions for the UK vehicle fleet, information is needed on road use. Roads were divided into four classes: urban, motorway, rural single carriageway, and rural dual carriageway.[2] The speed distribution in each class was chosen to be Gaussian (with cut-offs at 0 and 200 km/h) with the widths dependent on the mean speed as shown in Table 1, Department of Transport statistics' give the vehicle kilometres driven in each road class (Table 2). Using information about the proportion of petrol-engine to DERV-engine (diesel) vehicles, estimates of the number of petrol-engine vehicle kilometres were derived (Table 3).

Calculation of emissions

The information on mean speeds, vehicle kilometres, and speed distribution curves is entered into a computer program which calculates the emissions as follows:

1. For each road type, emissions are calculated as the product of vehicle distance travelled (k) and standard emission per kilometre (E).

2. Standard emissions per kilometre are determined as a function of average speed (classes) as derived from assumed speed-distribution curves.

3. Available information on vehicle kilometres travelled is combined with assumptions about speed distribution points to calculate kilometres travelled at typical speeds.

4. Typical speeds (v) can be associated with typical emission factors per kilometre of distance travelled.

For each type of road, total emissions are determined by multiplying speed-dependent emission factors by the number of kilometres travelled at the various typical rates of speed, and then adding up the sums of these speed classes.

5. The fraction of vehicle kilometres in each class, f(i), is determined by dividing the number of vehicle kilometres in the speed class by the total vehicle kilometres for a given road type.

6. A single emission factor, e(i), is applied to all the vehicle kilometres in the class. The emission curves have been tabulated at 5 km/h intervals, through linear interpolation between the appropriate points on the emission curves for the velocity v(i) concerned. The emission for each speed class is f(i)e(i)k, and the emission from the road type is a summation of this:

$$E = \underline{k \sum_{i} f(i)e(i)}$$

where E = total emissions for the given road type;
k = total vehicle kilometres driven by all vehicles of a given road type;
f(i) = vehicle kilometres in each speed class;
e(i) = emission factor applied to all vehicles kilometres in each class; and
i = speed class.

This procedure was repeated for each type of road, and the results summed to provide the total estimated UK emissions. The same program can be used with different emission factors, for estimates of NO_x, CO, and VOC.

This procedure is used for petrol-engine motor vehicles. In principle, it may also be used for diesel-powered vehicles. However, speed-related emission information is not yet available for a sufficient number of vehicles to allow reliable estimates to be made. Estimates of emissions from diesel vehicles continue to be made using emission factors applied to fuel-consumption statistics.[2]

Estimates of lead and sulphur emissions from motor vehicles are based on the lead and sulphur content of the fuels, with the assumption that 70 percent of the lead and all the sulphur is emitted. Lead emissions from vehicle should fall in the future as after the end of 1985 the maximum permitted level of lead in petrol was 0.15 g/l, a reduction from the average content in the UK of 0.38 g/l in 1984.

Table 4 shows the emissions estimates for the years 1980 to 1985. The sample of cars used in deriving the speed-related emission curves could not represent vehicles on the road much earlier than 1980, hence the speed-related emission factors could not be used to estimate emissions prior to

1980 without further consideration. This is discussed below. The estimates published each year by the Department of the Environment[12] are, for historical reasons, based on fuel-consumption data. This leads to minor differences in the final figures, but these are smaller than the uncertainties in the estimates.

The effect of varying the parameters was investigated. The results are summarized in Table 5. These sensitivity results suggest that any errors introduced by the calculation method are within the uncertainties of the emission measurements.

Evaporative emissions

A major source of volatile organic emissions from road traffic is from evaporation -- from motor vehicles themselves and from the storage, distribution, and sale of motor fuels. It has been assumed that such emissions can be approximated by applying emission factors to statistics on the sale of petrol. A factor of 5.9 t/kt of fuel delivered is used for estimating evaporative emissions from motor vehicles, and 0.55 percent of fuel delivered is assumed to evaporate before it reaches the motor. Table 6 lists the sources of evaporation and Table 7 the emissions.[2,8]

The emission factors used were first derived in the US[9] and by Brice and Derwent[8]. There are two methods for measuring evaporation from motor vehicles; the canister method and the shed test. The canister method uses carbon canisters attached to potential sources on the vehicle. This approach has some disadvantages:

1. It cannot be used for some sources, such as throttle spindles and fuel pipes.
2. It depends on the tester correctly assessing all sources on a vehicle.
3. The canister restricts vapour from leaving the vehicle, and therefore leads to lower measurements than the true emission.

Unlike the shed method, however, the canister method can be used while the vehicle is in operation.

The shed test is used to overcome these problems. The vehicle is placed in a sealed room where the ambient temperature is controlled. The temperature is varied through a cycle that is designed to represent daily emissions. In the United States, the shed test was used more often than the canister method. Of 178 vehicles, 87 percent were shed tested. However, to date no standard test procedure has been agreed upon in Europe.

Estimates of no, emissions for other years

Introduction

To construct a time series of emissions estimates, emission factors for each year must be known. The most complete estimates would be obtained from measured emissions factors taken at sufficient intervals so as to capture their dependence on technological changes which affect emissions. Emission estimates should also consider details of the age distribution of the vehicle fleet, which serves as a good proxy for technology implemented, and should also consider information on speed and distance of travel to determine emissions, particularly of NO,. This section seeks to estimate NO_X emissions from petrol-engine motor vehicles for years before and after the period 1980-1985, for which the existing measurements are considered representative.

Generally, emission factors are not measured with sufficient frequency, and so some estimates must be made. Regulatory or relevant technical information is used as an additional source of data. In this case it is assumed that relationships between speed and emissions are stable for relatively short periods of study. That allows a constant factor to be used for a given engine type, a given speed class, and a given road category.

For each year, an emission factor is needed for each of the three engine-size ranges appropriate to the “Luxembourg Agreement”” (see Table 34 for emissions standards for ECE 15.00 • 15.04) and for each of the four road classes -- a total of twelve factors. A single factor for each speed/engine class can be used if it is assumed that the road classes continue to have the same mean speeds and standard deviations, and if the emission is found using the 1984 curves multiplied by a factor to adjust them to another year.

The age distribution of total vehicle kilometres travelled against vehicle age will be needed. For this report two age distributions were used, one based on the age distribution of current motor vehicles and a second on age distribution biased towards newer vehicles, since they tend to travel farther (Table 8 from UK Department of Transport Statistics’).

Using the age distribution to calculate the emissions for year x, the number of vehicle kilometres driven by vehicles first registered in year y is estimated. This figure is then broken down into speed/engine classes (tables 3-15) and emissions for each class are summed to provide a total emission from vehicles of year y. This is repeated for all years y and these are summed to provide an emission for year x.

This has been repeated to provide emission estimates for all years from 1972 to 2010. For the future NO_x emission estimates, four cases were considered, comprising two age distributions with, for each, an upper and a lower estimate of national total vehicle kilometres as published by the Department of Transport’.

Emission factors for other years

Future emission factors were based on projections of technologies which are likely to be required to comply with the proposed ECE emission limits”. It was assumed that the so-called “Luxembourg” emission limits would be met by small and medium-sized vehicles (<21) through use of compression, lean-bum engines with an oxidation catalyst, but that larger vehicles would use 3-way catalysts. The emission factors were assumed to be the estimated emissions from these technologies rather than the limits in the proposed regulations. The factors are listed in Table 9[10,11]. These assumed factors are strictly for the cold-start ECE cycle, as are the MIRA (Motor Industries Research Association) test results described below. These tests have an average speed of 19 km/h. In the absence of measurements of emissions at other speeds, the results should be adjusted to reflect other driving patterns. The factors were scaled using the ratio between the WSL test result at 19 km/h, and the WSL result for as received vehicles at the speed of each road class as shown in Table 10.

Table 9 also shows how two factors, Ti and Tj, were used to simulate the gradual inclusion of the new technologies into the new-car fleet. Large and small vehicles were assumed to be introduced over one transition year, with 40 percent of vehicles using emission controls in the transition year while medium-sized vehicles, with engines between 1.4 and 2 litres, were given an extra year, with 40 percent in the first and 60 percent in the second transition year. The dates of introduction also changed for each size class as appropriate.

For earlier years, it is difficult to propose precise emission factors, since no speed-related emissions were measured. WSL measurements and surveys by MIRA[3,4,6,7] have covered vehicles produced before ECE 15.00 emission controls were introduced (1970) up to vehicles manufactured to ECE 15.03 (1977). The MIRA 204 car study', which was carried out on a sample representative of the UK car fleet of 1981/82, provides the largest sample of measurements. However, the detailed interpretation of the data is difficult, owing to the wide variation in the results.

A number of options may arise concerning the variation of the NO_X emission factor over the sample:

1. The emission varies with the ECE regulations (15.00 - 15.03).
2. The emission varies with the vehicle's mileage.
3. The emission varies with engine size.
4. The emission is unrelated to any of these.

Data from the MIRA studies on vehicle mileage, emission, engine size, and the ECE regulation in force when the vehicle was manufactured were analyzed to see if this would indicate which of the above options was most appropriate. The results of the MIRA studies are summarized in Table 11. The latest study' suggests that NO_X emissions from regulation ECE 15.03 cars are higher than those from cars built to the previous variants of regulation 15. However, the position is complicated by the fact that the earlier study[6] found an average NO_X emission over the ECE cycle for ECE 15.03 cars higher than that found for 15.00 cars', as is clear from Table 12. Furthermore, the two samples of 15.00 cars[6,7] suggest that there may be a mileage effect, in that the earlier sample (with the higher NO_X emissions) had accumulated significantly lower mileage than the later sample. Although the MIRA report displays the data in many different ways, there is no direct plot of emission against vehicle mileage, therefore the data was analyzed statistically.

The most significant correlation between the four sets of data was, not surprisingly, between the ECE regulation and vehicle mileage -- older vehicles have, in general, travelled farther (correlation coefficient of 0.62). A regression of emission against vehicle mileage gave a correlation coefficient of 0.28, while a multiple regression against vehicle mileage and engine size had a correlation coefficient of 0.31.

The earlier MIRA study of 201 vehicles was also examined, as these were all made to ECE 15.00 but had higher emission factors than in the later test. Correlations were poor; that between emissions and mileage was 0.01, and between emission and engine size was 0.17. Combining the two data sets and examining the ECE 15.00 vehicles alone gave a correlation coefficient between emission and mileage of 0.3 1.

However, significance tests showed that the correlations between mileage and emission for the MIRA 204 car test and when the two MIRA studies were combined were significant at the 99.9 percent level. This implies that although there may be some relationship between emissions and vehicle mileage (and aging effect) it is smaller than the variation between individual vehicles. Nevertheless, an aging effect was incorporated into some of the calculations. In this option (discussed more fully below), the initial emissions were assumed to be independent of the date of manufacture and were assumed to decrease in linear fashion for seven years at the same percentage rate per year as that obtained from the emission factor for ECE 15.00 vehicles for the first MIRA study to the factor for similar vehicles in the later MIRA tests. This gave rise to an "aging factor" -- the emission factor as a fraction of the initial emission factor for vehicles of a particular age (Table 13).

In order to investigate the range of possible options for historical NO_x emissions, four cases were considered and are described below. The various emission factor options are detailed in Table 12.

Case 1

The emission factors are based on WSL measurements and have remained unchanged for years prior to 1983 and will not change until new emission-control technology is introduced. These factors are the result of using the speed distribution described in the calculation of emissions and then dividing by the number of vehicle kilometres to give an emission per kilometre.

Case 2

Examination of the WSL speed - emission curves[3] suggests that the emissions from earlier vehicles, corresponding to ECE 15 .00 and ECE 15 .O 1 regulations, may have lower emissions than later vehicles. The emission factors are reduced for these vehicles (Table 12), keeping the factors for ECE 15.02 to ECE 15.04 the same as for Case 1.

Case 3

The MIRA 204 car study' provides emission factors for vehicles according to the ECE regulation in force at the time they were first registered (Table 13). These factors are for a standard ECE cold-start test which has an average speed of 19 km/h. The corresponding factor from the WSL speed - emission curves at 19 km/h was found and the ratio between the two factors was used to scale the WSL emission factors to give those used (Table 12). This is explained in Appendix A. Recent work at WSL on a small sample (-6) of ECE 15.04 cars (tuned) gives a mean ECE cold-start emission of 6.1 g/test. Little investigation of tuned/as received differences has been carried out, so as a worst-case assumption, this emission factor of 6.1 g/test has been applied to ECE 15.04 cars.

Case 4

Cases l-3 assume that each vehicle has an emission factor which remains constant throughout its working life. This may not be the case, although there is little information available on systematic trends in individual vehicle emissions of NO_x (or other pollutants) with age. The available information was discussed above. Assuming that there is an "aging" effect, aging factors listed in Table 13 were used to reduce the emission. factors for vehicles according to their age in the year for which the total emission was being calculated. This factor was taken from the difference between the emissions from ECE 15.00 vehicles in the two MIRA studies. (A reduction from 6.96 g/test to 4.34 g/test was made with vehicles about 6 years old in the latter case.)

Finally, information is required on the distribution of vehicles between different road types (Table 14) and the engine size distribution (Table 16). These are derived from current data and are assumed not to change with time. The errors that this will introduce are uncertain, particularly in the case of future vehicle kilometres over the different road types, as average speed differences on each road type can significantly affect the total emissions, especially of CO and VOC. Estimates of vehicle kilometres are taken from Department of Transport figures and projections (tables 16 and 17[5]).

Derived emission estimates based on the conditions of each case study are provided in tables 18 through 21, based on the Luxembourg Agreement; in tables 22 through 25, using 3-way catalysts; in tables 26 through 30 using emission estimates of CO and VOC; and in Table 31, Case 1, based on reductions in the vehicle base.

B. EMISSIONS FROM THE PRODUCTION OF SECONDARY FUELS[13]

Fuel use can be broadly divided into two categories, 1) direct use as a fuel, as in heating, and 2) as input into the production of other, secondary fuels. Emissions from the former group may be calculated simply by multiplying fuel consumption by an appropriate emission factor for the particular pollutant. Previously, a similar approach was used for secondary fuel production, in which separate emission factors were applied for all fuels. There are now methods of calculation for SO_2 and CO, so that a correct mass balance can be performed. The mass of sulphur or carbon in the input fuels is estimated and then apportioned between the product and direct emission or retention in the process. For other emissions where this is not appropriate, emission factors are used. Table 32 includes emission factors for production processes previously included in the source category “fuel conversion”.

C. EMISSIONS FROM SHIPPING

An estimate of the emissions from shipping within UK coastal waters (within 12 miles of the coast) was made for all pollutants for the years 1970 to 1988. The Department of Energy’s annual Digest of Energy Statistics (DEn, 1989) gives consumption statistics for fuel oil and marine diesel (gas oil) relating to marine vessels in three categories: fishing, other coastal and inland shipping, and marine bunkers.

In the case of fishing and coastal vessels, all fuel was assumed to be used within UK waters. These vessels predominantly burn gas oil. Emissions for each pollutant were calculated by applying an emission factor to the digest fuel consumption, summarized in Table 33, which also gives source literature. Since no more detailed information on number of craft and type of engine were available for these vessels, NO,, CO and VOC factors were taken mid-range of those in the literature. Emission factors for the small amount of fuel oil burned by these vessels were the same as those outlined below for other UK shipping.

Much of the fuel held in marine bunkers is used on long voyages by large vessels. That requires a separate approach for estimating emissions from these vessels in UK waters. The basis for the calculation of these emissions from other UK shipping was statistics on ship arrivals by size and type of ship, as provided by British Ports Federation Limited for 1987 (BPFL, 1989). The total fuel consumption of these vessels within UK waters was estimated by applying typical times spent in port and within coastal waters, and estimating fuel consumption by type of fuel, vessel, and mode of operation, whether in port or cruising (Hurford, 1989).

Further research is being carried out to refine this calculation for different types of vessels. Emission factors of NO,, VOC, and CO by mode of operation were available (USEPA, 1985), while factors for CO,, SO,, and black smoke were taken as similar to other source categories (see Table 32) and applied to the total calculated fuel consumption in UK waters. Table 33 summarizes the factors used. For SO, it is likely that bunker fuel oil has a higher sulphur content than that assumed for other sources where fuel oil is used. No allowance was made for this in the present estimate. Emissions of pollutants for all years were scaled on Digest of Energy marine bunker fuel-consumption statistics by fuel.

D. METHANE

Methane was previously included under emissions of VOCs. However, emissions of methane from fuel combustion make up only a small percent of total emissions. VOC emission factors for combustion sources were estimated to be 1.75% methane. And factors for road transport, processes, and solvents have no methane components. Gas-leakage emission factors are estimated at 91% methane, based on the composition of natural gas. The following are additional sources of methane.

a. Coal Mines - An initial estimate of methane in 1987 was provided by British Coal (British Coal, 1989). This estimate included emissions from both deep-mined and open-cast pits. Emissions on an annual basis were estimated by scaling the 1987 emission against total pit production each year.

b. Landfill - The DoE's annual Digest provided information on the amount of waste landfilled in England and Wales each year. Using population figures, this was scaled to include Scotland and Northern Ireland. The total methane generated, M, from waste landfilled in year, y, was given by:

$$M(y) = w.p.d.f.(16/12)$$

where w = mass of waste landfilled in year, y,
p = fraction of carbon that is potentially decayable,
d = fraction of p that actually decays,
f = fraction of carbon-forming methane (assumed 50%, with 50% as CO_2 on a per-molecule basis),
and 16/12 represents the ratio of the molecular mass of methane to carbon.

All these factors vary considerably from site to site and may need to be revised in the light of better data.

Landfilled waste emits methane for a number of years. Emissions vary according to the conditions of the landfill. In the absence of more detailed data it was assumed that:

- 5% of potential emission M(y) is emitted in year y,
- 10% of potential emission M(y) is emitted in each of the nine succeeding years,
- 5% of potential emission M(y) is emitted in year y+10.

These estimates are subject to large uncertainties. While figures are a guide to the relative importance of the different sources, the absolute value of the emissions is very uncertain.

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Table 1. Speed Distributions on Four Road Types

Road Class	Average speed (kph)	Average Speed / Standard Deviation
Motor way	115	6
Non-Built-up		
Dual Carriageway	95	5
Single Carriageway	75	5
Urban	40	5

Source: DTp

Table 2. Traffic Activity Statistics

Vehicle Type	Year	Billion Vehicle Kilometres		
		Motorways	Built-Up Roads	Non-Built-Up Roads
Cars and Taxis	1981	21,076	104,859	77,615
	1982	22.272	110,386	82,109
	1983	23,493	108,096	88,415
	1984	26,190	103,640	91,960
	1985	28,350	105,870	95,170
Motorcycles, etc.	1981	172	4,151	2,393
	1982	182	4,334	2,548
	1983	185	3,633	2,387
	1984	200	3,930	2,110
	1985	190	3,500	1,950
Buses, Coaches				
	1981	239	2,011	954
	1982	255	2,094	949
	1983	294	2,045	952
	1984	300	1,930	970
	1985	330	1,780	460
Light Vans	1981	1,824	10,945	8,598
	1982	1,976	11,379	8,417
	1983	2,205	10,863	8,843
	1984	2,480	10,850	9,070
	1985	2,800	10,970	9,460

Table 3. Traffic Activity (Gasoline Only) By Type of Road

	Billion Vehicle Kilometres				
	1981	1982	1983	1984	1985
Motorways	23,015	24,028	25,907	27,989	30,370
All Non-Built-Up	85,812	91,097	96,598	101,168	103,305
All Built-Up	116,317	122,284	118,903	114,812	116,666

Table 4.
Emissions from Petrol-Engined Motor Vehicles (k tonne)

Pollutant	1980	1981	1982	1983	1984	1985	1985 as % of UK Total
NOx	494.0	483.0	497.0	503.0	513.0	527.0	29
CO	4055.0	3965.0	4176.0	4183.0	4179.0	4216.0	85
VOC							
- Exhaust	362.0	354.0	375.0	375.0	374.0	377.0	19
- Evaporative	113.0	110.0	114.0	115.0	119.0	120.0	6
- Total from Vehicle	475.0	464.0	489.0	490.0	493.0	497.0	25
- US Marketing	105.0	102.0	106.0	108.0	111.0	112.0	5
- Total Petrol	580.0	567.0	595.0	598.0	604.0	609.0	3
SO2	27.0	26.0	23.0	16.0	16.0	16.0	<1
Pb	7.5	6.7	6.8	6.9	7.2	6.5	

Emissions from DERV-Engined Motor Vehicles (k tonne)

Pollutant	1980	1981	1982	1983	1984	1985	1985 as % of UK Total
NOx	177	166	172	185	203	213	12
CO	216	228	235	254	277	291	4
VOC	38	37	38	41	45	47	2
SO2	30	27	26	26	27	28	<1

Table 5.
Combustion Emissions from Petrol-Engined Motor Vehicles
(not including evaporative)

Effect of Altering Speeds

Change to Speed Distributions	% Change in Emissions NOx	co2	voc
Increase all speeds by 10%	5.2	-5.1	-6.9
Decrease all speeds by 10%	-3.2	7.5	9.1
Mean built-up speed = around 20 km/h	6.2	51.0	97.0
Mean built-up speed = around 30 km/h	4.0	22.0	52.0
Increase built-up speed by 10%	-1.8	-8.2	-5.9
Decrease built-up speed by 10%	2.2	7.9	6.9

Parameters Used to Calculate Emissions 1983

Road Class	V km x 1 Million	% of Total	Emissions NOx	co	voc	Km/h Mean Speed
Motorway	25.9700	10	17	10	7	110
Built-Up	118.9030	49	41	63	64	40
Non-Built-Up	96.5890	40	42	27	29	77
- Dual c/w	9.6589	4	5	3	3	95
- Single c/w	86.9301	36	37	24	26	75
Total	240.5890	100	100	100	100	

Table 6. VOC-Motor Spirit Evaporative Emission Factors

Location	% Loss of Motor Spirit Deliveries
Storage (refineries, depots, etc.)	0.14
Transport to Filling Station	0.06
At Petrol Station	0.17
Filling Vehicles	0.18
Total	0.55

Table 7. Motor Spirit Evaporative Emissions (k tons)

Year	From Vehicle in Use	Marketing*	Total Emission	Motor Spirit consumption x Million Tons
1980	113	105	218	19.145
1981	110	103	213	18.718
1982	114	106	220	19.247
1983	115	108	223	19.566
1984	119	111	230	20.226
1985	120	112	232	20.403

*All categories in Table 6.

Table 8. Vehicle Age Distributions Used

Age Years	% of Vehicle Kilometres Distribution 1	% of Vehicle Kilometres Distribution 2
0	11	13
1	10	12
2	9	11
3	9	10
4	9	9
5	9	9
6	7	7
7	6	6
8	6	6
9	5	5
10	5	4
11	5	3
12	3	2
13	2	2
14	2	1
15	2	0

Estimated from DTp Statistics

Table 9. NOx Emission Factors for Vehicles Registered in Future Years (For ECE Reg. 15 Cold-Start Test)

Year	NOx Emission Factor Engine Size (g/test)		
	>2 1	2-1.4 1	cl.4 1
1987	x	x	x
1988	x	x	x
1989	x	x	x
1990	Ti	x	3.5
1991	1.5	Ti	3.5
1992	1.5	Tj	3.5
1993	1.5	3.5	3.5
Future Years	1.5	3.5	3.5

X = Appropriate emission factor for ECE 15.04 vehicles

Ti, Tj = Transition between ECE 15.04 and new emission factor, based on new technology and emission limits.

> Ti assumes that 40% of the vehicles will meet the new emission limits and
>
> Tj assumes that 60% of vehicles registered in that year will meet the new limits.

These factors are used to reflect the fact that vehicles employing new technology will be phased in over a short period.

Table 10. Future NOx Emission Factors Adjusted for Road Drives at Appropriate Speeds

Vehicle type	19 kph	Motorway	Urban	Rural	
				Dual Carriageway	Single
HCLB	1.810	1.995	0.919	1.548	1.239
3-Way Catalyst	0.506	0.855	0.394	0.663	0.535
WSL Speed-Emission Curve Value, Current Vehicles	1.960	3.210	1.820	2.420	2.050

All factors as "as-received" road drives.

Table 11. Emissions Surveys of In-Service Vehicles (As Received)

Emissions are in g test -1 compliance, per cent of limit in parenthesis

		Ece Regulation 15 Level					
Survey	Pollutant	Pre	00	01	02	03	Overall
105 cars	CO	169.00			-	-	
Baseline 1968	HC**	10.78		-	-	-	
Ref 1	NOx			-	-		
	Idle CO%	6.08		-	-		
201 cars	CO		169.00 (136)	-	-	-	-
1975/76	HC**		8.23 (91)	-	-	-	-
Ref 2	NOx		6.96 (6)	-	-	-	-
	Idle CO%		5.90 (130)	-	-	-	
204 cars	C 0	177.00 (149)*	214.00 (175)	171.00 (174)	186.00 (182)	116.00 (137)	172.00
1982183	HC**	9.01 (103)*	10.30 (115)	7.98 (105)	8.07 (104)	6.32 (91)	8.26
Ref 3	NOx	4.06 (39)”	4.34 (39)	4.67 (43)	4.17 (36)	6.19 (63)	4.70
	Idle CO%	6.60 (148)*	7.10 (7)	5.70 (6)	6.20 (138)	5.00 (144)	6.10

Reference 1	Hayes, C.D. Atmospheric Pollution from Petrol Engines (Baseline Exhaust emissions of Vehicles Tested to the European Procedure).
Reference 2	Williams, C., Southall, M. In-Service Emissions of Cars Manufactured to Meet ECE REgulations 15. MIRA Report K3404 (Rev 2). 1976.
Reference 3	Williams, C., Everett, M.J. In-Service Emissions of 204 Vehicles Manufactured Between 1971 and 1982. MIRA Report K32126, 1983.

* Percentage of least stringent ECE R15.00 Levels.

** Multiply by 2.3 to obtain equivalent 0 4 emission.

Table 12. Emission Factors: Vehicles Manufactured Prior to 1986, Petrol-Engined (Road Drives, As Received)

	Emission Factor g/km			
			Rural	
	Motorway	Urban	Single c/w	Dual c/w
1. All	3.21	1.82	2.42	2.05
2. ECE 15.04) ECE 15.03)	3.21	1.82	2.42	2.05
ECE 15.02) All others earlier	2.675	1.25	2.025	1.585
3. ECE 15.04)	3.42	1.94	2.58	2.19
ECE 15.03) ECE 15.02	2.31	1.31	1.74	1.48
ECE 15.01	2.59	1.47	1.95	1.66
ECE 15.00	2.41	1.37	1.81	1.54
Pre ECE 15	2.25	1.28	1.69	1.44
4. All	3.42	1.94	2.58	2.19

but reducing by approximately 5% of the initial value for each year after the vehicle is manufactured (Table 13).

Table 13. Aging Factor

Age	Factor
0	1
1	0.946
2	0.892
3	0.839
4	0.785
5	0.731
6	0.677
7	0.624
8 and older	0.624

Table 14. Road Type Distribution

Road Type		Fleet Fraction (%)
Motorway		10
Urban		50
Rural	Dual Carriageway	4
	Single Carriageway	36

Table 15. Engine Size Distribution

Engine Size (Litres)	Fleet Fraction (%)
<1.4	41
1.4-2	50
>2	9

Table 16. Traffic Fo asts

Vehicle Kilometre Indices 8 00

	Actuals				Lower and Upper Forecasts 1982 = 100				
	1970	1975	1980	1982	1990	1995	2000	2005	2010
Cars and Taxis	66	77	94	100	116	122	126	131	135
					129	143	154	165	175
Heavy Goods Vehicles	91	95	104	100	99	99	99	99	99
					107	110	114	117	119
Light Vans	77	87	97	100	107	111	115	120	125
					113	124	135	147	159
Buses and Coaches	98	88	93	100	100	100	100	100	100
All Motor Traffic (except two-wheelers)	69	79	95	100	114	119	123	127	131
					126	139	149	159	167

Table 17. Vehicle km = Total Petrol Engined

(Billion Vehicle km)

Year	Low	High
Actual		
1973	183.558	
1974	180.148	
1975	182.115	
1976	191.299	
1977	196.373	
1978	204.376	
1979	203.527	
1980	217.263	
1981	222.274	
1982	229.717	
1983	233.544	
1984	242.794	
1985	250.341	
Forecast		
1986	252.840	258.830
1987	255.340	266.350
1988	257.840	274.360
1989	260.340	282.370
1990	262.840	290.380
1991	264.440	296.500
1992	268.040	302.630
1993	270.640	308.760
1994	273.240	314.890
1995	275.840	321.010
1996	277.622	325.910
1997	279.400	330.810
1998	281.190	335.710
1999	282.970	340.610
2000	284.750	345.510
2001	286.970	350.440
2002	289.200	355.380
2003	291.420	360.310
2004	293.650	365.250
2005	295.880	370.180
2006	297.700	374.710
2007	299.520	379.230
2008	301.340	383.760
2009	303.150	388.290
2110	304.970	293.810

Table 18. Emission Estimates NOx Case 1
Luxembourg Agreement

Year	Lowvhkm		Highvhkm	
	d1	d2	dl	d2
2010	338	338	436	436
2009	336	336	431	431
2008	334	334	426	426
2007	333	332	422	421
2006	333	331	419	416
2005	335	330	419	413
2004	337	330	420	411
2003	342	332	423	411
2002	348	336	428	413
2001	357	342	436	418
2000	368	350	446	425
1999	379	361	457	435
1998	393	374	469	447
1997	408	389	483	461
1996	424	406	498	476
1995	443	425	516	495
1994	462	445	532	513
1993	481	467	548	533
1992	500	490	565	554
1991	514	507	576	569
1990	529	527	585	582
1989	532	531	577	576
1988	531	530	565	564
1987	527	527	550	550
1986	522	522	533	533
1985	517	517	517	517
1984	501	501	501	501
1983	482	482	482	482
1982	474	474	474	474
1981	459	459	459	459
1980	448	448	448	448
1979	420	420	420	420
1978	422	422	422	422
1977	405	405	405	405
1976	395	395	395	395
1975	376	376	376	376
1974	372	372	372	372
1973	379	379	379	379

dl and d2 are the different age distributions

Table 19. Emission Estimates NOx Case 2
Luxembourg Agreement

Year	Lowvhkm		High Vh km	
	d1	d2	d1	d2
2010	338	338	436	436
2009	336	336	431	431
2008	334	334	426	426
2007	333	332	422	421
2006	333	331	419	416
2005	335	330	419	413
2004	337	330	420	411
2003	342	332	423	411
2002	348	336	428	413
2001	357	342	436	418
2000	368	350	446	425
1999	379	361	457	435
1998	393	374	459	447
1997	408	389	483	461
1996	424	406	498	476
1995	440	425	512	495
1994	456	444	525	511
1993	472	462	539	528
1992	488	483	551	546
1991	494	496	554	557
1990	503	510	556	564
1989	499	508	541	551
1988	490	499	522	531
1987	479	488	500	509
1986	465	474	475	485
1985	449	458	449	458
1984	424	433	424	433
1983	397	404	397	404
1982	379	384	379	384
1981	355	358	355	358
1980	335	335	335	335
1979	314	314	314	314
1978	315	315	315	315
1977	303	303	303	303
1976	295	295	295	295
1975	281	281	281	281
1974	278	278	278	278
1973	283	283	283	283

dl and d2 are the different age distributions

Table 20. Emission Estimates NOx Case 3
Luxembourg Agreement

Year	Lowvhkm		Highvhkm	
	d1	d2	dl	d2
2010	338	338	436	436
2009	336	336	431	431
2008	334	334	426	426
2007	333	332	422	421
2006	333	331	419	416
2005	336	330	420	413
2004	339	331	422	412
2003	345	334	426	413
2002	352	339	433	416
2001	363	346	444	422
2000	375	356	456	432
1999	389	368	468	443
1998	405	383	483	458
1997	422	401	500	475
1996	437	420	514	493
1995	457	441	531	513
1994	475	461	548	531
1993	493	483	562	551
1992	508	506	573	571
1991	516	520	579	583
1990	527	535	582	591
1989	521	530	565	575
1988	511	521	544	555
1987	496	507	517	529
1986	476	488	486	499
1985	457	459	457	469
1984	429	439	429	439
1983	399	406	399	406
1982	376	382	376	382
1981	347	350	347	350
1980	340	343	340	343
1979	315	318	315	318
1978	313	315	313	315
1977	297	298	297	298
1976	285	286	285	286
1975	269	270	269	270
1974	265	265	265	265
1973	268	268	268	268

dl and d2 are the different age distributions

Table 21. Emission Estimates NOx Case 4
Luxembourg Agreement

Year	Lowvhkm		Highvhkm	
	dl	d2	d1	d2
2010	260	267	335	344
2009	258	266	331	340
2008	257	264	327	336
2007	256	262	324	332
2006	256	261	322	329
2005	257	20	321	326
2004	259	260	322	324
2003	262	262	324	324
2002	266	264	327	325
2001	273	269	333	328
2000	280	274	340	333
1999	288	282	347	339
1998	298	291	356	348
1997	309	302	366	358
1996	322	316	378	371
1995	33	333	394	387
1994	356	351	410	405
1993	375	373	428	426
1992	396	398	448	450
1991	412	418	462	469
1990	430	440	476	486
1989	435	446	472	484
1988	435	446	462	475
1987	432	444	451	463
1986	428	440	437	449
1985	424	435	424	435
1984	411	422	411	422
1983	395	406	395	406
1982	389	400	389	400
1981	376	387	376	387
1980	368	378	368	378
1979	344	354	344	354
1978	346	355	346	355
1977	332	341	332	341
1976	324	333	324	333
1975	308	317	308	317
1974	305	313	305	313
1973	310	319	310	319

dl and d2 are the different age distributions

Table 22. Emission Estimates NOx Case 1 with 3-Way Catalyst

Year	Lowvhkm		High Vh km	
	d1	d2	d1	d2
2010	152	152	197	197
2009	152	152	194	194
2008	151	151	192	192
2007	152	150	192	190
2006	153	150	193	189
2005	159	151	200	189
2004	168	155	208	193
2003	178	162	220	201
2002	192	172	236	211
2001	210	185	257	226
2000	231	202	280	245
1999	253	222	304	268
1998	377	246	331	294
1997	304	274	360	324
1996	334	304	392	357
1995	368	339	428	394
1994	402	375	464	433
1993	437	415	499	473
1992	473	458	534	517
1991	499	490	559	549
1990	526	523	581	578
1989	532	531	577	576
1988	531	530	565	564
1987	527	527	550	550
1986	522	522	533	533
1985	517	517	517	517
1984	501	501	501	501
1983	482	482	482	482
1982	474	474	474	474
1981	459	459	459	459
1980	448	448	448	448
1979	420	420	420	420
1978	422	422	422	422
1977	405	405	405	405
1976	395	395	395	395
1975	376	376	376	376
1974	372	372	372	372
1973	379	379	379	379

d1 and d2 are the different age distributions

Table 23. Emission Estimates NOx Case 2 with 3-Way Catalyst

Year	Lowvhkm		Highvhkm	
	d1	d2	dl	d2
2010	152	152	197	197
2009	152	152	194	194
2008	151	151	192	192
2007	152	150	192	190
2006	153	150	193	189
2005	159	151	200	189
2004	168	155	208	193
2003	178	162	220	201
2002	192 .	172	236	211
2001	210	185	257	226
2000	231	202	280	245
1999	253	222	304	268
1998	377	246	331	294
1997	304	274	360	324
1996	334	304	392	357
1995	365	339	425	394
1994	396	374	457	431
1993	429	411	489	468
1992	460	451	519	509
1991	479	479	538	537
1990	500	506	552	559
1989	499	508	541	551
1988	490	499	522	531
1987	479	488	500	509
1986	465	474	475	485
1985	449	458	449	458
1984	424	433	424	433
1983	397	404	397	404
1982	379	384	379	384
1981	355	358	355	358
1980	335	335	335	335
1979	314	314	314	314
1978	315	315	315	315
1977	303	303	303	303
1976	295	295	295	295
1975	281	281	281	281
1974	278	278	278	278
1973	283	283	283	283

dl and d2 are the different age distributions

Table 24. Emission Estimates NOx Case 3
with 3-Way Catalyst

Year	Lowvhkm		Highvhkm	
	dl	d2	dl	d2
2010	152	152	197	197
2009	152	152	194	194
2008	151	151	192	192
2007	152	150	192	190
2006	154	150	194	189
2005	160	151	201	190
2004	169	156	211	194
2003	181	164	224	202
2002	196	174	241	214
2001	216	188	264	230
2000	239	207	290	251
1999	262	229	316	276
1998	289	256	345	306
1997	319	285	377	338
1996	347	318	408	374
1995	382	355	444	413
1994	416	391	479	451
1993	449	431	512	492
1992	480	473	542	534
1991	501	503	562	564
1990	523	531	578	586
1989	521	530	565	575
1988	511	521	544	555
1987	496	507	517	529
1986	476	488	486	499
1985	457	469	457	469
1984	429	439	429	439
1983	399	406	399	406
1982	376	382	376	382
1981	347	350	347	350
1980	340	343	340	343
1979	315	318	315	318
1,978	313	315	313	315
1977	297	298	297	298
1976	285	286	285	286
1975	269	270	269	270
1974	265	265	265	265
1973	268	268	268	268

dl and d2 are the different age distributions

Table 25. Emission Estimates NOx Case 4
with 3-Way Catalyst

Year	Lowvhkm		Highvhkm	
	dl	d2	dl	d2
2010	117	120	151	155
2009	116	120	149	153
2008	116	119	148	152
2007	116	118	147	150
2006	117	118	148	149
2005	121	119	152	149
2004	127	121	158	151
2003	134	126	166	156
2002	143	133	176	163
2001	156	141	190	173
2000	169	153	206	185
1999	184	167	222	201
1998	201	183	240	219
1997	220	203	261	240
1996	243	226	286	265
1995	271	254	316	296
1994	301	286	347	330
1993	334	324	381	369
1992	370	367	417	414
1991	398	401	446	449
1990	427	436	472	482
1989	435	446	472	484
1988	435	446	462	475
1987	432	444	451	463
1986	428	440	437	449
1985	424	435	424	435
1984	411	422	411	422
1983	395	406	395	406
1982	389	400	389	400
1981	376	387	376	387
1980	368	378	368	378
1979	344	354	344	354
1978	346	355	346	355
1977	332	341	332	341
1976	324	333	324	333
1975	308	317	308	317
1974	305	313	305	313
1973	310	319	310	319

dl and d2 are the different age distributions

Table 26. Emission Factors for Future Years

Pollutant	Vehicle Technology	Emission (ECE Cold Start R15 Cycle) g/test	Ratio Urban Drive/ECE Cold Start	Emission Urban Drive Tuned g/km
NOx	Lean Burn + Oxidation Catalyst	3.5	1.35	1.181
	3-Way Catalyst	1.5		0.506
VOC	Lean Burn + Oxidation Catalyst	2.0	0.84	0.445
	3-Way Catalyst	2.0		0.445
CO	Lean Burn + Oxidation Catalyst	10.0	1.48	3.700
	3-Way Catalyst	7.0		2.590

These emissions are not converted to "as-received" emissions from "tuned" as it has been assumed that in the future vehicles with fuel injection and more sophisticated engine-management systems should show much smaller differences between "tuned" and "as received" than do current vehicles.

Table 27. CO and VOC Emission Factors for Petrol-Engined Motor Vehicles (Road Drives, as Received)

Pollutant		Engine Size	Motorway	Urban	Rural		19 kph Equivalent
					Dual c/w	Single c/w	
CO	Future	<2.1	1.418	1.979	1.156	1.052	3.700
		>2.1	0.993	1.385	0.809	0.736	2.590
	ECE 15.04 + Earlier	All	15.880	22.160	12.450	11.780	41.440
VOC	Future	<2.1	0.122	0.245	0.126	0.138	0.445
		>2.1					0.445
	ECE 15.04 + Earlier	All	1.010	2.030	1.040	1.140	3.700

Table 28. Emission Estimates CO

Year	Lowvhkm		Highvhkm	
	d1	d2	dl	d2
2010	461	461	594	594
2009	459	459	587	587
2008	456	456	581	581
2007	464	453	588	574
2006	477	456	601	574
2005	515	466	644	584
2004	565	491	703	611
2003	631	537	780	663
2002	714	595	878	731
2001	824	675	1007	824
2000	986	778	1197	944
1999	1154	919	1389	1107
1998	1338	1101	1597	1315
1997	1555	1300	1841	1540
1996	1825	1534	2142	1801
1995	2119	1816	2466	2114
1994	2411	2124	2778	2447
1993	2724	2465	3108	2813
1992	3040	2824	3433	3189
1991	3315	3138	3717	3518
1990	3632	3489	4013	3855
1989	3821	3691	4144	4004
1988	3965	3858	4219	4106
1987	4092	4023	4268	4196
1986	4223	4189	4315	4280
1985	4367	4367	4367	4367
1984	4236	4236	4236	4236
1983	4074	4074	4074	4074
1982	4008	4008	4008	4008
1981	3878	3878	3878	3878
1980	3790	3790	3790	3790
1979	3551	3551	3551	3551
1978	3565	3565	3565	3565
1977	3426	3426	3426	3426
1976	3337	3337	3337	3337
1975	3177	3177	3177	3177
1974	3143	3143	3143	3143
1973	3202	3202	3202	3202

dl and d2 are the different age distributions

Table 29. Emission Estimates CO with 3-Way Catalyst

Year	Lowvhkm		Highvhkm	
	dl	d2	dl	d2
2010	332	332	427	427
2009	330	330	422	422
2008	328	328	417	417
2007	337	326	427	413
2006	352	329	444	415
2005	392	342	491	428
2004	446	368	555	458
2003	516	418	639	516
2002	605	480	744	590
2001	724	565	881	690
2000	891	674	1081	818
1999	1065	822	1282	990
1998	1257	1012	1501	1209
1997	1483	1220	1756	1444
1996	1762	1463	2069	1717
1995	2066	1756	2405	2043
1994	2369	2075	2731	2391
1993	2694	2429	3073	2771
1992	3021	2801	3411	3163
1991	3305	3125	3705	3504
1990	3630	3486	4011	3852
1989	3821	3691	4144	4004
1988	3965	3858	4219	4106
1987	4092	4023	4268	4196
1986	4223	4189	4315	4280
1985	4367	4367	4367	4367
1984	4236	4236	4236	4236
1983	4074	4074	4074	4074
1982	4008	4008	4008	4008
1981	3878	3878	3878	3878
1980	3790	3790	3790	3790
1979	3551	3551	3551	3551
1978	3565	3565	3565	3565
1977	3426	3426	3426	3426
1976	3337	3337	3337	3337
1975	3177	3177	3177	3177
1974	3143	3143	3143	3143
1973	3202	3202	3202	3202

dl and d2 are the different age distributions

Table 30. Emission Estimates VOC

Year	Lowvhkm		High Vh km	
	d1	d2	dl	d2
2010	57	57	74	74
2009	57	57	73	73
2008	57	57	72	72
2007	58	56	73	71
2006	**60**	57	**76**	**72**
2005	**66**	58	**82**	**73**
2004	**73**	62	91	**77**
2003	83	69	103	**86**
2002	96	78	18	**96**
2001	113	90	138	110
2000	131	106	160	128
1999	151	124	182	150
1998	173	146	207	175
1997	197	171	234	202
1996	224	197	263	232
1995	255	229	296	266
1994	285	262	329	302
1993	317	297	361	339
1992	349	335	394	379
1991	373	365	418	409
1990	397	394	439	436
1989	403	402	437	436
1988	402	402	428	428
1987	400	400	417	417
1986	396	396	405	405
1985	392	392	392	392
1984	380	380	380	380
1983	366	366	366	366
1982	360	360	360	360
1981	348	348	348	348
1980	340	340	340	340
1979	319	319	319	319
1978	320	320	320	320
1977	307	307	307	307
1976	299	299	299	299
1975	285	285	285	285
1974	282	282	282	282
1973	287	287	287	287

dl and d2 are the different age distributions

Table 31. Effect on Emissions of Future Technological Options for Petrol-Engined Motor Vehicles (Case 1)

	Option	% Reduction in UK Petrol-Engined Vehicle 1980 Base		% Reduction in Total UK Emissions on 1980 Base	
		2000	2010	2000	2010
NOx	>2 1 Three-Way <2 1 HCLB + Ox	10-29	12-32	2-7	3-8
NOx	All Three-Way	43-59	60-69	11-15	15-18
CO	>2 1 Three-Way <2 1 HCLB + Ox	68-79	84-88	51-59	62-65
CO	All Three-Way	71-82	89-91	53-61	66-67
VOC	Both Options*	61-63	77-78	11-12	14-15

*Exhaust emissions only.

Table 32. Summary of Emission Factors (kg/ton, kg/Mth Gases)

Fuels	Sources	CO2 as Carbon	Methane	so2	NOx	voc (non CH4)	co	Black Smoke
<u>Solid Fuels</u>								
Coal	Domestic	676.6 (720)	0.125	19.36*	1.5	9.975	45.00	40.000 (-)
	Power Stations	588.23 (590)	0.001875	28.88*	9	0.148125	0.50	0.250 (-)
	Railways	659.6 (680)	0.000875	26.6*	4.8	0.069 125	4.10	20.000 (-)
	Production of Coke	710 (700)	0.000875	26.6*	4.8	0.069 125	4.10	1.000 (-)
	of Town Gas	710 (700)	0.000875	28*	4.8	0.069 125	4.10	1 .000 (-)
	of SSF	710 (700)	0.000875	24.2*	4.8	0.069 125	4.10	1 .000 (-)
	Other	659.6 (680)	0.000875	26.6*	4.8	0.069 125	4.10	1.000 (-)
Anthracite	Domestic	813.4 (-)	0.015625 (-)	16 (-)	1.5 (-)	1.23438 (-)	45.00	5.600 (-)
Coke	Domestic	803.6 (-)	0.015625 (-)	16 (-)	1.5 (-)	I .23438 (-)	6.60	5.600 (-)
	Power Stations	795.4 (-)	0.000875 (-)	19 (-)	4.8 (-)	0.069 125 (-)	4.10	0.225 (-)
	Production of Coke	820 (-)	0.000875 (-)	19 (-)	4.8 (-)	0.069 125 (-)	4.10	0.225 (-)
	of SSF	820 (-)	0.000875 (-)	19 (-)	4.8 (-)	0.069 125 (-)	4.10	0.225 (-)
	Blast Furnaces	820 (-)	0.000875 (-)	0	4.8 (-)	0.069 125 (-)	4.10	0.225 (-)
	Other	796.5 (-)	0.000875 (-)	19 (-)	4.8 (-)	0.069 125 (-)	4.10	0.225 (-)
Petroleum Coke	Refineries	800 (-)	0.000875 (-)	19 (-)	4.8 (-)	0.069 125 (-)	4.10	0.225 (-)
SSF	Domestic	774.2 (670)	0.015625	16	1.5 (-)	1.23438	45.00	5.600 (-)
	Power Stations	766.3 (670)	0.000875	19	4.8	0.069125	6.60	0.225 (-)
	Agriculture	766.3 (670)	0.000875	19	4.8	0.069 125	0.65	0.225 (-)
	Production of SSF	790 (670)	0.000875	19	4.8	0.069 125	4.10	0.225 (-)
	Blast Furnaces	766.3 (670)	0.000875	0	4.8	0.069 125	4.10	0.225 (-)
	Other	766.3 (670)	0.000875	19	4.8	0.069 125	4.10	0.225 (-)
<u>Oils</u>								
Aviation Spirit	Aircraft	P (-)	P (-)	P (-)	P (-)	P (-)	P (-)	P (-)
Turbine Fuel								
Burning Oil (P)	Domestic	859 (868)	0.000875	0.2*	2.1	0.069 125	0.16	0.007 (-)
Burning Oil	Ail	859 (868)	0.000875	0.62	2.1	0.069125	0.16	0.007 (-)
DERV	Road Transport	857 (848)	P	3.8	P	P	P	18 (-)

Table 32. Summary of Emission Factors (kg/ton, kg/Mth Gases) (Continued)

Fuels	Sources	CO2 as Carbon	Methane	SO2	NOx	VOC (non CH4)	CO	Black Smoke
Fuel Oil	Power Stations	850 (799)	0.001125	54.8*	10.71 (6.9)	0.088875	1.27	1 (-)
	Coastal	850 (-)	0.001875 (-)	38.904*	6.3 (-)	0.148125 (-)	0.32 (-)	1 (-)
	Fishing	850 (-)	0.001875 (-)	38.904*	6.3 (-)	0.148125 (-)	0.32 (-)	1 (-)
	Other UK Shipping	850 (-)	0.001875 (-)	38.904*	6.3 (-)	0.148125 (-)	0.32 (-)	1 (-)
	Other	850 (799)	0.0075	38.904*	7.4	0.05925	0.5	1 (-)
Gas Oil	Power Stations	857 (848)	0.000875	5.0*	11.37 (4.5)	0.069125	0.24	0.75 (-)
	Coastal	857 (-)	0.1125 (-)	5.0* (-)	70 (-)	8.8875 (-)	3 (-)	1.5 (-)
	Fishing	857 (-)	0.025 (-)	5.0* (-)	80 (-)	1.975 9-)	2 (-)	1.2 (-)
	Other UK Shipping	857 (-)	0.001875 (-)	5.0 (-)	3.2 (-)	0.148125 (-)	0.58 (-)	0.75 (-)
	Agriculture	857 (848)	0.001625	5.0*	4.5	0.128375	0.24	0.75 (-)
	Railways	857 (848)	0.165625	5.0*	50.6	13.0844	19.28	0.75 (-)
	Other	857 (848)	0.000875	5.0*	4.5	0.069125	0.24	0.75 (-)
Miscellaneous	Refineries	800 (-)	0.00075 (-)	38.904* (-)	7.4 (-)	0.05925 (-)	0.5 (-)	1 (-)
Naphtha	Refineries	940 (-)	0.00075 (-)	38.904* (-)	7.4 (-)	0.05925 (-)	0.5 (-)	1 (-)
Petrol	Road Transport	855 (876)	P	0.8*	P	P	P	0.645 (-)
- Evaporation		0	0	0	0	5.9	209.304	0 (-)
- Marketing		0	0	0	0	5.5	0	0 (-)
	Refineries	855 (-)	0.000875 (-)	0.8* (-)	4.5 (-)	0.069125 (-)	0.00025 (-)	1 (-)
Vapourising Oil	All	859	0.000875	0.8	2.1	0.069125	0.16	0.007 (-)
Gases								
Blast Furnace Gas	All	6274000 (1441000)	1.9125	0	10550	151.088	250	0 (-)
Coke Oven Gas	All	1559000 (1441000)	1.9125	143000	10550	151.088	250	0 (-)
Colliery Methane	All	1537000 (1441000)	1.9125	0	10550	151.088	250	0 (-)
LPG	Domestic	1874000 (1441000)	10.5625	0	5275	834.438	863	0 (-)
	Power Stations	1874000 (1441000)	1.9125	0	26380	151.088	250	0 (-)
	Other	1874000 (1441000)	1.9125	0	10550	151.088	250	0 (-)
Natural Gas	Domestic	1537000 (1441000)	4.3125	0	5275	340.688	863	0 (-)
	Power Stations	1537000 (1441000)	1.9125	0	26380	151.088	250	0 (-)
	Other	1537000 (1441000)	1.9125	0	10550	151.088	250	0 (-)

Table 32. Summary of Emission Factors (kg/ton, kg/Mth Gases) (Continued)

Fuels	Sources	CO2 as Carbon	Methane	so2	NOx	voc (non CH4)	co	Black Smoke	
OPG	Power Stations	1627000 (144 1000)	1.9125	0	26380	151.088	250	0 (-)	
	Other	1627000 (1441000)	1.9125	0	10550	151.088	250	0 (-)	
Town Gas	Domestic	1599000 (1441000)	4.3125	0	5275	340.688	863	0 (-)	
	Power Stations	1599000 (144 1000)	1.9125	0	26380	151.088	250	0 (-)	
	Other	1599000 (1441000)	1.9125	0	10550	151.088	250	0 (-)	
Non-Fuel									
Agriculture	Incineration	200	0.08125	0	1.5	6.14875	31.2	14	kg/ha (-)
Domestic		200	0.009375	0	1.5	0.740625	17.5	15	(-)
Industrial		194	0.09375	0	1	7.40625	10	7.5	(-)
Combustion	Cement	137.3	0	0	0	0	0	0	(-)
	Forests	0	0	0	0		0	0	(-)
	Gas Leakage	0	1807.25	0	0	178.75	0	0	(-)
	Gas Flaring	1537000 (1441000)	0	0	0	0	0	0	(-)
	Gas Production	1537000 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0	(-)
	Processes	0	0	0	0	263.2	0	0	(-)
	Solvents	0	0	0	0	658	0	0	(-)
	Acid Production	0 (-)	0 (-)	S (-)	N (-)	0 (-)	0 (-)	0	(-)
	Landfill	0 (-)	X (-)	0 (-)	0 (-)	0 (-)	0 (-)	0	(-)
	Cattle	0 (-)	X (-)	0 (-)	0 (-)	0 (-)	0 (-)	0	(-)
	Other Animals	0 (-)	X (-)	0 (-)	0 (-)	0 (-)	0 (-)	0	(-)
	Flaring and Venting	0 (-)	X (-)	0 (-)	0 (-)	0 (-)	0 (-)	0	(-)
	Coal Mines	0 (-)	X (-)	0 (-)	0 (-)	0 (-)	0 (-)	0	(-)

Notes

(-) Source/fuel included for first time
P Performance-related factors
* Factors for 1988 sulphur contents only

S 3.28 double absorption, 13.33 single absorption
N Range 3 to 12 kg/tons
x No simple factor, see text

Table 33. Summary of Emission Factors Used for Shipping

		g/kg		
	Fuel Oil	Gas Oil		
		Fishing	coastal	Other UK shipping
co2	850	857	857	857
Total VOC	0.15*	2”	9”	0.45*
• Methane	0.0019	0.025	0.1125	0.0056
- Non-Methane	0.1481	1.975	8.8875	0.4444
so2	38.9	5	5	5
NOx	6.3*	80”	70”	3.2*
co	0.32*	2”	3”	0.58*
Black Smoke	1	1.2”	1.5”	0.75

° Mid-range values of those suggested by NSPCA, 1988.
*USEPA, 1985.

Emission factors for S02, C02, and black smoke are as for other source categories given in Table 1.

Table 34. Europe: New Automobile Exhaust Emission-Control History, Gasoline-Powered Automobiles

Year (a) and regulation	Pollutant Standard (b) g/km CO	HC	NOx
1970 (15)	25 - 55 (100 - 220) (c)	2 - 3.2 (8 - 12.8) (c)	NR (f)
1974 (15-01)	20 - 44 (80 - 176) (c)	1.7 - 2.7 (6.8 - 10.9) (c)	NR (f)
1976 (15-01)	20 - 44 (80 - 176) (c)	1.7 - 2.7 (6.8 - 10.9) (c)	2.5 - 4 (10 - 16) (c)
1977 (15-03)	16 - 36 (65 - 143) (c)	1.5 - 2.4 (6 - 9.6) (c)	2.1 - 3.4 (8.5 - 13.6) (c)
1981 (15-04)	17 - 33 (70 - 132) (c)	6 - 8.7 (23.8 - 35.0) (c, d)	
1985 Conclusions CE	6-8-11 (25 - 30 - 45) (c,e)	1.6 - 2 - 4 (d) (6.5 - 8 - 15) (c, d, e)	0.8 - 1.5 (3.5 - 6) (c, e)

(a) Year of adoption of regulation by ECE/Geneva, except for the last line concerning the "Luxembourg conclusions" for the European Communities.

(b) Varies with vehicle weight (except for 1985). Dates of actual introduction are given by countries in the next table.

(c) Figures in parenthesis are the g/test values; test is European test defined by corresponding regulations.

(d) Total HC + NOx.

(e) Values vary according to engine size (over 2 litres - 1.4 to 2 litres - under 1.4 litres). Prospective compliance dates are 1988189, 1991193, 1990191.

(f) Not regulated.

Source: OECD, Environment and Economics, 1986.

Table 35. Dates of Introduction of ECE Exhaust Emission Regulations

Country	Regulation 15	15.01	15.02	15.03	15.04
Germany	Sep. 1972	Dec. 1974	Mar. 1977	Mar. 1978	Apr. 1983
France	Oct. 1971	Jan. 1974	Jan. 1977	Jan. 1978	Oct. 1982
United Kingdom	Nov. 1973	Apr. 1977	Apr. 1982	Jan. 1983	Jan. 1985
Italy	Apr. 1973	Jan. 1975	Oct. 1978	Jan. 1982	Jan. 1985
Belgium	Jan. 1973	Jan. 1975	Oct. 1978	Jan. 1984	Jan. 1985
Ireland	Nov. 1973	Jan. 1977	Oct. 1978	Jan. 1984	Jan. 1985
Netherlands	Jan. 1973	Jan. 1975	Oct. 1978	Jan. 1982	Jan. 1985
Spain				Jan. 1983	Jan. 1985
Denmark	Jan. 1973	Jan. 1975	Oct. 1978	Jan. 1982	Jan. 1985

Note on the treatment of MIRA Results

The MIRA (Motor Industries Research Association) data of Table 11 cannot be used as they stand because they relate to measurements made according to the cold-start ECE test cycle. This corresponds to an average speed of 18.7 kph. These resutls were converted into emissions at higher speeds by comparing them with WSL results at 20 kph and using the ratio to scale WSL results at higher speeds.

Table Al shows the MIRA test results[7] which refer to cold-start ECE tests on "as received" vehicles at an average speed of 18.7 kph. This data is then converted to a "tuned" 18.7 kph basis using the factors given by MIRA (tables of ref 7) and shown in Table ref A2. These are converted to a g/km basis from a g/test result by dividing by 4 and then to the 18.7 kph urban drive figures using a factor of 1.3, which was the Potter and Savage[4] estimate of the relationship between the ECE cold start for tuned vehicles and an approximately 20 kph urban drive (as received).

Table 3 gives the emission factors estimated from the Potter and Savage results as described in this report for several speeds.

To derive the factors used in Case 3, the following equation is used:

$$F(x) = W(x) * M(20)/W(20)$$

where F(x) = factor used in Case 3 (Table 12) for mean speed x;
W(x) = Potter and Savage result at mean speed;
W(20) = Potter and Savage result at mean speed 20 kph;
M(20) = MIRA result expressed as urban drive (Table Al).

Table A1. MIRA NOx Emission Factors

Regulation in Force When Vehicles Were Registered	g/test as received MIRA (Table 11)	g/km	"as received" 20 kph Urban Drive Equivalent
Pre-regulation	4.06	1.015	1.370
ECE 15.00	4.34	1.085	1.485
ECE 15.01	4.67	1.1675	1.576
ECE 15.02	4.17	1.0425	1.407
ECE 15.03	6.19	1.5475	2.089

Table A2. WSL Emission Factors

	Mean Speed (kph)	Emission Factor (g/km)
ECE Cycle	19	1.96
Urban	40	1.82
Rural Single Carriageway	75	2.05
Rural Dual Carriageway	95	2.42
Motorway	115	3.21

CHAPTER FOUR

EMISSION INVENTORIES OF AIR POLLUTANTS IN THE UNITED STATES OF AMERICA

CONTENTS

Glossary of terms and acronyms

US	United States of America
SIP	State Implementation Plan
NAAQS	National ambient air quality standard
ADP	Automatic data processing
EPA	Environmental Protection Agency
VOC	Volatile organic compound
SCC	Source classification code
SIC	Standard industrial code
CO	Carbon monoxide
SO_2	Sulphur dioxide
NO_x	Nitrogen oxides
Melsic ton	Tonne (= 1000 kilogrammes)
Ton	907 kilogrammes
SO_x	Sulphur oxides
EIB	EPA’s Emission Inventory Branch
NADS	EPA’s National Air Data Branch
DOE	Department of Energy
MW	Megawatt
Bhl	British thermal unit
LTO	Landing and take-off cycle of aircraft
FHWA	Department of Transportation Federal Highway Administration
FTP	Federal Test Procedure
LDGV	Light-duty gasoline powered vehicles

LDDV	Light-duty diesel powered vehicles
LDGT1	Light-duty gasoline powered trucks, O-600 lbs
LDGT2	Light-duty diesel powered trucks, 6001-8500 lbs
GVW	Gross vehicle weight
LDDT	Light-duty, diesel powered trucks, types 1 and 2
HDGV	Heavy-duty gasoline powered trucks (> 8500 lbs)
HDDV	Heavy-duty diesel powered trucks (> 8500 lbs)
MC	Motorcycles
RVP	Fuel volatility
I/M prog.	Inspection and maintenance programmemes
ATP	Anti-tamping programmemes
BER	Basic emission rate
MSL	Mean sea level
RFP	Reasonable further progress (inventory)
RVP	Reid vapor preserve
MVMA	Motor Vehicle Manufacturers' Association
NIPER	National Institute for Petroleum and Energy Research
HPMS	Hightway Performance Monitoring System
FAUA	Federal aid urbanized area
AIRS	Aerometric information Retrieval system
NAAQS	National ambien air quality standard
VRS	Vapor recovery system
VMT	Vehicle miles travelled
AADT	Annual average daily traffic
N-HIPS	National highway inventory and performance study
State	means state of the U.S.A.

FTA	Federal Transit Administration
UTPS	Urban transportation planning system
MSA	Metropolitan statistical area
CMSA	Consolidated metropolitan statistical area
NECMA	North east county metropolitan area
SAF	Seasonal adjustment factor
THC	Total hydrocarbons
EF	Emission factor
LTO	Landing and take off (i.e. aircraft operations)
TIM	Time-in-mode (of aircraft operation)
FAA	Federal Aviation Administration
FAEED	FAA Aircraft engine emmission database
APU	Auxiliary power unit (of an aircraft)
ICC	Interstate Commerce Commission
GTM	Gross ton mile
gal	gallon
SOCMI	Synthetic organic chemical facilities
POTW	Publicly owned treatment waters
TSDF	Treatment, storage and disposal facilities
AQCR	Air quality maintenance area
SCC	Source classification code

A. INTRODUCTION' AND OVERVIEW

An emission inventory is, ideally, a comprehensive, accurate and current accounting of air pollutant emissions and associated data from sources within the inventory area over a specific time interval. The major purpose of the inventory is to quantify all emissions within a region. In addition to emission data, the inventory data system will include source, dispersion modelling, pollution control, and compliance information, all of which can be used to determine the present and projected effects of emissions on ambient air quality.

In the United States (U.S.), many state agencies initially developed emission inventories to assist them in the development of State Implementation Plans (SIPs). These plans were required by Section 110 of the Clean Air Act and set forth the state's strategy for attaining and maintaining national ambient air quality standards (NAAQS). The use of an inventory became mandatory for certain areas with adoption of the Clean Air Act amendments in 1977. With passage of the Clean Air Act Amendments of 1990, the role of inventories in air quality strategies became even more important. The nonattainment plan provisions (Section 172) of the 1977 amendments require the use of an inventory to document emissions in nonattainment areas.

The emission inventory comprises three source categories: point, area, and mobile sources. The information contained in this chapter is broken down by source. A glossary of relevant terms and references (Appendix A) follows. For more detailed information, other sources may be consulted; many are listed in the Environmental Protection Agency's Procedures for Emission Inventory, Preparation Volume V: Bibliography, which is available from the EPA Office of Air Quality Planning and Standards, Emission Inventory Branch (MD-14), Research Triangle Park, NC 27711, USA.

Because an emission inventory is the repository for pollutant related data, it is the key element in all agency programmes aimed at improving and maintaining air quality within the agency's jurisdiction. Although the major purpose of the inventory is to quantify all emissions within the total jurisdiction, the agency may at times focus its activities on specific pollutants, such as nonattainment pollutants, or special geographical areas, such as areas of high emission density. Once the key sources and source categories are identified, the source and emission data are obtained by means of survey questionnaires, source inspections, permit application reviews, statistical data source analysis or other means. Actual quantification of emissions is accomplished through the use of source tests, material balances, or the application of emission factors. Once this initial quantification effort is completed, the inventory must be regularly maintained by updating source activity information and by adding or deleting sources as such events occur.

Whatever the intended use of the immediate inventory activity, it must be conducted using standard, documented methods. Documentation and consistency of methods will ensure a quality comparison of data over time. It is also necessary that standard procedures for maintaining and updating the comprehensive inventory be developed to ensure that the inventory remains accurate and complete.

When planning the scope of the emissions inventory, it is important to consider the data processing resources available. If the organization has access to automatic data processing (ADP) capabilities, a large-scale inventory is possible. Manual techniques, which are practical for small inventories, are incapable of efficiently handling the extensive amount of data collected for a comprehensive emissions inventory.

B. POINT SOURCES[2]

1. Introduction

Under ideal circumstances all stationary sources would be considered point sources. In the U.S., state agencies are required to report point source emissions data annually to the EPA through their respective regional offices for certain sources. Point sources subject to the annual emissions reporting requirements are:

> Any facility that actually emits a total of 90.7 metric tons (100 tons) per year or more of particulate matter, sulphur oxides, hydrocarbons, or nitrogen oxides.
>
> Any facility that actually emits a total of 907 metric tons (1000 tons) per year or more of carbon monoxide.
>
> Any facility that actually emits a total of 4.5 metric tons (5 tons) per year or more of lead or lead compounds measured as elemental lead.

In addition, reporting of annual emissions from individual emissions points within a facility is required for those points for which:

> Actual emissions of particulate matter, sulphur oxides, hydrocarbons and nitrogen oxides equal or exceed 22.7 metric tons (25 tons) per year.
>
> Actual emissions of carbon monoxide equal or exceed 227 metric tons (250 tons) per year.
>
> Actual emissions of lead, or lead compounds measured as elemental lead, equal or exceed 4.5 metric tons (5 tons) per year.

Emissions from stationary sources not included in the point source inventory must be accounted for in the inventory of area sources.

2. Identification of point sources

The method of categorizing point sources will determine the size of the inventory. One alternative is to select an emission level of a particular pollutant in order to distinguish point from area sources. The selected emission level will determine the number of stationary sources to be included in the inventory. The distribution of source categories and pollutants will change as the point source emission level is lowered for all pollutants. This alternative may be simpler to manage when first compiling a point source inventory since the inventory will only include the largest polluting sources.

The second alternative is to include all facilities of a source category regardless of the size of the facility. Gasoline marketing and dry cleaning are two examples of source categories that are significant emitters of VOC but whose individual sources generally emit appreciably less than the U.S. standard tons per year. However, this option may require greater resources depending on the size of a particular industry.

In addition to defining the emission cutoff limit and any specific source categories or pollutants to be included in the inventory, the number of sources to be contacted and the data requirements and methods of data collection need to be determined. These considerations play a major role in determining the resources necessary to achieve the objectives of the inventory.

If the process responsible for emissions is known, a determinant, such as number of employees, which correlates with emissions from the process can be used to estimate emissions and to identify point sources. Other parameters, such as sales, can be used to estimate emissions, however, employment is generally the most readily available parameter. Correlative relationships between employment and emissions are only rough guidelines, and should therefore be used with caution as shown by the range of values exhibited within the several VOC sources shown in Table B-1.

Table B-1 Standard Industrial Classification (SICs) Associated with VOC emissions; emission per employee ranges

General 2-Digit SIC Categories	Specific 4-Digit SIC Categories	Emission-per-employee Ranges (tonne/employee/yr)
20 Food	Alcoholic beverages (2085)	0.075
21 Tobacco	Not surveyed	
22 Textiles	Coating (2295), Non-wovens (2297), Dyeing (2231)	0.536-0.89
23 Apparel	Not surveyed	
24 Lumber & wood	Finished product (2435), (2492)	0.024-0.07
25 Furniture & fixtures	SIC: (2511), (2514), (2521), (2522), (2542)	0.08-0.24
26 Paper	Bags, box (2643), (2651), (2653), Coated papers (2641)	1.0-1.25
27 Printing	Newspaper publishing (2711), Comm. printing (2751), (2754)	0.08-0.5
28 Chemicals	Organic chemical mfg. (2821), (2823), (2861), Chemical coating (2851), Specialty chemical (2842), Carbon black (2895)	0.32-0.357
29 Petroleum	All companies	0.11-2.12
30 Rubber, Plastic	Footwear (3021), Plastics (3041), (3069)	0.16-0.256

General 2-Digit SIC Categories	Specific 4-Digit SIC Categories	Emission-per-employee Ranges (tonne/employee/yr)
31 Leather	Mfg. shoes (3149), Bags (3161), Personal goods (3172), Leather refinishing (3111)	0.13
32 Stone, clay, etc.	Glass products (3321)	0.03-0.092
33 Primary metal	Treating (3398), Tubing (3357)	0.10-0.267
34 Fab. metal	Screws (3451-2), Metal stampings (3469), Plating (3471), Too mfg. (3423), (3429)	0.19-0.281
35 Machinery	Industrial machines	0.03-0.048
36 Elect. Machinery	Devices (3643), Semicond (3674)	0.04-0.07
37 Transpt. equip.	Boats (3732), Truck bodies (3711, 13, 14 15)	0.11-0.855
38 Instruments	Optical frames (3832), Precision instruments	0.04-0.199
39 Misc. Mfg.	Jewelry (3914-15), Toys (3944), Writing instr. (3951, 53)	0.07-059
5171 Bulk terminals	All surveyed	
7216 Dry cleaning	All surveyed	

3. Data requirements

The type of data required will be determined by the ultimate use of the inventory. Algorithms that will be used to calculate emission estimates on an annual, seasonal or hourly basis; or to calculate any other values (e.g. projected future emissions) should be defined. Understanding such algorithms is important in determining the data to be collected. The data requirements defined below are those necessary for developing a comprehensive emission inventory that can be used for mathematical dispersion modelling.[5]

1. Definition, general information and identification -- geographic information, facility identification number, point number to identify individual emitting points in one facility, year of record, facility name and address, facility contact person, Source Classification Code (SCC; to identify basic process or industry activity) and SIC code.

2. Fuel combustion data -- combustion rate, sulphur content, ash content and heat content.

3. Solid waste combustion data -- combustion rate and estimated heat content.

4. Evaporative loss data -- capacity of storage tanks, vapour pressure of material stored, type of tank, size and condition.

5. Emission estimates -- emission estimates from an individual point source can be made by the following methods:

   a. Stack test results or other emission measurements.
   b. Material balance using expertise and engineering knowledge of the process.
   c. Emission factors.
   d. Rough estimates.

6. Modelling information -- coordinates of emitting point, stack height, altitude of stack base (above sea level), stack diameter, stack exit gas temperature, exhaust flow rate and plume rise.

7. Control equipment -- equipment controlling each individual air pollutant at the emission point and its relative efficiency in controlling each pollutant.

8. Compliance data -- allowable emissions, existing local/provincial/national regulations, imminent legislation which will require source to comply with specific limitations, compliance status, applicable control regulations and emergency control action programme.

9. Land use data -- normal number of operating hours per day, operating days per week, operating weeks per year, number of employees at facility and land area of facility.

10. Data confidentiality -- sources which submit data may request that all or part be kept confidential. Those items which are to be kept confidential must be clearly indicated on data system along with restrictions on their use. In the U.S., quantities and kinds of emissions are not held confidential.

4. **Data collection**

There are several methods available for the collection of point source emission data. Typical methods include mail and telephone surveys, plant inspections, and use of agency permit and compliance files. Often it is necessary to use a combination of these methods to acquire the desired data.

Telephone Survey

If only a few industries are involved, if a small amount of information is needed from each one, and if written verification is not necessary, a telephone survey may suffice. In addition, plant inspection by agency personnel may be applicable when there are only a few industries and/or a small geographic area involved. These direct communication survey techniques can be inexpensive and quite effective in obtaining the required data.

Mail Survey

In many instances, however, in particular if there are numerous industries, a great deal of information needed, or a large geographical area to be inventoried, the mail survey is the most practical method for conducting an emission inventory. The primary purpose of the mail survey is to obtain source and emission data by means of a questionnaire mailed to each facility identified as a potential point source.

Questionnaires

The questionnaire can be prepared as either industry-specific for each source category or general for all source'categories .[6] If the mailing list is long, or if the agency is unfamiliar with many of the sources to be surveyed, a general questionnaire is advisable. Usually a general questionnaire is merely a collection of process-specific questionnaires sent out as one document. Appendix C of reference [2] contains an example of a general emission inventory questionnaire which can be mailed to any industrial facility.' This form is EPA's questionnaire for point source reporting. Appendix C contains the general instructions for completing the questionnaire and supplemental instructions which are industry-specific. Descriptions of major activities and process/operating units, feed materials and products which are typical for a specific industry category are identified to help the source owner complete the questionnaire. It is important to specify the units in which the data should be reported along with any special notes applicable to an industry grouping. The facility must provide a plot plan and process flow diagram suitably labelled to identify pertinent emission information contained in the questionnaire.

Industry-specific questionnaires are advantageous for certain sources. Appendix D of reference [2] includes an example of a source specific questionnaire sent to operators of grain elevators, Inventory accuracy is increased when industry-specific questionnaires are used since extraneous questions are eliminated and the terminology is industry-specific, reducing confusion in answering. However, this approach has disadvantages. The design of industry-specific questionnaires requites significant resources and skill. Returned questionnaires cannot be processed uniformly across different industries due to the variations in format. In addition, an in-depth knowledge of the emission producing operations at a source is required to ensure the proper questionnaire is sent to each source. This can prove difficult when surveying a large, multiproduct corporation involved in integrated production of various industrial products.

Plant inssections

Plant inspections are a direct means of obtaining information or of verifying data that were submitted in the questionnaire. The data gathered during a plant inspection are generally the same as those solicited in a questionnaire. Standard plant inspection forms should be developed to help the agency conduct the formal plant visit. Such forms will assist the inspector in performing a thorough inspection by specifying the information to be obtained as well as serving as a guide for maintaining data consistency.

5. Data analysis

It is necessary that submitted data be checked to assess validity and consistency. Finding and correcting errors and inconsistencies in the source and emission data are necessary to ensure that data are complete, accurate and suitable for use by the agency in the development and assessment of control strategies. The following are potential sources of error found in most emission inventories.[4]

Missing facilities or sources,
Duplicate facilities or sources,
Missing operating or technical data,
Erroneous technical data,
Improper facility location data,
Inconsistent area source categories or point source sizes,
Inaccurate or outdated data,
Errors in calculations,
Errors in emission estimates,
Reported emissions wrong by orders of magnitude.

This list entails simple cross-checking of sources and verification of completeness of submitted data. Additional checks of reasonableness of data should be conducted by engineering or technical staff. A quick review can detect any numbers which are obviously too high or low and identify unreasonable responses such as “no emissions,” "100 percent control efficiency,” etc. Engineering assessments may also include more detailed review of data to reveal errors not readily discernible by quick-scans. The assessment techniques employed may include:

Emission estimate calculations using emission factors or material balances to check reliability of responses.
Process parameter ranges set within acceptable limits to determine excess air or stack flow values.
Limits establishing stack temperature ranges. Maximum temperatures which can be expected for coal, oil, and natural gas-fired boilers are presented in Table E-l.
Fuel usage data can be checked by dividing the annual fuel consumption by the number of hours of operation per year.
Different gas cleaning devices have characteristic ranges of efficiency when used in conjunction with various combustion sources and industrial processes. An efficiency range can be developed using emission factors from government and state agencies.

Maximum and minimum values for source classification codes and parameter values are available from NEDS (National Air Data Branch, U.S. Environmental Protection Agency, Research Triangle Park, NC, 27711, USA).

Table E-l Examples of parameter check values

Parameter for which check is needed	Source	Check value
Actual volume flows	Boiler-coal	1220 scfm/10^6 Btu/hr
	Boiler-oil	1195 scfm/10^6 Btu/hr
	Boiler-gas	≤190 scfm/10^6 Btu/hr
Stack temperature	Boiler-coal <250 mmBtu/hr	≥320°
	Boiler-oil <250 mmBtu/hr	≥500°
	Boiler-oil >250 mmBtu/hr	≥350°
	Boiler-gas <250 mmBtu/hr	≥600°
Actual velocity		4,000 fpm
Actual velocity		>6,000 fpm
Stack height	(all stacks)	21,000 ft
Stack height	(boilers)	≤40 ft
Operating time		
hours/day		>24
days/week		>7
weeks/year		>52
Control efficiency		>0 for no controls

6. Estimation of emissions

There are three basic methods for determining emissions from point sources: source test data, material balances, and emission factors. The three methods are discussed below.

Source test data

This method of estimating emissions is usually the most accurate of the three. Source test data should be used if the data were obtained under conditions which are representative of or relatable to operating conditions normally encountered at the source, using test conditions of known accuracy and precision. If facility operation and test methods employed during the source test cannot be adequately characterized, the source test data should not be used.

Material balances

Material balances are commonly used for estimating emissions from many source categories, primarily VOC sources. In its simplest form, the material balance assumes that all VOC entering the process is emitted. However, situations often exist where this assumption does not apply.[4] VOC may be retained in the product, destroyed in the process, or physically removed for reprocessing or disposal. In other cases, such as bulk storage of petroleum products, the amount of solvent lost by evaporation is small compared to the capacity or throughput of the source and cannot be accurately determined by a material balance.

Emission factors*’

Stack test results or other emission measurements are not always available for each point source in the inventory. One of the most useful tools available for estimating emissions from both point and area sources is the emission factor. An emission factor is an estimate of the quantity of pollutant released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity. In most cases emission factors are expressed simply as a single number, with the underlying assumption that a linear relationship exists between emissions and the specified activity level over the probable range of application. The emissions from a process are therefore estimated by multiplying the emission factor by the activity of the process (SCC unit). The SCC unit is a process parameter, usually production rate, which can be correlated with emissions.

Additionally, empirical formulas have been developed for several source categories that allow the agency to base its emissions estimates on a number of variables instead of just one. As a rule, the most reliable emission factors are those based on numerous and representative source tests or on accurate material balances.

The use of an emission factor to estimate emissions from a source necessitates that the agency have complete source and control device information. In many cases, including most combustion sources, the emission calculation merely involves the multiplication of the appropriate emission factor by the source activity, such as fuel combustion, for the time interval in question. If a control device is in place, an adjustment factor equal to (1 ▪ fractional control device efficiency) should be multiplied by the uncontrolled emission estimate to account for the effect of the device. In AP-42[9], as in most cases, emission factors typically represent uncontrolled emissions or emissions before the action of any control device. The EPA document AFSEF consolidates all currently available emission factors into one document. This document is also available on computer diskette.[21]

Emission factors are most accurate when the relationship between process data and emissions is direct and relatively uncomplicated.’ If, for example, the sulphur content of eastern bituminous coal used as fuel in a large industrial boiler is known, the use of the emission factor (38 S lbs of sulphur oxide per ton of coal, where S is the sulphur content of the coal in percent)[9] to estimate sulphur dioxide is accurate for most uses of the inventory. The sulphur in bituminous coal is converted virtually completely (95 percent) to SO, and conversion of SO, to particulate sulphate and SO, (normally 1 to 3 percent) prior to emission is not considered significant from the standpoint of the accuracy of the inventory of sulphur dioxide emissions. An entirely different situation exists, however, in the case of estimating the emissions of the oxides of nitrogen from an industrial boiler. The emission factor for nitrogen oxides, as given in AP-42,[9] varies with both the type and size of the combustion unit, from 6 to 55 lb of NO, per ton of coal. This is because the factors affecting NO, production include flame and furnace temperature, residence time of the combustion gases in the combustion zone, rate of cooling, amount of excess air, as well as the amount of nitrogenous compounds in the fuel. Thus, the emission factor of 18, which is applicable to a pulverized coal boiler burning 100 tons per hour, is an average value. Actual emission values for specific boilers may differ significantly from the quantities estimated using the average factor.

If an emission factor for a specific source or source category will not provide a reasonably accurate emission estimate, it is always better to rely on actual stack test data. Conversely, if an emission factor will provide accurate emission estimates, stack testing may represent an ineffective use of valuable time and resources.

Available emission factors

EPA report No. AP-42[9] "Compilation of Air Pollutant Emission Factors", is a compilation of emission data for use by individuals and groups responsible for conducting air pollution emission inventories. Emission factors provided in this document cover most of the common emission source categories: fuel combustion by stationary sources; combustion of solid wastes; evaporation of fuels, solvents, and other volatile substances; various industrial processes; and miscellaneous sources. When source-test data are unavailable, these factors can be used to estimate the quantities of air pollutants (particulates, CO, SO_x, NO_x and hydrocarbons) emitted from a source or source category. Qualitative estimates of the quality of the emission factors are provided for each tabular listing of emission factors.

When an emission factor is not available in AP-42 for a specific source, it is often possible to acquire emission data from various technical publications. Numerous EPA reports are available which present the results of engineering investigations concerning air emissions from a number of different processes. EPA New Source Performance Standards documents and Control Techniques Guidelines documents, and other EPA reports are potential sources of information from which emission factors can be developed. Fugitive emission factors for a number of industrial operations are presented in Reference 10. That report and similar engineering reports are assigned to the Environmental Protection Technology Series which are available through the National Technical Information Service, Springfield, Virginia 22161, USA. It is important to note that AP-42 is regularly updated to reflect the information available in the EPA reports mentioned above.

7. Calculation of emissions using emission factors

In order to calculate emissions from emission factors, various inputs to the estimation algorithm are required. These inputs are:[9]

Activity information from the source inventory,
Emission factors to translate activity information into "uncontrolled" emission estimates, and
Control device efficiency information to provide the basis for estimation of emissions to the atmosphere after passage through the control device(s).

The basic emission estimation algorithm is:

$$E = R \times EF \times (1 - C/100)$$

where:

E = emission estimate for source (at the process level),
R = activity level (such as throughput),
EF = emission factor (such as lb emitted/throughput), and
C = control device efficiency (in percent).

The accuracy of the emission estimate is equally dependent upon the relative accuracy of each of these components. Errors introduced into any one of these components will affect the final emission estimate.

Activity data

Activity data are generally reported as fuel consumption rate or process weight for fuel burning equipment and industrial processes, respectively. The optimum activity data are hourly values, although in some cases only shift, daily, weekly, or even monthly data are available. If hourly values are not known, the hourly average value can be calculated from the operating pattern: for example, 5 days per week, 8 hours per day, closed for holidays, and a 2-week vacation period.

Note that conversion factors may have to be applied to convert reported consumption or production values to units that correspond to the SCC emission unit; gallons to pounds, barrels to gallons, cubic meters to cubic feet, etc. If SCC units do not comply with the common unit used in the country of inventory, it may be simpler to convert the SCC units to local measurements.

Typical sample calculations for mass emissions in lb/hr are shown below for fuel activity data and process activity data.

Example 1: Calculation of particulate emissions using fuel activity data for coal-fired utility boiler.

Given the following pertinent data:

Firing rate (R)	30 tons/hr
Average ash content (A)	7.5 percent
Emission factor (EF)	13A lb/ton
Collector efficiency (C)	95 percent

Emissions are calculated using:

$$E_{part.} = R \times EF \times (1 - C/100)$$

where $E_{part.}$ = mass emission of particulates (lb/hr).

In this case:

$$E_{part.} = 30 \times 13(7.5) \times (1 - 95/100) = 146.25 \text{ lb/hr.}$$

Example 2: Calculation of particulate emissions using process activity data for electric induction furnace.

Given the following pertinent data:

Process Weight (R)	30 tons/hr
Emission factor (EF)	1.5 lb/ton
Collector efficiency (C)	95 percent

Emissions are calculated using:

$$E_{part.} = R \times EF \times (1 - C/100)$$

where $E_{part.}$ = mass emission of particulates (lb/hr).

In this case:

$$E_{part.} = 30 \times 1.5 \times (1 - 95/100) = 2.25 \text{ lb/hr.}$$

Control device efficiency

Control device efficiency is the third element of the linear emission algorithm. Control device efficiency may be determined for specific equipment by source tests to measure concentrations before and after the control device. However, because of possible variation in control device operation with process, control device malfunction and deterioration over time, etc., the measurement is subject to the potential limitations of all source tests.

When test data are not available for a specific control device, literature values may be used for estimating control efficiency. EPA publication AP-42[9] supplies control device efficiencies for control devices which are commonly encountered in industrial applications. These control efficiency estimates, in reality, may not be precisely applicable to specific control devices. In addition, a control device may be improperly sized for effective control of the process under consideration. Therefore, the estimate should be tempered with knowledge of the process and engineering judgment.

A third method of obtaining a control device collection efficiency is to employ the manufacturer's design specification or guaranteed performance specification subject to field verification. However, the design collection efficiency reported by manufacturers is the efficiency obtainable under optimum conditions which may not represent actual conditions. Some assessment of design efficiency may be required to adjust for these source conditions.

8. Temporal adjustment of the annual inventory

Most emission inventories have traditionally estimated annual emissions. However, emissions from many source categories are subject to large seasonal and/or hourly variations. Some source categories exhibit pronounced temporal dependence due to changes in activity levels or to physical changes resulting from climatic conditions. For example, a public school or university will consume most of its fuel during the winter heating season. Diurnal patterns of activity will also be apparent. Consequently, it will be necessary to obtain hourly consumption data on a seasonal or monthly basis to determine these fuel use patterns. The questionnaire should request sufficient activity level information so that the desired variations can be determined.

9. Inventorying major point source categories

Although an in-depth technical description of major source categories and their emissions is not provided in this manual, the following discussion will identify some specific problem areas encountered in inventorying emissions from major source categories, and their possible solutions. These major categories are:

1. Combustion (including incineration),
2. Chemical manufacturing,
3. Food and agriculture,
4. Metallurgical industries,
5. Mineral products,
6. Wood products,
7. Petroleum industry, and
8. Evaporation loss sources.

The exceedingly large number of industrial processes to be inventoried is indicated by the industrial source list compiled from AP-42[9] and shown in Table K- 1. This list is not all inclusive of the U.S. industrial base. Although it is not possible to comprehensively discuss the special problems of each of these processes, some of the more widespread problems that are encountered when inventorying industrial emissions and identifies some techniques for developing inventory information. Specific problems and inventory techniques that are applicable to the major categories of chemical manufacturing, food processing and agriculture, metallurgical processes, mineral products, wood products, the petroleum industry and evaporation loss sources are discussed in somewhat more detail.

Special problems in developing point source emission inventories include estimating fugitive emissions; accounting for factors influencing emissions, such as process variability, equipment malfunctions, and upset conditions; and estimating emissions from processes which do not have emission factors. Fugitive emissions from stock piles, material handling and transfer, process leaks, hoods, and roof monitors may represent a substantial portion of actual emissions from many facilities. A list of 19 industrial processes, their major sources of fugitive particulate emissions, and estimates of annual uncontrolled emissions and the percentage of the fugitive contribution to total uncontrolled emissions are shown in Table K-2." The emission estimates, largely based on process data for various years in 1970, are not supported by extensive test data.[10] They should be used only to identify sources and provide a rough measure of their potential contribution to emissions from the industrial processes shown.

Table K-l Industries, emissions and controls

Products/process	Types of emissions expected	Types of controls used
Adipic acid	Co, VOC, NO,, particulates	Incineration, thermal reduction scrubbers, carbon absorbers, **flaring**
Synthetic ammonia	CO, CO_2, NH,, NO,, SO,, organics	Process modification
Carbon black	CO, NO,, SO,, organics, particulates, trace elements	Gas filter, flare, incineration, scrubber

Products/process	Types of emissions expected	Types of controls used
charcoal	CO, CO,, VOC, NO,, organics	Afterburner
Chlor-alkali	CO, CO,, H_2, Hg	Alkaline scrubber, chlorine recovery, process modification
Explosives	Acid mist, NO,, SO,, particulates	Acid recovery, fume recovery, ESD scrubber
Hydrochloric acid	HC1	Absorption scrubber
Hydrofluoric acid	SO_2, hydrofluoric acid, florosilic acid paxticulates	Additives, bag filter, covers, scrubber
Nitric acid	NO_x	Catalytic combustor
Paint and varnish	VOC	Absorbers, afterburners, condensers
Phosphoric acid	Fluorine, particulates	Condenser, cooling pond, demister, ESP scrubber
Phthalic anhydride	CO_2, SO,, particulates	Scrubber, incineration
Plastics	Monomers, solvents	Absorption, condensers, floating roof tanks
Printing ink	CO_2, organics, particulates	Afterburners, condensers, scrubbers
Soap and detergents	**Organics,** particulates	Cyclone, scrubber
Sodium carbonate	NH_3, particulates	Ammonia recovery
Sulphuric acid	SO,, acid mist	Process modification, scrubber
Sulphur recovery	SO_2, H_2S, COS, CS_2	Process modification
Synthetic fibers	CS_2, H_2S, VOC, oil vapor and mist	Adsorption
Synthetic rubber	Monomers, particulates	Fabric filter
Terephthalic acid	NO_x	
Lead alkyl	Alkyl lead vapor, particulate lead oxide	Incineration, scrubber
FOOD AND AGRICULTURE INDUSTRY		
Alfalfa dehydration	**Particulates**	Cyclone, fabric filter
Coffee roasting	NO,, organics, particulates	Afterburner

Products/process	Types of emissions expected	Types of controls used
Cotton ginning	Particulates	Cyclone, **filter,** screen, unifilter
Feed and grain, mills and elevators	Particulates	Cyclones, fabric filter
Fermentation	H_2S, organics	Process modification
Fish processing	H_2S, organics, particulates	Afterburner, cyclone, scrubber
Meat smokehouses	Organics, particulates	Afterburner, ESP, scrubber
Ammonium nitrate fertilizer	NH,, NO_X, particulates	Mist eliminator, scrubber, wet cyclone
Phosphate fertilizer	NH,, SO,, ammonium chloride, fluoride, hydrogen fluoride, silicon tetrafluoride	Scrubber
Starch manufacture	Particulates	Scrubber
Sugar cane processing	Particulates	
Bread baking	Organics	None
Urea	NH,, particulates	Condenser, scrubber
Beef cattle feedlots	Ammonia, malodorous gases, particulates	Housekeeping
Defoliation and harvesting of cotton	Arsenic acid, DEF, paraquat particulates, sodium chlorate	Process modification
Harvesting of grain	Particulates	Process modification
METALLURGICAL INDUSTRY		
Primary aluminum production	VOC, SO_2, alumina, fluorides, hydrogen fluoride, organics, particulates	Alumina absorption, centrifugal collectors, ESP, multiple cyclones, scrubbers
Metallurgical coke manufacture	CO, VOC, H_2S, NO,, carbon disulphide, particulates	Process modification
Primary copper smelting	SO,, particulates	Cyclone, ESP, fabric filter, scrubber
Ferroalloy production	CO, particulates	Flare or combustion (of CO), particulate control device
Iron and steel production	CO, fluorides, particulates (mainly iron oxide, manganese, aluminum, silicon)	Cyclone, ESP, fabric filter, flaring or combustion (of CO)

Products/process	Types of emissions expected	Types of controls used
Primary lead smelting	SO_2, particulates	Centrifugal collector, ESP, fabric filter, tubular cooler, sulphuric acid plant, sulphur recovery, DMA adsorption process, ammonia adsorption
Zinc smelting	SO_2, particulates	Conversion of SO_2, particulates to sulphuric acid, ESP, fabric filter
Secondary aluminum operations	Fine particulates, chlorine	ESP, fabric filter
Secondary copper smelting and **alloying**	Particulates	ESP, fabric filter, scrubber
Grey iron foundries	CO, particulates	ESP, fabric filter, scrubber
Secondary lead smelting	SO,, particulates	Gas settling/cooling chamber cyclone, demister, fabric filter, scrubber
Secondary magnesium smelting	NO,, SO,, particulate MgO	
Steel foundries	VOC, NO,, SO,, particulates	ESP, fabric filter, scrubber
Secondary zinc processing	CO, NO,, particulates	
Storage battery production	Lead, particulates	Fabric filter, scrubber
Lead oxide and pigment production	Lead, particulates	Cyclone, fabric filter, settling chamber
Miscellaneous lead products	HC, particulate lead	ESP, fabric filter, rotoclone, scrubber, process modification
Leadbearing ore crushing and grinding	Lead, particulates	Cyclone, fabric filter, process modification, housekeeping
MINERAL PRODUCTS **INDUSTRY**		
Asphaltic concrete	Particulates	Cyclone, fabric filter, scrubber, spray tower
Asphalt roofing	**Organics**, particulates	Afterburner, ESP, filter, scrubber
Bricks and related clay products	NO,, SO,, fluorides, particulates	Cyclone, ESP, fabric filter, scrubber
Calcium carbide	CO, SO,, acetylene, particulates	Scrubber

Products/process	Types of emissions expected	Types of controls used
Castable refractories	Fluorides, particulates	Cyclone, ESP, fabric filter, scrubber
Portland cement	NO,, SO,, particulates	ESP, fabric filter, multicyclones
Ceramic clay	NO,, acid gases, fluoride, particulates	Cyclone, ESP, fabric filter, scrubber, settling chamber
Clay and fly ash sinterings	Particulates	Cyclone, fabric filter, scrubber
Coal cleaning	NO,, SO,, organics, particulates	Cyclone, scrubber, water spray
Concrete patching	Particulates	Enclosure
Glass fiber	CO, VOC, NO,, SO,, particulates	Afterburner, ESP, fabric filter, incinerator, scrubber, wet handling
Frit	Particulates	Fabric filter, scrubber
Glass	CO, NO,, SO,, organics, particulates	ESP, fabric filter, scrubber
Gypsum	Particulates	Cyclone, ESP, fabric filter
Lime	CO, NO,, SO,	Cyclone, multiple cyclone, fabric filter, settling chamber
Mineral wool	SO,, fluorides, particulates	Afterburner, scrubber
Perlite	Particulates	Fabric filter
Phosphate rock processing	SO,, fluoride, particulates	ESP, fabric filter, scrubber, process modification
Sand and gravel	Particulates	Water spray
Stone quarrying and processing	Particulates	Cyclone, fabric filter
Coal conversion	Hazardous organics, metal carbonyls, trace elements, toxic gases (CO, H_2S, HCN, NH_3, COS, CS_2), particulates	Afterburner, ESP, fabric filter, incineration, scrubber, water spray, housekeeping maintenance, process modification
Taconite ore processing	Particulates	Centrifugal collector, cyclone, multiple cyclone, rotoclone, ESP, fabric filter

Products/process	Types of emissions expected	Types of controls used
PETROLEUM INDUSTRY		
Petroleum refining	CO, VOC, NH,, NO,, SO,, aldehydes, cyanides, particulates	Cyclone, ESP, incineration, scrubber, vapor recovery system, process modification, housekeeping maintenance
Natural gas processing	SO_x	Flaring, incineration, process modification
WOOD PRODUCTS INDUSTRY		
Chemical wood pulping	CO, H_2S, SO_x, NO_x, dimethyl, disulphide, methyl mercaptan, particulates, dimethyl sulphide	Absorption, ESP, mist eliminator, multiciclone, scrubber, process
Pulpboard	Particulates	Not available
Plywood veneer and layout operations	Organics, particulates	Condenser, cyclone
Woodworking waste collection operations	Particulates	Cyclone, fabric filter
EVAPORATION LOSS SOURCES		
Dry cleaning	Volatile organic compounds	Carbon absorber, incineration
Surface coating	Volatile organic compounds	Carbon absorber, afterburner
Storage of petroleum liquids	Volatile organic compounds	Pressure tank, variable vapor space tank, fixed or floating roof
Transportation and marketing of petroleum liquids	Volatile organic compounds	Carbon absorber, condenser
Cutback asphalt, emulsified asphalt, and asphalt cement	Volatile organic compounds	
Solvent degreasing	Volatile organic compounds	Carbon absorber, condenser cover
Waste solvent recovery	Volatile organic compounds, particulates	Floating roof tank, scrubber, condenser, incineration
Tank and drum cleaning	Volatile organic chemicals	Flare, absorption

Variations in emissions due to normal process variability or abnormal conditions of operation can result in greatly increased emissions which can be difficult to quantify. For example, the efficiency of many control devices, such as electrostatic precipitator, cyclonic collectors, condensers, sorption columns and incinerators can be altered appreciably as a result of changes in process, including feedstock changes, which result in flow variations, changes in particle resistivity or other modifications of pollutant and waste-stream characteristics, etc. The effect of such changes on efficiency are not always subject to rigorous analysis.

Equipment malfunctions or process upsets also can result in increased emissions and are a recurring problem at some facilities, either because of old or poorly maintained equipment or because of the inherent nature of the process. Such excess emissions are difficult to quantify and require a search of plant records to determine the frequency and duration of excess emissions and the application of sound engineering judgment to estimate their magnitude.

The inventorying agency is likely to identify facilities and processes for which no emission factors have been developed. In inventorying such sources, the agency will request and probably obtain an estimate of the type and quantity of emissions from each operation. To validate this estimate, the agency must obtain from the facility a description of the test procedures used. If the test procedures are not valid or if no estimate is provided, the agency can perform a source test or else require the source to perform a test using accepted procedures. If testing is not possible, emission data obtained rom the current literature for processes which are similar to the one in question can be used by experienced agency process technologists and engineers to estimate emissions.

Combustion

Combustion sources include external combustion boilers, internal combustion turbines and reciprocating engines. Uncontrolled emissions will generally exceed 100 tons/yr of any one criteria pollutant for the following combustion systems if operated 8,000 hr/yr.[12]

Coal-fired boilers -- 4 x 10^6 Btu/hr
Residual oil-fired boilers -- 12 x 10^6 Btu/hr
Distillate oil-fired boilers -- 70 x 10^6 Btu/hr
Natural-gas-fired boilers -- 110 x 10^6 Btu/hr
Internal combustion -- 10 x 10^6 Btu/hr

The above point source (100 tons/yr) cutoff sizes are approximate values only. Actual values will depend on many factors, including fuel characteristics, furnace type, size, age, load, and other operating characteristics. Emission factors for internal combustion sources are not as reliable as emission factors for external combustion sources.[13]

The majority of air emissions from combustion sources are stack emissions. However, fugitive emissions from coal and ash storage piles and drift from cooling towers are other possible sources of emissions which should be considered when compiling the combustion source inventory.

External combustion sources

The emission factors used for large utility boilers are considered adequate for all furnace types (such as pulverized units, cyclones, and stokers), pollutants, and fuels (with the possible exception of wood-fired boilers). The principal factor affecting the accuracy of particulate emission estimates is the control device efficiency. The sensitivity of emissions to control device efficiency estimates is most pronounced at high efficiencies. An order of magnitude underestimation of emissions can occur, for example, if a control unit with a design efficiency of 99.5 percent is actually operated at an average efficiency of 95 percent. For this reason, stack test data should be used to determine actual emissions whenever possible. The use of stack test data, however, provides no assurance that conditions at the time of test were representative of normal plant operation. Records of equipment maintenance and malfunctions and continuous monitoring data should be examined to provide some measure for equipment performance over a long-term basis.

Emissions of SO_X from combustion sources can be accurately estimated for bituminous and anthracite coals, fuel oil, and natural gas by assuming that 95 percent of fuel sulphur is emitted as SO_X. Approximately 98 percent of the SO_X is emitted as SO_2, the remainder being SO,. For coals of high alkali ash content, such as lignite and some western subbituminous coals, the coal sulphur emitted as SO_X is appreciably less, of the order of 50 percent.[14] The remaining sulphur is bound in the ash. Stack test data will be needed to determine SO_X emissions from coals containing high alkali ash.

Emissions of NO_X from combustion sources are a function of fuel nitrogen content and furnace operating parameters such as temperature and excess air. The AP-42[9] emission factors for utility boilers show the average effect of fuel and furnace type on NO_X emissions. These factors accurately depict NO_X emissions from most efficiently operated utility boilers.

Emission factors for smaller nonutility boilers are not as reliable as those for utility boilers due to a smaller emission data base and greater variability in operating parameters for the nonutility boilers. Small boilers tend to be less well maintained and are often subject to frequent startups and shutdowns and low load operational cycles. Generally, particulate and NO_X emissions decrease and hydrocarbon and carbon monoxide emissions increase with decreasing load. However, particulate emissions can increase drastically at conditions which are well below the normal design load.

In compiling the inventory of external combustion sources, furnace design and fuel type must be clearly distinguished because of the impact of these factors on emissions. Units burning more than one fuel should receive further attention to determine if the fuels are burned separately or dual-fired. Such information can be useful in assessing temporal emission variations and in conducting research programmes, such as studies of acid rain and SO_2 emissions.

Internal combustion sources

Emissions from internal combustion sources are a function of unit design, load, and fuel. NO_X emissions are significant due to the high temperatures of combustion, and increase with load. Emission factors for CO and HC are appreciably higher than those for external combustion.

Table K-2 Major sources of fugitive particulate emissions

Industry and total uncontrolled fugitive particulate emissions, Mg/yr (tons/yr)	Major sources of fugitive particulate emissions	Nationwide uncontrolled fugitive particulate emissions by source category		Percent of annual uncontrolled particulate emissions
		Mg/yr	(tons/yr)	
1. Foundries 106,719 (117,872)	Hot metal and slag transfer, casting and refining	68,856	(76,152)	65
	Metal melting operations	22,436	(24,710)	21
	Core preparation	11,425	(12,584)	11
2. Portland cement 697,589 (768,961)	Loading, unloading and storage	538,937	(594,077)	77
	Crushing, grinding and screening	127,421	(142,078)	18
3. Minerals and extraction and beneficiation 648,401 (714,096)	Crushing, grinding and screening	359,013	(395,387)	55
	Transfer and conveying	97,206	(107,056)	15
	Drilling and blasting	76,956	(84,752)	12

Industry and total uncontrolled fugitive particulate emissions, Mg/yr (tons/yr)	Major sources of fugitive particulate emissions	Nationwide uncontrolled fugitive particulate emissions by source category		Percent of annual uncontrolled particulate emissions
		Mg/yr	(tons/yr)	
	Overburden removal	56,093	(62,668)	9
4. Iron production 99,450 (110,070)	Sintering	67,100	(74,000	67
	Hot metal and slag, transfer, casting and refining	31,600	(35,200)	32
5. Secondary lead 4,250 (4,684)	Hot metal and slag, transfer, casting and refining	3,384	(3,730)	79
	Reverberatory furnace	594	(656)	14
6. Primary aluminum	Reduction cells	24,620	(27,140)	47
	Transfer and conveying	19,000	(21,999)	36
	Crushing, grinding and screening	5,310	(5,850)	10
7. Asphaltic concrete 46,845 (51,638)	Transfer and conveying	28,740	(31,680)	61
	Loading, unloading and storage	14,370	(15,840)	31

Industry and total uncontrolled fugitive particulate emissions, Mg/yr (tons/yr)	Major sources of fugitive particulate emissions	Nationwide uncontrolled fugitive particulate emissions by source category		Percent of annual uncontrolled particulate emissions
		Mg/yr	(tons/yr)	
8. Limestone manufacturing 44,824 (49,410)	Crushing, grinding and screening	36,388	(40,111)	81
9. Coke manufacturing 131,700 (145,400)	Charging	63,800	(70,400)	48
	Quenching	38,200	(42,200)	29
	Pushing	25,500	(28,100)	19
10. Secondary aluminum 1,808 (1,995)	Fluxing (chlorination)	1,425	(1575)	79
	Chin (rotary) dryer	223	(245	12
11. Secondary brass/bronze 766 (842)	Metal melting	358	(393)	47
	Insulation burning	275	(303)	36
	Rotary dryer	69	(76)	9

Industry and total uncontrolled fugitive particulate emissions, Mg/yr (tons/yr)	Major sources of fugitive particulate emissions	Nationwide uncontrolled fugitive particulate emissions by source category		Percent of annual uncontrolled particulate emissions
		Mg/yr	(tons/yr)	
12. Secondary zinc 429 (472)	Metal melting	290	(319)	66
	Crushing, grinding and screening	138	(152)	32
13. Lumber and furniture 8,665 (9549)	Sawing	7,078	(7,802)	82
	Log debarking	544	(599)	6
	Wood taste storage and unloading	425	(468)	5
14. Concrete batching 31,026 (34,200)	Loading, unloading and storage	31,026	(34,200)	100
15. Primary copper 19,977 (22,024)	Metal melting	18,153	(20,675)	94
16. Grain elevators 1,238,127 (1,364,803)	Headhouse (legs)	602,368	(663,996)	49
	Transfer and conveying	378,868	(417.631)	31

Industry and total uncontrolled fugitive particulate emissions, Mg/yr (tons/yr)	Major sources of fugitive particulate emissions	Nationwide uncontrolled fugitive particulate emissions by source category		Percent of annual uncontrolled particulate emissions
		Mg/yr	(tons/yr)	
	Loading, unloading and storage	117,104	(195,887)	14
17. Primary zinc 1,806 (1,991)	Hot metal and slag transfer, casting and refining	1,198	(1,321)	66
	Sintering	608	(670)	34
18. Primary lead 11,742 (12,945)	Sintering	6,978	(7,689)	59
	Metal melting	2,326	(2,566)	20
	Crushing, grinding and screening	692	(763)	6
	Silver retort building			
19. Steel manufacturing 61,520 (68,250)	Metal melting	51,600	(57,300)	84
	Hot metal and slag transfer, casting and refining	9,600	(10,600)	15

Solid waste incineration and open burning

The three major incinerator categories can be broken down and described by owner:

1. Commercial/institutional -- includes hospitals, shopping centers, restaurants, etc.
2. Governmental -- incineration of waste such as sewage sludge and municipal waste.
3. Industrial -- range from small units burning general plant trash to large suspension-fired boilers burning over 500 tons of shredded plant trash, product waste, and sludge per week.

All questionnaires used to collect point source data from industry should request an accounting of the amount and type of waste burned.

Chemical manufacturing

The chemical process industry consists of a wide variety of facilities producing a multitude of products. Individual facilities may produce several products, operate several interconnected unit operations, and have numerous emission points.

Typical emissions, along with usual control systems, used in 22 segments of the industry are presented in Table K- 1. The majority of emissions from the chemical process industry are gas phase emissions and are often controlled by incineration, adsorption and absorption. Combinations of control equipment are sometimes used where several types of pollutants must be removed from the waste-gas stream or where a high collection efficiency is needed. Pollution control in this industry is often economically advantageous, as many constituents of the emissions can be recovered and recycled into the process.[9]

Special problems in the chemical process industry are often related to the complexity of the processes and the manner in which emission streams are treated. Fugitive VOC emissions from synthetic organic chemical manufacturing are also a problem.” A great deal of time and effort will be required to identify all emission points and estimate total emission rates from a complex process with several individual operations. In many operations several processes may be ducted to a single stack, making it difficult to assign emission rates to each specific process. The agency questionnaire should request that this information be provided in sufficient detail to accurately explain the relationships among the various processes.

Emission factors for the 22 segments of the chemical process industry listed in Table K-l are provided in AP-42. Because the emission factors for some of these processes are based on limited data or were estimated using material balances derived for similar processes, the reliability of emission mass balance techniques may be more amenable to chemical process sources than other sources, because some U.S. manufacturers routinely calculate losses with a high degree of accuracy.

Food and agriculture

Examples of some of the processes, operating units, products and feed materials used in the food and agriculture industry are listed in Appendix B. Several steps are often involved in transforming the raw materials into consumer products, many of which create emissions. For most segments of this industry the primary concern is with particulate emissions. Cyclones, baghouse filters, and scrubbers are therefore the principal devices used to control emissions.

If stack test data are unavailable, emissions must be estimated, usually by comparison with a **similar** process. However, comparison with operations for which emission factors are available may lead to inaccurate estimates. For example, particulate emissions from a grain elevator storing wheat will vary with the type of wheat stored and duration of storage. As a result, emission factors may not be accurate when applied to specific facilities or localities. When emission factors are unavailable or of high uncertainty, the agency should attempt to locate more reliable data from publications (AP-42) or a more in-depth use of questionnaires.

Metallurgical industries

Examples of processes, operating units, products and feed materials, and products of the metallurgical industry are given in Appendix C, page C-14. The majority of pollutants result from various furnace operations. Table K-l lists the types of emissions expected and pollution controls used in 18 segments of the metallurgical industry. Effluent pollutants consist primarily of submicron dusts and fumes resulting from the vaporization and condensation of charge materials. Impurities present in the charge such as grease and oil can lead to increased emissions, both particulate and organic. Combustion products will also be present in the gas stream when a fuel-burning furnace is used. Fluoride is emitted from primary aluminum and steel production processes in both particulate and gaseous form, thereby creating a difficult control problem?

Pollution control equipment used with furnaces must be capable of operating at elevated temperatures and providing reasonable control efficiency for submicron particulates. Control devices meeting these requirements include ESPs, scrubbers, and baghouse filters using glass fiber fabrics or some other high temperaturic fabric?

There are several potential sources of fugitive emissions in the metallurgical industry. Process sources such as furnaces and open sources such as storage piles and raw materials handling operations can result in significant particulate emission. A ranking of emission points within steel mills is shown in Table K-3. While it is recognized that fugitive emissions may constitute a large percentage for the total particulate emissions, very few studies have provided quantitative emission data. References 17, 18, and 19 are examples of studies which will be of value to the inventorying agency in assessing emissions from the various sources of fugitive emissions.

Table K-3 Steel mill source priority ranking for particulate emissions

	Model plant lb/hr	Industry total tons/yr[a]
1. Coke quenching	283	38,000
2. Blast furnace casthouse	156	25,000
3. BOF stack	143	22,000
4. Material stockpiles	120	18,000
5. Roadway travel	118	18,000
6. Coke combustion stack	110	18,000
7. BOF charge and tap	97	16,000
8. Coke pushing	62	9,800

	Model plant lb/hr	Industry total tons/yr[a]
9. Sinter, misc. fugitives	64	9,600
10. Sinter windbox	60	9,000
11. EAF charge, tap, slag	54	8,400
12. Coal preparation	52	8,200
13. Open hearth stack	50	8,000
14. coke door leaks	49	7,800
15. EAF stack	46	7,300
16. Sinter discharge end	42	6,300
17. Blast furnace top	26	4,100
18. Ore screening	25	3,600
19. Teeming	18	4,100
20. BOF misc. fugitives	15	2,400
21. Coke topside leaks	14	2,300
22. Coal charging	14	2,000
23. Reheat furnaces	13	2,200
24. Blast furnace combustion	12	2,000
25. Open hearth roof monitor	12	2,000
26. Open area	8	1,200
27. machine scarfing	5	740
28. BOF hot metal transfer	4	720
29. Open hearth misc. fugitives	4	700
30. Soaking pits	3	630
31. EAF misc. fugitives	4	600
32. Open hearth hot metal transfer	4	210

[a] Tons per year--multiply by 0.9078 to obtain metric tons/yr (100 kg.).

BOF--Basic Oxygen Furnace
EAF--Electric Arc Furnace

Source: Development of Inhalable Particulate Emission Factors for Ferrous Metallurgical Sources, Programme Overview paper, Peer Review for Metallurgical Process Branch, IERL, U. S. EPA, 19 February 1981.

Mineral products

The mineral products industry consists of a broad range of processes used to produce numerous nonmetallic products. A description of many of the processes and operating units used, feed materials used and products produced are listed in Appendix D, while Table K-l lists the types of emissions which can be expected and typical controls used in 21 segments of the industry.

Most emissions in the mineral product industry are particulates resulting from quarrying; material storage; and transfer, drying, crushing, screening, conveying, and packaging operations. Since emissions are produced primarily by mechanical wear, they are in most cases identical chemically to the parent material.[9]

Control systems for drilling, transport, crushing, screening and packaging operations typically include hood capture ducted to a fabric filter or cyclone. Wet suppression is used whenever possible, particularly during quarrying where it is often the only method of control used. Emission factors for the 21 industry segments listed in Table K-l have been established and are presented in AP-42.[9] The accuracy of these factors may be affected by the rate at which material is processed, the method of transfer, the moisture content of raw material , and the degree of enclosure of transfer points, processes, and storage areas. In addition, excess emissions are often caused by overloading process equipment such as kilns, dryers, and furnaces which result in higher gas velocities through pollution control equipment and a high frequency of breakdown or malfunction.

Use pounds or tons (200 pounds) whenever possible. Also gallons for liquids and 1000 cubic feet for gases can be used.

Wood products

Operations that make up the wood products industry include timber harvesting and transportation, saw mills and planing mills, veneer and plywood mills, hardboard and insulation board mills, particle board mills, pulp and paper mills and whole-wood products. Four segments of the industry which can cause significant emissions are listed in Table K-l. A description of the major process/operation units, feed materials, and products produced by the industry are presented in Appendix E.

Pulping is accomplished by one of three processes: Kraft pulping, acid sulphite pulping, and neutral sulphite pulping, each producing different amounts and types of emissions. Emissions consist mainly of particulates and various sulphur compounds with scrubbers being the most common control device used. Emission factors are presented in AP-42[9] for the Kraft and acid sulphite processes. Emission factors for the neutral sulphite process are not provided, but are available in other EPA publications.

Emissions generated from plywood, veneer and layout, and woodworking waste collection operations consist mainly of particulates. A simple cyclone is generally considered an adequate control method due to the relatively large particle size, while baghouse filters can be used to capture essentially all of the emissions. Emission factors for fugitive sources of particulates form plywood, veneer and layout operations and for cyclone-controlled woodworking operations are provided in AP-42.’

Organic compounds are also emitted from veneer drying operations, a fraction of which can be recovered by condensation. Emission factors are dependent upon the type of wood used and are so presented in AP-42.[9]

Petroleum industry

The petroleum industry consists of crude oil and natural gas production, petroleum refining and natural gas processing. Major activities, processes and operating units typical of the petroleum industry are presented in Appendix F. Table K-l lists emissions which can be expected and typical controls used by the industry.

Air contaminants emitted from crude oil and natural gas production consist chiefly of light saturated hydrocarbons. Hydrogen sulphide gas may also be emitted in some production areas. The principal emission sources are process equipment (well drilling and pumping) and storage vessels. Internal combustion engines, mostly natural gas-fired compressors, are also a source of emissions. Acceptable control methods for drilling and pumping operations include smokeless flares and general maintenance procedures.

In refining, petroleum crude oil is converted into more than 2500 products. Major potential refining emissions include hydrocarbons, sulphur oxides, carbon monoxide, nitrogen oxides, particulate matter, aldehydes and ammonia. Major emission sources include vacuum distillation, catalytic cracking, thermal cracking, utility boilers, heaters, compressor engines, blowdown and sulphur recovery systems. In addition, fugitive emissions consisting mainly of hydrocarbons and sulphur compounds are emitted from wastewater systems, cooling towers, pipeline fittings, relief valves, pump and compressor seals, asphalt blowing, sweetening, storage and transfer operations.[9]

Emissions are largely dependent upon production capacity, the type of crude oil processed, type and complexity of the processing employed, air pollution control measures in use, and the degree to which maintenance and good housekeeping practices are used. Emission factors for many, but not all, petroleum refinery operations are provided in AP-42.[9]

Evaporation loss sources

Evaporation loss sources of concern are those producing VOC emissions. A list of eight major sources of VOC emissions along with typical pollution controls used is shown in Table K-l. Emission sources include organic solvents emitted from dry cleaning, surface coating and degreasing operations in addition to volatile organics emitted from petroleum products. A description of the processes from which organic solvents may be emitted, the feed materials commonly used, and the products produced are given in Appendix G.

Carbon adsorption, condensation, and incineration are the primary methods of controlling VOC emissions from many operations emitting solvents. Control efficiency for carbon adsorption systems properly designed and maintained are in excess of 90 percent. However, poor maintenance and improper operation of equipment may result in excess emissions.

For many sources of VOC emissions, the best method of estimating emissions from solvent evaporation is the mass balance. In this case, it is assumed that all of the solvent used in a process evaporates into the atmosphere. Therefore, the only information needed to calculate emissions is the amount of solvent purchased over the time interval of concern, with emissions being equal to the quantity of solvent purchased less any solvent returned to reprocessors.[4]

References for Sections A and B

Note: Detailed reference information may be obtained from Procedures for Emission Inventory Preparation, Volume V: Bibliography, EPA-450/4-81-026e, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, U.S.A., September 1981.

1. Procedures for Emission Inventory Preparation. Volume I: Emission Inventory Fundamentals EPA-450/4-81-026a, U.S. Environmental Protection Agency, Research Triangle Park, NC: September 1981.

2. Procedures for Emission Inventory Preparation. Volume II: Point Sources, EPA-450/4-81-026b, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1981.

3. Code of Federal Regulations (CFR), Title 40. Part 51.

4. Procedures for Preparation of Emission Inventories for Volatile Organic Compounds, Volume I, Second Edition, EPA-450/2-77-028, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1980.

5. Hammerle, J.R., Emission Inventory, Chapter 17 of Air Pollution, A.C. Steen, Editor, Academic press, New York, 1977.

6. Development of Questionnaires for Various Emission Inventory Uses, EPA-450/3-78-122, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1979.

7. EPA Form OMB No. 158-R0075.

8. Regional Air Pollution Study: Point Source Methodology and Emission Inventory EPA-450/4-78-042, U.S. Environmental Protection Agency, Research Triangle Park, NC, July '1978.

9. Compilation of Air Pollutant Emission Factors, Third Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1980.

10 Assessment of Fugitive Particulate Emission Factors for Industrial Processes, EPA-450/3-78-107, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1978.

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12. Preliminary Emissions Assessment of Conventional Combustion Systems. Volume II, EPA-600/2-76-046b, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1976.

13. Emissions Assessment of Conventional Combustion Systems, Volumes I through V and Summary Report, EPA Contract No. 68-02-2197, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1981.

14. Environmental Assessment Data Systems: Systems Overview Manual, EPA-600/8-80--005, U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1980.

15. Guideline Series--Control of Volatile Organic Fugitive Emissions from Synthetic Organic Chemical, Polymer, and Resin Manufacturing Equipment. Preliminary Draft prepared for Emissions Standards and Engineering Division, Office of Air Quality planning and Standards, U.S. Environmental Protection Agency, Contract No. 68-02-3168, January 1981.

16. Danielson, J.A., Air Pollution Engineering Manual. Air Pollution Control District: County of Los Angeles. EPA Publication AP-40. May 1973.

17. Fugitive Emissions From Integrated Iron and Steel Plants EPA-600/2-78-050, U.S. Environmental Protection Agency, Research Triangle Park, NC, March'1978.

18. Particulate Emission Factors Applicable to the Iron and Steel Industry, EPA-450/4-79-028, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1979.

19. Operation and Maintenance of Particulate Control Devices on Selected Steel and Ferroalloy Processes, EPA-600/2-78-037, U.S. Environmental Protection Agency, Cincinnati, OH, March 1978

20. Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, EPA-450/4-91-016, Prepared for U.S. Environmental Protection Agency under Contract Number 68-D9-0173 by Alliance Technologies Corporation, Chapel Hill, NC, May 1991.

21. AIRS Facility Subsystem Source Classifications Codes and Emission Factor Listing for Criteria Air Pollutants, EPA-450/4-90-003, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1990.

APPENDIX A

GLOSSARY OF IMPORTANT TERMS USED IN U.S. - EPA PRACTICE

This section provides definitions of terms employed by air pollution control agencies in conducting emission inventories and related regulatory functions. The terms presented in Appendix A provide a working basis for consistency among local, state and Federal agencies.

The words and terms listed in Appendix A were collected from various publications such as the Federal Register, EPA Documents and Manuals, State Implementation Plans, and the Clean Air Act. The references serve to identify terminology used by Federal and State Governments in regulations governing air pollution control and prevention. These references are provided in parenthesis at the end of the definition, where available.

Activity level: Any variable parameter associated with the operation of a source (e.g., production rate, fuel consumption, etc.) that may be correlated with the air pollutant emissions from that source.

Aerometric Information Retrieval System (AIRS): A computer-based repository of information about airborne pollution in the United States. The system is administered by EPA's National Air Data Branch (NADB) in the Office of Air Quality Planning and Standards (OAQPS). Point source emissions data will be stored on AIRS Facility Subsystem (AFS). Area and mobile source emissions data will be stored on AIRS Area and Mobile Sources Subsystem (AMS).

Air Quality Control Region (AQCR): Designated by the Administrator pursuant to Sec. 107 of the Clean Air Act, for air quality planning purposes. (40 CFR 81)

Allowable Emissions: The emission rate calculated using the maximum rated capacity of the source (unless the source is subject to enforceable permit conditions which limit the operating rate or hours of operation or both) and the most stringent of the following:
(i) Applicable standards as set forth in 40 CFR Part 60 and Part 61 (NSPS, NESHAPS),
(ii) The applicable State Implementation Plan emission limitation, or
(iii) The emission rate specified as a permit condition. (40 CFR 51.23)

AP-42: EPA Document Number AP-42, *Compilation of Air Pollutant Emission Factors,* Environmental Protection Agency, Research Triangle Park, North Carolina. Supplements are published regularly. This document includes process descriptions and emission factors for a broad range of criteria pollutant emission sources.

Area source: Normally, an aggregation of all sources not defined as point sources in a specific geographic area. Area sources usually include all mobile sources and any stationary sources too small, difficult, or numerous to classify as point sources. The area source emissions are assumed to be spread over a broad area.

Baseline projection: Estimate of emissions expected in future years, based on a growth and emission control scenario. Baseline emissions controls for a given projection year include only those controls that have been legally mandated at the time of preparing the projection.

Breathing loss: Loss of vapors from storage tanks due to diurnal warming and cooling.

Clean Air Act Amendments of 1990 (CAAA): The CAAA were passed by Congress in October 1990 and signed into law by President Bush on November 15, 1990. November 15, 1990 is considered the date of enactment of the CAAA. Title I of the CAAA addresses the topic of NAAQS nonattainment, including standards for ozone and CO.

Control strategy: A combination of measures designated to achieve the aggregate reduction of emissions necessary for attainment and maintenance of a national standard. (40 CFR 51.1)

Control strategy projection inventory: An inventory of emissions, for a future year, which differs from the baseline inventory in that it takes into account the expected impact of a proposed control strategy.

Correction factors: Special multipliers employed in emissions calculations to adjust the resulting emissions estimates more accurately by taking into account special parameters such as temperature, pressure, operating load, etc. Appropriate correction factors are particularly important in accurately calculating organic emissions from mobile sources and petroleum product storage and handling operations.

Crankcase emissions: Airborne substances emitted to the atmosphere from any protion of the engine crankcase ventilation or lubrication systems. (40 CFR 85.002)

Criteria pollutant: Any air pollutant for which national primary and secondary ambient air quality standards have been promulgated, including: sulfur oxides, particulate matter, carbon monoxide, ozone, hydrocarbons, nitrogen dioxide, and lead. (Clean Air Act, Sec. 109, 40 CFR 50.5-50.12)

Degreasing: Any operation in which impurities such as greases and oils are removed from a surface using an organic solvent.

Diffusion modeling: A mathematical technique for calculating the atmospheric distribution of air pollutants based on emissions data and meteorological data for an area. Also referred to as dispersion modeling.

Documentation (inventory): A compilation of the methods, assumptions, calculations, references, etc., that are employed in the development of an inventory.

Dry cleaning: The practice of cleaning textile materials by treatment with organic solvents. The most common dry cleaning solvents are perchloroethylene and Stoddard.

Emission factor: An estimate of the rate at which a pollutant is released to the atmosphere as the result of some activity, divided by the rate of that activity (e.g., production rate or throughput).

Emission inventory: A compilation of information relating to sources of pollutant emissions, including location, quantity of emissions, number and type of control devices, stack dimensions and gas flow rates, and additional pertinent details.

Empirical Kinetic Modeling Approach (EKMA): A source/receptor relationship developed by EPA for estimating the overall reduction of volatile organic compound levels needed in an urban area based on existing oxidant levels and VOC/NO_x ratios.

Evaporative losses: Emissions caused by the vaporization of materials (generally solvents) at normal atmospheric temperature and pressure conditions.

Exhaust gas: Any gas, along with any particulate matter and uncombined water contained therein, emitted from a source to the atmosphere.

Floating Roof: A storage vessel cover consisting of a double deck, pontoon single deck, internal floating cover or covered floating roof, which rests upon and is supported by the petroleum liquid being contained, and is equipped with a closure seal or seals to close the space between the roof edge and the tank wall. (40 CFR 60.111)

Fugitive emissions: Emissions which do not pass through stacks, vents, or other functionally equivalent opening. (40 CFR 51.24)

Fugitive organics: Organic compounds that are not emitted from a source through stacks, vents, or other confined air streams.

Gasoline marketing operations: The operations and systems associated with the transportation of gasoline from refineries to bulk terminals, to bulk storage, to dispensing outlets and to vehicle gas tanks.

Gridding and subcounty allocation: The practice of distributing emissions or any other parameter from a larger geographical area (usually a county) to a smaller geographic area (i.e., a grid) using data presumed to be proportional to the parameter being distributed.

Hydrocarbons: Any compounds containing only carbon and hydrogen. The term “hydrocarbon” is often used synonymously with “volatile organic compound,” although the latter also includes hydrocarbon derivatives, as well.

Indirect source: Facility, building, structure or installation, real property, road or highway which attracts, or may attract, mobile sources of pollution; i.e., parking lots, parking garages. (Clean Air Act (42 .S.C. 1857 Seq) Sec. 110)

Imprecision (emissions inventory): That error in an emissions inventory due to the variability (or random error) in the data used in determining the inventory.

Inaccuracy (emissions inventory): That error in an emissions inventory due to omissions, errors and biases in the data used in determining the inventory.

Inventory: A compilation of source, control device, emissions and other information relating to sources of a pollutant or group of pollutants.

Land use projection: Estimate of land use in a future year (often given in terms of land use maps representing the projected conditions).

Material balance: Technique used to estimate emissions from a source by accounting for the weights of one or more substances in all incoming and outgoing process streams.

Methane: The simplest hydrocarbon species; often excluded from VOC measurements or inventories because it is essentially unreactive in atmospheric photochemical reactions.

Mobile source: Any moving source of air pollutants, such as automobiles, vessels, locomotives, aircraft, etc.

Motor vehicles: Motor powered vehicles such as automobiles, trucks, motorcycles and buses, operated primarily on streets and highways.

National Emissions Data System (NEDS): An automatic data processing system developed by EPA for storage and retrieval of source and emissions data. NEDS has been replaced by AIRS (see AIRS).

Nitric oxide (or nitrogen oxide): One of the two oxides of nitrogen which are collectively referred to as NO, (*q.v.*). The amount of nitric oxide (NO) in NO, is often reported in terms of the equivalent weight of nitrogen dioxide (NO_2), in which case its true weight is only 30/46 of the reported weight.

Nitrogen dioxide: One of the two oxides of nitrogen which are collectively referred to as NO, (*q.v.*). The total weight of NO, is often reported "as nitrogen dioxide (NO_2)", which is not the true weight of the mixture but the weight which would be attained if all the nitric oxide (NO) were converted to NO_2.

Non attainment area: Any air pollutant in an area which is shown by monitored data or which is calculated by air quality modeling to exceed any National Ambient Air Quality Standard for such pollutant. (Clean Air Act Sec. 171(a) (2) (I) (2))

Nonmethane: Excluding methane (CH,).

Nonmethane hydrocarbon: All hydrocarbons, or all VOC, except methane.

Office of Business Economics, Research Service (OBERS): Acronym used in reference to projections prepared jointly by the U.S. Department of Commerce, Bureau of Economic Affairs, Office of Business Economics, and the U.S. Department of Agriculture, Economic Research Service, for the U.S. Water Resources Council.

Oxides of nitrogen: In air pollution usage, this comprises nitric oxide (NO) and nitrogen dioxide (NO_2); usually expressed in terms of the equivalent amount of NO,.

Ozone: Three atoms of oxygen (0,) combined through complex photochemical reactions involving volatile organic compounds and oxides of nitrogen; the principal chemical component of the photochemical oxidant formed in photochemical air pollution.

Ozone control strategy: A plan developed by an agency to control ambient ozone levels within its jurisdiction.

Ozone precursors: Volatile organic compounds and oxides of nitrogen, as air pollutant emissions and as air contaminants which undergo a series of reactions under the influence of ultraviolet light from the sun, to form photochemical oxidants, including ozone.

Ozone season: That period of the year during which conditions for photochemical ozone formation are most favorable. Generally, sustained periods of direct sunlight (i.e., long days, small cloud cover) and warm temperatures.

Particulate Matter: Any finely divided solid or liquid material, other than uncombined water, as measured by the reference methods specified under each applicable subpart, or an equivalent or alternative method. (40 CFR 60.2)

Paraffins: Saturated, nonaromatic hydrogen compounds, also known as long-chain alkanes.

Photochemistry: The chemistry of reactions which involve light as the source of activation energy.

Photochemical model (air quality): A detailed computer model that estimates ozone concentrations both as a function of space and time by directly simulating all of the physical and chemical processes that occur during the photochemical process.

Point source: Generally, any stationary source for which individual records are collected and maintained. Point sources are usually defined as any facility which releases more than a specified amount of a pollutant.

Process variable: Any condition associated with the operation of a process, including the quantities and properties of any materials entering or leaving any point in the process, which is, or may readily be, monitored, measured, etc., during the normal course of process operation.

Process weight rate: The process weight charged per unit of time. The term is loosely used interchangeably with operating rate. However, operating rate may cover either input to or output from a process, whereas strictly speaking, process weight rate should cover only material input to a process.

Reactivity: A measure of the rate and extent to which a volatile organic compound will react, in the presence of sunlight and nitrogen oxides, to form photochemical ozone.

Reasonably Available Control Technology (RACT): Reasonably available control technology is defined as the lowest emissions limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technical and economic feasibility.

Rule Effectiveness (RE): A measure of the ability of the regulatory program to achieve all the emissions reductions that could be achieved by full compliance with the applicable regulations at all sources at all times. It reflects the assumption that regulations typically are not 100 percent effective due to limitations of control techniques or shortcomings in the enforcement process. EPA allows the use of an 80 percent default value, but gives states the option to derive local, category-specific RE factors.

Rule Penetration (RP): With regard to penetration into the inventory, it is the portion (in percent) of the area source category that is covered by the regulation.

Seasonal adjustment: Used with reference to annual average rates of pollutant emissions, this is the factor needed to calculate daily or hourly average rates for one season (in the case of ozone, summer rates are most commonly required).

Secondary Emissions: Emissions which occur or would occur as a result of the construction or operation of a major stationary source or major modification, but do not necessarily come from the major stationary source or major modification itself. For purposes of this section, secondary emissions must be specific and well defined, must be quantifiable, and must impact the same general area as the secondary source or modification which causes the secondary emissions. (40 CFR 51.24)

Source Classification Codes (SCC): Code giving specific identification of the source, and defining the units of activity levle, and emission factors related to point source activity levels. Emissions may be calculated by multiplying emission factor for each SC and the activity level.

Stack: Any chimney flue, conduit, or duct arranged to conduct emissions to the ambient air. (40 CFR 51.328)

Standard Industrial Classification (SIC) Codes: A series of codes devised by the Office of Management and Budget to classify establishments according to the type of economic activity in which they are engaged.

State Implementation Plan (SIP) inventories: Emissions inventories required as part of the overall State Implementation Plan for achieving the National Ambient Air Quality Standards. States are required under the Clean Air Act to submit these plans to the U.S. Environmental Protection Agency.

Solvent: Any organic compound, generally liquid, that is used to dissolve another compound or group of compounds.

Source: Any person, device or property that contributes to air pollution.

Source category: Any group of similar sources. For instance, all residential dwelling units would constitute a source category.

Source (process) information: Information collected on each point source in an inventory that describes that source, such as location, fuel use and fuel characteristics, operational data, stack data or other identifiers. Source information, together with emissions and control device data, comprise the basic elements of an emissions inventory. For area sources, this information is usually limited to activity levels.

Source/receptor model: A model or relationship that predicts ambient ozone levels based on precursor emissions strengths (of NO, and VOC) and various meteorological parameters. Source/receptor models may range in complexity from simple empirical or statistical relationships (such as rollback or the Empirical Kinetic Modeling Approach (EKMA)) to detailed photochemical atmospheric simulation models.

Source test: Direct measurement of pollutants in the exhaust stream(s) of a facility.

Spatial resolution: The degree to which the location of a source can be pinpointed geographically within an inventory area.

Species: With regard to VOC, a specific chemical which is part of a particular volatile organic compound, such as methane, 2-hexane, 1,1,1-trichloroethane, etc. With regard to NO,, a species is either nitric oxide (NO) or nitrogen oxide (NO_2).

Species class: Any grouping of VOC compounds, combined in accordance with regulatory policy or rules specified by input instructions for a photochemical simulation model. Also called "reactive class" or "reactivity class."

Stack parameters: Parameters characteristic of a stack and stack gases, as required far input to some models. Typically included are stack height, inner diameter, volume flow rate and temperature of gas, all of which are needed to calculate effective stack height (i.e., stack height plus plume rise).

Stationary source: A source which remains at a fixed location while emitting pollutants. Generally, any nonmobile source of air pollutants.

Submerged fill pipe: Any fill pipe the discharge opening of which is entirely submerged when the liquid level is 6 inches (15cm) avove the bottom of the tank; or when applied to a tank which is loaded from the side, means any fill pipe the discharge opening of whcih is entirely submerged when the liquid level is 18 inches (45cm) above the bottom of the tank.

Surface coating: Operations involving the application of paints, varnishes, lacquers, inks, fabric coatings, adhesives and other coating materials. Emissions of organic compounds result when the volatile portion of the coating evaporates.

Surrogate indicator: (1) For spatial resolution, a quantity for which distribution over an area is known or accurately estimated and which may be assumed similar to the emissions distribution from some source category for which spatial allocation is unknown. (2) For growth, a quantity for which official growth projections are available which may be assumed similar to that of activity in some source category for which projections are needed.

Temporal resolution: (1) The process of determining or estimating what emissions may be associated with various seasons of the year, days of the week, or hours of the day, given annual totals or averages. (2) A measure of the smallest time interval with which emissions can be associated in an inventory.

Transportation planning model: A system of computer programs which are used in simulating the performance of existing and future transportation systems in an urban area.

Urban Airshed Model (UAM): An air quality simulation model that provides estimates of pollutant concentrations for a gridded network of receptors, using assumptions regarding the exchange of air between hypothetical box-like cells in the atmosphere above an emissions grid system. Mathematically, this is known as an Eulerian model (cf. Trajectory model).

Urban Transportation Planning System: An urban transportation planning battery of computer programs distributed jointly by the Urban Mass Transit Administration and the Federal Highway Administration.

Vehicle miles traveled (VMT): An estimated total of number of miles traveled by all vehicles, or by all vehicles of a given category, in a specified region for a specified period of time; often used as a surrogate indicator for spatial resolution of motor vehicle emissions.

Vehicle mix: Composition of vehicular traffic as determined by the fraction of vehicle miles traveled by each class of vehicle.

Volatile organic compounds (VOC): Organic compounds include all compounds of carbon except carbonates, metallic carbides, carbon monoxide, carbon dioxide, and carbonic acid. A volatile organic compound (VOC) is any organic compound that, when released to the atmosphere, can remain long enough to participate in photochemical reactions. While there is no clear line of demarcation between volatile and nonvolatile organics, the predominant fraction of the VOC burden is made up of compounds which evaporate rapidly at ambient temperatures.

Volume percent: The number of volumes of a given component in 100 volumes of a mixture. In gaseous mixtures, equivalent to mole percent.

Weight percent: The number of weight or mass units of a given component in 100 units of a mixture.

Zone: A subdivision of a study area, constituting the smallest geographic area for which data are aggregated and basic analyses made.

Endnotes:

1. Procedures for Emission Inventory Preparation, Volume I: Emission Inventory Fundamentals, EPA-450/4-81-026a, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, U.S.A., September 1981.

Note: Detailed reference information may be obtained from Procedures for Emission Inventory Preparation, Volume V: Bibliography, EPA-450/4-81-026e, U. S. Environmental Protection Agency, Research Triangle Park, NC 27711, U.S.A., September 1981.

APPENDIX B

FOOD AND AGRICULTURAL PRODUCTS/PROCESSES
(Supplemental Instructions)

These supplemental instructions provide industry related examples for certain items of the Air Pollutant Emissions Report (APER). Although not intended to be all inclusive of the industry covered, the examples are directed towards industries related to your and should be helpful in the completion of the APER.

DESCRIPTION OF PROCESS/OPERATING UNIT

Examples include:

- Open field burning (specify crop, weeds, etc.)
- orchard heater
- conveyors, gram elevators, hoppers, bins, piles
- separator, cotton gin, crusher, grinder, mill blender
- roaster, smoker, renderer, stoner
- cooler, dryer
- incineration, compost, land fill (waste disposal)
- packager, loader
- storage tanks, silos

FEED MATERIAL

Feed material examples are:

- farm grown products (specify)
- cotton, grain (specify) coffee beans, sugar cane, tobacco leaves, alfalfa
- fish, meat, poultry (specify)
- materials in storage
- waste material

PRODUCTS

Typical products may be:

- canned, preserved products (specify)
- sugar cotton, cereal, grain oil, coffee, flour, starch
- meal, feed, tobacco
- canned fish, fish oil, type of meat
- lard, tailow
- beer, whisky, wine

UNITS

Units standard to the industry may be used to indicate feed and product throughput (i.e. bale of cotton, barrels of whisky). Please specify units used and define in space at bottom of page 4 (i.e. bale = 500 lbs, barrel = 50 gal.) Recommended units are pounds or tons (2000 pounds) for solids and gallons for liquid.

APPENDIX C

METALLURGICAL INDUSTRY
(Supplemental Instructions)

These supplemental instructions provide industry related examples for certain items of the Air Pollutant Emissions Report (APER). Althoughnot intended to be all inclusive of the industry covered, the examples are directed towards industries related to yours and should be helpful in the completion of the APER.

DESCRIPTION OF PROCESS/OPERATING UNIT

Examples include:

A. Non ferrous

- Copper
    - Roaster (multi-hearth, fluid bed)
    - Reverberatory furnace
    - Converter
    - Refinery furnace
- Lead
    - Sinter plant (updraft, downdraft)
    - Blast furnace
    - Dross kettles
    - Refinery kettles
    - Retorts
    - Kilns
- Zinc
    - Roaster plant
    - Sinter plant
    - Retorts
- Aluminum
    - Baking furnace
    - Reduction cell (horizontal sodeberg/vertical sodeberg)
    - Sweating furnaces
    - Crucible
    - Reverberatory furnaces

B. Ferrous

- Sinterplant
- Coke oven (type)
- Blast furnaces
- Open hearth furnaces
- Electric arc furnaces
- Basic oxygen furnaces
- Scarfing
- Rolling mills
- Finishing and coating
- Cupula
- Soaking pits

C. General

- Material handling
- Mixing
- Crushing
- Sizing
- Bedding

FEED MATERIALS

Typical feed materials include:

- ore, scrap, salvage, precipitates, slag
- ferroalleys, coke, pig iron, matte, calcines
- minerals (specify)
- copper, zinc, tin, lead, etc.
- flux (specify)

- sand
- materials in storage

PRODUCTS

Typical products include:

- aluminum, magnesium, copper, etc.
- coke
- brass, bronze, steel
- galvanized, tin plate
- pig iron, cast iron, metal ingots, blister copper
- steel (sheet, plate, strip, bar, rod, tube, pipe, structural)
- other specified metal products

UNITS

Units used should be specified. Use pounds or tons (2000 lbs) whenever possible. Additionally 1000 gallons can be used for liquids and 10^6 or 10^3 standard cubic feet for gases. Other units, if used, should be converted to pounds, tons, gallons or cubic feet. Show conversions at bottom of page.

APPENDIX D

MINERAL PRODUCTS
(Supplemental Instructions)

These supplemental instructions provide industry related examples for certain items of the Air pollutant Emissions report (APER). Althoughnot intended to be all inclusive of the industry covered, the examples are directed towards industries related to yours and should be helpful in the completion of the APER.

DESCRIPTION OF PROCESS/OPERATING UNIT

Examples include:

- surface mine, quarry, excavator (collection)
- conveyor, hopper (handling)
- crusher, grinder, blender, size (physical process)
- dryer, smelter, calciner, melter, kiln, oven
- furnaces (reverberatory, induction, rotary)
- blow chamber, cooler
- storage tanks, bins, piles, silo
- sprayer, saturation tanks
- packager, pelletizer, fiber former

FEED MATERIALS

Feed materials examples are:

- stone, gravel, clay
- coal, coke, lignite, shale
- alumina, magnesia, silica, zirconia
- lime, basic mixed ores, minerals
- borosilicate, cement, gypsum
- materials in storage

PRODUCTS

Products may include:

- asphalt, asphalt roofing
- calcium carbide, cement, ceramics, clay
- glass, fiberglass, mineral wool, frit
- gypsum, lime, perlite, brick
- cleaned coal
- magnesium carbonate, calcium borate, etc.

UN-ITS

Units common to the industry may be used to indicate feed and product throughputs (i.e. cubic yard of concrete, barrels of cement). Please specify units used and define in space at bottom of page 4 (i.e. cement barrel = 376 lb).

APPENDIX E

LUMBER AND WOOD PRODUCTS
(Supplemental Instructions)

These supplemental instructions provide industry related examples for certain items of the Air Pollutant Emissions Report (APER). Although not intended to be all inclusive of the industry covered, the examples are directed towards industries related to yours and should be helpful in the completion of the APER.

DESCRIPTION OF PROCESS/OPERATING UNIT

- enter *woodworking* if several types of woodworking are being done at one area. If specific procedures are being carried out at specified areas enter actual units: saws, planers, sander, chipper, etc.
- pneumatic conveyor
- open storage
- retort for wood treatment
- venner assembler and press
- dryer (veneer, lumber, etc.)
- surface coating (spray booth, roiler coater, etc.)
- mixing tank, storage tank (specify liquid)
- waste burner, waste handling

FEED MATERIALS

Typical feed materials include:

- logs, lumber, veneer
- specify type of wood (pine, walnut, etc.)
- specify preservative, resins used (creosote)
- specify surface coating used
- adhesives

PRODUCTS

Typical products include:

- lumber (type), plywood, veneers
- boxes, crates
- office furniture
- poles, pilings

UNITS

Units standard for the industry may be used to indicate *feed* and *product* throughputs. Please specify units used and define in pounds or tons in space provided at bottom of page 4. Recommended units are pounds or tons (2000 pounds) for most inputs and gallons for liquid fuels.

WOODPULP PROCESSING
(Supplemental Instructions)

These supplemental instructions provide industry related examples for certain items of the Air Pollutant Emissions Report (APER). Although not intended to be all inclusive of the industry covered, the examples are directed towards industries related to yours and should be helpful in the completion of the APER.

DESCRIPTION OF MAJOR ACTIVITY

Conversion of wood to pulp (If more than one process exists at a plant, each would be a mjor activity. Specify processes.(i.e. kraft, sulfite, neutral sulfite, semi-chemical, etc.)

Manufacture of products from pulp (each independent series of processes would be listed as a separate major activity).

DESCRIPTION OF PROCESS/OPERATING UNIT

Examples of entries include:

- recovery, furnace, lime kiln
- smelt dissolving tank
- cooker/digester/blow tank
- evaporator, dryer
- pulp refiner, beater, finisher

- cutter, sander

FEED MATERIALS

Typical feed materials include:

- wood chips, cotton rags, textile waste, paper stock
- sodim slats (specify)
- slaked lime
- sulfurous acid
- resins, colors, sizing
- specify solvents used for treatment, de-inking, etc.

PRODUCTS

Typical products include:

- pulp
- paperboard, pulpboard, partieleboard
- paper

UNITS

You may enter units normally used in the industry for quantities of feed and products and define at bottom of page 4 in pounds or tons. Use pounds, tons (2000 pounds) or gallons when possible. Also, supply the following conversion factors to convert process materials utilized at your facility into equivalent tons of unbleached air-dry kraft pulp.

equivalent tons unbleached air-dry kraft pulp =

pounds reburned lime

pounds dry solids in spent liquor

APPENDIX F

PETROLEUM REFINING/NATURAL GAS PROCESSING/OIL & SOLVENT RF-REFINING
(Supplemental Instructions)

These supplemental instructions provide industry related examples for certain items of the Air Pollutant Emissions Report (APER). Although not intended to be all inclusive of the industry covered, the examples are directed towards industries related to yours and should be helpful in the completion of the APER.

TYPICAL DESCRIPTIONS OF MAJOR ACTIVITIES

- Crude oil distillation (atmospheric & vacuum)
- Deasphalting
- alkylation
- isomexization
- thermal cracking
- coking processes (delayed & fluid)
- calatytic cracking (fluid bed & moving bed)
- asphalt production
- sulfur recovery
- sulfuric acid manufacture
- acid gas treating (MEA and DEA absorbents)
- hydrotreating (hydrodesulfurization)
- reforming
- hydrocracking
- hydrogen production
- sweetening (merox)
- light ends recovery (LPG)
- waste water treating
- clay filtering
- blowdown recovery

- sotrage tank farms
- marketing activities
- cooling towers
- steam generation

TYPICAL DESCRIPTIONS OF PROCESS/OPERATING UNITS

- reactor vessels (distillation columns)
- regenerator vessels (catalyst & clay regeneration, TCC kilns)
- surge hoppers (use for TCC's)
- process heaters (include CO boilers)
- incinerators
- pumps
- compressors
- flares (only associated with "blowdown recovery")
- loading equipment (only associated with "marketing activities")
- process drains (only associated with "waste water treating")
- oil-water separators (only associated with "waste water treating)
- sour water strippers (only associated with "waste water treating")
- sludge disposal equipment (only associated with "waste water treating")
- vacuum jets
- hydrocarbon storage tanks (only associated with "storage tank farms")
- emulsifiers (only associated with "asphalt production")
- oxidizers (only associated with "asphalt production")
- solid material sotrage (use for coke piles, catalyst & clay storage)
- solid material conveyers

SPECIAL NOTES

- "Crude Oil Distillation" (Major Activity)

  1) Section II, Item 4 - In Major Activity Products, do not include atmospherically distilled fractions which are fed to vacuum distillation columns.

  2) Section IV - List each distillation column as a process/operating unit. All feed materials and products should be listed for each column in Part 2.

- "Fluid Catalytic Cracking" (Major Activity)

  1) Section IV, Part 1 - List reactor and regenerator vessels as separate process/operating units.

  2) Section IV, Part 2 - Feed material for the reactor should reflect fresch oil feed while feed material for the regerator should be recirculated catalyst.

  3) Section VI - Cyclones which are contained within the regerator vessel should be listed as "internal" or "process" cyclones. External control devices should be listed separately.

- "Marketing Activites" (Major Activity)

  1) Section IV - For each loading apparatus, show the Reid Vapor Pressure of the loaded material in Part 1, Item 5c.

  2) Section VI - For each loading apparatus, show the loading technique (submerged fill, bottom loading, splash loading) "Type of Air Cleaning Equipment", Item 2b.

- "Sulfur Recovery" (Major Activity)

  1) Section II, Item 4 - The major activity product for this category should be the total product sulfur from the Claus and tail gas clean up units.

  2) Section III - Tail gas clean up systems should be treated as air cleaning equipment for the purposes of this form, and their relationship to the Claus process equipment should be shown in this section.

  3) Section IV, Part 1 - All process/operating units in the sulfur recovery system should be listed, starting with the acid gas burner and including the Claus catalytic reactors, incinerators, and any associated process combustion units.

4) Section V - Emission data need only be provided for the final emission point of the system (i.e., the tail gas incinerator or the tail gas clean up unit vent) and associated process heaters.

5) Section VI - Data related to a tail gas clean up system should be shown in this section.

- "Pumps and Compressors" (Process/Operating Units)

  1) Section IV - For each pump and compressor, show the Reid Vapor Pressure of the material handled in Part 1, Item 7e.

  2) Section VI - For each pump or compressor, show the type of seal used under "Type of Air Cleaning Equipment", Item 2a.

- "Oil Water Separators" (Process/Operating Units)

  1) Section IV - For each oil-water separator, show the Reid Vapor Pressure of the waste water stream in Part 1, Item 7e.

  2) Section VI - For each oil-water separator, show the type of cover used under "Type of Air Cleaning Equipment", Item 2a.

- "Flares" (Process/Operating Units)

Section IV - For emergency flares, show waste gas feed rates in Item 7. (No data need be shown for outpus in Item 8). Also, include pilot flame fuels in Items 10 and 11 of Section IV. For continuously operated flares, show the waste gas feed rates in Items 10 and 11. The total sulfur content of the feed to the flare should be shown in Item 10c for both emergency and continuous flares.

APPENDIX G

MISCELLANEOUS EVAPORTIVE SOURCES
(Supplemental Instructions)

These supplemental instructions provide industry related examples for certain items of the Air Pollutant Emissions Report (APER). Although not intended to be all inclusive of the industry covered, the examples are directed towards industries related to yours and should be helpful in the completion of the APER.

For operations involving organic liquid storage or solvent usage, Sections VII and IX of the APER should also be completed.

DESCRIPTION OF PROCESS/OPERATING UNIT

Entries may include:

- solvent dip, rinse, dry (may be separate or combined)
- blender, mixer
- degreaser, cleaner, passivator
- spray bath, flow coater, dip tank, electroplater (surface coat)
- baking, curing, drying units
- liquid handling, transfer
- masking area
- waste disposal

FEED MATERIALS

a. Typical feed materials include:

  - perchlorethylene, toluene, acetone, etc. (solvents/thinners)
  - dyes, pigments, resins
  - paint, varnish, rubber, metal salts, etc. (surface coatings)
  - acids, bases (specify etchants)
  - chemical composition of solutions used

b. Rates

Specify actual quantity expended for milling, etching, cleaning solutions.

PRODUCTS

a. Typical products are:

- cleaned fabrics
- milled, coated products
- paint, varnish, inks, etc.

b. Rates

Output rates for large finished products need not be entered (i.e., autos, large appliances, furniture)

UNITS

Generally use tons (2000 pounds) for all inputs and outputs including solvents. For liquid transfers use 1000 gal units.

C. STATIONARY AREA SOURCES'

1. Introduction

Stationary area sources represent a collection of many small, unidentified points of air pollution emissions within a specified geographical area, all emitting less than the minimum level prescribed for point sources. Since stationary area sources are generally too small and/or too numerous to be surveyed and characterized individually, all area source activities must be identified and emissions from these activities collectively estimated.

Area source category definitions are established by identifying activities possessing similar operating and emission characteristics that can be grouped together and handled collectively. Area sources can be grouped into four types of general activity categories:

Fuel combustion sources,
Solid waste incineration and open burning sources,
Fugitive dust sources, and
Evaporative volatile organic compound sources.

These major groupings can be further divided into subcategories to facilitate the accurate estimate of emissions based on the application of emission factors to activity level information.

Table A-l lists a number of area source categories within each of the four major activity areas listed above. These area source categories are listed for example only, and do not represent all potential categories. An agency will want to prepare its own working list based on sources within its jurisdiction and the level of detail desired. Mobile sources have not been included in this table since they are covered in Chapter V.

The area source categories used by EPA's Emission Inventory Branch (EIB) and the National Air Data Branch (NADS) to compile and report area source data are included in Table A-l.

2. Area source activity levels

Area source emissions are estimated for each source category by multiplying an emission factor by some known indicator of collective activity, such as production, employment, or population, that can be correlated with the air pollutant emissions from that source. For example, the total amount of gasoline handled by service stations in an area can be used to estimate collective evaporative losses from gasoline handling.

Several methods are available for estimating area source activity levels and emissions. Estimates can be derived by (1) treating area sources as point sources, (2) surveying local activity levels, (3) apportioning national or regional activity totals to local inventory areas, (4) using per capita emission factors, or (5) by using emissions-per-employee factors. Each method has distinct advantages and disadvantages when used for developing area source emissions estimates. The merits of these methods must be evaluated on a source-category-specific basis.

Table A-l Listing of area source categories

Combustion by Fuel (all criteria pollutants)*

- Residential
- Commercial/Institutional
- Industrial
- Stationary engines

Solid Waste Incineration (all criteria pollutants) and Open Burning Sources (all criteria pollutants--primarily particulates, carbon monoxide, and volatile organic compounds)

- Residential Incineration and Open Burning*
- Commercial/Institutional Incineration and Open Burning*
- Industrial Incineration and Open Burning*
- Governmental Incineration and Open Burning
- Prescribed Burning
  - Slash Burning*
  - Agricultural Burning*
  - Leaf Burning*
  - Frost Control (orchard heaters)*
- Forest Wildfires*
- Structural Fires

Fugitive Dust (particulates)

- Unpaved Roads*
- Unpaved Airstrips*
- Paved Roads
- Construction Site Activity*
- Land Tilling*
- Tilled Land
- Harvesting
- Feed lots
- Pesticide Residues
- Miscellaneous Wind Erosion*
- Miscellaneous Sources
  - County Grain Elevators
  - Fertilizer Mixing
  - Feed Grain Preparation
  - Sawmills
  - Scrap Metal Salvage
  - Metal Melting and Casting
  - Aggregate Storage/Handling
  - Structural and Dimensional Stone Preparation
  - Woodworking Operations

Evaporative Loss of Volatile Organic Compounds (VOC)

- Solvent Purchased (consumed)*
- Gasoline Marketing*
- Fuel Storage/Handling
- Surface Coating
- Print Shops
- Degreasing
- Dry Cleaning
- Cutback Asphalt
- Natural Gas and Petroleum Field Operations
- Pesticides
- Household Products
- Miscellaneous Sources
    - Fermented Beverages
    - Auto Body Shops
    - Plastics Processing

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* Categories included in the NADB file of area source categories.

3. Fuel combustion sources

External combustion sources used for space heating and other functions, and internal combustion turbines and electricity generation are included in this major area source category. The value for internal combustion units is subject to the greatest uncertainty due to the pronounced effect of engine type (turbine or reciprocating engine), operating parameters, and fuel, on emissions of nitrogen oxides, carbon monoxide, and hydrocarbons.[2]

External combustion sources

All criteria pollutants are emitted during fuel combustion. Each source may emit only small quantities of pollutants, but because of their great number, their collective contribution can be significant.

Sources are grouped by fuel into the following three categories, representing the use of the fuel-burning equipment.[3]

Residential -- Structures containing fewer than 20 dwelling units.

Commercial/Institutional -- Establishments, not classified as point sources, engaging in retail and wholesale trade, schools, hospitals, government facilities and apartment complexes with 20 or more dwelling units. The commercial/institutional sector covers all establishments defined by Standard Industrial Classification (SIC)[4] groups 50 through 99.

Industrial -- All manufacturing establishments not classified as point sources. Included are those establishments defined by SIC groups 20 through 39.

Collectively, these three use categories account for the predominance of nonpoint combustion source emissions.[3] The breakdown of fuel use into three categories provides the basis for apportioning emissions to regional and subregional levels and is useful for the formulation of strategies to achieve air quality goals.

Fuel use

Area source emissions from the three use categories are reported for each major fuel. The subdivision by fuel, in addition to providing valuable information to the agency, is needed to relate activity levels to AP-42 emission factors.' The seven major fuels accounted for by area combustion sources in the U.S. are:

Anthracite Coal -- mined almost exclusively in Pennsylvania, it is used mainly by residential sources in states that are within economical shipping distance of Pennsylvania.

Bituminous Coal -- including sub-bituminous and lignite coals, is available in most areas of the country. It is used primarily by the commercial/institutional and industrial source categories.

Distillate Oil -- fuel oil grades 1, 2, and 4, and diesel fuel and kerosene, are considered distillate type oils. Residential and commercial/institutional sources are the largest consumers.

Natural Gas -- is used by all three source categories.

Liquified Petroleum Gas (LPG) -- may be used in some areas by all categories.

Wood -- is primarily a residential fuel, although it may be used by all source categories.

In addition to these major fuels, some coke and process gas may be used by area sources. Area source use of these fuels is low in the U.S., but may be high in other countries.

Fuel use data should be obtained from local sources of information if possible. Sources of information include local fuel dealers and agencies involved in permit registration, energy policy, commerce, taxation, and land use planning. Local suppliers of coal, wood, oil, and natural gas can be important sources of information. Activity levels derived from dealers must take into account shipments into and out of the area.

If local data sources are inadequate then literature sources must be used. The information referenced in U.S. publications includes sale of fuel oils, gas, and coal, census information, and climatological data.

Emissions from external combustion area sources must be determined at the spatial and temporal levels of resolution required by the agency. Fuel used in the inventory area by the source category, minus the fuel used by point sources within the inventory area, is multiplied by the appropriate emission factors in AP-42 to obtain criteria pollutant emissions before control.

Apportionment of national totals to regional or subregional levels by NADB relies on techniques and correlative relationships which are similar to those used for allocating fuels to source categories. Combustion source data compiled at the regional level are generally sufficient for most applications. However, certain inventory applications, such as dispersion modelling, will require finer spatial resolution.

A comprehensive inventory of area combustion sources is designed to estimate emissions for any time period. Most inventories are planned to provide annual data. In preparing more detailed temporal inventories, it is generally assumed that the temporal distribution of residential, commercial/institutional, and industrial fuel use (for area source space heating) is identical. This assumption should be verified, possibly through obtaining hourly natural gas flow data for various customer classifications from local gas dealers. Natural gas consumption data adjusted for nonheating uses can be correlated with local temperature data to show the relationship between outdoor temperature and fuel use for space heating. This relationship can be applied to all fuel types to estimate seasonal consumption for space heating. Monthly billing records, obtained from local fuel dealers, will also provide an estimate of monthly and seasonal fuel consumption patterns.

Emission factors

Criteria pollutant emission factors can be found in AP-42 and its supplements for all fuels. It is usually acceptable to assume that the sulphur and ash contents of a fuel used within a region are similar for the residential, commercial/institutional, and industrial source categories.

Lead emissions from area source combustion categories will be negligible for normal fuels.[6,7] The use of used automotive lubricating oils for space heating, however, may result in locally significant lead emissions due to the generally high lead content of such oils.[7]

For coal-fired sources some care must be exercised in selecting furnace types and their associated AP-42 emission factors for use in calculating emissions. Pulverized units, cyclones, and spreader stokers, because of their size, would almost invariably be reported as point sources. Most residential units would be hand-fired overfeed stokers. Under-fired stokers account for over 80 percent of commercial/institutional units of less than 10×10^6 Btu/hr thermal input. However, some overfeed and other stoker types could be used. The particulate emission factors for bituminous underfeed and overfeed stokers are 2A (A=ash content in percent) and 5A, respectively. Significant error in the combustion source particulate emission estimate could result in locations burning large amounts of coal, if overfeed stokers predominate, and the emission factor for underfeed stokers is used.

Determination of state fuel use by source category

The following is a description of the procedures used by the NADB to allocate DOE state fuel use data to the three source categories. The procedure is diagrammed in Figure C-l for fuel oil.

NOTE: Calculations given below rely on data compiled by DOE in various publications. Since these amounts will not relate to emission calculations outside local areas, further measurements will have to be taken by users of this manual to obtain reliable results. The references have been listed for the sake of illustration.

Residential fuel use

Residential fuel use is calculated for each fuel type using the following empirical equations. The correlative relationships and their constants shown below were developed in the early 1970s, and because of the current emphasis on fuel conservation, may tend to overestimate residential fuel use.

Distillate Oil (gal/yr)

$$F_{DO} = \frac{(0.01288D + 30.41R - 79.54)}{0.14} S_{DO} + 250W_D \qquad \text{(C-1)}$$

Residual Oil (gal/yr)

$$F_{RO} = 0 \qquad \text{(C-2)}$$

Natural Gas (therms*/yr)

$$F_{NG} = 47.5 \times A \times D^{0.367} \times (S_{NG} / W_{NG})^{0.588} \times R^{0.125} \qquad \text{(C-3)}$$

LPG (therms/yr)

$$F_{LPG} = (376 + 0.209D) S_{LPG} + H_C + H_W \qquad \text{(C-4)}$$

Coal (tons/yr)

$$F_C = 0.003874\ e\ (7.6414 - (1000/D)) \qquad \text{(C-5)}$$

Wood (tons/yr)

$$F_W = 0.0017 \times S_W \times D \times (R/5) \qquad \text{(C-6)}$$

where F = fuel use, in units shown;

A = total number of natural gas customers, obtained from American Gas Association' or local suppliers;

D = degree-days; * each degree of declination below 65°F in mean outdoor temperature, averaged over a 24-hour period, is a degree day;

H_C = therms of LPG used for cooking, regional average therms obtained from the American Gas Association';

H_W = therms of LPG used for water heating.

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*1 therm = 10^5 Btu.

The procedure for determining state area source fuel consumption by the commercial/institutional source category is to (1) obtain fuel use data from local sources (i.e. Department of Energy publications), (2) subtract calculated residential fuel use from the total, (3) allocate a fraction of the remaining fuel to the commercial/institutional category, and (4) subtract commercial/institutional point source fuel use. Allocation procedures will differ depending upon the fuel used. Specific step-by-step procedures for each major fuel are presented below.

Fuel Oil

1. Calculate residential fuel oil consumption for region using Equations (C-l) and (C-2).

2. Subtract residential fuel oil from fuel used for heating to obtain commercial/institutional and industrial fuel total.

3. Allocate remaining fuel oil to the category using the following expression:

$$F_{C/I} = (F_{C/I} + F_{Ind}) \frac{\text{State employment in SIC groups 50-99}}{\text{State employment in SIC groups 20-39 and 50-99}} \qquad \text{(C-7)}$$

4. Subtract point source commercial/institutional fuel oil.

Natural Gas

1. Allocate commercial/institutional and industrial state fuel use total to their respective categories using Equation (C-7).

2. Subtract point source commercial/institutional natural gas fuel use from allocated commercial/institutional fuel above to obtain state area source fuel use.

LPG

1. Subtract calculated residential fuel use from residential and commercial/institutional fuel use total to obtain state commercial/institutional fuel use.

2. Subtract point source commercial/institutional LPG fuel use to obtain state area source fuel use.

Bituminous Coal

1. Assign bituminous coal from “retail sales category” (Reference 10) to the residential category if needed to make up the difference between calculated coal consumption (Equation C-5) and available area source anthracite.

2. The remaining bituminous fuel used for “retail sales” is assigned to the commercial/institutional category.

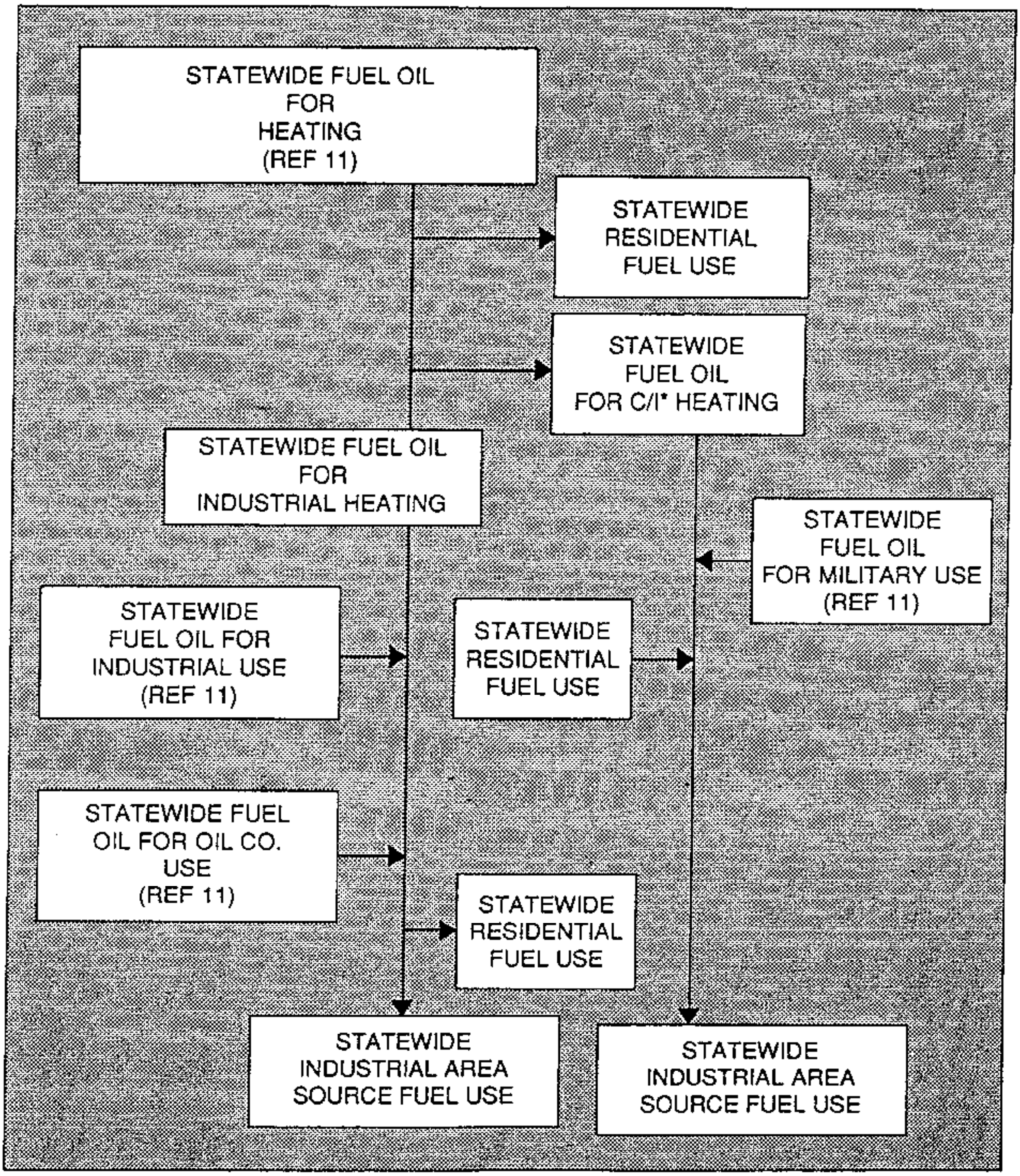
3. Subtract point source commercial/institutional fuel use to obtain state area source bituminous coal.

Anthracite Coal

1. Allocate available anthracite (total anthracite minus residential area source and point source anthracite used by utilities) to the commercial/institutional category using Equation (C-7).

Fig. C.l

Procedure for determination of state area source fuel oil use by source category



*C/I = commercial/institutional

2. Subtract point source commercial/institutional fuel use from result above to obtain area source fuel use.

Wood

Wood is not generally used by the commercial/institutional category unless there is evidence at the local agency level to indicate otherwise.

Industrial use

State area source industrial fuel use is determined as follows for the major fuels.

Fuel Oil

Industrial fuel used for heating (total fuel oil used for heating minus the fuel used for residential and commercial/institutional heating as determined above), plus fuel oil for industrial and oil company use, (from Reference 11), represents the total industrial fuel oil use within the state (see figure .C-1). Subtract point source fuel use to obtain state area source industrial fuel consumption. The agency should note that oil companies bum a substantial quantity of fuel oil in oil tank heaters to control residual oil viscosity. Whether these sources will be included in the area source inventory depends on source size and point/area source size cut-offs set by the agency.

Natural Gas

State industrial area source natural gas use is obtained by subtraction of the sum of the total commercial/institutional gas use and industrial point source gas use from the combined commercial/institutional and industrial total (given in Reference 12).

LPG

State industrial area source LPG use is the industrial use total (given in Reference 13) minus LPG used by industrial point sources.

Bituminous Coal

Subtract point source use from the total state industrial coal use (reference 10) for the industrial area total.

Anthracite Coal

Anthracite coal use by the industrial source category is the difference between the total fuel available for allocation minus the fuel used by the commercial/institutional category, as calculated by Equation (C-7). Subtract industrial point source use to obtain area source use by the industrial category.

Wood

Industrial area source wood consumption is considered to be negligible in the U.S. However, some wood-related industries will bum wood waste. A survey of a potential sources is necessary in certain locations.

Stationarv internal combustion engines

Internal combustion sources for electricity generation, industrial, and commercial/ institutional applications are grouped into two types: gas turbines and reciprocating engines. A basic gas turbine consists of a compressor, a combustor, and a turbine. High-pressure air is supplied by the compressor to the combustor. Fuel is mixed with the air in the combustor and burned. Combustion products are then expanded through the turbine to drive a rotor and generate power. A variety of advanced models have evolved from the simple gas turbine, and are classified into three general operating cycles: simple open cycle, regenerative open cycle, and combined cycle. In the simple open cycle, the hot gas discharged from the turbine is exhausted to the atmosphere. In the regenerative open cycle the gases are passed through a heat exchanger to preheat the combustion air. Preheating the air increases the efficiency of the turbine. In the combined cycle, the gas discharged from the turbine is used as auxiliary heat for a steam cycle. The combined cycle system offers a great increase in the combined efficiency of the overall system. Gas turbines use gas or liquids, such as distillate oil and kerosene, as fuel. In open-cycle gas turbines, where the products of combustion come in direct contact with the turbine blades, combustion gases must be free of corrosive ash and large particulates (≥2µm) which cause erosion.

Reciprocating internal combustion engines may be classified into spark-ignition and compression-ignition engines. The spark-ignition engines use gas or volatile liquids such as gasoline as fuel, whereas the compression-ignition engines use liquid fuels of low volatility such as low-grade kerosene and distillate oil (diesel fuel). All distillate oil reciprocating engines are compression ignited, and all gasoline reciprocating engines are spark ignited. Spark ignited gasoline engines have very limited use for electricity generation and industrial applications, because of their poor part-load economy and their demand for premium fuel. Gas-fired reciprocating engines are mostly spark ignited, but gas can also be used in a compression ignition engine if a small amount of diesel fuel is injected into the compressed air/gas mixture to initiate combustion. Such compression ignition engines are known as dual-fuel engines, and are normally designed to bum any mixture ratio of gas and diesel fuel. Most of the large bore, high power engines for utility and industrial applications are four-stroke cycle, compression-ignition engines designed to operate on diesel fuel or dual fuel, and either two-stroke cycle or four-stroke cycle spark-ignited gas engines.

Commercial/institutional internal combustion sources are generally reciprocating engines burning either natural gas or fuel oil. There are appoximately 4,000 engines currently in use by municipalities for water and sewage pumping. Average size is 400 hp or approximately 0.3 megawatts (MW). (Note: 1,000 horsepower = 746 kw; 1 MW = 1,341 horsepower.) At an average thermal input rate of about 7,500 Btu/hp-hr for reciprocating engines, these units consume about 3 x 10^6 Btu/hr and emit less than 100 tons/year of any critieria pollutant. They generally should be considered as area sources, as should a larger number of smaller units used for light-duty applications and emergency power generation.

The lack of data concerning the number, size, areas of application, and hours of operation of small- to medium-sized internal combustion systems presents serious problems to the agency interested in compiling an inventory of emissions from this source category. Although stationary internal combustion sources consume a relatively small percentage (~10 percent) of all fuel consumed by stationary combustion sources, it has been estimated that they account for approximately 20 percent of NO, and 9 percent of hydrocarbon stationary source combustion emissions. The preponderance of emissions are from the industrial sector, with 80 percent of industrial emissions attributed to reciprocating engines.[2]

Fuel use

There are no literature sources that can be used to estimate fuel use by small- and medium-sized stationary internal combustion sources. A survey by the agency of manufacturers, oil and gas companies (the principal industrial users of such systems), and municipalities will be required. A survey is particularly important in areas that have oil and gas transmission pipelines and oil and gas production activities.

Emission factors and estimates

Emissions from internal combustion sources are estimated by multiplying fuel consumption by an emission factor. Emission factors are given in AP-42 for pipeline compressor engines firing natural gas, and for gas- and oil-fired electric utility turbines. It is important to ensure that the most recent emission data is used.

4. Solid waste incineration and open burning sources

Solid waste incineration and open burning have changed substantially in the U.S. since the 1970s due to the enactment of air-pollution regulations. There has been a marked decrease in the number of operating incinerators, and judgement is necessary to assess their quantitative value.

Source categories falling under the major heading of solid waste incineration and open burning include those listed in Table D-l. Prescribed burning and wildfires are distinct categories, and are distinguished from the incineration and open burning categories that bum wastes generated by residential, commercial, and industrial sources.

Many facilities in the source categories listed in Table D- 1, such as municipal incinerators and many industrial incinerators, will be point sources or located at a major facility included in the point source inventory. Emissions from those facilities accounted for in the inventory of point sources must be excluded in the inventory of area sources.

Incineration

Incineration (and open burning) sources are classified according to origin into residential, commercial/institutional, and industrial categories. Criteria pollutant emissions from incineration are affected by the type of waste burned, incinerator design, and the presence of stack gas control equipment. The type of waste incinerated will affect emissions due to variations in moisture content, heating value, chemical composition and ash content. However, the effects of these factors on emissions from urban wastes have not been quantified. The emission factors given in AP-42 are average values -- that is, all urban refuse wastes are assumed to be homogeneous.

Incinerator design has a direct bearing on emissions. Consequently, area source emission calculations are based on the design mix of area source incinerators. The area source incineration are classified according to their design as follows:

Single chamber -- the earliest and simplest design, consisting of one combustion chamber. These constitute approximately 25 percent of all incineration units currently operating in the U.S.

Multichamber -- equipped with an ignition as well as a combustion chamber. These units have a much lower emission rate than single chamber units of comparable size. Their primary use is in commercial and industrial applications. Multichamber units comprise approximately 68 percent of all area source incinerators.

Controlled air -- combines tight combustion air controls with a built-in afterburner. The relatively sophisticated design and controls built into controlled air units result in substantially lower emission rates. The majority of these units are currently used to incinerate pathological wastes. Recent documents indicate that controlled air incinerators make up 2 percent of the total incinerator population. However, this percentage is likely to increase as more stringent emission controls become mandatory.

In an inventory of area source incinerators, it is assumed that the sources are not equipped with stack-gas-control equipment. Generally, incinerators that are equipped with emission control systems to achieve emission standards are point source incinerators.

Emissions from area source incinerators are estimated by identifying the activity level of each incinerator subcategory (residential, commercial/institutional, and industrial) and then applying an appropriate emission factor to obtain subcategory emissions. The inventorying agency will need to maintain separate records in the inventory for each subcategory. This will permit changes in the records to reflect changes in regulations, such as outlawing open burning, which would affect only one subcategory.

To determine the activity level of incineration, it will be necessary to survey a representative sector of the inventory region to develop or modify waste-generation factors. Using these factors, it will then be possible to estimate the quantities of waste disposed of by on-site incinerators using population and employment data.

Emission factors for incineration are presented in AP-42. However, they may need to be modified based on the type of waste that is incinerated. The emission factors for incinerators are expressed in terms of pounds of pollutant per ton of waste charged. When multiplied by the appropriate activity levels (tons of waste incinerated), they will yield uncontrolled emission rates.

Sample calculation: Emissions from incinerators

The following example is presented to illustrate the general procedures for evaluating emissions generated by area source incinerators.

Given: The inventory region is located in EPA Region V.

Table D.1

Solid waste incineration and open burning source categories

- Incineration
  - Residential
  - Commercial/Institutional
  - industrial

- Open Burning
  - Residential
  - Commercial/Institutional
  - Industrial

- Prescribed Burning
  - Agricultural
  - Slash
  - Frost Control
  - Leaf

- Forest Fires

- Structural Fires

Step I Determine the activity level

The EPA waste generation factors to estimate on-site incineration for this region are:

Residential: 61 tons/1000 population
Commercial/institutional: 87 tons/1000 population
Industrial: 420 tons/1000 manufacturing employees

A survey of a representative sector of the inventory region (group of counties of the state) shows that the above waste generation factors are high by roughly 35 percent for each category. The modified activity level factors are then calculated to be:

Residential: 40 tons/1000 population
Commercial/institutional: 56 tons/1000 population
Industrial: 273 tons/1000 manufacturing employees

A review of the point-source incinerator file shows that agency personnel involved in the point-source inventory have determined 50 percent of all commercial/institutional wastes and 85 percent of all industrial wastes are accounted for in the point source inventory. The activity levels are modified to represent only area source incinerators:

Residential: 40 tons/1000 population
Commercial/institutional: (56) (0.5) = 28 tons/1000 population
Industrial: (273) (0.15) = 41 tons/1000 manufacturing employees

Step II Determine activity levels as a function of incinerator design

The activity levels for each category can now be proportioned among incinerator design types (single chamber, multiple chamber, and controlled air) as follows:

	Residential	Commercial/institutional	Industrial
Single chamber	100%	25%	38%
Multiple chamber	0	73	58
Controlled air	0	2	4

Residential (given the inventory region is 25 percent urban and 75 percent rural):
Flue-fed modified: 40 (0.25) = 10 tons/1000 population/year;
Single chamber: 40 (0.75) = 30 tons/1000 population/year.

Commercial/institutional:
Single chamber: 28 (0.25) = 7 tons/1000 population/year,
Multiple chamber: 28 (0.73) = 20 tons/1000 population/year,
Controlled air: 28 (0.02) = 0.6 tons/1000 population/year.

Industrial:
Single chamber: 41 (0.38) = 16 tons/1000 manufacturing employees/year;
Multiple chamber: 41 (0.58) = 24 tons/1000 manufacturing employees/year,
Controlled air: 41 (0.04) = 1.6 tons/1000 manufacturing employees /year.

Step III Obtain population and manufacturing employment statistics

From published data: [15,16]

Population of inventory region: 5,500,000
Number of manufacturing employees: 550,000

Step IV Obtain particulate emission factors (AP42)

Residential:
Flue fed: 6 lb/ton
Single chamber: 35 lb/ton

Commercial/Institutional:
Single chamber: 15 lb/ton
Multiple chamber: 7 lb/ton
Controlled air: 1.4 lb/ton

Industrial:
Single chamber: 15 lb/ton
Multiple chamber: 7 lb/ton
Controlled air: 1.4 lb/ton

Step V Calculate emissions

Emission estimate = Activity data x population employment x emission factor

Residential:
Flue-fed modified: 10 tons/100 population/yr x 5,500 x 6 lb/ton = 330,000 lb/yr
Single chamber no primary burner: 30 tons/1000 population/yr x 5,500 x 35 lb/ton
= 5,775,000 lb/yr.

Commercial/Institutional:
Single chamber: 7 tons/1000 population/yr x 5,500 x 15 lb/ton = 577,500 lb/yr
Multiple chamber: 20 tons/1000 population/yr x 5,500 x 7 lb/ton = 770,000 lb/yr
Controlled air: 0.6 tons/1000 population/yr x 5,500 x 1.4 lb/ton = 4,620 lb/yr

Industrial:
Single chamber: 16 tons/1000 manufacturing employees/yr x 550 x 15 lb/ton
= 132,000 lb/yr
Multiple chamber: 24 tons/l000 manufacturing employees/yr x 550 x 7 lb/ton
= 92,400 lb/yr
Controlled air: 1.6 tons/1000 manufacturing employees/yr x 550 x 1.4 lb/ton
= 1,232 lb/yr.

If desired, total emissions may be calculated by summing total residential, commercial/institutional and industrial emissions as follows:

Emissions = 339,000 + 5,775,000 + 577,500 + 770,000 + 4,620 + 132,000 + 92,400 + 1,232
= 7,682,752 lb/yr (3,481 tons/yr)

Open burning

As stated in the beginning of this section, the agency should be aware that prescribed burning and wildfire emission sources are distinct categories. Consequently, these categories should not be included in the open burning category.

As with small incinerators, the activity level for open burning can not be accurately correlated to some other easily identifiable factor such as populations. Since regulations for open burning vary in different countries, general assumptions concerning open burning activity cannot be made.

To determine emissions from open burning sources, the agency must develop estimates of the activity levels. Existing regulations and their effectiveness should be considered in developing these estimates. If an area of the country requires burning permits, an estimate of the activity level in that region can be obtained by contacting the local officials responsible for issuing permits. Additional information can often be obtained from agencies in charge of regulating solid-waste disposal. If information cannot be obtained at either the local or regional level, then nationally averaged activity level factors must be used.

The procedures followed for calculating emissions are generally the same as previously detailed for incinerator sources. The quantities of waste accounted for in the point source open burning file should be subtracted for the total waste disposed of in this manner before calculating the area source emissions.

Prescribed fires

The prescribed burning category includes agricultural burning, slash burning, leaf burning, and orchard heaters for frost control. These source categories have a seasonal occurrence and therefore a characteristic time when they release emissions. The agency should account for these temporal variations in the emission rate by estimating and recording emissions for the most active month(s) or season(s) in addition to the annual emission totals.

5. Fugitive dust sources

Fugitive dust emissions are particulate matter entrained and suspended by wind, vehicular traffic or other means. The following categories are recognized anthropogenic sources of fugitive dust emissions: unpaved roads and airstrips, paved roads, agricultural activities, construction activities, feed lots, and industrial area sources. The natural source of dust is primarily wind erosion of miscellaneous open areas.

It should be noted that fugitive dust emissions from all of the above anthropogenic sources, with the exception of the feed lot category, are primarily the result of vehicle related traffic and LTOs. These fugitive dust categories are maintained separately in the area source file distinct from the inventory of mobile source tailpipe (combustion related) and crankcase and evaporative loss emissions which are the subject of Section V, Mobile Sources. The distinction between the fugitive dust and mobile source categories is maintained because of significant differences in inventorying procedures, the pollutants emitted and methods of control. Fugitive dust sources emit only particulates, an estimated six times the particulate emissions from mobile sources and over 20 times greater than all other area sources of particulate matter.

Table E.l

Fugitive dust source emission factors (uncontrolled)[a]

Source	Uncontrolled emission rate	Units	Equation symbols
1. Unpaved roads	$E = \frac{VMT}{yr}\left[5.9\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.8}\left(\frac{d}{365}\right)\right]$	Pounds/yr	VMT - Vehicle miles traveled s - Material silt content (%)
2. Unpaved airstrips	$E = \frac{LTO}{yr} \times 2.0\left[0.49s\left(\frac{S}{30}\right)\left(\frac{d}{365}\right)\right]$	Pounds/yr	S - Vehicle speed (mph) W - Vehicle weight (tons)
3. Paved roads	$E = \frac{VMT}{yr}\left[0.45\left(\frac{s}{10}\right)\left(\frac{L}{5000}\right)\left(\frac{W}{3}\right)^{0.8}\right]$		d - Number of dry days per year
4. Agricultural tilling	$E = \text{Acres of farmland} \times 1.1s\,[(S/5.5)/(PE/50)^2]$	Pounds/yr	L - Surface dust loading on paved road (pounds/mile)
5. Wind erosion of fallow fields	$E = \text{Acres of fallow field} \times 3400\left[\frac{\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{(PE/50)^2}\right]$	Pounds/yr	PE - Thornthwaites Precipitation Evaporation Index
6. Construction activities	$E = 1.2$ Active acres	Tons/month	e - Surface erodibility (tons/acre-year)
7. Cattle feed lots	$E = \frac{\text{1000 head of cattle}}{\text{year}} \times 8$	Tons/yr	f - Percentage of time wind speed exceed 12 mph E - Emissions (given units)
	or		
	$E = \text{Feed lot acres} \times 3$	Tons/yr	

[a] These emission factors will soon be uptated in AP-42.

Historically, due to the difficulty in measuring fugitive dust emissions, little attention has been given to these sources. As a result, the database describing emission rates has not been adequately defined. Although fugitive emission factors for many open source categories have been published in AP-42 and other publications, the reliability rating for the majority of these factors is not high. Engineering judgment and extrapolation from related sources have played a large part in fugitive dust emission factor development, and few of the emission factors are supported by extensive test data.

Emission factors for fugitive dust sources are, in most cases, specific to a given geographical area. They are often dependent upon a number of parameters, including soil characteristics and climate. Sound professional judgment must be exercised by agency personnel in adjusting existing emission factors to reflect local conditions.

Prior to the collection and validation of the data required for the estimation of emissions from fugitive dust sources, the inventorying agency must prepare the following:

1. A list of all fugitive dust source categories which exist within the agency's jurisdiction. This includes potential industry-related area sources.
2. A list of the parameters necessary for the calculation of emissions, including activity levels and emission factors and their associated parameters.

The list of fugitive dust sources should be as complete as possible to establish the impact of all source categories on the total inventory. Although considerable effort may be required initially to establish the impact of all potential source categories, this effort will contribute to the reliability of the inventory and will simplify future inventory efforts and updates.

Data requirements for the calculation of emissions are best identified by examination of the equations used to calculate emissions from open fugitive dust sources. The formulae have been developed to provide for the application of correction factors which reflect the effect of local transportation, soil and climatic conditions. Emissions from industry-related sources will require careful consideration, but in most cases can be estimated using techniques developed for identical or related point sources.

Equations for uncontrolled emission rates from major open fugitive dust emission sources are given in Table E- 1. As shown, a number of factors influence emissions from certain source categories. These factors are often difficult to quantify. As a result, estimated values or simplified equations are often used. Miscellaneous industrial processes such as small grain elevators and woodworking operations are not listed in Table E- 1. Emission estimates from these industrial sources must be based on estimated activity levels determined through association with the number of employees, production rates or other statistical indicators, and emission factors based on, or extrapolated from, similar or related point sources and/or engineering judgment.

6. Evaporative volatile organic compound sources

This category includes operations/industries such as gasoline marketing, dry cleaning, numerous types of surface coating, degreasing, pesticide use, cutback asphalt, and solvents in household products.

This section presents procedures for inventorying VOC sources and provides specific guidance on the eight major categories of evaporative VOC sources listed in Table F-l. Each area source category listed in Table F-l will be described in more detail later. In some of these source categories, all of the sources will meet the definition of an area source. However, other area source categories may include sources already in the point source inventory file. Emissions from sources in the points source file must be subtracted from the area source emission estimate to avoid "double-counting" these facilities.

Additional sources of areawide VOC emissions not shown in Table F-l include the fuel combustion and solid-waste categories discussed previously. Mobile source emissions of VOC, generally the largest VOC emitting category, are fully treated in Section V, Mobile Sources, and are not addressed in this section.

Six general procedures for inventorying evaporative VOC area source categories are available. Each approach has distinct advantages and disadvantages. The six procedures are (1) use of point source inventorying methods, (2) use of local activity level data, (3) apportioning state or national data, (4) per capita emission factors, (5) emission-per-employee factors? and (6) scaling up the inventory.[39]

Use of point source inventorying methods

There are several reasons for using point source methods to inventory small sources that are maintained in the area source inventory. First, there may be only a few sources within the geographical area being inventoried, making it practical to inventory each source individually. Second, it may be very difficult to correlate available activity level data for the sources to their evaporative VOC emissions. Some bulk gasoline storage plants are a good example of small sources (emissions of about 10 to 70 tons/yr) that are small in number and can readily be inventoried individually. The available activity level indicator for the source category is gasoline sales which cannot be easily correlated to the amount of gasoline throughput required to calculate emissions for bulk plants. Therefore, inventorying agencies should contact the bulk plants individually to obtain gasoline throughput data.

Another reason for using point source methods would be the availability of sufficient data on individual small sources to directly calculate VOC emissions. For example, records may be available from another agency which show the location and amount of solvent handled by each dry cleaner within the inventory area. At this point, the agency may decide whether an individual point source record will be coded and maintained for each facility or whether the resulting individual activity levels and emission estimates will be collectively handled in the area source inventory.

Direct plant contact is also the best way to identify the type of VOC used by a facility. Because many solvents, particularly those used for degreasing,[23] are considered nonreactive under atmospheric conditions, the agency will want to identify those solvents and maintain them separately within the inventory.

Use of local activity level data

Sometimes, local surveys have been performed that provide activity level data. For example, local trade associations may have data on the amount and types of architectural surface coating, or the amount and types of dry cleaning or degreasing solvents used in an area. Tax, highway, and energy departments or other state or local agency records may provide activity level estimates for other area source categories, including gasoline sales or cutback asphalt use. Hence, the inventorying agency

Table F.1

Evaporative VOC area source categories

Source category	Emissions[a]	Procedure recommended
Petroleum marketing	5	Use local activity level data Point source method
Tank truck unloading Vehicle fueling Storage tank losses Tank truck transit losses		
Degreasing	5	Point source methods Survey Emissions per employee
Dry cleaning	2	Survey Per capita emission factor
Surface coating	10	Use local activity level data Survey Per capita emission factor
Industrial Nonindustrial Architectural coating Auto body refinishing		
Graphic arts	2	Per capita emission factor
Commercial/consumer solvent use	5	Per capita emission factor
Cutback asphalt	1	Local activity level data
Pesticides	1	Local activity level data Apportion statewide data

[a] Emissions are indicated by an approximate relative scale. Ten is the category with largest VOC emissions, 1 is the category(ies) with smallest emissions, and the remaining numbers indicate the relative quantities of emissions on a linear scale.

should survey various local trade associations and agencies to determine the availability of information that can be used for compiling an inventory of area sources.

Apportioning state or national data

If local data are not available, state or national data can be apportioned to local areas. This may be done by indicators such as population, number of employees or number of facilities. For example, if pesticide application data are available only on a statewide basis from the agricultural department, this data could be apportioned to counties by the number of acres of agricultural land or the number of agricultural employees.

Major drawbacks of this approach are that additional data and resources are needed to apportion activity level estimates to the local level, and accuracy is lost in the process. If state and local data are not available, then national data may have to be apportioned to the local inventory area. Apportioning national data to the local level is less accurate than most available methods and should be done only when absolutely necessary.

Per capita emission factors

Population per capita emission factors can be applied to some area source categories that cannot be inventoried using one of the above procedures. As an example, solvent evaporation from consumer and commercial products such as waxes, aerosol products, and window cleaners cannot be routinely determined by the local agency from any local sources, nor will surveys generally yield such information. The use of per capita factors is based on the assumption that, in a given area, emissions can be reasonably associated with population. This assumption is valid over broad areas for certain activities such as dry cleaning, architectural surface coating, and solvent evaporation from household and commercial products.

Emissions-per-employee factors

This procedure is similar to using population per capita emission factors, except that emissions are correlated to the number of employees in the source category. Emissions-per-employee factors are usually used to estimate emissions from small industrial source categories for which an SIC code as been assigned and for which employment data at the local level are available. Because many facilities within the industrial classifications of interest will be point sources of VOC emissions, it will be possible to develop emissions-per-employee factors by SIC from data in the point source inventory, to account for emissions from small area sources. This approach may also be used where the agency surveys a fraction of the area sources within a given category. In this case, employment is used as an indicator to “complete” the inventory to account collectively for missing sources and emissions in the area source file. Parameters other than employment, such as sales data or number of facilities, can be used to develop emission estimates? However, employment is generally the most readily available parameter.

Scaling up the inventory

When compiling an emissions inventory, situations may arise where no data can be gathered from some segment of a source category. The pharmaceutical manufacturing industry is a good example, with major manufacturers included as point sources and the multitude of small operations, usually employing less than 25 people, not even listed by any agency. Auto refinishing presents a similar problem since operations are carried out on a fairly large scale by a few specialty shops and on a much smaller scale by numerous auto-body shops. In these cases, the inventory can be "scaled up" to provide for a rough accounting of the missing emissions. To the extent that the resulting emissions estimates are generally reported collectively, scaling up can be considered an area source approach. Any VOC source category is a potential candidate for scaling up.

In scaling up an inventory, the data gathered through plant contacts are used to extrapolate emission data for missing sources. The following formula shows the basic computation involved for a particular source category.

$$\text{Nonreported emissions} = \frac{\text{Reported Emissions}}{\text{Coverage Fraction}} - \text{Reported Emissions} \qquad \text{(F-1)}$$

Coverage fraction is a measure of the extent to which some indicator such as employment, number of plants, production, or sales is represented or "covered" by the questionnaire responses. The problem becomes one of determining the most appropriate indicator that can be used to estimate the fraction of coverage the agency's point source inventory did obtain.

The most commonly used coverage indicator for scaling up the inventory is the number of employees within pertinent SIC codes.[4] When employment within appropriate SIC categories is used, the above equation changes as follows:

$$\text{Nonreported emissions} = \frac{\text{Reported Emissions}}{\text{Reported Employment}} \times \text{Total Employment} - \text{Reported Emissions} \qquad \text{(F-2)}$$

In Equation F-2, the ratio of reported emissions to reported employment is an emissions-per-employee factor. Equation F-2 can be used in two ways to estimate missing point source emissions.

The recommended use of Equation F-2 is to derive values of both reported emissions and reported employment for each SIC category directly from the local point source database. One advantage of this approach is that the resulting emissions-per-employee factors are tailored to the area of concern. One potential disadvantage is that the resulting factors, if based only on point source data, may not be representative of the smaller sources to which these factors will generally be applied.

The alternative to using values of reported emissions and employment directly from the local point source inventory is to apply emissions-per-employee factors that have been developed from inventory data in other areas. One distinct advantage of using "borrowed" emissions-per-employee factors is that reported employment is not needed; therefore the technique can be used even if employment data are not collected for each point source. However, the disadvantage to this method is that few emissions-per-employee factors are available in the literature, and an inventorying agency generally does not know which specific operations are covered by published factors. As a result, since the applicability of published emissions-per-employee factors to an agency inventory may be questionable, the agency should try to develop emissions-per-employee factors tailored to its own particular area. Moreover, these factors should be developed at a SIC level preventing misapplication to employees not engaged in VOC-emitting operations.

Extreme caution should be exercised when scaling up. This approach is somewhat inexact, and should not be used to estimate the bulk of VOC emissions in an area.

Specific methods and techniques

Specific methods and techniques for inventorying eight major evaporative VOC area source categories are presented below. These source categories include most but not all possible VOC sources. The inventorying agency should inventory all area source categories that may have significant VOC emissions by applying the methods and techniques discussed in this chapter.

Petroleum liquids marketing and storage

The petroleum liquids marketing and storage area source category must be carefully separated from the point source category of the same name. The area source category usually covers VOC emissions from tank truck unloading and service station operations; while bulk plants may be included under either an area or a point source category. Gasoline is the petroleum liquid of primary concern; however, aviation and marine fuels should also be considered. Diesel fuel is not usually included because of its low volatility. The relative magnitude of emissions from the marketing of gasoline is given in Table F-2. Emission factors for VOCs from gasoline loading operations and other petroleum products are given in AP-42.

Gasoline can be purchased from service stations, auto repair garages, parking garages, convenience stores, and similar types of businesses. In addition, gasoline may be distributed to vehicles through various nonretail outlets. Because outlets other than service stations account for roughly a quarter of all gasoline handled, care should be taken they are covered in the area source inventory.[24,25]

The method for determining emissions from petroleum liquid (gasoline) marketing and storage is as follows:

1. Determine quantity of gasoline sold from tax data or transportation planning agency data.

2. Determine the quantity of gasoline distributed through nonretail outlets from local survey data, or use 30 percent of the quantity of gasoline sold.[24,25]

3. Sum 1 and 2 to obtain total gasoline distributed.

4. Determine the percent of service stations equipped with submerged fill underground storage tanks from local survey data, or use a value of 90 percent, as suggested-by recent studies.[26-29]

5. Consider whether Stage I and II vapour controls for tank and vehicle filling, respectively, are required and, if so, determine the percent of facilities with vapour control equipment installed and operating.

6. Based on gasoline throughput determined in steps 1 and 2, and emission factors in Table F-2, determine VOC emissions from tank truck unloading, tank breathing losses, vehicle refuelling and spillage.

The emission' factors shown in Table F-2 are AP-42 emission factors. Because they are subject to revisions, they should be checked with EPA before using them to determine emissions from petroleum marketing. They are shown here to illustrate the emission estimation procedure presented below.

Table F.2

Gasoline marketing and storage

Emission point	Emission factor,[a] lb/ 10^3 gal
Filling underground tank	
Splash fill	11.5
Submerged fill	7.3
Stage I	0.3
Tank breathing losses	1.0
Vehicle refueling	9.0
With Stage II	0.9
Spillage	0.7

[a] **The user should refer to the current edition of AP-42 to ensure the use of the** most up-to-date emission factors.

From local activity level data and survey data determine:

Retail gasoline:	Retail gasoline consumption (10^3 gal/yr).
Nonretail gasoline:	Nonretail gasoline consumption (10^3 gal/yr).
Submerged fill:	Proportion of services stations equipped with submerged fill storage tanks (convert from percent).
Splash fill:	Proportion of service stations <u>not</u> equipped with submerged fill or Stage I equipment.
Stage I:	Proportion of service stations equipped with Stage I control equipment.
Stage II:	Proportion of service stations equipped with Stage II control equipment.
Bulk plant:	Bulk plant throughput, 10^3 gal/yr.

The following equations apply:

Tank truck Unloading loss, lb/y- = (Nonretail gasoline + retail gasoline)
[(Submerged fill x 7.3) + (Splash fill x 11.5)
+ (Stage I x 0.3)].

Tank breathing loss, lb/yr = (Nonretail gasoline + retail gasoline) x 1.0.

Vehicle refuelling loss, lb/yr = (Nonretail gasoline + retail gasoline)
[(I-Stage II) x 9 + (Stage II x 0.9)]

Spillage loss, lb/yr = (Nonretail gasoline + retail gasoline) x (0.7).

Area source VOC emissions from other petroleum liquids may be determined using the above method and emission factors provided in AP-42.

Dry cleaning

Virtually all commercial and self-service dry cleaning facilities are area sources. Industrial dry cleaning facilities may be either point or area sources. Dry cleaners emit one of three types of solvents: perchloroethylene (70 percent of U.S. dry cleaning emissions), petroleum distillates or Stoddard solvent (30 percent of U.S. emissions) or trichlorotrifluoroethane (negligible).[30,31] There are several methods of inventorying dry cleaning emissions; two widely applicable methods are given below.

Method 1

1. Send survey forms to a representative sample of dry cleaners taken from the telephone directories. The data to be collected are: number of employees, quantity of clothes cleaned (ton/yr), type and net amount of solvent used (solvent purchased minus solvent returned for recycle), and normal operating schedule. Assume that all of the solvent used is emitted, and check the survey values with emissions calculated as the product of the AP-42 emission factors and the quantity of clothes cleaned.

2. Project calculated emissions to the dry cleaning area source category by either the number of nonpoint source employees (in SICs 72 15, 7216, and 7218) or by number of area source facilities.

Method 2

A less accurate method requiring less resources is to use per capita emission factors as follows:[31]

0.36 lb Stoddard/capita-yr from commercial plants

0.84 lb perchloroethylene/capita-yr from commercial plants

0.30 lb perchloroethylene/capita-yr from self service facilities

For this method, it is necessary to subtract out any emissions included in the point source inventory.

Degreasing (solvent cleaning operations)

There are basically three types of degreasers: small cold cleaners, open top vapour degreasers, and conveyorized degreasers. A typical cold cleaning unit emits approximately one third metric ton of VOC per year. In contrast, typical open top vapour degreasers and conveyorized degreasing units emit, respectively, 10 and 27 metric tons of VOC per year. These larger units are commonly used in the metal-working industry. The design and operation of each of these types of degreasers will vary, as will emissions and the types of control measures used. References 30 and 32 provide detailed descriptions of processes and emissions from degreasing units.

A broad spectrum of organic liquids including petroleum distillates (special naphthas), chlorinated hydrocarbons, ketones and alcohols are used in solvent cleaning operations. Development of degreasing emission estimates is complicated by a number of factors. First, some degreasers are large enough to be considered point sources, and yet a large fraction of all degreasers will fall below any reasonable point source cutoff and thus must be accounted for as area sources. Second, degreasing operations are not associated with any particular industrial activity. Instead, degreasing of some sort may be carried out in a wide variety of industries, including (1) metal-working facilities (automotive, electronics, appliances, furniture, jewelry, plumbing, aircraft, refrigeration, business machinery, fasteners), (2) nonmetal working facilities (printing, chemical, plastics, rubber, textiles, glass, paper, electric power), (3) maintenance cleaning operations (electric motors, fork lift trucks, printing presses), and (4) repair shops (automobile, railroad, bus, aircraft, truck, electric tool). Third, the practice of solvent waste reprocessing at some degreasing facilities complicates the use of material balance estimates of solvent loss. Fourth, the fact that some of the VOC emissions associated with degreasing occurs at the solvent waste disposal site complicates the location of emissions within the inventory area. Fifth, many of the solvents used for degreasing are considered photochemically nonreactive, and hence must be excluded from an inventory of reactive VOC emissions. [23,32] Reactivity is defined as a measure of the rate and extent with which a VOC will react in the presence of sunlight and nitrogen oxides to form photochemical oxidants. The nonreactive VOCs are:[3]

Methane
Ethane
1,1,1-Trichloroethane (methyl chloroform)
Methylene chloride
Tricliloroflüoromethane (CFC 11)
Dichlorodifluoromethane (CFC 12)
Chlorodifluoromethane (CFC 22)
Txifluoromethane (FC 23)
Trichlorotrifluoroethane (CFC 113)
Dichlorotetrafluoroethane (CFC 114)
Chloropentafluoroethane (CFC 115)

Open vapour (OTV) cleaners and conveyorized cleaners should be included in the point source inventory whenever possible. These types of equipment tend to be associated with industrial plants that are already included in the point source inventory. Cold cleaners are smaller and will be included primarily in the inventory of area sources. For open top vapour and conveyorized cleaners that are not included in the point source, one of the following methods may be used to project emissions for the category.

Method 1

Survey a sample population of facilities in SIC codes 25, 28, 30 and 33 through 39. The relative magnitude of VOC emission by SIC category is shown in Table F-3. The survey should establish the number of each type of equipment operated, quantity and type of solvent consumed, operating schedule, waste solvent disposal method, and number of employees at the facility. (The inclusion or exclusion of exempt solvent will be a decision of the agency based on the purpose of the inventory.) Calculate emissions per employee or emissions per facility factor for each SIC code. Multiply these factors by either the number of employees or the number of facilities in each SIC in each county. Point source emissions are subtracted from the calculated total emissions.

Table F.3

Solvent cleaning emissions by SIC category”

SIC	Group	Release emissions
25	Furniture and Fixtures	1
28	Chemicals and Allied Products	1
30	Rubber and Miscellaneous Plastic Products	1
33	Primary Metal Industry	9
34	Fabricated Metal Products	8
35	Machinery, Except Electric	10
36	Electric and Electronic Equipment	6
37	Transportation Equipment	1
38	Instruments and Related Products	1
39	Miscellaneous Manufacturing	1
75	Auto Repair, Services and Garages	2

[a] Includes point and area source category emissions.

[b] Emissions are indicatedbyan approximate relative linear scale from 1 to 10; 1 indicating the least emissions and 10 the most.

Method 2

Instead of establishing a sample population through a survey, the data on open top vapor and conveyorized cleaners in the point source inventory can be used. The point source data could be used to establish emissions per employee factors for each SIC code. *County Business Patterns*[33] data is used to project the area source category emissions. This method may produce high estimates due to the potential bias of using data only from facilities large enough to be included in the point source category. All point source emissions should be subtracted from the area source projection.

VOC emissions from cold cleaners can be inventoried either by using Method 1 above, or through a per capita estimation procedure. A 3 lb/capita-yr emission factor is used for a reactive VOC emission inventory.[31] Cold cleaner emissions that are in the point source inventory are subtracted out. Total VOC emissions are approximately 4 lb/capita-yr of which 25 percent are 1,1,1-trichloroethane, methylene chloride, and trichlorotrifluoroethane.[32]

Surface coating

Surface coating operations can be separated into two groups, industrial and nonindustrial. Industrial surface coating operations for such products as appliances, automobiles, paper, fabric, and cans are usually point sources of volatile organic compounds, although small area sources do exist. Because there is no reliable area source inventory techniques for small industrial surface coating operations, the agency should try to include as many sources as possible in the point source inventory.[3] Nonindustrial surface coating includes refinishing of automobiles and architectural coatings which are better inventoried as area sources.

Architectural surface coatings (trade paints) are primarily used by painting contractors and home owners. Sales and distribution data from wholesale and retail suppliers of solvent-borne paints, varnishes and other surface coatings provide the most accurate activity level data. Distributors should be contacted directly, either through questionnaires or telephone surveys. Necessary information includes quantities of solvent-borne and water-borne coatings sold, and the average solvent content of each type of coating sold. Also the quantity of thinning and cleaning solvents and their densities should be obtained. To convert gallons (volume) of solvent to pounds (mass), densities of 6.5 and 8.6 lb/gal may be assumed for solvent-borne and water-borne coatings, respectively. A density of 7.0 lb/gal may be assumed for thinning solvents. In the absence of solvent content data for coatings, solvent-borne and water-borne coatings may be assumed to be 54 and 8 percent solvent by weight, respectively? However, solvent contents of coatings vary greatly, and local data should be used if available. It is assumed that all solvent in the coatings evaporates upon application. An alternative method for estimating emissions that can be used in the absence of local data is the application of a national activity level factor (for the U.S.) of 4.6 lb/capita-yr.[31] Thinning and cleanup emissions are included in this factor.

One approach to inventorying automobile refinishing emissions is to use an emission-per-employee factor and to apply it to the number of employees in SICs 7531 and 7535. Based on nationwide estimates of solvent loss from automobile refinishing and employment in these two SICs, and average factor of 2.6 ton/employee-year may be applied as an estimate of auto body shop emissions in the area.[35]

An alternative is to use a per capita emission factor of 1.9 lb/capita/year.[23] Because auto body refinishing may be generally expected to relate to human activity, such a population based approach will provide reasonable emission estimates. All VOC emissions from auto body refinishing are reactive.[3]

Graphic arts

The graphic arts or printing industry in the U.S. consists of approximately 40,000 facilities. About half of these establishments are in-house printing services in nonprinting industries. Printing of newspapers, books, magazines, fabrics, wall coverings, and other materials is considered to be a graphic arts application.

An emission factor of 0.8 lb/capita/year is recommended for estimating VOC emissions from small graphic arts facilities which emit less than 100 tons per year. Graphic arts facilities which emit more than 100 tons of VOC per year are excluded from this factor and are inventoried by point source procedures. All VOC emissions from this industry are considered reactive.[3]

Commercial/consumer solvent use

Certain commercial/consumer uses of products containing VOC are not easily quantified using questionnaires, surveys or other inventory procedures yielding locale-specific emission estimates. Thus, a factor of 6.3 lb/capita/year is recommended for estimating reactive VOC emissions from this category.[3] This factor includes the following commercial/consumer subcategories:

	Reactive VOC
Household products	2.0 lb/capita/year
Toiletries	1.4 lb/capita/year
Aerosol products	0.8 lb/capita/year
Rubbing compounds	0.6 lb/capita/year
Windshield washing	0.6 lb/capita/year
Polishes and waxes	0.3 lb/capita/year
Nonindustrial adhesives	0.3 lb/capita/year
Space deodorants	0.2 lb/capita/year
Moth control	0.1 lb/capita/year
Laundry treatment	0.1 lb/capita/year
Total	6.3 lb/capita/year

These factors are based on national estimates of solvent use in each of these end use categories. The major organic materials comprising this 6.3 lb/capita/year factor are special naphtha, alcohols, carbonyls and various other organics. Nonreactive halogenated compounds used in aerosols and other products are excluded from this factor.

It should not be inferred that the commercial/consumer factor is a catchall estimate to account for deficiencies in point source or area source inventories. Specifically, the factor does not include: small cold cleaning degreasing operations, dry cleaning plants, auto refinishing shops, architectural surface coating applications, graphic art plants, cutback asphalt applications, and pesticides not used for home and garden applications. These categories must be inventoried by point or area source procedures and be tabulated separately.

Cutback asphalt paving

Cutback asphalt is a type of liquified road surface that is prepared by blending or "cutting back" asphalt cement with various kinds of petroleum distillates. VOCs arc emitted to the atmosphere as the cutback asphalt cures and as the petroleum distillate, used as the diluent, evaporates. The diluent content of cutbacks ranges from 25 to 45 percent by volume, averaging 35 percent. Gasoline or naphtha is used as the diluent in "rapid cure" cutback (RC), kerosene is used in "medium cure" cutback (MC), and low volatility fuel oil type solvents are used in "slow cure" road oils (SC).[36]

The two major variables affecting both the quantity of VOC emitted and the time over which emissions occur are (1) the type and (2) the quantity of petroleum distillate used as diluent. As an approximation, long term emissions from cutback asphalts can be estimated by assuming that 95 percent of the diluent evaporates from rapid cure cutback asphalts, 70 percent from medium cure cutbacks, and about 25 percent from slow cure asphalts, by weight percent. These percentages are applicable in estimating emissions occurring during the ozone season. Some of the diluent appears to be retained permanently in the road surface after application?

Because the use of cutback asphalts varies so much from area to area, local records should be consulted to determine use in the area of concern. Data should be obtained from the state or local highway department or highway contractors on the quantity of each type of cutback applied, as well as the diluent content of each. From these data, the equations or tables of AP-42 can be used to compute long term solvent evaporation. If the diluent content is not known by the local highway department personnel, default values of 25, 35, and 45 percent can be assumed for slow-cure, medium-cure, and rapid-cure cutbacks, respectively.

Pesticide amlications

Pesticides broadly include any substances used to kill or retard the growth of insects, rodents, fungi, weeds, or microorganisms. Pesticides can be divided into three basic categories: synthetics, nonsynthetics (petroleum products), and inorganics.

Formulations are commonly made by combining synthetic pesticides with various petroleum products. The synthetic pest killing compounds in such formulations are labelled as "active" ingredients, and the petroleum product solvents acting as vehicles for the active ingredients are labelled "inert". Neither of these toxicological designations should be interpreted as indicators of photochemical reactivity. Inorganic pesticides are not of interest in the inventory.[37]

Local, state, and federal departments of agriculture (including branches concerned with forest pests control) should be contacted to determine the quantities and types of pesticides applied within the inventory area. The quantity of inorganics should first be eliminated from the above total. Then, as a crude estimate, the remaining synthetic and nonsynthetic total should be multiplied by a factor of 0.9 to estimate the amount that evaporates and can be considered photochemically-reactive VOC.[37]

Pesticide application in agricultural areas may range from 2 to 5 lb/yr/harvested acre.[36] This use includes both synthetic and nonsynthetic material in the pesticide formulation. These factors should be applied as a check on the figures determined from local sources.

Pesticide use for nonagricultural applications should be determined by contacting appropriate state and local agencies, including local public health departments, parks departments, highway departments, or private concerns such as utilities, extenninators, and landscapers. These groups will know the extent of pesticide application for insect control and weed killing, in addition to that used in agricultural applications. The same types of data are obtained and the same procedures followed for estimating evaporative VOC as are suggested for agricultural pesticides. Commercial/consumer pesticide use is quantified under the subcategory headings of household products and moth control under "Commercial/consumer solvent use" above. Commercial/consumer pesticide usage is reported to be less than 0.25 lb/capita/year.[3]

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D. MOBILE SOURCES

1. Introduction

This section presents specific methods that can be used to identify sources, estimate emissions, and establish and maintain a useful, current mobile source emissions inventory. Mobile sources being very varied, than presenting a large number of requirements for the establishment of emission inventiories, the presentation of U.S. practices in this section may appear to be unduly short. The reader wanting a more complete description of methods is referred to the publication, from which the current section is abstracted: Procedures for Emission Inventor-v Preoaration - Volume IV: Mobile Sources, EPA-450/4-81-026 X (Revised), U. S. Environmental Protection Agency, Research Triangle Path, July 1992. The table of contents of the base publication indicates its scope and detail and is therefore reproduced below:

TABLEOFCONTENTS

Note: Page numbers in this Table of Contents refer to the publication on which the presentation here is based: Procedures for Emission Inventorv Prenaration - Volume IV: Mobile Sources, EPA-450/4-8 l-026 d (Revised), U. S. Environmental Protection Agency, Research Triangle Path, 1992.

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2. Mobile sources

Mobile sources are a subcategory within the area source category of pollutant emission sources. However, the inventorying procedures are different from those for other area source subcategories and mobile source emissions represent a major portion of the total emissions of volatile organics (VOC), nitrogen oxides (NOx), and carbon monoxide (CO).

The mobile sources for which inventory and emission calculation procedures are presented in this document are highway vehicles, nonroad mobile sources, aircraft, and locomotives. Recreational marine equipment and commercial marine vessels are discussed in the nonroad mobile source section. The procedures describe how to calculate tailpipe emissions and emissions from the fuel carried on the vehicle (evaporative VOC emissions) for these four mobile source categories. The emissions that result from tire wear and travel over roads or other surfaces should be calculated from the procedures discussed in Section C above (area sources).

Highway Vehicles

Highway vehicles include all vehicles registered to use the public roadways. The predominant emissions source in this category is the automobile, although trucks and buses are also significant sources of emissions.

The total highway vehicle population can be characterized by eight individual vehicle type categories:

- Light duty gasoline powered vehicles (LDGV);
- Light duty gasoline powered trucks, from 0 to 6000 lb. gross vehicle weight (LDGT1);
- Light duty gasoline powered trucks, from 6001 to 8500 lb. gross vehicle weight (LDGT2);
- Heavy duty gasoline powered vehicles (HDGV);
- Light duty diesel powered vehicles, from 0 to 6000 lb. gross vehicle weight (LDDV);
- Light duty diesel powered trucks (LDDT);
- Heavy duty diesel powered vehicles (HDDV);
- Motorcycles (MC).

Numerous characteristics for each vehicle type are necessary before emissions can be calculated. These characteristics include, among others, model year, the age distribution of vehicles within the class, annual mileage by vehicle age, and average speed.

Nonroad Sources

This mobile source category includes a diverse set of source types. The movement of sources in this category occurs on surfaces other than the public highways. Nonroad vehicles can be classified into ten categories:

- Lawn and Garden Equipment,
- Industrial Equipment,
- Airport Service Equipment,
- Construction Equipment,
- Recreational Equipment,
- Agricultural Equipment,
- Recreational Marine Equipment,
- Logging Equipment,
- Light Commercial Equipment,
- Commercial Marine Vessels.

These categories are difficult to inventory, since few data are available to determine either their activity levels or operating characteristics.

Aircraft

Aircraft include all types of aircraft, whether civilian, commercial, or military. Emissions from idling, taxiing, and during landings and takeoffs are included. Landing and takeoff cycle (LTO) emissions are those that occur between ground level and an altitude of about 3000 feet. Aircraft emissions above 3000 feet need not be included in either the base year emission inventory or in the modeling inventory.

The larger civil and commercial airports with continuously manned control towers maintain records of LTO cycles by type of aircraft as part of their standard operating procedure. Smaller airports also maintain these records to the extent that their control towers are manned or landing fees are recorded. Difficulty may be encountered in obtaining data on military aircraft operations at military airports.

EPA has compiled a complete set of emission factors for different types of aircraft operating in the different modes (idle, taxi, LTO).

Locomotives

Locomotives include all fossil fuel fired locomotive engines operated on railways. The quantity of fuel used by locomotives and the size, in horsepower, of the locomotives are necessary to calculate emissions from this source.

3. Emissions from highway vehicles

In most urban areas, highway vehicles represent the largest single source of carbon monoxide (CO) emissions and contribute significantly to the area's production of volatile organic compounds (VOC), sulfur oxides (SOx) and oxides of nitrogen (NOx).

Emission estimates for highway vehicles are usually based on the combination of two fundamental measures of activity: travel and the average rate of pollutants emitted in the course of travel. Both measures reflect complex patterns of behavior.

The Environmental Protection Agency and the Department of Transportation Federal Highway Administration (FHWA) have developed a series of tools/models to estimate the rate of emissions produced by vehicles per mile of travel and the amount of travel itself. The knowledge base and disciplines required to understand and operate these models are distinct, as are their audiences. This distinction generally ensures that environmental analysts have little appreciation for the accuracy of the travel estimates produced by transportation analysts and vice versa.

The purpose of this chapter is to provide guidance for preparing the highway vehicle portion of mobile source emission inventories, particularly those associated with the development of State Implementation Plans (SIPs) for ozone (03) and CO. The accuracy of the inventory will be no better than the accuracy of the estimates of either the emission rates or vehicle miles traveled (VMT).

This chapter responds to concerns that little effort has been devoted to the development of accurate projections of travel within non-attainment areas, that projections of attainment dates have been based on dated information and that highway vehicles are responsible for a greater portion of the emissions inventory than recent estimates have suggested. Because of these concerns, the earlier guidance on the use of available travel estimates has been carefully reviewed and updated.

Guidance on the use of MOBILE 4.1 vs MOBILE 5 for the 1990 base year inventory and other inventories

EPA accepts 1990 base year emission inventories prepared with either MOBILE4.1 or MOBILE5 emission factors. Since MOBILE5 will incorporate the new vehicle standards for VOC and NOx mandated by the Clean Air Act (CAA), estimates of those emissions for years after 1990 will be significantly different from those estimated by MOBILE4.1.

MOBILE 4.1: Abstract of contents

MOBILE4.1 is a computer program that estimates hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) emission factors for gasoline-fueled and diesel highway motor vehicles. The program uses the calculation procedures and emission factors presented in Compilation of Air Pollutant Emission Factors -- Volume II: Highway Mobile Sources (AP-42, Fourth Edition, September 1985; Supplement A to AP-42 Volume II, January 1991).

MOBILE4.1 calculates emission factors for eight individual vehicle types in two regions (low- and high-altitude) of the country. MOBILE41 emission estimates depend on various conditions such as ambient temperature, speed, and mileage accrual rates. Many of the variables affecting vehicle emissions can be specified by the user. MOBILE4.1 will estimate emission factors for any calendar year between 1960 and 2020, inclusive. The 25 most recent model years are considered to be in operation in each calendar year. MOBILE4.1 supercedes MOBILE4, and is to be used by the States in the preparation of the highway mobile source portion of the 1990 base year emission inventories required by the Clean Air Act Amendments of 1990. Compared to MOBILE4, MOBILE41 incorporates several new options, calculating methodologies, emission factor estimates, emission control regulations, and internal program designs.

Requests for copies of the MOBILE4.1 program diskettes or tape, and for additional copies of this User's Guide, should be directed to:

National Technical Information Service (NTIS)
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Telephone: (703) 487-4650

Questions concerning MOBILE4.1 or this User's Guide should be directed to:

U. S. EPA Motor Vehicle Emission Laboratory
Office of Mobile Sources
2565 Plymouth Road
Ann Arbor, MI 48105
Attn: MOBILE4.1

Telephone: (313) 668-4325 (FTS 374-8325)
(313) 668-4462 (FTS 374-8462)

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The release of MOBILE5 will be accompanied by a supplement explaining the differences between MOBILE4.1 and MOBILE5 and the additional inputs contained in MOBILES.

Mobile source emission estimation Process: Overview of factors influencing; motor vehicle emission inventories

The primary components of an emission factor model (i.e. a model estimating motor vehicle **combustions** to emissions) include the base emission factors, characterization of the vehicle fleet, fuel characteristics, vehicle operating conditions and the effect of local ambient conditions, the effect of alternative I/M programs and the effect of tampering and misfueling. None of these factors is static: technology is continually evolving, leading to changing in-use emission performance. Changes in fuel prices and economic conditions lead to changes in vehicle sales and travel patterns. A substantial effort is required to accurately quantify these factors and to stay current with the influence of all of these factors on vehicular emission levels.

Vehicle Fleet Activitv

It is standard practice in preparing highway vehicle emission inventories to express vehicle activity in terms of vehicle miles traveled, and the emission factors in units of grams per mile of travel. Actually, vehicles also emit hydrocarbons while stationary. Estimates of emission-producing activities that do not involve travel are built into MOBILE4. 1. These non-moving emissions are spread over estimated miles of travel by vehicles of a particular age and output as an equivalent per mile emission factor. Therefore, EPA will accept VMT as the measure of local vehicle activity for all inventories required under the Clean Air Act.'

VMT can be estimated in several possible ways. Direct observation via traffic counts (usually at a sample of roadway points with statistical expansion to represent the universe of all roadways in the area) and highway/transit network models are the more preferred approaches. EPA does not recommend reliance on fuel sales data, owner reports, or periodic odometer surveys as substitutes.

Emission Factors

Emission rates are computed from test measurements of in-use vehicles at various odometer readings designed to capture two fundamental processes: the baseline emission rate and the deterioration that takes place as the vehicle ages. Linear regressions are performed on the data to quantify the level of pollutants emitted by each model years vehicles. The results are commonly referred to as the intercept, or zero-mile (ZM), emission rate and the slope, or deterioration rate (DR), that occurs over each 10,000 mile interval.

Fleet Characteristics

The emission factors quantify the performance of individual model year vehicle fleets by vehicle type. The age distribution, the rate of mileage accumulation and the mix of travel experienced by each vehicular category can significantly alter the fleet average emission rate. While the emission factor models employ national average distributions for each of the factors, local input is allowed, often encouraged, and, for some inputs, required. Differences between local and national average distributions can alter the emissions contributions of the individual vehicle categories.

Fuel Characteristics

Emission test measurements are conducted on a standardized test fuel known as Indolene. The characteristics of this fuel are well defined and ensure that test results are repeatable. Since consumers cannot purchase Indolene at their local service stations and differences between the volatility of local

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[1] VMT must usually be disaggregated such that each subset of it can be reasonably represented by a single emission factor determined by one set of inputs of the types described below. EPA also accepts trip-based activity methods.

fuels and Indolene can influence the level of both evaporative and tailpipe pollutants, MOBILE4.1 requires local input of fuel volatility.

Correction Factors

To ensure the repeatability of measurements, standardized test conditions have been specified for each vehicle category. They include driving cycle, temperature, humidity, vehicle load, and the distribution of starting conditions. Since not all vehicle trips match these test conditions, a series of correction factors has been developed to allow the emission factor model to account for differences.

Control Programmes

Emission factors are based on the performance of vehicles independent of any local control programs such as I/M, anti-tampering and Stage II refueling. Each of these programs is designed to reduce the level of pollutants emitted by vehicles operating under in-use conditions. Further, differences in program designs can have a significant impact on their effectiveness in reducing emissions. Therefore, it is important to specify correctly program parameters in order to estimate correctly their effect on vehicular emissions.

Overview of MOBILE4.1 Input Requirements

MOBILE4.1, EPA's computes separate emission estimates for eight vehicle categories:

- Light-duty gasoline-powered vehicles (LDGV), i.e., passenger cars;
- Light-duty diesel-powered vehicles (LDDV), i.e., diesel-powered passenger cars;
- Light-duty gasoline-powered trucks, type 1 (LDGT1), i.e., pickup trucks and vans that have a gross vehicle weight (GVW) of 0 - 6000 pounds;
- Light-duty gasoline-powered trucks, type 2 (LDGT2), i.e., pickup trucks, vans, and other small trucks that have a GVW of 6001 - 8500 pounds;
- Light-duty diesel-powered trucks, types 1 & 2 (LDDT);
- Heavy-duty gasoline-powered trucks (HDGV), i.e., all vehicles with a GVW greater than 8,500 pounds, powered by gasoline engines;
- Heavy-duty diesel-powered vehicles (HDDV), i.e., all diesel powered trucks with a GVW greater than 8,500 pounds; and
- Motorcycles (MC).

The emission factors produced by MOBILE4.1 are derived from measurements conducted under standardized test conditions. For light-duty vehicles, the standard set of test conditions is referred to as the Federal Test Procedure (FTP). It involves the simulated operation of a vehicle over a specific driving cycle, the Urban Driving Cycle, under controlled operating and environmental conditions, during which emissions are measured in three sequences. The Urban Driving Cycle represents an average trip over an urban network that includes travel on local and arterial streets, major arterials, and expressways. The basic test conditions include:

- Ambient temperature range of 68°F to 86°F;
- Absolute humidity adjusted to 75 grains of water per pound of dry air;
- Average speed of 19.6 mph with 18 percent idle operation;
- Average percent of VMT in cold start operation of 20.6 percent;

- Average percent of VMT in hot start operation of 27.3 percent;
- Average percent of VMT in stabilized operation of 52.1 percent; and
- Average trip length of 7.5 miles.

In order to understand fully the derivation of emission factors and the influence of these conditions on emission levels, refer to Chapter 2 of the MOBILE4.1 User's Guide. A condensation of that material is included below.

MOBILE4.1 inputs can be altered to reflect city-specific conditions. A brief review of each of the primary options is presented below.

Fleet Characteristics

The distribution of travel across the eight vehicle categories determines how the individual emission factors are weighted to produce a composite emission factor for the entire highway vehicle fleet. The LDGVs generally comprise over 50 percent of the travel recorded in any area of the country and, therefore, tend to be the dominant source of highway emissions. HDDVs are an important source of NOx emissions. MOBILE4.1 will calculate the VMT mix based on national data characterizing registration distributions, annual mileage accumulation rates by age, diesel sales fractions, and vehicle counts. These values may not, however, be representative of certain areas, such areas where pickup trucks form a larger share of the vehicle population or rural areas where a broader distribution of vehicles exists.

The primary effect of the rate of mileage accumulation by age (in combination with registration data) is to determine the relative weighting of each model years contribution to the average emission factor computed for each vehicle category. MOBJLE4.1 provides the option of using a national average value or inputting data characterizing local conditions.

Registration distributions are calculated in MOBILE4.1 as national average values or inputting data characterizing local registrations. The areas most likely to be distinct from national average values are rural areas, areas in which cars do not rust out and urban areas at either end of the economic spectrum.

Fuel Specifications

Evaporative and, to a lesser extent, exhaust emissions vary with fuel volatility. EPA's new vehicle certification program and much'of its in-use vehicle testing program use gasoline with a fuel volatility (RVP) of 9.0 psi. In recent years much of the country has been supplied with gasoline of higher volatility. MOBILE4.1 adjusts estimated emission factors to account for the effects of volatility, to be provided as necessary.

Correction Factors

Emission factors are very sensitive to the average speed that is assumed. In general, emissions tend to increase as average speeds decrease from the 19.6 mph average FTP speed. MOBILE4.1 does not assume an average speed; rather it requires that an estimate of the speed experienced by vehicles operating in the area and roadway segment or collection of interest be specified.

Temperature has an effect on both the exhaust and the evaporative emission levels. MOBILE4.1 deals with these effects separately. In general, exhaust emissions are at a minimum at the temperature specified for the FTP (75°F), with emissions increasing as temperature either increases or decreases from that value. Ambient temperature level is to be provided as an input to the model.

Emission factors based on FTP measurements are collected for three separate segments, usually referred to as bags because the vehicle exhaust is collected in three separate teflon bags, each with differing emissions performance. The three bags correspond to the following modes of ooeration: cold start, hot stabilized, and hot start. Bag 1, the cold start mode, reflects conditions experienced at the beginning of a trip when the engine and the emission control system begin operation at ambient temperature and are not performing at optimum levels (i.e., the catalyst is cold and has not reached the "light off' temperature needed to efficiently control emissions coming from the engine) until part way through the trip. The hot start mode, Bag 3, reflects the condition of an engine that has been restarted after being turned off for 10 minutes and, therefore, has not cooled to ambient conditions. Under this circumstance the engine and catalyst are warm and, although not at peak operating efficiency when started, still have significantly improved emissions performance relative to the cold start mode. Bag 2, the hot stabilized mode, reflects the condition of the engine when the vehicle has been in continuous operation long enough for all systems to have attained stable operating temperatures. The proportion of **VMT** accumulated in cold and hot start modes must be specified based on the conditions in the area to be modeled. Specifications must be made for catalyst and non-catalyst vehicles separately. .

Information can be gathered regarding correction of emissions for the follwoing minor operating parameters:

- Air conditioning;
- Extra vehicle loading;
- Trailer towing;
- NOx humidity.

Generally, it is difficult to quantify the extent of these vehicle operating parameters, and their effect on emission factors tends to be small. Therefore, few resources ought to be expanded to develop the inputs needed.

Tampering and Misfueling

The basic emission factors in MOBILE4.1 receive an adjustment to account for estimates of vehicle tampering rates as a function of accumulated mileage for each gasoline-fueled vehicle category and eight categories of tampering (e.g., air pump disablement, misfueling, etc.). These rates are combined with offsets (the increase in emissions that results from the given type of tampering) and added to the non-tampered emission factors. Options are available to input local tampering rates. The use of local information must be supported by an approved survey. If locally developed information is not available, a national average rate is used by MOBILE4.1.

Control Programs

The refueling of gasoline-fueled vehicles results in the displacement of fuel vapor from the vehicle fuel tank to the atmosphere.

There are two basic approaches to the control of vehicle refueling emissions, generally referred to as "Stage II" (at the pump) and "onboard" (in the vehicle) vapor recovery systems. MOBILE4.1 can model refueling emissions with no controls as well as with either or both of the control options.

Many areas of the country have implemented inspection and maintenance programmes as a means of further reducing mobile source air pollution. MOBILE4.1 can model the impact of an operating I/M program on the calculated emission factors. There is no average national I/M program; local inputs must be supplied.

Some areas of the country have implemented anti-tampering programmes to reduce the frequency and related emission impacts of emission control system tampering. MOBILE4.1 allows the effects of such a program on the calculated emission factors to be estimated. Due to the wide variation in the characteristics of ATPs and the lack of a national program, there is no national average estimate of ATP parameters.

Guidance on selecting MOBILE 4.1 inputs[2]

MOBILE4.1 may be used to develop highway vehicle emission factors and emission inventories. This section contains EPA's recommendations and suggestions with regard to determining appropriate MOBILE4.1 inputs. However, for many inputs there is no single correct answer or recommendation that is best for every local area.

Emission Factors

The basic emission rates (BERs) used in MOBILE4.1 are expressed as linear equations and consist of a zero-mile level and one or two deterioration rates.[3] There are different BER equations in MOBILE4.1 for each vehicle type/pollutant/model year group, with the model year groups defined on the basis of applicable emission standards and emission control technologies used. Although MOBILE4.1 provides the capability to change the BER equations, the BERs in MOBILE4.1 accurately reflect all promulgated emission standards as of late 1990.

MOBILE4.1 provides two options for region: low-altitude and high-altitude. Low-altitude emission factors are based on conditions representative of approximately 500 feet above mean sea level (+500 ft MSL), and high-altitude factors are based on conditions representative of approximately +5500 ft MSL. For the majority of MOBILE4.1 applications, low-altitude is the appropriate choice. For those areas designated as high-altitude by EPA for mobile source regulatory purposes, generally those counties that lie "substantially" above +4000 ft MSL, high-altitude should be selected.

The value used for calendar year in MOBILE4.1 defines the year (as of January 1) for which emission factors are to be calculated. It is frequently referred to as the calendar year of evaluation.

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[2] This section is in part a condensation of material that appears in the User's Guide to MOBILE4.1, Chapter 2. It is not a substitute for the User's Guide. You are advised to obtain and thoroughly read the User's Guide before running the model. It is available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161 (703/487-4650). The NTIS accession number is PB91-228759.

[3] A deterioration rate is the gram per mile increase in emissions per 10,000 miles accumulated mileage.

The 1990 base year SIP inventories represent emissions during a typical day in the pollutant season, most commonly summer for ozone and winter for CO. Thus, base year VOC inventories should be based on interpolation of the calendar year 1990 and 1991 MOBILE4.1 emission factors.[4] CO SIP inventories should be based on emission factors from January 1990 regardless of the three-month period for which CO is being modeled.

Fleet Characteristics

The vehicle miles traveled mix specifies the fraction of total highway VMT that is accumulated by each of the eight regulated vehicle types. The VMT mix is used in MOBILE4.1 only to calculate the composite (all vehicle) emission factor for a given scenario on the basis of the model's eight vehicle class-specific emission factors.

MOBILE4.1 calculates a typical urban area VMT mix based on national data characterizing model-year-specific registration distributions and annual mileage accumulation rates by age for each vehicle and fuel type,[5] the fraction of travel by each vehicle type that occurs in typical urban areas, and the total number of vehicles of each vehicle type.

For SIP-related highway vehicle emission inventory development in moderate and above non-attainment areas,' EPA expects states to develop and use their own specific estimates of VMT by vehicle type and highway functional system.[6] VMT fractions based on local estimates of VMT by vehicle type should be used as input to MOBILE4.1.[7]

Each VMT mix supplied as input must consist of a set of eight fractional values, representing the fraction of total mobile source VMT accumulated by each of the eight vehicle types. All values must be between zero and one, and the eight values must sum to 1.0.

MOBILE4.1's emission factor calculations rely in part on travel fractions for vehicles of each given age within a vehicle type which in turn are based on estimates of the average annual mileage accumulation by age (first year'to 25th-and-greater years of operation) for each of the eight vehicle types, and the registration distributions by age (age 0-1 to age 24 and 25+) for each vehicle type, except motorcycles, for which annual mileage accumulation rates and registration distributions are only provided for the first to 12thand-later years of operation (ages 0-1 to 11 and 12+).

To use locality-specific annual mileage accumulation rates by age, a total of 200 input values is required: the estimated annual mileage accumulated by vehicles of each of the eight types for each of 25 ages.

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[4] For example, if most exceedances of the ozone National Ambient Air Quality Ozone Standard occur during the months of June, July, and August, then the appropriate base year emission factor is the average of the January 1, 1990 and January 1, 1991 emission factors.

[5] Total HDDV registrations and annual mileage accumulations are also distributed within the model by truck weight class.

[6] Highway functional systems are commonly designated as the interstate system, other freeways and expressways, other principal arterials, minor arterials, and collectors.

[7] Ozone and carbon monoxide non-attainment areas classified as marginal, submarginal, or transitional may use the MOBIU4.1 default VMT mix if no local estimate is readily available.

To use locality-specific registration distributions by age, a total of 200 input values is also required. For each vehicle type, a set of 25 values is required to represent the fraction of all vehicles of the given type that are of a given age.

If locality-specific mileage accumulation rates and/or registration distributions by age are not used, the infonnation in MOBILE4.1 is used for all calendar years evaluated.

EPA recommends the use of the national annual mileage accumulation rates by age that are included in MOBILE4.1. Most local sources of data on mileage accumulation rates by age are subject to sampling bias or data entry errors, and the use of such data should be approached with caution.

EPA recommends and encourages the use of actual locality-specific 1990 registration distributions by age to develop base year SIP emission inventories. The exception to the use of local data would be in those areas that have relatively few local HDDV registrations, but that experience significant interstate trucking activity.

EPA will issue at a later date additional guidance on how 1990 registration distributions by age can be adjusted to reflect future years. This guidance will provide a mathematical routine that preserves the average age of the fleet in 1990, while retaining the general shape of the local distribution for 1990 and earlier model years.

Methods for estimating the annual mileage accumulation rates by age and the registration distributions by vehicle type and age are presented in the report Techniques for Estimating MOBILE2 Variables.[8]

Running loss emissions are a form of evaporative volatile organic compound (VOC) emissions that occur while the vehicle is being operated. Running loss emissions are different from "traditional" evaporative emissions that occur after the vehicle has been driven(hot soak evaporative emissions) and while it is parked during periods of rising ambient temperatures (diurnal evaporative emissions).

The level of running loss emissions depends on several variables: average vehicle speed, ambient temperature, fuel volatility, and the duration (length) of the trip. Test data show that for any given set of conditions (average speed, ambient temperature, and fuel volatility), running loss emissions are zero to negligible at first, but increase significantly as trip duration lengthens.

Since reliable local data on the distribution of trip durations is often unavailable, EPA will accept the use of the model's typical distributions for the estimation of running loss VOC emission factors. Where the transportation modeling process[9] can produce reliable inputs for trip duration, use of such inputs will produce a more accurate estimate of the benefits attributable to SIP measures which shorten average trip lengths without eliminating entire trips.

Most SIP inventories will be constructed by adding together emission estimates for several functional classifications of roadway. EPA recommends that one area-wide trip length distribution be used for all roadway classifications, due to the complexity of trying to develop separate distributions.

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[8] "Techniques for Estimating MOBILE2 Variables" and "Additional Techniques for Estimating MOBILE2 Variables," Energy and Environmental Analysis, Inc. for EPA (EPA Contract Number 68-03-2888).

[9] "Length of trip" as used here refers to the duration of the trip (how long, in minutes, the vehicle has been travelling, not on the distance traveled in the trip (how far the vehicle has been driven).

Sales of diesel powered light-duty vehicles and trucks underwent a surge in the late 1970s and early 1980s, peaking at 5.9% of LDV sales in the 1981 model year, and at 9.3% of LDT sales in the 1982 model year. Since then diesel sales have fallen precipitously.

MOBILE4.1 uses a single set of registration distributions by age and annual mileage accumulation rates to describe all LDVs, and another set to describe all LDTs. This is due in part to the fact that it is nearly impossible to develop such information for gas and diesel LDVs and LDTs separately, and in part since there is little evidence to suggest that typical use patterns and mileage accumulation rates are different for gas and diesel LDVs and for gas and diesel LDTs.

Diesel sales fractions represent the share of LDV and LDT sales in a given model year. The use of model-year-specific diesel sales fractions allows MOBILE4.1 to internally split the LDVs and LDTs into gas and diesel sub-categories, which have distinctly different emission rates.

If vehicle registration data that distinguish between gas and diesel LDVs and gas and diesel LDTs exist, it is possible to input local diesel sales fractions by model year. Since they apply to vehicles of ages 1, 2, 3, ... to 25-and-older, different sets of fractions are required for each calendar year, and for each scenario.

This option has been provided in MOBILE4.1 for two reasons. First, some users performing highway vehicle emission factor modeling may have access to vehicle registration data, or data from other sources, enabling them to characterize diesel sales of LDVs and LDTs in the area being modeled. Particularly if these sales fractions differ significantly from those included in MOBILE4.1, it will enhance the accuracy of the emission factors and inventory to use those sales fractions as model input. Second, as can be seen by the sharp rise and equally sharp fall of diesel sales in the late 1970s and early 1980s, it is extremely difficult to forecast diesel sales fractions for future model years. This provision will allow modelers to account for future increases in diesel sales, if such increases occur.

RVP Determination

The basic emission rates that underlie the emission factor calculations are developed from vehicles tested at FTP conditions, including a fuel volatility of 9 psi Reid Vapor Pressure (RVP). For other fuel volatility levels, MOBILE4.1 adjusts the emission factors for exhaust and evaporative emissions as well as for running loss, resting loss, and refueling loss emissions.

Vehicle emission rates increase as the volatility of the fuel increases, for temperatures between 45°F and 75°F and for RVP values between 9.0 and 11.7 psi. This effect is most pronounced at higher RVP levels and at higher ambient temperatures. Since there is a significant interaction effect between RVP and temperature, it is important that RVP and temperature inputs to MOBILE4.1 be consistent. That is, RVP and temperature should be chosen in such a way that they represent the same time period.” In general, use July 1990 RVP levels to estimate VOC and CO emissions during the ozone non-attainment season . Use January 1990 RVP levels to estimate CO emissions during the CO non-attainment season.

Gasoline survey data should be used to determine historical RVP, if quality-assured survey data are available. The survey samples should be drawn at the pump, not “upstream” of the pump at a refinery or fuel distribution terminal.

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[10] High RVP fuel is used in the winter months to facilitate vehicle starting. If the same high RVP fuel were used in the summer, a vehicle could experience vapor lock and stall.

An adequate basis for determining RVP is the MVMA National Gasoline Survey, published semi-annually” by the Motor Vehicle Manufacturers’ Association. Ordering and price information is available from:

Motor Vehicle Manufacturers’ Association
300 New Center Building
Detroit, MI 48202
Phone (313) 872-4311

Other regularly published gasoline volatility surveys can also be used. In the U.S., one of such surveys is performed by oil companies and compiled by the National Institute for Petroleum and Energy Research (NIPER). The MVMA survey is city-specific, while the NIPER survey is not.

For an area without its own survey data and for which it is not possible to use a city or district for which survey data exist, RVP can be determined from the applicable RVP limit[12] adjusted by either a non-compliance margin or a compliance safety margin. Where ASTM limits were the applicable limit, average RVP often exceeded the ASTM limit (non- compliance margin) by an amount that varied with the year and the ASTM limit itself. On the other hand, gasoline regulated by EPA or state RVP limits usually has had an average RVP below the EPA or state ceiling.

All parts of the United States will be subject to more stringent EPA summer RVP limits beginning in 1992, with the highest limit being 9 psi. There are no plans for EPA to establish winter RVP limits. If there are no state standards for future winter RVP or if they are the same as the state limit in 1990/91, the 1990/91 winter RVP input should be used for future years.

Oxygenated Fuels

MOBILE4.1 can model the effects of two types of oxygenated fuels, gasoline/alcohol blends and gasoline/ether blends, on exhaust carbon monoxide (CO) emissions[13] provided that the following information is input:

- Ether blend market share (as a fraction);
- Average oxygen content of ether blend fuels (percent weight, expressed as a fraction);
- Alcohol blend market share (as a fraction);
- Average oxygen content of alcohol blend fuels (percent weight, expressed as a fraction);

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[11] The data reflected in MVMA National Gasoline Survey are generally collected as of January 15th and July 15th.

[12] Historically, fuel volatility was subject to voluntary limits according to ASTM Standard D439, “Standard Specification for Automotive Gasoline.” More recently, fuel volatility has been subject to federal and/or state regulatory requirements.

[13] Reductions in exhaust CO emissions are estimated for gasoline-fueled vehicle types (LDGV, LDGT1, LDGT2, HDGV, and MC). No effects on exhaust VOC or NOx emission factors or on any of the evaporative components of VOC emissions are currently modeled with the exception that, if the oxygenated fuels have a higher volatility than base gasoline in an area, exhaust and evaporative emissions will be increased to reflect the increased volatility of the oxygenated fuels. MOBILE5 will contain adjustments for exhaust HC.

- RVP waiver. (If oxygenated fuels must meet the same RVP limits as gasoline, this indicator is set to 1; if such fuels have been granted a 1 .O psi waiver, this indicator is set to 2.[14])

Areas that are known to have significant market penetration of either blends and/or alcohol blends should characterize the relative market shares and oxygen content of these fuel blends and account for them in their mobile source emission inventory.

Assistance is required when modeling the effects of oxygenated fuels if any of the following situations apply:

- the fuels available in an area include blends containing both ether(s) and alcohol(s) in the same fuel;
- an RVP waiver greater than 1.0 psi is applicable to oxygenated fuels in an area;
- no RVP waiver is in effect, but the volatility of base gasoline is currently below the regulated limit (in this situation, the practical effect may be same as if a waiver were in effect);
- if two or more types of alcohol blends are marketed under different RVP waiver treatment (for example, gasoline/methanol blends might not be given the same waiver as gasoline/ethanol blends).

Correction Factors

There is considerable variation in vehicle emission factors as average vehicle speed changes. In general, however, exhaust emissions are at a minimum at about 48 mph. All emission rates (VOC, CO, NOx) display very high emissions at very low speeds, with emissions decreasing (sharply at first and then more slowly) as average speed increases, until minimum emissions are reached at around 48 mph. Above 48 mph, further increases in speed result in increased emissions.

MOBILE4.1 will calculate emission factors for average speeds of 2.5 to 65.0 mph, in increments of 0.1 mph. One average speed may be used for all vehicles, or a different average speed may be used for each vehicle type.

Selection of vehicle speeds is a difficult and complex process. Although it is appropriate for some purposes to use an average speed for all vehicle trips and vehicle types within urban areas as a whole, such an approach is not suitable for SIP inventory preparation. Instead, VMT should be left disaggregated into subsets that have roughly equal speed, with separate VOC, CO, and NOx emission factors for each subset? At a minimum, speeds should be estimated separately by roadway functional class.

The recommended approach to estimating speeds is to post-process the output from a local travel demand network model. Two documents that provide guidance on speed estimation for areas

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[14] Gasoline/ether blends are assumed to have the same RVP as gasoline, indicated by the regular RVP value input.

[15] Since emissions are a non-linear function of speed, with significant curvature at low and high speeds, total daily area-wide emissions are to some degree incorrectly estimated if VMT "events" occurring at significantly different speeds are averaged together.

using network models are: Highway Vehicle Speed Estimation Procedures for Use in Emissions Inventor& and A Study of Highway Vehicle Emission Inventory Procedures in Selected Urban Areas.

The report, Highway Vehicle Speed Estimation Procedures for Use in Emissions Inventories, focuses on speed estimation methods that are extensions of traffic assignment procedures. The basic method presented takes the link-specific traffic estimates provided as an output by a UTPS-type highway assignment model and calculates speeds based on the estimated highway volume-to-capacity ratios and a set of speed formulas that are more specific to different road types than the formula built into most assignment models? As such, this method is not as simple as using the direct traffic assignment output without modification.”

A second approach to estimating speeds using travel demand network models is to use the output from traffic assignment directly.[18] If the network model assigns traffic to links on the basis of a capacity restraint algorithm, then the associated link speeds are likely to be more accurate than if another type of assignment methodology is used.[19,20] However, the unique manner in which the traffic assignment algorithm manipulates speed for a particular link does not necessarily provide an accurate estimate of speed for that link but rather provides a value that optimizes the traffic assignment over the entire congested network.

Post-processing with better speed formulas is often combined-with a direct link to the emission factor model, and link speeds are either used directly as MOBILE inputs[21] or grouped into ranges based on the speed at which VMT occurs on each link?

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[16] In most metropolitan areas, transportation planners calibrate their highway assignment models to replicate observed volume levels, treating highway speeds only as tools to obtain good volume estimates rather than as critical outputs in their own right. In many cities, assignment-predicted speeds are too high to match actual conditions; in some cities, they are too low.

[17] For those urban areas that can demonstrate that their assignment-predicted link speeds closely match observed speed data and/or speeds estimated using the Federal Highway Administration’s Highway Capacity Manual, the assignment-predicted link speeds may be used directly in vehicle emissions inventories.

[18] If the year for which the inventory is being calculated is not the same as one of the years for which the network model has been run, speeds may be interpolated between chronologically adjacent network model runs.

[19] The capacity restraint method is a common type of traffic assignment algorithm. It is based on the inverse relationship between speed and congestion. It attempts to model congested speeds during peak conditions for all facility types. As congestion increases, vehicle operating speeds decrease. The capacity restraint methodology is used as the default formula in many urban areas’ traffic assignment models.

[20] A potential problem with the use of any single function is that it may not account well for the variations in traffic operating conditions across all types of links, especially on very congested links. A single formula may be unable to accurately estimate speed for facility types having very different operating characteristics. A more appropriate procedure would include separate equations for estimating speed for each facility class for each condition, i.e., peak versus off-peak travel.

[21] In this case, emission factors are developed for each highway link and multiplied by the VMT on each link to calculate link-specific vehicle emissions.

[22] Typically, a range would be one or two mph. If this approach is used, emission factors are calculated for the midpoint of each speed range and multiplied by the associated VMT.

This disaggregation of VMT by functional system avoids most of the undesirable VMT averaging that might otherwise cause errors in the emission inventory. Further accuracy improvements can be obtained by dividing the day into separate time periods so that congested VMT and free-flowing VMT are not mixed. While two periods are the minimum split to get more homogeneity in vehicle speeds, more than two periods are possible.

Estimating emissions for separate time periods within the day also requires that particular attention be paid to the treatment of the temperature inputs to MOBILE4.1. The sum of the emissions within the periods should be logically consistent (except for the effect of the speeds) with that which would result from using the 24-hour approach. In order to achieve this consistency, the 24-hour minimum and maximum temperatures should be used to determine diurnal evaporative emissions for each of the time period-specific MOBILE4.1 runs.

Ambient temperature, on the other hand, should be set to the VMT-weighted average temperature of the period in question. For example, if the night period extends from 7 pm to 6 am, the temperature for each of the hours occurring during the night should be weighted by the percent of night period VMT in each hour.[23, 24]

If no network model is available, and in marginal and sub-marginal non-attainment areas, the national speed estimates listed in Table 3-l may be used? Individual areas may be able to obtain comparable but locally specific speed estimates through their state DOT or FHWA division office. These speeds are calculated from HPMS traffic counts and site-specific speed formulas and are not actual speed observations.

Table 3-l

Geographic Area	Roadway Functional Classification	Autos, Vans, Pickups	All Trucks
Rural	Interstates	57.3	43.6
	Other principal arterials	45.4	36.0
	Minor arterials	39.9	33.3
	Major collectors	35.1	29.8
	Minor collectors	30.5	24.4

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[23] The recommended method of apportioning daily VMT to specific hours is to use the state's continuous monitors available within the FAUA. If no such monitors exist within the inventory area, then the state may rely on other continuous monitors located in areas similar in geographic, land use and demographic characteristics, or on those areas' final Airshed Emission Preprocessor profiles.

[24] Hour-by-hour temperatures should be determined from the lo-worst-days method used to determine the minimum and maximum temperatures for inventory purposes.

[25] SOURCE: Federal Highway Administration, Highway Performance Monitoring System, Impact Analysis for 1989 Base Year.

Geographic Area	Roadway Functional Classification	Autos, Vans, Pickups	All Trucks
Urban	Interstates	46.3	39.0
	Other freeways & expressways	43.3	36.5
	Other principal arterials	18.9	16.0
	Minor arterials	19.6	19.6
	Collectors	19.6	16.4

The basic emission rates that underlie the emission factor calculations are developed from emission data from vehicles tested at FTP conditions, including an ambient temperature of 75°F (24°C). MOBILE4.1 uses temperature correction factors to correct the emission factors for other temperatures.

MOBILE4 1 correction factors apply to temperatures in the range of 0°F (-18°C) to 110°F (43°C). If a temperature below 0°F is entered, a warning message is issued, and 0°F is used in the calculations. Similarly, if a temperature above 110°F is entered, a warning message is also issued, and 1 10°F is used in the calculations.

The temperature used to adjust the exhaust emission factors for all three pollutants, the hot soak component of evaporative emissions, refueling emissions, and resting loss and running loss emissions can be calculated on the basis of the input minimum and maximum daily temperatures.[26] Alternatively, the model can use a single temperature that represents ambient conditions at a particular time.

However, even if a single temperature is used as the basis of the temperature correction factors for all exhaust emissions, hot soak evaporative emissions, refueling emissions, and resting loss and running loss emissions,[27] minimum and maximum daily temperatures will still be used to calculate the diurnal component of evaporative emissions.

Minimum and maximum daily temperatures are used directly in MOBILE4.1 to calculate the diurnal portion of evaporative VOC emissions and to estimate the temperature of dispensed fuel for use in calculating refueling emissions. Unless overridden,[28] the temperatures used in calculating temperature corrections for exhaust VOC, CO, and NOx emissions, the hot soak portion of evaporative

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[26] The maximum temperature must not be less than the minimum temperature.

[27] Logically, the single temperature used to represent a typical day must be between a typical day's minimum and maximum temperatures.

[28] A single ambient temperature can also be used to determine the temperature corrections for exhaust VOC, CO, and NOx emissions, hot soak evaporative emissions, dispensed fuel temperature in the refueling emissions calculations, and resting loss and running loss emissions, through the choice of a value for the control flag TEMFLG (see the "User's Guide to MOBIfX4.1," section 2.1.14). This approach is not recommended unless modeling a short time period, such as an hour. Refueling emissions should always be modeled using the "full day" approach; hourly temperatures should not be used. Diurnal emissions can only be modeled directly in MOBILE4.1 using the "full day" approach, since the algorithm used is inaccurate over the very small temperature rises (1 to 5°F) typical of a single hour.

emissions, and resting loss and running loss VOC emissions are also calculated by MOBILE4.1 based on the minimum and maximum temperatures entered as input to the model.

While the basic exhaust emission rates for VOC, CO, and NOx are based on the standard test temperature of 75°F (24°C), MOBILE4.1 also adjusts these rates for other temperatures. Using the minimum and maximum daily temperatures and a representative profile of temperature versus time of day, MOBILE4.1 first calculates a temperature for each pollutant representing average emissions over the course of the day and then adjusts the exhaust emission factors for temperature effects accordingly.[29]

Hot soak emissions at FTP conditions are based on a temperature of 82°F (28°C). Again using the minimum and maximum temperatures, MOBILE4.1 calculates a temperature by which to adjust hot soak emissions.

Resting loss and running loss VOC emissions are also dependent on temperature. As in the cases of exhaust and hot soak emissions, MOBILE4.1 calculates appropriate average temperatures for estimating resting loss and running loss emissions, weighted to account for differing emission levels at different temperatures in the range of the minimum and maximum daily temperatures and differing travel fractions over the course of a day.

EPA recommends that the minimum and maximum daily temperatures be used to determine the temperatures for corrections to the emission factors, if daily average, rather than hour-by-hour, emissions are to be estimated. Minimum and maximum temperatures are normally calculated from the most recent three-year period for which validated ozone and/or CO monitoring data exists at the time the emission inventory is due.

Determine the consecutive three-month period with the highest frequency of NAAQS exceedance days occurring in the inventory area. The same consecutive three-month period applies for each year, with a total of nine months used to determine temperature. If the months containing the highest frequency of exceedances are not consecutive, or if two or more sets of consecutive months have the same frequency, use the months of June, July, and August for ozone modeling and the months of November, December, and January for carbon monoxide modeling.

Next, list the 10 highest concentrations[30] that occurred in the inventory area during those nine months and the dates of those concentrations.[31]

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[29] The algorithm used in MOBILE4.1 to determine temperatures for correcting emissions on the basis of the input minimum and maximum temperatures takes into account both the typical 24-hour diurnal temperature profile for a day having the specified minimum and maximum, and the typical distribution of travel over the course of 24 hours. Thus, the emission factors calculated in this way are appropriately weighted for trips, vehicle miles traveled, and emissions at different temperatures and result in factors that can be multiplied by total daily VMT when total daily emissions are the desired result.

[30] The 10 highest concentrations need not all be exceedences.

[31] There are four exceptions to selecting the 10 highest concentrations: 1) More than 10 concentrations may be needed to identify 10 unique dates. 2) If the 10th ranked concentration level occurs on more than one day, all of those days should be included in the temperature calculation. 3) If only two years of validated monitoring data exist for the entire MSA monitoring network, use the seven highest concentrations. 4) If only one year of data exists for the entire MSA monitoring network, use the four highest values.

The ten highest ozone concentrations for each site in a county and the dates on which they occurred are contained in the Aerometric Information Retrieval System (AIRS) AMP440/Maximum Values Report. Eight-hour average CO concentrations and the dates on which they occurred can be found in the AIRS AMP350 raw data report The AMP355/Standard Report contains the CO values that exceed the NAAQS. These reports are available from EPA's National Air Data Branch. To obtain copies of these reports, contact Tom Link, U.S. EPA Office of Air Quality Planning and Standards, at (919) 541-5456.

Determine the maximum and minimum temperatures for each of the 10 days for the area being inventoried.

If there is more than one meteorological station within the non-attainment area, use the station that best represents the conditions of most mobile source emissions within the inventory area.

One important determinant of emissions performance is the mode of vehicle operation. EPA's emission factors are based on testing over the FTP cycle, which is divided into three driving segments (referred to as "bags"), each with differing associated emissions performance:

Bag	Operating Mode
1	Cold start - first 505 seconds of a cold-start trip (or less, if the trip ends before 505 seconds);
2	Stabilized - all operation beyond 505 seconds of a trip;
3	Hot start - first 505 seconds of a hot-start trip (or less, if the trip ends before 505 seconds).

Emission data from each of these modes reflect the fact that emissions generally are highest when a vehicle is first started, i.e., is operating in the cold-start mode. At that time, the vehicle, engine, and emission control equipment (particularly the catalytic converter and oxygen sensor) are all at ambient temperature and, therefore, are not performing at optimum levels.

The hot start mode represents the case of a vehicle that was operating, was turned off, and then was restarted. In this case the vehicle was not turned off for sufficient time to have cooled completely to ambient temperatures. Since the vehicle is partially warmed up, emissions during a hot start are generally lower than during a cold start. However, since the vehicle is not yet completely warmed up, emissions are generally higher than when the vehicle is completely warmed up and operating in what is known as stabilized mode. During stabilized mode the vehicle has been in continuous operation long enough for all emission control systems to have attained relatively stable, fully "warmed-up" operating temperatures.

MOBILE4.1 uses three inputs to indicate vehicle operating mode.[32] These inputs represent VMT; that is, the percentage of VMT (not the percentage of vehicles) accumulated by non-catalyst vehicles in cold-start mode (PCCN), by catalyst-equipped vehicles in hot-start mode (PCHC), and by

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[32] The values corresponding to the FTP cycle are: PCCN 20.6 %
PCHC 27.3 %
PCCC 20.6 %

catalyst-equipped vehicles in cold-start mode (PCCC). The three specified values must all be expressed as percentages (not as fractions). Each value must lie between 0.0% and 100.0%, and the sum of PCHC + PCCC must not exceed 100%.

Historically EPA has defined cold starts to be any start that occurs at least four hours after the end of the preceding trip for non-catalyst vehicles and at least one hour after the end of the preceding trip for catalyst-equipped vehicles. Hot starts are those starts that occur less than four hours after the end of the preceding trip for non-catalyst vehicles and less than one hour after the end of the preceding trip for catalyst-equipped vehicles. The shorter time interval associated with the cold/hot start definition for catalyst-equipped vehicles reflects the fact that catalytic converters do not operate at intended efficiency until they are fully warmed up.[33]

In the absence of supporting data for values other than those listed above, EPA believes that the values reflecting FTP conditions are appropriate. This is particularly true when the emission factors being modeled are individually or collectively intended to represent a broad geographic area (Metropolitan Statistical Area, entire state) and/or a wide time period (days, months). When the modeling is intended to represent highly localized conditions (specific highway links) or very limited periods of time (single hours), it may be possible to develop more representative values for these variables? Areas known to have average trip lengths significantly shorter or longer than 7.5 miles may also merit the use of alternate values.[35]

MOBILE4.1 can provide four additional corrections to the exhaust emission factors for LDGVs, LDGT1s, and LDGT2s. These corrections are used to represent unique conditions not typically assumed in MOBILE4.1 runs, and include the emissions effect of air conditioning (A/C)

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[33] Catalysts begin to operate at full efficiency once they reach about 600°F (316°C). Since non-catalyst vehicles do not depend on attainment of such high temperatures for stabilization of emissions performance, they can remain partially warmed up for up to four hours.

[34] Some transportation emissions modeling approaches are based on the concepts of trip-start emissions and running emissions, rather than the method described above. In this alternative approach, trip-start emissions are assumed to be instantaneous and are calculated as the difference between MOBIIJ4.1 total "start" emissions and total "stabilized" emissions. Total start emissions per trip are the product of the 100% cold- (or hot-) start emission factor in grams per mile and the 3.59-mile distance attributed to the first 505 seconds of the FTP driving cycle. Total stabilized'emissions are the product of the 100% stabilized emission factor in grams per mile and the same 3.59-mile distance and same speed as that used to estimate start emissions. Start emissions are calculated as the grams per trip event times trip productions, and are typically located at the centroids. Total stabilized emissions are the product of the sum of the MOBILE4.1 stabilized exhaust and running loss emission factors in grams per mile and the total distance traveled during the course of the trip. Trip end emissions are simply the "hot soak" emissions expressed in grams per trip event times trip attractions. Trip end emissions are also typically located at centroids. Daily diurnal emissions are calculated as the emissions in grams per vehicle times vehicles present, and must also be assigned to specific hours and locations. Methods for this assignment vary. If the transportation model produces reliable estimates for the relevant trip parameters, this alternative method is believed to be a more accurate way to locate mobile source emissions within the inventory area than is the use of average FTP hot/cold percentages.

[35] The drivingcycle used in FTP testing is 7.5 miles long. If shorter trips are preponderant within a given area, it is possible that the percentage of VMT occurring in one of the "start" modes is greater than the national average. Similarly, if longer trips predominate, the percentage of VMT occurring in the "stabilized" mode may be greater.

usage, extra loading, and trailer towing. There is also a humidity correction factor, which applies only to exhaust NOx emissions?

If these corrections are to be applied, either six or ten inputs will be required. If six values are required, they are an A/C usage fraction (for all LDGVs and LDGTs), three extra load usage fractions (for LDGVs, LDGTls, LDGT2s), a trailer towing fraction (for all LDGVs and LDGTs), and a humidity level (for all LDGVs and LDGTs plus motorcycles). If ten values are required, they are an A/C usage fraction (for all LDGVs and LDGTs), three extra load usage fractions (for LDGVs, LDGTls, LDGT2s), three trailer towing fractions (for LDGVs, LDGTls, LDGT2s), a humidity level (for all LDGVs and LDGTs plus motorcycles), and dry bulb and wet bulb temperatures (used to calculate an A/C usage fraction for LDGVs and LDGTs).

In most cases, ozone pollution episodes occur during summer months and very warm to hot temperatures. It is reasonable to assume that vehicle air conditioning usage is high under such conditions. The air conditioning correction factors that are calculated in MOBILE4.1 will increase vehicle emissions, and areas that believe their motor vehicle inventory has been underestimated in the past may choose to use them.[37]

The humidity correction for NOx emissions accounts for the fact that when "excess" water vapor is present, some of the heat of combustion heats water vapor rather than enhancing NOx formation.

Control Programs

In general, VMT should be disaggregated so that vehicles generating the VMT are subject to a common control program.[38] This issue applies especially for I/M versus no I/M and ATP versus no ATP areas, specifically interstate areas but also where the inventory area is partially designated attainment and partially designated non-attainment.

The refueling of gasoline-fueled vehicles results in the displacement of fuel vapor from the vehicle fuel tank to the atmosphere. There are two basic approaches to the control of vehicle refueling emissions, generally referred to as "Stage II" (at the pump) and "onboard" (on the vehicle) vapor recovery systems (VRS).

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[36] The humidity correction factor is also applied to NOx emissions from motorcycles.

[37] There is some uncertainty surrounding the air conditioning correction factors. The emissions effect of operating the air conditioner for late model year vehicles is not well quantified. Also, the fraction of vehicles equipped with air conditioning (built into MOBILE4.1) is substantially higher for the vehicle fleet of the late 1980s than it was for the fleet of the late 1970s, which magnifies the consequence of a possible error. Thus, the use of the air conditioning corrections to emissions is acceptable but not required in the development of SIP inventories.

[38] VMT should also be disaggregated so that the set of operating conditions under which the vehicles are generating the VMT is fairly homogeneous.

There are five approaches available in MOBILE4.1 for modeling vehicle refueling emissions:

- Model uncontrolled refueling emissions for all gasoline-fueled vehicle types;
- Model refueling emissions assuming a Stage II VRS requirement;
- Model refueling emissions assuming an onboard VRS requirement;
- Model refueling emissions assuming both Stage II and onboard VRS requirements;
- Account for refueling emissions by some means other than MOBILE4.1.

No additional inputs are required for either the first or the last approach. Additional information is needed, however, to model the effects of either or both VRS requirements on refueling emissions.

Four inputs must be provided to model the effect of a Stage II VRS requirement: the start year (calendar year in which the requirement takes effect), the phase-m period (number of years for Stage II VRS installation to be completed), and the system efficiency (in percent) at controlling refueling emissions from light-duty vehicles and trucks, or from heavy-duty vehicles.

Only two inputs are required to model the effect of an onboard VRS requirement: the starting model year and which of the four possible vehicle types (LDGV, LDGT1 , LDGT2, HDGV) are subject to the requirement.

Both sets of inputs must be supplied to model both VRS requirements concurrently.

The refueling emission factors can be calculated in grams per gallon of dispensed fuel (g/gal) or in grams per mile (g/mi). The preferred approach is to calculate g/gal refueling emission factors that reflect the applicable Stage II requirements, then multiply the g/gal emission factor by total gasoline sales. This is the most accurate method of estimating the contribution of refueling emissions to the inventory, particularly for areas with reliable data on gasoline sales.[39] This method also accounts for refueling emissions generated when gasoline is purchased in an area but consumed largely outside of the area, and does not include refueling emissions for through traffic that does not refuel in the area.[40] When good data on gasoline sales is not available, the use of the g/mi refueling emission factor is more convenient and, while also more approximate, acceptable for SIP inventory development.

The overall effectiveness of a Stage II vapor recovery system at controlling refueling emissions depends on a number of factors, including the baseline efficiency of the system used, the portion of total area gasoline consumption handled by service stations exempt from Stage II requirements, and the frequency and stringency of enforcement programs. In general, the effectiveness of a Stage II VRS at controlling refueling emissions will be greater for light-duty vehicles and trucks than for heavy-duty vehicles, since HDGVs are more likely to be refueled at service stations (or other fuel dispensing locations, such as private refueling depots) that will be exempted from Stage II requirements.

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[39] State tax revenue receipts on county gasoline sales are often used for this purpose in the US.

[40] One alternative to using MOBILE4.1 to calculate refueling emissions is to use the applicable AP-42 emission factors. However, the effects of an onboard vapor recovery system requirement cannot be modeled accurately using this approach. MOBILE4.1 makes use of improved predictive equations to calculate refueling emission factors, and these have not yet been incorporated into AP-42.

Emissions from fuel spillage also can be modeled using MOBILE4.1. The "baseline" spillage factor (assuming no controls) is 0.31 g/gal of dispensed fuel. If no controls are assumed, this factor is added to MOBILE4. l's calculated displacement loss, which, in turn, is based on ambient temperature and RVP. If Stage II is modeled, then the in-use efficiency percentages input determine the reduction in both displacement and spillage.

Displacement loss can be separated from fuel spillage, using the grams per gallon emission factors from the expanded evaporative output. If no controls are used, fuel displacement emissions should be calculated by subtracting the 0.31 g/gal spillage factor from the emission factor. In this case, spillage would be 0.31 g/gal.

To model the effects of Stage II on displacement and spillage losses, the percent emission reduction for LDGVs, LDGTs, and HDGVs must be input. These percentages are then multiplied by the 0.31 g/gal spillage factor to arrive at a value for spillage. Displacement loss is then calculated as the gram/gallon emission factor minus the calculated spillage loss.

Inspection and maintenance (I/M) programmes may reduce mobile source air pollution. MOBILE4.1 can model the effect of an operating I/M program, based on the specification of certain parameters that describe the programme.

I/M refers to "inspection and maintenance" programs, which are inspections of vehicles using a measurement of tailpipe emissions and which require that all vehicles with tailpipe emissions higher than the program cutpoints be repaired to pass a tailpipe emission retest. Inspections that are aimed at verifying the presence and proper connection of emission control devices are called anti-tampering programs.

The following program parameters must be specified in order to model an I/M program:

- Program start year (calendar year that program begins);
- Stringency level (percent);
- First (earliest) and last (latest) model years of vehicles subject to the requirements of the program;
- Waiver rates (percent of failed vehicles; one rate applicable to pre-model year 1981 vehicles and one rate applicable to 1981 and later model year vehicles);
- Compliance rate (percent);
- Program type (centralized; decentralized and computerized; or decentralized and manual);
- Frequency of inspection (annual or biennial);
- Vehicle types covered by the program;
- Test type (idle, 2500/idle, loaded/idle);
- Whether alternate I/M credits are to be supplied;
- IM240 transient test first model year;
- Purge system test first model year;
- Pressure system test first model year.

The last three parameters in the list above are optional. They refer to the earliest model year of vehicles subject to:

- transient testing of HC and CO emissions (where the vehicle is tested on a chassis dynamometer over a transient driving cycle, and mass emissions are measured using a constant volume sampling (CVS) system);
- functional purge testing of the evaporative emission control system;
- functional pressure testing of the evaporative emission control system.

Vehicle miles traveled (VMT)

This section describes two methods of estimating highway vehicle miles traveled. Both are related to the Department of Transportation's (DOTs) Highway Performance Monitoring System (HPMS).

Highway Performance Monitoring System (HPMS)[41]

Since the VOC, NO_x, and summer CO emission inventories are typical summer day inventories, VMT for ozone non-attainment areas should be adjusted to the summer season using the inverse of the factors used to adjust summer 24- and 48-hour counts to AADT. Similarly, VMT for winter CO emission inventories should be adjusted using the same technique. Modeling inventories for particular days should also be adjusted for average day-of-week variations in VMT.

Urban areas with populations over 50,000 are required to maintain formal transportation planning programs in order to meet Federal requirements for securing transportation funds. These programs are intended to establish the analytical basis for assessing current and future transportation needs and for evaluating projects that will satisfy those needs. Although not a requirement of this process, the Highway Performance Monitoring System can be very useful to it.

The Highway Performance Monitoring System was developed by the U.S. Department of Transportation Federal Highway Administration in the mid-1970s to collect and report information on the nation's highways. Traffic data reporting for the system is documented in the HPMS Field Manual and the Traffic Monitoring Guide.

The HPMS universe consists of all public highways or roads within a state. The reporting strata for the HPMS include type of area (rural, small urban, and individual or collective urbanized areas) and functional class. In rural areas the functional classes are Interstate, Other Principal Arterial, Minor Arterial, Major Collector, and Minor Collector. In urban areas they are Interstate, Other Freeway or Expressway, Other Principal "Arterial, Minor Arterial, and Collector. A third level of stratification based on 13 volume groups was added as a statistical device to reduce sample size, insure the inclusion of higher volume sections in the sample, and increase the precision of VMT at a lower sample rate.

The HPMS sample design is a stratified simple random sample. The sample size estimation process was tied to annual average daily traffic, although nearly 75 data items are collected. The

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[41] HPMS VMT refers to the vehicle miles traveled reported to the Federal Highway Administration's Highway Performance Monitoring System. Under this program, traffic counts taken on samples of an area's roadway network are adjusted for day-of-week and season and expanded to include the area's entire roadway network.

decision for using AADT was based partly on the fact that AADT is one of the most variable data items in the HPMS. As such, the reliability of the other data is expected to equal or exceed that of AADT.

The HPMS sampling element was defined on the basis of road segments or links that include both directions of travel and all travel lanes within the section. AADT variability was estimated based on data from the 1976 National Highway Inventory and Performance Study (NHIPS). Sample size was determined and the sample selected as a simple random sample within strata according to predetermined levels of precision. For the higher volume strata the sample size is estimated on the basis of providing a 90% confidence that the sample strata mean was within ± 5% of the universe strata mean.

Typically 24- or 48-hour counts are taken on each sample segment once every three years. These short counts are adjusted, based on day-of-week and season, to annual averages using a small number of continuous traffic recorders. The HPMS expansion factors are computed as the ratio of universe mileage to sample mileage within each stratum. This procedure expands the HPMS sample to represent the universe of all roadways in the area by multiplying each segment's AADT, segment length, and expansion factor and summing the product for each sample section. Axle correction factors are also incorporated into the process.[42] Growth factors are used to convert counts on sections unmonitored during a year to current year annual estimates, i.e., segments not counted during the year of record are estimated by multiplying the earlier counts by growth factors.

VMT used to construct mobile source emission inventories should be consistent with that reported through the HPMS. However, since the Federal Aid Urbanized Area geographic boundaries of HPMS are not generally coincident with EPA's non-attainment area boundaries, the two estimates of VMT will not necessarily be identical.

Consistency between HPMS VMT and SIP VMT means, in general, that the same factors used to seasonally adjust and expand the HPMS 24- and 48-hour samples by functional system and volume group to annual average daily traffic (AADT) VMT within the FAUA should also be applied to all segments within the non-attainment area. This in effect assumes that all roads of a given functional system and volume group are used with equal intensity, allowing geographic allocation of total HPMS VMT within the non-attainment area based only on knowledge of roadway miles.

HPMS-base annual average daily VMT should also be adjusted for seasonal effects. Since the VOC, NOx, and summer CO emission inventories are typical summer weekday inventories, VMT for ozone non-attainment areas should be adjusted to the summer season using the inverse of the factors used to adjust the 24- and 48-hour counts to AADT. Similarly, VMT for winter CO emission inventories should be adjusted using the same technique.

Since base year emission inventories must also be calculated for a typical day, a similar adjustment using the inverse of the factors used to adjust the 24- and 48-hour counts to AADT should be made to convert typical summer day VMT to typical summer weekday VMT and to convert typical winter day VMT to typical winter weekday VMT.

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[42] Vehicle counts taken by axle counting equipment require adjustment by axle correction factors. An adjustment factor is the ratio of vehicles to axles as determined by a vehicle classification count.

It may also be necessary to allocate daily VMT to each hour of the day. This is commonly done for purposes of preparing emissions estimates for the photochemical grid models used in forecasting ozone concentrations.[43] The recommended method of apportioning daily VMT to specific hours is to use the state's continuous monitors available within the FAUA. If no such monitors exist within the non-attainment area being modeled, then the state may rely on other continuous monitors located in areas similar in geographic, land use, and demographic characteristics, or on those areas' final Air-shed Emission Preprocessor profiles.

To be consistent with HPMS, the SIP functional systems should, with few exceptions, be identical to the HPMS functional systems (Interstate System, Other Freeways and Expressways, Other Principal Arterials, Minor Arterials, and Collectors)?

The recommended method for estimating VMT on each HPMS functional system is to allocate VMT on the basis of roadway miles and functional class. The underlying assumption in this methodology is that VMT is generally a function of total roadway miles and that this relationship becomes stronger as individual types of highway facilities within specific areas are considered.

The general process of estimating VMT in rural and small urban areas[45] involves the apportionment of statewide VMT to the county or other area for which mobile source emissions estimates are required. Statewide VMT data are tabulated by all state transportation agencies and reported to the Federal Highway Administration, which, in turn, annually publishes these and other similar data in Highway Statistics. Highway Statistics is based upon and consistent with HPMS.[46]

Central to the overall method of estimating VMT in rural and small urban areas is the development of apportioning factors, which, when applied to the statewide total, yield areawide VMT. Several options exist for apportioning VMT, such as roadway miles, motor vehicle registrations, population, and fuel sales.[47] The option selected will depend on the availability of the required data. A key component of this process is the assistance of state and county transportation engineers and planners who should be able to provide the best assessment of both data availability and quality.

Once the apportioning method has been developed, the resulting factors are applied to statewide VMT to produce estimates of areawide travel. Other data are applied to yield VMT by

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[43] The Urban Airshed Model and its associate emissions preprocessor is an example of such a model. EPA also maintains the Regional Oxidant Model, a mesoscale phdochemical model providing coverage of the Northeastern United States.

44 One exception is that the Interstate System and Other Freeways and Expressways may be combined into a single functional system. A second exception is that the Collector, Local, and Frontage Roads may be combined into a single functional system.

[45] If a state has the capability of reporting rural or small urban area VMT directly, the indirect methods described here for apportioning state-level VMT data to the applicable area are not appropriate.

[46] HPMS data submitted to FHWA on or before September 15th of the year following the year of record are included in Highway Statistics. FHWA therefore considers the data in Highway Statistics preliminary and subject to revision within the following twelve months.

[47] The recommended method for apportioning VMT in a completely rural non-attainment area is by roadway miles.

roadway classification and vehicle type. Statewide VMT estimates are available directly from state transportation and highway agencies.

The recommended method of allocating statewide VMT to rural or small urban areas is on the basis of roadway miles by functional class. The underlying assumption in this method is that VMT is generally a function of total roadway miles and that this relationship becomes stronger as individual types of highway facilities within specific areas are considered.

State transportation and highway agencies report total roadway miles by functional class (i.e., interstate, other freeways and expressways, other principal arterials, minor arterials, and collectors) in urbanized, small urban, and rural areas, for both the Federal-Aid and non-Federal-Aid portions of the highway system. A summary of these data is published by FHWA in Highway Statistics as Table HM-20, which is shown here as Table 3-4. Roadway miles and VMT are reported in exactly the same format, i.e., by functional class on Federal-Aid and non-Federal-Aid highways in both urban and rural portions of each state. The one additional set of data required is the areawide roadway miles disaggregated by the same categories as those for the statewide data. This information should be available directly from the state transportation agency, or it can be derived based on input from both state and county transportation agencies.

One of the remaining three apportioning methods may be used as an alternative to apportioning by roadway miles in rural counties if the state can demonstrate that the recommended method is either not feasible or less accurate than one of ‘the alternative methods. Such might be the case in rural counties entirely outside of the non-attainment area but within a photochemical modeling domain.

The first of these alternative methods utilizes motor vehicle registration data to derive an apportioning factor. The premise here is that the amount of travel occurring in an area is a function of the area’s vehicle population. This method assumes that travel by vehicles registered outside the area is balanced by travel outside the area by vehicles registered in the area and that individual areawide travel patterns are not significantly different from the statewide average for the area in question.

A second alternative method for allocating statewide VMT apportions statewide VMT to the area based on the relative area and state population. This method has the advantage of utilizing data that are routinely available from several sources, such as the Bureau of Census and state and county agencies, and therefore VMT estimates can be developed with minimal effort.

Finally, statewide VMT can be apportioned to the area based on fuel sales data. An assumption inherent in this method is that VMT and fuel sales are directly related. In order for this method to be practical, areawide fuel sales data must be available. If such data are not available, one of the other methods will need to be used.

All U.S. states collect taxes on motor fuel sold within their boundaries, and formal records are maintained regarding both the fuel throughput and the revenue derived therefrom. Since these statistics are usually aggregated as state totals, special processing may be required to identify fuel sales by area. The data requirements should be discussed with appropriate officials in the state taxation or revenue agency. As a minimum, total annual sales (gallons) of gasoline and diesel fuel in both the area and state are required.

Table 3-4

Public road and street mileage - 1990

by fonctional system

MILEAGE AS OF DECEMBER 31, 1990
COMPILED FROM REPORTS OF STATE AUTHORITIES

TABLE HM-20
SEPTEMBER 1991

STATE	RURAL							URBAN							TOTAL MILEAGE
	INTERSTATE	OTHER PRINCIPAL ARTERIAL	MINOR ARTERIAL	MAJOR COLLECTOR	MINOR COLLECTOR	LOCAL	TOTAL	INTERSTATE	OTHER FREEWAYS AND EXPRESSWAYS	OTHER PRINCIPAL ARTERIAL	MINOR ARTERIAL	COLLECTOR	LOCAL	TOTAL	
ALABAMA	6 2	1,994	3,884	11,681	6,971	18,736	73,818	247	21	1,008	1,611	1-707	12,280	16,854	80,672
ALASKA	1 0	53	902	1,904	906	7,134	11,936	61	-	106	81	184	1,147	1,649	13,486
ARIZONA	1 9	1,037	2,181	3,744	3,058	25,876	36,945	130	39	993	1,010	650	10,846	14,067	51,612
ARKANSAS	4 9	1,931	3,167	12,460	6,630	14,911	69,408	123	105	696	998	.006	4,812	7,877	77,086
CALIFORNIA	1 4 6	.932	6,596	12,921	9,891	56,896	89,662	983	1,263	5,941	8,312	7. 47	49,678	73,922	163,574
COLORADO	7 9	.901	1,947	7,302	12,066	12,400	66,408	148	164	929	1,140	1. 66	7,794	11,272	77,660
CONNECTICUT	9	225	472	960	1,137	6,162	9,086	232	191	710	949	1. 16	8,907	10,806	19,981
DELAWARE	-	164	183	609	152	2,791	3,829	41	1	138	136	.68	1,133	1,616	6,444
DIST. OF COL.	-	-	-	-	-	-	-	12	24	99	1	66	869	1,102	1,102
FLORIDA	1,010	2,670	3,409	4,686	5,195	43,073	60,061	416	269	1,835	4	4-60	38,229	48,034	108,095
GEORGIA	873	2,705	5,874	14,034	7,266	57,121	87,873	372	148	1,468	1	1 08	16,820	21,728	109,601
HAWAII	6	13	387	466	113	1,511	2,587	36	63	84	1	.80	1,090	1,612	4,088
IDAHO	630	1,646	1,027	4,882	3,808	46,111	60,006	75	-	184	397	385	1,388	2,420	62,436
ILLINOIS	1,415	2,741	6,081	14,199	3,676	76,930	103,941	646	83	2,372	9,167	3,291	22,624	32,003	136,944
INDIANA	863	1,102	5,134	9,764	10,303	48,884	74,040	265	112	1,346	2,288	1,961	11,878	17,860	91,908
IOWA	646	5,163	4,890	13,687	16,399	86,101	109,765	137	-	921	1,2	1,0	6,398	8,788	112,641
KANSAS	712	3,260	4,466	22,728	9,321	83,997	124,473	160	90	577	1,038	770	8,470	9,106	133,578
KENTUCKY	679	1,838	1,756	7,215	9,272	41,616	61,976	184	90	497	1,094	902	4,926	7,692	69,668
LOUISIANA	656	1,084	1,676	7,362	4,305	31,368	46,330	188	28	1,018	1,111	1,148	8,799	12,280	58,820
MAINE	913	735	1,088	3,276	2,254	12,228	19,896	63	14	223	297	394	1,613	2,494	22,389
MARYLAND	169	499	1,142	1 9 1	1,893	10,848	16,462	231	191	691	958	1,174	8,846	12,290	28,752
MASSACHUSETTS	170	242	769	2 0 7	1,961	8,091	13,230	397	274	1,846	2,419	2,726	13,188	20,846	34,076
MICHIGAN	772	2,398	3,869	7 2 1	7,483	69,060	90,773	466	200	1,862	3,689	2,790	17,690	28,678	117,449
MINNESOTA	688	3,357	6,923	6 6 4	11,878	77,339	116,169	217	138	686	1,648	1,843	9,879	14,208	129,397
MISSISSIPPI	660	1,676	4,137	1 04	2,909	44,278	66,164	124	34	600	681	763	5,164	7,356	72,620
MISSOURI	841	2,762	3,708	8 02	6,430	74,647	105,488	336	270	1,039	1,627	1,497	10,270	15,039	120,627
MONTANA	1,144	2,102	9,312	8 81	9,261	46,626	69,116	47	-	171	211	226	1,616	2,271	71,387
NEBRASKA	444	2,719	4,212	11 68	9,233	69,386	87,461	37	10	375	537	406	3,688	4,962	92,403
NEVADA	498	609	1,178	2 328	2,466	36,371	42,440	46	36	172	342	432	2,056	3,084	45,624
NEW HAMPSHIRE	180	319	664	1 236	1,230	6,776	12,403	44	33	180	366	342	1,469	2,433	14,836
NEW JERSEY	126	279	648	1 734	1,264	7,711	11,760	270	289	1,366	2,088	1,919	16,800	22,502	34,262
NEW MEXICO	906	1,376	2,293	4 201	2,373	38,089	49,238	94	3	469	331	285	4,326	5,498	54,736
NEW YORK	854	1,788	4,630	6 293	10,799	48,966	73,329	646	762	2,407	4,168	3,843	26,997	37,813	111,242
NORTH CAROLINA	709	2,009	2,039	10 611	9,060	51,133	76,446	228	207	1,746	2,204	1,376	13,486	19,245	94,890
NORTH DAKOTA	630	1,207	4,198	11 107	7,488	60,176	84,706	40	-	166	270	226	1,120	1,811	86,617
OHIO	847	1,680	3,313	11 793	7,124	67,416	92,172	726	367	2,167	2,792	4,146	21,241	31,428	113,600
OKLAHOMA	723	1,879	3,220	21,409	9,092	69,369	99,682	207	189	782	1,863	1,206	7,836	12,083	111,766
OREGON	695	2,266	2,467	9,643	7,927	64,271	86,669	132	56	666	1,018	975	5,665	8,410	94,969
PENNSYLVANIA	1,166	1,788	5,968	7,980	8,376	62,886	88,164	403	384	2,815	2,822	3,191	18,729	28,344	116,608
RHODE ISLAND	21	74	92	201	163	982	1,623	49	64	348	291	498	3,338	4,588	6,111
SOUTH CAROLINA	673	1,519	3,437	8,634	4,004	36,636	54,703	118	34	689	896	1,159	6,447	9,343	64,046
SOUTH DAKOTA	631	2,318	3,387	11,498	6,966	48,163	72,962	47	3	170	232	114	1,168	1,734	74,696
TENNESSEE	780	1,069	4,168	5,464	10,782	47,046	69,299	282	-	1,325	870	1,811	10,952	15,340	84,639
TEXAS	2,282	7,903	6,914	37,937	18,626	43,614	217,176	847	826	3,944	5,684	6,883	70,692	88,776	305,961
UTAH	792	68	1,063	3 160	4 170	27,003	37,669	145	13	248	429	476	4,263	5,676	43,244
VERMONT	286	29	748	1 913	986	8,716	12,941	34	16	109	130	178	714	1,180	14,121
VIRGINIA	777	62	3,646	0 206	399	34,002	52,449	299	167	1,002	1,642	1,404	10,717	15,261	67,700
WASHINGTON	619	79	2,677	7 349	680	45,118	65,039	240	192	1,269	1,709	1,777	11,083	16,260	81,299
WEST VIRGINIA	427	512	1,728	.352	2 161	20,336	31,516	90	70	216	328	404	1,968	3,076	34,592
WISCONSIN	616	3 289	6,068	.742	6 606	66,360	95,481	124	166	1,066	1,906	1,427	9,726	14,395	109,876
WYOMING	863	1 023	2,098	.486	7 455	23,339	37,261	60	3	167	200	320	1,212	1,962	39,213
TOTAL	33,647	83,802	1.4,736	436,365	293,912	2,30,427	3,122,788	11,527	7,670	61,987	74,666	78,248	633,276	767,383	3,880,161
PERCENT - AREA	1.1	2.7	4.8	14.0	9.4	68.2	100.0	1.5	1.0	6.9	9.9	10.3	70.4	100.0	-
PERCENT - TOTAL	0.8	2 2	3 8	3	7.6	54.7	80.6	0 3	0.2	3	9	2.0	3.8	9 5	00.0

Table 3-5

Private and commercial highway use of special fuels by months - 1990[1]

COMPILED FOR THE CALENDAR YEAR FROM AN ANALYSIS OF MOTOR-FUEL USE

(THOUSANDS OF GALLONS)

TABLE MF-26
OCTOBER 1991

STATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL 2/	CHANGE FROM 1989	
														GALLONS	PERCENT
ALABAMA	43.232	41.200	48.886	48.495	60.494	60.066	62.027	61.341	46.087	47.116	46.001	46.250	571.081	36.066	6.7
ALASKA	6.871	5.340	6.040	7.141	7.884	8.068	8.270	8.202	7.368	7.226	6.897	6.022	83.624	25.062	42.8
ARIZONA	27.148	26.363	29.100	27.200	28.009	28.000	27.876	28.806	26.761	28.430	28.619	28.982	331.071	5.577	1.7
ARKANSAS	29.206	27.686	32.368	32.755	34.668	34.376	36.280	34.414	31.173	33.026	31.660	29.614	386.802	-436	-0.1
CALIFORNIA	140.057	135.388	159.896	158.916	182.844	182.103	188.958	171.183	164.322	161.368	142.651	149.136	1.862.810	-91.721	-4.7
COLORADO	15.810	14.538	18.889	18.642	18.188	18.704	19.406	19.817	17.778	17.448	15.631	15.689	208.216	18.600	9.8
CONNECTICUT	13.886	13.220	18.194	16.898	18.386	18.404	18.739	17.241	16.920	16.864	14.869	14.710	188.197	-13.813	-6.8
DELAWARE	3.715	3.528	4.128	4.229	4.726	4.948	6.487	5.380	4.882	4.468	4.128	3.862	53.256	-210	-0.4
DIST. OF COL.	1.664	2.044	1.833	1.743	1.944	2.038	1.670	1.782	2.040	2.177	1.871	2.022	22.818	-536	-2.3
FLORIDA	70.789	87.692	77.872	73.868	71.474	69.702	69.533	89.871	88.411	88.058	68.287	88.702	843.849	-16.144	-1.8
GEORGIA	64.824	69.072	70.178	74.886	78.421	76.788	78.284	80.412	73.732	74.078	68.981	89.221	867.438	19.703	2.3
HAWAII	2.036	1.914	2.169	2.162	2.264	2.238	2.344	2.286	2.097	2.158	2.027	2.120	26.795	1.208	4.8
IDAHO	8.848	8.617	10.464	10.700	11.387	11.769	12.734	12.490	11.477	10.900	9.838	9.016	128.236	15.101	13.3
ILLINOIS	83.439	77.984	91.329	91.662	95.376	86.261	88.766	101.729	91.871	93.284	87.182	86.191	1.096.000	88.984	8.8
INDIANA	53.284	48.794	68.954	60.663	84.280	55.060	67.896	58.186	61.194	82.618	59.172	66.118	726.928	-9.703	-1.3
IOWA	24.384	22.768	27.239	28.667	31.222	31.447	85.112	32.837	29.308	28.907	27.677	26.248	376.714	22.790	6.6
KANSAS	20.817	18.127	23.336	24.162	26.973	28.038	54.368	28.318	23.606	24.468	23.178	22.393	314.068	5.661	1.8
KENTUCKY	36.430	38.234	41.180	42.404	44.021	43.286	43.363	43.873	40.200	41.671	38.144	38.927	488.662	-26.766	-5.0
LOUISIANA	31.316	28.443	32.777	32.890	33.865	32.580	32.777	32.666	30.080	30.288	28.367	27.570	374.698	-247	-0.1
MAINE	7.874	7.862	8.366	9.334	9.896	10.414	10.347	11.082	8.966	9.156	7.663	9.501	111.378	-12.202	-9.8
MARYLAND	26.878	26.221	29.449	30.294	31.090	31.074	32.361	32.387	29.062	30.010	28.789	27.662	364.729	-678	-0.2
MASSACHUSETTS	19.732	17.960	21.641	21.488	22.825	23.961	24.476	24.688	22.248	22.091	20.764	20.309	262.061	-28.632	-9.8
MICHIGAN	39.824	38.242	43.819	43.940	47.147	48.109	48.966	60.408	45.971	46.346	43.469	40.518	534.648	-822	-0.2
MINNESOTA	24.720	23.048	28.450	27.363	29.671	30.407	31.845	31.710	28.634	28.969	26.335	26.880	334.610	-1.040	-0.3
MISSISSIPPI	22.186	22.098	27.811	24.334	28.463	30.077	32.407	31.228	26.137	28.534	27.068	24.987	328.349	7.168	2.2
MISSOURI	43.384	40.413	47.841	48.606	63.240	64.260	66.687	66.608	60.813	62.299	47.486	45.978	694.302	-64.074	-8.6
MONTANA	8.674	8.160	8.684	10.191	11.181	12.121	12.985	12.873	11.081	10.579	8.489	8.448	126.348	4.429	3.7
NEBRASKA	16.708	14.429	17.601	18.086	20.134	20.618	21.741	21.346	16.760	18.724	18.630	16.301	220.284	9.817	4.7
NEVADA	10.016	9.144	10.896	10.798	10.964	11.720	12.434	12.724	10.850	11.615	10.809	10.438	132.138	2.178	1.7
NEW HAMPSHIRE	3.868	3.677	4.141	4.099	4.498	4.700	4.881	5.196	4.477	4.462	3.834	3.828	51.768	-8.507	-14.1
NEW JERSEY	33.883	30.968	36.700	34.659	38.207	36.714	38.926	37.058	35.193	36.461	34.380	33.830	422.488	-32.873	-7.2
NEW MEXICO	17.277	16.087	18.947	17.767	19.469	19.748	19.837	20.326	17.878	19.793	17.493	17.877	222.698	14.283	6.9
NEW YORK 3/	83.872	58.714	68.803	69.646	78.880	76.391	80.206	82.289	72.488	76.133	68.170	67.396	868.648	148.006	20.6
NORTH CAROLINA	48.398	47.201	62.180	61.043	66.488	66.883	64.984	66.617	60.867	64.284	48.770	47.892	627.676	5.816	1.0
NORTH DAKOTA	8.618	5.783	6.984	7.994	8.717	8.782	9.126	9.191	8.242	8.326	7.273	8.708	93.126	-303	-0.3
OHIO	73.197	68.606	81.821	79.891	82.014	84.426	87.614	89.248	80.374	82.110	77.768	78.068	864.868	-88.762	-8.2
OKLAHOMA	31.239	29.220	34.371	34.166	38.844	37.193	37.299	36.678	33.423	34.660	34.330	32.764	412.127	19.863	5.1
OREGON 4/	23.882	21.898	27.929	27.897	29.828	31.363	33.319	32.708	30.608	28.876	26.777	24.098	338.960	23.416	7.4
PENNSYLVANIA	68.941	66.680	78.859	77.612	81.890	81.424	83.764	86.082	78.723	82.170	76.207	72.388	931.830	4.924	0.5
RHODE ISLAND	2.813	2.837	3.278	3.362	3.674	3.728	4.001	3.881	3.468	3.438	3.186	3.172	40.827	-12.694	-23.8
SOUTH CAROLINA	30.804	31.021	38.599	36.768	36.726	36.473	37.909	38.079	36.418	36.303	33.430	33.007	422.826	14.834	3.6
SOUTH DAKOTA	6.811	6.327	7.286	7.881	9.233	10.231	10.978	10.989	8.738	8.087	7.418	8.831	100.902	7.136	7.8
TENNESSEE	46.867	42.866	48.981	51.813	54.770	61.730	66.134	67.322	49.724	60.697	61.244	49.238	607.876	17.686	3.0
TEXAS	114.866	109.822	126.083	121.232	124.084	121.660	125.225	125.784	115.384	114.243	116.089	113.673	1.428.266	-4.306	-0.3
UTAH	13.678	12.818	16.063	14.818	16.606	16.976	16.601	15.809	16.461	16.506	14.420	14.283	180.927	18.987	11.7
VERMONT	3.186	2.967	3.298	3.277	3.605	3.762	3.942	4.062	3.641	3.696	3.227	3.202	41.861	-4.893	-10.6
VIRGINIA	41.890	38.128	46.123	45.341	48.068	49.374	49.318	60.611	45.777	44.741	42.344	43.643	544.983	-31.688	-5.5
WASHINGTON	27.118	24.468	30.786	23.811	32.092	32.491	34.833	36.032	31.729	29.567	28.824	26.428	363.028	-1.626	-0.4
WEST VIRGINIA	14.520	13.880	16.024	13.429	17.065	16.930	17.123	17.412	16.626	16.362	16.176	15.291	192.826	12.313	6.8
WISCONSIN	30.748	28.798	33.864	35.274	40.243	40.864	43.628	43.383	39.533	38.823	38.028	32.612	443.898	10.738	2.6
WYOMING	11.398	10.660	13.987	13.626	16.834	17.319	18.210	19.122	16.029	14.898	12.812	11.829	178.724	6.902	4.1
TOTAL	1.611.706	1.617.683	1.780.358	1.788.583	1.879.940	1.888.696	2.011.140	1.971.165	1.782.099	1.806.893	1.688.493	1.666.165	21.398.904	124.218	0.6
PERCENTAGE	7.53	7.09	8.32	8.36	8.78	8.83	9.40	9.21	8.33	8.44	7.94	7.78	100.00	-	-

1/ THIS TABLE IS ONE OF A SERIES (MF-21 THROUGH MF-26) GIVING AN ANALYSIS OF MOTOR-FUEL CONSUMPTION BASED ON REPORTS FROM STATE MOTOR-FUEL TAX AGENCIES. SPECIAL FUELS AS SHOWN IN TABLE MF-26 CONSIST PRIMARILY OF DIESEL FUEL WITH SMALL AMOUNTS OF LIQUEFIED PETROLEUM GASES. HIGHWAY USE OF SPECIAL FUELS IS REPORTED BY THE STATES. IN ORDER TO APPROXIMATE ACTUAL USE, THE MONTHLY DISTRIBUTIONS ARE ESTIMATED BY THE FEDERAL HIGHWAY ADMINISTRATION USING TRAVEL DATA.

2/ FOR SOME STATES, DATA ARE NOT COMPARABLE TO P[illegible] YEARS DUE TO CHANGES IN DATA ANALYSIS AND/OR IMPROVEMENTS IN REPORTING PROCEDURES.

3/ PRELIMINARY DATA.

4/ VEHICLES CONSUMING SPECIAL FUELS AND PAYING MILEAGE TAX TO THE PUBLIC UTILITY COMMISSIONER ARE NOT REQUIRED TO PAY THE GALLONAGE TAX. GALLONAGE REPORTED HERE INCLUDES MOTOR FUEL CONSUMED BY VEHICLES THAT PAY THE MILEAGE TAX. THIS GALLONAGE IS ESTIMATED BY THE STATE

Table 3-6

Highway use of gasoline by months - 1990[1]

COMPILED FOR THE CALENDAR YEAR
FROM AN ANALYSIS OF MOTOR-FUEL USE

(THOUSANDS OF GALLONS)

TABLE MF-28
OCTOBER 1991

STATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL 2/	CHANGE FROM 1989	
														GALLONS	PER-CENT
ALABAMA	166.438	148.466	175.764	174.328	181.514	160.076	187.067	184.593	165.703	169.399	184.877	168.319	2.065.919	-3.957	-0.2
ALASKA	18.036	15.113	18.774	20.191	21.726	22.813	23.378	23.190	20.805	20.427	16.872	17.027	238.161	34.011	16.8
ARIZONA	134.303	130.373	143.958	134.969	138.561	138.661	137.907	141.609	132.337	140.691	131.191	133.486	1.637.846	-81.847	-4.8
ARKANSAS	91.329	88.072	101.000	102.203	107.881	103.260	110.031	107.379	97.268	103.046	98.471	92.091	1.203.811	-18.948	-1.4
CALIFORNIA	958.289	922.180	1.104.064	1.084.842	1.126.828	1.120.706	1.158.094	1.183.464	1.068.911	1.046.410	986.220	1.031.048	12.808.065	-168.016	-1.3
COLORADO	112.829	105.079	122.070	120.201	131.460	135.186	140.254	143.234	128.479	126.094	112.978	112.531	1.490.476	11.481	0.8
CONNECTICUT	97.628	92.422	106.220	109.756	114.661	114.681	117.024	120.641	111.298	110.908	103.878	102.836	1.301.716	-43.941	-3.3
DELAWARE	23.173	22.010	25.767	26.399	29.490	30.888	34.246	33.680	29.225	27.829	26.767	24.104	332.478	-3.878	-1.2
DIST. OF COL.	11.271	14.830	14.019	12.845	14.102	14.700	12.116	12.927	14.797	16.790	13.572	14.884	165.613	-8.963	-5.1
FLORIDA	469.196	467.039	538.356	509.020	493.860	491.815	480.449	482.781	458.876	476.786	471.703	481.615	5.830.693	9.978	0.2
GEORGIA	263.440	236.326	279.668	297.625	304.436	305.818	315.659	320.333	293.724	295.108	274.718	276.766	3.466.675	-10.139	-0.3
HAWAII	28.474	26.778	30.206	30.242	31.842	31.326	32.769	31.975	29.340	30.206	28.368	29.866	360.888	-2.600	-0.7
IDAHO	32.078	31.242	37.938	38.819	41.283	42.631	46.156	46.281	41.608	39.618	36.867	32.682	464.899	20.360	4.6
ILLINOIS	388.026	362.566	424.890	426.217	443.631	447.605	463.900	473.086	427.236	433.866	406.340	396.174	5.092.208	268.946	5.4
INDIANA	189.774	177.348	209.968	216.864	228.869	233.718	241.813	242.862	217.738	222.664	210.746	199.871	2.589.010	19.209	0.7
IOWA	84.135	78.661	93.988	98.914	107.729	108.607	224.657	113.304	101.117	103.192	96.166	87.117	1.298.381	-17.379	-1.3
KANSAS	78.828	71.890	87.719	90.788	97.836	97.872	204.361	98.934	89.490	91.969	87.128	84.177	1.180.600	-45.214	-3.7
KENTUCKY	132.425	131.713	149.690	154.140	160.012	157.344	167.300	169.480	148.131	161.115	138.866	141.603	1.779.908	-12.328	-0.7
LOUISIANA	149.721	140.768	166.705	167.242	161.897	165.810	166.306	156.168	143.811	144.706	136.672	131.812	1.790.914	-121.427	-6.3
MAINE	40.856	40.740	48.640	48.426	61.646	64.030	63.684	67.498	46.818	47.801	39.257	49.281	677.864	702	0.1
MARYLAND	147.770	139.714	163.097	167.813	178.856	172.137	179.211	179.407	180.938	168.241	168.363	162.883	1.986.028	-66.876	-3.3
MASSACHUSETTS	176.766	169.311	191.892	191.428	203.391	213.370	218.038	219.904	198.198	196.796	184.890	180.920	2.334.468	-85.045	-3.6
MICHIGAN	308.750	280.988	338.163	340.639	385.604	372.963	379.693	390.783	368.387	369.288	338.910	314.118	4.144.034	-42.139	-1.0
MINNESOTA	138.383	129.020	148.120	163.178	165.636	170.218	177.144	177.620	169.730	182.164	147.746	145.814	1.872.667	-81.830	-4.2
MISSISSIPPI	80.866	80.628	101.346	96.981	107.328	109.601	110.097	113.789	95.243	105.977	98.753	91.066	1.196.622	4.867	0.4
MISSOURI	196.979	182.668	218.114	223.631	240.645	245.108	261.016	260.746	229.537	238.249	214.503	198.884	2.684.847	26.812	1.0
MONTANA	28.422	26.738	31.338	33.391	38.638	39.718	42.660	42.181	38.307	34.686	31.091	27.863	410.718	2.412	0.6
NEBRASKA	62.748	48.467	69.310	68.738	67.618	69.245	73.019	71.687	63.032	62.884	66.621	54.748	759.805	7.087	1.0
NEVADA	47.631	43.397	61.418	61.230	61.983	65.620	69.006	60.384	60.641	56.118	51.293	49.597	627.063	17.028	2.8
NEW HAMPSHIRE	38.886	34.101	39.480	39.088	42.866	44.810	46.538	49.660	42.689	42.640	37.606	37.467	493.609	-20.868	-4.1
NEW JERSEY	282.661	240.088	278.760	267.907	280.880	284.810	286.248	293.461	272.819	282.644	286.697	280.701	3.276.142	-117.231	-3.5
NEW MEXICO	80.306	66.187	87.633	62.016	87.921	68.932	69.243	70.966	82.404	69.087	60.849	61.706	777.137	-7.404	-0.9
NEW YORK 3/	432.348	397.434	472.499	470.763	619.061	510.322	542.908	656.873	490.638	608.678	481.443	456.208	6.018.961	278.034	5.0
NORTH CAROLINA	262.897	241.469	288.825	276.467	283.843	265.769	261.274	289.822	280.724	277.742	249.487	244.991	3.210.880	-6.830	-0.2
NORTH DAKOTA	21.707	19.258	23.268	24.827	29.026	29.242	30.390	30.609	27.444	27.724	24.219	22.608	310.104	-9.066	-2.8
OHIO	350.671	326.371	392.196	382.946	393.120	404.882	419.482	427.807	386.257	393.683	372.771	374.158	4.624.942	-112.984	-2.4
OKLAHOMA	122.766	114.818	136.063	134.263	144.779	146.912	148.569	144.137	131.338	136.198	134.901	126.747	1.619.464	27.966	1.8
OREGON	82.826	84.994	108.414	108.878	116.780	121.701	129.352	128.964	118.412	111.308	103.940	93.648	1.316.692	-2.401	-0.2
PENNSYLVANIA	351.370	317.602	371.883	374.818	396.990	393.738	404.999	418.283	380.872	397.341	368.609	360.038	4.606.001	-49.539	-1.1
RHODE ISLAND	24.868	26.072	28.988	29.617	32.488	32.936	36.364	34.379	30.655	30.376	28.138	28.030	360.740	-6.619	-1.6
SOUTH CAROLINA	129.142	129.672	152.992	163.699	153.622	162.462	168.489	169.176	148.046	151.756	139.742	137.978	1.788.852	49.646	2.9
SOUTH DAKOTA	24.178	22.458	26.881	28.333	32.774	36.321	38.971	39.005	31.019	28.891	28.327	24.249	368.187	-909	-0.3
TENNESSEE	188.483	170.620	184.648	206.668	217.028	206.833	219.978	228.068	187.851	201.721	203.898	196.918	2.418.720	-78.463	-3.1
TEXAS	681.290	660.880	741.304	718.482	736.388	721.018	742.160	746.634	683.828	677.064	682.136	673.682	8.462.733	122.188	1.6
UTAH	62.870	49.932	68.184	67.276	69.933	61.761	63.779	64.987	59.723	59.933	55.797	65.247	749.331	-24.064	-3.3
VERMONT	21.261	19.798	22.006	21.866	24.044	25.106	26.308	27.078	24.296	24.868	21.630	21.382	279.248	8.788	3.2
VIRGINIA	224.778	210.969	243.290	244.486	258.168	265.208	266.916	272.380	248.618	241.233	228.304	234.768	2.838.282	-11.973	-0.4
WASHINGTON	168.853	160.367	189.186	183.386	197.216	199.671	212.833	216.288	194.986	181.823	177.136	162.414	2.250.968	-7.562	-0.3
WEST VIRGINIA	61.258	58.979	67.802	64.310	71.996	71.426	72.239	73.468	69.717	68.984	64.023	64.511	813.499	8.586	1.1
WISCONSIN	139.282	130.420	153.329	159.769	182.266	186.080	197.136	196.614	179.061	176.838	163.176	147.701	2.009.548	-6.070	-0.3
WYOMING	18.207	18.863	22.367	21.786	25.294	27.684	30.806	30.843	26.804	23.797	20.457	19.054	282.290	-16.146	-5.4
TOTAL	8.353.216	7.881.983	9.215.203	9.206.626	9.667.826	9.702.391	10.226.016	10.131.097	9.176.100	9.288.190	8.747.556	8.612.052	110.184.150	-356.470	-0.3
PERCENTAGE	7.58	7.14	8.36	8.36	8.77	8.80	9.28	9.19	8.33	8.43	7.94	7.82	100.00	-	-

1/ THIS TABLE IS ONE OF A SERIES (MF-21 THROUGH MF-26) GIVING AN ANALYSIS OF MOTOR-FUEL CONSUMPTION BASED ON REPORTS FROM STATE MOTOR-FUEL TAX AGENCIES. HIGHWAY USE OF GASOLINE WAS ESTIMATED BY THE FEDERAL HIGHWAY ADMINISTRATION (FHWA) BY SUBTRACTING NONHIGHWAY USE FROM TOTAL USE. IN ORDER TO MAKE THE DATA UNIFORM AND COMPLETE, NONHIGHWAY USES OF GASOLINE WERE ESTIMATED BY FHWA OR DATA WERE OBTAINED FROM OTHER SOURCES. THE RESULTING GALLONAGES DIFFER IN MANY INSTANCES FROM THE UNADJUSTED DATA RECORDED IN TABLE MF-2. IN ORDER TO APPROXIMATE ACTUAL USE, THE MONTHLY DISTRIBUTIONS WERE ESTIMATED BY FHWA USING TRAVEL DATA. THE ENTRIES IN TABLE MF-28 WILL NOT AGREE WITH THOSE IN TABLE MF-33GA. TABLE MF-28 SHOWS HIGHWAY USE ONLY WHILE TABLE MF-33GA REFLECTS GROSS GALLONS OF GASOLINE REPORTED BY WHOLESALE DISTRIBUTORS TO THE STATE TAXING AGENCIES EACH MONTH. GASOHOL IS INCLUDED WITH GASOLINE.

2/ FOR SOME STATES, DATA ARE NOT COMPARABLE TO PRIOR YEARS DUE TO CHANGES IN DATA ANALYSIS AND/OR IMPROVEMENTS IN REPORTING PROCEDURES.

3/ PRELIMINARY DATA.

Travel Demand Network Models

A common and highly useful information source for the preparation of the baseline inventory is a transportation planning model run configured to the same base year (1990). With this tool one is able to combine the appropriate travel estimates with emission factors developed by MOBlLE4.1 to prepare an estimate of the emissions inventory. In addition, network model results can be used to develop certain critical inputs to the emission factor program. These include speeds, vehicles' operating conditions, trip starts, trip ends, number of trips per day per vehicle, and vehicle mix. In addition, network models can be used to spatially and temporally allocate VMT, and therefore emissions, within the non-attainment area. However, since EPA and DOT have both endorsed the Highway Performance Monitoring System as the most appropriate means by which to measure VMT, the VMT estimates produced by the transportation planning process should be made consistent with HPMS.

Generally, local air quality agencies do not operate the transportation planning models themselves so that they must work with the agencies responsible for the operation of such models. The initial development of new transportation planning model runs requires a substantial effort.

An important element of the transportation planning process is an assessment of the regional highway network. An extensive effort is required to collect and integrate the information needed to assess how the network is currently' used and where growth will occur in the future. The mathematical models used to assess the effects of growth on the highway network allow the transportation analyst to evaluate the improvements' that are needed and when they should be constructed. From the perspective of air quality, important products of these models are estimates of VMT and speed on each of the links coded into the highway network.

Basic requirements of the transportation planning process are an understanding of where travel occurs, what factors stimulate it, and how demand is satisfied. The Federal Highway Administration and the Federal Transit Administration (FTA) developed a series of models to help communities satisfy these requirements. Historically, the most frequently used model has been the Urban Transportation . Planning System (UTPS).[48] In recent years many variations of the UTPS have been developed in the private sector as Federal funding for the model decreased and sufficiently powerful microcomputers became available.“'

Responsibility for implementing and operating transportation planning models generally falls into two categories: metropolitan planning organizations and state Departments of Transportation. In some cases, transportation or planning agencies within communities operate the models. Responsibility for 'operating the models generally falls outside of the jurisdiction of the air quality planning agency. Thus, the development of an emissions inventory for an urban area requires a cooperative effort between the air quality agency and the relevant transportation planning agency.

Despite the fact that air quality planners are not responsible for operating the highway network models, it is important that they have an understanding of the principles guiding the operation of the models and the information that they generate. A transportation planner should be actively involved

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[48] Supplement 1 to "Methodology to Calculate Emission Factors for On-Road Motor Vehicles", California Air Resources Board, Technical Support Division, January 1988.

[49] UTPS as a computer system is no longer supported by either FHWA or PTA. However; although some of the conventions used by UTPS may not be identical to those used by the other UTPS-type programs, they are similar, since, generally, UTPS served as the prototype for these other programs.

in both generating and assessing the travel information used to prepare a highway emissions inventory estimate.

UTPS-type models consist of manual and computerized planning procedures that provide decision-makers with information on long-range transit and roadway travel patterns. UTPS-type computer-based packages allow planners to simulate the operation of a transportation system to determine what would happen if population and economic activity increased and/or if changes were made in either the roadway or transit networks. When population, economic activity, and roadway and transit network inputs are matched to historical conditions, an estimate of VMT for that year is produced. The estimate, however, is based on many assumptions and estimates, not on direct observation of travel in that year. UTPS-type computer packages consist of a number of programs that parallel steps in the transportation planning process. In general, this process involves the following major steps:

- Representation of the roadway or transit system;
- Estimation of the number of current and future drivers and transit riders, the numbers of trips of various types they will choose to take in a typical day, and their trip origins and destinations;
- Assignment of trips to appropriate roads and transit routes; and
- Preparation of maps, tables and graphs to display results and compare different transportation alternatives.

The capabilities of a UTPS-type package include estimation of the impacts of long-range land development, transportation system costs, travel demand, and major facility and corridor travel volumes. The package has been characterized as "data hungry". For most applications, planners must prepare a description of the roadway and/or transit networks as well as detailed demographic and economic forecasts. In addition, policy makers must agree on transportation alternatives to be tested and identify the impacts about which they are interested. Depending on the complexity of problems to be addressed, the availability of raw data, and the experience of the analytical staff, preparing initial inputs for a UTPS-type model can take from two months to over two years. The following discussion provides a more detailed overview of steps involved in configuring a UTPS-type package to a community.

The development of a realistic abstraction of the existing highway and/or transit network is the most time-consuming step required to implement a UTPS-type package. A network describes the characteristics of roads or transit lines to the computer in the same way a map describes roads to a driver.

Exception to the Use of HPMS VMT

Since 1990 ground counts submitted to HPMS may not be as comprehensive and of as high a quality as FHWA intends all states to obtain for 1993 and later and since it may be possible for network-based travel demand models to be validated for 1990, this guidance allows for the use of travel demand models to estimate 1990 VMT under certain circumstances. However, this method is not considered to be viable for most areas due to the general disrepair of a large number of network models. Areas should use this method only if their network model is particularly strong and their 1990 HPMS data are particularly weak, and only after consulting with EPA.

An affected area with a strong network-based travel demand model that is based on reasonably recent demographic trip-making data may use its model to estimate 1990 VMT under the following conditions:

- Urban areas within the state were not sampled separately under HPMS in 1990;
- The state Department of Transportation did not adequately follow HPMS guidance in 1990, resulting in poor quality traffic counts;
- The state has made substantial progress in preparing its 1990 inventory using a network-based model and does not have the time and resources to switch approaches and still meet the Clean Air Act expectations for the November 1992, 1993, and 1994 SIP submittals.

An area using this method should make sure that all VMT in the entire non-attainment area is included in the estimate. Most network-based models normally do not assign intra-zonal trips, VMT on some local roads, or trips on functional classes outside of the modeling area. States may use any reasonable method to estimate VMT on those functional systems that are within the non-attainment area but that are not included in the model.

4. Emissions from nonroad sources

Nonroad sources include motorized vehicles and equipment which are normally not operated on public roadways to provide transportation. Section 213(a) of the 1990 Clean Air Act directs EPA to conduct a study of emissions from nonroad engines and vehicles in order to determine if such emissions cause, or significantly contribute to, air pollution which may be reasonably anticipated to endanger public health or welfare. This study was completed in November 1991.[50] The Clean Air Act also requires EPA to regulate emissions from nonroad engines and vehicles within 12 months after completion of the study if EPA makes a determination that these sources are significant contributors to concentrations of ozone or carbon monoxide (CO) in more than one area which has failed to attain the National Ambient Air Quality Standards (NAAQS) for these pollutants.

This chapter summarizes and discusses information from several studies, which EPA used to define emission factors and inventories for nonroad equipment. It also discusses work updating and expanding nonroad equipment inventories for use by state and local agencies. The nonroad inventories for the 24 non-attainment areas in the November 199 1 EPA nonroad report are presently being updated to include areas that are within the recently redefined non-attainment boundaries. Inventories will also be compiled for nine additional areas. The ten nonroad equipment categories are listed below.

- Lawn and Garden Equipment
- Agricultural Equipment
- Logging Equipment
- Light Commercial Equipment
- Industrial Equipment
- Construction Equipment
- Airport Service Equipment

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[50] US. Environmental Protection Agency. Nonroad Engine and Vehicle Emission Study, Report and Appendices, EPA-21A-2001, Washington, D.C., Office of Air and Radiation, November 1991.

- Recreational Equipment
- Recreational Marine Equipment
- Commercial Marine Vessels

A description of these categories, including the 79 equipment types within them, can be found in Appendix B of this chapter. In general, each equipment type comes in three possible engine types: diesel, 4-stroke, and 2-stroke. However, for some types of equipment, there are no two-stroke engines, but units fueled by propane or CNG are in service. For simplicity, propane and CNG equipment is included in the 2-stroke engine type tables, but with their correct emission factors when operated on gaseous fuel.

Inventory Options

In its nonroad report[51], EPA developed two emission inventories for the first nine categories listed above and a single inventory for the tenth. The first nine categories consist of nonroad engines and vehicles for 24 areas. Inventories for the last equipment category (commercial marine vessels) are only approximate and available for only six areas.

For the first inventory, designated as Inventory A, EPA used commercially and publicly available data so that the method could be repeated by state agencies and other groups. EPA used confidential industry-supplied sales and other data, which are not publicly available, for the second inventory, Inventory B. The second inventory provided EPA with a cross check for the first inventory results. Both inventories agreed reasonably well.

EPA has contracted with Energy and Environmental Analysis, Inc. to update the nonroad equipment inventories based on new non-attainment boundaries for ozone and carbon monoxide for the 24 areas in the nonroad report. These areas, which were selected to be geographically representative of areas with significant air pollution problems, are defined as metropolitan statistical areas (MSAs), consolidated metropolitan statistical areas (CMSAs), north east county metropolitan areas (NECMAs), or air basins. The exact definitions of these terms can be found in the State and County Metropolitan Area Data Book, U.S. Bureau of the Census, 1986.

Air quality non-attainment boundaries, established by the Office of Air Quality Planning and Standards, are defined in the November 6, 1991, Federal Register Notice[52]. A county or MSA/CMSA was divided if a state and/or local government could show that sources in a part of the county or MSA/CMSA did not contribute significantly to violations of the ambient standard.

In addition, EPA is developing inventories for nine additional areas. With these additional areas, EPA will have determined nonroad inventories for all moderate-2 or worse non-attainment areas for CO (greater than 12.7 ppm), all the areas in serious or worse non-attainment for ozone (16.0 ppm or greater), and several miscellaneous areas.

Limited data for commercial marine vessels can be found in the EPA nonroad report for six areas. The three types of commercial vessels include harbor, ocean-going, and fishing vessels.

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[51] U.S. Environmental Protection Agency. Nonroad Engine and Vehicle Emission Study, Report and Appendices, EPA-21A-2001, Washington, D.C., Office of Air and Radiation, November 1991.

[52] U.S. Environmental Protection Agency. Designation of Areas for Air Quality Planning Purposes, 40 CFR Part 81, Final Rule, Washington, D.C., Office of Air and Radiation, November 6, 1991.

Explanation of EPA Provided Inventory

Nonroad emission inventories have been calculated for 33 areas, including all areas that are serious and above for ozone and moderate-2 and above for carbon monoxide. The inventories can be used in mm to develop the Area and Mobile Source (AMS) inputs for the Aerometric Information and Retrieval System (AIRS). The AMS inputs can in turn be used to recreate nonroad inventories. Since the AMS methodology is the official way to calculate and document the inventory, the use of AMS inputs is needed.

The following general information is included in the overall EPA nonroad inventory tables:

- Equipment population (for ozone and CO non-attainment areas)
- Emission factors (g/hp-hr, g/hr, g/gal, g/day)
- Hours&ear (gallons/year in some cases)
- Average horsepower
- Average load
- Evaporative emission season (229 days)
- 1/SAF[53] (tons per year/tons per summer day)
- l/SAP (tons per year/tons per winter day)
- VOC tons per summer day (ozone non-attainment area)
- NOx tons per summer day (ozone non-attainment area)
- CO tons per summer day (ozone non-attainment area)
- CO tons per winter day (CO non-attainment area)
- Particulates tons per year
- Population (human) and tons/person

Each non-attainment area is broken down into individual counties and, where appropriate, portions of counties that are included within the non-attainment boundaries (i.e., townships and boroughs). The above information is given as needed for each county or sub-county, as well as the non-attainment area as a whole. The sub-county boundaries are defined in the November 6, 1991, 40 CFR Part 81.[54]

Emission factors are given for 79 equipment types and include VOC, CO, NOx, and particulates. VOC emissions are divided into the following subcategories:

- exhaust
- evaporative
- crankcase
- refueling

These emission factors are derived from EPA and other test data with appropriate extrapolations to the different equipment types. Evaporative emissions presently include only diurnal emissions assumed to occur for 229 days of the year. Note that particulate inventories are being

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[53] SAF stands for seasonal adjustment factor. The columns 1/SAF are taken directly from the spread sheets used for the EPA nonroad report. Although, SAF itself is in units of tons per seasonal day/tons per year and is used to multiply the annual inventory to obtain seasonal tons/day.

[54] U.S. Environmental Protection Agency. Designation of Areas for Air Quality Planning Purposes, 40 CFR Part 81, Final Rule, Washington, D.C., Office of Air and Radiation, November 6, 1991.

calculated simply because the information is available. These calculations are only being done for ozone and CO non-attainment boundaries, rather than the specific boundaries for PM,,. The reason for this is that the emphasis of the present work is on ozone and CO non-attainment. A sample inventory calculation using the given information is shown in Appendix 4-C.

It is important to note that the definition of VOC excludes methane and ethane but includes formaldehyde and acetaldehyde. Instead of VOC, the 1991 EPA nonroad report contains total hydrocarbons (THC, as measured by a flame ionization detector), which includes methane and ethane but excludes formaldehyde and part of acetaldehyde. In the process of revising the emission inventories for the original 24 areas and developing inventories for the additional areas, THC has been converted into VOC for 4-stroke and diesel equipment using a correction factor. This is being done in order for the data to be compatible with AMS. For 2-stroke engines it is being assumed that THC is equivalent to VOC (that is, a THC to VOC correction factor of 1.00). One reason for this assumption is that 2-stroke emissions contain significant amounts of unburned fuel, for which THC and VOC are the same, compared to 4-stroke engines. Another reason is that no quantitative data exists on methane, ethane, and aldehyde emissions from 2-stroke engines.

The seasonal adjustment factor is provided to calculate winter and summertime inventories for VOC, CO, NOx, and particulates. The annual inventories are adjusted so that the output is in tons per summer day (tpsd) for the ozone non-attainment areas. Emission inventories for CO are also adjusted so that the output is in tons per winter day (tpwd) for the CO non-attainment areas.

For each CMSA, tables are available in hard copy (paper) or on disk in a text or Lotus format. Again, separate information is given for 2-stroke, 4-stroke, and diesel engines. All 79 equipment types spanning 9 nonroad engine categories are included. However, as mentioned earlier, the commercial marine vessel category is not included.

Another important point to make on the eventual application of these data is that diesel, 4-stroke, and 2-stroke engine emissions all have different exhaust HC speciations. The 4-stroke gasoline and diesel engines can use the standard EPA motor vehicle speciations. For the present time, we recommend that the standard EPA speciation for non-catalyst gasoline engines also be used for 2-stroke and propane engines. In addition, evaporative emission speciation differs from exhaust, consisting of more volatile fuel components with no combustion products. However, in order to keep inventory speciation simpler, the two categories are being combined based on the relative amounts of exhaust and evaporative emissions for the 2-stroke and 4-stroke engines.

The AMS system has the following five mandatory inputs.

- Annual activity level (hp-hr, gal, hrs, day)
- Emission factor (g/hp-hr, g/gal, g/hr, g/day)
- Period throughput (% annual activity based on emission mass during 3 month period)
- Adjustment factor? (weekday, Saturday, Sunday, operating fractions)
- Category operating parameters

The first two inputs have to be compatible so that one can calculate overall emissions. The EPA nonroad report generally gives exhaust emissions in g/hp-hr units but sometimes they are given

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[55] Adjustment factors are not mandatory for calculations to proceed in AMS, but should be provided if modeling will be done.

in g/gal and g/hr units. Evaporative emissions are in g/day but can be artificially converted into one of the above units by knowing how many horsepower-hours, gallons, or hours of operation occur each day.

Item #1, the annual activity level for an equipment type, has to be the sum of all activity within an area (that is, equipment type population times activity per unit piece of equipment) rather than activity per unit equipment type, as given in the EPA nonroad report Therefore, these levels will be greatly different from one area to another. It is important to note that the activity levels will be different for each county or portion of a county within a non-attainment area due to the changes in equipment population from one county to another.

Item #2, emission factors, are directly available from the November 1991 EPA nonroad study for CO and NOx. Approximate factors arc available for particulates. These factors are in g/hp-hr, g/gal, and g/hr. The underlying emission factors are the same for all non-attainment areas. However, as with motor vehicles, there are separate emission factors for exhaust, crankcase, evaporative (diurnal), and refueling VOC. In addition, there will eventually be information on evaporative (hot soak), running loss, and resting loss HC. There is no nonroad emission factor model, such as MOBILE 4.1, to combine exhaust and evaporative emissions that are in different units. The nonroad report multiplies each emission factor by the appropriate activity level to compile the composite VOC inventory.

For development of the base year inventory and for AMS data entry, a single composite emission factor for VOC, combining the different sources of VOC (i.e., evaporative versus exhaust), is being provided. This composite factor is being created by dividing the total VOC in annual tons by the activity levels. The total evaporative inventory, which is dependent only on equipment population and days per year, is divided by activity levels (hp-hr, hours, or gallons of fuel) as one part of the emission factor. Since this particular fraction (evaporative inventory/activity level) will vary from area to area, the overall Item #2 VOC emission factors will vary slightly from one area to another.

Item #3, period throughput, is the percent of annual activity occurring in the 3 month summer and winter periods. This is being calculated from the EEA infoxmation for summer and winter. The tons per winter day and tons per summer day are being compared to tons per year in deriving these factors. The throughput is based on emission tons rather than activity level. Therefore, it is compatible with the annual emission factors in calculating summer and winter inventories.

Item #4, adjustment factors, account for activity variation in different periods of the week (weekdays, Saturdays, Sundays). EPA has no quantitative information here. EPA recommends the same treatment that is implicit in the November 199 1 nonroad report, assuming all nonroad activity is distributed equally over every day of the week. For this case, the adjustment factor is 1.0. This is an approximate assumption and, in the aggregate, may be justified because some categories (e.g., construction equipment) operate mostly during the week while others (e.g., recreational equipment and recreational marine equipment) operates largely on weekends. The states may use their own judgement or data to assign other factors.

Item #5, category operating parameters, are days/week and weeks/year for equipment operation. The states should assume that the equipment operates seven days/week and 52 weeks/year. This is an artificial treatment which will make the calculations work out properly, since the period throughput already accounts for weeks/year because it is emission weighted.

General Methodology Used In Deriving; Emission Inventories

This section explains the methodology developed and used by EEA and EPA to update emission inventories for a given non-attainment area from the 1991 EPA nonroad report. Much of the information in this section has been taken directly from an EEA draft report entitled, “Methodology to Estimate Nonroad Engine and Vehicle Emission Inventories at the County and Sub-County Level,” which gives information primarily for the New York area and describes the methodology planned for use for the other areas? This methodology is frequently generic in nature with extrapolations being made to smaller areas from equipment populations in larger areas.

The following inputs are used to develop nonroad emission inventories.

- The equipment populations in a given area;
- The annual hours of use of each type of equipment adjusted for geographic region and for the season of interest for each pollutant studied;
- The average rated horsepower of each type of equipment;
- The typical load factor for each type of equipment;
- An emission factor (EF).

The emission factor is defined as the' average emissions of each pollutant per unit of use (gram/horsepower-hour) for each category of equipment. In order to calculate emission factors for nonroad equipment, EPA compiled and used data from past tests and studies, as well as new data supplied to EPA from engine manufacturers. Using these data, EPA developed emission factors for tailpipe exhaust, refueling, evaporative, and crankcase emissions with appropriate adjustments to account for in-use emissions. These emission factors can be found in Appendix I of the EPA nonroad report.[57]

For the EPA nonroad report, EEA estimated equipment populations by CMSA or NECMA using regression analysis of state level populations and activity indicator statistics.[58] EEA relied on Power Systems Research (PSR) as a major source of data for national and state equipment populations, annual hours of use, load factors, horsepower, 2-cycle/4-cycle distributions, and LPG/CNG penetrations. Linear relationships were derived between economic activity indicators and equipment category populations. County-level indicators were summed across each CMSA or NECMA and these sums were plugged into the corresponding fitted regression to arrive at equipment population estimates for each area in the study.

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[56] Energy and Environmental Analysis, Inc. Methodology To Estimate Nonroad Engine and Vehicle Emission Inventories At the County and Sub-County Level, Draft Report to the Environmental Protection Agency. Arlington, Virginia, February 11, 1992.

[57] U.S. Environmental Protection Agency. Nonroad Engine and Vehicle Emission Study, Report and Appendices, EPA-21A-2001, Washington, D.C., Office of Air and Radiation, November 1991.

[58] Energy and Environmental Analysis, Inc. Methodology To Estimate Nonroad Equipment Populations By Nonattainment Areas, prepared for U.S. Environmental Protection Agency, September 1991.

Equipment Categories

Category 1, lawn and garden equipment, includes 14 types of **equipment.**[59, 60] These are mostly powered by small gasoline engines having less than 25 horsepower. Examples of these are listed below.

- lawnmowers
- trimmers
- ♏♎♑♏❒⬧
- brush cutters
- chainsaws

Some larger lawn and garden equipment types, such as those listed below, have diesel engines.

- chippers/grinders
- rear engine riding mowers
- wood splitters
- commercial turf equipment

The main source of data used by EPA in its nonroad report to derive the emission factors for gasoline engines in this category was the California Air Resources Board (CARB) Technical Support Document (TSD).[61] CARB relied on testing done by manufacturers, Southwest Research Institute, and Heiden Associates for the Portable Power Equipment Manufacturers Association (PPEMA). Since there were no emissions data available for the small percentage of lawn and garden equipment that have diesel engines (rear engine riding mowers, lawn and garden tractors, wood splitters/chippers, stump grinders, and commercial turf equipment), the emission factors for diesel light commercial equipment (less than 50 horsepower) were considered to be the substitutes for use in the nonroad equipment study. Please refer to tables I-3 and I-4 in the appendix of the nonroad report for the actual emission factors. The activity indicators used by Energy and Environmental Analysis, Inc. (EEA) for developing lawn and garden equipment populations included the number of single family housing units in a given area and SIC 078 -Landscape and Horticultural Services (Employees).

The agricultural equipment category is comprised of 11 types of equipment. They are listed below:

- tractors
- combines
- swathers
- fertilizer spreaders
- agricultural mowers (> 5 h.p.)
- cotton pickers
- balers
- ⧫♓●●♏❒⬧
- sprayers
- harvesters
- strippers

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[59] U.S. Environmental Protection Agency. Nonroad Engine and Vehicle Emission Study, Report and Appendices, EPA-21A-2001, Washington, D.C., Office of Air and Radiation, November 1991.

[60] Energy and Environmental Analysis, Inc. Methodology To Estimate Nonroad Equipment Populations By Nonattainment Areas, prepared for U.S. Environmental Protection Agency, September 1991.

[61] California Air Resources Board. Technical Support Documents for California Exhaust Emission Standards and Test Procedures for 1994 and Subsequent Model Year Utility and Lawn and Garden Equipment Engines, attachment C to CARB Mailout #90-64, El Monte, California: State of California, December 1991.

Some specialized equipment, such as cotton pickers and strippers have relatively small populations and can only be found in certain areas of the country. For agricultural equipment using gasoline, the emission factors used to calculate emission inventories were from the Fourth Edition of AP-42.[62] The factors found in AP-42 were selected because no other sources had specific emission factors by equipment type for gasoline nonroad equipment. For particulate emission factors for gasoline equipment, a value of 1.64 lb./1000 gallons was used. For diesel agricultural equipment, emission factors were taken from a report by Environmental Research and Technology, Inc. (EAT).[63] Emission factors were given by equipment category. Emission factors for particulate matter were taken from AP-42, Fourth Edition. Table I-07 in the nonroad report presents the chosen emission factors from EAT in grams/horsepower-hour, and table I-08 gives the emission factors converted to pounds/1000 gallons of fuel. EEA used data from the 1987 Census of Agriculture to derive activity indicators for agricultural equipment. SIC 07 - Agricultural Services (Employees), modified to exclude SIC 78 (used for the lawn and garden category), was found to be the best activity indicator for this category.

The logging equipment category includes the following equipments types:

- chainsaws (> 5 h.p.)
- shredders (> 5 h.p.)
- skidders
- delimbers
- fellers
- bunchers
- other miscellaneous equipment

Significant amounts of logging equipment can only be found in parts of the United States where large-scale logging operations take place, such as the Pacific Northwest. Emission factors for this category were taken from the CARB Technical Support Document and data submitted to EPA by the Engine Manufacturers Association (EMA).[64] SIC 241 (Employees) was chosen by EEA as the best activity indicator to distribute logging equipment populations.

Light commercial equipment is categorized as having engines under 50 horsepower. This equipment is used in various wholesaling, retailing, and manufacturing capacities. Examples of this category include various types of the following equipment.

- electrical generators
- pumps
- compressors

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[62] U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors, Volume II, EPA Report No. AP-42, Fourth Edition, Research Triangle Park, North Carolina, Office of Air Quality Planning and Standards, September 1985.

[63] Environmental Research and Technology, Inc. Feasibility, Cost, and Air Quality Impact of Potential Emission Control Requirements on Farm, Construction, and Industrial Equipment in California, Document PA841, sponsored by the Farm and Industrial Equipment Institute, Engine Manufacturers Association, and Construction Industry Manufacturers Association, May 1982.

[64] Ingalls, M.N. Nonroad Emission Factors of Air Toxics, Report No. 08-3426-005. San Antonio, Texas, Southwest Research Institute, February 1991.

Emission factors recommended by SwRI[65] and contained in a report produced by Radian Corporation[66] were used for equipment fueled with diesel in this category. For equipment using gasoline, emission factors for utility and lawn and garden equipment from the CARB Technical Support Document were used.

Somewhat related to the light commercial equipment category, the industrial equipment category includes equipment used in manufacturing and warehousing operations. This category includes the types of equipment listed below.

- forklifts
- boom lifts
- scissor lifts
- industrial sweepers
- scrubbers
- blowers
- vacuums
- scrapers
- winches
- hoists
- conveyors

For both gasoline and diesel industrial equipment, emission factors found in Volume I of AP-42 were used. These factors were developed by SwRI in 1973.[67] EEA use total wholesale activity (number of establishments) as the indicator for the distribution of light commercial equipment populations.

The category of construction equipment includes 27 kinds of equipment.[68, 69] These types are listed below:

- paving equipment
- roofing equipment
- signal boards
- cable layers
- drilling rigs
- excavators
- industrial saws
- ♍❒♋■♏⬧
- cement/mortar mixers
- crushing/processing equipment
- dozers
- backhoes
- loaders
- tractors

The emission factors used for diesel construction equipment were derived from data from EMA. For some types of diesel equipment, EMA emission factors were unavailable. In these cases, EPA used factors from AP-42, Fourth Edition, which were originally derive from the EAT report

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[65] Weaver, C.S. Feasibility and Cost Effectiveness of Controlling Emissions from Diesel Engines in Rail, Marine, Construction, Farm, and Other Mobile Off-Highway Equipment, Final Report for U.S. Environmental Protection Agency. Sacramento, California, Radian Corporation, February 1988.

[66] Hare, CT., and K.J. Springer. Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines, Final Report Part 5, Heavy-Duty Farm, Construction, and Industrial Engines. San Antonio, Texas, Southwest Research Institute, October 1973.

[67] California Air Resources Board, Mailout #90-58. El Monte, California, State of California, September 7, 1990.

[68] U.S. Environmental Protection Agency. Nonroad Engine and Vehicle Emission Study, Report and Appendices, EPA-21A-2001, Washington, D.C., Office of Air and Radiation, November 1991.

[69] Energy and Environmental Analysis, Inc. Methodology To Estimate Nonroad Equipment Populations By Nonattainment Areas, prepared for U.S. Environmental Protection Agency, September 1991.

mentioned earlier.” For the actual emission factors, please refer to Table I-09, which compares the AP-42 and the EMA emission factors, in the appendix of the EPA nonroad report. For gasoline construction equipment, the emission factors which EPA selected came from the fourth edition of AP-42. For particulate matter and aldehyde construction equipment emission factors, EPA used the gasoline and diesel agricultural equipment emission factors. Local construction activity was used by EEA to determine local construction equipment populations.

For airport equipment, only equipment owned by each airline was included (EEA). Airport equipment owned and operated by the airport authority was inventoried within the other categories. This was done to prevent double counting. This category also does not include aircraft engines, which are addressed in elsewhere. Examples of this equipment are listed below.

- load lifters
- de-icing equipment
- heating units
- utility service equipment
- starting units
- baggage conveyors
- towing/pushback tractors
- misc. service vehicles

The emission factors for industrial equipment were also applied to airport service equipment. Air carrier operations, including certified carriers, air taxis, supplemental air carriers, commercial operators of large aircraft, and air travel clubs, were used by EEA as the activity indicator for determining local airport equipment populations.

The recreational category includes a varied array of equipment. Examples of these are listed below:

- all terrain vehicles (ATVs)
- minibikes
- snow and ice maintenance equipment,
- go-carts
- gasoline powered golf carts
- snowmobiles
- industrial personnel carriers/ATVs

Some equipment in this category is limited to certain specific areas or regions. Golf carts are mostly found in resorts and golf courses. Snowmobiles and snow/ice maintenance equipment are mostly found in areas that have a significant amount of snowfall. Emission factors developed by CARE3 for off-road motorcycles with both 2- and 4-stroke engines were used by EPA. EPA also applied these emission factors to all-terrain vehicles, minibikes, golf carts, and specialty vehicle carts. For snowmobiles, very little data exist on emission rates. EPA is considering using emission factors found in AP-42, which were derived from testing done by SwRI in 1974.[71] SIC 557 - Motorcycle Dealers (Establishments) was the primary indicator used by EEA to determine local

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[70] Environmental Research and Technology, Inc. Feasibility, Cost, and Air Quality Impact of Potential Emission Control Requirements on Farm, Construction, and Industrial Equipment in California, Document PA841, sponsored by-the Farm and Industrial Equipment Institute, Engine Manufacturers Association, and Construction Industry Manufacturers Association, May 1982.

[71] Booz Allen & Hamilton, Inc. Commercial Marine Vessel Contributions to Emission Inventories, Final Report to Environmental Protection Agency. Los Angeles, California, October 7, 1991.

recreational equipment populations. For some areas SIC 557 had no data. In such cases, SIC 55 - Automotive Dealers and Service Stations (Employees) - was used as a substitute.

Five types of recreational marine vessels are addressed in the nonroad report, These are listed below:

- vessels with inboard engines
- vessels with outboard engines
- vessels with stemdrive engines
- sailboats with auxiliary outboard engines
- sailboats with auxiliary inboard engines

Emission factors for outboard engines were derived from test data supplied to EPA by the National Marine Manufacturers Association, which tested 25 two-stroke and three four-stroke outboard engines. Please refer to Tables I-l 1 a and I-l lb in the November 1991 EPA "Nonroad Engine and Vehicle Emission Study" for further information. For four-stroke outboards, emission factors recommended by SwRI were used for particulate matter emissions.[72] Since no data were available for 2-stroke outboard engine particulate matter emissions, EPA used emission factors from the CARB Technical Support Document for utility and lawn/garden equipment as approximations.[73] For inboard/sterndrive gasoline engines, EPA derived emission factors on the basis of test data on three 4-stroke gasoline marine inboard/sterndrive engines supplied by NMMA (See table I-l lc in the appendix of the EPA nonroad report). The particulate emission factor used was 1.64 lb./1000 gal (0.74 grams/gallon). Please refer to Section 1.2.2 of Appendix I of the EPA November 1991 nonroad study for more information. EPA used test data on a small diesel sailboat inboard and three large diesel inboard engines, which NMMA supplied, as the basis for calculating emission factors for inboard diesel engines. Please refer to table I-l 1d in appendix of the EPA nonroad study for more information. The activity indicator that EEA used to distribute marine engine populations at the county level consisted of taking a ratio of the water surface area of the given county to the total water surface area of the state in which the county is located. This includes miles of public beach with an assumed operating distance from shore of one mile, as well as inland waterways. Data on miles of public beach were found in the National Oceanic and Atmospheric Administration's (NOAA) National Estuarine Inventory: Data Atlas. 1988. Data on inland water covered surface area were derived from a census report entitled, Area Measurements Renorts. GE-20. No. 1. 197Q.

Commercial marine vessels can be subdivided into three categories, including ocean-going, harbor, and fishing vessels. These vessels have similar characteristics of size, speed, engine design, and distance traveled. Booz Allen & Hamilton developed the commercial marine vessel inventories and emission factors under contract to EPA for the EPA nonroad study. These are contained in The Booz Allen & Hamilton final report.[74] In addition, the emission factors are contained in tables I-12a and I- 12b in Appendix I of the EPA nonroad report. In developing commercial marine populations for six ports (Baltimore, Baton Rouge, Houston-Galveston, New York-New Jersey, Philadelphia, and

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[72] U.S. Environmental Protection Agency. Designation of Areas for Air Quality Planning Purposes. 40 CFR Part 81, Final Rule, Washington, D.C., Office of Air and Radiation, Novemeber 6, 1991.

[73] Energy and. Environmental Analysis. Inc. Methodology To Estimate Nonroad Engine and Vehicle Emission Inventories At the County and Sub-County Level, Draft Report to the Environmental Protection Agency. Arlington, Virginia, February 11, 1992.

[74] Booz Allen & Hamilton, Inc. Commercial Marine Vessel Contributions to Emission Inventories. Final Report to Environmental Protection Agency. Los Angeles, California, October 7, 1991.

Seattle-Tacoma), Booz Allen & Hamilton requested data from several sources, including port authorities, Lloyds exchange, local marine exchanges, bar pilots associations, maritime trade organizations, state regulatory and licensing boards, and the U.S. Army Corps of Engineers. For the ports of Houston-Galveston and Baton-Rouge, inventories were based on data published in Waterborne Commerce of the United States. Calendar Year 1988.[75] For fishing vessel populations, data supplied by the National Marine Fisheries Service was used? For ports in non-attainment areas not addressed in the Booz Allen & Hamilton report, EPA relied on data from SIP inventories and the 1985 National Emissions Report.[77]

Sample Inventorv Calculation

Sample OMS and EEA Inventory Calculation for VOC

Exhaust

(g/hp-hr) x (rated hp) x (percent of rated hp typically used)

x (hrs/yr per engine) x (equipment population) x (ton/g)

= (tons/yr)

Evaporative

(g/day) x (229 days/yr)* x (equipment population) x (ton/g) =

(tons/yr)

* Evaporative diurnal VOC emissions are assumed to occur 229 days/year, which includes each day of the ozone season, no winter days, and most other days. Future OMS work will determine emission factors for hot soak, running loss, and resting loss emissions.

Refueling

Refueling emissions are the sum of the spillage and vapor displacement emissions. They are calculated on a g/gal basis and then, as appropriate, converted to a g/hp-hr or g/hr basis to be in the same unit as the exhaust emission factors. Please see Appendix I (pages 26-31) of the EPA nonroad study for details on the calculations. The example below is shown for a g/gal emission factor:

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[75] U.S. Army Corps. of Engineers. Waterborne Commerce of the United States, Calendar Year 1988, Water Resources Support Center.

[76] U S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Fisheries of the United States, 1990, Washington D.C., U.S. Government Printing Office, May 1991.

[77] U.S. Environmental Protection Agency. 1985 National Emissions Report, Research Triangle Park, NC, Office of Air Quality Planning and Standards, March 1991.

(g/gal) x (gal fuel used) x (equipment population) x (ton/g)

= (tons/yr)

The total of these three emission categories are combined to give total annual VOC emissions as shown below.

Total annual VOC emissions = Exhaust VOC + Evaporative VOC + Refueling VOC

Annual emissions for CO and particulates are calculated using just the exhaust portion of this example.

The total annual emissions (tons/year) can be apportioned to tons/summer day or tons/winter day by use of one of the conversion factors developed by EEA.

SAF (tons per summer day/tons per year)
SAF (tons per winter day/tons per year)

These factors consider different fractions of summer and winter operations for the rune equipment categories in three different geographical are-as of the country (northern, central, and southern). Thus, the factors vary from area to area.

By use of these conversion factors, the following inventories are obtained.

VOC tons per summer day
NOx tons per summer day
CO tons per summer day (0, area)
CO tons per winter day (CO area)
Particulate tons per summer day
Particulate tons per winter day

The conversion factors can also be applied to particulates if one is considering the 24-hr. particulate National Ambient Air Quality Standard instead of the annual average.

5. Emissions from aircraft

This chapter describes the procedure for calculating emissions from civilian and military aircraft within an inventory area. The basic methodology determines aircraft fleet make-up and level of activity and then calculates air pollutant emissions on an annual basis. Variations to the methodology, which account for seasonal changes or specific operational considerations, are discussed. Changes expected in the fleet in the future and the effect on emissions are also briefly described. Finally, a method for converting total hydrocarbon (THC) emissions to volatile organic compound (VOC) emissions is presented at the end of the chapter.

The inventory methodology and emission factors have been updated since the last edition of this report This chapter also updates the emission factor information that appears in Compilation of Air Pollutant Emission Factors. Fourth Edition and Supplements, AP-42.[78]

Overview of the inventory methodology

Preparing an emissions inventory for aircraft focuses on the emission characteristics of this source relative to the vertical column of air that ultimately affects ground level pollutant concentrations. This portion of the atmosphere, which begins at the earth's surface and is simulated in air quality models, is often referred to as the mixing zone. The aircraft operations of interest within this layer are defined as the landing and takeoff (LTO) cycle. The cycle begins when the aircraft approaches the airport on its descent from cruising altitude, lands, and taxis to the gate. It continues as the aircraft taxis back out to the runway for subsequent takeoff and climbout as it heads back up to cruising altitude. Thus, the five specific operating modes in an LTO are:

- Approach
- Taxi/idle-in
- Taxi/idle-out
- Takeoff
- Climbout

Most aircraft go through a similar sequence during a complete operating cycle. Helicopters may combine certain modes such as takeoff and climbout.

The LTO cycle provides a basis for calculating aircraft emissions. During each mode of operation, the aircraft engines operate at a fairly standard power setting for a given aircraft category. Emissions for one complete cycle for a given aircraft can be calculated by knowing emission factors for specific aircraft engines at those power settings. Then, if the activity of all aircraft in the modeling zone can be determined for the inventory period, the total emissions can be calculated. Each of the dominant factors that affect the emissions from this source is discussed below.

For a single LTO cycle, aircraft emissions vary considerably depending on the category of aircraft and the resulting typical flight profile. Aircraft can be categorized by use. Commercial aircraft include those used for scheduled service transporting passengers, freight, or both. Air taxis also fly scheduled service carrying passengers and/or freight but usually are smaller aircraft and operate on a more limited basis than the commercial carriers. Business aircraft support business travel, usually on an unscheduled basis, and general aviation includes most other non-military aircraft used for recreational flying, personal transportation, and various other activities.

For the purpose of creating an emissions inventory, business aircraft are combined with general aviation aircraft because of their similar size, use frequency, and operating profiles. In this inventory methodology they are referred to simply as general aviation. Similarly, air taxis are treated much like the general aviation category because they are typically the same types of aircraft Military aircraft cover a wide range of sizes, uses, and operating missions. While they often are similar to civil aircraft, they are handled separately because they typically operate exclusively out of military air bases and frequently have distinctive flight profiles. Helicopters, or rotary wing aircraft, can be found in

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[78] Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources, AP-42, U.S. Environmental Protection Agency, Ann Arbor, Michigan, September, 1985. (Aircraft data from February 1980.)

each of the categories. Their operation is distinct because they do not always operate from an airport but may land and takeoff from a heliport at a hospital, police station, or similarly dispersed location. Military rotorcraft are included in the military category and non-military rotorcraft are included in the general aviation category since information on size and number are usually found in common sources. However, they are combined into a single group for calculating emissions since their flight profiles are similar.

Commercial aircraft typically are the largest source of aircraft emissions. Although they make up less than half of all aircraft in operation around a metropolitan area their emissions usually represent a large fraction of the total because of their size and operating frequency. This may not hold true, of course, for a city with a disproportionate amount of military activity or a city with no major civil airports.

Aircraft pollutants of significance are hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and particulates (PM,,). The factors that detennine the quantity of pollutant emitted are the emission index for each operating mode (pounds of pollutant per 1000 pounds of fuel consumed), the fuel consumption rate, and the duration of each operating mode. HC and CO emission indexes are very high during the taxi/idle phases when aircraft engines are at low power and operate at less than optimum efficiency. The emission indexes fall as the aircraft moves into the higher power operating modes of the LTO cycle. Thus, operation in the taxi/idle mode, when aircraft are on the ground at low power, is a significant factor in calculating total HC and CO emissions. For areas which are most concerned about the contribution of aircraft to the inventory of HC and CO, special attention should be paid to the time the aircraft operate in the taxi/idle modes.

NO, emissions, on the other hand, are low when engine power and combustion temperature are low but increase as the power level is increased and combustion temperature rises. Therefore the takeoff and climbout modes have the highest NO, emission rates. If NO, is a primary concern for the inventory area, special effort should focus on determining an accurate height of the mixing layer, which affects the operating duration of climbout.

Sulfur emissions typically are not measured when aircraft engines are tested. In evaluating sulfur emissions, it is assumed that all sulfur in the fuel combines with oxygen during combustion to form sulfur dioxide. Thus, sulfur dioxide emission rates are highest during takeoff and climbout when fuel consumption rates are high. Nationally the sulfur content of fuel remains fairly constant from year to year at about 0.05% wt. for commercial jet fuel, 0.025% wt. for military fuel, and 0.006% wt for aviation gasoline. This is the basis for the sulfur dioxide emission indexes. If the sulfur content of fuel varies significantly on a local basis, the emission index can be adjusted according to a ratio of the local value to the national value.

Particulates form as a result of incomplete combustion. Particulate emission rates are somewhat higher at low power rates than at high power rates since combustion efficiency improves at higher engine power. However, particulate emissions are highest during takeoff and climbout because the fuel flow rate also is high. It is particularly difficult to estimate the emissions of this pollutant. Direct measurement of particulate emissions from aircraft engines typically are not available, although emission of visible smoke is reported as part of the engine certification procedure.

The aircraft powerplant is the source of emissions of the key pollutants that result from fuel combustion. Emission rates vary depending on the fuel consumption rate and engine specific design factors. In 1984, EPA established standards for HC emissions. In developing the emission limits, EPA defined an operating regimen to standardize the engine certification testing procedure and method for determining engine HC emissions. The standard applies to jet engines over 6,000 lbs-thrust and emissions are calculated based on a specific LTO cycle. EPA considered in-use engine deterioration when the standards were developed but concluded that, because of the high levels of maintenance of aircraft engines for reasons of safety and fuel economy, emission performance. would not deteriorate significantly. The operating parameters used in the standard for the LTO cycle can be used as default values in calculating emissions when more specific information is not known.

When the standards went into effect, some engines in production could already meet them due to design changes made previously for improved fuel efficiency. Other engines had to be redesigned to reduce their HC emissions so that they could remain in' production. In-service engines were not required to be retrofitted in the normal course of periodic servicing and rebuilding. These older engines, many of which remain in service, have HC emissions that exceed the standard. New engine designs, produced since the standards went into effect, have HC emissions much lower than the standards. As a result of design changes made to the engines that meet the HC standard, emissions of CO also generally went down while NO, emissions tended to increased. However, the change in these pollutants was much less dramatic than the decrease in hydrocarbons. The smoke number for the newer engines also is lower due to specific design changes intended to reduce smoke production, which is regulated by EPA.

During the LTO cycle, aircraft operate for different periods of time in various modes depending on their particular category, the local meteorological conditions, and operational considerations at a given airport. The "Time-In-Mode," or TIM, as used in this methodology, takes these factors into consideration. Table 5-1 shows representative LTO cycle times for several aircraft categories.

Duration in approach and climbout depends largely on the local meteorology. Since the period of interest is during operation of the aircraft within the air modeling zone, the inversion layer thickness determines how long the aircraft is in this zone. The inversion layer thickness is also known as the mixing height or mixing zone since the air in this layer is completely mixed and pollutants emitted anywhere within the layer will be carried down to ground level. When the aircraft is above the mixing layer, whether on descent or when climbing to cruising altitude, the emissions tend to disperse, rather than being trapped by the inversion, and have no ground level effect.

Taxi/idle time, whether from the runway to the gate (taxi/idle-in) or from the gate to the runway (taxi/idle-out), depends on the size and layout of the airport, the amount of traffic or congestion on the ground, and airport-specific operational procedures. Taxi/idle time is the most variable of the LTO modes. Taxi/idle time can vary significantly for each airport throughout the day, as aircraft activity changes, and seasonally, as general travel activity increases and decreases.

The takeoff period, characterized primarily by full-throttle operation, typically lasts until the aircraft reaches between 500 and 1000 feet above ground level when the engine power is reduced and the climbout mode begins. This transition height is fairly standard and does not vary much from location to location or among aircraft categories.

This methodology describes techniques and data sources for determining the critical variables in the inventory calculations. When an inventory is being created for a particular area, the fleet make-up, aircraft activity, and times-in-mode will be specific to that area. Engine emission indexes, on the other hand, depend on the engine design and are provided in reference tables.

Inventory methodology

The steps in the methodology are basically the same for each aircraft classification and each location, even though several factors used in creating an inventory are site specific.

(1) Identify all airports to be included in the inventory
(2) Determine the mixing height to be applied to the LTO cycle
(3) Define the fleet make-up for aircraft category using each airport
(4) Determine airport activity as the number of LTOs for each aircraft category
(5) Select emission indexes for each category
(6) Estimate a time-in-mode for each aircraft category at each airport
(7) Calculate an inventory based on the airport activity, TIM, and aircraft emission factors.

For a specific region where an emissions inventory is being created, steps one and two, the airports to be included and the mixing height, will be determined largely by the assumptions used in defining the scope of the modeling area. Steps three through six are repeated for commercial aircraft, general aviation, military aircraft, and helicopters. The primary difference in creating an inventory for each type of aircraft is the references used to determine the fleet make-up and activity. The following sections discuss each of these steps. Steps one and two are discussed in terms of the specific modeling area while steps three through six are addressed together for each aircraft category.

Maps and regional information directories are good sources for identifying civil airports and military air fields. Special attention may have to be paid to the inclusion of all airports and landing strips with significant air traffic, so as to capture all major contributions to the emissions inventory.

The height of the mixing zone influences only the time-in-mode for approach and climbout. This factor is significant primarily when calculating NO, emissions rather than HC or CO. If NO, emissions are an important component of the inventory, specific data must be gathered on mixing heights. If NO, emissions are unimportant, mixing height will have little effect on the results and the default value of 3000 feet can be used for more generalized results.

Mixing height should be determined in conjunction with those responsible for the air quality modeling of the region to insure that assumptions used for creating different sections of the overall inventory are consistent.

The next four steps relate specifically to creating an emissions inventory for commercial aircraft. Definition of the mix of commercial aircraft that uses each airport (step three) can be found in Airport Activity Statistics of Certified Route Air Carriers [79] published annually by FAA. All of the commercial aircraft that used the airport for the given year are listed, along with the number of departures during the year. This is the fleet that should be used for the inventory.

In step four the number of LTOs is determined by aircraft type. Since Airport Activity Statistics of Certificated Route Air Carriers lists departures, which are equivalent to LTOs, it is again the preferred source. The total departures performed for all service (both scheduled and non scheduled) should be used as the number of LTOs for each aircraft type.

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[79] Airport Activity Statistics of Certificated Route Air Carriers, U.S. Department of Transportation, Research and Special Programs Administration, Federal Aviation Administration, Calendar Year 1989. NTIS Report Number ADA 229303.

The engines used on each aircraft type must be determined to select **the emission factors for** step five. Table 5-2 lists aircraft and the corresponding engines used to power them. Many aircraft use only a single engine model, while others have been certified to use engines from two or three different manufacturers. When a single engine is listed for an aircraft model, emissions data for that engine should be used. For aircraft with engines from more than one manufacturer, defining the specific engine mix used on the fleet of aircraft operating at a specific airport may be extremely difficult. Individual airlines probably are the only source of detailed fleet data on specific engine models and they likely do not have it readily available. To develop a representative engine mix for aircraft with more than one engine model, the percentage of each model likely to be found on those aircraft in the U.S. fleet is shown adjacent to the engine model number in Table 5-2. The recommended procedure for compensating for the lack of detailed engine data is using the percentages shown in the table as weighing factors. For example, Boeing 757-200 cargo aircraft have been sold to U. S. airlines with Pratt & Whitney PW2040 engines as well as Rolls Royce RB.211-535E4 engines. The number of aircraft with each engine model is 15 and 43, respectively, to give the percentages shown in Table 5-2 of 26 and 74. These percentages can be used to divide the total LTOs for B 757-200 cargo aircraft into two groups representing the two engine types. This makes the inventory more representative than assigning a single engine for all cargo versions of B 757-200s, since the emission factors are different for each engine.

After identifying the engines included in the fleet, engine emission factors are used to calculate mass of emissions. For some of the engines shown in Table 5-2, emission factors have never been determined. For these engines it is necessary to use emission factors from an alternative engine. Table 5-3 lists alternative engines recommended by the engine manufacturers. For most of these engines, emission factors are available for a very similar engine, usually one of the same model and a related series. For a small number of engines there is no emissions data available and there are no suggested alternatives. In these instances there are three approaches available. First, the needed data may appear in the latest update of the FAEED data base. The FAA should be contacted for the latest version of the data base as mentioned earlier. Second, for an aircraft with several potential engine types, where no emissions data is available for one engine, the recommended procedure is to reallocate the market share among the engines for which data is available. Third, if emission rate information (fuel consumption and emission index) for an engine model still cannot be located the engine manufacturer should be contacted directly.

After the engine types have been identified, fuel flow rates and emission indexes can be found in Table 5-4. The data in this table has been updated since the last edition of this reference and of AP-42, to include new engine models and to reflect new data on models already in AP-42. The next version of AP-42 may have some additional new data for engines that have not been updated here. The fuel flow rates and emission indexes that appear in Table 5-4 for commercial aircraft are based on information engine manufacturers provide to FAA and the International Civil Aviation Organization. These data are representative of production engines. Emission indexes are given for specific fuel flow rates which are representative of the power settings used during the different operating modes. The emission index multiplied by the fuel flow rate gives an emission rate.

Step 6 is to specify a time-in-mode for each aircraft type. Take-off time is fairly standard for commercial aircraft and represents the time for initial climb from ground level to about 500 feet. The default take-off time for calculating emissions is 0.7 minutes (42 seconds) and, unless more specific data is available, should be used in this methodology. The time in the approach and climbout modes depends on mixing height. As mentioned earlier, a default mixing height of 3000 feet was assumed for calculating an approach time of 4 minutes and a climbout time of 2.2 minutes, which can be used if specific information on mixing height is unavailable.

Table 5-1

Default time-in-mode for various aircraft categories[1]

Aircraft	Time in Mode (Minutes) Taxi/ Idle-out	Takeoff	Climbout	Approach	Taxi/ Idle-in	Total
CIVIL[2]						
Commercial Carrier						
Jumbo, long and medium range jet	19.0	0.7	2.2	4.0	7.0	32.9
Turboprop	19.0	0.5	2.5	4.5	7.0	33.5
Transport-piston	6.5	0.6	5.0	4.6	6.5	232
General Aviation						
Business jet	6.5	0.4	0.5	1.6	6.5	15.5
Turboprop	19.0	0.5	25	4.5	7.0	33.5
Piston	12.0	0.3	5.0	6.0	4.0	273
Helicopter	3.5		6.5	6.5	3.5	20.0
MILITARY[3]						
Combat[4]						
USAF	18.5	0.4	0.8	3.5	11.3	34.5
USN[5]	6.5	0.4	0.5	1.6	6.5	15.5
Trainer - Turbine						
USAF T-38	12.8	0.4	0.9	3.8	6.4	-24.3
USAF general	6.8	0.5	1.4	4.0	4.4	17.1
USN[5]	6.5	0.4	05	1.6	6.5	15.5
Transport - Turbine[6]						
USAF general	9.2	0.4	12	5.1	6.7	22.6
USN	19.0	0.5	25	4.5	7.0	33.5
USAF B-52 and KC-135	32.8	0.7	1.6	5.2	14.9	552
Military - Piston	6.5	0.6	5.0	4.6	6.5	23.3
Military - Helicopter	8.0	-	6.8	6.8	7.0	28.6

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[1] SOURCE: AP-42, Compilation of Air Pollutant Emission Factors. Volume II: Mobile Sources, U.S. Environmental Protection Agency, Ann Arbor, Michigan, September, 1985. (Aircraft data from February 1980).

[2] Civil aircraft data is for large congested metropolitan airports.

[3] USAF - U.S. Air Force, USN - U.S. Navy.

[4] Fighters and attack aircraft only.

[5] Time-in mode is highly variable. Taxi/idle out and in times as high as 25 and 17 minutes, respectively, have been noted. Use local data base if possible.

[6] Includes all turbine aircraft not specified elsewhere (i.e., transport, cargo, observation, patrol, antisubmarine, early warning, and utility).

Table 5-2

Commercial aircraft types and engine models

Aircraft[1]	Engine Type[2]	No. of Engines	Engine Model (% of Aircraft) and Manufacturer[3]			
Aerospatiale ATR-12	TP	2	PW120(53)PWC	PW121(47)PWC		
Airbus A-300-B4	TF	2	CF6-50(100)GE			
Airbus A-300-600	TF	2	CF6-80C2A5(100)GE			
Airbus A-310-200	TF	2	CF6-80A3(0)GE	JT9D-7R4E1(100)PW		
Airbus A-310-300	TF	2	CF6-80C2A2(0)GE	PW4152(100)PW		
Airbus A-320-200	TF	2	CFM56-5A(100)GE			
BEECH 18[4]	TP	2	R-985-AN(100)PW[5]			
BEECH BII-C99	TP	2	PT6A-36(100)PWC			
BEECH BII-1900	TP	2	PT6A-65B(100)PWC			
Boeing B-707-300B	TF	4	JT3D-3B(100)PW			
Boeing B-707-300C	TF	4	JT3D-3B(100)PW			
Boeing B-727-100	TF	3	JT8D-7(16)PW	JT8D-7A(4)PW	JT8D-7A/7B(<1)PW	JT8D-7B(73)PW
			JT8D-7D(4)PW	JT8D-9(1)PW	JT8D-9A(2)PW	
Boeing B-727-100'	TF	3	JT8D-7A(6)PW	JT8D-7B(91)PW	JT8D-9(1)PW	JT8D-9A(2)PW
Boeing B-727-200	TF	3	JT8D-7A(<1)PW	JT8D-7B(16)PW	JT8D-9(20)PW	JT8D-9A(9)PW
			JT8D-15(26)PW	JT8D-15A(21)PW		
			JT8D-15B(<1)PW	JT8D-17(3)PW	JT8D-17A(1)PW	JT8D-17R(3)PW
Boeing B-737-100/200	TF	2	JT8D-7B(19)PW	JT8D-9A(39)PW	JT8D-15(10)PW	JT8D-15A(24)PW
			JT8D-17(7)PW	JT8D-17A(1)PW		
Boeing B-737-200C	TF	2	JT8D-7A(10)PW	JT8D-9/9A(5)PW	JT8D-9A(16)PW	JT8D-15(5)PW
			JT8D-17(32)PW	JT8D-17A(32)PW		
Boeing B-737-300	TF	2	CFM56-3(100)GE[6]			
Boeing B-737-400	TF	2	CFM56-3(100)GE			
Boeing B-747'	TF	4	JT9D-7F(100)PW			
Boeing B-747F[4]	TF	4	JT9D-7F(33)PW	JT9D-7Q(17)PW	JT9D-7R4G2(11)PW	JT9D-70A(39)PW
Boeing B-747SP	TF	4	JT9D-7A(85)PW	JT9D-7A-SP(15)PW		
Boeing D-747-200	TF	4	CF6-50(3)GE[7]	CF6-80C2B1(0)GE	JT9D-3A(7)PW	JT9D-7(1)PW
			JT9D-7A(55)PW	JT9D-7AH(13)PW	JT9D-7F(5)PW	JT9D-7Q(13)PW
			JT9D-7R4G2(3)PW			

Table 5-2

Commercial aircraft types and engine models (continued)

Aircraft[1]	Engine Type[2]	No. of Engines	Engine Model (% of Aircraft) and Manufacturer[3]			
Boeing B -747400	TF	4	PW4056(100)PW			
Boeing B-757-200	TF	2	RB.211-535E4(1)RR	PW2037(92)PW	PW2040(7)PW	
Boeing B-757-200[4]	TF	3	PW2040(26)PW	RD.21 1-535E4(74)RR		
Boeing B-767-200	TF	2	CF6-80A2(59)GE	CF6-80C2B2(12)GE[8]	JT9D-7R4D(29)PW	
Boeing B-767-300	'I-F	2	CF6-80C2B6(100)GE[9]	PW4060(0)PW	RB.211-524H(0)RR	
Brit. Air Corp. BAC- I I 1-200	TF	2	Spey Mk 5 I I(100)RR[10]			
Brit. Aero. BAc-146- I	TF	4	ALF502R-5(100)Lyc			
Brit. Aero. BAc-146-2	TF	4	ALF502R-5(100)Lyc			
Brit. Aero. Concorde	TF	4	Olympus 593 Mk610(100)RR			
Brit. Aero. JETSTREAM 31	TP	2	TPE 331-10UF(100)Grt[10]			
CESSNA 404[4]	P	2	TSIO-520-VB(100)Con[10]			
Convair CV-580	TP	2	501D13H(100)All.[10]			
Convair CV-640[4]	TP	2	Dart 542-4(100)RR			
de Havilland DASH-7	11'	4	PT6A-50(100)PWC			
de Havilland DHC-6	TP	2	PT6A-20(26)PWC	PT6A-27(74)PWC		
de Havilland DHC-8	1-P	2	PW120(17)PWC	PW 120A(83)PWC		
EMBRAER[11]	TP	2	PT6A-34(100)PWC			
EMBRAER EMB-120	TP	2	PW118(85)PWC	PW118A(15)PWC		
Fairchild Ftt-227	TP	2	Dart 532-7(100)RR			
Fokker 100	TF	2	Tny 620-15(75)RR	Tay 650(25)RR		
Fokkcr F-27 SERIES	TP	2	Dart 514-7(15)RR	Dart 528-7E(10)RR	Dart 532-7(5)RR	Dart 532-7N(3)RR
			Dart 532-7P(24)RR	Dart 532-7R(3)RR	Dart 535-7R(9)RR	Dart 536-7E(2)RR
			Dart 552-7R(29)RR			
Fokkcr F-28-1000	TF	2	Spey 555-15(100)RR			
Fokkcr F-28-4000/600	TF	2	Spey 555-15H(12)RR	Spey 555-15P(88)RR		
Lockheed L-100-30[4]	TP	4	501D22A(100)All.[10]			
Lockheed L-188A/C	TP	4	501D13(100)All.[10]			

Table 5-2

Commercial aircraft types and engine models (continued)

Aircraft[1]	Engine Type[2]	No. of Engines	Engine Model (% of Aircraft) and Manufacturer[3]			
Lockheed L-188A/C[4]	TP	4	501D13(100)AL[10]			
Lockheed L-1011/100/200	TF	3	RB.211-22B(99)RR	RB.211-524B4(1)RR		
Lockheed L-1011-500 TR	TF	3	RB.211-524B4(100)RR			
McDonnell Douglas DC-6[4]	P	4	R2800(100)PW[10]			
McDonnell Douglas DC-6A[4]	P	4	R2800(100)PW[10]			
McDonnell Douglas DC-8-60	TF	4	JT3D-3B(57)PW	JT3D-7(43)PW		
McDonnell Douglas DC-8-61[4]	TF	4	JT3D-3B(100)PW			
McDonnell Douglas DC-8-62[4]	TF	4	JT3D-3B(15)PW	JT3D-3BDL(21)PW	JT3D-7(64)PW	
McDonnell Douglas DC-8-63F[4]	TF	4	JT3D-3B(24)PW	JT3D-7(42)PW	JT3D-735B4(7)PW	JT8D-7(27)PW
McDonnell Douglas DC-8-70	TF	4	CFM56-2-C1(100)GE			
McDonnell Douglas DC-8-71	TF	4	CFM56-2(100)GE			
McDonnell Douglas DC 9-10	TF	2	JT8D-7(100)PW[10]			
McDonnell Douglas DC-9-15F	TF	2	JT8D-7(15)PW	JT8D-7A(4)PW	JT8D-7A/7B(4)PW	
			JT8D-7B(77)PW			
McDonnell Douglas DC-9-30	TF	2	JT8D-7(0)PW	JT8D-7A(5)PW	JT8D-7B(68)PW	
			JT8D-9A(23)PW	JT8D-15(3)PW		
			JT8D-17(1)PW			
McDonnell Douglas DC-9-40	TF	2	JT8D-15(100)PW			
McDonnell Douglas DC-9-50	TF	2	JT8D-17(87)PW	JT8D-17A(13)PW		
McDonnell Douglas DC-9-80[12]	TF	2	JT8D-209(5)PW	JT8D-217(12)PW	JT8D-217A(36)PW	
			JT8D-217C(25)PW	JT8D-219(22)PW		
McDonnell Douglas DC-10-10	TF	3	CF6-6(100)GE			
McDonnell Douglas DC-10-10[4]	TF	3	CF6-6(100)GE			
McDonnell Douglas DC-10-30	TF	3	CF6-50(100)GE			
McDonnell Douglas DC-10-30[4]	TF	3	CF6-50(100)GE			
McDonnell Douglas DC-10-40	TF	3	JT9D-20(100)PW			
McDonnell Douglas MD-11	TF	3	CF6-80C2D1F(100)GE	PW4460(0)PW		
NAMC YS-11	TP	2	Dart 542-10J(25)RR	Dart 542-10K(75)RR		
Saab SF-340A	TP	2	CT7-5A( )GE[13]	CT7-5A2( )GE[13]	CT7-7E( )GE[13]	
SHORTS 360	TP	2	PT6A-65AR(17)PWC	PT6A-65R(55)PWC	PT6A-67R(28)PWC	
Swearingen SWEAR-METRO I	TP	2	TPE 331-11U-611G( )GA[14]	PT6A-45R( )PW[13]		

Table 5-2

Commercial aircraft types and engine models (concluded)

[1] Source of Aircraft, Type, and No. of Engines is Airport Activity Statistics of Certificated Route Air Carriers, U.S. Department of Transportation, Research and Special Programs Administration, Federal Aviation Administration, Calendar Year 1989. NTIS Report Number ADA 2390303.

[2] Engine Types: TF - Turbofan, TJ - Turbojet, TP - Turboprop, P - Piston

[3] Following the engine model is the percent of aircraft in parentheses which correspond to the particular engine and the engine manufacturer. GE engine data obtained from GE Aircraft Engines: Commercial Program Status, Volume 1, (General Electric, 1991, Cincinnati, Ohio) and Office of Combustion Technology, GE Aircraft Engines (One Neumann Way MD A309, Cincinnati, Ohio 45215-6301, 513/774-4438). Corresponding percents of aircraft refer to U.S. commercial and government aircraft in operation as of 12/31/90. P&W, P&WC, and RR engine data obtained from Turbine-Engined Fleets of the World's Airlines 1990 (Exxon Corporation, supplement to Air World, Volume 42, Number 2, 1990). Corresponding percents of aircraft refer only to U.S. airlines. Engine Manufacturers: Con - Teledyne/Continental, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, PW - Pratt & Whitney, PWC - Pratt & Whitney Canada, RR - Rolls Royce

[4] AU Cargo Services.

[5] Percent of aircraft assumed 100%.

[6] Refers to B-737-300 and -500 aircraft.

[7] Refers to B-747-200, -300, and SR aircraft.

[8] Refers to B-767-200ER aircraft. GE combined the number of aircraft in operation of B-767-200ER and -300ER aircraft. It is assumed that an equal distribution between the two aircraft models exists.

[9] Refers to B-767-300ER aircraft. GE combined the number of aircraft in operation of B-767-200ER and -300ER aircraft. It is assumed that an equal distribution between the two aircraft models exists.

[10] Source of engine information is Modern Commercial Aircraft, Green, W., J. Mowinski, and G. Swanborough, 1987. Percent of aircraft assumed 100%.

[11] Assumed EMB-110 aircraft.

[12] Assumed MD-80 aircraft.

[13] Source of engine information is Modem Commercial Aircraft. Percent of aircraft unknown.

[14] Source of engine information is Modem Commercial Aircraft. Engine refers to METRO III aircraft. Percent of aircraft unknown.

[15] Source of engine information is Modem Commercial Aircraft. Engine refers to METRO IIIA aircraft. Percent of aircraft unknown.

Table 5-3

Alternative source of emission data for some aircraft engines’

Manufacturer	Engine Model	Source for Emissions Data’
GE	CF6-6	CF6-6D
	CF6-50	CF6-50E/C1/E1/C2/E2
	CT7-5A	CT7-5
	CT7-5A2	CT7-5
	CT7-7E	CT7-5
GE (SCNECMA)	CFM56-2	CFM56-2B
	CFM56-2-C1	CFM56-2B
	CFM56-5A	CFM56-5A1
P&W	JT3D series	Contact manufacture?
	JT8D-7D	JT8D-7/7A/7B
	JT8D-15B	JT8D-15
	JT9D-3A	Contact manufacturer
	JT9D-7A-SP	JT9D-7F/7A
	JT9D-7AH	JT9D-7F/7A
	JT9D-20	JT9D-7F/7A
	JT9D-70A	JT9D-70/59/7Q
	PW4060	PW4460
RR	RB211-535E.5	Contact manufacturer[4]
	RB211-535F5	Contact manufacturer
	TRENT 600 series	Contact manufacturer
	TRENT 700 series	Contact manufacturer
	SPEY MK506	Contact manufacturer
	SPEY MK555-15	SPEY MK555
	SPEY MK555-15P	SPEY MK555
	SPEY MK555-15H	SPEY MK555
	SPEY MK512	Contact manufacturer
	TAY MK651	Contact manufacturer
	Dart 514-7	Dart RDa7
	Dart 528-7E	Dart RDa7
	Dart 532-7	Dart RDa7
	Dart 532-7N	Dart RDa7
	Dart 532-7P	Dart RDa7
	Dart 532-7R	Dart RDa7
	Dart 535-7R	Dart RDa7
	Dart 536-7E	Dart RDa7
	Dart 542-4	Dart RDa10
	Dart 542-10J	Dart RDa10
	Dart 542-10K	Dart RDa10
	Dart 552-7R	Dart RDa7

Table 5-3

Alternative source of emission data for some aircraft engines[1]

(concluded)

[1] FAA Aircraft Engine Emission Database does not identify these alternative emission factors. A manual adjustment to the database output may be required.

[2] As recommended by engine manufacturers.

[3] For information, contact the Office of Certification & Airworthiness, Commerical Engine Business, United Technologies Pratt & Whitney, 400 Main Street, East Hartford, Connecticut 06108, 203/565-2269.

[4] For information, contact Manager_Project Combustion, Rolls Royce plc. P.O. Box 31, Derby DE2 88J England. Telephone - 0332 242424.

Table 5-4

Modal emission rates - Civil aircraft engined

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2[3]	Particulate
501D22A[4] All.	Takeoff	100%	39.60	0.28	2.04	8.88	0.54	
	Climbout	85%	36.63	0.89	2.06	9.22	0.54	
	Approach	30%	19.00	1.96	5.10	7.49	0.54	
	Taxi/Idle	7%	10.17	17.61	43.61	3.52	0.54	
0-200[4] Con	Takeoff	100%	0.75	20.81	974.10	4.87	0.11	
	Climbout	85%	0.75	20.81	974.10	4.87	0.11	
	Approach	40%	0.43	33.22	1187.84	1.14	0.11	
	Taxi/Idle	7%	0.14	29.00	644.42	1.58	0.11	
TSIO-360C[4] Con	Takeoff	100%	[illegible]	9.17	1081.95	2.71	0.11	
	Climbout	85%	1.66	9.55	960.80	4.32	0.11	
	Approach	40%	1.02	11.31	995.08	3.77	0.11	
	Taxi/Idle	7%	0.19	138.26	592.17	1.91	0.11	
CF6-6D GE 39.3	Takeoff	100%	229.63	0.30	0.50	40.00	0.54	
	Climbout	85%	189.29	0.30	0.50	32.60	0.54	
	Approach	30%	64.01	0.70	6.50	11.40	0.54	
	Taxi/Idle	7%	22.86	21.00	54.20	4.50	0.54	
CF6-45 GE 45.6	Takeoff	100%	281.22	0.10	1.00	30.60	0.54	
	Climbout	85%	234.13	0.10	1.30	26.60	0.54	
	Approach	30%	80.03	0.70	8.20	10.50	0.54	
	Taxi/Idle	7%	26.72	32.70	59.20	3.90	0.54	
CF6-45A/A2 GE 45.6	Takeoff	100%	268.12	0.09	0.43	15.45	0.54	
	Climbout	85%	219.97	0.14	0.34	21.61	0.54	
	Approach	30%	78.31	0.35	5.01	9.36	0.54	
	Taxi/Idle	4%	21.56	2.72	24.04	3.40	0.54	
CF6-50E/C1/E1/C2/E2 GE 51.8	Takeoff	100%	321.17	0.60	0.50	36.50	0.54	
	Climbout	85%	254.63	0.70	0.50	29.60	0.54	
	Approach	30%	87.86	1.00	5.70	9.70	0.54	
	Taxi/Idle	3%	[illegible]34	49.30	81.30	2.40	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines' (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2[3]	Particulate
CF6-80A	Takeoff	100%	283.73	0.29	1.00	29.80	0.54	
GE	Climbout	85%	237.44	0.29	1.10	25.60	0.54	
J6.Y	Approach	30%	81.35	0.47	3.10	10.30	0.54	
	Taxi/Idle	4%	19.84	6.29	28.20	3.40	0.54	
CF6-80A1	Takeoff	100%	283.73	0.29	1.00	29.80	0.54	
GE	Climbout	85%	237.44	0.29	1.10	25.60	0.54	
46.1)	Approach	30%	81.35	0.47	.3.10	10.30	0.54	
	Taxi/Idle	4%	19.84	6.29	28.20	3.40	0.54	
CF6-80A2	Takeoff	100%	298.15	0.30	1.00	29.60	0.54	
GE	Climbout	85%	249.34	0.37	1.10	26.60	0.54	
48.6	Approach	30%	84.79	0.45	2.80	10.80	0.54	
	Taxi/Idle	4%	1Y.84	6.28	28.20	3.40	0.54	
CF6-80A3	Takeoff	100%	298.15	0.30	1.00	29.60	0.54	
GE	Climbout	85%	249.34	0.37	1.10	26.60	0.54	
48.9	Approach	30%	84.79	0.45	2.80	10.80	0.54	
	Taxi/Idle	4%	19.84	6.28	28.20	3.40	0.54	
CF6-80C2A1	Takeoff	100%	317.46	0.08	0.56	32.22	0.54	
GE	Climbout	85%	258.34	0.09	0.54	24.85	0.54	
57.9	Approach	30%	84.13	2.00	2.19	9.76	0.54	
	Taxi/Idle	7%	26.32	9.19	42.24	3.99	0.54	
CF6-80C2A2	Takeoff	100%	280.03	0.14	0.58	27.90	0.54	
GE	Climbout	85%	230.82	0.1 I	0.56	20.7 I	0.54	
52.5	Approach	30%	76.12	0.25	3.04	9.52	0.54	
	Taxi/Idle	7%	25.00	10.74	46.65	3.Y I	0.54	
CF6-80C2A3	Takeoff	100%	325.00	0.08	0.59	34.44	0.54	
GE	Climbout	85%	264.9s	0.10	0.57	25.45	0.54	
58.9	Approach	30%	85.85	0.2 I	2.15	IO.01	0.54	
	Taxi/Idle	7%	26.72	9.21	42.18	3.96	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines' (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2[3]	Particulate
CF6-80C2A5	Takeoff	100%	WI.40	0.07	0.52	34.38	0.54	
GE	Climbout	85%	275.40	0.08	0.52	22.86	0.54	
60.1	Approach	30%	90.87	0.20	1.93	9.11	0.54	
	Taxi/Idle	7%	27.38	8.99	41.65	3.79	0.54	
CF6-80C2B1	Takeoff	100%	302.25	0.08	0.58	28.11	0.54	
GE	Climbout	85%	247.75	0.09	0.55	21.26	0.54	
56.0	Approach	30%	81.48	0.21	2.37	8.83	0.54	
	Taxi/Idle	7%	25.93	9.46	43.22	3.73	0.54	
CF6-80C2B1F	Takeoff	100%	311.25	0.08	0.52	28.06	0.54	
GE	Climbout	85%	253.04	0.09	0.52	21.34	0.54	
57.2	Approach	30%	83.60	0.20	2.19	8.97	0.54	
	Taxi/Idle	7%	27.12	9.68	43.71	3.74	0.54	
CF6-80C2B2	Takeoff	100%	281.88	0.08	0.57	23.89	0.54	
GE	Climbout	85%	232.94	0.10	0.55	18.65	0.54	
52.0	Approach	30%	76.32	0.22	2.65	8.77	0.54	
	Taxi/Idle	7%	25.40	11.17	48.02	3.70	0.54	
CF6-80C2B4	Takeoff	100%	321.43	0.08	0.56	29.30	0.54	
GE	Climbout	85%	262.17	0.09	0.54	21.80	0.54	
57.2	Approach	30%	85.98	0.21	2.33	8.90	0.54	
	Taxi/Idle	7%	26.32	9.74	43.91	3.67	0.54	
CF6-80C2B6	Takeoff	100%	WI.14	0.07	0.52	30.81	0.54	
GE	Climbout	85%	275.27	0.08	0.52	22.94	0.54	
60.1	Approach	30%	90.74	0.20	1.93	9.11	0.54	
	Taxi/Idle	7%	27.38	8.99	41.66	3.79	0.54	
CF6-80C2D1F	Takeoff	100%	337.83	0.08	0.52	32.54	0.54	
GE	Climbout	85%	268.39	0.10	0.53	23.55	0.54	
60.2	Approach	30%	85.36	0.21	1.98	9.18	0.54	
	Taxi/Idle	7%	26.01	9.96	44.41	3.79	0.54	
CT7-5[5]	Takeoff	100%	13.36	1.00	2.50	13.80	0.54	
GE	Climbout	90%	12.43	1.00	2.70	13.20	0.54	
	Approach	30%	5.95	1.50	5.30	6.90	0.54	
	Taxi/Idle	7%	1.98	4.00	35.40	2.20	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines' (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
CFM56-2A	Takeoff	100%	148.55	0.03	0.90	21.05	0.54	
GE (SNECMA)	Climbout	85%	122.62	0.04	1.00	17.18	0.54	
24.0	Approach	3090	45.64	0.10	3.40	8.62	0.54	
	Taxi/Idle	7%	17.46	1.17	24.90	4.12	0.54	
CFM56-2B	Takeoff	100%	132.54	0.05	0.90	19.06	0.54	
GE (SNECMA)	Climbout	85%	110.72	0.08	0.90	16.30	0.54	
22.0	Approach	30%	42.59	0.10	3.70	8.14	0.54	
	Taxi/Idle	7%	16.27	1.67	29.50	3.66	0.54	
CFM56-3	Takeoff	100%	134.92	0.04	0.00	18.50	0.54	
GE (SNECMA)	Climbout	85%	111.51	0.05	0.90	16.00	0.54	
20.1	Approach	30%	44.71	0.10	3.50	8.40	0.54	
	Taxi/Idle	7%	16.01	1.83	31.00	3.90	0.54	
CFM56-3B	Takeoff	100%	150.79	0.04	0.90	20.70	0.54	
GE (SNECMA)	Climbout	85%	123.02	0.05	0.90	17.30	0.54	
22.0	Approach	30%	47.62	0.08	3.10	8.70	0.54	
	Taxi/Idle	7%	17.20	1.25	27.00	4.10	0.54	
CFM56-3-B4	Takeoff	100%	116.40	0.04	0.90	16.60	0.54	
GE (SNECMA)	Climbout	85%	96.56	0.05	1.10	14.50	0.54	
18.5	Approach	30%	35.71	0.11	4.20	8.00	0.54	
	Taxi/Idle	7%	14.55	3.33	38.50	3.90	0.54	
CFM56-3C	Takeoff	100%	156.09	0.04	0.90	20.17	0.54	
GE (SNECMA)	Climbout	85%	128.31	0.04	1.00	17.15	0.54	
23.5	Approach	30%	44.97	0.09	3.20	8.88	0.54	
	Taxi/Idle	7%	IS.87	2.14	33.40	4.00	0.54	
CFM56-5A1	Takeoff	100%	142.8	0.13	0.83	28.03	0.54	
GE (SNECMA)	Climbout	85%	116.40	0.23	0.87	23.10	0.54	
25.0	Approach	30%	39.68	0.40	2.47	9.48	0.54	
	Taxi/Idle	7%	14.55	1.53	18.00	4.36	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines' (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Row (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2[3]	Particulate
TFE 731-2 Grt 3.51	Takeoff	100%	27.12	0.11	1.39	15.25	0.54	
	Climbout	85%	22.88	0.13	2.03	13.08	0.54	
	Approach	30%	8.86	4.26	22.38	5.90	0.54	
	Taxi/Idle	7%	3.17	20.04	58.60	2.82	0.54	
TFE 731-3 Grt 3.7	Takeoff	100%	29.76	0.06	1.13	19.15	0.54	
	Climbout	85%	24.60	0.07	1.62	16.02	0.54	
	Approach	30%	9.52	1.41	15.56	6.92	0.54	
	Taxi/Idle	7%	3.44	9.04	47.70	3.72	0.54	
TPE 331-3[6] Grt	Takeoff	100%	7.63	0.11	0.76	12.36	0.54	1.75
	Climbout	90%	6.82	0.15	0.98	11.86	0.54	1.47
	Approach	30%	4.17	0.64	6.96	9.92	0.54	2.40
	Taxi/Idle	7%	1.87	79.11	61.52	2.86	0.54	2.95
ALF 50X-2 Lyc 7.x)	Takeoff	100%	52.90	0.02	0.40	13.43	0.54	
	Climbout	85%	42.80	0.02	0.30	12.03	0.54	
	Approach	30%	15.50	0.18	3.97	6.47	0.54	
	Taxi/Idle	7%	6.31	6.65	45.63	3.38	0.54	
ALF 502R-3 Lyc 6.69	Takeoff	100%	45.98	0.06	0.43	11.20	0.54	
	Climbout	85%	38.10	0.05	0.50	9.94	0.54	
	Approach	30%	13.58	0.29	8.43	6.15	0.54	
	Taxi/Idle	7%	5.71	651	44.67	3.30	0.54	
ALF 502R-5 Lyc 6.96	Takeoff	100%	47.37	0.06	0.30	13.53	0.54	
	Climbout	85%	39.09	0.05	0.25	10.56	0.54	
	Approach	30%	13.68	0.2[illegible]	7.10	13.53	0.54	
	Taxi/Idle	7%	5.40	5.39	40.93	3.78	0.54	
0-320[4] Lyc	Takeoff	100%	1.48	11.78	1077.44	2.19	0.11	
	Climbout	85%	1.11	12.38	989.51	3.97	0.11	
	Approach	40%	0.78	19.25	1221.51	0.95	0.11	
	Taxi/Idle	7%	0.16	36.92	1077.00	0.52	0.11	

Table 5-4

Modal emission rates - Civil aircraft engined (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
D-36	Takeoff	100%	83.86	0.00	0.50	26.00	0.54	
MKB	Climbout	85%	70.50	0.00	0.40	22.00	0.54	
14.3	Approach	30%	27.91	0.00	2.70	9.00	0.54	
	Taxi/Idle	7%	0.00	5.40	20.70	5.50	0.54	
NK-86	Takeoff	100%	267.07	0.00	1.30	13.60	0.54	
NPO	Climbout	85%	218.26	0.00	1.70	10.00	0.54	
2Y.5	Approach	30%	75.66	0.00	5.00	3.80	0.54	
	Taxi/Idle	7%	32.14	4.40	27.60	2.50	0.54	
IAE V2500	Takeoff	100%	147.22	0.10	055	37.13	0.54	
P&W	Climbout	85%	122.22	0.11	0.55	30.82	0.54	
25.0	Approach	30%	44.18	0.15	0.77	13.45	0.54	
	Taxi/Idle	7%	16.40	0.22	7.76	5.91	0.54	
JT3D-7[4]	Takeoff	100%	165.93	0.50	.90	12.70	0.54	
P&W	Climbout	85%	136.47	0.40	1.90	9.60	0.54	
	Approach	30%	51.40	2.10	19.50	5.30	0.54	
	Taxi/Idle	7%	16.88	123.00	138.99	2.30	0.54	
JT8D-7/7A/7B	Takeoff	100%	130.85	0.40	1.50	17.10	0.54	
P&W	Climbout	85%	107.32	0.50	2.00	13.50	0.54	
13.9	Approach	30%	37.84	1.60	10.50	5.50	0.54	
	Taxi/Idle	7%	17.08	10.60	35.50	2.70	0.54	
JT8 D-Y/YA	Takeoff	100%	137.57	0.47	1.24	17.93	0.54	
P&W	Climbout	85%	111.91	0.47	1.66	14.21	0.54	
14.5	Approach	30%	39.42	1.73	9.43	5.64	0.54	
	Taxi/Idle	7%	17.46	10.00	34.50	2.90	0.54	
JT8D-11	Takeoff	100%	148.28	0.40	1.20	18.90	0.54	
P&W	Climbout	85%	120.85	0.45	1.90	14.60	0.54	
15.0	Approach	30%	44.17	1.40	9.40	5.80	0.54	
	Taxi/Idle	7%	19.25	10.00	35.00	2.75	0.54	
JT8D-15[7]	Takeoff	100%	155.82	0.25	0.72	19.12	0.54	
P&W	Climbout	85%	135.00	0.25	1.01	15.01	0.54	
15.5	Approach	30%	45.01	1.57	9.12	5.97	0.54	
	Taxi/Idle	7%	19.54	10.33	33.88	3.01	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines[1] (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2[3]	Particulate
JT8D-15A	Takeoff	100%	147.49	0.25	1.08	18.10	0.54	
P&W	Climbout	85%	118.45	0.33	1.20	13.90	0.54	
15.5	Approach	30%	41.27	0.65	2.90	6.60	0.34	
	Taxi/Idle	7%	18.15	2.29	12.43	3.10	0.54	
JT8D-17[7]	Takeoff	100%	164.68	0.66	0.75	19.30	0.54	
P & W	Climbout	85%	131.88	0.75	1.01	15.26	0.54	
16.0	Approach	30%	46.83	1.86	8.13	6.23	0.54	
	Taxi/Idle	7%	19.44	9.57	29.56	3.29	0.54	
JT8D-17A	Takeoff	100%	155.16	0.25	1.07	19.10	0.54	
P&W	Climbout	85%	123.60	0.30	1.16	14.30	0.54	
16.0	Approach	30%	43.70	0.64	2.88	6.70	0.54	
	Taxi/Idle	7%	18.53	2.02	12.46	3.20	0.54	
JT8D-17AR	Takeoff	100%	180.56	0.21	0.93	24.50	0.54	
P&W	Climbout	85%	138.49	0.27	1.08	16.00	0.54	
17.4	Approach	30%	47.28	0.55	2.68	8.00	0.54	
	Taxi/Idle	7%	19.54	1.33	10.70	3.20	0.54	
JT8D-17R	Takeoff	100%	187.44	0.21	0.95	25.30	0.54	
P & W	Climbout	85%	135.90	0.27	1.03	17.60	0.54	
17.4	Approach	30%	49.67	0.53	2.54	8.40	0.54	
	Taxi/Idle	7%	20.50	0.95	9.43	3.30	0.54	
JT8D-209	Takeoff	100%	157.54	0.35	1.03	22.80	0.54	
P&W	Climbout	85%	130.00	0.50	1.40	19.00	0.54	
19.2	Approach	30%	47.51	1.69	4.37	8.80	0.54	
	Taxi/Idle	7%	17.24	4.03	14.10	3.50	0.54	
JT8D-217/217A/217C	Takeoff	100%	174.60	0.28	0.80	25.70	0.54	
P & W	Climbout	85%	142.59	0.43	1.23	20.60	0.54	
20.8	Approach	30%	50.70	1.60	4.17	9.10	0.54	
	Taxi/Idle	7%	18.15	3.33	12.27	3.70	0.54	
JT8D-219	Takeoff	100%	179.10	0.37	0.73	27.00	0.54	
P&W	Climbout	85%	143.52	0.42	1.20	20.80	0.54	
21.7	Approach	30%	50.49	1.59	4.07	9.13	0.54	
	Taxi/Idle	7%	17.78	3.48	12.63	3.60	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines[1] (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
JT9D-7[4] P&W	Takeoff	100%	269.03	0.05	0.20	29.40	0.54	
	Climbout	85%	219.88	0.10	0.50	21.40	0.54	
	Approach	30%	77.47	1.00	9.60	7.80	0.54	
	Taxi/Idle	7%	30.82	29.80	77.02	3.10	0.54	
JT9D-7F(modV)/ 7A(modV) P&W 46.7	Takeoff	100%	286.67	0.30	0.40	46.00	0.54	
	Climbout	85%	233.33	0.30	0.40	34.40	0.54	
	Approach	30%	82.50	0.50	2.90	7.80	0.54	
	Taxi/Idle	7%	28.97	26.00	54.00	3.10	0.54	
JT9D-7R4D/7R4D1 P&W 46.7	Takeoff	100%	271.83	0.15	0.51	38.50	0.54	
	Climbout	85%	221.96	0.12	0.48	32.00	0.54	
	Approach	30%	100.44	0.13	1.36	9.80	0.54	
	Taxi/Idle	7%	27.17	1.25	10.00	4.10	0.54	
JT9D-7R4E/E1 (A1500) P&W 52.4	Takeoff	100%	280.16	0.16	0.57	41.60	0.54	
	Climbout	85%	228.04	0.13	0.53	34.20	0.54	
	Approach	30%	86.36	0.13	1.23	10.40	0.54	
	Taxi/Idle	7%	29.23	1.11	8.27	4.10	0.54	
JT9D-7R4E1(H) (A1-600) P&W 45.5	Takeoff	100%	293.39	0.15	0.67	36.90	0.54	
	Climbout	85%	241.93	0.13	0.67	29.70	0.54	
	Approach	30%	84.66	0.22	1.46	8.50	0.54	
	Taxi/Idle	7%	29.17	3.35	14.00	3.50	0.54	
JT9D-7R4G2 P&W 53.8	Takeoff	100%	321.30	0.15	0.74	41.30	0.54	
	Climbout	85%	248.68	0.14	0.63	32.10	0.54	
	Approach	30%	87.17	0.18	1.40	8.80	0.54	
	Taxi/Idle	7%	29.62	1.55	11.82	3.80	0.54	
JT9D-7R4H1/H2 P&W 53.9	Takeoff	100%	332.28	0.15	0.74	45.10	0.54	
	Climbout	85%	264.42	0.14	0.63	34.20	0.54	
	Approach	30%	95.60	0.18	1.39	8.90	0.54	
	Taxi/Idle	7%	32.36	1.48	11.63	3.80	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines[1] (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
JT9D-70/59/7Q	Takeoff	100%	323.00	0.20	0.20	31.60	0.54	
P&W	Climbout	85%	264.50	0.20	0.20	25.60	0.54	
51.1	Approach	30%	90.00	0.30	1.70	7.80	0.54	
	Taxi/Idle	7%	31.35	12.00	53.00	3.00	0.54	
PW2037	Takeoff	100%	203.44	0.05	0.40	31.10	0.54	
P&W	Climbout	85%	167.46	0.06	0.41	24.80	0.54	
37.6	Approach	30%	52.78	0.21	2.30	10.30	0.54	
	Taxi/Idle	7%	18.65	1.26	23.10	4.40	0.54	
PW2040	Takeoff	100%	241.01	0.03	0.20	47.70	0.54	
P&W	Climbout	85%	191.54	0.04	0.20	27.70	0.54	
40.8	Approach	30%	65.21	0.18	2.60	11.00	0.54	
	Taxi/Idle	7%	20.50	2.36	23.60	4.40	0.54	
PW2041	Takeoff	100%	253.57	0.03	0.20	37.00	0.54	
P&W	Climbout	85%	203.18	0.04	0.20	29.00	0.54	
42.3	Approach	30%	68.39	0.16	2.50	11.00	0.54	
	Taxi/Idle	7%	21.03	2.23	23.10	4.50	0.54	
PW4056/4156	Takeoff	100%	309.79	0.06	0.44	28.10	0.54	
P&W	Climbout	85%	255.29	0.01	0.57	22.90	0.54	
55.9	Approach	30%	87.04	0.13	2.00	11.60	0.54	
	Taxi/Idle	7%	27.51	1.92	21.86	4.80	0.54	
PW4152	Takeoff	100%	287.96	0.13	0.12	26.90	0.54	
P&W	Climbout	85%	236.11	0.16	0.17	22.70	0.54	
51.9	Approach	30%	78.44	0.15	1.09	11.10	0.54	
	Taxi/Idle	7%	23.41	0.74	12.76	4.90	0.54	
PW4158	Takeoff	100%	328.18	0.09	0.40	30.20	0.54	
P&W	Climbout	85%	265.08	0.02	0.54	23.70	0.54	
57.9	Approach	30%	90.21	0.14	1.88	11.80	0.54	
	Taxi/Idle	7%	27.91	1.78	20.99	4.80	0.54	
PW4460	Takeoff	100%	350.13	0.10	0.37	32.30	0.54	
P&W	Climbout	85%	275.80	0.03	0.51	24.70	0.54	
59.9	Approach	30%	92.99	0.14	1.78	12.00	0.54	
	Taxi/Idle	7%	28.17	1.66	20.32	4.90	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines[1] (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2[3]	Particulate
JT15D-1 P&WC 2.39	Takeoff	100%	19.58	0.01	2.65	7.60	0.54	
	Climbout	85%	16.40	0.01	3.50	6.77	0.54	
	Approach	30%	6.75	4.43	40.50	3.44	0.54	
	Taxi/Idle	7%	3.04	50.50	132.00	1.75	0.54	
JT15D-4 P&WC 2.72	Takeoff	100%	22.45	0.09	2.10	9.23	0.54	
	Climbout	85%	18.92	0.19	3.18	8.56	0.54	
	Approach	30%	7.80	5.15	32.00	5.39	0.54	
	Taxi/Idle	7%	3.45	40.00	97.00	2.63	0.54	
PT6A-27[6] P&WC	Takeoff	100%	7.08	0.00	1.01	7.81	0.54	
	Climbout	90%	6.67	0.00	1.20	7.00	0.54	
	Approach	30%	3.58	2.19	23.02	8.37	0.54	
	Taxi/Idle	1%	1.92	50.17	64.00	2.43	0.54	
PT6A-41” P&WC	Takeoff	100%	8.50	1.75	5.10	7.98	0.54	
	Climbout	90%	7.88	2.03	6.49	7.57	0.54	
	Approach	30%	4.55	22.71	34.80	4.65	0.54	
	Taxi/Idle	7%	2.45	101.63	115.31	1.97	0.54	
Dart RDa7 RR	Takeoff	100%	23.55	1.00	3.20	5.60	0.54	
	Climbout	85%	20.77	1.10	3.50	4.50	0.54	
	Approach	30%	10.77	3.00	33.30	0.90	0.54	
	Taxi/Idle	7%	6.84	23.90	91.40	0.70	0.54	
Dart RDa10 RR	Takeoff	100%	28.17	0.00	2.20	4.30	0.54	
	Climbout	85%	22.49	0.00	3.00	3.90	0.54	
	Approach	30%	10.44	0.00	23.20	2.20	0.54	
	Taxi/Idle	7%	6.96	8.90	41.40	1.60	0.54	
M45H-01 RR 7.28	Takeoff	100%	65.87	0.75	6.20	11.50	0.54	
	Climbout	85%	55.03	0.74	7.90	9.30	0.54	
	Approach	30%	19.31	7.40	51.00	3.60	0.54	
	Taxi/Idle	7%	7.01	59.50	178.40	1.50	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines’ (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
OLYMPUS 593 MK610	Takeoff	100%	841.94	2.90	29.00	9.50	0.54	
RR	Climbout	65%	308.07	1.70	19.90	9.30	0.54	
37.0	Descent	15%	90.61	22.00	73.20	2.50	0.54	
	Approach	34%	154.90	11.40	52.90	3.50	0.54	
	Taxi/Idle	7%	55.69	33.40	100.10	1.70	0.54	
RB.211-22B	Takeoff	100%	246.83	0.36	2.48	34.32	0.54	
RR	Climbout	85%	203.97	0.39	4.14	25.63	0.54	
41.0	Approach	30%	73.15	7.73	26.38	8.05	0.54	
	Taxi/Idle	7%	30.03	65.37	93.17	2.70	0.54	
RB.211-524B/B2/B3/B4	Takeoff	100%	315.21	0.52	1.83	47.00	0.54	
RR	Climbout	85%	256.48	0.40	2.82	33.00	0.54	
49.1	Approach	30%	91.67	4.98	20.00	9.75	0.54	
	Taxi/Idle	1%	35.98	50.60	82.10	3.53	0.54	
RB.211-524C2	Takeoff	100%	328.04	0.00	0.66	41.90	0.54	
RR	Climbout	85%	267.20	0.22	1.63	32.30	0.54	
50.5	Approach	30%	97.88	4.42	18.90	10.40	0.54	
	Taxi/Idle	7%	39.68	54.20	81.00	3.37	0.54	
RB.211-524D4[7]	Takeoff	100%	322.12	0.02	0.53	56.97	0.54	
RR	Climbout	85%	257.96	0.42	1.15	41.06	0.54	
51.9	Approach	30%	94.97	4.68	16.44	9.68	0.54	
	Taxi/Idle	7%	38.50	45.11	71.87	4.12	0.54	
RB.211-5246	Takeoff	100%	346.56	2.28	0.59	58.71	0.54	
RR	Climbout	85%	275.13	1.46	0.43	40.54	0.54	
56.8	Approach	30%	92.59	1.14	1.01	9.56	0.54	
	Taxi/Idle	7%	34.39	3.28	13.74	4.63	0.54	
RB.211-524H	Takeoff	100%	361.11	1.00	0.90	65.80	0.54	
RR	Climbout	85%	287.04	0.60	0.40	46.30	0.54	
59.5	Approach	30%	93.92	0.30	1.00	10.30	0.54	
	Taxi/Idle	7%	34.39	0.50	11.70	4.80	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines[1] (continued)

Model-Series Manufacturer-[3] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
RB.211-535C	Takeoff	100%	238.10	0.25	0.70	33.71	0.54	
RR	Climbout	85%	194.45	0.14	0.27	24.89	0.54	
36.7	Approach	30%	71.43	0.44	0.84	6.37	0.54	
	Taxi/Idle	7%	26.46	1.44	18.79	3.44	0.54	
RB.211-535E4	Takeoff	100%	246.03	0.69	1.01	52.70	0.54	
RR	Climbout	85%	199.74	0.94	1.23	36.20	0.54	
39.5	Approach	30%	75.40	1.33	1.71	7.50	0.54	
	Taxi/Idle	7%	25.13	2.85	15.44	4.30	0.54	
SPEY MK511	Takeoff	100%	117.59	0.98	1.81	23.37	0.54	
RR	Climbout	85%	96.03	1.32	2.06	19.18	0.54	
11.3	Approach	30%	36.91	7.23	20.30	7.94	0.54	
	Taxi/Idle	7%	15.74	56.73	97.96	1.48	0.54	
SPEY MK511-8	Takeoff	100%	117.86	0.09	0.12	22.70	0.54	
RR	Climbout	85%	96.03	0.12	0.63	17.30	0.54	
11.3	Approach	30%	36.77	0.18	2.65	7.20	0.54	
	Taxi/Idle	7%	16.80	3.69	31.77	3.60	0.54	
SPEY MK555[8]	Takeoff	100%	73.50	0.74.	0.41	19.61	0.54	
RR	Climbout	85%	60.13	1.27	0.16	15.07	0.54	
9.89	Approach	30%	22.66	5.43	17.96	6.12	0.54	
	Taxi/Idle	7%	11.74	71.84	74.68	2.26	0.54	
TAY MK620-15/MK611-8	Takeoff	100%	100.53	0.80	0.70	21.10	0.54	
RR	Climbout	85%	83.33	0.30	0.80	16.80	0.54	
13.8	Approach	30%	30.42	0.90	3.90	5.70	0.54	
	Taxi/Idle	7%	14.55	3.40	24.10	2.50	0.54	
TAY MK650[9]	Takeoff	100%	115.61	0.40	1.70	19.80	0.54	
RR	Climbout	85%	94.58	0.40	2.00	16.50	0.54	
15.1	Approach	30%	33.60	0.90	6.50	4.60	0.54	
	Taxi/Idle	7%	15.74	3.30	33.80	1.70	0.54	

Table 5-4

Modal emission rates - Civil aircraft engines[1] (concluded)

SOURCE: ICAO Engine Exhaust Emissions Dtabank (ICAO Committee on Aviation Environmental Protection, Working Group 3 Meeting, Mariehamn, Aland., October 1989), unless othewise noted.

[2] MANUFACTURERS: All. - Allison, Con - Teledyne/Continental, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, P&W - Pratt & Whitney, P&WC - Pratt & Whitney Canada, RR - Rolls-Royce

SO_2 emissions based on national average sulfur content of aviation fuels from Aviation Turbine Fuels, 1989, Dickson, Cheryl L. and Paul W. Woodward, March, 1990, NIPER Report Number NIPER-164 PPS, National Institute for Petroleum and Energy Research, IIT Research Institute, Bartlesville, Oklahoma.

[4] Source of data is AP-42, Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources, U.S. Environmental Protection Agency, Ann Arbor, Michigan, September, 1985. (Aircraft data from February 1980).

[5] Source of engine data is General Electric Office of Combustion Technology, GE Aircraft Engines, One Neumann Way MD A309, Cincinnati, Ohio 45215-6301, 513/774-4438.

[6] Source of data is AP-42. Source of Particulate data is AP-42 Reference 4 (M. Platt, et al., The Potential Impact of Aircraft Emissions upon Air Quality, APTD-1085, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1971). The indicated reference does not specify series number for this model engine.

Source of engine data is ICAO, ICAO Engine Exhaust Emissions Databank. Data are sales weighted averages of two versions of this engine. The basis is 93% high emission combustors and 7% low emission combustors.

[8] Source of engine data is ICAO, ICAO Engine Exhaust Emissions Databank. Data are sales weighted averages of two versions of this engine. The basis is 77% high emission combustors and 23% low emission combustors.

[9] Source of engine data is Rolls Royce Combustion Research Department, Rolls Royce plc. P.O. Box 31, Derby DE2 88J England. Telephone - 0332 242424.

The mode most likely to vary by time for each specific airport is taxi/idle time. Total taxi/idle time for a very congested airport can be as much as three or four times longer than for an uncongested airport. Taxi/idle-in time typically is shorter than taxi/idle-out time because there are usually fewer delays for aircraft coming into a gate than for aircraft lining up to takeoff. For a large congested airport the taxi/idle-out time can be three times longer than taxi/idle-in time. Taxi/idle time also may vary by aircraft type. For example, wide-body jets may all use special gates at the terminal that place them further from the runway than narrow-body jets or small regional commuter aircraft so their taxi/idle-in and taxi/idle-out times are longer. Because of the variation in taxi/idle time, it is important to get data specific to the airports of interest in the inventory. Commercial airlines must keep track of their taxi/idle time at each airport for different aircraft types so that their flight schedules reflect anticipated daily and seasonal variations. These data are important to the airlines since they report schedule delays to the Department of Transportation as a measure of their operating performance. Therefore, the airlines' Flight Operations departments at their headquarters locations are the best source of data for taxi/idle time by aircraft type at a particular airport. Since all airlines using a particular airport will experience similar taxi/idle times it is only necessary to get information from a single source. For the inventory calculations, taxi/idle-in and taxi/idle-out time are added together to get a total time for the taxi/idle mode.

The final step in the procedure is to calculate total emissions for each aircraft type and to sum them for a total commercial aircraft emission rate. The following series of equations illustrates the calculation:

Adjust Approach and Climbout TIM to Represent Local Conditions

These equations adjust the times-in-mode, which are based on a default mixing height of 3000 feet, to an airport specific value based on the local mixing height. Equation 5-2 assumes the climbout mode begins with the transition from takeoff to climbout at 500 feet and continues until the aircraft exits the mixing layer.

$$TIM_{app-C} = 4 \text{ X } (H/3000) \qquad (5\text{-}1)$$

$$TIM_{clm-C} = 2.2 \text{ X } [(H-500)/2500] \qquad (5\text{-}2)$$

TIM_{app-C} • time in the approach mode for commercial aircraft, in minutes

TIM_{clm-C} • time in the climbout mode for commercial aircraft, in minutes

H mixing height used in air quality modeling for time and region of interest

Calculate Emissions for Each Aircraft Type

$$E_{ij} = \Sigma\ (TIM_{jk}) \text{ X } (FF_{jk}/1000) \text{ X } (EI_{ijk}) \text{ X } (NE_j) \qquad (5\text{-}3)$$

E_{ij} = total emissions of pollutant i, in pounds, produced by aircraft type j for one LTO cycle

TIM_{jk} = time in mode for mode k, in minutes, for aircraft type j

FF_{jk} = fuel flow for mode k, in pounds per minute, for each engine used on aircraft type j

EI_{ijk} = emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel,in mode k for aircraft type j

NE_j = number of engines used on aircraft type j

Calculate Total Emissions for All Commercial Aircraft

$$E_{Ti(C)} = \sum (E_{ij}) \times (LTO_j) \quad (5\text{-}4)$$

$E_{Ti(C)}$ - total emissions of pollutant i, in pounds, produced by all commercial aircraft operating in the region of interest (where j covers the range of commercial aircraft operating in the area)

LTO_j - total number of LTO cycles for aircraft type j, during the inventory period.

After completing this series of equations, the inventory of emissions is complete for commercial aircraft. The next series of calculations is a repeat of steps three through six for general aviation aircraft.

The overall methodology for general aviation and air taxi aircraft is similar to that for commercial aircraft. Unfortunately, defining the fleet mix and associated activity level of general aviation and air taxi aircraft is more difficult than for commercial aircraft. FAA does not track operations by aircraft model for the general aviation category and no other sources of these data cover all states. For some states, this information is available for some airports from the State Airport Authority or from the operations officials at individual airports. Detailed model information for aircraft operating in the inventory area is difficult to locate, except perhaps for air taxis, and may add only relatively small improvement in accuracy to the emissions inventory compared to treating general aviation and air taxis as though they were made up of a representative mix of aircraft. For some smaller airports, air taxi activity may predominate and it may be possible to locate aircraft specific information on the operations there.

Where information on specific aircraft is available, it can be combined with engine-specific emission factors and the time in each operational mode to estimate total engine emissions from the general aviation and air taxi categories. Table 5-4 shows emission factors for the various engines. Table 5-5 shows some examples of the aircraft and engine combinations.

Table 5-5

General aviation aircraft types and engines models[1]

Aircraft		No. of Seats	No. of Engines	No. of Aircraft[2]	Engine	Mnf[3]
Piston						
	Bellanca 7GCBC Seaplane	3	1	567	O-320	Lyc
	Cessna 150	2	1	13760	O-200	Con
	Cessna 337 series	6	2	1151	TSIO-360C	Con
	Piper PA- 18 series	2	1	3590	O-320[4]	Lyc
Turbojet						
	Aerospatiale SN601 Corvette	16	2	1	JT15D-4	PWC
	Canadair CL-600 Challenger	13	2	61	ALF502L-2	Lyc
	Dassault Bregue Falcon 10	7	2	126	TFE731-2	Grt
	Dassault Bregue Falcon 50	10	3	125	TFE731-3	Grt
	Gates Learjet 35/36	10	2	67	TFE731-2-2B	Grt
	Gates Learjet 35A/36A	10	2	342	TFE731-2-2B	Grt
	Israel Aircraft IAI 1124	10	2	151	TFE731-3	Grt
	Learjet 31	10	2	6	TFE731-2	Grt
	Mitsubishi MU-300 series	11	2	75	JT15D-4	PWC
Turboprop						
	de Havilland DHC-6-300	22	2	40	PT6A-27	PWC
	Fairchild Pilatus PC6 series	8	1	8	PT6A-27[5]	PWC
	Helio Aircraft HST-550A Stallion	10	1	1	PT6A-27	PWC
	Piper PA-42 series	11	2	105	PT6A-41[6]	PWC

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[1] Source of aircraft, corresponding engines, and number of engines is FAA Aircraft Engine Emission Database (FAEED), U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, 1991. Source of number of seats, aircraft type, and number of aircraft is Census of U.S. Civil Aircraft, U.S. Department of Transportation, Federal Aviation Administration, Office of Management Systems, Calendar Year 1989.

[2] No. of Aircraft refers to Total U.S. Registered Aircraft as of December 31, 1989.

[3] ENGINE MNF ABBREVIATIONS: Con - Teledyne/Continental, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, P&W - Pratt & Whitney, PWC - Pratt & Whitney Canada, RR - Rolls-Royce

[4] Engine refers. to a Pk-18-150 Super aircraft.

[5] Engine refers to a PC6/B2H2 aircraft.

[6] Engine refers to a PA-42 Cheyenne aircraft.

If the detailed estimation procedure is being followed based on specific aircraft and engines, airport specific estimates on time-in-mode might be used if available from airport officials. These data likely vary quite widely because of the many different types of services provided by this aircraft category.

Adjust Approach and Climbout TIM to Represent Local Conditions

$$TIM_{app-G} = 6 \text{ X } (H/3000) \qquad (5\text{-}5)$$

$$TIM_{clm-G} = 5 \text{ X } [(H-500)/2500] \qquad (5\text{-}6)$$

TIM_{app-G} = time in the approach mode, in minutes

TIM_{clm-G} = time in the climbout mode, in minutes (assumes transition from takeoff to climbout occurs at 500 feet)

H mixing height used in air quality modeling for time and region of interest

Calculate Emissions for Each Aircraft Type

The emission factors that appear in Table 5-4 for general aviation and air taxi aircraft have not been updated since the last version of AP-42. The next edition of AP-42 should include updates to much of the date that appears in the table.

$$E_{ij} = \Sigma (TIM_{jk}) \text{ X } (FF_{jk}/1000) \text{ X } (EI_{ijk}) \text{ X } (NE_j) \qquad (5\text{-}7)$$

E_{ij} = total emissions of pollutant i, in pounds, produced by aircraft type j for one LTO cycle.

TIM_{jk} = time in mode for mode k, in minutes, for aircraft type j

FF_{jk} = fuel flow for mode k, in pounds per minute, for each engine used on aircraft type j (from Table 5-4)

EI_{ijk} = emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel, in mode k for aircraft type j (from Table 5-4)

NE_j = number of engines used on aircraft type j (from Table 5-5)

Calculate Total Emissions for All General Aviation or Air Taxi Aircraft

$$E_{Ti(G)} = \Sigma E_{ij} \qquad (5\text{-g})$$

$E_{Ti(G)}$ = total emissions of pollutant i, in pounds, produced by all general aviation or air taxi aircraft operating in the region of interest (where j covers the range of aircraft operating in the area)

LTO_j = total number of LTO cycles for aircraft type j, during the inventory period

Where detailed information on specific aircraft mix and activity is unavailable, a rough estimate of emissions for each aircraft category can be made using emission indices based on a representative fleet mix. The following indices were calculated based on 1988 fleet data for general aviation aircraft:

HC	0.394 pounds per LTO
CO	12.014 pounds per LTO
NO_x	0.065 pounds per LTO
SO_2	0.010 pounds per LTO

Since air taxis have fewer of the smallest engines in their fleet and more turboprop and turbojet engines, their emission factors are somewhat different:

HC	1.234 pounds per LTO
co	28.130 pounds per LTO
NO_x	0.158 pounds per LTO
SO_2	0.015 pounds per LTO

FAA Air Traffic Activity contains information on the number of military operations at airports with FAA-operated traffic control towers. This information can be used in much the same way as for general aviation aircraft, however, military air bases are not included in this reference. The information only addresses military operations at civil airports. Military air bases included in the modeling area should be apparent from maps of the area. For these bases, it likely will be difficult to get good information on fleet make up and activity. In some cases, information may be available from the Office of the Base Commander on fleet make-up and possibly some measure or estimate of activity such as LTOs for one day or one month. Where specific information is available for aircraft type and LTOs, Table 5-6 lists military aircraft and their engines, and Table 5-7 lists the modal emission rates for these engines.

If data on fleet make up and activity are obtained from the base commander or the environmental support offices; the. procedure for calculating an inventory for military aircraft is the same as that used for both commercial and general aviation.

Adjust Approach and Climbout TIM to Represent Local Conditions

$$TIM_{app-M} = 4 \times (H/3000) \qquad (5-9)$$

$$TIM_{clm-M} = 1.4 \times [(H-500)/2500] \qquad (5-10)$$

TIM_{app-M} time in the approach mode for military aircraft, in minutes

TIM_{clm-M} - time in the climbout mode for military aircraft, in minutes (assumes transition from takeoff to climbout occurs at 500 feet)

H mixing height used in air quality modeling for time and region of interest

Calculate Emissions for Each Aircraft Type

$$E_{ij} = \sum (TIM_{jk}) \; X \; (FF_{jk}/1000) \; X \; (EI_{ijk}) \; X \; (NE_j) \qquad (5\text{-}11)$$

E_{ij} total emissions of pollutant i, in pounds, produced by aircraft type j for one LTO cycle

TIM_{jk} • time in mode for mode k, in minutes, for aircraft type j

FF_{jk} fuel flow for mode k, in pounds per minute, for each engine used on aircraft type j (from Table 5-7)

EI_{ijk} emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel, in mode k for aircraft type j **(from** Table 5-7)

NE_j number of engines used on aircraft type j (from Table 5-6)

Calculate Total Emissions for All Military Aircraft

$$E_{Ti(M)} = \sum E_{ij} \qquad (5\text{-}12)$$

$E_{Ti(M)}$ • total emissions of pollutant i, in pounds, produced by all military aircraft operating in the region of interest (where j covers the range of military aircraft operating in the area)

Variations to the inventorv calculation mocedure

There are several variations to the basic inventory procedure that can adjust the period covered by the inventory or address some operational procedures followed by some pilots or airlines that affect aircraft emissions.

The calculation procedure described in the methodology does not address daily or seasonal variations. If the air quality modeling period requires emissions data that accounts for these variations, certain adjustments must be made to the equations. The daily or seasonal variations will be exhibited in LTOs, mixing height, and idle time, primarily idle-out.

The references for determining LTOs give a data on an annual basis and adjustment may be necessary to capture changes over time. The frequency of LTOs at most civil airports are reasonably uniform during daylight hours with lower activity during the night and uniform during week days with lower activity on the weekends, although some airports that cater to recreational flying may show higher activity on weekend days. For most large urban airports, LTOs are uniform on a monthly basis with a slight increase in activity during the summer, which typically is a time of high travel, although some regions may attract more travelers during the winter as a result of their climate. The seasonal variation in activity at smaller urban airports or airports that serve smaller cities may be more pronounced because of factors that affect travel on a local basis such as tourism or seasonal business activity. Obtaining specific information on daily and seasonal variation is difficult. The best source likely will be the airport operators, many of who keep some type of records of activity such as total

Table 5-6

Military aircraft types and engine models[1]

Aircraft	Type[2]	Operator[3]	No. of Engines	Engine Model	Mnf[4]
Combat					
Boeing B52-H Stratofortress	TF	USAF	8	TF33-P-3	PW
Boeing EC- 135C	TF	USAF	4	TF33-P-5	PW
Douglas A-4 Skyhawd	TJ	USN	1	J52-P-8B	PW
Douglas A-4M Skyhawk[6]	TJ	USMC	2	J52-P-408	PW
General Dynamics F-16 Fighting Falcon'	TF	USAF	1	F101DFE	PW
	TF	USAF/USN	1	F100-PW-200[1]	PW
Grumman A-6 Intrude?	TJ	USN	2	J52-P-8B	PW
Grumman E-2 Hawkeye[5]	TP	USN	2	T56-A-16	All.
Grumman EA-6B Prowler[6]	TJ	USMC/USN	2	J52-P-408	PW
Grumman F-14 Tomcat!	TF	USN	2	TF30-P-412A	PW
Learjet Corp C-21-A	TF	USAF	2	TFE 731-2-2B	Grt
Lockheed S-3 Viking'	TF	USN	2	TF34-GE-400	GE
LTV Aircraft A-7E Corsair II	TF	USN	1	TF41-A-2	All.
McDonnell Douglas AV-8'	TF	USMC	1	F402	RR
McDonnell Douglas F-4 Phantom II[5]	TJ	USAF/USN	2	J79-GE-10B	GE
McDonnell Douglas F-4B Phantom II[6]	TJ	USMC/USN	2	J79-GE-8D	GE
McDonnell Douglas F-4N Phantom II[6]	TJ	USN	2	J79-GE-8D	GE
McDonnell Douglas F-4S Phantom II	TJ	USN	2	J79-GE-10	GE
McDonnell Douglas F-15C/D Eagle	TF	USAF	2	F100-PW-100	PW
McDonnell Douglas F/A-18 Home?	TF	USN	2	F404-GE-400	GE
McDonnell Douglas RF-4B Phantom II[6]	TJ	USMC	2	J79-GE-8D	GE
Northrop F-5E Tiger II	TJ	USAF/USN	2	J85-GE-21	GE
Northrop F-SF Tiger II	TJ	USAF/USN	2	J85-GE-21	GE
Northrop RF-SE Tigereye	TJ	USAF	2	J85-GE-21	GE
Rockwell OV- 10 Bronco'	TP	USAF/USMC	2	T76-G-12A	Grt
Vought A-7 Corsair II[5]	TF	USAF/USN	1	TF4 l-A-2	Au.
Trainer					
Boeing T-43A	TF	USAF	2	JT8D-9	PW
CASA C-101 Ariojet	TF		1	TFE 731-2	Grt
FMA Cordoba PAMPA IA.63	TF		1	TFE 731-2	Grt
Grumman Gulfstream	TF	USN	2	Dart RDa7	RR
McDonnell Douglas D F-15	TF	USAF	1	F100-PW-100	PW
McDonnell Douglas F-15 C/D Eagle	TF	USAF	2	F100-PW-100 /200[7]	PW
McDonnell Douglas F/A- 18 Hornet'	TF	USN	2	F404-GE-400	GE
Mitsubishi T-2[5]	TJ	USN	2	J85-GE-2	GE

Table 5-6

Military aircraft types and engine models[1] (continued)

Aircraft	Type[2]	Operator[3]	No. of Engines	Engine Model	Mnf[4]
Transport					
Australia Govt Nomad 22B	TP		2	250B17B	All.
Australia Govt Nomad 24	TP		2	250B 17B	All.
BEECH C-12A/B/C	TP	Army/USAF	2	PT6A-41	PWC
Boeing B-747-200	TF		4	JT9D-7R4G2	PW
Boeing C-135B Stratolifter	TF	USAF	4	TF33-P-5	PW
Boeing E-4A/B NEACP	TF	USAF	4	CF6-50E	GE
Boeing VC-25A	TF	USAF	4	CF6-80C2B1	GE
de Havilland W-18A	TP	Army	2	PT6A-27	PWC
Fairchild C-26A	TP	NG	2	TPE 331	Grt
Grumman C-1A Trade?	P	USN	2	R-1820	W
Grumman Gulfstream	TF	USAF	2	Dart RDa7	RR
LASC Georgia C-141B Starlifter	TF	USAF	4	TF33-P-7	PW
Lockheed C-130E Hercules	TP		4	T56-A-7	All.
Lockheed C-130 Hercules[5]	TP		4	T56-A-16	All.
Lockheed C-141 Starlifter	TF	USAF	4	TF33-P-7	PW
Lockheed L-100 Hercules	TP		4	501D22A	All.
McDonnell Douglas C-9A Nightingale	TF	USAF	2	JT8D-9	PW
McDonnell Douglas C-9B	TF	USN	2	JT8D-9	PW
McDonnell Douglas KC-10A Extender	TF	USAF	3	CF6-50C2	GE
McDonnell Douglas VC-9C	TF	USAF	2	JT8D-9	PW
Utility					
BEECH RU-23 1 J	TP	Army	2	PT6A-41	PWC
BEECH UC-12F/M	TP	USMC/USN	2	PT6A-41	PWC
Helicopter					
Bell UH-1, AH-1[5]	TS	Army	1	T53-L-11D	Lyc
Boeing Vertol H-46 Sea Knight[5]	TS	USMC/USN	2	T58-GE-8F	GE
Boeing Vertol H-46E Sea Knight[6]	TS	USMC/USN	2	T58-GE-16	GE
Costruzioni HH-3F	TS	USCG	2	T58-GE-5	GE
Kaman H-2 Seasprite[5]	TS	USN	2	T58-GE-8F	GE
Sikorsky H-3 Sea King series[5]	TS		2	T58-GE-8F	GE
Sikorsky H-53 Sea Stallion/ Super Stallion’	TS		3	T64-GE-415	GE
Sikorsky HH-3E Jolly Green Giant	TS	USAF	2	T58-GE-5	GE
Sikorsky SH-3E	TS		2	T58-GE-5	GE
Sikorsky SH-3F	TS		2	T58-GE-5	GE
Sikorsky SH-6lAA	TS		2	T58-GE-5	GE

Table 5-6

Military aircraft types and engines models[1] (concluded)

[1] SOURCE: FAA Aircraft Engine Emission Database (FAEED), (U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, **1991)** unless otherwise noted.

[2] Source of Type information is "Aviation Week & Space Technology," McGraw-Hill Publication, March 18, 1991.
TYPES: P - Piston, TF - Turbofan, TJ - Turbojet, TP - Turboprop, TS - Turboshaft

[3] Source of Operator information is Encyclopedia of Modern Military Aircraft, Taylor, Michael, 1987.
OPERATORS: Army, NG - National Guard, USAF - U.S. Air Force, USCG - U.S. Coast Guard, USMC - U.S. Marine Corps, USN - U.S. Navy, US - USAF, USCG, USMC, & USN.

[4] ENGINE MANUFACTURERS: All. - Allison, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, PW - Pratl & Whitney, W - Curtis Wright

[5] Source of aircraft and corresponding engine information is Example of an Air Base Emissions Inventory for the County of San Diego (1987), Aircraft Environmental Support Office, AESO Report No. 2-91, San Diego, California, March 1991.

[6] Sources: Engines - Summary Table of Gaseous and Particulate Emissions from Aircraft Engines, Aircraft Environmental Support Office, AESO Report No. 6-90, San Diego, California, June 1990.
Aircraft, Type, and No. of Engines - "Aviation Week & Space Technology," McGraw-Hill Publication, March 18, **1991.**
Classification and Operator - Encyclopedia of Modern Military Aircraft, Taylor, Michael, 1987.

[7] Source: "Aviation Week & Space Technology," McGraw-Hill Publication, March 18, 1991.

Table 5-7

Modal emission rates - Military aircraft engines’

Model-Series Manufacturer^{2} Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	$SO_2{}^{3}$	Particulate
250B17B^{4}	Takeoff	Military	4.42	0.26	7.8 I	6.60	0.54	
All.	Climbout	95%	4.08	0.37	9.02	5.96	0.54	
	Approach	30%	1.42	5.18	48.59	2.24	0.54	
	Idle	Idle	1.05	20.16	97.30	1.43	0.54	
501D22A^{4}	Takeoff	Military	39.60	0.28	2.04	8.88	0.54	
All.	Climbout	95%	36.63	0.89	2.06	9.22	0.54	
	Approach	30%	19.00	1.96	5.10	7.49	0.54	
	Idle	Idle	10.17	17.6 t	43.61	3.52	0.54	
T56-A-7^{4}	Takeoff	Military	34.65	0.38	2.12	9.28	0.54	1.78^{5}
All.	Climbout	95%	31.80	0.47	2.4I	9.22	0.54	I.575
	Approach	30%	17.55	0.47	3.5 I	7.4 l	0.54	2.85^{5}
	Idle	Idle	9.13	20.99	31.93	3.83	0.54	2.925
T56-A-15^{6}	Takeoff	100%	39.87	0.18	1.60	I l.71	0.54	
All.	Climbout	90%	36.45	0.18	1.60	10.18	0.54	
	Approach	30%	19.10	0.28	3.00	6.38	0.54	
	Idle	7%	8.23	14.96	17.69	2.50	0.54	
l-56-A. 16	Takeoff	Military	36.98	0.16	0.65	10.45	0.54	
All.	Climbout	Military	36.98	0.16	0.65	IO.45	0.54	
	Approach	75%	33.27	0.17	0.42	9.93	0.54	
	Idle	L/S Gr.idle	9.98	27.32	30.1 l	3.53	0.54	
T63-A-5A^{7}	Takeoff	Military	3.58	0.08	7.54	5.07	0.54	
All.	Climbout	75%	2.92	0.24	14.3 I	4.6 l	0.54	
	Approach	30%	1.75	3.27	38.59	2.90	0.54	
	Idle	Gr.idle	1.02	20.30	79.15	I.42	0.54	
TT41-A-2^{7}	Takeoff	Intermediate	149.00	0.64	1.64	22.46	0.54	
All.	Climbout	Intermediate	149.00	0.64	1.64	22.46	0.54	
	Approach	75% M/C	100.00	0.73	2.17	16.85	0.54	
	Idle	Idle	18.17	51.36	94.80	1.71	0.54	

Table 5-7

Modal emission rates - Military aircraft engined (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO,	SO_2[3]	Particulate
J85-GE-2[7] GE	Takeoff	Military	48.17	0.45	21.56	6.40	0.54	
	Climbout	75%	35.92	0.64	28.38	5.67	0.54	
	Approach	30%	17.42	2.40	65.53	4.02	0.54	
	Idle	Gr.idle	9.33	11.86	111.86	3.68	0.54	
J85-GE-21[4] GE	Takeoff	Afterburner	177.50	0.10	36.40	5.60	0.54	
	Climbout	Military	53.33	0.25	21.56	5.00	0.54	
	Approach	85%	20.00	2.58	46.25	2.92	0.54	
	Idle	Idle	6.67	24.25	159.00	1.25	0.54	
T58-GE-5[4] GE”	Climbout	70%	14.77	0.79	5.64	7.22	0.54	0.90[5]
	Approach	50%	14.77	0.79	5.64	7.23	0.54	0.90[5]
	Idle	Idle	2.22	96.99	169.17	1.50	0.54	0.75[5]
T58-GE-8F[7] GE	Takeoff	Takeoff	13.10	0.40	9.03	5.47	0.54	
	Climbout	Approach	9.68	1.12	17.28	4.47	0.54	
	Approach	Cruise	10.45	0.80	14.13	4.68	0.54	
	Idle	Idle	2.20	130.43	178.44	1.43	0.54	
T58-GE-16[7] GE	Takeoff	Military	17.00	1.32	7.73	11.60	0.54	
	Climbout	5% Normal	12.98	0.63	10.89	9.47	0.54	
	Approach	60% Normal	10.93	0.38	14.56	7.88	0.54	
	Idle	Gr.idle	250	40.91	139.73	3.03	0.54	
T64-GE-6B[7] GE	Takeoff	Max.cont.	23.80	0.55	1.50	10.11	0.54	
	Climbout	Military	22.83	0.51	1.87	9.80	0.54	
	Approach	75% hp	17.72	0.41	4.27	7.80	0.54	
	Idle	Idle	5.35	13.24	57.27	2.75	0.54	
T64-GE-413[7] GE	Takeoff	Maximum	28.68	0.37	0.49	11.42	0.54	
	Climbout	Intermediate	27.68	0.34	0.67	10.92	0.54	
	Approach	75% hp	21.45	0.35	1.94	8.54	0.54	
	Idle	Idle	4.33	17.28	51.83	2.62	0.54	

Table 5-7

Modal emission rates - Military aircraft engines[1] (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000 lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
T64-GE-415[7] GE	Takeoff	Max.rated	33.42	0.19	1.47	10.83	0.54	
	Climbout	Military	31.93	0.28	1.29	9.99	0.54	
	Approach	75%	24.88	0.13	2.10	8.09	0.54	
	Idle	Idle	4.48	24.35	74.33	2.12	0.54	
TF34-GE-400[7] GE	Takeoff	Military	63.33	0.39	5.95	7.51	0.54	2.11[10]
	Climbout	75% rpm	7.67	2.63	33.57	3.42	0.54	6.85[10]
	Idle	Idle	8.08	14.99	90.98	1.69	0.54	3.26[10]
T76-G-12A[7] Grt	Climbout	Military	6.37	0.05	1.69	7.18	0.54	
	Approach	High idle	3.53	6.13	24.59	4.50	0.54	
	Idle	Gr.start	3.00	10.31	28.39	4.30	0.54	
TFE 731-2[8] Grt 3.51	Takeoff	100%	27.12	0.11	1.39	15.25	0.54	
	Climbout	85%	22.88	0.13	2.03	13.08	0.54	
	Approach	30%	8.86	4.26	22.38	5.90	0.54	
	Idle	7%	3.17	20.04	58.60	2.82	0.54	
T53-L-11D[7] Lyc	Takeoff	Takeoff	11.50	0.27	3.85	7.75	0.54	
	Climbout	Military	11.42	0.26	3.34	6.34	0.54	
	Approach	Nor.rated	10.75	0.57	6.83	6.43	0.54	
	Idle	Fl.Idle	3.70	13.57	37.79	2.53	0.54	
	Idle	Gr.Idle	2.42	58.09	31.51	1.58	0.54	
F100-PW-100[4] P & W	Takeoff	Military	736.67	0.10	55.10	16.50	0.54	0.00[11]
	Climbout	95%	173.33	0.05	1.80	44.00	0.54	0.83[11]
	Approach	30%	50.00	0.60	3.00	11.00	0.54	0.33[11]
	Idle	Idle	17.67	2.26	19.34	3.94	0.54	0.09[11]
F101DFE P&W	Takeoff	Military	167.88	0.10	0.90	19.69	0.54	
	Climbout	Military	167.88	0.10	0.90	19.69	0.54	
	Approach	75% Thrust	109.77	0.20	0.90	12.04	0.54	
	Idle	Idle	14.45	4.10	44.20	2.58	0.54	

Table 5-7

Modal emission rates - Military aircraft engines[1] (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2[3]	Particulate
J52-P-6B[7] P&W	Takeoff	Military	105.47	0.33	3.01	9.00	0.54	7.75
	Climbout	75% Thrust	66.28	0.65	6.00	5.84	0.54	13.13
	Approxh	3000lbs Thrust	38.35	0.82	16.57	3.91	0.54	
	Idle	Idle	11.90	23.88	86.37	2.07	0.54	19.94
J52-P-8B[7] P & W	Takeoff	Military	122.83	0.93	0.71	13.05	0.54	
	Climbout	75% Thrust	72.00	0.58	3.00	10.10	0.54	
	Approxh	3000lbs Thrust	38.33	1.72	10.54	6.34	0.54	
	Idle	Idle	11.33	42.20	63.78	1.79	0.54	
J52-P-408[7] P&W	Takeoff	Military	157.98	0.57	1.47	12.32	0.54	
	Climbout	Intermed 2	95.87	0.67	3.18	8.38	0.54	
	Approxh	Intermed 1	43.45	1.40	11.12	6.17	0.54	
	Idle	Idle	12.98	28.33	55.96	2.38	0.54	
J57-P-10[7] P & W	Takeoff	Military	139.50	0.86	1.16	10.37	0.54	
	Climbout	Nor.rated	120.83	1.00	1.79	9.00	0.54	
	Approach	75% Thrust	94.50	0.76	3.21	7.40	0.54	
	Idle	Idle	18.33	96.60	80.52	1.87	0.54	
J57-P-420[7] P & W	Takeoff	Afterburner	662.02	2.54	14.20	5.16	0.54	
	Climbout	75% Thrust	96.12	1.09	4.32	6.99	0.54	
	Approach	30% Thrust	56.88	4.54	14.83	4.45	0.54	
	Idle	Idle	22.03	76.46	80.74	1.53	0.54	
JT8D-9/9A[8] P&W 14.50	Takeoff	100%	137.57	0.47	1.24	17.92	0.54	
	Climbout	85%	111.91	0.47	1.66	14.21	0.54	
	Approach	30%	39.42	1.73	9.43	5.64	0.54	
	Idle	7%	17.46	10.00	34.50	2.90	0.54	
JT9D-7R4G2[8] P&W 53.84	Takeoff	100%	321.30	0.15	0.74	41.30	0.54	
	Climbout	85%	248.68	0.14	0.63	32.10	0.54	
	Approach	30%	87.17	0.18	1.40	8.80	0.54	
	Idle	7%	29.62	1.55	11.82	3.80	0.54	

Table 5-7

Modal emission rates - Military aircraft engines[1] (continued)

Model-Series Manufacturer[2] Rated Dry Output (1000lb thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb)				
				HC	CO	NO_x	SO_2[3]	Particulate
TF30-P-6C[7] P&W	Takeoff	Military	111.67	0.91	1.56	13.28	0.54	
	Climbout	75% Thrust	59.33	0.54	4.75	7.38	0.54	
	Approach	30%' Thrust	33.83	1.84	14.87	4.77	0.54	
	Idle	Idle	11.17	12.92	70.58	2.03	0.54	
TF30-P-412A P&W	Takeoff	Afterburner	796.67	0.20	10.79	4.79	0.54	
	Climbout	Military	117.50	0.77	1.38	19.60	0.54	2.98[12]
	Approach	75% Thrust	71.67	1.48	3.43	10.74	0.54	7.99[12]
	Idle	Idle	15.33	36.45	55.60	3.22	0.54	8.96[12]
TF33-P-3/5/7[4] P&W	Takeoff	Afterburner	166.32	0.30	1.50	11.00	0.54	8.00[5]
	Climbout	Military	122.05	0.40	1.80	9.00	0.54	14.00[5]
	Approach	85%	63.28	3.79	9.01	7.30	0.54	13.98[5]
	Idle	Idle	14.10	91.96	88.53	1.77	0.54	5.20[5]
Dart RDa7[4] RR	Takeoff	Military	23.48	6.21	3.40	6.04	0.54	
	Climbout	95%	20.80	1.72	3.41	4.45	0.54	
	Approach	30%	10.75	0.00	33.30	0.88	0.54	
	Idle	Idle	6.85	62.09	91.51	0.71	0.54	
F402[7] RR	Takeoff	100%	178.53	0.40	2.70	14.80	0.54	
	Climbout	85%	103.10	0.70	8.20	8.00	0.54	
	Idle	Idle	18.95	15.80	106.30	1.70	0.54	
.65-W-5F[7] W	Takeoff	Military	115.77	0.61	5.31	5.23	0.54	
	Climbout	8000 rpm	99.50	0.72	7.39	5.71	0.54	
	Approach	7450 rpm	72.83	0.35	12.61	7.30	0.54	
	Idle	Idle	22.00	9.78	47.16	2.46	0.54	
R-1820 W	Takeoff	IRP	19.43	94.68	531.73	1.72	0.54	
	Climbout	IRP	14.37	48.49	435.03	2.09	0.54	
	Approach	75% M/C	5.38	5.57	384.83	6.50	0.54	
	Idle	Idle	1.48	150.56	474.16	0.00	0.54	

Table 5-7

Modal emission rates - Military aircraft engines[1] (concluded)

[1] SOURCE: Example of an Air Base Emissions Inventory for the County of San Diego (1987) (Aircraft Environmental Support Office, AESO Report No. 2-91, San Diego, California, March 1991), unless otherwise noted.

[2] MANUFACTURERS: AIL. - Allison, Con - Teledyne/Continental, CP - United Aircraft of Canada, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, P&W - Pratt & Whitney, RR - Rolls-Royce, W - Curtis Wright

[3] SO, emissions based on national average sulfur content of aviation fuels from Aviation Turbine Fuels, 1989, Dickson, Cheryl L. and Paul W. Woodward, NIPER Report Number NIPER-164 PPS, National Institute for Petroleum **and** Energy Research, IIT Research Institute, Bartlesville, Oklahoma, March 1990.

[4] Source of data is AP-42, Compilation of Air Pollutant Emission Factors. Volume II: Mobile Sources, U.S. Environmental Protection Agency, Ann Arbor, Michigan, September, 1985, (Aircraft data from February 1980). Nitrogen oxides reported as N02. HC refers to total hydrocarbons (Volatile organics, including unburned hydrocarbons and organic pyrolysis products).

[5] Includes all "condensable particulates," and thus may be much higher than solid particulates alone (AP-42).

[6] Source of data is FAA Aircraft Engine Emission Database (FAEED), U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, 1991.

[7] Source of data is Summary Tables of **Gaseous** and Particulate Emissions from Aircraft Engines, Aircraft Environmental Support Office, AESO Report No. 6-90, San Diego, California, June 1990.

[8] Source of data is ICAO Engine Exhaust Emissions Databank, ICAO Committee on Aviation Environmental Protection, Working Group 3 Meeting, Mariehamn, Aland., October 1989.

[9] Includes all "condensable particulates," **and** thus may **be** much higher than solid particulates alone. Data are interpolated values **assumed for** calculational purposes, in tie absence of experimental data (AP-42).

[10] Particulate data refers to TF34-GE-400A engine.

[11] Particulates refer to dry particulates only (AP-42).

[12] **Source** of Particulate data is Table 4. Particulate Mass Emissions From the TF-30-P-414 Engine, **Summary** Tables of **Gaseous and** Particulate Emissions from Aircraft Engines, Aircraft Environmental Support Office, AESO Report No. 6-90, San Diego, California, June 1990.

number of LTOs, number of visitors/passengers, number of cars using the parking lots, or some similar measure that may be representative of the daily or seasonal variation in use of the airport. Another source of information on the daily and weekly variation of LTOs is published flight schedules. These schedules can be reviewed to evaluate the number of scheduled flights during daylight hours versus night-time hours or week day versus weekend. It would be difficult to use this source to evaluate seasonal variations.

Mixing height changes throughout the day and from season to season depending on meteorological conditions such as wind, cloud cover, temperature, and humidity. The adjustments to the time in approach and climbout mode should be based on a weighted average of the mixing heights for the time periods of interest, using variations in LTOs as the weighing factors.

Taxi/idle time may vary in proportion to variations in LTOs because they are partially a function of airport congestion such that the greater number of LTOs the more likely that airport congestion will increase the time for aircraft to taxi to the runway. The airlines' scheduling departments are the best sources of taxi/idle-time data and their projections typically show daily variations estimated for a particular season. Airport operators also may have information on taxi/idle time variation during a day or from one season to another.

Very few measurements have been made of particulate emissions from aircraft engines. However, for most turbine engines, EPA does limit the amount of smoke that may be emitted. This limit is specified as a smoke number. Attempts have been made to derive a correlation between smoke and particulates which could be used to create a particulate emission index based on smoke number. Thus far, these efforts do not match experimental results very closely.

Other emission sources

When large aircraft are on the ground with their engines shut down, they need power and preconditioned air to maintain the aircraft's operability. If a ground-based power and air source is unavailable, an auxiliary power unit (APU), which is part of the aircraft, is operated. These units are essentially small jet engines, which generate electricity and compressed air. They bum jet fuel and generate exhaust emissions like larger engines. Information on APU's and aircraft models and model emission rates are included in Table 5-8 and 5-9.

For general aviation aircraft, there are evaporative emissions that result from refueling and fuel spillage. Emissions also occur from preflight checks of the aircraft and diurnal temperature cycles that cause the fuel tanks to vent. Refueling emissions are addressed in Volume I, Section 5.4.1. EPA is continuing to evaluate the other emission sources and may provide information in the next update to AP-42.

Effect of future changes to the fleet

Airlines continually acquire newer aircraft, gradually phasing out older models. While commercial aircraft often remain in service for more than 25 years, over time, this process phases out the aircraft using engines that do not meet EPA's hydrocarbon emission standard. The current world aircraft fleet averages 12.4 years old according to the 1990 World Jet Inventory published by the Boeing Corporation.[80] Significant among the older aircraft are engines that do not meet the EPA

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[80] World Jet Airplane Inventory, Boeing, Commercial Airplane Group, Year-End 1990.

Table 5-8

APU’S and aircraft models’

Auxiliary Power Unit (Shaft HP)	Aircraft Model	No. of Aircraft
COMMERCIAL		
Allied-Signal Aerospace Company Garrett Auxiliary Power Division		
GTP 30 Series	Fairchild F-27’	
GTCP 30 Series	Dassauit-Bregue Falcon 20[2]	
	Jet Commander[2]	
GTCP 35-300	Airbus A-321[3]	
GTCP 36 Series	Airbus A320	132
(80 HP)	Aerospatiale ATR-42[2]	
	Brit. Aero. BAe 146	149
	Canadair CL600/CL601[2]	
	Dassault-Bregue Falcon 50[2]	
	Embraer EMB- 120[2]	
	Fokker F-28	193
	Fokker F- 100	56
	NAMC YS-11[2]	
	Saab Fairchild 340[2]	
GTC 85	Convair CV-580[2]	
GTCP 85 Series	Boeing B-707	206
(200 HP)	Boeing B-727	1,652
	Boeing B-737	1,825
	Lockheed L- 1 00[2]	
	McDonnell Douglas DC-8	300
	McDonnell Douglas DC-9	842
	McDonnell Douglas MD-80	806
GTCP 331 Series	Airbus A-300-600	85
(143 HP)	Airbus A-310	175
	Airbus A-330[3]	
	Airbus A-340[3]	
	Boeing B-757	328
	Boeing B-767	343
	Boeing B-777[3]	
GTCP 660	Boeing B-747	671
(300 HP)		
TSCP 700	Airbus A-300-B2	52
	Airbus A-300-B4	184

Table 5-8

APU’S and aircraft models’ (continued)

Auxiliary Power Unit (Shaft HP)	Aircraft Model	No. of Aircraft
(142 HP)	McDonnell Douglas DC-10	365
	McDonnell Douglas MD-11	3
Hamilton Standard		
ST-6	Lockheed L-1011	226
Pratt & Whitney		
PW 901A	Boeing B-747	103
MILITARY		
Allied-Signal Aerospace Company Garrett Auxiliary Power Division		
GTC 36-200	McDonnell Douglas F-18 Hornet	
GTCP 36 Series (80 HP)	Gulfstream II (VC-1 IA)	
	Gulfstream III (C-20A/B)	
	Lockheed S-3A Viking	
GTC 85 Series	Gulfstream I (VC-4A)	
	Lockheed C-130 Hercules	221
GTCP 85 Series	McDonnell Douglas C-9	23
	Lockheed C-141 StarLifter	254
	Boeing T-43	15
GTCP 660-4 (300 HP)	Boeing E-4 NEACP	4
JFS 100 Series	Douglas A-4M Skyhawk	
	Vought A-7D Corsair II	335[6]
JFS 190-1	McDonnell Douglas F-15 Eagle	895

Table 5-8

APU'S and aircraft models[1] (concluded)

[1] SOURCES: Civil • Federal Express Fleet Guide (Federal Express Aviation Services, Inc., January, 1991), unless otherwise noted.
Military • Reference Guide • Auxiliary Power Systems, Garrett Turbine Engine Company, Phoenix. Arizona

[2] SOURCE: Reference Guide • Auxiliary Power Systems, Garrett Turbine Engine Company, Phoenix, Arizona.

[3] New aircraft scheduled to enter production.

[4] No. of Aircraft refers to Airbus A-300 aircraft.

[5] No. of Aircraft refers to the total number of aircraft in the Air National Guard, Air Force Reserve, Air Force, and Coast Guard inventories.
SOURCES: Air National Guard, Air Force Reserve, Air Force • "AIR FORCE Magazine," Air Force. Association, May 1991.
Coast Guard • United States Coast Guard, 2100 Second Street, SW, Washington, DC 20593-0001, 202/267-0952.

[6] No. of Aircraft refers to 14 A-7 and 321 A-7D aircraft.

Table 5-9

Modal emission rates - Auxiliary power units[1]

Model-Series (Shaft HP at Load)	Mode	Fuel Flow (lb/min)	HC	Emission Rates (lb/1000 lb) CO	NO$_x$	SO$_2$
GTC85-72 (200)	Load	**3.50**	**0.13**	14.83	**3.88**	0.54
GTCP100-54 (400)	Load	6.88	0.16	5.89	5.95	0.54
GTPC95-2 (300)	Load	4.88	0.36	3.20	5.65	0.54
T-62T-27 (100)	Load	1.70	7.79	42.77	3.94	0.54
WR27-1 (85)	Load	2.33	0.21	5.66	4.63	0.54

[1] SOURCE: Summary Tables of Gaseous and Particulate Emissions from Aircraft Engines (Aircraft Environmental Support Office, AESO Report No. 6-90, San Diego, California, June 1990), unless otherwise noted.

standard such as the Spey MK511 and older JT8Ds and CF6-50s. The JT8Ds and CF6-50s are prevalent on B-727s, DC-9s, and DC-10s, many nearly 20 years old. As new aircraft are added to the fleet the older aircraft are the most likely to be retired. The effect is one of replacing older, dirty engines with newer engines on the new aircraft that are much cleaner from an emissions standpoint. Airport noise regulations also are forcing changes to the commercial aircraft fleet. National noise regulations which were recently passed by Congress are forcing airlines to phase out use of loud aircraft by 2000. This can be accomplished by retiring the loud, older aircraft, replacing their engines with newer, quieter ones, or modifying the engines to muffle the noise. The first two alternatives result in aircraft with reduced emissions. Because this legislation is so new, the airlines are yet to formulate specific plans meeting the requirements.

Since specific plans to upgrade their fleets have not been announced recently by the airlines, it is difficult to project what future changes will be and how they will affect the inventory of emissions for all locations. Some carriers will update their fleets more quickly than others so there may be changes that can be captured on an area specific basis. If it is desirable to project changes to the inventory for this source category, the predominant airlines for the airports included in the inventory area should be contacted for their specific plans. EPA is continuing to look at better data sources and methods for projecting changes to aircraft fleet emissions.

Another change that will 'affect future. emissions from aircraft is the growth in travel. Air travel has experienced strong growth over the past several years and this growth is expected to continue for the foreseeable future. Many existing airports are near capacity and others will reach their capacity limits in the near future. This will have two effects: air traffic at small feeder airports and regional hubs will grow and the current major hubs will experience additional congestion. The net effect these changes will have on air quality is unclear. Increased congestion at some airports will increase taxi/idle times but the expanded use of smaller airports may relieve congestion at others.

Converting from total hydrocarbons (THC) to volatile organic compounds (VOC)

It may be necessary to determine the level of volatile organic compounds (VOC) emitted from aircraft engines. Since the emission factors for exhaust HC contained in this document represent total hydrocarbons (THC), this section illustrates the method that is recommended for converting THC to VOC emissions.[81]

The commercial and military aircraft fleets are dominated by turbine engines. Therefore, a single correction factor can be used to convert THC to VOC emissions for each aircraft category as follows.

$$VOC_{COMMERCIAL} = THC_{COMMERCIAL} \times 1.0947 \qquad (5\text{-}14)$$

$$VOC_{MILITARY} = THC_{MILITARY} \times 1.1046 \qquad (5\text{-}15)$$

The general aviation (GA) fleet and, to a much lesser extent, the air taxi (AT) fleet may have a significant proportion of piston engines, in addition to turbine engines. Therefore, separate correction factors should be used for each engine type within the respective aircraft categories if the

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[81] Memorandum from R. Cook to R. Wilcox, "Exhaust THC to VOC Correction Factors for Aircraft," July, 1992.

detailed, aircraft-specific inventory methodology described above was used to estimate THC emissions. Otherwise, if the alternative, fleet-average procedure as described was used, a single correction factor can be used for each aircraft category.

Detailed Methodology

$$VOC_{GA\ PISTON} = THC_{GA\ PISTON} \times 0.9649 \quad (5\text{-}16)$$

$$VOC_{GA\ TURBINE} = THC_{GA\ TURBINE} \times 1.0631 \quad (5\text{-}17)$$

$$VOC_{AT\ PISTON} = THC_{AT\ PISTON} \times 0.9649 \quad (5\text{-}19)$$

$$VOC_{AT\ TURBINE} = THC_{AT\ TURBINE} \times 1.0631 \quad (5\text{-}20)$$

Alternative. Fleet-Average Methodology

$$VOC_{GA\ FLEET} = THC_{GA\ FLEET} \times 0.9708 \quad (5\text{-}18)$$

$$VOC_{AT\ FLEET} = THC_{AT\ FLEET} \times 0.9914 \quad (5\text{-}21)$$

6. Emissions from locomotives

This chapter illustrates how a state or local agency can calculate emissions from locomotives within an inventory area. Railroad locomotives used in the United States are primarily of two types: electric and diesel-electric.[82] Electric locomotives are powered by electricity generated at stationary power plants and distributed by either a third rail or overhead catenary system. Emissions are produced only at the electrical generation plant, which is considered a point source and therefore not of interest here. Diesel-electric locomotives, on the other hand, use a diesel engine and an alternator or generator to produce the electricity required to power its traction motors. Emissions produced by these diesel engines are of interest in emission inventory development. Emissions for hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), sulfur dioxide (SO_2), and particulate matter (PM) from this source are covered in this chapter.

This chapter of the base document is a complete revision of the corresponding chapter in the previous edition of this document. In addition, this chapter also updates the emission factor information that appears in Compilation Of Air Pollutant Emission Factors, Fourth Edition And Supplements, AP-42.

Other sources of emissions from railroad operations include the small gasoline and diesel engines used on refrigerated and heated rail cars. These engines are thermostatically controlled, working independently of train motive power, and fall in the category of off-highway equipment which are addressed elsewhere in this document.

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[82] A third type, steam locomotives, is used in very localized operations, primarily as tourist attractions, and emissions from these locomotives are insignificant. In addition, the particulate emissions from operating steam locomotives is so large that nearly all of it falls to the surface within 50 meters.

Railroads can be separated into three classes based on size. Class I railroads[83] represent the largest railroad systems in the country. Because of their size, Class I railroads operate over a large geographic area. Also, they carry most of the interstate freight and carry most of the passenger service. They are required to keep detailed records of their operations and to report yearly to the Interstate Commerce Commission (ICC).

Class II[84] and III[85] railroads represent the remainder of the rail transportation system and generally operate within smaller areas. These smaller railroads are not subject to the same reporting requirements, and their recordkeeping may be less extensive. Also, their fleet of locomotives tends to be older, with the Class I railroads buying almost all of the new locomotives.

Locomotives within each of the Classes can perform two different types of operations: line haul[86] and yard (or switch). Line haul locomotives, which perform the line haul operations, generally travel between distant locations, such as from one city to another. Yard locomotives, which perform yard operations, are primarily responsible for moving railcars within a particular railway yard.

Overview of recommended inventorv methodology

Three steps are necessary in order to assess locomotive emissions within an inventory area. First, railroad operations are separated into three distinct categories: Class I line haul, Class II and Class III line haul, and yard. Second, emissions for each pollutant are calculated for each of the three categories using either the recommended methods described the alternative methods described before. Third, the total locomotive emissions in the inventory ‘area are calculated by summing the quantities of each pollutant for each of the three dategories.

The methods illustrated in this chapter are based on annual inventories and annual data. Developing inventories for shorter time periods is straight forward because railroad traffic is relatively constant throughout the year and therefore, less than annual calculations can be done by simple apportionment. In addition, the recommended methods are based on a national locomotive fleet mix and average fuel consumption figures.

Recommended methods

The recommended methods for Class I line haul, Class II and Class III line haul, and yard, are discussed separately below.

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[83] Class I railroads are classified by the Interstate Commerce Commission as having annual revenues greater than $93.5 million.

[84] Class II railroads are classified by the Interstate Commerce Commission as having annual revenues greater than $18.7 million but less than $93.5 million.

[85] Class III railroads are classified by the Interstate Commerce Commission as having annual revenues less than $18.7million.

[86] In this chapter, line haul operations include intermodal freight service, mixed freight service, and passenger service.

For Class I line haul locomotives, emissions are calculated by multiplying the amount of fuel consumed in the inventory area by the appropriate emission factors:

Inventory Area Emissions = Fuel Consumption x Emission Factors

If Class I line haul locomotives only traveled within the inventory area, fuel consumption could be determined directly from the amount of fuel dispensed into the units. However, these line haul locomotives travel predominantly interstate. Hence, they do not necessarily bum the fuel in the same location where the fuel was pumped, making it impossible to determine fuel consumption in the area of interest in this manner.

In order to determine inventory area fuel consumption, it is necessary to allocate the total amount of fuel consumed "systemwide" for Class I railroads to the inventory area. This is done by dividing the traffic density (expressed in Gross Ton Miles or GTM) for each Class I railroad track segment within the inventory area by the systemwide fuel consumption index (expressed in Gross Ton Miles per gallon or GTM/gal) for that railroad. This process is repeated for each railroad.

Fuel consumption, for each Class I railroad within an inventory area, is therefore specifically calculated using the following formula:

Fuel Consumption = Traffic Density (GTM) / Fuel Consumption Index (GTM/gal)

For every track segment within a state, each Class I railroad maintains information on traffic density (GTM), length (miles), direction, and geographic location. Therefore, it is possible to calculate the traffic density for an inventory area by summing the traffic densities for each track segment or portion thereof within the inventory area.

The gross ton mile information may be supplied in one of two ways. The first way is without the weight of the locomotives included. The second way is with the weight of the locomotives included. This distinction is important when calculating the fuel consumption index.

The fuel consumption index (GTM/gal), for each Glass I railroad within an inventory area, should be calculated by dividing the systemwide gross ton miles (GTM) by the systemwide fuel consumption (gal). See the following formula:

Fuel Consumption Index (GTM/gal) = System Gross Ton Miles/System Fuel Consumption

Each Class I railroad is required to report these statistics each year to the ICC in an annual report entitled "R- 1." The R-l report should be used, for each carrier, to obtain information on annual fuel consumption, total gross ton miles including locomotives, and, when needed, total gross ton miles excluding locomotives. An example of these schedules is included in Table 6-1.

The fuel consumption index will vary depending on whether the weight of the locomotives is included in the calculation? Also, calculating fuel consumption within the inventory area requires the multiplication of traffic density by fuel consumption index; therefore, it is important to match the units of each of these components. If traffic density is supplied without the weight of the locomotives included, then the fuel consumption index should be determined without the weight of the locomotives included in the calculation. If traffic density is supplied with the weight of the locomotives included,

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[87] The fuel consumption rate will be less if the weights of the locomotives are not included in the calculation.

then the fuel consumption index should be determined with the weight of the locomotives included in the calculation.

The fuel consumption index, with locomotives, is calculated by dividing total gross ton miles with locomotives, Schedule 755: line 104, by the total fuel consumed, Schedule 750: line 1. The fuel consumption index, without locomotives, is calculated by dividing total gross ton miles without locomotives, Schedule 755: line 104 minus line 98, by the total fuel consumed, Schedule 750: line 1. Examples of these calculations are shown in Table 6-2.

Now that fuel consumption has been calculated, inventory area emissions are determined by multiplying that value by the fleet average emission factors for each pollutant (expressed in pounds per gallon of fuel burned (lbs/gal). The recommended default emission factors for all line haul locomotives are shown in Table 6-3.

Table 6-1 Copy of schedules 750 and 755 from R-l Report for Santa Fe, 1990.

750. CONSUMPTION OF DIESEL FUEL (Dollars in Thousands)		
LOCOMOTIVE		
Line No.	Kind of locomotive service (a)	Diesel oil (gallons) (b)
1.	Freight	304,370,694
2.	Passenger	
3.	Yard switching	7,522,208
4.	Total	311,892,902
5.	COST OF FUEL	226,890
6.	Work Train	75,845

755. RAILROAD OPERATING STATISTICS • Concluded				
Line No.	Cross check	Item Description (a)	Freight Train	Passenger Train
		6. Gross Ton-Miles (thousands (K)	xxxxxx	xxxxxx
98.		6-01 Road Locomotives	24,631,118	
		6-02 Freight Trains, Crs., Cnts., and Caboose	xxxxxx	xxxxxx
99.		6-020 Unit Trains	10,345,677	xxxxxx
100.		6-021 Way Trains	4,002,717	xxxxxx
101.		6-022 Through Trains	136446,265	xxxxxx
102.		6-03 Passenger-Trains, Crs. & Cnts.		
103.		6-04 Non-revenue	11,215,578	xxxxxx
104.		6-05 TOTAL (lines 98-103)	186,661,355	

Table 6-2 Sample Calculation of Inventory Area Fuel Consumption for Santa Fe in Illinois

Inventory Area Emissions = Fuel Consumption x Emission Factors

Fuel Consumption = Traffic Density x Fuel Consumption Index

Traffic Density Without Locomotives

If the traffic density data for Illinois are supplied without locomotive weight included, emissions would be calculated as followed:

Traffic Density

Santa Fe Traffic Density in Illinois:
(Furnished by Santa Fe without
locomotives) = 7,329,000,000 GTM

Fuel Consumption Index

Santa Fe System
Fuel Consumption:
Schedule 750: line 1 = 304,370,694 gal

Santa Fe System
Gross Ton Miles (w/o locomotives):
Schedule 755: line 104 - line 98
(186,661,355,000 - 24,631,118,000) = 162,030,237,000 GTM

Santa Fe Fuel Consumption
Index (w/o locomotives)
(162,030,118,000 / 304,370,694) = 532 GTM/gal

Fuel Consumption

Fuel Consumption for
Santa Fe in Illinois
(7,329,000,000 / 532) = 13,776,316 gal

Traffic Densitv With Locomotives

If the traffic density data for Illinois are supplied with locomotive weight included, emissions would be calculated as follows:

Traffic Density

Santa Fe Traffic Density in Illinois:
(Furnished by Santa Fe with
locomotives) = 8,445,000,000 GTM

Fuel Consumption Index

Santa Fe System
Fuel Consumption:
Schedule 750: line 1 = 304,370,694 gal

Santa Fe System
Gross Ton Miles (with locomotives):
Schedule 755: line 104 = 186,661,355,000 GTM

Santa Fe Fuel Consumption
Index (with locomotives)
(186,661,355,000 / 304,370,694) = 613 GTM/gal

Fuel Consumption

Fuel Consumption for
Santa Fe in Illinois
(8,445,000,000 / 613) = 13,776,508 gal

Emission Factors

The emission factors for line haul locomotives are located in Table 6-l above. Emissions can now be calculated as follows:

$$\text{Emissions (Tons)} = \frac{\text{Emission Factor (lbs/gal)} \times \text{Fuel Consumption (gal)}}{2{,}000}$$

Example for HC: (0.0211 X 13,776,508)/2,000 = 150.16 Tons

Table 6-3 Line Haul Locomotive Emission Factors[88]

Pollutant	Emission Factor (lbs/gal)
HC	0.0211
CO	0.0626
NOx	0.4931
SO_2*	0.0360
PM	0.0116

* SO_2 calculated based on a fuel sulfur content of 0.25 percent by weight.

Table 6-2 gives a full example of how to calculate emissions from the Class I line haul locomotives in an inventory area, using the Santa Fe railroad in the State of Illinois.

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[88] Locomotive Emission Factors for Inventory Guidance Document, Office of Mobile Sources, U.S. EPA, June 1991.

Similar to the recommended method for Class I line hauls, emissions from Class II and III line haul locomotives are calculated by multiplying the amount of fuel consumed in the inventory area by the appropriate emission factors.

Inventory Area Emissions = Fuel Consumption x Emission Factors

Since Class II and III railroad companies are not required to file R-l reports, annual fuel consumption should be obtained directly through interviews or letters with each Class II and III railroad operating within the inventory area. This approach is sufficient because, unlike Class I line haul operations, most Class II and III line haul travel is predominantly within a relatively small geographic area. Therefore, in many instances, it is unnecessary to apportion system fuel use to an inventory area, because the fuel is consumed by the locomotives within the inventory area.

However, for the small number of Class II and III railroads operating outside the inventory area, EPA recommends simply allocating the fuel consumption by track length or track density (GTM). Each Class II and III railroad can supply both track length and track density information.[89] So, the percentage of fuel consumed is based on the percentage of track length or track density within the inventory area. If, for example, 30 percent of the track length, for a particular railroad, runs within the inventory area, then, in order to apportion the total fuel consumed in the inventory area, multiply the total fuel consumption for the railroad by 0.30.

The emission factors for Class II and III line haul locomotives are assumed to be the same as Class I locomotives.

The recommended method for yard locomotives is different from the method used for line haul locomotives. Yard locomotive emissions, for each pollutant, are derived by multiplying the number of yard locomotives operating within the inventory area by the amount of emissions generated by each unit during the year. See the formula below:

Inventory Area Emissions = Number of Yard Locomotives x Annual Emissions Per Yard Locomotive

Since yard locomotives operate within the boundaries of a railway yard, it is possible to calculate the number of locomotives operating within an inventory area through interviews with the railway yard managers, who keep accurate records of yard locomotive operations. If this first approach proves unproductive, the number of yard locomotives can be determined by actually counting the units operating in each railway yard during a day. This is sufficient because the number of yard locomotives in operation each day remains relatively constant throughout the year. Switch yard engines are sent to railroad maintenance facilities according to regular schedules. When a particular yard locomotive is away getting maintenance or repair, the yard will replace the unit with another of approximately the same horsepower.

EPA estimates that the average yard engine emits the following amount of each pollutant per year:

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[89] In addition, tabulations of track mile data may be available for counties, Metropolitan Statistical Areas (MSA), or urban areas from some state transportation agencies, or from the county or metropolitan planning organization within whose jurisdiction the study area is located. Alternatively, route miles can be obtained by direct measurement from an appropriate map, such as the County Series maps, U.S. Geologic Survey maps, U.S. Transportation Zone maps, or locally prepared maps.

Table 6-4 Annual Emissions Per Yard Locomotive

Pollutant	Annual Emissions (lbs/yr)
HC	4,174
c o	7,375
NOx	41,608
so,*	3,075
PM	1,138

* SO, calculated based *on* a fuel sulfur content of 0.25 percent by weight.

These emission levels were calculated as follows. EPA estimated that, based on a reasonable activity **or** duty cycle and typical fuel consumption rates, the average yard engine consumes 228 gallons of fuel per day.[90] Since yard locomotives can be assumed to operate 365 days a year (this assumes that when a yard engine is taken in for repairs it is replaced during that period), the average yard engine consumes 82,490 (226 X 365) gallons of fuel per year.

EPA also detennined that the average yard locomotive has the following emission factors (lbs/gal):

Table 6-5 Emission Factors For Yard Locomotives

Pollutant	Emission Factor (lbs/gallon)
HC	0.0506
c o	0.0894
NOx	0.5044
SO_2*	0.0360
PM	0.0138

* SO_2 calculated based on a fuel sulfur content of 0.25 percent by weight.

Therefore, the annual emissions per yard locomotive, Table 6-2, were determined by multiplying the fuel consumption estimate (85,410 gal/year) by each emission factor in Table 6-3.

Tailoring: methods

EPA recognizes that railroad operations may vary significantly from the national average and that some state and local air quality agencies may have access to more detailed information regarding the locomotive activity in their inventory area. Because of this, EPA has developed two additional methodologies tailoring the emissions calculations based on actual locomotive fleet, or roster, data and local operational characteristics.

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[90] The fuel consumption data used for this calculation were considered proprietary by the locomotive manufacturers and hence could not be printed in this document.

As explained above,the recommended method for calculating total emissions in an inventory area requires multiplying a fleet averaged emission factor by fuel consumption. An implicit element of the composite emission factor is the locomotive roster. If the actual roster for an inventory area is different from the one used in the recommended method, then the composite emission factor, calculated using the recommended method for the inventory area, could be different than if the composite emission factor were calculated using the actual locomotive roster.

Another element implicit in both the composite emission factor and the estimate of fuel consumption is the duty cycle which an engine goes through during operation. If the actual duty cycle in an inventory area is different from that assumed in the recommended method, then the values used in the recommended method for the inventory area could be different than if the values were calculated using the actual duty cycle for that area.

The roster tailoring method requires the development of an area specific roster, and subsequently the calculation of new fleet average emission factors. These new emission factors will then be substituted for the national fleet average emission factors in the method recommended above, and subsequently, will be multiplied by the fuel consumption figure to give the emissions for the inventory area. The tailoring method for both line haul and yard locomotives will be the same, but, the new tailored rosters should be calculated separately.

The Agency believes that the duty cycles which are indicated in the recommended methods are reasonably representative of railroad operations across the nation, including nonattainment areas. These duty cycles, for line haul and yard locomotives, are shown in the following table:

Table 6-6 Locomotive Duty Cycles

	Time in Notch (%)	
Throttle Notch	Line Haul	Yard
8	1	1
7	3	0.5
6	4	0.5
5	4	1
4	5	2
3	4	4
2	4	7
1	4	7
Idle	49	77
Dynamic Brake	12	0
Total	100	100

If local conditions are likely to result in duty cycles that are substantially different from those shown above, State or local authorities may consider adjusting the emissions inventory methodology to incorporate this information. Any modifications, however, should be done in consultation with local railroad officials to determine if actual duty cycle measurements are available for this purpose, or if less specific adjustments are appropriate, based on past operating experience.

The emission factors for SO_2 are calculated based on the amount of sulfur contained in the fuel.[91] These emission factors are based on a sulfur content of 0.25 percent sulfur by weight. EPA recognizes that the amount of sulfur contained in diesel fuel may vary significantly from one inventory area to another. In order to tailor sulfur emission factors based on the inventory area fuel sulfur content, a recalculation should be performed by first calculating an adjustment factor and then multiplying by the sulfur emission factor.

Tailored Sulfur = Adjustment Factor x Guidance Document SO_2 Emission Factor.

The adjustment factor is determined by dividing the inventory area sulfur percentage by the existing sulfur percentage. If the inventory area had a fuel sulfur content of 0.20 percent, then the adjustment factor would be 0.80 (0.20/0.25). In order to recalculate the emission factor, multiply the sulfur emission factor, 0.0340 lbs/gal, by the adjustment factor, 0.80, to get an answer of 0.0272 lbs/gal.

Alternative method

EPA believes that the line haul locomotive methods presented in this chapter are practical, feasible, and accurate. However, if for some unforeseen reason it is not possible to acquire, or apportion, fuel consumption as required by these methods, an alternative approach, such as the one described in EPA's Report to Congress On Railroad Emissions • A Study Based On Existing Data, (no date available at time of printing) may be appropriate. This particular alternative, if needed, may be most appropriate for inventorying congested urban areas.

Converting from total hydrocarbons (THC) to volatile organic compounds (VOC)

Since the emission factors for HC contained in this document represent total hydrocarbons as measured by a flame ionization detector (THC_{FID}), this section illustrates the conversion factor method recommended for converting THC_{FID} to VOC emissions.

The method listed below was derived from an April 21, 1992, EPA memorandum from Greg Janssen to Phil Lorang entitled "THC to VOC Correction Factors for Nonroad Emissions Inventories" (the memorandum). Since locomotive emissions are created by large diesel engines, and since locomotive diesel correction factors do not exist, EPA has assumed that the correction factors for heavy-duty diesel vehicles (HDDV) can also be used as locomotive correction factors.

The method for converting THC to VOC was based on the methodology for nonroad conversion and is as follows:

$$VOC_{LOCOMOTIVE} = THC_{FID\ LOCOMOTIVE} \times \frac{NMHC_{FID\ HDDV}}{THC_{FID\ HDDV}} \times \frac{VOC_{HDDV}}{NMHC_{FID\ HDDV}}$$

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[91] It is assumed that all of the elemental sulfur in the fuel is oxidized into SO_2.

where

$THC_{FID\ LOCOMOTIVE}$ represents the total hydrocarbon emissions measured from locomotives by FID,

$\frac{NMHC_{FID\ HDDV}}{THC_{FID\ HDDV}}$ is a non-methane hydrocarbon correction factor and represents the ratio of non-methane hydrocarbons to total hydrocarbons, as emitted by heavy duty diesel vehicles, and

$\frac{VOC_{HDDV}}{NMHC_{FID\ HDDV}}$ is a VOC correction factor and represents the ratio of VOC to non-methane hydrocarbons, as emitted by heavy duty diesel vehicles.

Using the same method illustrated in Attachment 3 of the memorandum, EPA determined that $NMHC_{FID\ HDDV} = 1.07$ g/mile and $THC_{FID\ HDDV} = 1.10$ g/mile.[92] Furthermore, the VOC correction factor, as derived for HDDV in Appendix 3 in the memorandum, was determined to equal 1.0332.

Thus, EPA has determined that the correction factor to determine VOC emissions from locomotives is as follows:

$$VOC_{LOCOMOTIVE} = THC_{FID\ LOCOMOTIVE} \times \frac{1.07}{1.10} \times 1.0332$$

or

$$VOC_{LOCOMOTIVE} = THC_{FID\ LOCOMOTIVE} \times 1.005$$

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[92] Springer, 1979 (EPA-460/3-79-007) (PP. 47,98)

E. AIR TOXIC EMISSIONS INVENTORY’

Air toxics are generally defined in the U.S. as those chemicals which pose a threat of cancer when emitted into the air and water. The procedures for developing and compiling this type of inventory are the same as those covered previously for criteria pollutants. The purpose of this discussion is to outline briefly the subjects covered by air toxics and to reference where additional information is available for further research.

It may prove helpful as part of the planning process to conduct some sort of screening study before commencing with the detailed air toxics inventory. The general idea of a screening study is to develop preliminary estimates of emissions and associated risks and to allow the agency to focus its program and resources on the most important sources and pollutants. EPA’s “Six-Month Study” is an example of a national screening study conducted to evaluate maximum individual lifetime risks, additive risks, and aggregate cancer incidence.[4]

The major difference between air toxics inventories and criteria pollutant inventories is in substance coverage. In this regard, limiting the number of substances included in the detailed inventory to those causing most of the problem may be one of the most valuable outcomes of the screening study. Table E-l provides an abbreviated list of compounds for consideration in an air toxics emissions inventory.

Table E-l Core list of compounds for consideration in an air toxics emission inventory’

Arsenic
Asbestos
Benzene
Beryllium
1,3 Butadine
Cadmium
Carbon Tetrachloride
Chloroform
Chromium
Coke Oven Emissions
Ethylene Dibromide
Ethylene Dichloride
Ethylene Oxide
Formaldehyde
Gasoline Vapors
Mercury
Methylene Chloride
Perchloroethylene
Polycyclic Organic Matter[b]
Radionuclides
Trichloroethylene
Vinyl Chloride
Vinylidene Chloride

[a] These compounds were selected because EPA has (1) set NESHPAS for them under Section 112 of the Clean Air Act, or has listed or intends to list them, or (2) identified them as important contributors to aggregate cancer incidence in its Six-Month Study.[4]

[b] Also defined as "PIC" or products of incomplete combustion, in EPA’s “Six-Month Study."[4] B(a)P is used as a surrogate for calculating risk and aggregate cancer incidence from PIC exposure in this study.

In general, the kinds of data needed for modelling air toxics around point sources are the same as for criteria pollutants, since for most releases, air toxics are assumed to behave in the same ways as criteria pollutants. The fundamental reason for this inherent similarity is that most air toxics are a subset of either particulate matter (PM) or volatile organic compounds (VOC); most toxic metals and heavy organics are emitted in the PM fraction while most toxic light organics are associated with the VOC fraction. Therefore, the same dispersion models may be used in certain air toxics applications. To model point sources, detailed stack, exhaust, and sometimes building parameters are needed, as well as temporally resolved emissions estimates. Different and more exacting source data may be required for modelling short-term releases than for projecting annual averages. The input requirements to each model will vary, of course, and cannot be summarized here. Various available models are described in References 2 and 3.

Agencies traditionally have compiled estimates of annual emissions. Annual estimates of air toxic emissions are appropriate when the agency is evaluating potential cancer risks, since carcinogenesis involves long-term exposures. Shorter term emission estimates may also be useful for modelling short-term, maximum concentrations around certain sources, such as when estimating acute health effects posed by certain pollutants. In addition, allowable emission limits may be expressed on a short-term time frame.

Agencies have generally only considered routine, predictable emissions in their inventories -- that is, those emissions that could be expected to recur in a certain time frame. Routine emissions would include continuous emissions, both process and fugitive, and intermittent emissions from scheduled, but discontinuous, operations such as batch processes, startups, shutdowns, and maintenance operations. Accidental releases would be short term and unscheduled and may involve events that are catastrophic in nature. Accidental events could involve control equipment failure or bypass, pressure relief, equipment openings, and spills. There is a fine line between what some may consider irregularly occurring, but predictable, events and accidental events. The latter would not necessarily be expected to happen at every plant within a given reporting year and may be difficult to handle in a representative manner in the air toxics inventory.

Process, or stack, emissions have traditionally been the focal point of emission inventories. Fugitive emissions can be a very important component from some source categories (such as organic chemical manufacturing) and should not be overlooked. Important sources of fugitive emissions include material storage loading and unloading operations, process valves, flanges, pump seals, open-ended lines, sampling ports, etc.

Just as criteria pollutant emission factors can be applied to activity levels or throughput to estimate emissions, so can air toxic emission factors be applied for the same purpose. The major source of air toxics emission factors is the EPA series entitled Locating And Estimating Air Emissions From Sources Of (Substance Or Source Category) and the document Toxic Air Pollutant Emission Factors A Compilation For Selected Air Toxic Comnounds And Sources.

Table E-2 shows an example of possible results from an inventory screening study in which the emissions data have been modeled to estimate aggregate cancer incidence. These data show the relative risk associated with various point and area sources in a given area. This kind of screening exercise would provide some basis for the agency to focus any subsequent data collection and control efforts. Of course, any screening estimates of emissions and risk would probably be considered preliminary, to be followed by more detailed estimates for the more important sources and pollutants.

Table E-2 Percent of cancer risk associated with point and area sources’

Point Sources	% of Total Incidence[b]
Chemical production/usage	10
Metal manufacturing	8
Petroleum refining	5
Rubber production	5
Utilities	3
Publicly owned treatment works (POTWs)	2
All others	16
Total point source	49
Area sources	
Road vehicles	22
Solvent usage	10
Gasoline marketing	9
Waste oil burning	8
Woodsmoke (stoves/fireplaces)	0.5
All other	1.5
Total area source	51

[a] In 35 counties, from Reference 5.

[b] Because of the uncertainties in the incidence calculations used to derive these estimates, the numbers should be regarded as rough indicators only. They will not necessarily apply to any given geographical area.

Source category coverage

Although most sources of air toxics should already be included in complete criteria pollutant inventories, every source will not emit toxic compounds. A summary of the available nationwide emission totals for the substances evaluated in EPA’s “Six-Month. Study"[4] reveals several characterizations that may be useful in understanding which compounds are generally associated with which sources.

Roughly half of the toxic substances are largely emitted from synthetic organic chemical facilities (SOCMI), users of these chemicals as feed stocks, or facilities that produce these chemicals indirectly as contaminants or byproducts. Major emitting points within SOCMI include equipment leaks (from pumps, valves, compressors, etc.), storage and handling losses (loading, unloading, and breathing losses from railroad cars, storage tanks, etc.), process vents (distillation towers and reactor processes), and secondary and indirect sources (such as wastewater treatment).

Solvent use accounts for the major release of a number of substances including cyclohexane, methylethylketone, chlorobenzene, nitrobenzene, perchloroethylene, trichloroethylene, methyl chloroform, cresols, acrolein, methylene chloride, and xylenes. Solvent loss occurs from evaporation during surface coating, degreasing, dry cleaning, printing, etc. Minor point and area sources are significant contributors.

Metal processing includes emissions from mining, refining, and the production of alloy and metal products. Emissions of zinc, manganese, copper, cadmium, nickel, and beryllium are all significant. Although not explicitly identified with this category, chrome plating is a very important source of chromium emissions.

Mobile sources are major emitters of benzene, toluene, isomers of xylene, POM, and formaldehyde. Large percentages of all benzene, toluene, POM, and xylene emanate from mobile sources, primarily from tailpipe emissions and evaporation from gasoline-powered vehicles.

Stationary fuel combustion is the largest emitter of POM and several metals (beryllium, chromium and nickel) and an important source of chlorine, cadmium, copper, formaldehyde, and manganese. Generally, smaller sources such as woodstoves will be the most important emitters of POM.

Nontraditional sources are those sources which have not traditionally been included in criteria pollutant inventories, but which may be significant emitters of air toxics. Potentially important nontraditional sources are listed below:

Publicly-owned treatment works (POTWs) -- that is, municipal sewage treatment plants.

Treatment, storage, and disposal facilities (TSDFs) which handle hazardous waste in the following kinds of operations:

landfills and land treatment
surface impoundments and treatment tanks
waste piles
drum handling
unloading and storage
recycling
deep well injection
incineration

Waste oil combustion
Wood combustion (stoves, fireplaces)
Drinking water aeration
Cooling towers
Hospital and medical supply sterilizers

Methylene chloride and methyl chloroform (1,1,1-tricNoroethane) are emitted in important quantities from solvent use, aerosols, etc., but may not be accounted for in VOC inventories that have been adjusted to remove non-photochemically reactive compounds.

These brief characterizations can not cover the broad perspective offered by the "Six-Month Study": but this summary may offer some help in the screening process in understanding and characterizing the general distribution of air toxics emissions.

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F. PRESENTATION OF INVENTORY OF EMISSIONS

The final phase of an emission inventory activity is to present the data that have been collected, compiled and analyzed. The diversity of applications for which an emission inventory can be used has resulted in a variety of methods for data presentation, from unorganized raw listings to aggregated summary reports. Specific display methods are dependent upon many factors, including the type and amount of data required, the purpose of the data summary, and the audience to which the summary is directed.'

1. Overview

The basic "unit" of emission inventory data is the individual source record. These source records contain all relevant source and emission point identifiers. Complete emission inventory reports, containing one such record for each emission point, are typically used by state and local agencies in their source-oriented activities, such as enforcement inspections and plant reviews. For other studies, source data summaries, focusing on one or more source identifiers, can be compiled. These identifiers can generally be placed into the following four categories:

1. Source category -- all facilities, individual emission points, SIC (common industry), SCC (common process), area sources, mobile sources, fugitive sources.

2. Geographic category -- national, state, county, air quality control region (AQCR), air quality maintenance areas (AQMA), other (defined for specific projects).

3. Pollutant category -- individual criteria pollutants, all criteria pollutants, special (NESHAPS, Reactive VOC, etc.).

4. Other -- energy use (by fuel), control device application.

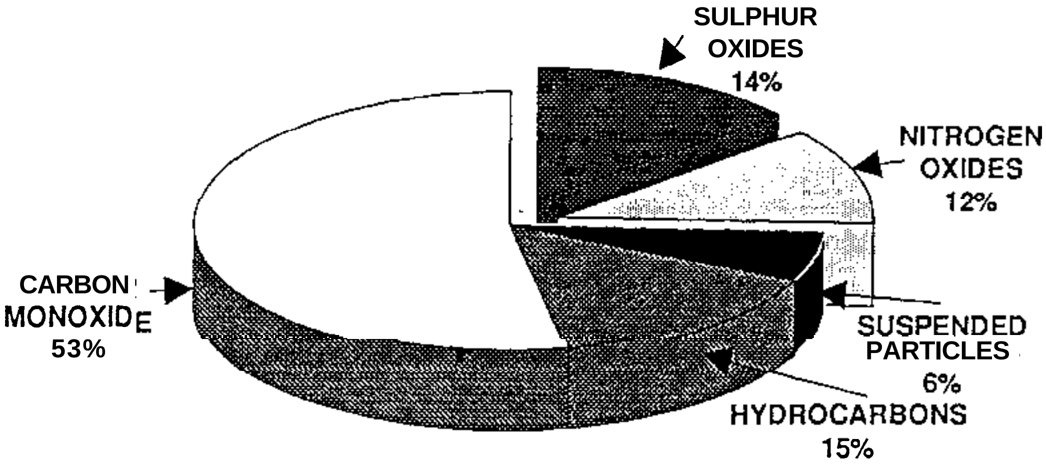
Data summaries are usually compiled relating these identifiers. Once the specific data requirements of a project are defined and the appropriate data summaries are obtained from an agency's emission inventory, the data must be presented in an appropriate fonnat. The following examples shown are taken from EPA reports and reflect U.S. emissions. However, the techniques shown are useful for reporting local air pollution problems.

2. Presentation techniques

The most common method of presenting emission inventory data is the tabulated summary. A second major presentation technique is the pie chart. This method, like all graphic displays, is often useful when presenting data to those who do not have the time and/or expertise to interpret detailed tabular summaries. Pie charts present component data as percentage of the whole and, therefore, are useful for representing the relative contributions of various emission source categories in a given area. Pie charts simplify the comparison of emission data from various sources by concisely summarizing large amounts of information that may occupy several pages of tables in a report.

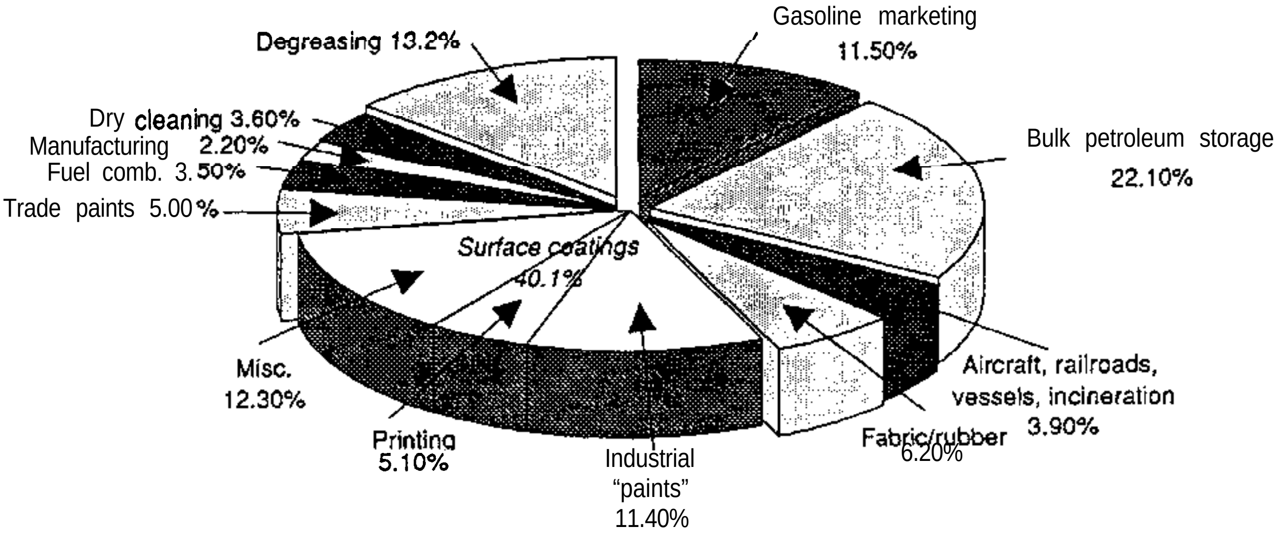
Time series charts represent another display technique. These charts display changes over time of one or several components, and are often used in emission trend reports. Knowledge of emission variations will aid regulatory personnel in such activities as planning the operation of air quality

Air emissions of pollutants in the United States



Source: National Air Quality, Monitoring and Emission Trends report, 1977,
US EPA, december 1978.

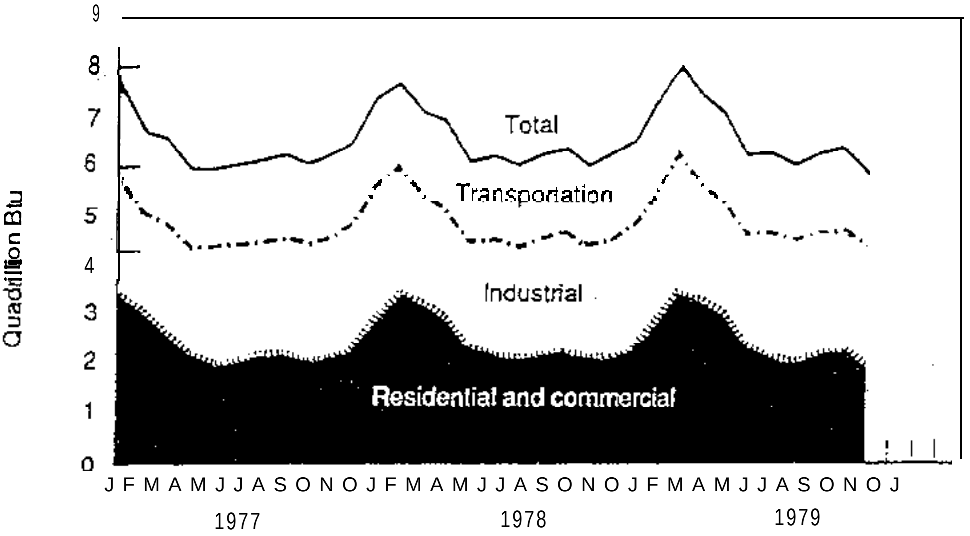
An example of pie chart displaying the distribution of VOC emissions in a survey area



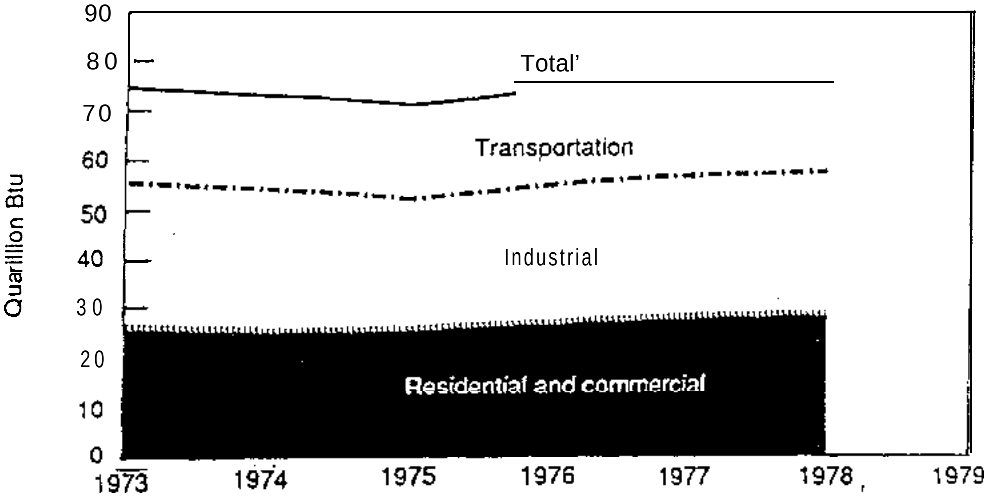
Note: Highway vehides are excluded
Source: Reference 4.2

Energy consumption by economic sector

Monthly

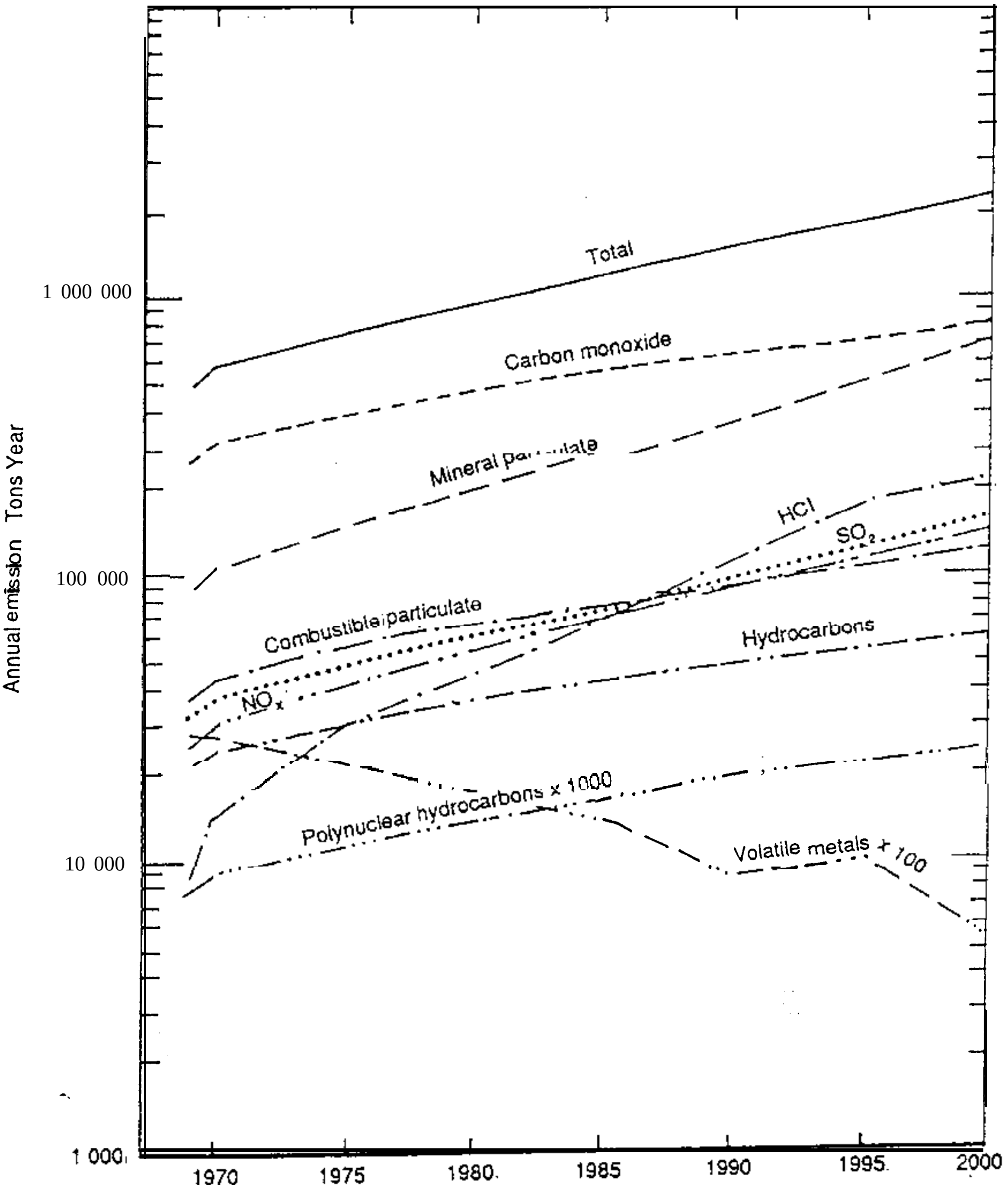


Yearly



* Btu consumption for all sectors is cumulated to create total.

Total annual emission estimates for U.S. municipal incineration systems



Source: Reference 5.

monitoring stations; scheduling enforcement activities; and establishing air quality management priorities, based on historical or projected emission estimates.

Bar charts are another common method of presenting emission data. When used to present historical trends of multiple sources, the bar chart clearly shows the trend in overall emissions as well as the trend in emissions from individual components, particularly those of major contributors.

Another graphic technique for the presentation of air quality data is the emission density map. The emission density presentations identify the spatial distribution of emissions. They clearly indicate specific areas of concern, and have been used by agencies to present justification for adoption of area specific emission regulations.

The tabular and graphic display techniques referred to in this section do not represent the only methods of presenting emission inventory data. The specific purpose of the summary, the source indicators that are to be summarized, the data reporting capabilities of the data system, and the environmental awareness of the audience must be considered before specific techniques are selected and used.

3. Documentation of the inventory

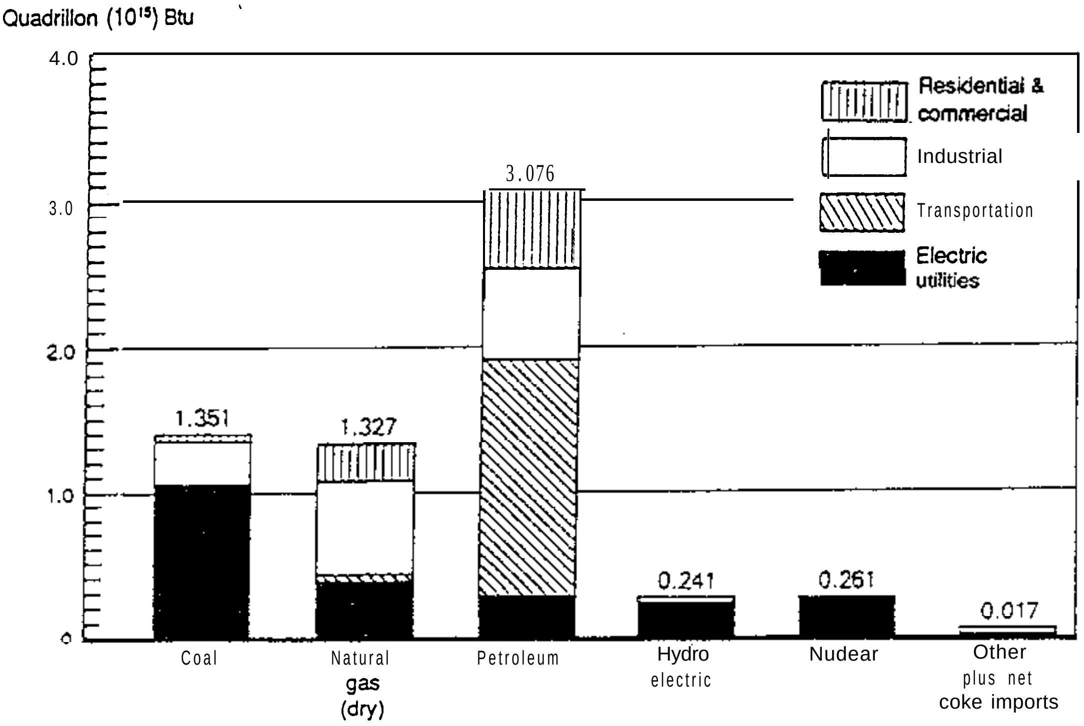
In addition, documentation of the emission inventory is necessary for all inventory uses. Documentation entails keeping a record of all methods, assumptions, sample calculations, references, and results employed in the compilation effort. The goals of documentation are to provide a written explanation to both the agency and outside users as to how the inventory was compiled and as to its reliability. Proper documentation of the inventory will help an agency when future inventories are conducted.

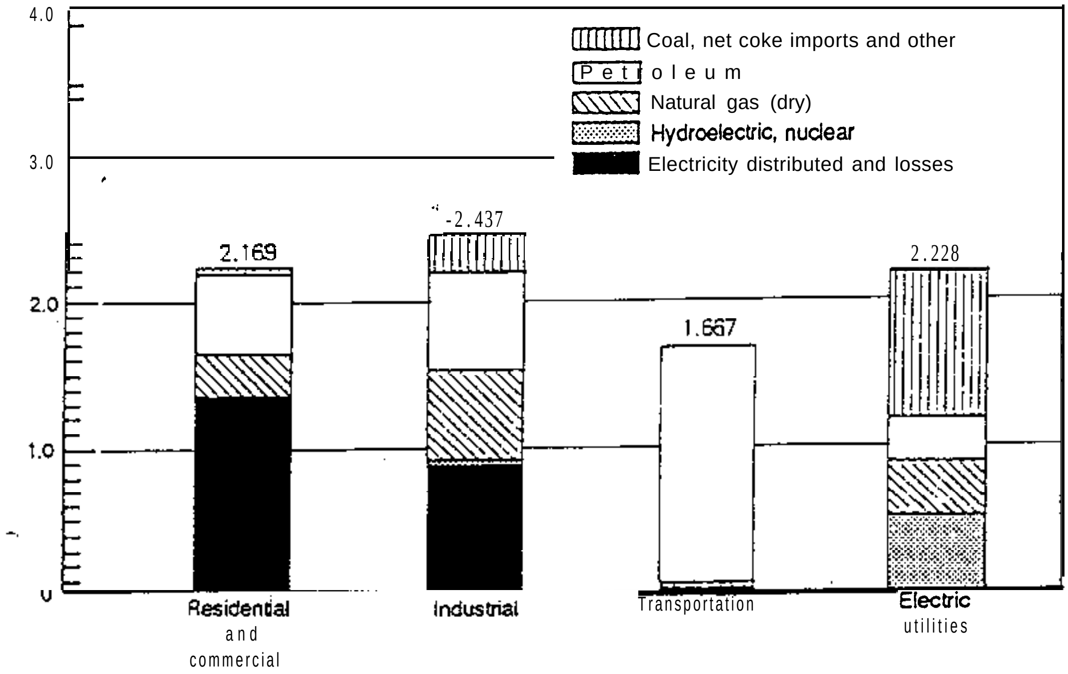
The following types of documentation of point source procedures will achieve inventory goals.[2]

1. Background information on reasons for compiling the inventory, future uses, how it evolved, and the significant changes from emissions of previous years.
2. Geographic area covered.
3. Population, employment, and economic data.
4. Time interval represented.
5. Proposed or promulgated control strategy programs that will affect the baseline inventory.
6. Baseline emission estimates summarized by source category in tabular format.
7. A narrative for each category of the inventory, containing the following: procedures used to collect/analyze data, sources of data, copies of questionnaires, questionnaire statistics, emission factor citation, method of calculation, assumptions, items not included, quality assurance procedures, and references.

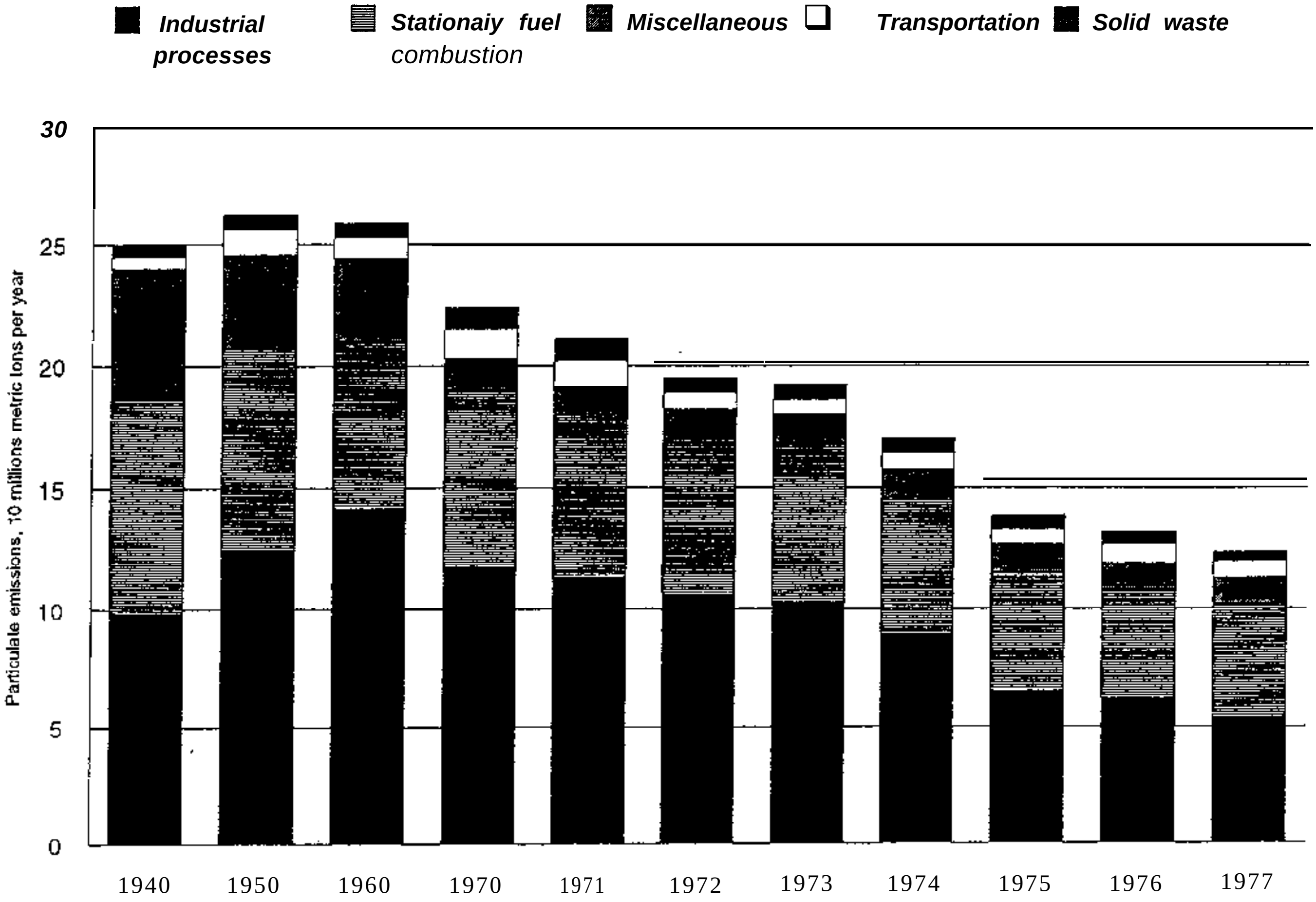
A technically sound inventory, if well-documented, can be useful for several years with only annual updating. Proper documentation will allow the agency to update the inventory in prompt and efficient manner and to readily institute procedural changes reflecting advances in methods and procedures for inventory preparations.

Energy consumption by economic sector

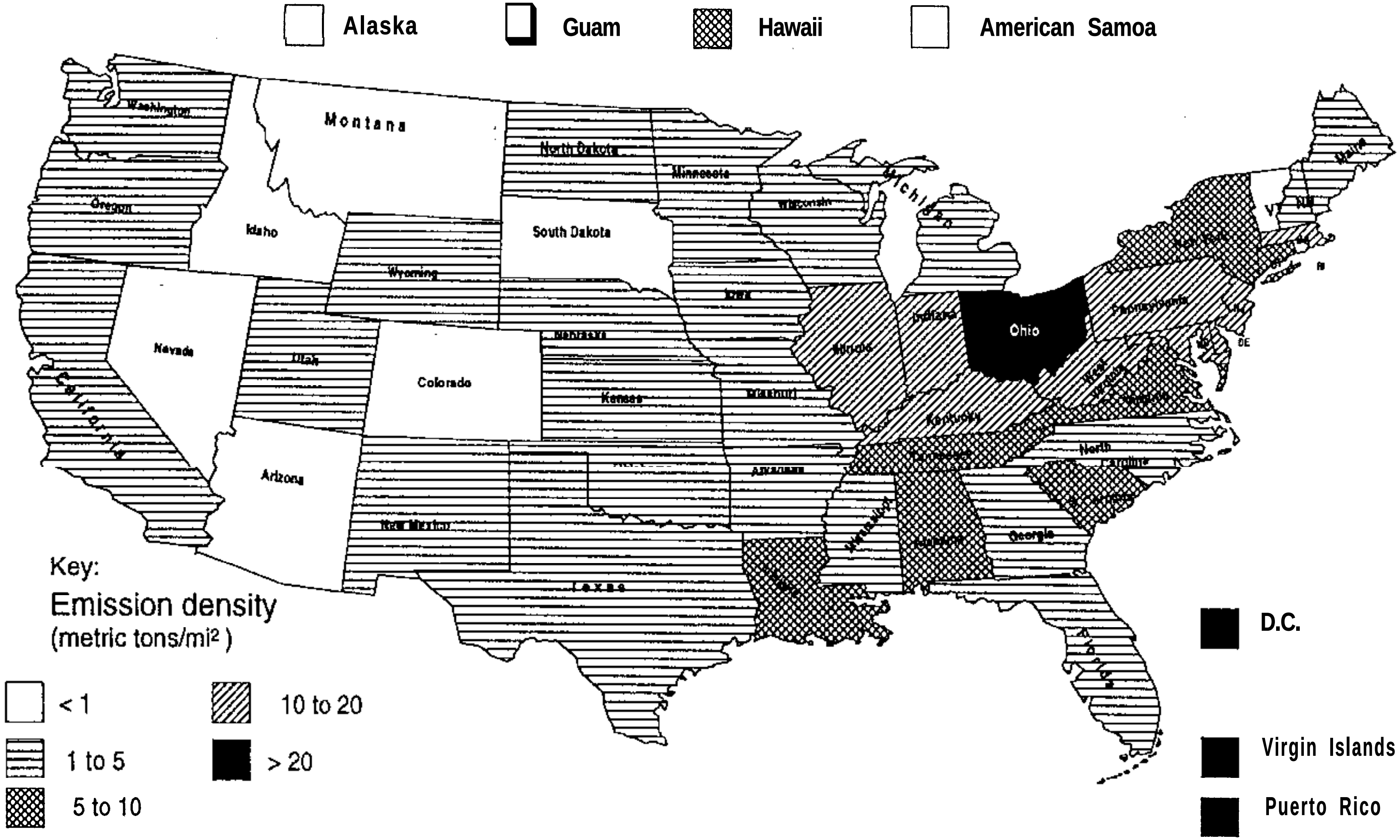




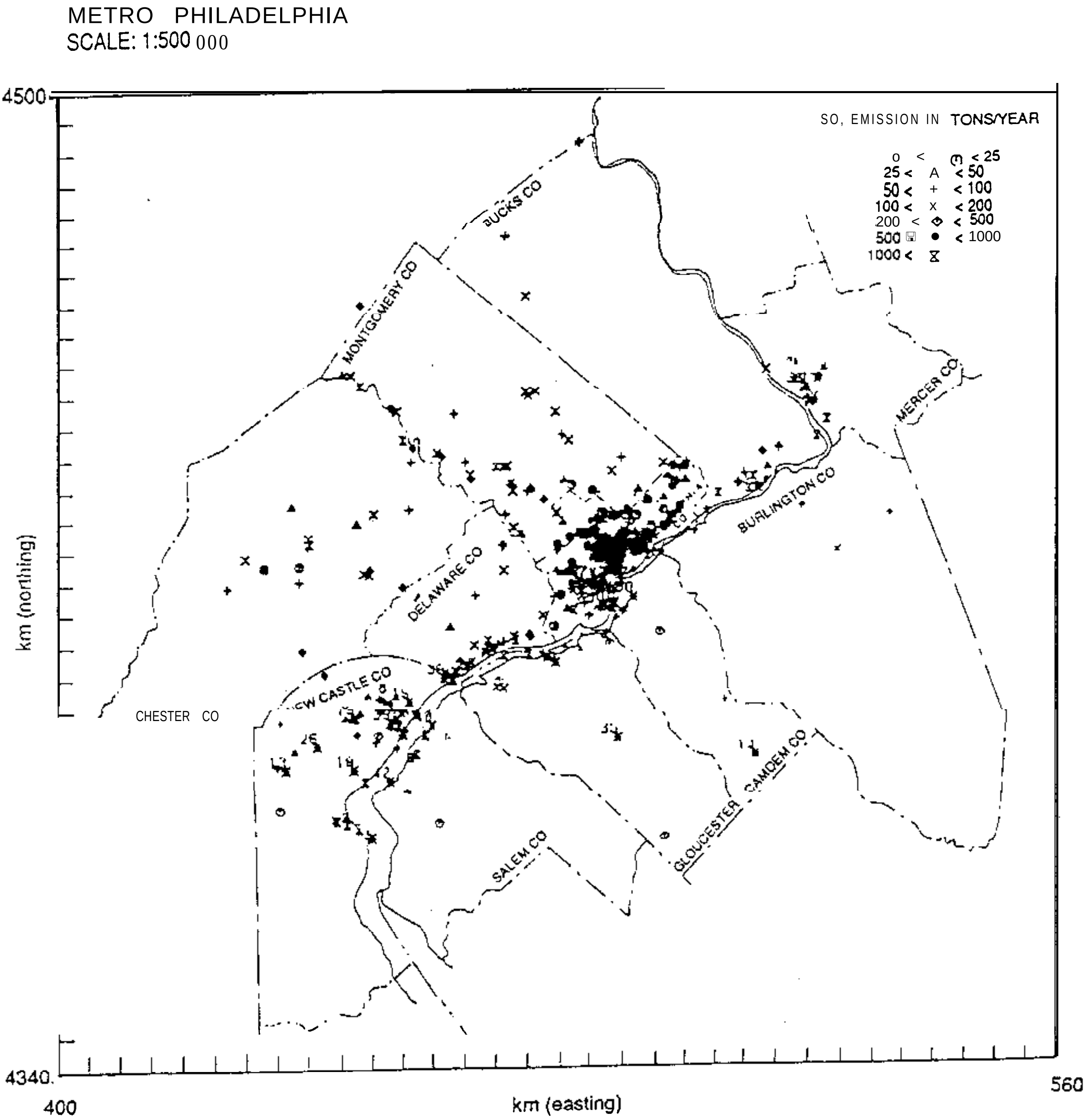
Historical particulate emissions by source category



Particulate emission density, by state



Location and emission rate of all plants emitting SO,



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PART FOUR:
ESTIMATION OF EMISSIONS TO WATER
(selected national practices)

CHAPTER ONE

WASTE-WATER DISCHARGES IN THE NETHERLANDS

CONTENTS

A. INTRODUCTION

A special inquiry surveys the quantities, origin, and destination of oxygen-demanding materials and a number of heavy metals discharged into waste-water by economic or industrial activities and by private households on a national and regional scale. The survey is annual because of the rate of change of major parameters over time. Oxygen-demanding materials are defined as suspended and dissolved biodegradable substances. The heavy metals include Cd (cadmium), Hg (mercury), Cr (chromium), Cu (copper), Pb (lead), Ni (nickel), Zn (zinc), and Ag (silver). Arsenic (As), not a heavy metal, is also included. References to Dutch law in this chapter are to the Surface Waters Pollution Act.

When they reach surface waters, oxygen-demanding materials are broken down by bacteria. This process consumes oxygen. In well-functioning ecosystems, there is an equilibrium between the quantity of oxygen consumed and the quantity of oxygen produced by green submerged plants and/or oxygen dissolved from ambient air. If an excess of oxygen-demanding materials consumes more oxygen than is supplied, there will be a shortage. This will result in an anoxic (oxygen-free) situation in surface water. In that case only a limited number of life forms can exist, and the surface water deteriorates. In The Netherlands this was the situation in the early Sixties. Although 9 per cent of the country's surface consists of water, the surface waters are shallow, which means that the actual quantity of surface water in the Netherlands is (unexpectedly) small and consequently vulnerable to pollution.

Heavy metals are dangerous for all forms of aquatic life, for other animals, and for humans. These metals do not break down, and so build up in the environment, for example in underwater sediments.

B. CONCEPT

The quality of the surface waters in the Netherlands is controlled by some 35 regional Water Quality Management and Control Authorities, who, for purposes of levying and control, determine the discharge of water pollutants by all companies and private households in their districts. These water boards refer to the discharged amounts of oxygen-demanding materials in a unit of measure called "inhabitant equivalent," or I.E. (see Glossary in Part Five).

Households

The water boards levy each private household for the waste-water it discharges, using a standard number of 3.5, 3, 2.8, or 1 inhabitant per household. This introduces a discrepancy between the levied and the actually discharged domestic pollution. To eliminate this discrepancy, CBS considers the total discharged domestic pollution in waste-water (expressed in I.E.) to be equal to the average population (from the CBS population census) in the statistical year under consideration.

Industry

The amount of oxygen-demanding materials discharged in industrial waste-water is also expressed, for levying purposes, in the number of inhabitant equivalents. All companies are legally obligated to report their waste-water data annually to the water boards.

For large companies, the water boards actually measure or monitor the discharges. For recalculation into the number of I.E.'s, the water boards use a formula, laid down by law:

$$\mathrm{I.E.} = \frac{(\mathrm{COD}}{136} + 4.57\ \mathrm{N\text{-}Kj})$$

where

- Q : daily discharged volume (m^3) measured
- COD : chemical oxygen-demand (g/m^3) measured
- N-Kj : Kjeldahl nitrogen ; the amount of organically bound nitrogen (gN/m^3)
- 4.57 : a factor for the oxygen demand of the Kjeldahl nitrogen
- 136 : the statutary average daily oxygen demand of the discharged waste-water of one inhabitant

In the case of smaller and/or unspecifically polluting companies, the water boards determine the amounts of biodegradable polluting substances in the waste-water via computation through emission factors based on governmental research. These emission factors (see the Appendix), prescribed each year by law, quantify the amount of pollution generated by a company or industry on the basis of production and/or specific input figures, such as number of employees or input of raw materials.

Companies that discharge an amount of less than 10 I.E. in their waste-water are levied at the same rate as private households. These companies produce waste-water comparable to domestic waste-water.

The water boards also collect data on the discharges of heavy metals by companies. As not all water boards levy the discharge of heavy metals, only the data on discharges known to the water boards are recorded. Most water boards, however, try hard to estimate the actual discharge of heavy metals.

Every year CBS collects data from all the country's water boards. Because of the tough datachecks run by the water boards, this integral approach is more reliable and efficient than even a sample survey among enterprises, which would be very labour-intensive. Use of this outside information means that this is secondary statistics derived from the databases of the water boards. As the water boards are distributed over the country, their districts bordering each other, the collected data enable regionalization of the statistics.

If no data are available from water boards or similar institutions in a country, an alternative method may be to calculate discharges using emission factors for similar processes. In the Netherlands, only the Emission Registration has practical experience with this method, and only for minor cases.

C. METHODS USED IN DATA COLLECTION

Using water board data

To collect the data, questionnaires[1] are sent to the water boards, seeking information on effluent output by numbers and types of companies. By law, the water boards are not allowed to transmit data from individual companies. They may only supply aggregated data in clusters, according to the Industrial Categories (ICW) specified by law. Therefore the industrial discharges in the CBS questionnaire are classified according to the ICW. The data on total discharges of oxygen-demanding materials and heavy metals are broken down into four destinations:

- sewage treatment plants;
- fresh State waters;
- salt and brackish State waters;
- other surface water managed by regional water boards.

To improve response, the CBS approaches major water boards by telephone after it has sent the enquiry. Sometimes visits are made. If data on certain questions are lacking, estimates are made on the basis of previous data. Because information can only be extracted from the water boards once they have completed their levying, a time-lag of two years between the statistical year and the availability of the results is unavoidable.

- *Data processing*

Because the ICW differs significantly from the Standard Industrial Classification (SIC) used by CBS, CBS rearranges the data so that they comply as much as possible with the SIC. This introduces some inaccuracies in the results, because the water boards do not classify small companies ($<$ 10 I.E.) according to the ICW. CBS rearranges these small companies under SIC on the basis of statistics of numbers of employees working in each SIC activity. The rearrangements are also used to correct some non-response and other minor deficiencies in the aggregated data set.

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[1] Copies of the questionnaire can be obtained from the ECE secretariat upon request.

The total discharge of heavy metals in waste-water, including fugitive emissions, is estimated. This mass-balance-like estimate is based on the following input data:

a) the heavy metal load of sewage sludge;
b) efficiencies of sewage-treatment plants in treating heavy metals;
c) recorded discharges of heavy metals in waste-water;
d) the partition by destination of domestic and industrial waste-water,
e) the proportion of domestic and industrial waste-water in the influent of public sewage-treatment plants.

Some of these data are derived from a separate integral CBS survey of public sewage treatment plants.

- *Results*

Results are disseminated for oxygen-demanding materials and for each monitored heavy metal in waste-water for 22 SIC activities, including 12 industrial activities. The data are reg-ionalized for each of the 12 Dutch provinces. Table 1 shows the aggregated results for the year 1987, by origin and destination for the Netherlands as a whole. The estimate of the total discharge in 1987, including fugitive discharges, of heavy metals before and after treatment in public sewage treatment plants is provided in Table 2.

Using emission factors

Total discharges of oxygen-demanding materials can be estimated on the basis of emission factors. The Appendix contains a list of emission factors for most ICW categories. Less up-to-date emission factors can also be found in the following manual: Handbook of Emission Factors (Ministry of Environment), especially in Part II: “Industrial Sources,” which also contains many references. This publication is available in English from SDU Publishers, The Hague. Reference is made to Appendix I of the Netherlands chapter on air pollution in Part Three of this volume. It contains the contents of the book and lists background literature. The emission factors cited refer to the situation in the Netherlands and may be different for other countries and other years. Data about emission-determining units such as input, intermediate consumption or output, and manpower, can be found in production and labour statistics according to SIC. These are available from statistical offices and/or economic institutions. However, many emission factors are given for specific production processes. Hence process data for specific industries or processes should be known.

Table 1
Discharge of oxygen-demanding materials and recorded heavy metals in waste water by origin and destination

SIC-Activity	Biodegradable	Cadmium	Mercury	Chromium	Copper	Lead	Nickel	Zinc	Silver	Arsenic
	1000 i.e.	1000 kg								
Households, private	14 665									
Companies >= 10 i.e.										
1 Agriculture	24									
2/3 Industry	6 400	8.3	0.7	103.2	26.1	19.7	24.8	148.2	2.3	8.0
a.w.										
20/21 food, beverages and tobacco	3 746	**0.0**	**0.0**	0.3	3.4	0.5	3.4	10.5	**0.0**	0.1
22 textile industry	217	**0.0**	**0.0**	0.5	2.0	0.1	0.2	2.8		0.0
23 clothing manufacturing	0									
24 manufacture of leather produ	41	**0.0**		1.2	0.0	0.0	0.0	0.1	-	-
26 paper industry	302	**0.0**	**0.0**	0.0	1.6	0.1	0.1	3.0		
27 printing, publishing etc.	36	**0.0**		0.2	0.3	0.1	0.0	0.4	1.3	0.0
28/29/30 chemical and petroleum indu	1428	**8.0**	0.6	86.6	10.0	10.9	7.9	90.9	0.1	7.6
31 rubber and plastics industry	2									
32 building material, earthenware, glass	8				0.0	0.1	0.0	0.4		
33 basic metals industry	154	0.2	0.1	2.7	1.3	2.3	1.6	10.9	**0.0**	x
34 manufacture of metal product	137	0.2	0.0	11.7	7.5	5.5	11.4	29.2	0.9	0.1
4/6 Public utilities, construction, tourism and trade	1403	**0.0**		0.0	0.1	0.2	0.0	0.6	**0.0**	
a.w.										
40 power plants	14	**0.0**		0.0	0.0	0.1	0.0	0.2	**0.0**	
67 hotels, bars, restaurants etc.	541			0.0	0.1	0.0		0.2		
68 car repair shops	90	**0.0**		0.0	0.0	0.0	0.0	0.3	**0.0**	

Table 1 (Continued)
Discharge of oxygen-demanding materials and recorded heavy metals in waste water by origin and destination

SIC-Activity		Biodegra-dable	Cadmium	Mercury	Chromium	Copper	Lead	Nickel	Zinc	Silver	Arsenic
7-9	Services and transport	2 164	**0.1**	**0.0**	**0.8**	48.0	1.8	**1.0**	7.7	0.3	**0.8**
a.w.											
90	administration, military facili	59			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**		
92	educational institutes	294	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.1**	0.1	**0.0**	**0.0**
93	hospitals	699	**0.0**	**0.0**	0.1	**0.8**	**0.0**	**0.0**	2.3	0.2	**0.0**
94	welfare services	356	-	-	-		-				-
96	sport and recreation	30									-
98	other services	190	**0.0**	**0.0**	**0.0**	0.3	0.2	0.0	0.4	**0.0**	x
	other companies, n.e.c.	1 594	**0.0**	**0.0**	**0.6**	3.6	1.6	0.9	4.9	0.1	**0.8**
Small companies < 10 i.e.					-	-	-	-			-
Total discharge		24 925	8.4	0.7	**104.0**	31.0	21.7	25.8	156.5	2.6	8.8
o.w. into											
	public sewage treatment plan	19 735	0.2	0.1	10.2	14.7	7.0	11.5	42.3	2.5	0.1
	state waters, through waterbo	1 249	0.1	0.0	0.1	0.0	0.0	0.0	0.0		0.0
	fresh state waters, direct	1 150	7.8	0.6	92.7	14.2	13.6	11.8	87.4	0.0	8.2
	salt state waters, direct	407	0.3	0.0	0.7	0.9	0.8	2.1	15.6		0.5
	other surface waters	2 384	0.0	0.0	0.3	1.2	0.3	0.5	11.3	0.0	0.1

CBS/NL

Table 2. Heavy metals in waste-water, 1987

	Total discharge (1) 1,000 kg	0. w. fugitive emissions		Net discharge (2)
		Households	Industry	
Cadmium	10.9	1.5	1.0	9.5
Mercury	1.6	0.5	0.3	1.0
Chromium	140.0	21.0	15.0	111.0
Copper	235.0	119.0	85.0	112.0
Lead	129.0	63.0	45.0	56.0
Nickel	77.0	30.0	21.0	64.0
Zinc	709.0	323.0	230.0	374.0
Arsenic	12.5	2.2	1.5	10.4

1) Recorded discharges and fugitive discharges before treatment in public sewage-treatment plants.

2) Total gross discharge, minus the load on public sewage-treatment plants, plus the discharge of effluents.

Appendix
Waste-water emission coefficients

al category of water	unit	i.e./unit:
la Car repair shops inclu. car washes	1 m3 water used	0.03 1
1 b Overhaul workshops	1 m3 water used	0.031
2 Potato starch plants	1000 kg potatoes	0.89
3 Potato processing industry	1000 kg potatoes	0.1 - 0.54
4 Beer breweries	1000 kg beer	0.27 - 1.1
5 Chemical industry	100 man days	7.3
7 Mushroom cultivation farms	100 m2 crop surface	0.4
8 Fruit-preserving plants	1000 kg fruits	0.14 - 0.63
10 Vegetable-preserving plants	1000 kg vegetables	0.14 - 1.5
11 Vegetable-washing plants	1000 kg vegetables	0.08 - 0.73
12 Distilleries	1 m3 water used	0.036
13 Varnish and paint plants	1 m3 water used	0.023
14 Tanneries and fur processing	1000 kg raw material	0.48 - 2.74
15 Soft-drink factories	1000 1 lemonade	0.073
17 Margarine, fat, and edible oil plants	1000 kg raw material	0.54
18a Metallurgy plants	100 man days	0.023
18b Metal processing and galvanic plants	100 man days	0.023
18c Printing and photo industries	100 man days	0.023
19 Malt houses	1000 kg wheat	0.14
20 Paper mills	1000 kg paper	1.3 - 6.3
21 Perfume and cosmetics manufacturing industry	100 man days	3.6
24 Poultry slaughterhouses	1000 kg slaughtered weight	0.18 - 0.63
25 Lubricants manufacturing industry	100 man days	3.6
26a Slaughterhouses	1000 kg slaughtered weight	0.14 - 0.73
26b Fat-melting plants	1000 kg raw material	0.1 - 1.1
28 Board mills	1000 kg board	3.01
29 Sugar factories and refineries	1000 kg sugar beets	0.23
30 Textile and clothing industry	100 man days	0.14
31 Barrel washeries	1 m3 water used	0.36
32 Livestock farming	100 days/animal	0.036 - 3.6
33 Fish-processing factories	1000 kg fresh fish	0.13 - 1.7
34 Fish-flour factories	1000 kg fish	2.05
35 Meat-processing industry	1000 kg product	0.04 - 0.45
36 Laundries	1000 kg laundry	0.14 - 4.5

Appendix (Continued)
Waste-water emission coefficients

al category of water	unit	i.e./unit:
38 Soap factories	1000 kg soap	0.34
39 Dairies	1000 kg raw material	0.04 - 2.7
40 Swimming pools and bathing houses	100 man days	2.8
41a Educational institutes	1 m3 water used	0.023
41 b Barracks, prisons	1 m3 water used	0.023
41c Hospitals and health services	1 m3 water used	0.2
41 d Homes for the elderly	1 m3 water used	0.023
and welfare services	1 m3 water used	
41e Hotels, bars, and restaurants	1 m3 water used	0.023
42a Chocolate, cocoa, confectionary manufacturing industry	1000 kg product	0.18 - 0.36
42b Bread and pastry manufacturing industry	1 m3 water used	**0.18**
43 Egg-processing industry	1000 kg eggs	0.27 - 0.54
44a Power stations	1 m3 water used	0.023
44b Rubber vulcanising and synthetic leather plants	1 m3 water used	0.023
44c Building material, glass and ceramics industries	1 m3 water used	0.023

CBS/NL

CHAPTER TWO

ESTIMATING PROCEDURES FOR PREPARING STATISTICS ON DISCHARGES TO WATER IN SWEDEN

(1990)

CONTENTS

A. INTRODUCTION

Statistics on discharges to water from municipal waste-water treatment plants are produced within Statistics Sweden (SCB) by the unit for environment statistics. So far the statistics have been produced every third year (in 1984, 1987, 1990). The information is used to support decisions on measures to improve the environment and to monitor the effects of the decisions. The statistics also are used in different planning activities and research projects often linked to data on water quality.

The statistics are produced in close cooperation with environmental protection agencies, especially the National Environmental Protection Agency (SNV). The discharges from large industrial plants not served by municipal waste-water treatment plants are calculated by the SNV.

The following description of methodology concerns statistics at the SCB and discharges of eutrophicating substances. Statistics on discharges of metals have so far not been produced due to lack of primary data, but are planned for 1990-91. The methodology is similar to the techniques described in this report.

B. STATISTICAL CONTENTS

The statistics concern discharges of oxygen-demanding substances (BOD and COD), phosphorus (total P), and nitrogen (total N). The following variables are included:

1) Municipal waste-water treatment plant, name
2) Region, county, municipality, and drainage basin
3) Number of persons served
4) Location of plant at the coast or in the interior of the country
5) Treatment method: mechanical, biological, chemical, chemical-biological, and additional treatment with filtration and nitrogen reduction
6) Waterflow, cubic metres per 24 h, average for the year
7) BOD content, mg. per litre

8) COD content, mg. per litre
9) P content, mg. per litre
10) N content, mg. per litre

C. TREATMENT PLANTS COVERED

The survey covers treatment plants satisfying the following conditions:

1) They are municipal -- that is, municipalities have principal responsibility for the plants. (There are private treatment plants as well.)

2) They are in operation.

3) They have discharges to water (infiltration plants with discharges to the ground -- and indirectly to groundwater -- are not included).

4) They serve at least 200 persons (the limit has long been used and is linked to the concept of urban area: the lower limit for Swedish urban areas is 200 persons).

The distribution of treatment plants by size is given in the following table:

Size class (persons served)	Treatment plants		Persons served	
	Number	Percent	Number*	Percent
200 - 1 999	793	66	535	7
2 000 - 9 999	271	23	1 182	1
10 000 - 19 999	61	5	852	11
20 000 - 49 999	51	4	1 521	19
50 ooo - 99 999	12	1	879	11
100 000 -				
Total	1 200	100	7 964	100

• ' Thousands

Most of the plants, or two thirds, are small, serving fewer than 2 000 persons. They account for only 7 per cent of the persons served.

In the survey for 1990, the lower limit for the number of persons served has raised to 1 000 or 2 000 persons. In this way time and resources were saved while 90 to 95 per cent of the discharges and the persons served are still being covered.

D. PRIMARY DATA AND DATA COLLECTION

There are four main data sources:

1) A questionnaire on waste-water treatment plants is sent to all municipalities. It asks about the number of persons served, dimensions of the plant, treatment method, and method for sludge treatment. The response rate is nearly 100 per cent.

2) Annual reports of treatment plants with information on contents of polluting substances and metals in effluent waste-water. Annual reports are available for about 55 per cent of treatment plants.

3) Selection of data from a computer-based environmental information system containing data from environmental control programmes. The selection concerns the same data as are taken from the annual reports. Ten counties, corresponding to about 30 per cent of the primary data, deliver data to the information system.

4) Reports and compilations from remaining counties, and different laboratory protocols, account for the last 15 per cent of primary data. Most of this information is collected through correspondence and telephone calls.

All treatment plants have complete information on important background variables: county, municipality, drainage basin, treatment method, number of persons served, and discharges to the sea or to the interior of the country. Nonresponse is not permitted for these important variables. It is, however, permitted for other variables. (See the next section on estimation methodology.) It must be stressed that it is vital that the primary data are as uniform as possible. The data must refer to the same year. They also must be as comparable as possible between different treatment plants.

E. ESTIMATION METHODOLOGY

When there is no nonresponse, the annual amount of pollution is calculated as the product of pollution content (mg. per litre) and watefflow (cubic metres per 24 h) and a factor 0.000365 for transformation from mg. per 24 h to tons annually. Watefflow and pollution content are annual averages (arithmetic means).

In case of nonresponse on watefflow, values are imputed (that is, missing values are replaced) according to the following method (linear regression applied to size classes):

Missing values on	are replaced by						
Watefflow	0.563 x persons*	-	10	for	200 -1 999	persons	(r=0.49)
	0.493 x persons	-	12	for	2 000 - 19999	persons	(r=0.87)
	0.524 x persons	-	3 096	for	20 000 -	persons	(r=0.96)

• ’ Number of persons served

The calculation implies about **500** litres per person per 24 h. The regression equations are based on data from treatment plants having values for waterflow and numbers of persons served (1 ,112 plants).

In the case of valid data on content of BOD, COD, phosphorus, and nitrogen, the pollution amounts are calculated in the same manner as in the response case.

In case of nonresponse on content of BOD, COD, phosphorus, or nitrogen, the missing data are replaced with standard assessment values (grams per person and 24 h). The standard assessment values are multiplied by the number of persons served, and the result will be estimated pollution inflow to the treatment plant. The amount is reduced by a percentage, depending on the treatment method, to determine effluent pollution emitted from the treatment plant. The effluent pollution is reported in tons. More effective treatment methods imply a greater reduction of pollution inflow and are reflected in the table by larger percentages.

Mission values on	are replaced by standard assessment value	and are reduced by (per cent)				
		mechanical treatment	biological treatment	chemical treatment	chemical biological treatment	additional treatment
P	3.5 grams	--	40	90	90	90
N	11 grams	15	30	30	30	50
BOD	70 grams	30	90	90	90	90
COD	150 grams	30	90	90	90	90

*/ With filtration and nitrogen reduction

F. DATA QUALITY

There is great variation in the content and quality of the collected data. The variation cannot be interpreted as a common statistical deficiency, because the primary data arise from administrative processes and have to meet supervision and control demands formulated by the Environmental Protection Law before they meet the needs of statistics production. The environmental control programmes vary depending on plant size, location at the coast or in the interior of the country, treatment method, and age. Additional variation comes from different policies and priorities of the local environmental protection agencies. In conclusion, the administrative supervision and control processes generate primary data with a large variation in content and quality.

The annual average watefflow per 24 h is always calculated as the total annual volume of inflowing water to the treatment plant divided by 365. Trouble in the operation of the plant and technical mismanagement in measuring the waterflow can cause less reliable data. At present, the quality of the water-flow data is unknown. In the 1987 survey, 93 per cent of the values were reported and only 7 per cent were imputed.

For the data on pollution content, two factors have a decisive influence on the quality: measurement accuracy and the number of different measurements/observations on which the annual average is based. At present, knowledge of the data quality is insufficient. An analysis is being planned that will be used for declaring the quality of the statistical results. However, in the latest survey a few obvious trends were observed:

1) The large treatment plants have better primary data than the small treatment plants, and have more measurements and smaller nonresponse.

2) The nonresponse varies very much by type of pollution; this is clearly demonstrated by the information in the following table:

	Missing values		Imputation, amount	Per cent of total amount
	Number	Per cent		
P content	39	3	16 tons	2
N content	1018	85	10 906 tons	43
BOD content	43	4	227 tons	1
COD content	291	24	7 706 tons	12

G. STATISTICS AND PRESENTATION

The statistics are presented as pollution in tonnes for a number of requested subgroups. An excerpt from the statistics for 1987 is given below.

DISCHARGES TO WATER FROM MUNICIPAL WASTE-WATER TREATMENT PLANTS IN 1987

	Phosphorus tonnes	Nitrogen tonnes	BOD tonnes	COD tonnes	Treatment plants	Persons served[1]
Total	1 050	25 600	16 700	66 300	1 200	7964
Coast/Interior						
Discharges from the coast	670	13 750	8 900	35 100	212	3 978
Discharges from interior of the country	380	11 850	7800	31 200	988	3 986
Major drainage areas						
Bothnian Bay	60	1 070	1 970	4 240	94	331
Bothnian Sea	220	2 750	3 600	11 510	299	992
Baltic Proper	300	13420	5060	27 400	425	3 906
Oresund	200	2240	1210	4 050	33	751
Kattegat	250	5 670	4 490	17 780	300	1 815
Skagerrak	20	460	380	1 320	49	169

Persons	Phosphorus tonnes		Nitrogen tonnes	BOD tonnes	COD tonnes	Treatment plants served[1]
Size classes						
200 - 1 999	100	1 500	1 600	5 300	793	535
2 000 - 9 999	130	3 400	2 400	8 930	271	1 181
10 000 - 19 999	110	2 600	2000	8 050	61	852
20 000 - 49 999	180	4 750	3 200	11 150	51	1 521
59 ooo - 99 999	140	2 750	2 850	7 900	12	879
100 000 -	390	10 600	4 650	25 000	12	2 996
Treatment methods						
Mechanical	5	20	90	220	19	6
Biological	290	1 370	1 570	3 200	155	375
Chemical	70	1470	2 840	6 260	208	480
Chemical-biological	610	19 700	10 840	49 700	759	5 935
Additional treatment[2]	70	3 050	1 380	6 920	59	1 168

1/ Thousands

2/ With filtration and nitrogen reduction

PART FIVE:
MATERIALS BALANCE SHEETS
(selected national practices)

MATERIALS BALANCE SHEETS FOR PHOSPHORUS AND NITROGEN IN THE NETHERLANDS

CONTENTS

Glossary of terms and acronyms

EC	European (Economic) Community
NL	The (Kingdom of the) Netherlands
CBS	Netherlands Central Bureau of Statistics
CBR	Central Business Register of the CBS
SIC	Standard Industrial Classification of all economic activities; CBS version (1974) of the EC-NACE (compatible with ISIC)
TÜV	Technische Uberwachungs-Verein (Germany)
SI	Système International des Poids et Mesures
TNO	Netherlands Organisation for Applied Scientific Research
SO_2	Sulphur dioxide
NO_x	Nitrogen (nitrous) oxides; expressed in NO_2 equivalents
CO	Carbon monoxide

CO_2	Carbon dioxide
VOC	Volatile organic compounds, methane (CH4) excluded
NH_3	Ammonia and ammonium compounds; expessed in NH3
TSP	Total in ambient air suspended particles; elsewhere used equivalents: SPM (suspended particulate matter), particulates, fine dust, aerosols
CFC	Chlorofluorocarboncompounds, including Bromocompounds
BOD	Biological Oxygen Demand: the oxygen used in bacterial degradation of pollutants in water. The BOD520 is measured over a period of 120 hours (5 days) at temperature of 20°C, without supply of light, and is generally used as a measure for the pollution of water with biologically degradable matter
COD	Chemical Oxygen Demand: the amount of oxygen equivalent to the amount of potassiumdichromate consumed in the oxydation of the sample
IE	Inhabitant equivalent: the amount of oxygen-demanding materials of which the oxygen consumption in biodegradation equals the average oxygen demand of the waste water from one inhabitant. For levying raw waste water, the IE is defined by law on the basis of BOD, or, alternatively, COD. One IE of raw waste water may therefore be equal to either 54 g. BOD520 or 136 g. (COD + 4.57 x Kjeldahl-nitrogen), both per 24 hours
Kjeldahl	Nitrogen assay, yielding values corresponding to approximately the sum of organically bound nitrogen and ammonium nitrogen

A. INTRODUCTION

When a substance is present in the environment to such an extent that it causes damage or may cause damage, it is necessary to study how it enters the environment and in what amounts. Such information is a prerequisite for efficient measures to limit emissions. It is sometimes useful to draw up a qualitative and quantitative inventory of how the substance is used, and to investigate related matters. This can be done on a national, regional, continental, or even global level. Such an inventory generally will be made on a national level, as the necessary information is usually available country by country. A complete description of how the substance is used can be given in a flow chart. If such a description covers only inflow and outflow, say for a certain country or a certain component of the environment, it is called a substance balance sheet. Strictly speaking, it may only be called a balance sheet if the inflow and outflow are described so accurately that it is clear what the positive or negative balance is; this is not usually the case. In practice, all forms of substance inventories are called substance balance sheets, even if they lack many of the necessary quantitive data. Up to now the CBS has drawn up balance sheets for the following substances: PCBs, mercury, phosphorus, organotin compounds, copper, selenium, arsenic, and nitrogen. Sulphur, cadmium, and zinc balance sheets are currently being worked on. A number of other institutes also have drawn up several balance sheets - - for cadmium, copper, mercury, bromine, and acrylonitrile.

Obviously, the first substances to be tackled were those whose problems for the environment had long been recognised: cadmium, mercury, PCBs, and phosphorus. When doubts began to be expressed about organotin compounds a few years ago, an inventory of the use of this group was drawn up. It may be desirable to repeat this process to monitor the effects of restrictive measures -- for example in the case of cadmium; other reasons for repeating balance sheets may be if a certain substance comes into the limelight (phosphorus) or if a previous inventory took place some time ago (copper). Inventories should really be made of the use of all substances which end up in the environment at toxic levels; this might help us to foresee environmental problems not evident at the moment but which might occur in the future if the substances continue to be used. This was the reason for drawing up the selenium and zinc balance sheets. The choice of new substances is done in consultation with experts from environmental research centres. The PCB and mercury balance sheets were done on request by the Ministry of Public Housing, Planning, and the Environment, which wanted a description of the use of these substances in aid of the OECD.

At the beginning of this chapter the general procedures for drawing up a balance sheet are discussed. Then guidelines pertaining to balances for phosphorus and nitrogen are described in detail. Finally, as an example of a substance balance sheet, the phosphorus balance sheet for the Netherlands is presented.

B. GENERALPROCEDURE

To draw up a balance sheet, considerable statistical information on a variety of subjects is required. In fact, a material's balance sheet largely is based on so-called secondary statistics. For the most part existing information determines the success of the project; also, it greatly influences the choice of the year of investigation. Sometimes part of the required information is not available for the year of investigation for earlier years. When this is so, one has to make educated guesses or estimates on the basis of data from abroad. Furthermore, the fact that we have to deal with statistics derived from other statistics makes it almost unfeasible to draw up a balance sheet with very recent data; we always have to deal with the delay time required for obtaining data from primary statistics. The first step in every study is the consultation of the technical literature (Ullmann, Kirk-Othmer) on how the substance is produced and where it is used. Subsequently an inventory is made of which of these processes takes place in the region under investigation. Once this is known, all the necessary data for the balance sheet and flow chart are gathered; these include imports, exports, production, processing, domestic sales, waste treatment, reuse, incineration of chemical waste or disposal to foreign dumping sites, all emissions into water, air, and soil, the behaviour of the substance in waste-water treatment and waste incineration, etc. The most important sources of information are trade organizations, experts at technical research institutions, and most of all companies known to make certain products or to use the substance concerned. In the Netherlands, the annually published list of industrial products and the producers and/or importers who supply these products is a valuable source of information [1].

Substances for which balance sheets are made are usually either elements -- such as heavy metals, phosphorus, or selenium -- or xenobiotic substances, such as PCBs. Xenobiotic substances can be produced from or decomposed to harmless substances such as carbon, oxygen, hydrogen, or chlorine. Elements, on the other hand, are imported or produced by mining activities and the only method for decreasing their presence is to remove them, by way of export of products or of chemical waste, or by discharge into the sea, into border-crossing rivers, or into the air. One exception is nitrogen, where nitrification and denitrification play a part. In the case of elements, non-intentional use, as it is called, should also be taken into account: their occurrence in minerals such as coal, crude oil, and ores. When these minerals are processed or used, substantial amounts of the substances concerned may be released; for selenium, the contribution by minerals is even greater than that from intentional use. Moreover, a downstream country such as the Netherlands must take into account that substances enter the country by way of rivers. That is especially true of the Rhine.

3. SOURCES OF DATA

Imports

- Intentional imports: foreign statistics. These entail some limitations due to the fact that a certain substance may be recorded under a combined item ("other compounds...") or make up part of a complete product (for example, cadmium in synthetics). Combined items can sometimes be broken down. The contribution of complete products has to be estimated, often with the aid of experts; sometimes inventories of the companies themselves can be used (for example, for mercury in batteries). Foreign-trade statistics are based on customs declaration forms which contain a description of the article concerned along with a statistical code and the name of the importer. With the forthcoming computerization of this procedure, the description of the article will no longer be stated, thus making it impossible to break down the combined items. Once the single market has been introduced in 1992, data on imports from other EC countries might not be available at all.

Imports via pollution in minerals can be calculated as the amount of mineral * the content. Each of the ores is processed by just one or only a small number of companies; these supply information on the content in as far this has been established. If this is not the case, then values are taken from the literature. In the Netherlands, coal has been analysed for a large number of elements and there is quite an accurate knowledge of the amounts of these elements entering the country every year. Data on oil are given by the oil industry or taken from the literature. The contribution of crude oil is quite difficult to calculate for most substances, partly because it is not known which of these substances stay in the Netherlands after the refining process.

- Production of xenobiotics and elements. (For xenobiotics see the section below on production statistics). The only mining activities in the Netherlands are the extraction of oil and natural gas. The producers supply figures on the contamination of these; along with natural gas, for example, a lot of mercury is extracted.

- Border-crossing rivers. For a number of substances such as cadmium and phosphorus, regular analysis by the State Water Authority gives an accurate picture of what enters the country by way of the Rhine and Meuse rivers; for phosphorus, the contribution of the smaller rivers is also known. Data on other substances are less accurate or are completely lacking.

- Border-crossing air pollution. This is more important than it was thought to be up to a short while ago, and metals are among the matters of concern. It is difficult to calculate the amounts of the various substances that enter or leave the country. There are some model calculations, but not for all substances.

Exports

- Foreign-trade statistics; see above

- Dumping of chemical waste abroad; the CBS has access to reports of the Ministry of Public Housing, Planning, and the Environment; however, these reports do not cover all dumping.

- Exports of material for reuse abroad; these are sometimes reported in foreign-trade statistics. If it is known that certain amounts of materials go abroad for reuse, it would be better to obtain data from the companies concerned.

- Flows to sea via river deltas and sluices. For some substances, such as phosphorus, this outflow is known accurately. For other substances it is known hardly or not at all. Dredging spoil contaminated by heavy metals may be dumped at sea; for some substances, the State Water Authority knows how much leaves the country annually.

Inland flows

Production and disuse

In principle, production statistics give data on the consumption of substances and on the production of the items and materials in which these substances are used. In practice, however, for many substances, few branches of industry keep detailed records. Usually, substances are not specified, or they are classified under nonspecific headings ("solvents," "other auxiliary materials," etc.). Small companies are only obliged to provide financial data. The most important sources of information on production and inland sales are the companies themselves. A difficult problem for most substance balance sheets is calculating just how much of a certain substance reaches the waste stage in a certain year. There are no direct data available on this. The CBS collects data on various kinds of waste, divided into various categories, but specific substances cannot be derived from these. In several cases, amounts have to be assumed equal to sales, as in the case of batteries or items whose consumption has been constant for years. Mostly, however, the amount of waste has to be established according to an alternative method, for example by analysing samples of household waste. The National Institute of Public Health and Environmental Hygiene monitors the composition of this waste. Sometimes there is a discrepancy between the amount of a substance actually found and the amount expected in view of the use. It is difficult to trace the causes of such differences.

Emissions into water and air

Data on these emissions are collected partly by the CBS and partly by other institutions, although of course not all substances are covered. At the CBS, there are data for heavy metals in waste water and sewage sludge obtained from surveys by the country's water-quality control authorities; and there are data on industrial process emissions in the air and emissions from large furnaces.

Moreover, we know how much of various categories of domestic and industrial waste is dumped and how much is incinerated. The emission registration of the Ministry of Public Housing, Planning and the Environment gives information on emissions into water and air of a large number of substances, but only for a limited number of years. Sometimes the companies themselves can give information, or estimates can be made with the aid of other data, such as processed amounts of material, or use can be made of the results obtained by research institutes.

It is important to keep up to date with which studies -- on a regular or incidental basis -- are in progress and which institutes carry them out. By seeking further information one often finds that there is much more factual information available than has been published.

D. GENERAL REMARKS

Initially, the CBS decided to draw up balance sheets because its staff had access to questionnaires on production statistics. Although the amount of useable data turned out to be small, as explained above, there were other unforseen advantages. As mentioned, individual declarations for foreign-trade statistics refer to importers. These companies are often willing to report who buys these imported materials, and their information can be useful in other respects. The most important advantage, however, is that the CBS has a reputation among businesses for reliability. "The environment" is apparently still a delicate subject, but industries know that the CBS will not use the figures entrusted to it for biased reporting and that it will never publish individual data without explicit written permission. The CBS would never want to betray this confidence, even though it sometimes limits possibilities [2].

E. PHOSPHORUS AND NITROGEN

Phosphorus and nitrogen as environmental pollutants

Phosphorus does not occur in its pure, elemental form in the environment. It does occur, however, in the form of phosphates in the soil, in the sea, in most human foodstuffs, and in numerous man-made compounds. In the form N,, nitrogen is the most abundant component of the earth's atmosphere. Incorporated into amino acids, nitrogen is one of the major constituents of proteins (c. 16 per cent). Potassium, phosphorus, and nitrogen are essential minerals (nutrients) for plant, animal, and human life. However, various developments have led to abnormal accumulations of phosphorus and nitrogen in the environment, and these have increased so drastically in recent decades that harmful effects have become apparent. The nutrient burden of fresh surface water plays an important if not crucial part in the process of eutrofication, which particularly involves algal bloom, oxygen deficiency, the death of fish, and decreasess in the number of species. Moreover, it is beginning to look as if an excess of nutrients also influences marine-water ecosystems. For this reason, an attempt is made to limit the levels of phosphorus and nitrogen in the environment. The nutrient burden on soil is important because of the danger that the nutrients will leach into groundwater and surface water. Furthermore, in the form of NH, and NO,, nitrogen contributes to the acidification of the environment.

If a meaningful and effective policy for limiting nutrients is to be implemented, insight into the size and relative significance of the various sources is an important starting point. The balance sheet and the flow chart are instrumental for such understanding.

Accumulation

Accumulation in an area under investigation is calculated as follows:

ACCUMULATION = SUPPLY - WITHDRAWAL

The main sources of supply are production, imports, and border-crossing air and water pollution. The main causes of withdrawal of these materials are exports and, again, border-crossing air and water pollution. Other, less important flows are taken into account in the sections below. In general, only a limited amount of data is needed to calculate the accumulation of phosphorus and nitrogen in a certain area. In the guidelines below, we use a country as the area of investigation. Naturally, other areas can be investigated, but in the scope of this manual it seems reasonable to limit the study to a country, since often the most complete amount of statistical and monitoring data available is national data.

The phosphorus and nitrogen balance sheets run parallel' because the items of supply and withdrawal are quite similar. To calculate balance sheets for phosphorus and nitrogen, the contributions of the following parameters pertaining to supply and withdrawal should be quantified; if possible, information sources will be indicated and some comments will be provided on the calculations.

- *Phosphorus balance sheet*

a. Mining of phosphate rock. Only important for those countries where phosphate rock deposits are exploited.
Source: production statistics of mining activities.
Calculation: quantity of rock X content of P (phosphate rock imported in the Netherlands contains c. 14.5 per cent P).

b. Imports and exports of animal and plant products (cattle feed and foodstuffs for human consumption).
Source: statistics of foreign trade.
Calculation: quantity of (group of) products X content of P'.

c. Imports and exports of organic and inorganic phosphorus compounds (including phosphate rock and fertilizers).
Source: statistics of foreign trade.
Calculation: quantity of (group of) products X content of P'.

d. Imports and exports of phosphorus-containing finished products (for example, detergents, baking powders, matches, as far as quantitatively important).
Source: statistics of foreign trade.
Calculation: quantity of product X content.

e. Variations in stocks of phosphorus-containing raw materials and/or products in industry (as far as known only of importance in the phosphate rock-processing industry).
Source: phosphate rock-processing industry.
Calculation: quantity of raw material/product X content.

f. Supply and withdrawal of phosphorus by border-crossing rivers.
Source: water quality and water quantity managing institutions.
Calculation: water supply X content.

g. Deposits and discharges from the country under investigation into other countries or into the sea.
Source: various.
Calculation: quantity/volume/supply X content.

- *Nitrogen balance sheet*

a. Production of ammonia in the fertilizer industry -- chemical industry -- by way of air nitrogen fixation.
Source: production statistics of fertilizer industry (chemical industry).
Calculation: Production of ammonia X content (NH, contains 82 per cent N).

b. Imports and exports of animal and plant products (cattle feed and foodstuffs).
Source: statistics of foreign trade.
Calculation: quantity of product (group of products) X content.

c. Imports and exports of organic and inorganic nitrogen compounds (including fertilizers).
Source: statistics of foreign trade.
Calculation: quantity of product (group of products) X content.

d. Imports and exports of finished nitrogen-containing products (for example, nylon and other synthetic materials) as far as quantitatively important for the environment.
Source: statistics of foreign trade.
Calculation: quantity X content.

e. Variations in stocks of nitrogen-containing raw materials and/or products in industry (as far as known, only of anyimportance in the chemical and fertilizer industries).
Source: chemical and/or fertilizer industry.
Calculation: quantity of raw material/product X content.

f. Supply and withdrawal of nitrogen by border-crossing rivers.
Source: water quality and water quantity managing institutions.
Calculation: water supply X content.

g. Deposits and discharges from the country under investigation into other countries or into the sea.
Source: various.
Calculation: quantity/volume/supply X content.

h. Supply and withdrawal of nitrogen by border-crossing air streams.
Source: statistics on air quality and emissions into the air.
Calculation: on the basis of air quality and emission data with the aid of air stream models.

i. Supply by oxydation of air nitrogen as a consequence of the burning of fossil fuels.
Source: statistics on emissions into the air (especially traffic emissions.
Calculation: see Chapter I.

j. Biological nitrogen fixation by papilionaceae.
Source: agricultural statistics.
Calculation: area X N_2 fixation per ha (Dutch situation: for peas/beans: 120 kg N/ha.yr; for luceme: 350 kg N/ha.yr.)

k. Other biological nitrogen fixation.
Source: literature.
Calculation: The contribution of this source is calculated on the basis of estimated values for natural land (10 kg/ha) and for cultivated land (4 kg/ha) (Dutch situation).

With micro-organisms, a considerable part of the accumulation of nitrogen is converted into volatile nitrogen compounds, especially the harmless N_2 and in N_2O. The latter gaseous compound, however, plays a role in the decay of the ozone layer and in the increase of the greenhouse effect. The amount of denitrification in underwater soil and in soil itself is so difficult to calculate -- so complex and dependent on so many variables -- that in the scope of this manual it is impossible to pay more attention to the subject. For the Netherlands, estimates are made on the basis of model calculations which simply are not applicable to other areas.

Use and emissions

To determine the importance of the various sources contributing to the inland accumulation of phosphorus or nitrogen, it is indispensible to have knowledge of the inland use of the various products and of accompanying emissions into water, air, and soil. Primarily the emissions are of great importance. Likewise, to calculate the emissions, it can be very useful to have some idea of the use of the emission-causing products.

Use

- *Phosphorus balance sheet*

a. Phosphate fertilizers.
Source: statistics of agricultural industry and of fertilizer industry.
Calculation: application of the quantity of $P2O5$ should be known.

b. Dicalcium and monocalcium phosphate as additives in mixed feeds.
Source: agricultural statistics, mixed feeds industry.
Calculation: If no information on the contents of dical- or monocal is available, the quantity of produced mixed feeds is multiplied with an averaged P-content of mixed feeds. To calculate the amount of supplied phosphate, the calculated quantity of phosphorus in mixed feed is corrected for the natural phosphorus content of the raw materials.

c. Sodium tri-polyphosphate (SIP) in detergents and in dishwasher detergents.
Source: production statistics of the detergent industry, supplemented with data from trade organizations.
Calculation: Quantity of consumed detergent * content STP * content P in STP (25.3 per cent).

d. Other phosphorus compounds; phosphoric acid in foodstuffs, organic phosphorus compounds in pesticides, phosphoric acid salts in baking powders, and other phosphorus-containing compounds with relatively small contributions to the phosphorus burden on the environment.
Source: various.
Calculations: various.

e. Foodstuffs for human consumption.
Source: agricultural statistics, supply balance sheets of agricultural and horticultural products.
Calculation: Consumption of products * corresponding P content (see also appendix 1). For the Netherlands the consumption of macronutrients is available from statistics on the consumption of foodstuffs.

f. Fodder: consumption of roughage and mixed feeds.
Source: statistics of foreign trade; agricultural statistics; supply balance sheets of agricultural and horticultural products; statistics on fodder consumption.
Calculations: consumption of raw material * corresponding P content (pay attention to the differences in content per kg product and per kg dry matter).

- *Nitrogen balance sheet*

a. Nitrogen fertilizers.
Source: agricultural statistics, statistics of the fertilizer industry.
Calculation: application of the quantity of active matter (kg N) should be available.

b. Other nitrogen compounds; nitrogen compounds in pesticides, some basic chemicals (acrylonitrile), melamine, nylon, and other compounds (the relative contribution to the nitrogen burden on the environment may be small).
Source: various.
Calculations: various.

c. Foodstuffs for human consumption.
Source: agricultural statistics, supply balance sheets of agricultural and horticultural products.
Calculation: Consumption of products X corresponding N content (see also appendix 1). For the Netherlands, the consumption of' macronutrients is available from statistics on the consumption of foodstuffs.

d. Fodder: consumption of roughage and mixed feeds.
Source: statistics of foreign trade; agricultural statistics; supply balance sheets of agricultural and horticultural products; statistics on fodder consumption.
Calculation: Consumption of raw material X corresponding N content (pay attention to differences in content per kg product and per kg dry matter).

Emissions

- *Phosphorus balance sheet*

Air:

a. Phosphate rock processing industry.
Source: Data from industry; eventually emission factors.
Calculations: none.

Water:

b. Domestic waste water.
Source: statistics on waste water discharges and on water quality management and control (see Chapter II).
Calculation: see Chapter II.

c. Industrial waste water.
Source: statistics on waste water discharges and on water quality management and control (see Chapter II); industry information (fertilizer industry, food-processing industry); emission registration (for Dutch institutions).
Calculation: see, among others, Chapter II.

d. Runoff and leachate from arable and natural land.
Source: Various agricultural research institutions, literature, model calculations.
Calculation: Simple approach: deposition of surplus X P content of upper ground water level. Better approach: model calculations, which, however, are not performed by the CBS.

e. Wet and dry deposition.
Source: statistics of rainwater quality.
Calculation: Annually averaged P content of rainwater X quantity of deposition per ha X area, supplemented by data concerning dry deposition.

Soil:

f. Application of manure.
Source: statistics on production and application of manure.
Calculation: Emission factor of phosphorus per animal X number of animals.

g. Application of phosphate fertilizers.
Source: agricultural statistics, fertilizer statistics.
Calculation: Data must be available on quantity of nutrient applied (kg $P2O5$).

h. Application of sewage sludge.
Source: statistics on waste water discharge and on water quality management and control (see Chapter II).
Calculation: see Chapter II.

i. Dumping of waste.
Source: waste statistics; statistics on chemical waste.
Calculation: quantity of dumped phosphorus containing waste X an appropriate P content. (Domestic waste mainly consists of vegetable, fruit, and garden wastes; phosphorus-containing chemical waste -- such as phosphogypsum and slags -- usually originates from the phosphate rock-processing industry.)

j. Dumping of dredging sludge.
Source: Ministry of Public Works; harbour works; seaport authorities.
Calculation: weight of dredging sludge X content. In the Netherlands, a distinction is made between sludge originating from rivers and from the sea; dredging sludge originating from rivers appears to be especially heavily polluted and to contain large amounts of nutrients.

k. Wet and dry deposition.
Source: statistics on rainwater quality.
Calculation: Annually averaged content of **P** of rainwater X quantity of deposits per ha X area, supplemented with experimental data on dry deposition.

- *Nitrogen balance sheet*

Air:

a. NO, emissions: mainly originating from traffic, refineries and power stations.
Source: statistics on air pollution, see Chapter I.
Calculation: see Chapter I.

b. NH, emissions: mainly originating from animal husbandry and from industry.
Source: statistics on air pollution.
Calculation: to calculate the ammonia emissions from cattle, ammonia emission factors are developed. For industrial air pollution, see Chapter I.

Water:

c. Domestic waste water.
Source: statistics on waste water discharges and on water quality management and control (see Chapter II).
Calculation: see Chapter II.

d. Industrial waste water.
Source: statistics on waste water discharges and on water quality management and control (see Chapter II); industry (fertilizer industry, food-processing industry); emission registration (Dutch institution).
Calculation: see Chapter II, among other information sources.

e. Runoff and leachate from arable and natural land.
Source: Various agricultural research institutions, literature, model calculations.
Calculation: simple approach: deposit surplus X nitrogen content of ground water. Better approach: model calculations which, however, are not performed by CBS.

f. Wet and dry deposits.
Source: Statistics on rainwater quality.
Calculation: Annually averaged N content of rain water X quantity of deposition per ha X area, supplemented by data concerning dry deposits.

Soil:

g. Application of manure.
Source: statistics on production and application of manure.
Calculation: emission factor of nitrogen per animal X number of animals.

h. Application of nitrogen fertilizers.
Source: agriculture statistics, fertilizer statistics.
Calculation: information on quantity of nutrients applied (kg N) must be available.

i. Application of sewage sludge.
Source: statistics on waste water discharges and on water quality management and control (see Chapter II).
Calculation: see Chapter II.

j. Dumping of waste.
Source: waste statistics, statistics on chemical waste.
Calculation: quantity of dumped nitrogen containing waste X an appropriate N content. (Vegetable, fruit, and garden wastes are the main source of nitrogen in domestic waste.)

k. Dumping of dredging sludge.
Source: Ministry of Public Works; harbour works; seaport authorities.
Calculation: weight of dredging sludge X nitrogen content. In the Netherlands, distinction is made between sludge originating from rivers and sludge originating from the sea; dredging sludge from rivers appears to be especially heavily polluted and to contain large amounts of nutrients.

1. Wet and dry deposits.
Source: statistics on rainwater quality.

Calculation: Annually averaged content of N in rainwater X deposits per ha X area, supplemented by experimental data concerning dry deposits.

F. EXAMPLE: THE PHOSPHORUS BALANCE SHEET FOR THE NETHERLANDS

As an example of a CBS balance-sheet study, the following sections give a brief outline of the phosphorus balance sheet for the Netherlands for 1986. Phosphorus is chosen for a number of reasons. First, it is an easy material to make up a balance in that it is a conservative material -- it does not disappear from the environment by disintegration or other physical and chemical processes. Moreover, there is a lot of available data, as phosphorus is included in nearly every monitoring programme. For these and other reasons, it is possible to get a balance sheet on phosphorus to tally within limited margins of error. Finally, data on phosphorus cover a number of years, making it possible to observe trends over time.

The phosphorus balance sheet for the Netherlands for 1986

To make up the balance sheet, the supply and withdrawal of phosphorus through economic flows and environmental flows are calculated; see Table 1 for results.

The balance sheet shows a large surplus, as was the case for many years prior to 1986. This surplus is the amount that remains in the country every year. Due to the nature of the use of phosphorus-containing products (see next section), all of the surplus ends up in the environment instead of remaining in durable products, as with some other materials. In 1986, the surplus amounted to approximately 159 million kg of phosphorus.

The pattern of the surplus hardly varies through the years. However, it is noteworthy that the inflow from border-crossing rivers has shown a decline for some time. It has gone from around 60 million kg of P per year in the Seventies to 46 million kg in 1986. It is also notable that net imports from animal and vegetable products (especially cattle feed) are still rising, from 34 million kg of P in 1970 to 57 million kg in 1986.

Table 1. Phosphorus balance sheet for the Netherlands, 1986

Supply	Million kg P	Withdrawal	Million kg P
Imports of animal and vegetable products	89.0	Exports of animal and vegetable products	32.0
Imports of inorganic phosphates	402.0	Exports of inorganic phosphates	308.0
among which -- phosphate rock	289.0	among which -- fertilizer	163.0
Industrial stockpiles	6.5		
Border-crossing rivers	47.0	Discharge of river water into sea	42.0
		Other discharges into sea	3.5
Total supply	544.5	Total withdrawal	385.5
		Accumulation	159.0

Application and use of phosphorus in the Netherlands

Use of raw materials in the phosphate-rock processing industry

There is an extensive phosphate-rock processing industry in the Netherlands. As phosphate rock does not occur as a mineral in the Netherlands, the industry depends completely on imports. The countries from which most of the phosphate rock is imported are the United States, Morocco, and Israel. In addition to phosphate rock, imported phosphoric acid is also an important raw material in this industry. In 1986,346 million kg of P were processed; that was about the same amount as in 1980 and 1983, but considerably more than in 1970. (See Table 2.)

The most important products in the phosphate-rock processing industry are artificial fertilizers (triple superphosphate and mixed fertilizers), dicalcium phosphate (added to cattle feed to increase the phosphorus content), sodium tripolyphosphate (in detergents), phosphoric acid, and phosphorus. Over 85 per cent of the production is exported. Processing of phosphate rock involves considerable emissions of phosphorus (among other things, phosphogypsum) into water.

Use of products containing phosphorus

Table 2 also shows the use of products containing phosphorus over a number of years. The table distinguishes between the use of inorganic phosphates produced by industry and the use of foodstuffs such as agricultural and horticultural products. The use of inorganic phosphates dropped by nearly a quarter between 1970 and 1986. This decrease was partly due to the lowering of the phosphorus content of soap powders and cattle feed (less sodium tripolyphosphate and dicalcium phosphate, respectively) and partly by the replacement of one source of phosphorus (artificial fertilizers) with another (animal manure). However, the total use of phosphorus in the Netherlands rose considerably during the period under review (22 per cent), largely because of increased imports of cattle feed. Whereas, in 1970, inorganic phosphates were still the most significant use of phosphates in the Netherlands (62 per cent), in 1986, phosphates in human and animal foodstuffs had taken their place.

Emissions of phosphorus into the environment

The use of products containing phosphorus in industry, households, and agriculture results in emissions of phosphorus into the environment, most importantly into the water and soil. Table 3 gives an overview of the sources of the emissions in 1986.

Emissions into water

Emissions into water involved over 30 million kg of P in 1986. Of this amount, 13 million kg came from the phosphate-rock processing industry and 12 million kg from households. About 2 million kg ended up in water as a consequence of agricultural activities. With the aid of data for 1983, it has been calculated [3] that of the inland sources of phosphorus, domestic waste water plays the most important part (32 per cent) in the eutrofication of Dutch surface water, followed by runoff and leaching from soil (14 per cent) and industrial waste water (10 per cent). The part played by border-crossing rivers was estimated at about 40 per cent.

Table 2. Phosphorus in the Netherlands: consumption

	1970	1980	1983	1986
	Unit: million kg P			
Raw materials in the phosphate-rock processing industry				
Phosphate rock	217.0	327.0	303.0	289.0
Phosphoric acid	8.0	33.0	48.0	57.0
Total raw materials	225.0	360.0	351.0	346.0
Phosphorus-containing products				
Fertilizer	48.0	36.0	36.0	36.0
Dicalcium phosphate	21.0	20.0	20.0	15.0
Sodium tripolyphosphate	11.0	12.0	9.5	10.0
Other inorganic phosphates	4.0	4.0	4.0	4.0
Subtotal	84.0	72.0	69.5	65.0
Food for human consumption	8.0	10.0	10.0	11.0
Cattle fodder	43.0	69.0	74.0	89.0
Subtotal	51.0	79.0	84.0	100.0
Total products	135.0	151.0	153.5	165.0

Table 3. Phosphorus in the Netherlands, 1986

	Kg P * million
Ambient air	0,4-0,6
among which	
phosphate-rock processing industry	0,4-0,6
Water	30,8-33,8
among which	
domestic waste water	12,0
industrial waste water	16,1
surface run-off and soil leaching	2-5
others	0,7
among which	
into the sea	2,8
soil	165,4-166,5
among which	
animal manure	107
fertilizer	36
sewage sludge	8,8
dredging spoil	5,7
others	7,9-9,0

Table 4. Accumulation of phosphorus in the Netherlands

	1970	1980	1983	1986
	kg P * million			
The Netherlands	151	135	150	159
among which				
fresh surface water	18	17-20	24-27	26-29
agricultural areas	87	85-88	88-91	94-97

Emissions into the soil

In 1986, the application of animal manure on agricultural land (107 million kg of P) was the most important source of the phosphorus burden on soil.

Animal manure, artificial fertilizers, and sewage sludge applied to agricultural land contain so much phosphorus (145 million kg in 1986) that the amount the crops withdraw is exceeded by about 60 million kg. As long as the soil is not saturated, this surplus remains fixed to soil particles. Once the soil is saturated, however, there is unlimited leaching of phosphorus into ground water.

Conclusions

As stated above, a balance sheet gives information about the various sources of a polluting substance. It provides information needed to implement efficient measures for reducing the related pollution. In the publication of the first phosphorus balance sheet for the Netherlands, for 1970 [4], an inventory of the most important sources served as the basis for a number of proposals to decrease the phosphorus burden on surface waters throughout the country. These proposals included:

- large-scale phosphate removal from urban waste water;
- replacement of phosphates in detergents;
- restrictions on the addition of phosphates to cattle feed and restrictions on the use of artificial fertilizers in certain problem areas;
- international negotiations to persuade upstream countries on the rivers Rhine and Meuse to take corresponding measures.

Comparison of the first balance for 1970 with the most recent data for 1986 (see tables 2 and 4) shows that there has been little progress in limiting phosphorus emissions. The measures proposed in the past have barely been implemented, if at all:

- In 1985, only 4 per cent of Dutch sewage-treatment plants had the means to remove phosphate, and even those with the means did not always use it.

- In spite of a reduction in the phosphorus content of soap powders, the intended decrease in the amount of phosphate from this source was overridden by an increase in the use of soap powders. (Note: After 1990 in the Netherlands, STP was no longer allowed in soap powders).

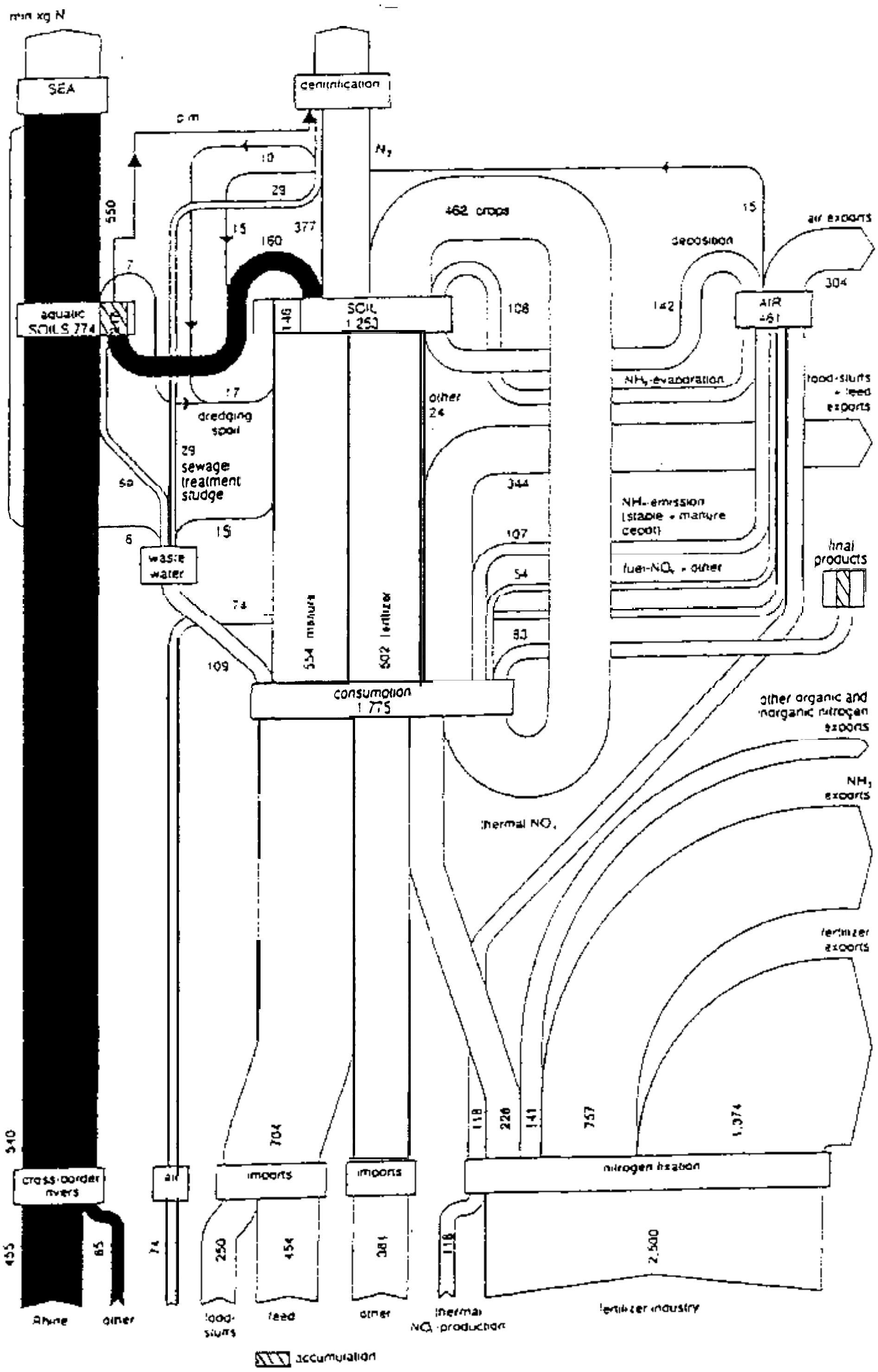
- The content of phosphorus in cattle feed also has decreased over time, but phosphate emissions from this source are still rising and the consumption of artificial fertilizers has decreased little since 1975.

- Only the inflow of phosphorus from border-crossing rivers seems to have shown a more or less structural decrease since the early Eighties, probably mainly due to a reduced phosphorus load in soap powders from Germany. (The phosphorus content of Gem-ran soap powders has decreased by about 70 per cent since 1975).

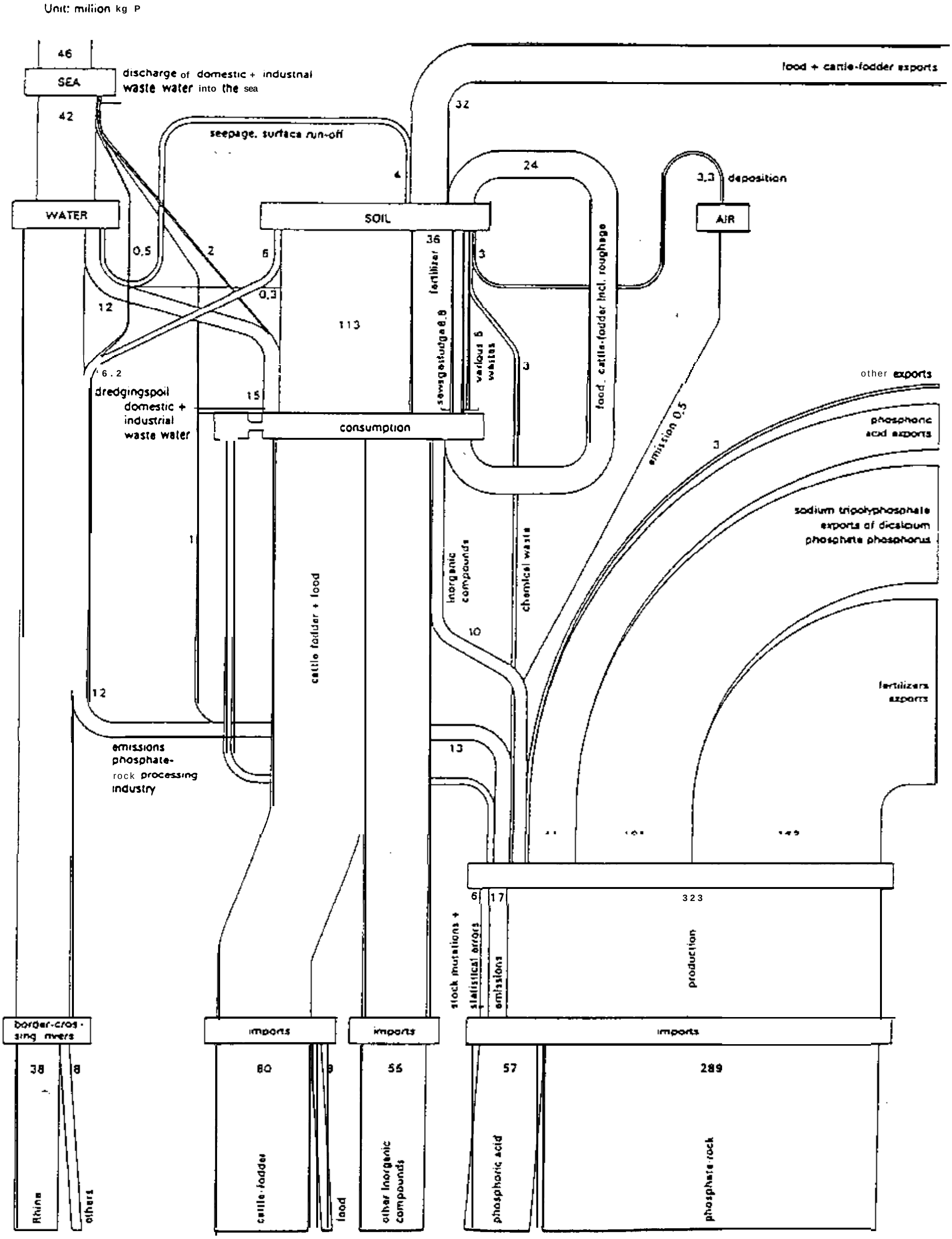
Note:

1) In the Appendix, the phosphorus and nitrogen contents of most common groups of animal and vegetable products are given. The classification and nomenclature correspond largely with that of the nation's foreign-trade statistics.

Flow diagram of nitrogen, 1986



Flow diagram of phosphorus in the Netherlands, 1986



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[4] Phosphates in Dutch fresh surface water; report of the ‘Stuurgroep Fosfaten’ of the Royal Dutch Chemical Society, Golterman, H.L. ed., Sigma Chemie (1976). (Text in Dutch.)

PUBLICATIONS ON SUBSTANCE BALANCE SHEETS BY THE NETHERLANDS CENTRAL BUREAU OF STATISTICS

Publications:

[In each publication, title, table of contents, summary, and explanation of the symbols used are given in English. The frequency of appearance and the availability of the publications are indicated by the following code: n=non recurrent s=sold out.]

PCB's in the Netherlands [n,s,]
Mercury in the Netherlands 1980 [n]
Copper in the Netherlands 1985 [n]
Phosphorus in the Netherlands 1970-1983 [n,s]
Copper in agriculture 1981-1985 [n]
(Statistical reports nr. 7)
Organotin compounds in the Netherlands 1985 [n]
Selenium in the Netherlands 1985 [n]

Articles:

[In Environmental Quarterly. Only abstracts in English.]

Phosphorus in mixed feeds [86/1]
Regional nutrient balances, 1982 [86/3]
The use of organotin compounds as stabilizers in PVC [87/2]
Organotin compounds in antifouling paints [87/3]
Copper in minerals [88/2]
Phosphorus balance sheet of the Netherlands, 1986 [88/4]
A nitrogen balance sheet for agricultural land in the Netherlands, 1984 [89/1]
Nitrogen balance sheet of the Netherlands, 1986 [89/4]
Emissions of arsenic [89/4]
Arsenic balance sheet of the Netherlands, 1987 [90/3]
Zinc in agriculture, 1988 [91/2]
Sulphur in fossil fuels [91/3]

APPENDIX. Phosphorus and nitrogen contents of common animal and vegetable products

Product	PHOSPHORUS Content	NITROGEN Content	Product	PHOSPHORUS Content	NITROGEN Content
	gP/kg	gN/kg		gP/kg	gN/kg
pulses	4.0	32.8	hatching eggs	2.0	19.2
seed potatoes	0.6	3.3	other eggs	2.0	19.2
other potatoes	0.6	3.3	peltries	0.0	0.0
seed-corn	3.3	17.1			
wheat	3.3	17.7	flower bulbs	0.6	3.0
other grains	3.5	17.7	trees, shrubs	0.6	2.0
			fresh cut flowers	0.6	2.0
copra	1.5	6.4	other ornamental plant products	0.6	2.0
palmnuts / palm kernels	2.7	14.2			
castor beans	5.9	25.0	cabbage lettuce	0.4	3.2
oil flax	8.6	34.4	onions	0.4	1.6
turnip rapeseed / rapeseed	7.4	32.0	tomatoes	0.2	1.6
mustardseed	5.9	25.0	cucumbers	0.3	0.8
POPPY seed	7.9	32.8	other fresh vegetables	0.4	1.6
hempseed	8.1	31.2			
sun-flower seeds	4.5	23.8	apples	0.1	0.0
sesame-seed	5.6	33.4	pears	0.3	0.8
cottonseed	7.1	48.0	other fresh fruits	0.2	1.2
safflowerseed	6.0	33.0	horticultural seeds	0.2	10.0
other oil seeds	5.9	32.0			
			fresh-water fish	2.0	27.0
			fresh salt-water fish (frozen, filleted)	2.0	27.0
agricultural seeds	6.0	43.0	molluscs and crustaceans	2.0	20.0
flax	2.7				
			subtropical fruits	0.4	1.5
horses	7.2	30.0	nuts	4.0	29.0
breeding cattle	7.2	25.5	citrus fruits	0.2	0.8

APPENDIX. Phosphorus and nitrogen contents of common animal and vegetable products (Continued)

Product	PHOSPHORUS Content gP/kg	NITROGEN Content gN/kg	Product	PHOSPHORUS Content gP/kg	NITROGEN Content gN/kg
calfs	7.0	29.9	coffee	1.9	0.0
other cattle	7.2	26.0	tea	3.1	0.0
pigs	5.0	24.0			
day-old chickens	5.5	30.4	spices	2.0	0.0
other living poultry	6.0	30.4	maize	2.5	14.2
sheep and goats	7.0	28.0	rice	2.0	12.0
pigeons, rabbits	7.0	28.0	groundnuts	3.5	43.2
other animals	7.0	28.0	soya beans	4.9	56.1
cocoa beans	5.0	20.0	provisionally preserved fruits	1.0	2.0
crude tobacco	3.0	0.0	vegetable preparations	0.5	4.0
natural rubber	0.0	0.0	fruit preparations	0.5	1.0
cotton	0.0	0.0	fruit-juices	0.1	1.0
other vegetable fibres	0.0	0.0			
			fresh-water fish products	2.0	25.0
horse meat	2.0	32.0	salt-water fish products	2.0	27.0
veal	2.3	32.0	fish oils	0.0	0.0
beef	2.0	32.0	fish preparations	2.0	25.0
whole and half pigs	5.0	24.0			
fat bacon	0.4	14.4	wheat-meal	3.5	16.0
			meal from other grains	3.3	17.0
hams	7.0	24.0	rice products	1.5	12.3
other pork	5.0	25.6	other products from grains	3.0	17.0
meat of sheep and goats	2.0	30.4	starch from grains	1.0	1.0
cattle slaughter	7.0	32.0			
pigs slaughter	4.0	25.0	animal proteins	28.0	90.0
			soya cakes	7.4	73.7

APPENDIX. Phosphorus and nitrogen contents of common animal and vegetable products (Continued)

Product	PHOSPHORUS Content gP/kg	NITROGEN Content gN/kg
broilers	5.5	30.4
other poultry meat	2.0	32.0
poultry slaughter	2.0	32.0
meat of other animals	4.0	30.0
poultry meat preparations	2.0	32.0
other meat preparations	4.0	27.0
guts and bladders	2.0	0.0
animal oils and fats	0.0	0.0
skins	0.0	0.0
liquid milk and milk products	1.0	5.3
whey and whey products	6.5	21.4
skimmed milk powder	10.0	56.0
other milk powder	10.0	41.6
condensed milk	2.3	12.5
butter	0.2	0.8
cheese	4.5	35.6
homogenised preparations	1.0	5.6
casein	6.6	126.6
frozen vegetables	0.4	4.0
provisionally preserved vegetables	0.5	4.0
dehydrated vegetables	5.0	25.0
dehydrated fruits	1.0	4.0
frozen fruits	0.2	1.0

Product	PHOSPHORUS Content gP/kg	NITROGEN Content gN/kg
oil cakes and other wastes from		
olives	7.2	30.0
maize germs	4.1	28.2
ground nuts	6.2	65.6
oil flax	8.5	51.8
copra and coconuts	5.3	33.9
palmnuts and palm kernels	6.0	27.7
cottonseeds	7.2	55.2
rape- and turnip rapeseeds	10.0	56.3
sunflower-seeds	6.0	50.7
sesame-seeds	7.2	71.0
other oil seeds	7.2	46.6
mixed feeds	5.5	27.0
hay, clover and other fodder crops	2.4	19.5
fodderbeets, tubers and carrots	0.4	2.8
straw and chaff from grains	0.7	3.5
molasses of cane sugar	0.7	5.6
other molasses	0.3	17.1
slops and wastes from distilleries	1.1	11.7
squeezed cane sugar and other sugar	1.2	37.9
beetpulp; dry matter > 87%	0.9	15.8
beetpulp; d.m. between 18% and 87	0.4	8.0
beetpulp; d.m. < 87%	0.1	2.0
bran from other grains	10.2	26.2

APPENDIX. Phosphorus and nitrogen contents of common animal and vegetable products (Continued)

Product	PHOSPHORUS Content	NITROGEN Content	Product	PHOSPHORUS Content	NITROGEN Content
	gP/kg	gN/kg		gP/kg	gN/kg
other bran from wheat	10.2	26.2	potato starch	1.0	0.0
bran from wheat (starch < 28%)	10.2	26.2	preparations of potato flour	1.0	3.2
other bran from other grains	10.2	26.2	dextrin	0.0	0.0
wastes from other starch industries	10.2	26.2	soya-oil	0.0	0.0
maize cakes (protein < 40%)	8.5	31.0	other vegetable oils and fats	0.0	0.0
maize cakes (protein > 40%)	8.5	101.9	processed vegetable oils and fats	0.0	0.0
bran from pulses	10.2	26.2	margarin and edible fats	0.2	1.0
bran/grindings from maize (starch <	10.2	26.2			
bran/grindings from rice (starch > 3	10.2	26.2	other edible vegetable products	1.0	2.5
bran/grindings from maize (starch >	10.2	26.2	various products for human consump	1.0	2.0
fodder from other vegetable wastes	3.0	5.0	egg products	2.0	19.2
draff from fruits/citrus fruit pulp	1.2	9.6			
draff/dregs	1.0	0.0	confectionery	0.0	0.0
wine lees	0.0	0.0	cocoa butter	2.0	0.0
draff from grapes	1.0	5.0	other cocoa products	2.0	10.8
acorns/wild chestnuts	1.0	5.0			
crude tartar	0.0	0.0	beer	0.3	0.0
			wine	0.1	0.0
manioc	1.0	4.2	spirits	0.0	0.0
sweet potatoes	1.2	4.5	other drinks	0.2	0.0
arrowroot	0.6	4.5	non-edible animal products (incl. oss	25.0	15.0
Jerusalem artichokes	0.6	4.5	other vegetable, non-edible products	3.0	4.0
lucerne meal	2.4	27.8			
			tobacco merchandise	2.0	0.0
sugar	0.0	0.0	albumin	13.0	80.0
			wool and hair	0.0	0.0
			not further specified products	2.0	1.0

PART SIX:
BILIOGRAPHY OF METHODOLOGICAL PAPERS
(Rev. 5 as of 3 November 1992)

BIBLIOGRAPHY OF METHODOLOGICAL PAPERS ON STATISTICS SUBMITTED TO MEETINGS CONVENED BY THE CONFERENCE OF EUROPEAN STATISTICIANS

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Note: The papers are allocated to the sub-areas of methodological concern as shown in Annex III to document CESf752. The submitting country, the reference symbol if any, and the meeting to which the paper was transmitted are shown in brackets behind each title. If the paper was submitted to one of the 'Work Sessions on Specific Methodological Issues in Environment Statistics', the meeting is identified by its venue and the year in which it was held. Subject to their availability, copies of the papers listed below can be obtained from the Statistical Division of ECE, Palais des Nations, CH- 1211 Geneva 10. Papers carrying a reference symbol are mostly available in English, French and Russian. Papers without such a symbol are available in English, except where another language is stated. Each paper is only listed once; alternative allocations of papers to sub-areas of environment statistics are possible.

A. METHODOLOGICAL PROBLEMS IN THE DESIGN, MEASUREMENT, PRODUCTION, PRESENTATION AND DISSEMINATION OF ENVIRONMENT STATISTICS

Approaches towards the identification and definition of environmental parameters

Requirements for the practical application of procedures and techniques ensuring the availability of statistical information on the natural environment in Poland (by Poland; CES/SEM. 12/R.5; Warsaw Seminar 1980)

- Techniques of data collection in the context of identification and control of environmental impact (by Poland; CES/SEM.12/R.6; Warsaw Seminar 1980)
- System of indicators and collection from enterprises and institutions of data on the protection of human environment in the USSR (by the USSR; CES/SEM.12/R.7; Warsaw Seminar 1980)
- Implementation of classifications and nomenclatures for environmental statistics (by Romania; CES/SEM. 12/R. 11; Warsaw Seminar 1980)
- Methodology for identifying environmental indicators for the state of environment report for Canada (by Canada; Helsinki 1983)
- Methodological basis for the development of ecological parameters used in environmental statistics (by Bulgaria; CES/SEM.22/R. 1; Rome Seminar 1988)
- Characteristics and parameters for the statistical description of ecosystems (by Bulgaria in the Russian language; CES/SEM.22/R.2; Rome Seminar 1988)
- Objectives, subject-matter and framework for environmental statistics in the USSR (by the USSR; CES/SEM.22/R.19; Rome Seminar 1988)
- Territorial delimitation of ecological disturbances and hazards in environment statistics (by Poland; Ottawa 1991)
- The experience of the CSO of Bulgaria in the collection, processing and presentation of statistical data on the environment. Some results from and perspectives for the integration of socio-demographic and economic statistics in the study of the environment (by Bulgaria; Ottawa 1991)

Collection of environmental data through sampling

Point sampling in Norwegian land use and environmental statistics (by Norway; CES/SEM. 12/R.4; Warsaw Seminar 1980)

Relationship between monitoring and survey data (by the Federal Republic of Germany; CES/SEM. 12/R.9; Warsaw Seminar 1980)

The use of environmental data in the economic decision-making process (by The Netherlands; CES/SEM. 12/R. 14; Warsaw Seminar 1980)

Sampling methods in compiling statistics on the quality of environment: Water quality statistics (by Finland; Helsinki 1983)

Problems and some approaches to statistical analysis of pollutant measurements in environment samples (by the USA; Helsinki 1983)

On applications of random techniques in environmental statistics (by Sweden; Helsinki 1983)

Estimating distribution of water quality parameters from two different concepts of populations of water masses in a river structure (by Norway; Wiesbaden 1985)

Vegetation and air pollution - spatial and temporal aspects of sampling in environmental monitoring (by Sweden; CES/SEM.22/R.8; Rome Seminar 1988)

Canadian experience in the development of environmental surveys (by Canada; Ottawa 1991)

Surveys of environmental investments and costs in Swedish industry (by Sweden; Ottawa 1991)

Sampling for environmental resources (by Portugal; Lisbon 1992)

Building-up of a sampling plan suitable for an enquiry into the generation of industrial wastes (by Portugal; Lisbon 1992)

Collection of environmental data through monitoring networks

Monitoring networks for the collection of water quality data of Finnish inland waters (by Finland; Helsinki 1983)

Incorporation of statistical aspects into the organization of systems of regular surveillance of the environment (by France; Helsinki 1983)

Experience with ecological statistics in the national environmental monitoring system (by Bulgaria; CES/SEM.22/R. 14; Rome Seminar 1988)

Collection of environmental data through other procedures

Data collection techniques on the living environment in Czechoslovakia (by Czechoslovakia; CES/SEM. 12/R.2; Warsaw Seminar 1980)

Data collection techniques (by Hungary; CES/SEM.12/R.3; Warsaw Seminar 1980)

Questions of co-ordination between national bodies involved in the collection and compilation of environmental statistics (by Finland; CES/SEM.12/R. 15; Warsaw Seminar 1980)

Issues and experiences in the development and co-ordination of environmental statistics in Norway (by Norway; CES/SEM. 12/R. 16; Warsaw Seminar 1980)

The use of industrial statistics to estimate the generation of recycled and waste residuals (by Finland; Paris 1984)

L'utilisation des statistiques économiques dans l'estimation de la production de déchets (by the Federal Republic of Germany in the French language; Paris 1984)

A case study on public opinion and local environmental policy (by Hungary; Wiesbaden 1985)

Methodological problems in collecting environmental data from governmental records and through socio-economic surveys (by the Federal Republic of Germany; Wiesbaden 1985)

Questions related to the environment in a household survey: Results from Swiss experience (by Switzerland; Wiesbaden 1985)

Surveys of the Austrian micro-census relating to environmental problems (by Austria; Wiesbaden 1985)

The Portuguese National Statistical Institute's contribution to environmental statistics (by Portugal; Lisbon 1992)

Méthodologie pour la collecte d'information sur la consommation des substances chimiques utilisées dans l'agriculture (by Portugal in the French language; Lisbon 1992)

Recent developments of information on the environment in Italy (by Italy; Lisbon 1992)

Collection, processing and evaluation of geographical information

The application of geographic information systems in Canadian environment statistics (by Canada; Voorburg 1988)

Geographical information systems and remote sensing as methodological elements of environmental economic comprehensive accounting (by Germany; Lisbon 1992)

Compilation of generalized environment statistics

Experience gained in the Netherlands with the transformation of cartographical into numerical land use information (by The Netherlands; CES/AC.52/7; meeting on land use statistics 1980)

Ditto, updated (by The Netherlands; Wiesbaden 1985)

Quality control and quality assessment of environment statistics

Economic analysis and ensuring the reliability of reported data for environmental records in the Byelorussian SSR (by the Byelorussian SSR; CES/SEM. 12/R. 1; Warsaw Seminar 1980)

Quality presentation in environment statistics - some Swedish examples (by Sweden; Budapest 1989)

Assessment and control of the quality of environment statistics (by the USSR in the Russian language; Budapest 1989)

Presentation, dissemination and storage of environment statistics

The presentation of environment statistics (by France; Wiesbaden 1985)

Ditto, updated (by France; CES/AC.40/27; meeting on frameworks for environment statistics 1985)

- Presentation of environment statistics: Environmental data maps (by Norway; CES/AC.40/29; meeting on frameworks for environment statistics 1985)

- The atlas and environmental statistics (by Portugal; Oslo 1986)

- Graphical presentation and statistical parameters of territorial data series (by Italy; Oslo 1986)
- Problems in the use of graphical methods for the presentation of statistical data (by Italy; Warsaw 1987)

- The computerized information system on the environment in Italy: Problems and perspectives (by Italy in the French language; CES/SEM.22/R.17; Rome Seminar 1988)

- Dissemination of environmental statistical data by the CBS of The Netherlands (by The Netherlands; Voorburg 1988)

- Presentation, diffusion et gestion des statistiques de l'environnement dans un cadre territorial: Une application. La maquette de l'atlas informatique permanent de l'Oservatoire de la Loire (by France in the French language; Ottawa 1991)

- Information management for environmental forecasting in statu nascendi (by The Netherlands; Ottawa 1991)

- Selection and presentation of a national set of preliminary environmental indicators: Canada's experience (by Canada; Ottawa 1991)

- Presentation, diffusion et stockage des statistiques de l'environnement en Bulgarie (by Bulgaria in the French language; Lisbon 1992)

Analysis of environmental parameters displaying variation over time and/or space

Analysing environmental time series: A brief review with two Finnish case studies (by Finland; Wiesbaden 1985)

Some methodological problems in environmental statistics concerning time series for long periods and large numbers of time series (by Sweden; Wiesbaden 1985)

B. LINKAGE PROBLEMS ASSOCIATED WITH THE INTEGRATION OF ENVIRONMENT STATISTICS, INCLUDING THEIR RELATIONSHIPS WITH OTHER STATISTICAL SYSTEMS

General methods of integration and harmonization of environment statistics

No submission under this heading.

Linkage to economic statistics

- Economic aspects of environmental activities, especially in the industrial sector (by the Federal Republic of Germany; CES/SEM. 12/R. 12; Warsaw Seminar 1980)
- Le compte satellite de l'environnement (by France in the French language; Paris 1984)
- L'articulation des comptes du patrimoine naturel et de la comptabilité économique nationale: l'exemple du compte des "Eaux continentales" (by France in the French language; Paris 1984)
- Elaboration de statistiques intégrées concernant les coûts et le financement de la gestion de l'environnement (by The Netherlands in the French language; Paris 1984)
- A design of integrated statistics on the cost and financing of environmental control (by The Netherlands; Paris 1984)
- Linking economic and environment statistics with particular reference to aspects of water economy (by the Federal Republic of Germany; Warsaw 1987)
- Regional nutrient balances in the Netherlands (by The Netherlands; Warsaw 1987)
- Aspects of the interrelationship between environment and other statistics (by the USSR in the Russian language; Warsaw 1987)
- An environmental module and the complete system of national accounts (by The Netherlands; Ottawa 1991)
- Plans for a system of environmental accounting in Sweden (by Sweden; Ottawa 1991)
- Integrated environmental-economic accounting (by the UN Statistical Office; Ottawa 1991)
- European system for the collection of economic information on the environment (SERIEE) (by Eurostat; Ottawa 1991)
- Use of macroeconomic models in analysis of environmental problems in Norway. Consequences for environmental statistics (by Norway; Ottawa 1991)
- Approaches to environmental accounting (by the ECE secretariat; Ottawa 1991)
- Excretion factors of animal manure calculation on the basis of statistics (by the Netherlands; Lisbon 1992)

Linkage to social and demographic statistics

Social concerns and the system of environmental statistics (by Hungary; CES/SEM. 12/R.13; Warsaw Seminar 1980)

Social aspects of environment statistics in the Austrian Central Statistical Office (by Austria; Budapest 1989)

Linkage through materials/energy balances and natural resource accounts

Substance balance sheets (by The Netherlands; Voorburg 1988)

Linkage through land information

The provision for linkages to various data systems in the development of land use statistics in Norway (by Norway; CES/AC.52/5; meeting on land use statistics 1980)

Linkage of land use data and other types of data in the USSR (by the USSR; CES/AC.52/6; meeting on land use statistics 1980)

Towards a spatial base for a national system of environmental statistics based upon aggregations of local government areas - recent Australian experience (by Australia; CES/SEM. 12/R.8; Warsaw Seminar 1980)

The place of the inventory of mapped ecozones in the system of ecological statistics (by France in the French language; CES/SEM.22/R.3; Rome Seminar 1988)

L'expérience française d'inventaire de l'occupation du territoire par télédétection dans le cadre du programme Européen "CORINE land cover" (by France in the French language; Budapest 1989)

Land use and environmental information in the Netherlands: a start with a GIS approach (by the Netherlands; Budapest 1989)
Sustainable agriculture. Assessment of agricultural pollution by combining land information and production statistics. The SIMJAR model (by Norway; Budapest 1989)

C. METHODOLOGICAL PROBLEMS IN THE DEVELOPMENT OF ENVIRONMENTAL INDICATORS AND INDICES

Indicators of the quality of environmental media

Experience gained with a river quality classification in England and Wales (by the United Kingdom; CES/AC.58/5; meeting on environmental indicators 1984)

From water quality to the ecosystem concept: Experience gained from a case study of the Stress-Response Environmental Statistical System as applied to the Laurentian Lower Great Lakes (by Canada; CES/AC.56/4; meeting on statistics of water use and quality 1982)

Indicators of water quality from an ecosystem perspective (by Canada; Helsinki 1983)

A new land evaluation in Hungary based on ecological potential (by Hungary; CES/SEM.22/R. 16; Rome Seminar 1988)

An examination of alternative air quality indicators to better understand global pollution (by the United States; Ottawa 1991)

Canadian database of air quality indicators (by Canada; Ottawa 1991)

Indicators of the quality of the biotic environment

Statistical indicators of the quality of foodstuffs: their use in the identification of impacts on trophical chains (by Portugal in the French language; CES/SEM.22/R.4; Rome Seminar 1988)

Soil characteristics for assessment of the quality of land (by Bulgaria; CES/SEM.22/R.5; Rome Seminar 1988)

Trends in bird populations as environmental indicators (by Finland; CES/SEM.22/R.6; Rome Seminar 1988)

Monitoring wildlife habitat: A critique of approaches (by the USA; CES/SEM.22/R.13; Rome Seminar 1988)

Ecological monitoring as part of the Finnish national forest inventory (by Finland; CES/SEM.22/R. 15; Rome Seminar 1988)

Indicators of pressures on the environment

Measures of ecosystem distress (by Canada; CES/AC.58/4; meeting on environmental indicators 1984)

Classification des activités industrielles selon leur pression sur l'environnement (by Sweden in the French language; Paris 1984)

Game statistics as indicators of population size and composition (by Norway; CES/SEM.22/R.7; Rome Seminar 1988)

Indicators of the environment in human settlements

No submission under this heading.

Indicators of the quality of life

Statistics on environmental aspects of the quality of life (by Hungary; Budapest 1989)

Indicators of economic aspects of environmental protection

No submission under this heading.

Development of comprehensive sets of environmental indicators

Environmental indicators (by Norway; Lisbon 1992)

D. METHODOLOGICAL PROBLEMS RELATED TO THE DEVELOPMENT OF ENVIRONMENT STATISTICS IN PARTICULAR AREAS

Interdependencies between classifications and collection methods

No submission under this heading.

Land use and related statistics

Recent developments in France concerning the use of Landsat earth resources satellite imagery for the collection of land use data (by France; CES/AC.52/3; meeting on land use statistics 1980)

Swedish experience in the use of particular data collection techniques for the compilation of land use statistics (by Sweden; CES/AC.52/4; meeting on land use statistics 1980)

"Ecological mapping" of the European Community (by the Environment Service of the European Economic Community; CES/AC.52/9; meeting on land use statistics 1980)

Statistics of soil quality

No submission under this heading.

Water use and quality and related statistics

Collection of water use statistics from users in the economic sector (by Bulgaria; CES/AC.56/3; meeting on statistics of water use and quality 1982)

Problems of co-ordination and harmonization of the statistics of water use and quality of water required by different organs in Czechoslovakia (by Czechoslovakia; CES/AC.56/5; meeting on statistics of water use and quality 1982)

Approaches followed in compiling aggregated water quality information, with particular reference to the design of sampling and laboratory systems (by Finland; CES/AC.56/6; meeting on statistics of water use and quality 1982)

Inventory of the degrees of pollution of surface waters in France (by France; CES/AC.56/7; meeting on statistics of water use and quality 1982)

Links between water quality standards and collection of water quality statistics - the Hungarian experience (by Hungary; CES/AC.56/8; meeting on statistics of water use and quality 1982)

Co-ordinating and harmonizing national data and statistics on water use and water quality (by the USA; CES/AC.56/9; meeting on statistics of water use and quality 1982)

Approaches for collecting information on water quality (by the USA; CES/AC.56/10; meeting on statistics of water use and quality 1982)

- Approaches followed in compiling aggregated water quality information, with particular reference to the design of sampling and laboratory systems (by Finland; CES/AC.56/24; meeting on statistics of water use and quality 1985)
- Aspects of the quality classification of flowing waters and stagnant inland waters in the German Democratic Republic (by the German Democratic Republic; CES/AC.56/25; meeting on statistics of water use and quality 1985)
- A suggestion on population and sampling approaches to the synoptic monitoring of water quality and water resources (by Norway; CES/AC.56/27; meeting on statistics of water use and quality 1985)
- Collection and dissemination of statistical data on water use and quality in Poland (by Poland; CES/AC.56/28; meeting on statistics of water use and quality 1985)
- Problems of water quality synthesis (by Finland; Warsaw 1987)
- Some methods in generalization and presentation of water quality statistics (by Hungary; Warsaw 1987)
- Work in progress on surface water quality classification using a water quality index (by Poland in both English and Russian; Warsaw 1987)
- On water quality classification (by Sweden; Warsaw 1987)
- Use of biocoenosis data in water quality monitoring (by Finland; CES/SEM.22/R.9; Rome Seminar 1988)
- An information system for water quality management (by Italy; CES/SEM.22/R.11; Rome Seminar 1988)
- Nitrate in groundwater - some findings from Swedish monitoring data (by Sweden; Stockholm 1990)
- A quality index for drinking water (by the Federal Republic of Germany; Stockholm 1990)

Statistics on the marine environment

Nitrogen loadings to the Baltic by source. A test for the drainage area of river Lagan (by Sweden; Stockholm 1990)

Statistical presentation of the state of the marine environment (by Finland; Stockholm 1990)

Chesapeake Bay - an overview (by the U.S.A.; Stockholm 1990)

Environmental monitoring of the Gulf of Finland: An approach based on remote sensing data (by the USSR; Stockholm 1990)

Air quality and related statistics

On the density and placement of the Hungarian precipitation chemistry network (by Hungary; Oslo 1986)

Future emissions to air in Norway: Forecasts based on the macro-economic model MSG-4E (by Norway; Oslo 1986)

Double-mass analysis of air quality data (by Finland; Oslo 1986)

Aims and tools for the management of statistical information regarding the atmospheric environment in Italy (by Italy; CES/SEM.22/R.12; Rome Seminar 1988)

Recent innovations in the development of Canadian emission inventories (by Canada; Ottawa 1991)

Fauna and flora and related statistics

Avifauna statistics in the Netherlands (by The Netherlands; CES/AC.40/28; meeting on frameworks for environment statistics 1985)

A monitoring system for natural flora, fauna and their habitat (by Hungary; CES/SEM.22/R. 10; Rome Seminar 1988)

From flora statistics to an ecotope classification (by The Netherlands; Stockholm 1990)

On the organization and methodology of fauna and flora statistics in the USSR (by the USSR; Stockholm 1990)

Waste and related statistics

Organization and problems of statistics of wastes in Bulgaria (by Bulgaria; Voorburg 1988)

Some conceptual, practical and theoretical problems in compiling Finnish waste statistics (by Finland; Voorburg 1988)

Statistics on household and similar wastes (by Hungary; Voorburg 1988)

Statistics on chemicals from an environmental point of view

Statistics on chemicals in Sweden (by Sweden; Lisbon 1992)

Development and presentation of noise statistics

Neighbour noise annoyance and psychiatric problems/diseases (by Norway; Voorburg 1988)

Estimation of noise pollution based on the measured physical parameters of noise (by Poland; Voorburg 1988)

Development and presentation of radiation statistics

No submission under this heading.

Economic aspects of environmental protection

Conceptual problems in statistics on investments for the protection of the environment (by the ECE secretariat; CES/AC.40/13; meeting on frameworks for environment statistics 1978)

Méthodes d'enquêtes utilisées en Autriche pour determiner les depenses dans le secteur de la protection de l'environnement (investissements et depenses courantes) (by Austria in the French language; Paris 1984)

Méthodes pour l'elaboration des données statistiques sur les investissements consacrés à la protection de l'environnement (by Bulgaria, in the French language; Paris 1984)

L'enquête statistique des investissements pour la protection de l'environnement (by Hungary in the French language; Paris 1984)

Etude statistique des biens de capital fixe et des depenses ordinaires destines à la protection de l'environnement (méthodes d'elaboration des données statistiques) (by Bulgaria in the French language; Paris 1984)

Environmental expenditure in state and regional planning. The Italian case. (by Italy; CES/SEM.22/R. 18; Rome Seminar 1988)

Evaluation of environmental public expenditure and related classification problems (by Italy; Ottawa 1991)

The calculation of a sustainable income in the Netherlands, environment statistics and other information requirements (by the Netherlands; Lisbon 1992)

Technological developments and the costs of environmental control (by the Netherlands; Lisbon 1992)

Investments made by industry for the protection and safety of the environment (by Portugal; Lisbon 1992)

Statistics of human settlements

Municipal environment statistics in Helsinki: some experiences gained in the compilation of the first compendium (by Finland; Budapest 1989)

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