CASE STUDY

Inventory of POPs in the Building and Construction Sector in Country A

Annex 1 to the Sectoral Guidance for Inventories of POPs and Other Chemicals of Concern in Buildings/Construction, Electrical and Electronic Equipment, and Vehicles

GGKP, 2024

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The case study is an Annex 1 to GGKP's “Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/construction, electrical and electronic equipment, and vehicles”. This case study was authored by Dr. Roland Weber (POPs Environmental Consulting, Schwäbisch Gmünd, Germany) in cooperation with Dr. Sabine Dworak (Technical University Vienna, Austria) who developed the dynamic MFA/SFA figures and modelling. Knowledge and Risk Unit, Chemicals and Health Branch, Industry and Economy Division, United Nations Environment Programme (UNEP) provided substantive contributions to develop this case study. The Green Growth Knowledge Partnership (GGKP) facilitated the design, layout, and dissemination of this material, ensuring its accessibility and alignment with global knowledge-sharing objectives.

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Annex 1: Case Study of Inventory of POPs in the Building and Construction Sector in Country A[1]

[1] This is a theoretical case study for a fictive "Country A" for educational purposes for learning the sectoral approach of POP inventories and understanding the benefits of dynamic material and substance flow analysis (MFA/SFA). It is an Annex to the GGKP *Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/ construction, electrical and electronic equipment, and vehicles* Geneva, 2024.

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1 Introduction

Construction and demolition (C&D) waste is increasing and accounts for over 30% of global waste, with the largest portion disposed of in landfills (Purchase et al. 2021).[2] Many chemicals used in the construction sector, particularly in insulation foams, plastic, sealants and paints are persistent organic pollutants (POPs), such as HBCD, PBDE, SCCP, PCB, PFOA) (UNEP 2021[3]; see Chapter 2 of GGKP sectoral inventory guidance). These chemicals pose risks to human health and the environment. Environmentally sound management of C&D waste, including identifying and inventorying materials containing POPs and other chemicals of concern (CoCs), is essential to mitigate these impacts.

The service life of buildings and construction materials is several decades up to centuries (Li et al. 2016[4]; UNEP 2021). Therefore, a large share of the plastic and foams with POP additives used in the last 70 years is still in use in buildings and construction. The same is true for other CoCs.

Given the large volumes of future waste, industrialized countries are shifting towards a(more) circular economy for C&D waste, emphasizing deconstruction to improve the recovery of materials and manage pollutants (USEPA 2022[5], European Commission 2024[6]). Plastics from buildings must also be managed in an environmentally sound manner under this approach. The German Environment Agency (2021)[7] conducted an initial assessment of the recycling potential of plastic from demolition waste. However, recycling efforts need to account for plastics containing POPs still in use, such as DecaBDE, SCCPs, PFOA, as well as legacy POPs where production has stopped, but are still in use in buildings (e.g. HBCD, c-PentaBDE, PCBs).

Please note: This theoretical case study is designed for educational purposes, focusing on the sectoral approach to POP inventories and demonstrating the benefits of dynamic material and substance flow analysis (MFA/SFA). MFA/SFA provides a cutting-edge assessment of POPs within various sectors, offering valuable insights for policymakers and the waste management industry on current waste stocks and future waste generation. The study approach could be used for country assessments with modified data of the amount of POPs used and duration of use. As initial step, countries would need to assess if they had relevant use of e.g. PCP in construction timber or if brominated flame retardants were used in insulation foams and other polymers which depends on flammability standards[8].

[2] Purchase et al. (2022) Circular Economy of Construction and Demolition Waste: A Literature Review on Lessons, Challenges, and Benefits. Materials. 15(1), 76. https://doi.org/10.3390/ma15010076.

[3] UNEP (2021) Chemicals of Concern in the Building and Construction Sector. Geneva 5 May 2021

[4] Li L, Weber R, Liu J, Hu J (2016) Long-term emissions of hexabromocyclododecane as a chemical of concern in products in China. Environ Int. 91, 291-300.

[5] USEPA (2022) Deconstruction Manuals for Construction and Demolition (C&D) Projects.

[6] European Commission (2024) EU Construction & Demolition Waste Management Protocol including guidelines for pre-demolition and pre-renovation audits of construction works. Updated edition 2024

[7] German Environment Agency (2021) Promoting the high-quality recycling of plastics from demolition waste and enhancing the use of recycled materials in construction products in accordance with the European Plastics Strategy.

[8] Charbonnet J, Weber R, Blum A (2020) Flammability standards for furniture, building insulation and electronics: Benefit and risk. Emerg. Contam 6, 432-441, https://doi.org/10.1016/j.emcon.2020.05.002.

2 Step 1: Planning of the inventory and identification of stakeholders

In this first step, the objectives and scope of the inventory were defined and a work plan was developed (see, for example, General Guidance on POP inventory development[9] and HBCD Inventory Guidance[10]). The POP inventory of the construction sector is expected to address the relevant POPs in the following life cycle stages:

- POPs in materials newly introduced in buildings in the inventory year
- Current use and stocks of POPs in buildings and other constructions
- POPs in construction & demolition waste for the inventory year
- Amount of POPs and materials in C&D waste recycled Total amount of insulation and other materials and related POPs disposed to landfills in the past

For the establishment of the POP inventory, a work plan was developed in June 2022 with the aim of finishing the update by the end of November 2022. The following stakeholders were considered relevant and were invited to the inventory workshop:

- Ministry of Construction and Housing; Ministry of Environment
- Authorities granting construction permits
- Authorities in charge of fire safety regulations and building codes
- National Statistical Office (NSO)
- Industry-producing EPS, XPS, PUR insulation and related industry associations
- Construction industry (in particular related to insulation and other polymers); importers and exporters of plastic/polymeric building materials
- Retailers of insulation boards and other polymers
- Construction & demolition waste companies
- Other relevant stakeholders in the country

3 Step 2: Choosing the inventory methodology

The POPs inventory was developed following a five-step inventory approach provided by the General Guidance on POP Inventories and Figure 1 of this sectoral POPs inventory guidance.

As this was the first sectoral POPs inventory for the construction sector, a Tier I assessment was first conducted (see below) followed by a Tier II inventory compilation. To predict future POP levels in construction waste, a dynamic substance flow analysis (a Tier III inventory approach) was recommended. However, due to the lack of analytical capacity, no material or C&D waste measurements were conducted.

A work plan was developed to compile data and distribute tasks. A multistakeholder team, led by the Stockholm Convention focal point and a University group specializing in construction and material science, was assembled to manage the task.

[9] UNEP (2020). General guidance on POPs inventory development. Revised from document UNEP/POPS/COP.9/INF/19/Add.1.
[10] UNEP (2021). Guidance on preparing inventories of hexabromocyclododecane (HBCD).

4 Step 3: Collecting and compiling the data

4.1 Tier 1 preliminary assessment

The initial assessment relies on collecting "low-hanging fruit" (e.g. existing information, desk studies, literature searches, interviews, etc.) The priority is to get an overview of the present and historical use of the chemical and its life cycle in the country for refining the scope and planning the inventory process:

(a) production; (b) uses; (c) waste management and potential recycling of materials containing the chemical; (d) waste storages (mainly in case of obsolete pesticides); and (e) understanding the life cycle of POPs and the potential for emissions (UNEP 2020).

In the preliminary assessment of the sectoral POP inventory guidance (Chapter 2: Building and Construction Sector) and other relevant inventory guidelines, the following findings were identified:

- Insulation foams have been increasingly used since the 1980s.
- From 2000 on, subsidies were given for low-energy housing including renovation of buildings.
- Various insulation materials were and are used (EPS, XPS, PUR and stone wool).
- The major used polymer in buildings and construction was PVC in plasticized (e.g. flooring and laminates) and rigid forms (e.g. window frames and doors).
- Various sealants were used in construction.
- Wood was used in the construction of houses and outdoor use (utility poles, railway sleepers).

To select POPs for the inventory, the sectoral guidance (especially Chapter 2)[11] and key references were reviewed, and individual POPs were assessed. Relevant inventory guidance documents, including those from the Stockholm Convention for HBCD,[10] PBDE,[12] SCCP,[13] PCNs/PCBs[14] and PCP,[15] were also consulted. Additionally, existing POP inventories in the construction sector were analysed, such as Myanmar's HBCD,[16] Switzerland's POP BFR inventory[17] and China's HBCD inventory.[4]

Since no national inventory of POPs in construction had been developed in the past, for all selected POPs the methodology to get data and calculate or estimate data needed to be developed. For the first inventory, an inception workshop was held in October 2022 and was used to develop a working group to develop a sectoral inventory for the construction sector with an emphasis on POPs.

[11] UNEP (2023) Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/ construction, electrical and electronic equipment, and vehicles.

[12] UNEP (2021). Draft guidance on preparing inventories of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants.

[13] UNEP (2019). Guidance on preparing inventories of short-chain chlorinated paraffins (SCCPs) (Detailed guidance).

[14] UNEP (2021) Guidance on preparing inventories of polychlorinated naphthalenes (PCNs).

[15] UNEP (2021). Guidance on preparing inventories pentachlorophenol and its salts and esters.

[16] The Republic of the Union of Myanmar (2021) National Implementation Plan of Myanmar for the Stockholm Convention on Persistent Organic Pollutants.

[17] Morf L; Buser A, Taverna R (2007) Dynamic Substance Flow Analysis Model for Selected Brominated Flame Retardants as a Base for Decision Making on Risk Reduction Measures (FABRO). NRP 50 Final Report. https://www.geopartner.ch/wp-content/uploads/2021/07/FABRO_Final_Report.pdf

For some of the POPs, the use in construction stopped decades ago (e.g. PCBs, PCNs and PCP) while others are still produced (SCCPs, decaBDE). After reviewing the inventory guidance documents and the gathered Tier I information, the decision was made to assess the following POPs in the construction sector:

- HBCD in EPS/XPS insulation
- PBDEs in PUR insulation and other polymers (PP/PE) used in construction
- SCCPs and MCCP (currently assessed in POPRC) in PVC and PUR foam sealants
- PCB in sealants and paints
- PCP and other POPs pesticides in wood

It is important to note that buildings and construction contain other CoCs, such as lead in paint, mercury, asbestos, ozone-depleting substances (CFCs/HCFCs), and greenhouse gases (HCFCs/HFCs) in insulation. These CoCs might be assessed in a synergistic inventory of the construction sector (see sectoral POPs inventory guidance). However, this first POP inventory in County A focused specifically on multiple POPs in buildings and construction.

The team collected existing national data, both past and present, on the import and use of HBCD and HBCD-containing articles from key stakeholders and sources, including (see Table B-1):

A) Assessment of the presence of relevant industries

The following were the outcomes of the assessment of relevant industries and importers:

- No production of POPs or brominated or chlorinated organics took place in the country; POPs were therefore imported as chemicals (e.g. HBCD for EPS/XPS production) or in products (PVC containing SCCPs or MCCPs[18]).
- There were four main importers of chemicals, which possibly could import flame retardants or plasticizers.
- At least three EPS/XPS producers were identified as offering insulation material.
- One of these producers also produced polyurethane (PUR) foam used in insulation.
- There was a range of importers of construction materials, such as PUR spray foam and paints.
- Two wood companies provided treated wood (PCP, creosote, and CCA) for the construction sector; several importers of wood products used in construction including utility poles.
- Two compounders of PVC imported PVC from abroad and produced pipes and cables.
- One producer of paints manufactured waterproofing and fire-retardant paint.

Contact details were compiled for the respective industries and importers for the detailed information compilation of the Tier II inventory. Also, a list of authorities relevant to the materials in the construction sector was compiled.

B) Assessment of fire safety regulations and building codes

Past and present fire regulations governing building and insulation materials were assessed, as they influence the use of flame retardants, including certain POPs (Chabonnet et al 2020).[19]

[18] MCCPs are proposed to be listed in the Stockholm Convention in 2025. MCCPs are often marketed in CP mixtures containing SCCPs above 1% and these mixtures are already considered POPs.

[19] Charbonnet J, Weber R, Blum A (2020) Flammability standards for furniture, building insulation and electronics: Benefit and risk. Emerg. Contam 6, 432-441, https://doi.org/10.1016/j.emcon.2020.05.002.

It was found that insulation polymers must comply with flammability standards (ISO 5660–1[20]), a requirement in place since the early 1990s.

C) Initial information on waste management of articles that may contain POPs;

An initial assessment of the waste management of construction materials was conducted. Until 2000, the largest share of construction and demolition waste was disposed of in landfills. Wood was recovered to a large extent and used either as firewood (70%) or for structures in gardens or public places (30%). Since 2020, a waste wood regulation requires the environmentally sound disposal of treated wood.

Two facilities in the country are recycling part of C&D waste. Additionally, the informal sector is involved in this process. This information was compiled as the basis for the Tier II assessment and discussed with stakeholders for initial feedback.

4.2 Tier 2 inventory based on available and estimated data; Tier 3 MFA/SFA elements

4.2.1 Methodology for data collection

The evaluation of available and relevant national data of the building and construction sector was conducted using the sectoral guidance (Chapter 4) approach and considers POPs-specific inventory guidance documents.

Basic information was compiled for the construction sector on the following:

- Information from EPS/XPS and PUR producers in the country (information on product and flame retardants used)
- National statistics information on insulation foams in buildings (EPS/XPS, PUR and other foam insulation) used in construction
- Amount of wood used in construction and wood preservatives used in the past
- Amount and type of sealants used in construction
- Paints in current and past use in construction (in particular waterproof and flame retardant paint)
- Treatment and management of plastic including insulation foam from construction
- Treatment and management of waste wood from construction
- Amount and management of polymers from construction and demolition waste
- International trade statistic for PUR spray foam[21]
- International trade statistics for import of PVC[21]

4.2.2 Service life of the major products/articles containing POPs

Key to assessing the presence of POPs in current use and waste is understanding the amount, installation date and service life of the respective products. The service life is also important for the dynamic material and substance flow analysis, helping to predict the amount of POPs in C&D waste over the coming decades. Information on the service life of products containing POPs is gathered according to national averages. If this data is unavailable, the best possible correlating data has to be considered. The available data should be reviewed for its relevance by chosen data quality criteria, for example, reliability, completeness, temporal and

[20] ISO 5660–1:2015 Reaction to fire tests Heat release, smoke production and mass loss rate Part 1: Heat release rate (cone calorimeter method).

[21] UN Comtrade database http://unstats.un.org/unsd/comtrade

geographical correlation, or other correlation.[22] A service life estimate can be determined for an MFA model.

Please note that an overall service life estimate is unattainable due to the diversity of national regulations and methodology in construction. However, selected studies may indicate a range suitable for deriving an appropriate model (Morf et al. 2007[17]; Dunant et al. 2023[23]; Viitanen 2014[24]; Li et al. 2016[4]; Wang et al. 2021[25]). For the current MFA/SFA calculation, the following service life were considered:

- Service life of insulation foams (EPS/XPS; PUR) approx. 50 years
- Service life for PVC flooring, wallcovering and foils: approx. 30 years
- Service life for PE and PP foils: approx. 30 years
- Service life of Thiokol sealants: approx. 50 years
- Service life of wood: outdoor like utility poles and railroad (40 years); indoor timber (75 years)

4.2.3 Material and substance flow analysis of POPs in the construction sector

For compiling the data in a visualized form and to gain an overview of the life cycle of materials containing POPs in the construction sector, a material flow analysis (MFA) of these materials and a substance flow analysis (SFA) of the relevant POPs have been performed.

4.2.3.1 Material and substance flow analysis

An MFA systematically shows the bulk material flows through society in a comprehensive way. The underlying principle of MFA is to account for all materials entering and leaving a system (e.g. country or city) based on a mass-balancing approach. The flow of materials/substances starts at a source (e.g. production or import) and ends at a sink (e.g. export or landfill).

SFA is a specific type of MFA used for tracing the flow of a selected chemical (or group of substances) through a defined system.[26,27]

A key aim of material flow analysis is to visualize the complex material/substance flow of a selected system (in this case the flow of POP in the construction sector in A country) in a simplified but correct manner to, for example, serve as a tool/support for decision making in waste management.

Dynamic MFA/SFA is a tool to also consider time-dependent developments for flows and stocks. In the present case studies, the stock and amount of the investigated substance in end-of-life products were determined by applying a Weibull lifetime-functions (form factor 5) to the input of the according substance. This allows a projection of expected stocks and end-of-life products, which need to be managed and hence support decision-making in regard to required treatment capacities.

[22] Laner D, Feketitsch J, Rechberger H and Fellner J (2016) A Novel Approach to Characterize Data Uncertainty in Material Flow Analysis and its Application to Plastics Flows in Austria. Journal of Industrial Ecology 20, 1050–63.

[23] Dunant CF, Shah T, Drewniok MP, Craglia M and Cullen JM (2021) A new method to estimate the lifetime of long-life product categories. Journal of Industrial Ecology 25(2), 321–332.

[24] Viitanen H (2014) 100 years‘ service life of wood in service class 1 and 2 – dry and moderately humid condition. Research Report Finnish Wood Research.

[25] Wang, C., Liu, Y., Chen, W.Q., Zhu, B., Qu, S., Xu, M., (2021). Critical review of global plastics stock and flow data. Journal of Industrial Ecology, 25(5), pp.1300-1317.

[26] Baccini P, Brunner PH (2012) Metabolism of the anthroposphere: Analysis, evaluation, design. 2nd edition, MIT Press, Cambridge US.

[27] Brunner PH, Rechberger H (2003) Practical Handbook of Material Flow Analysis. Lewis Publishers.

In the current study, the system boundary is Country A. The materials included in this study are insulation foams, other plastic, sealants and wood in buildings. The substances considered in the substance flow are HBCD in EPS/XPS, SCCP in PUR foam and PVC, PCB in sealants, and PCP and Lindane in wood. For these POPs robust data on the use amount and the time period of use could be established in the inventory. The system, therefore, comprises the materials in buildings and construction in country A and focuses on these POPs. The stocks and flows in the system include importation, in-use and end-of-life (recycling, thermal treatment, landfill/dump). No export of C&D waste has been discovered.

4.2.3.2 Overview of flows and stocks of POPs in construction

The strength of the material/substance flow analysis is the visualization of complex material and substance flows. For the current MFA/SFA, it was decided to use a dynamic MFA/SFA to develop predictions of the individual POP in insulation foam, other plastics, sealants and wood in country A for providing estimates for the amount of POPs and related waste volume in C&D waste in the coming decades which can be used for planning of the management of C&D waste.

4.2.4 Assessment and inventory of HBCD in EPS and XPS insulation foams in construction

Three manufacturers of EPS and XPS insulation foam were discovered in the country. Two manufacturers operated since the 1980s and one manufacturer started operation in 2002 after the government started to subsidise insulation of buildings in the green building project in 2001. All manufacturers were contacted and visited for an interview. The assessment revealed that all EPS/XPS manufacturers used HBCD as major flame retardants until 2016 when the use was stopped due to listing in the convention in 2013 and restriction by the government in 2015 with a stop of use by 2017 since alternatives were available. As alternatives, all three manufacturers use a polymeric flame retardant and two use also a brominated monomeric additive. Further, one factory produced rigid PUR foam and used decaBDE as flame retardant from 1985 until 2015 (see 4.2.5.1).

4.2.4.1 Inventory of EPS/XPS containing HBCD in construction

The information that was needed for HBCD calculation for EPS/XPS insulation foam:

- The information on the period of the use of HBCD in EPS/XPS
- The amount of HBCD and EPS used in this period
- The amount of HBCD and XPS used in this period
- If other flame retardants were used during this period and what alternative flame retardants substituted HBCD

All three producer provided sales data of EPS and XPS for their productions since 1980 and 2002 respectively until 2021. They also provided data on the time and amount of HBCD used on EPS/XPS (Figure B-1). The use of HBCD in Country A started in 1980 and stopped in 2017 (Figure B-1).

The EPS contained on average 0.8% HBCD. The XPS used contained on average 2.5% HBCD. The total stock of HBCD in 2017 in EPS/XPS insulation was 2,720 tonnes, which decreased already somewhat to 2,657 tonnes for the inventory year 2022 (Figure B-2). The total amount of HBCD containing EPS in 2017 was 204,034 tonnes, which also decreased to 199,238 tonnes in the inventory year 2022 (Figure B-4;

Figure **B-6**). The total amount of HBCD containing XPS in 2017 was 20468,011 tonnes, which also decreased to 66,413 t in the inventory year 2022 (Figure B-4) due to EPS/XPS entering EoL (Figure B-5).

In 2022, 16 tonnes of HBCD entered end-of-life in construction and demolition waste from buildings constructed in the 1980s (Figure B-3). Maximum HBCD in EoL is expected around 2050 with 75.6 tonnes (Figure B-3). The related EPS/XPS waste amount in 2050 is estimated at 5,674 tonnes EPS and 1,891 tonnes of XPS (Figure B-5). While the amount of EPS/XPS waste amount in the inventory year 2022 was 5,674 tonnes EPS and 1,891 tonnes of XPS (Figure B-5). The dynamic MFA/SFA with an estimated average service life of 50 years indicates that by 2060 still 529 tonnes of HBCD is expected in use (Figure B-2) in 39,709 tonnes of EPS and 13,236 tonnes of XPS (Figure B-4). The material flow analysis of EPS/XPS containing HBCD is compiled in

Figure **B-6** and the substance flow analysis of HBCD in EPS/XPS is compiled in Figure B-7.

Figure B-1. Annual use of HBCD in EPS/XPS insulation foams in construction in County A

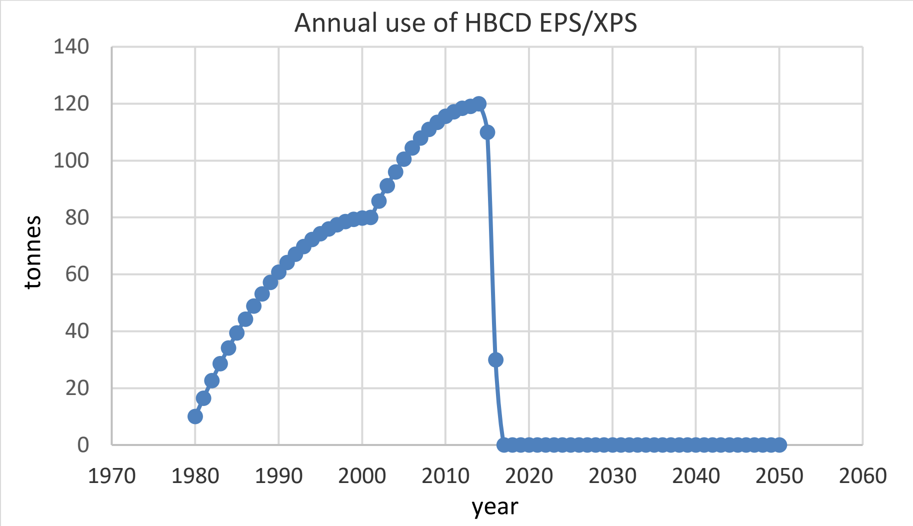


Figure B-2. In use HBCD in EPS/XPS insulation foam in construction in Country A

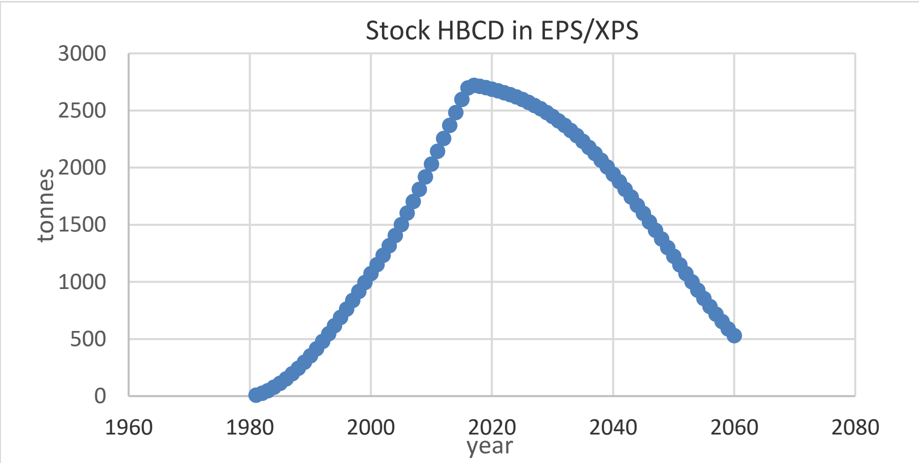


Figure B-3. Annual EoL HBCD in EPS/XPS insulation foam in Country A

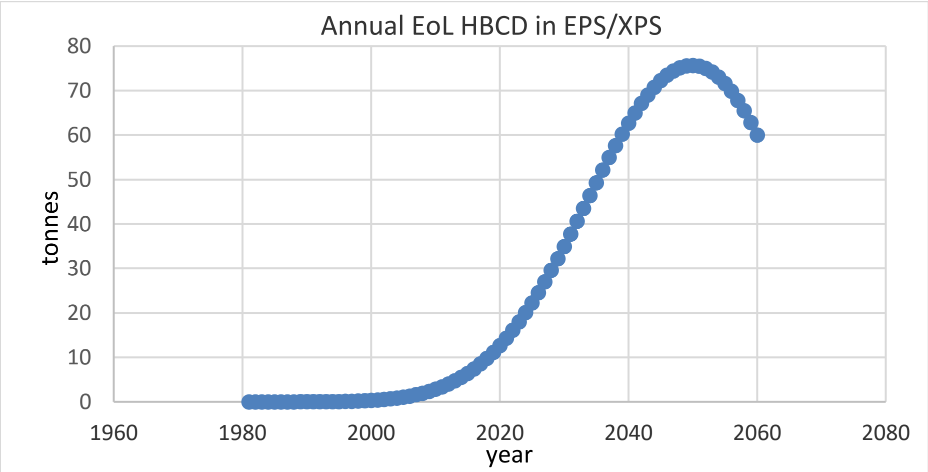


Figure B-4. Amount of in-use EPS/XPS containing HBCD in Country A

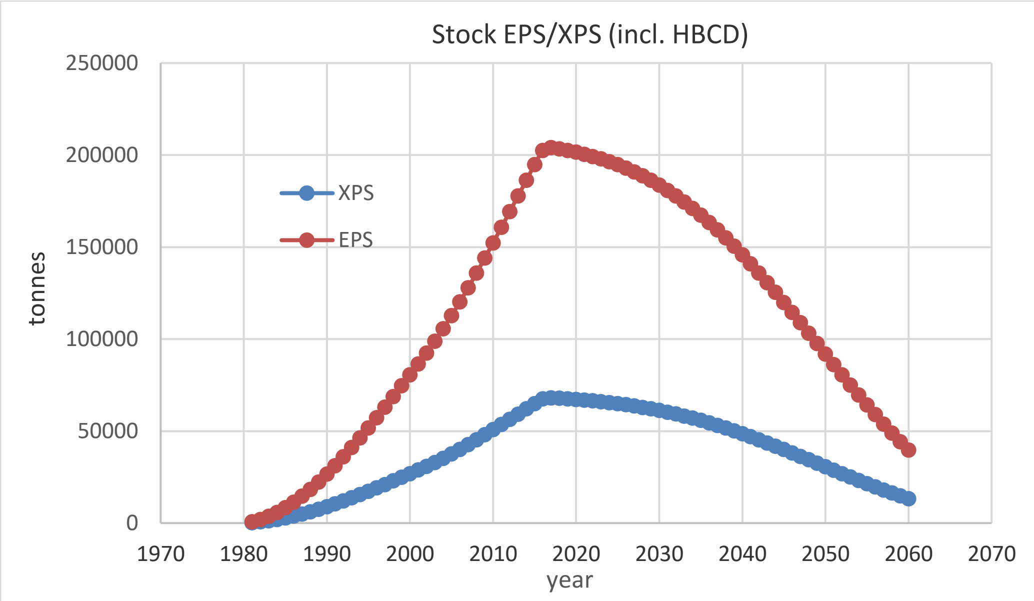


Figure B-5. Annual amount of EoL EPS/XPS containing HBCD in construction & demolition waste in Country A (note that EPS/XPS installed after 2017 containing other flame retardants are not included; however, they need to be separated from HBCD containing EPS/XPS)

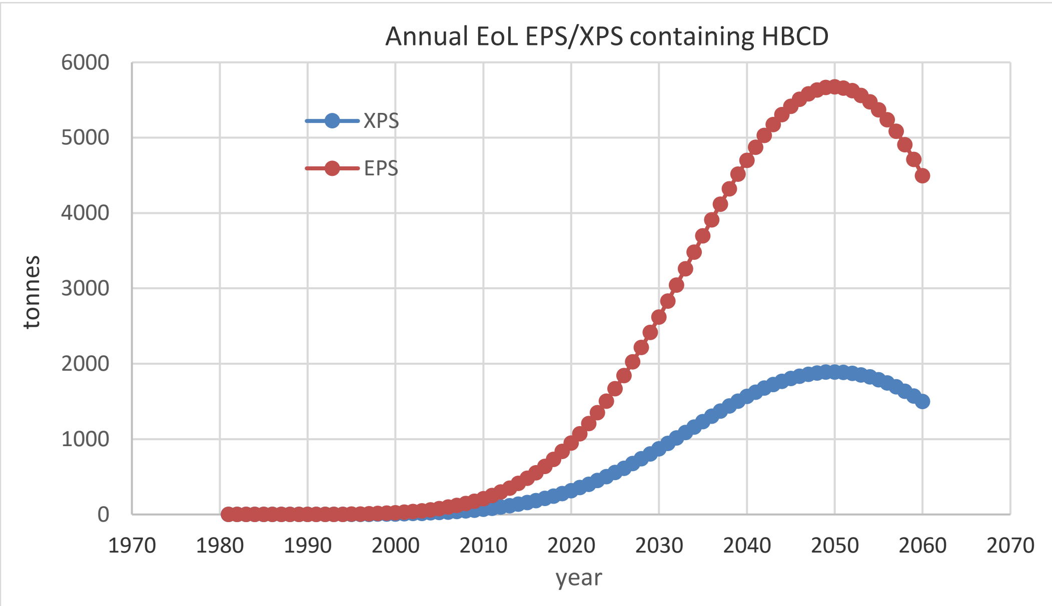


Figure B-6. Material flow analysis of EPS/XPS insulation containing HBCD in Country A (note that EPS/XPS installed after 2017 containing other flame retardants are not included here; however, they need to be separated from HBCD containing EPS/XPS)

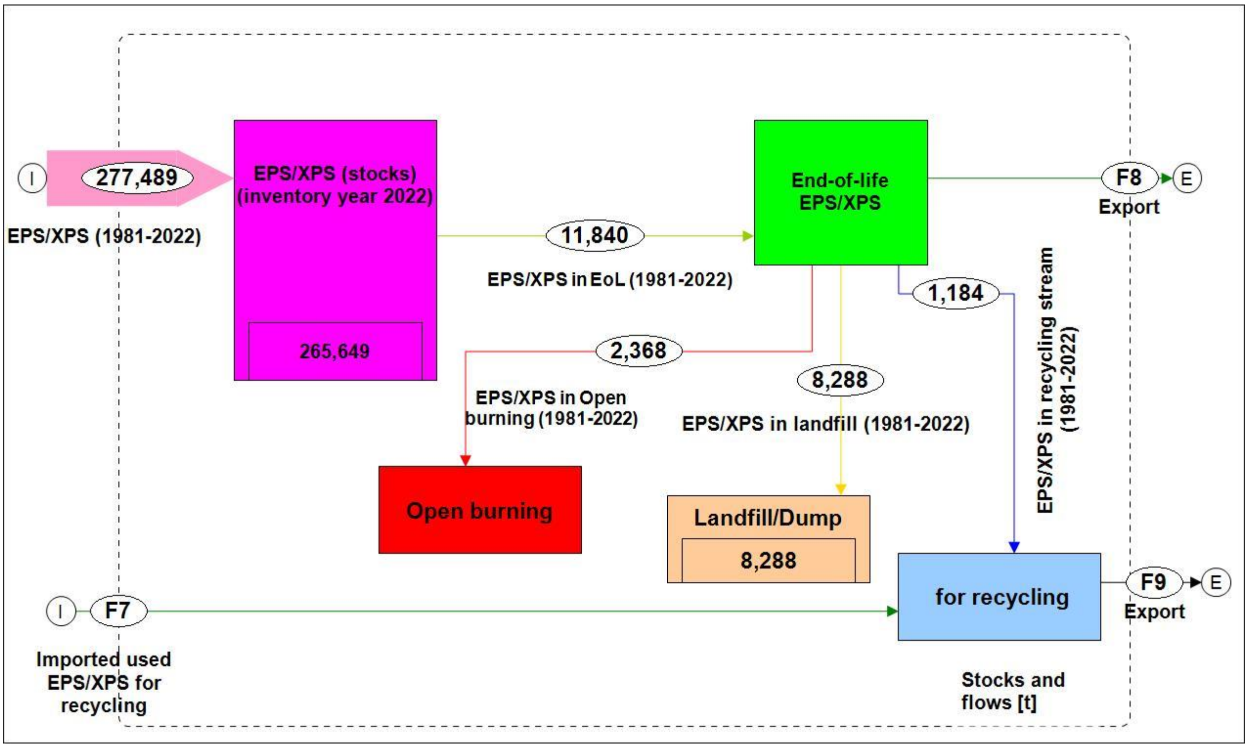
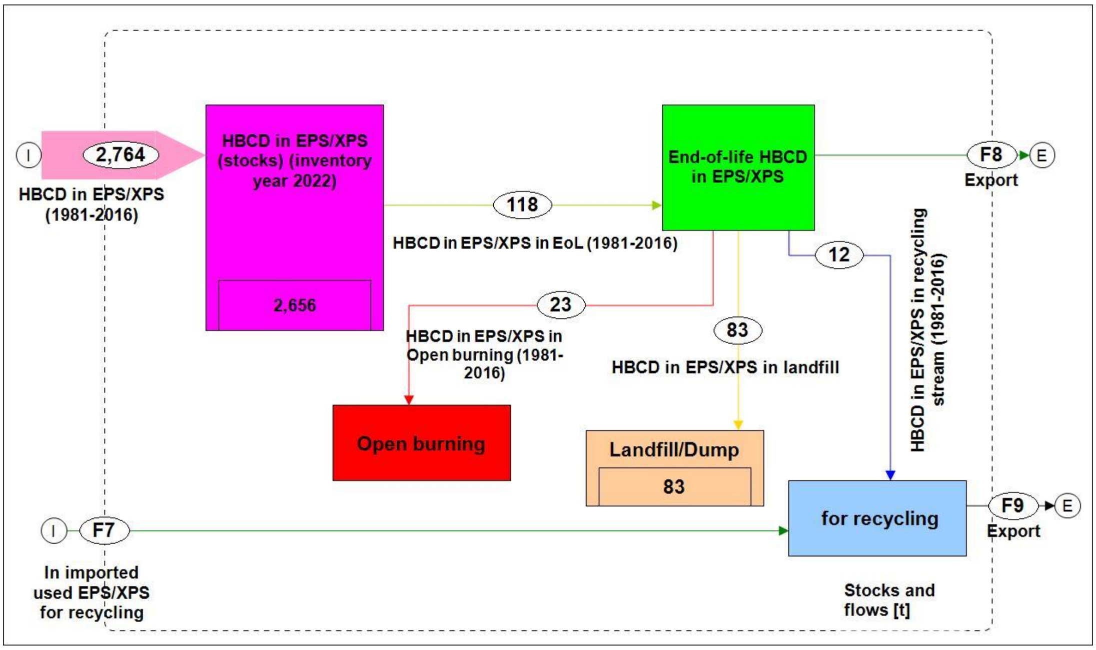


Figure B-7. Substance flow analysis of HBCD in EPS/XPS insulation in Country A



4.2.5 DecaBDE and c-PentaBDE (tetraBDE/pentaBDE) use in construction

DecaBDE and c-PentaBDE (containing tetraBDE/pentaBDE listed in 2009) were used in construction, particularly in PUR foams and PE and PP foils.[11,12] While the production and new use of c-PentaBDE ceased in 2004, the production and use of decaBDE continued under an exemption for PUR foam insulation until 2023.[11,12] In the assessment, it was found that one insulation foam producer was found to have used both c-PentaBDE and decaBDE as flame retardants, phasing out c-PentaBDE in 1995 and discontinuing decaBDE use in 2012. Production then shifted to phosphorous flame retardants instead. DecaBDE was also used in PE and PP as a flame retardant.

The information compiled for PBDEs was used for developing the PBDE inventory in construction for the use in PUR foams (rigid boards and flexible PUR foam and PUR spray foam) and PE and PP sheets.

4.2.5.1 PBDE in PUR

Records from the producer of PUR foam indicate that only a minor amount of c-PentaBDE was used from 1980 to 1995 (see Figure B-8 and Figure B-9). The total stock of c-PentaBDE (PBDEs listed 2009) in 1995 was 49 tonnes. This stock had already decreased to 46.4 tonnes in the inventory year 2022. It is estimated that by 2060 almost all c-PentaBDE containing PUR foam entered end-of-life (Figure B-9 and Figure B-10).

DecaBDE was used in PUR foam insulation from the 1980s to 2012 in Country A (Figure B-11). The total stock of decaBDE in 2012 was 6,408 tonnes in the year where new decaBDE use was stopped in Country A (

Figure **B-12**). This stock had decreased to 6,252 tonnes in the inventory year 2022 (

Figure **B-12**). It is estimated that in 2060 618 tonnes of decaBDE will be present in PUR foams in construction (

Figure **B-12** and Figure B-13). In 2060 about 112 tonnes of decaBDE is expected in end-of-life while for the inventory year 2022, only 30.3 tonnes of decaBDE entered end-of-life with a maximum of decaBDE in PUR insulation waste of 220.5 tonnes from construction in 2047 (Figure B-13).

The SFA of decaBDE in polymers in construction (PUR foam and PE/PP) is compiled in Figure B-20).

Figure B-8. Annual use of C-PentaBDE in PUR foams in construction in Country A

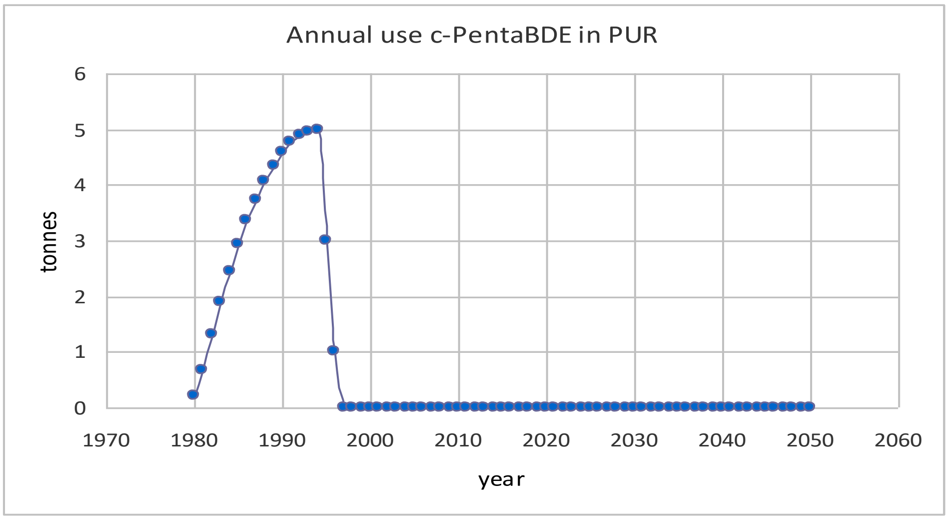


Figure B-9. Stock of c-PentaBDE in PUR foams in the construction sector in Country A

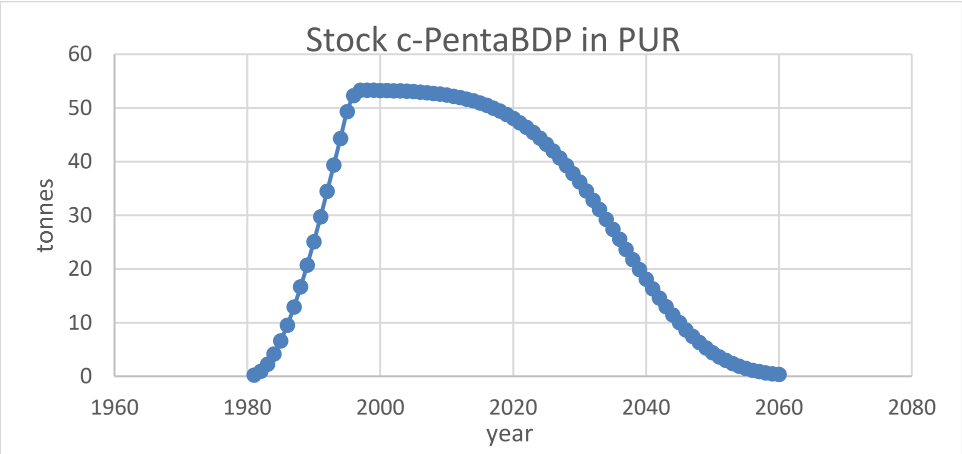


Figure B-10. Annual EoL of c-PentaBDE in PUR foam in Country A

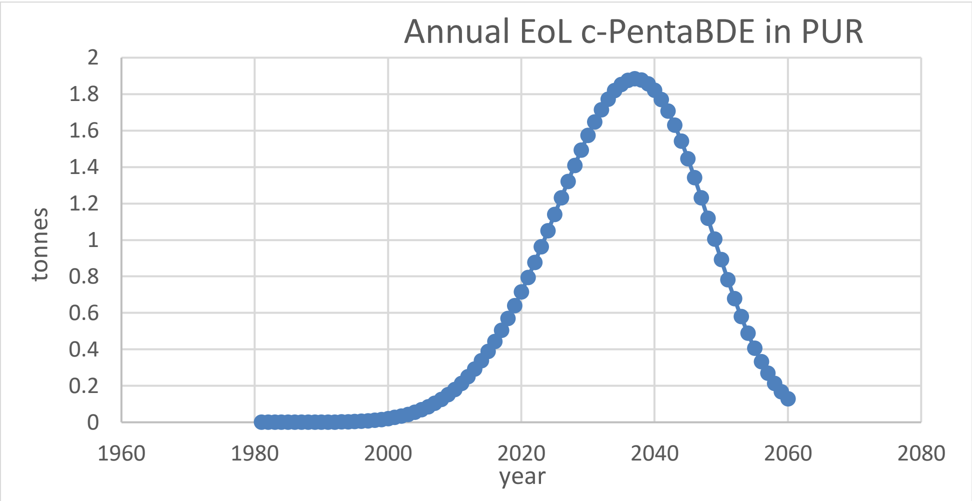


Figure B-11. Annual use of decaBDE in PUR foam in construction in Country A

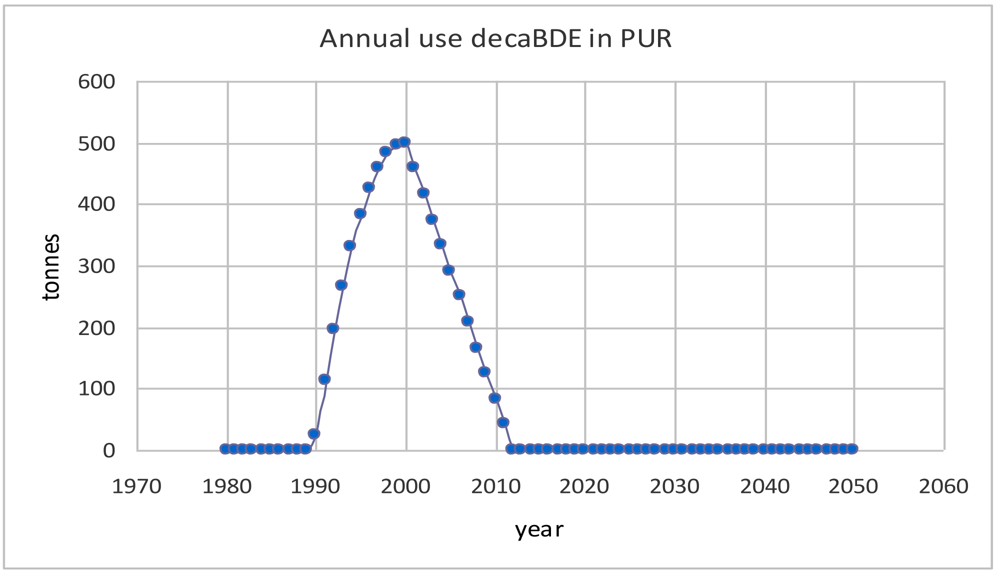


Figure B-12. In-use decaBDE in PUR foam in construction in Country A

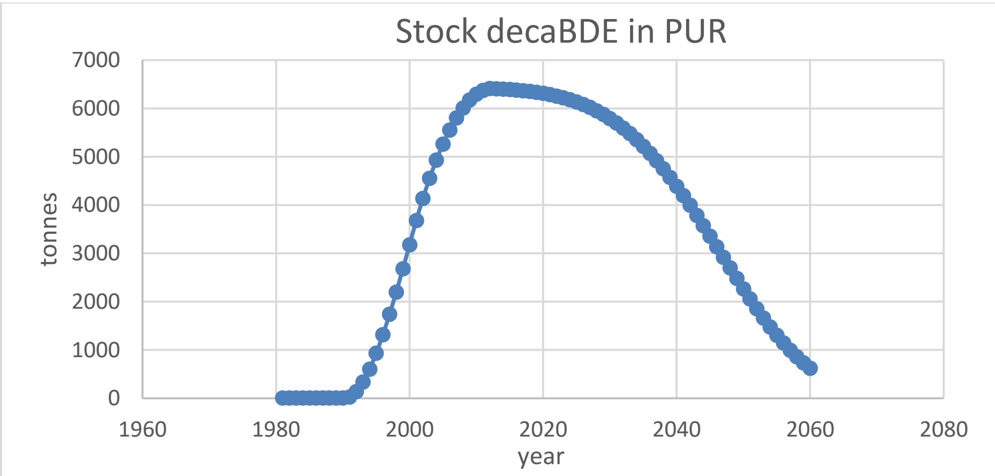
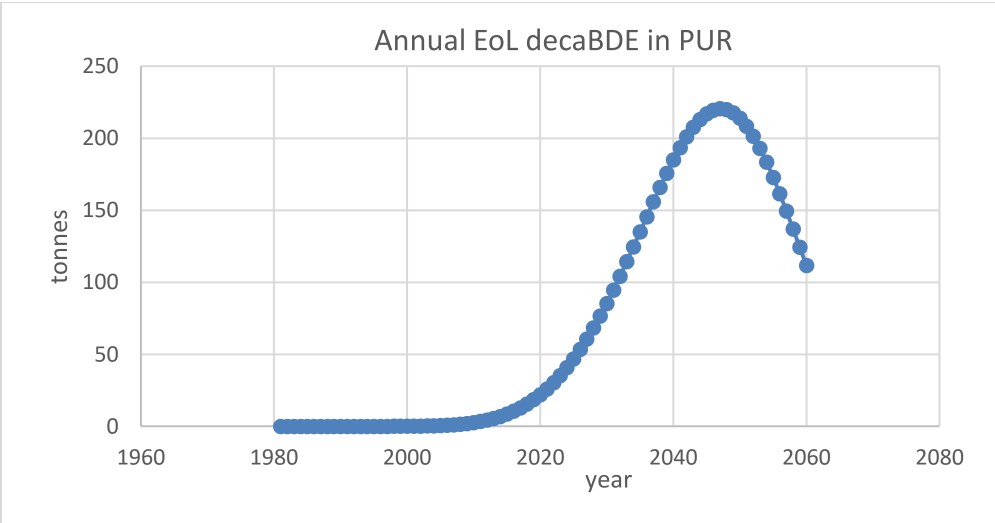


Figure B-13. Annual end-of-life of decaBDE in PUR foams from construction in Country A



4.2.5.2 PBDE in polyethylene (PE) and polypropylene (PP) foils

PBDEs have been used in PE and PP foils in construction. Data on PE and PP use in construction, sourced from the national building material association, was available from 2000 to 2020. However, flame retardant usage in these imported foils was unknown. Since decaBDE is a known flame retardant for this application, it was assumed that 50% of the PE and PP sheets used in construction contained decaBDE (10%) until 2017, when decaBDE was listed under the Stockholm Convention without exemptions for PE and PP in construction. Prior to 2000, building flammability standards did not require flame retardants in PE/PP in country A, so PE/PP used before 2000 was assumed to be non-flame retarded. Based on these assumptions and an average service life of 50 years, the total amount of in-use decaBDE in PP/PE foils was estimated (Figure B-15).

The National Implementation Plan (NIP) included an activity to monitor PBDEs, POPs and CoCs in plastic and other polymers in construction, and to clarify/verify past uses of POPs. Based on this assessment, the total in-use decaBDE in PE/PP foil in construction in 2020 was estimated to 583 tonnes in the year where new decaBDE use was stopped (Figure B-14). The amount of in-use decaBDE decreased slightly to 582 tonnes in the inventory year 2022 (Figure B-15). By 2060, 173 tonnes of decaBDE is expected to remain in use, with only 3 tonnes by 2080 (Figure B-15).

In 2022, only 0.6 tonnes of decaBDE in PP/PE was present in C&D waste, with a peak of 20.1 tonnes expected by 2055 (Figure B-16). The related PP/PE waste amount containing decaBDE was 5.8 tonnes in 2022 (Figure B-18), and is expected to increase to 201 tonnes in 2055 (Figure B-18). The maximum stock of PE/PP containing decaBDE in construction was 5,834.6 tonnes in 2020 and 5,815.8 tonnes in the inventory year 2022 (Figure B-17 and MFA in Figure B-19) with a prediction of an in-use amount of 1,732 tonnes in 2060 (Figure B-17). The total amount of PE/PP foil in use and end-of-life in C&D waste is higher, as it includes PE/PP foil installed before 2000 and those containing other flame retardants installed after 2017. Therefore, a larger amount of PE/PP waste will need to be managed, potentially requiring separation of decaBDE-containing foils if non-decaBDE foils are be recycled.

The MFA of the PE/PP foil in Country A containing decaBDE is compiled in Figure B-19 and the SFA of decaBDE in polymers in construction (PE/PP and PUR foam) is compiled in Figure B-20.

Figure B-14. Estimated annual use of decaBDE in PE/PP in construction in Country A (the flammability standard change in 2000 required flame retarded PE/PP in buildings)

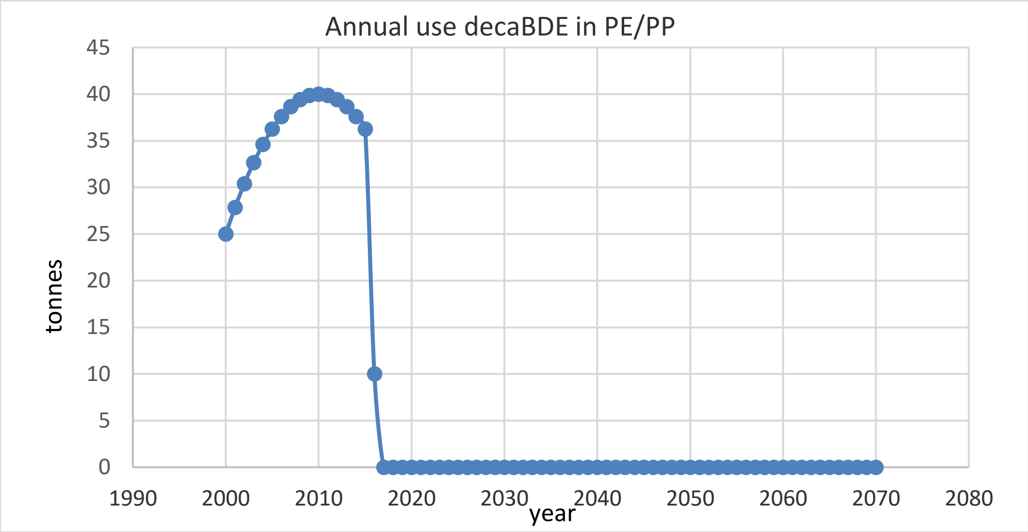


Figure B-15. In-use decaBDE in PE/PP in buildings in Country A

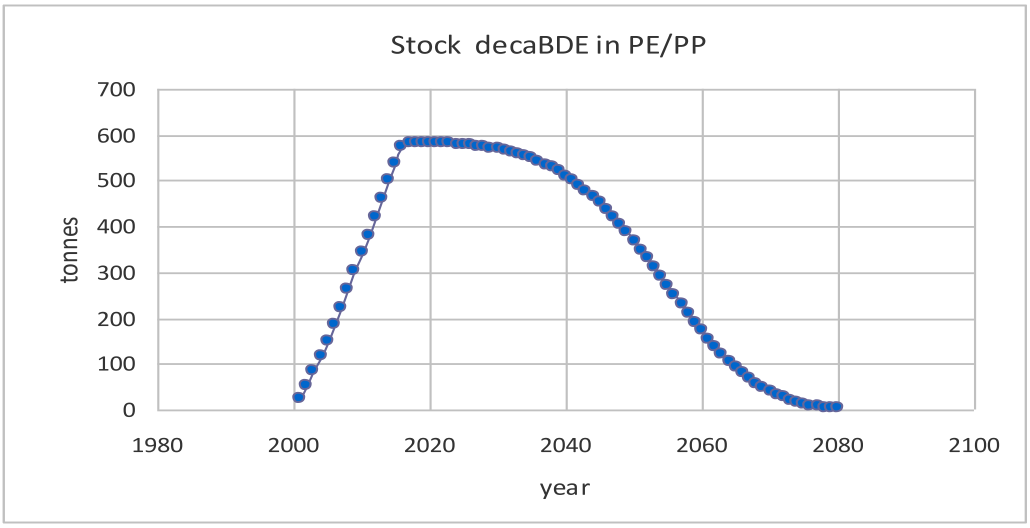


Figure B-16. Annual end-of-life of decaBDE in PE/PP in buildings in Country A

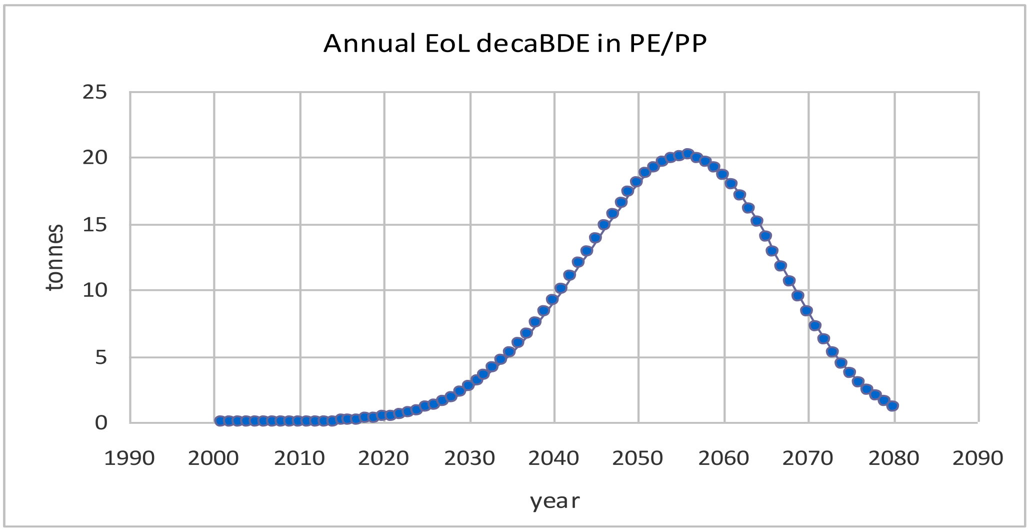


Figure B-17. In-use PE/PP containing decaBDE in construction in Country A

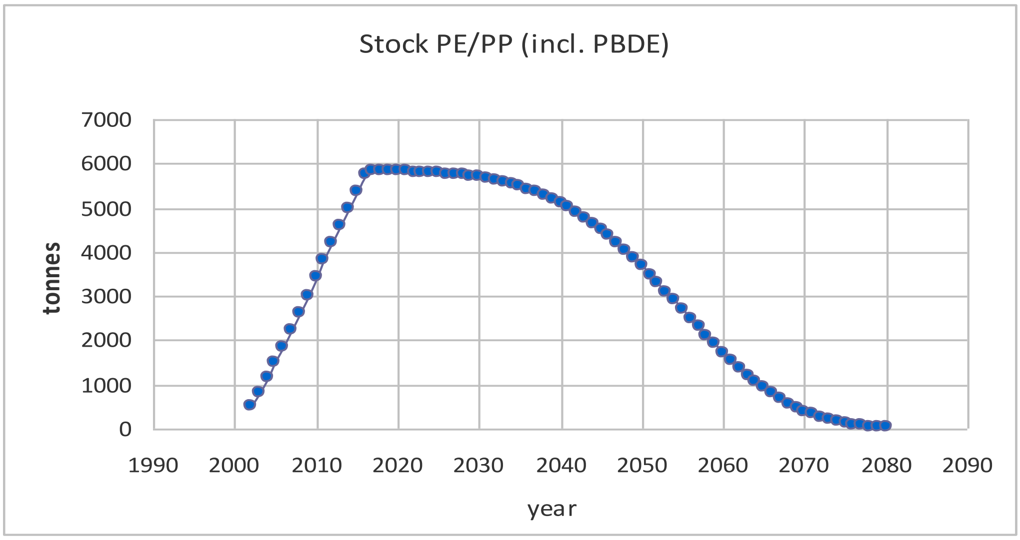


Figure B-18. Annual end-of-life PE/PP containing decaBDE in C&D waste in Country A

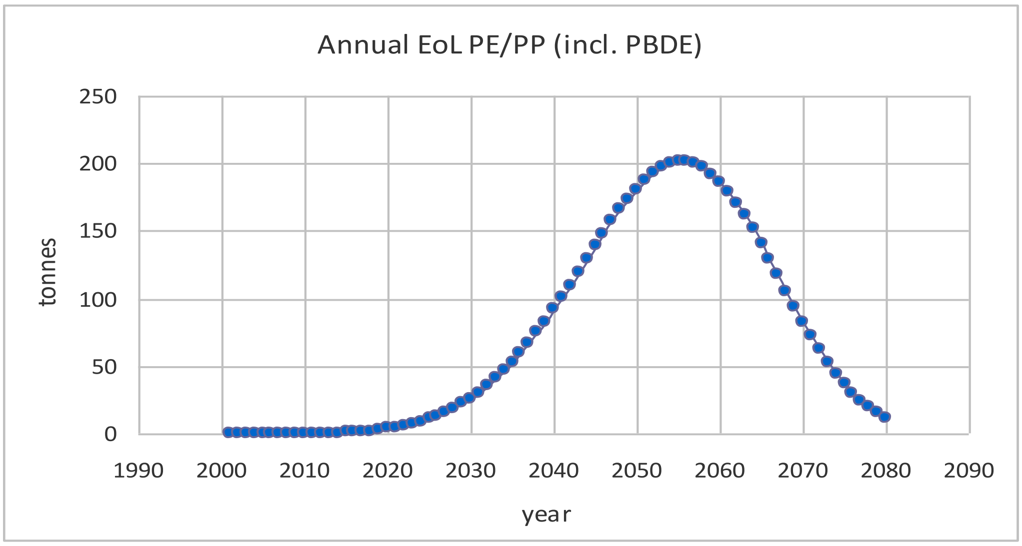


Figure B-19. MFA of PE/PP containing decaBDE in buildings in Country A

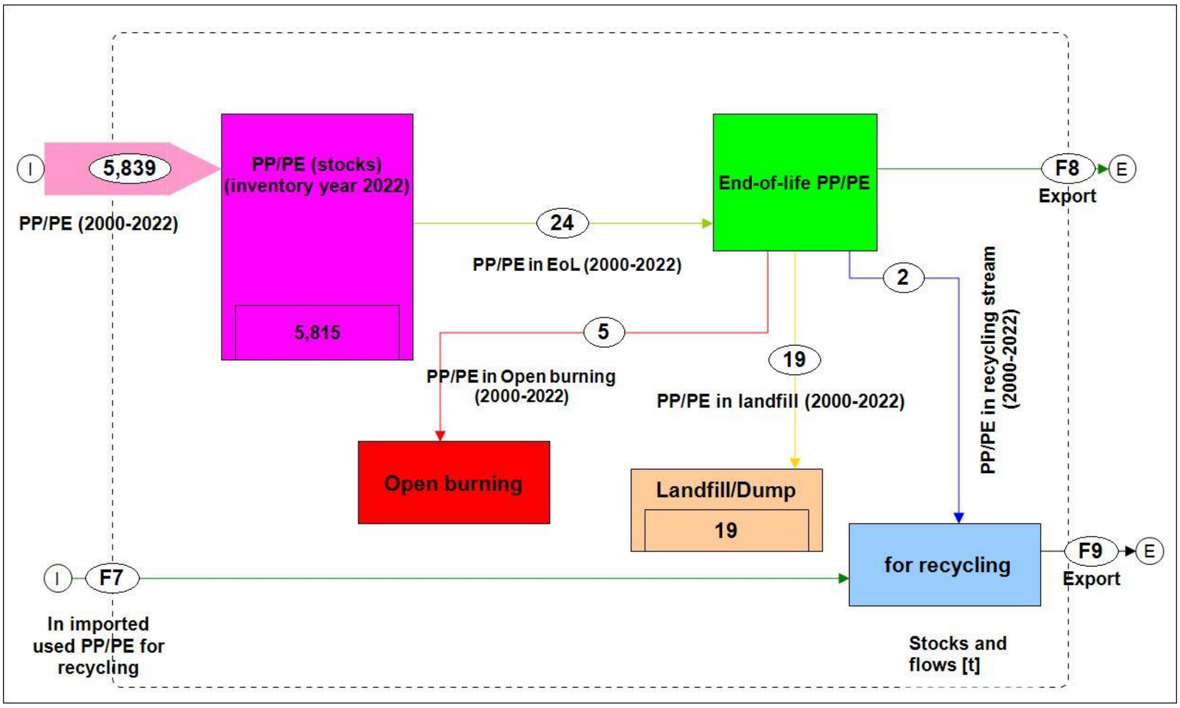
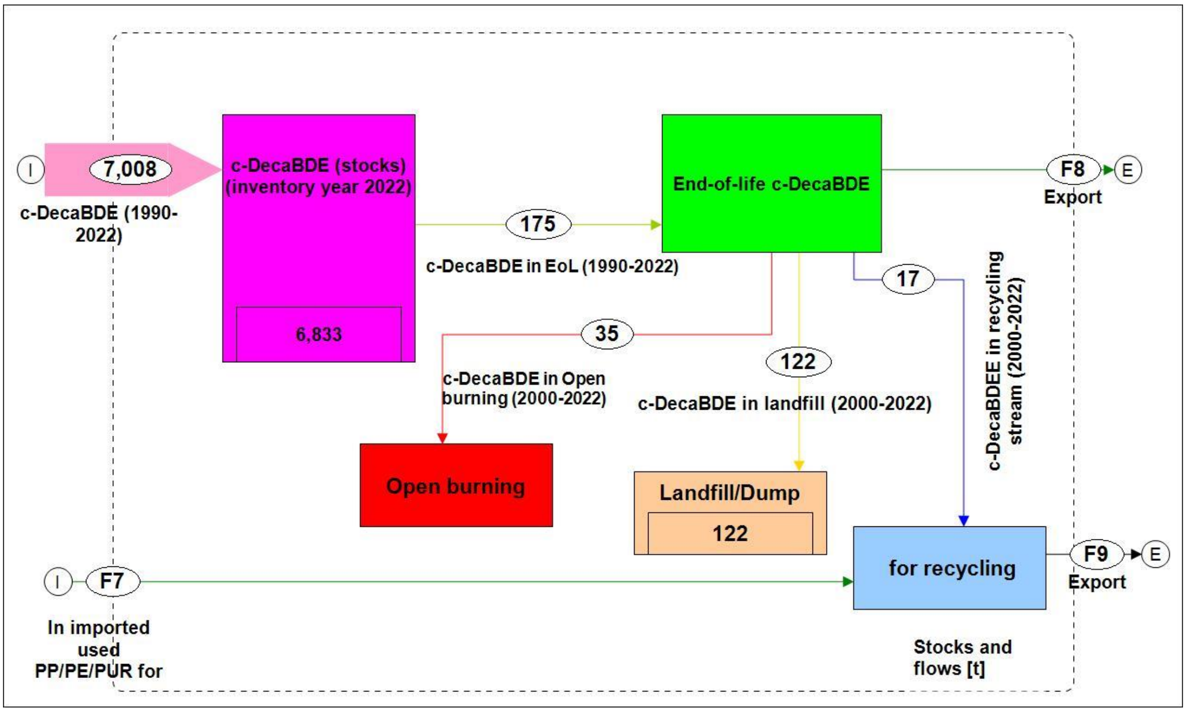


Figure B-20. SFA of decaBDE in PE/PP and PUR foam in buildings in Country A



4.2.6 Inventory of SCCP and MCCPs[18] in construction

4.2.6.1 Assessment of SCCP and MCCP[18] in PVC in construction

In the past 20 years, about 70% of SCCPs and MCCPs[18] have been used in PVC (Chen et al. 2022),[28] with more than 50% of all PVC used in construction. Since PVC containing SCCPs or MCCPs[18] are not labelled, estimating the share of PVC is challenging.[18] A recent study in Nigeria developed a methodology to estimate SCCP and MCCP imports[18] based on HS Codes of product groups potentially containing these additives (Babayemi et al. 2022).[29] For the PVC inventory, the study used only HS Codes of PVC-containing plasticizers.[29] As an impact factor for the different PVC categories, the monitoring of SCCPs and MCCPs[18] in materials and products in China was used (Chen et al. 2021).[30] The same approach[29] of estimating SCCPs and MCCPs[18] imports was taken for the current study. Since Country A did not have a PVC production, the import of PVC was the main source of PVC used.

Since over 50% of global PVC is used in construction, it was estimated that around 50% of imported PVC in Country A is applied in building projects. For SCCPs, the dynamic MFA/SFA model assumes production and use will cease in 2023 when the five-year exemption expires (Figure B-21). MCCP is expected to continue, with its listing in the Convention in 2025,[18] and specific exemptions likely extending until 2030. Therefore, the model assumes MCCP use in Country A will stop by 2030 (Figure B-24).

In 2022, the amount of SCCP in PVC used in construction was estimated at 5,997 tonnes, peaking at 6,358 tonnes in 2023 (Figure B-22). MCCP in PVC for construction was estimated at 8,696 tonnes in 2022, with a maximum of 14,235 tonnes projected for 2030 (Figure B-25). Only 28 tonnes of SCCP in PVC C&D waste were estimated for 2022, rising to 295 tonnes by 2042 (Figure B-23). For MCCP, 29 tonnes were present in PVC C&D waste in 2022, with a maximum of 623 tonnes forecasted for 2049 (Figure B-26).

[28] Chen C, Chen A, Zhan F, Wania F, Zhang S, Li L, Liu J (2022) Global Historical Production, Use, In-Use Stocks, and Emissions of Short-, Medium-, and Long-Chain Chlorinated Paraffins. Environ Sci Technol. 56, 7895–7904.

[29] Babayemi JO, Nnorom IC, Weber R (2022) Initial assessment of imports of chlorinated paraffins into Nigeria and the need of improvement of the Stockholm and Rotterdam Convention. Emerg. Contam. 8, 360-370 https://doi.org/10.1016/j.emcon.2022.07.004

[30] Chen C, Chen A, Li L, Peng W, Weber R, Liu J. (2021) Distribution and Emission Estimation of Short- and Medium-Chain Chlorinated Paraffins in Chinese Products. Environ. Sci. Technol. 55, 7335–7343.

Figure B-21. Annual use of SCCP in PVC in construction in Country A

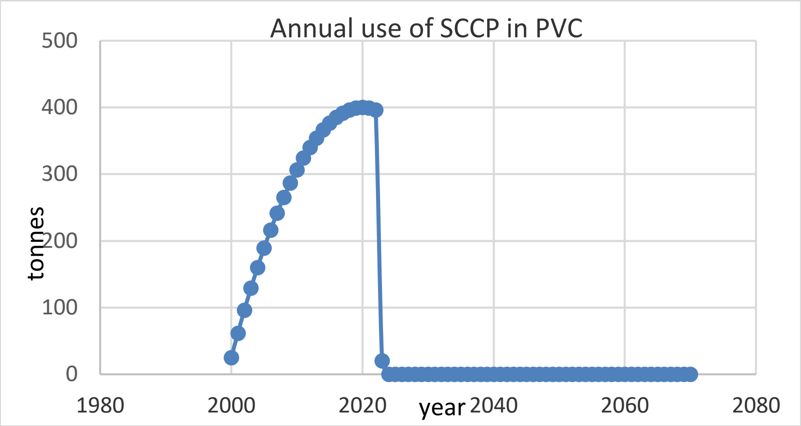


Figure B-22. SCCP in-use in PVC in construction in Country A

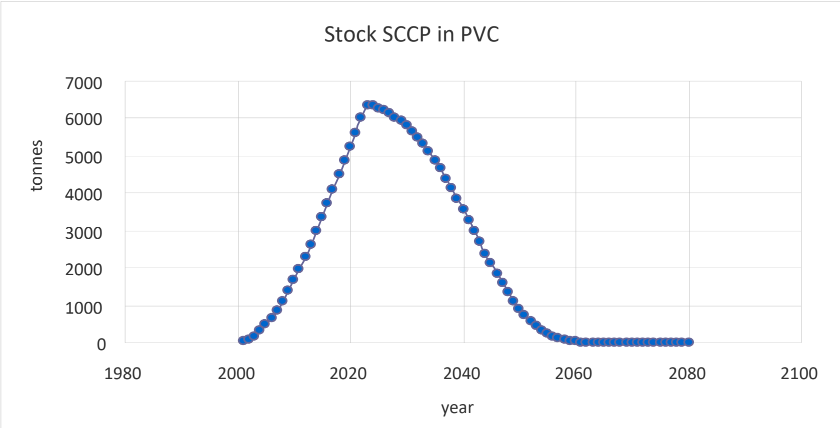


Figure B-23. Annual end-of-life of SCCP in PVC in construction

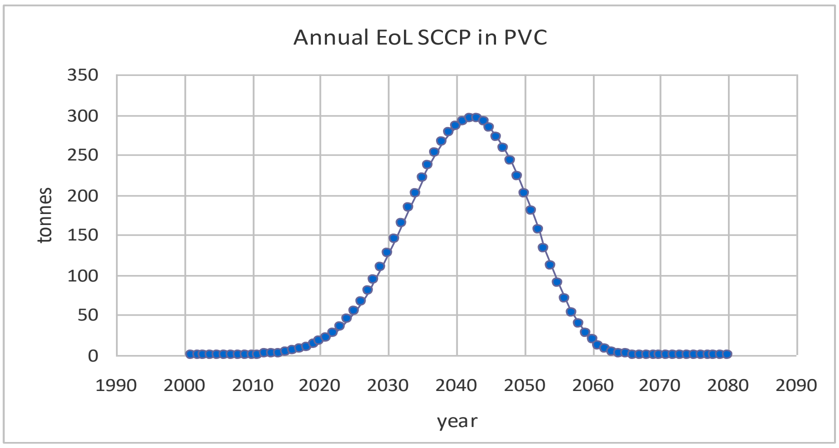


Figure B-24. Annual use of MCCP[18] in PVC in construction

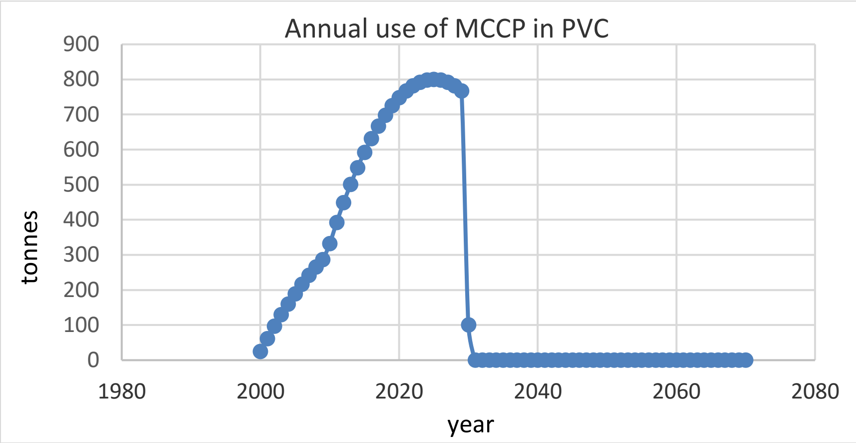


Figure B-25. In-use MCCP[18] in PVC in construction in Country A

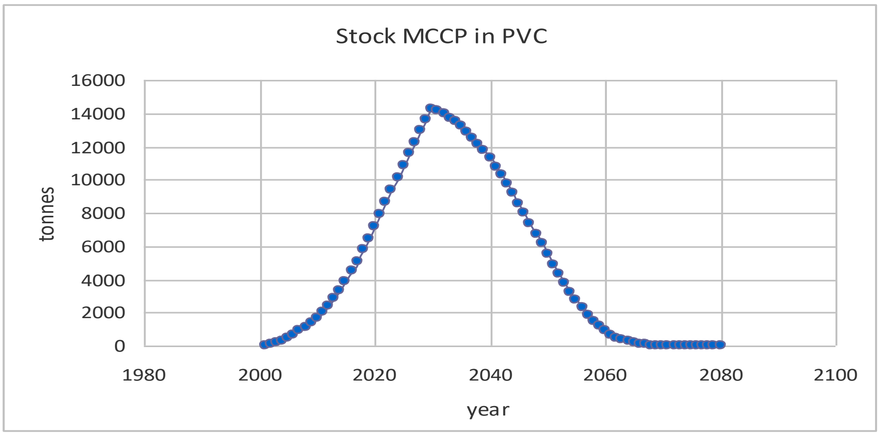
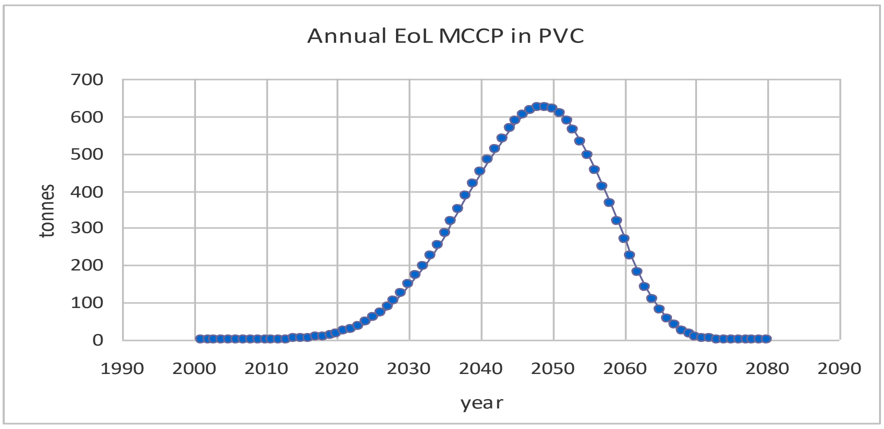


Figure B-26. Annual end-of-life of MCCP[18] in PVC in construction in County A



4.2.6.2 Assessment of SCCP and MCCP in PUR spray foam in construction

A relevant share of the production of SCCPs (5%) and MCCPs (6%) in China with the largest global production capacity are used in PUR spray foam adhesives (Chen et al. 2021).[28] PUR spray foam in Europe also contains up to 50% CPs by weight with mainly MCCP (Brandsma et al. 2021).[31]

The survey with insulation foam manufacturers indicated that spray urethane foams were not manufactured in Country A, but were only imported. All three insulation foam companies imported PUR spray foam. The companies provided data on the import and sales of PUR spray foam, including PUR spray foams sold by retailers. However, none of the companies were aware of the composition of the foam and the flame retardants they included.

Import and use data of PUR spray foam from 2000 to 2020 was available. SCCPs, exempted for adhesive use under the Stockholm Convention, including PUR spray foam, were listed in Annex A in 2017, with the exemption ending in 2023. The dynamic MFA/SFA assumes SCCPs use in PUR spray foams will cease in 2023 (Figure B-27). MCCP use[18] is expected to continue, but it may be listed under the Convention in 2025, with exemptions for MCCP[18] possibly extending until 2030 or later. The model assumes MCCP use in Country A will stop by 2030 (Figure B-26).

The total amount of SCCP in use in PUR spray foam in construction in the inventory year 2022 was estimated at 959 tonnes, with a maximum amount in use of 1,038 tonnes in 2024 (Figure B-28). The total amount of MCCP in use in PUR spray foam in construction in 2022 was estimated at 3,807 tonnes, with a maximum of 5,843 tonnes in 2031 (Figure B-31). For the inventory year 2022, it was estimated that only 1.7 tonnes of SCCP was included in PUR spray foam C&D waste while a maximum of 34 tonnes of SCCP in PUR spray foam in C&D waste was predicted for 2061 (Figure B-29). For MCCP for the inventory year 2022, it was estimated that only 1.7 tonnes was included in PUR spray foam C&D waste while a maximum of 174 tonnes of MCCP in PVC C&D waste was predicted for 2065 (Figure B-31).

[31] Brandsma, S. H., Brits, M., de Boer, J., & Leonards, P. E. (2021). Chlorinated paraffins and tris (1-chloro-2-propyl) phosphate in spray polyurethane foams–A source for indoor exposure?. J of Hazard Mater, 416, 125758.

Figure B-27. Annual use of SCCP in PUR spray foam in construction in Country A

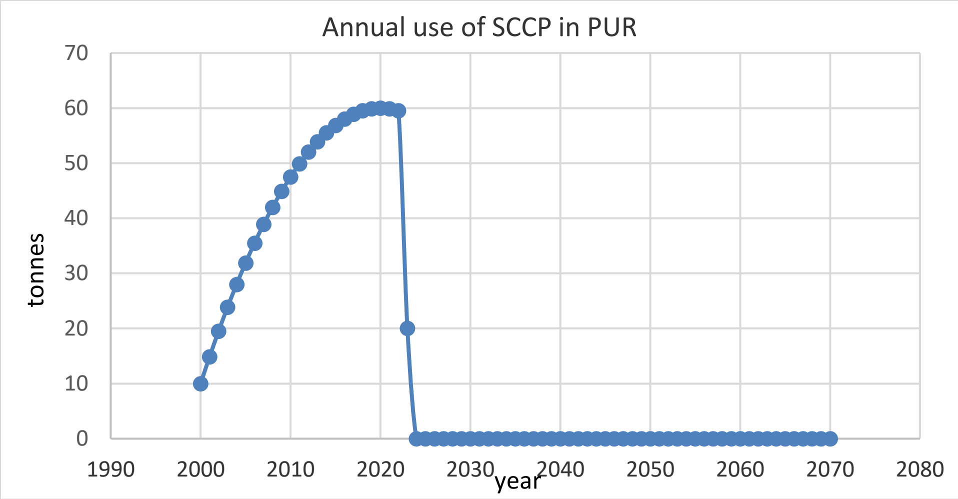


Figure B-28. In-use amount of SCCP in PUR spray foam in construction in Country A

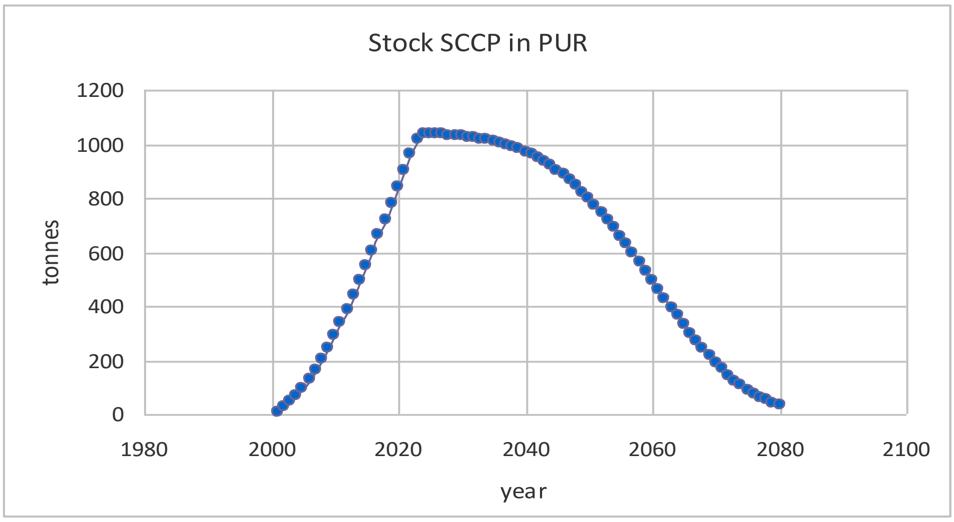


Figure B-29: Annual end-of-life SCCP in PUR spray foam in construction in Country A

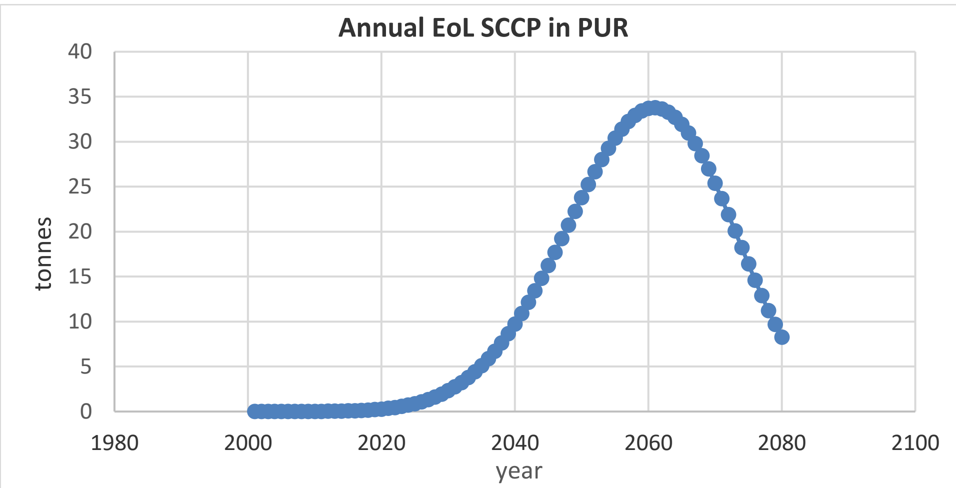


Figure B-30. Annual use of MCCP[18] in PUR spray foam in construction in Country A

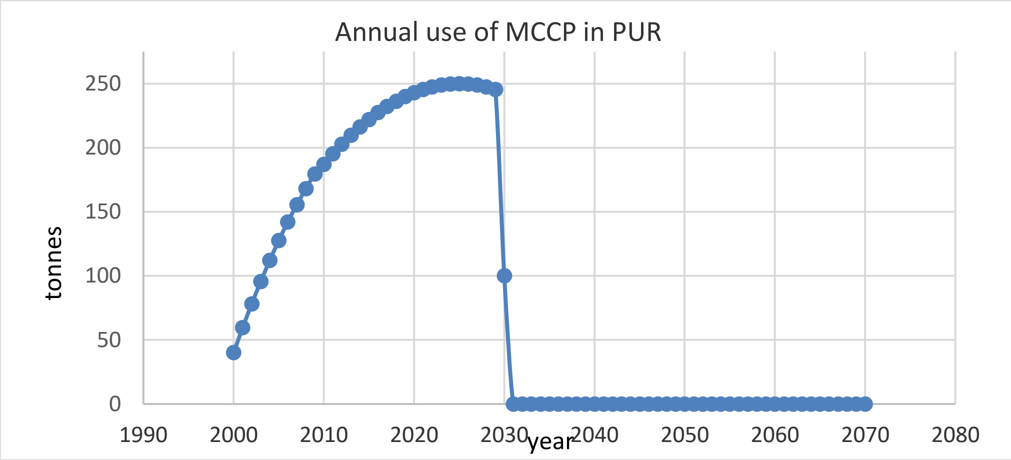


Figure B-31. Amount of MCCP[18] in-use in PUR spray foam in construction in Country A

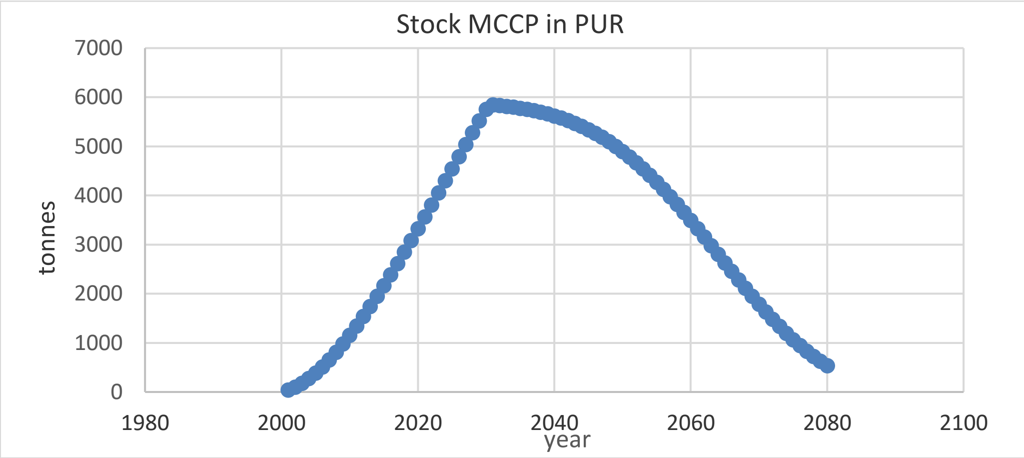
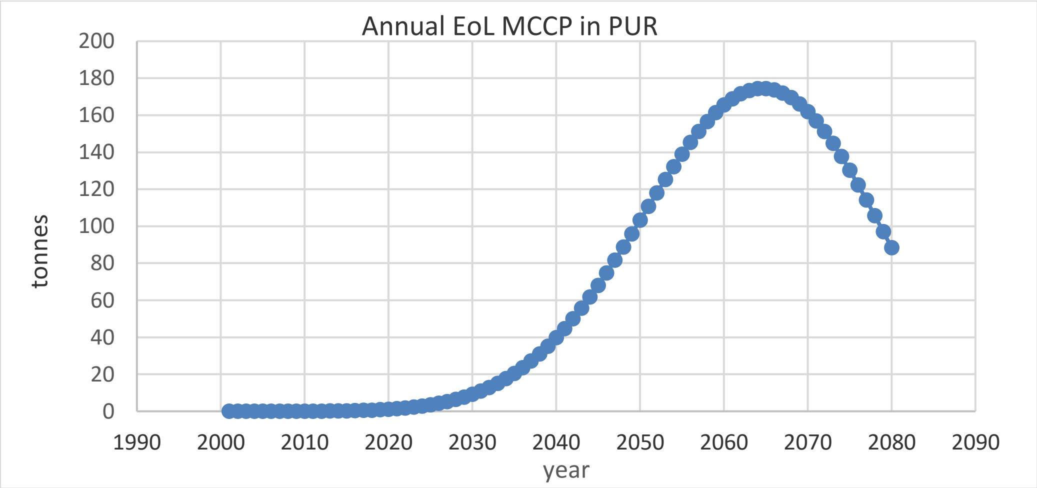


Figure B-32. Annual end-of-life of MCCP[18] in PUR in construction in Country A



4.2.7 Sealants in buildings and construction (PCBs, PCNs and SCCPs/MCCPs)

PCBs have been used in sealants, paints and cables in the construction sector from the 1950s to about 1975,[14] particularly in Thiokol sealants. The assessment of the use of Thiokol sealants in construction in the country revealed that they were not used in buildings, but that two dams constructed in 1968 and 1971 used sealants containing PCBs; 6 tonnes of sealant materials were used in the two dams. The average concentration of PCBs in the sealants was 10%[32] and therefore 0.6 tonnes of PCBs were used. An assessment of the two dams revealed that the sealants are still largely in the dam.

No information could be retrieved on the use of PCNs in sealants. Since the use was not confirmed and the overall production/use of PCNs was less than 10% of PCBs, no further assessment was conducted.

The use of SCCPs/MCCPs in PUR spray sealants is assessed under PUR foam above. For other sealants, the use of additives was not known and will be assessed in the NIP implementation.

4.2.8 Wood treated with PCP and other POP pesticides in the construction sector

According to the wood treatment companies, PCP was imported for wood treatment since the 1950s in the country until 2000 where a national restriction stopped all new imports of PCP. The maximum use of PCP was in the 1980s with approximately 80 tonnes per year and a slight decrease of use in the 1990s (See Figure B-33). Last remaining stocks of PCP (5 tonnes) were used in 2002 (Figure B-33). On average, 40% of the treated wood was used indoors with a service life of 75 years (Figure B-34). Approximately 60% of treated wood was used for utility poles and railway sleepers with an average service life of 40 years (
Figure **B-35**).

Considering service life and date use, the dynamic MFA/SFA shows that by 2002 slightly more than 1,200 tonnes of PCP had accumulated in wood during indoor use (Figure B-34) while the amount of PCP in outdoor use had accumulated to 1,520 tonnes in 2002 (
Figure **B-35**). With an average service life of 40 years, the amount of PCP in outdoor use had decreased by 2022 to approximately 705 tonnes and by 2050 most PCP in outdoor use had entered end-of-life (
Figure **B-35**). In 2022, the amount of PCP in end-of-life waste wood was estimated at 44.6 tonnes (Figure B-37; Table B-1). For indoor use, with an average service life of 75 years, the in-use amount slowly decreased and by 2050 an estimated 603 tonnes of PCP remained in use (Figure B-34). In 2022, 9.9 tonnes of PCP entered the waste stream from PCP-treated indoor use of wood (
Figure **B-36**). This is estimated to increase to 23.8 tonnes by 2050 where PCP in wood waste from indoor use reaches its maximum (
Figure **B-36**).

[32] PCBs concentration in Thiokol sealants were 2.8% to 22.3% (UNEP 2021)

Figure B-33. Annual use of PCP in wood treatment in Country A (outdoor & indoor use)

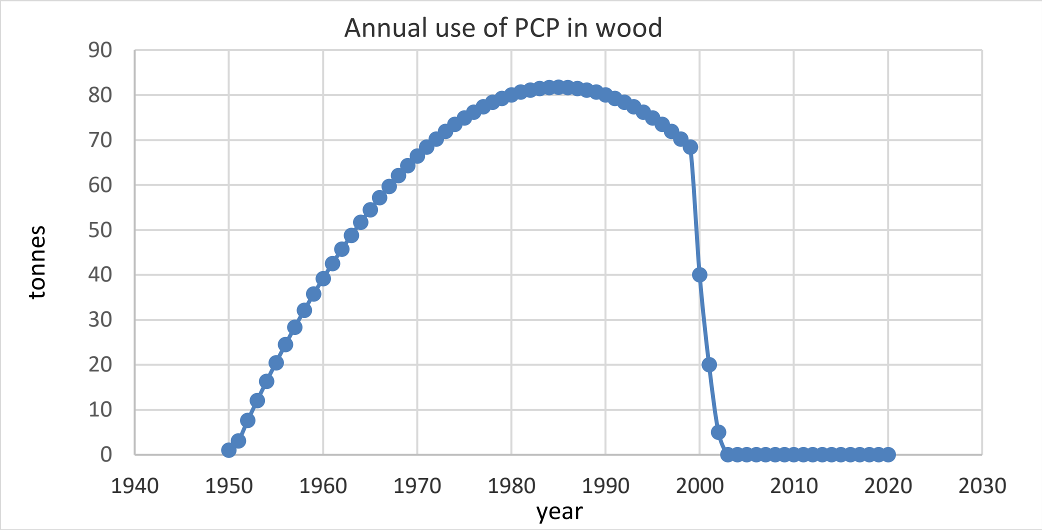


Figure B-34. Amount of PCP in use in wood indoors in Country A

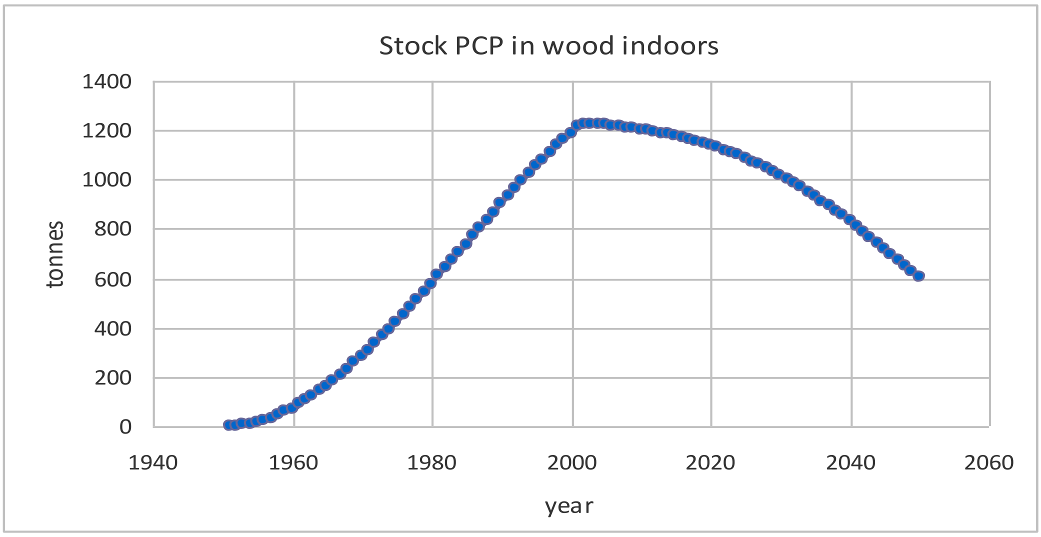


Figure B-35. PCP in use in wood outdoor (utility poles & railway sleeper) in Country A

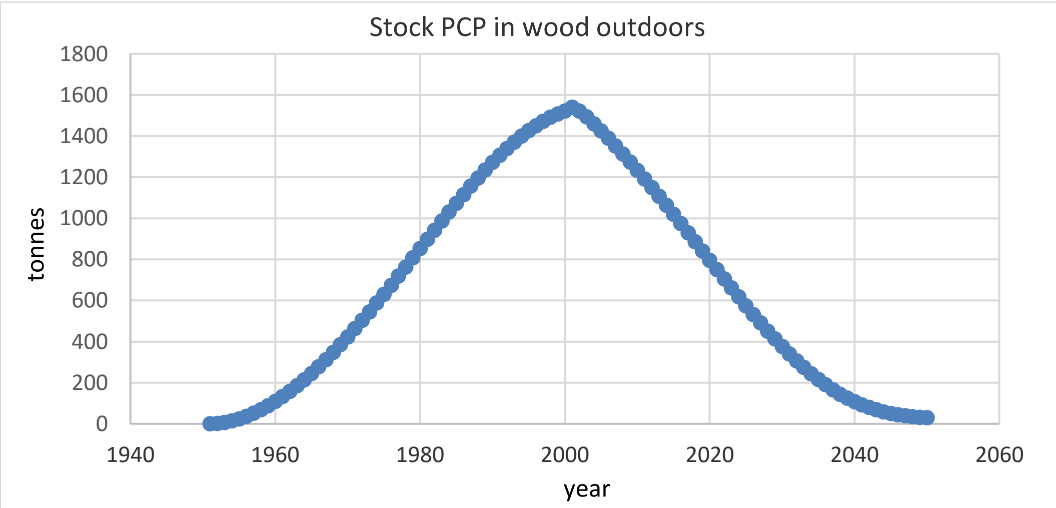


Figure B-36. Annual end-of-life of PCP in wood indoors in Country A

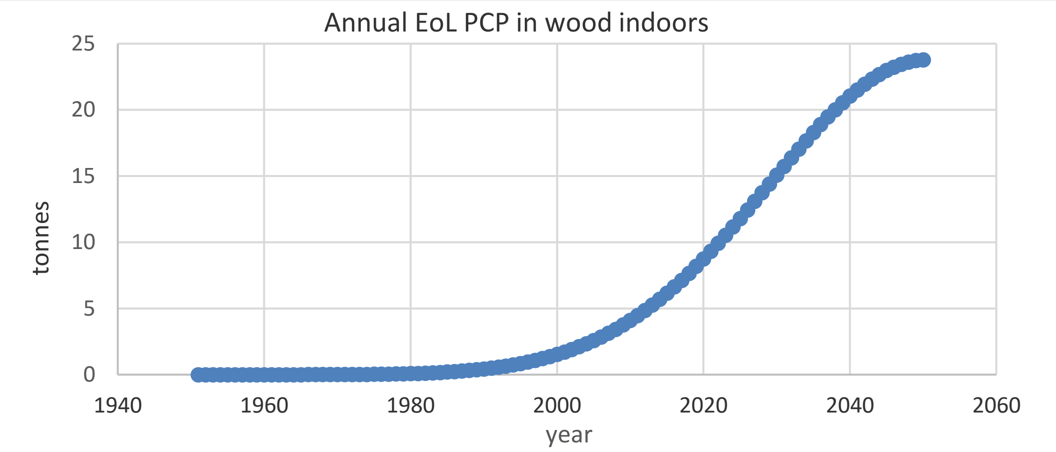
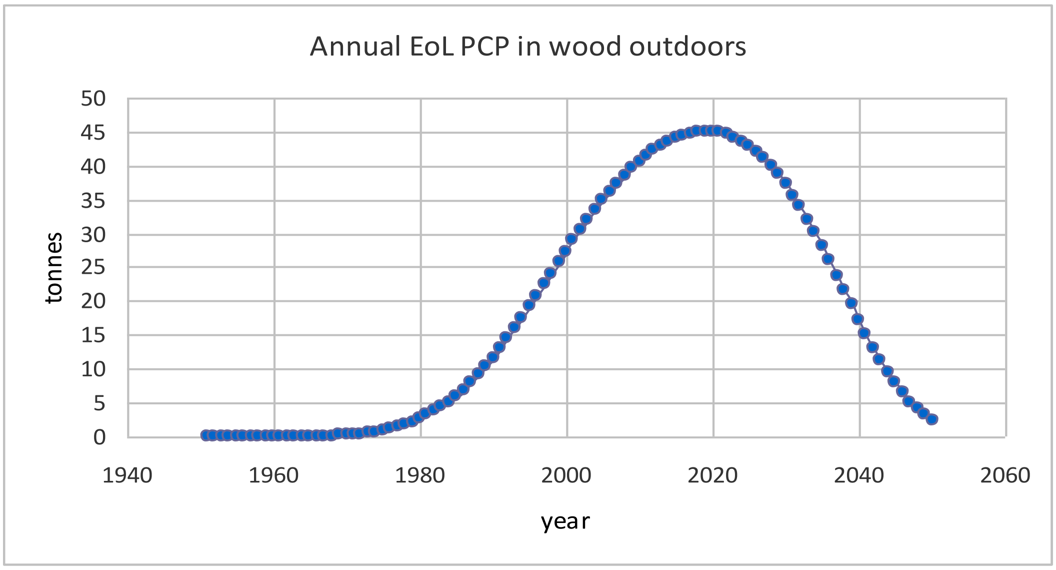


Figure B-37. Annual amount of PCP in end-of-life of wood outdoors (utility poles and railway sleepers)



According to information from the Ministry of Agriculture, no other POPs pesticides were used as wood preservatives in the country with the exemption of a minor amount of lindane and DDT in the 1960s, which could not be quantified. Major alternative wood preservatives used were chromated copper arsenate and creosote oil. In addition, these preservatives are hazardous and this wood needs finally be treated as hazardous waste.

4.2.9 Other POPs possibly present but not assessed (PFOS, PFOA and PFHxS) in the country

PFOS and PFOA have been used in the construction sector (see Section 2.2.3 in the Sectoral POPs inventory guidance[11]). However, no data on their use in this sector was found during the inventory assessment, promoting the inclusion of further assessment in the NIP action plan.

4.2.10 Halogenated phosphorous flame retardants

Halogenated phosphorous flame retardants have substituted PBDEs in PUR foam insulation boards. They are also used in PUR spray foam.[11] Since they are not listed as POPs, they were not quantified in this inventory. However, the high levels of PFRs in leachates in landfills in low- and middle-income countries highlight the need for ESM and avoiding the disposal of OPFR-treated materials in landfills.[11]

4.2.11 Summary of POPs in the construction sector in Country A in the inventory year

The Table B-1 below summarizes the total amount of POPs used in the life cycle: import, current use/stock and end-of life. The C&D waste has been disposed of in the past to landfills with the exemption of wood and metals, which were recovered. Therefore, the amount of POPs disposed of over the past 40 years has been compiled. Furthermore, with the dynamic MFA/SFA a reasonable prediction of POPs amount in C&D waste can be estimated for the coming decade(s) as described in this case study.

Table B-1: POPs in the construction sector and related life cycle stages in 2022 (in t)

(in tonnes)	POPs in new use in construction in the inventory year	Accumulated POPs in construction currently in use in inventory year	POP in C&D waste in the year (2022)
HBCD	0	2,656	16.1
decaBDE in PUR	0	46.4	0.9
decaBDE in PE/PP	0	581.6	0.6
PBDE (2009) in PUR	0	6,252	30.3
PBDE (2009) in PE/PP	0	5,815.8	5.6
SCCP in PVC	396.3	5,997.2	28.3
MCCP in PVC	781.3	8,606.3	29.4
SCCP in PUR	59.6	959.4	0.4
MCCP in PUR	247.5	3,807.3	1.7
PCP indoor	0	1,119.7	9.9
PCP outdoor	0	705.2	44.6

4.2.12 Other chemicals of concern

This first sectoral inventory of the construction sector did not assess other CoCs, such as heavy metals (e.g. lead, mercury), ODS/GHGs (CFCs, HFCs), PAHs, or PFRs (see Section 4.5 of the sectoral POP inventory guidance[11]). However, contacts were made with focal points from the Minamata, Basel and Rotterdam Conventions, as well as the UNFCCC GHG inventory team, to explore collaboration on a broader sectoral POP inventory covering pollutants across multiple MEAs. The Minamata initial assessment excluded mercury in buildings (only mercury lamps) and recommended future inclusion of mercury in buildings should be part of a mercury inventory.

Similarly, lead paint activities in the country only addressed current regulatory efforts, without assessing historical lead paint use. Future inventories should also cover lead paint in existing buildings and construction.

In addition, a contact to the Montreal Protocol team was established to see if an inventory of ODS and GHG stocks in the construction sector has been developed. Since this has not been done yet, it was concluded that in the refining of the POPs inventory, cooperation with the Montreal Protocol and GHG team should develop an inventory of CFCs, HCFC and HFCs gases in use/stock in the building sector.

5 Step 4: Managing and evaluating data

The current sectoral inventory of POPs in building and construction can be considered a preliminary inventory since it includes a range of uncertainties and assumptions (see below). The inventory considers the life cycle of POPs in building materials (insulation foam, other plastics, sealants and wood) – import, current use/stock, end-of-life treatment and disposal.

5.1 Evaluation of data and further improvement of the data

In this inventory step, data are assessed for completeness and plausibility, possibly including the comparison with data from other countries in the region.

The information gathered was assessed by stakeholders from the construction sector in a workshop and by commenting phase for the circulated inventory.

The inventory data were also compared with global production data, including per capita use as suggested by the Stockholm Convention QA/QC guidance document.[33]

Data gaps in this study have (partly) been filled by extrapolation of data. This was done, for example, for the import data before UN Comtrade data were available.

5.2 Gaps and uncertainties and improvements for developing a more robust inventory

5.2.1 Gaps and further assessment needs which might also be relevant for other countries

A range of major gaps were discovered that need to be addressed in the implementation (NIP):

- Some of the POPs are used in the construction sector, but no detailed information is available on frequency and concentration in (suspected) uses. This includes, in particular, PFOS, PFOA and PFHxS in the construction sector. Therefore, no inventory can be established. Rather, monitoring is needed and the labelling of products containing.
- For decaBDE and c-PentaBDE, there were some information gaps. For PE and PP sheets, the share of PE and PP treated with decaBDE was unclear and therefore, as middle bound approach, it was estimated that 50% of PE and PP contain decaBDE as flame retardant. For c-PentaBDE, only the use of PUR foam insulation was considered. The current estimate on decaBDE and c-PentaBDE in the construction sector has some uncertainty and monitoring of plastics in C&D waste and current used plastic is needed.
- The share of total use of PVC in the construction sector is based on the average use of PVC in the sector and not based on use data from the country. There is some uncertainty, but is considered relatively small.
- There is a lack of information on end-of-life management of C&D; the recovery of materials by the informal sector is unknown.
- The amount of POPs used in paints in the past and current imported paint is unknown.
- There is little data on PCNs in the construction sector.

[33] UNEP (2023) Short Guidance on implementing Quality Assurance and Quality Control (QA/QC) for POPs Inventories Data Validation.

5.2.2 Uncertainties in the preliminary assessment and means to address this uncertainty

The current preliminary inventory contains a range of uncertainties and assumptions:

- For decaBDE in PP/PE foil, an assumption that 50% of the foils from 2000 to 2017 contain decaBDE as flame retardant was made. Monitoring of PE/PP foil in C&D waste should be conducted, including information on the age of the building and the respective foil.
- For SCCPs and MCCPs, the estimate of imports in PVC and PUR spray foam from China is on a robust data basis. However, the amount of SCCP and MCCP in PVC from other regions has a high uncertainty and monitoring studies are needed for a robust assignment.
- The production and use pattern of SCCPs, MCCPs and LCCPs likely change with restrictions of SCCPs (exemptions stopped in 2023) and MCCPs (listing with exemptions in 2025). Therefore, the impact factors pattern will likely change in the future and production of SCCPs will reduce and possibly stop (and related assumptions were made in the inventories). However, there is a high uncertainty since a major CP producer (India) has not yet ratified SCCPs.
- DecaBDE is still produced in India, but there is no information on the use pattern. Therefore, there is a risk that some decaBDE is still used in new polymers in buildings.
- The service life estimates for some materials have uncertainties (e.g. wood in construction; PCB sealants in dams). The service life of respective materials should also be further assessed and possibly refined

5.3 Managing the data

The gathered general inventory data for the construction sector have been compiled:

- Insulation, other plastic and wood in the different life cycle stages in the construction sector.
- Materials in construction potentially contaminated by POPs and the amount of insulation materials, other plastics and wood.
- POPs (HBCD, PBDEs, SCCPs, MCCPs, PCBs and PCP/lindane) in the related materials.

These materials and POP substances have been compiled as a material/substance flow analysis.

The data, are valuable for managing C&D waste and predicting end-of-life plastics from C&D waste, will be shared with relevant departments (Ministry of Environment and other responsible ministries) and integrated into a database managed by the governmental body responsible for waste and resource management in cooperation with the National Statistical Office. A mechanism will be established to ensure that new data, particularly addressing gaps and uncertainties, are integrated into the database. This includes data relevant to other MEAs, such as XPS and PUR foam containing CFCs, HCFCs, HFCs and PUR foam containing mercury from mercury catalysts.

6 Step 5: Inventory report

The current case study of the construction sector has been established for this sectoral guidance. If countries develop similar inventor data and possibly MFA/SFA, then this can be included in the inventory reports for the individual POPs and included in the NIP update.