Annex 1[1]: Case Study of Inventory of POPs in the Building and Construction Sector in COUNTYRY A[2]

Table of Tables

[1] This is an Annex to the UNEP "*Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/ construction, electrical and electronic equipment, and vehicles*" Geneva, January 2023.
[2] This is a theoretical case study for a fictive "Country A" for educational purpose for learning the sectoral approach of POP inventories and understanding the benefits of dynamic material and substance flow analysis (MFA/SFA).

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Acknowledgement:

This case study has been developed by Dr. Roland Weber (POPs Environmental Consulting, Schwäbisch Gmünd, Germany), in cooperation with Dr. Sabine Dworak (Technical University Vienna, Austria) and Assoc. Professor Joshua Babayemi (University of Medical Sciences (UNIMED), Ondo, Nigeria) who developed the dynamic MFA/SFA figures and modelling.

1 Introduction

Construction and demolition (C&D) waste is the largest waste stream accounting for more than 30% of all waste generated and is increasing worldwide with the largest share of waste disposed to landfills (Purchase et al. 2021)[3]. Some of the chemicals used in the building and construction sector in particular in insulation foams, plastic and sealants/paints are POPs (e.g. HBCD, PBDEs, SCCPs, PCB, PFOA) (UNEP 2021[4]; see Chapter 2 of UNEP sectoral inventory guidance) with risk to human health and the environment.

The environmentally sound management of C&D waste containing POPs and other CoCs is important in order to ensure that the impacts of these chemicals on human health and the environment are minimized. This includes the identification and inventory of material stocks in the built environment containing POPs and other chemicals of concern.

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

Considering the large waste volumes which need to be managed in future, industrial countries move to a (more) circular economy for C&D waste with the approach of deconstruction to better recover individual waste fractions and managing pollutants (USEPA 2022)[5]. Within the deconstruction approach also plastic from buildings need to be managed in an environmentally sound manner. The German Environment Agency (2021)[6] made a first assessment of the recycling potential of plastic from demolition waste. For recycling and recovery of plastic and other materials, it need to be considered that a share of the plastic in buildings contain POPs which are still produced and used (e.g. DecaBDE, SCCPs, PFOA) and also some legacy POPs where production has stopped but which are still in the use in buildings (e.g. HBCD, c-PentaBDE, PCB).

Please note: This is a theoretical case study for a country for educational purpose for learning the sectoral approach of POP inventories and understanding the benefits of dynamic material and substance flow analysis (MFA/SFA) which is used for a state of art assessment of POPs in sectors and can inform policy makers and the waste management sector on current waste stocks and generation of waste in future.

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

In this first step the objectives and scope of the inventory was defined and a work plan developed (see e.g. General Guidance on POP inventory development[7] and HBCD Inventory Guidance[8]). 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;

[3]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

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

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

[6] 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.

[7] UNEP (2020). General guidance on POPs inventory development. Revised from document UNEP/POPS/COP.9/INF/19/Add.1.

[8] UNEP (2021). Guidance on preparing inventories of hexabromocyclododecane (HBCD).

- 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 end of November 2022.
The following stakeholder 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 code;
- 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 POP inventory was developed following the 5 step inventory approach provided by the General Guidance on POP Inventories and Figure 1 of this sectoral POPs inventory guidance.
Since it was the first sectoral POPs inventory for the construction sector, a Tier I assessment needed first to be conducted (see below) followed by a Tier II inventory compilation. For the prediction of future POP amount in construction waste additionally a dynamic substance flow analysis was suggested (one of Tier III inventory approach). Due to the lack of analytical capacity no measurements of materials or C&D waste was conducted.
A work plan was developed to compile data and distribute tasks. A multi stakeholder team was compiled for the task lead by the Stockholm Convention focal point and a Professor with expertise in the construction sector and material science.

4 STEP 3: collecting and compiling the data

4.1 Tier 1 preliminary assessment

The initial assessment relies on collecting "low-hanging fruit", i.e. existing information, desk studies, literature searches, interviews etc. First 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); (e) Understanding the life cycle of POP and the potential for emissions (UNEP 2020).
In the preliminary assessment of the information in the sectoral POP inventory guidance (Chapter 2 Building and construction sector) and other inventory guidance following findings were made:

- Insulation foams were 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 plasticised (e.g. flooring and laminates) and rigid form (e.g. window frames and doors)

- Various sealants were used in construction
- Wood were used in construction of houses and outdoor use (utility poles; railway sleepers)

For the selection of POPs to consider in the inventory, the sectoral guidance (in particular Chapter 2)[9] and respected references were studied and individual POPs assessed. For this also the respective POPs inventory guidance documents were consulted including the Stockholm Convention inventory guidance documents for HBCD[8], for PBDE[10], for SCCP[11], for PCNs/PCBs[12] and for PCP[13]. Furthermore, an assessment was conducted on existing inventories of POPs in construction such as the HBCD inventory in the NIP of Myanmar[14], the POP BFR inventory of Switzerland[15] and the HBCD inventory of China.[16]
Since no national inventory on POPs in construction had be 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 was used to develop a working group to develop a sectoral inventory for the construction sector with an emphasize of POPs.
For some of the POPs the use in construction has stopped decade ago (e.g. PCBs, PCNs and PCP) while others are still produced (SCCPs, decaBDE). After study of the inventory guidance documents and the gathered Tier I information it was decided to assess the following POPs in construction:

- HBCD in EPS/XPS insulation
- PBDEs in PUR insulation and in 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 needs to be stressed that there are other chemicals of concern in the buildings and construction like lead in paint, mercury, asbestos, or Ozone Depleting Substances (CFC/HCFC) or GHGs (HCFC/HFCs) in insulation. These CoCs might be assessed in a synergistic inventory of the construction sector (see this sectoral POPs inventory guidance. In this first POP inventory in County A the focus was on multiple POP inventories in buildings and construction.
The team collected following information as a basis existing past and present national data on the import and use of HBCD and articles containing HBCD from major stakeholders and sources including (see Table 1):

[9] UNEP (2023) Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/ construction, electrical and electronic equipment, and vehicles.
[10] UNEP (2021). Draft guidance on preparing inventories of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants.
[11] UNEP (2019). Guidance on preparing inventories of short-chain chlorinated paraffins (SCCPs) (Detailed guidance).
[12] UNEP (2021) Guidance on preparing inventories of polychlorinated naphthalenes (PCNs).
[13] UNEP (2021). Guidance on preparing inventories pentachlorophenol and its salts and esters.
[14] The Republic of the Union of Myanmar (2021) National Implementation Plan of Myanmar for the Stockholm Convention on Persistent Organic Pollutants.
[15] 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
[16] 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.

A) Assessment of the presence of relevant industries:

Following were the outcome of the assessment of relevant industries and importers:

- No production of POPs or brominated or chlorinated organics take 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[17])
- Four main importer of chemicals which possibly could import flame retardants or plasticizer
- At least 3 EPS/XPS producers were identified offering insulation material
- One of these producers also produce polyurethane (PUR) foam used in insulation
- A range of importers of construction materials such as PUR spray foam, paints
- Two wood companies providing 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 were compiled;

B) Assessment of fire safety regulations and building codes

The past and present fire regulations related to buildings and insulation materials were assessed since they determine the use of flame retardants including certain POPs (Chabonnet et al 2020)[18]. It was found that the flammability standard require that all polymers used for insulation requires to meet certain flammability standards (ISO 5660–1[19]). The requirement to meet certain flammability criteria existed since the early 1990s in the country.

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 to landfills. Wood was recovered to a large extent and used either as fire wood (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. Furthermore the informal sector

These information were compiled as basis for Tier II assessment and discussed with stakeholders for an initial feedback.

[17] Please note: MCCP is not listed in the Convention but is currently assessed by the POPRC, meet the Annex D criteria for a POP and is currently evaluated in the final risk management evaluation phase (Annex F). MCCP is often marketed in CP mixture containing SCCPs above 1% and these mixtures are already considered POPs.

[18] 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

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

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 by using the approach of the sectoral guidance (Chapter 4) and considering the POPs specific inventory guidance documents.
Basic information were compiled for the construction sector on the following:

- Information from EPS/XPS and PUR producer in the country (information on product and on 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 water proof 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[20]
- International trade statistics for import of PVC[20]

4.2.2 Service life of the major products/articles containing POPs

Important for the assessment of the presence of a POP in current use and waste is the amount and time of installation and the service life of the respective products. The service life is also important for the dynamic material and substance flow analysis to predict the amount of POPs in C&D waste the next 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, e.g. reliability, completeness, temporal and geographical correlation, or other correlation.[21] Finally, a service life estimate can be determined for an MFA model.
Please note: 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[15]; [22]Viitanen 2014[23]; Li et al. 2016[16]; Wang et al. 2021[24]). For the current MFA/SFA calculation the following service life were considered:

[20] UN Comtrade database http://unstats.un.org/unsd/comtrade/
[21] 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(5): 1050–1063.
[22] 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.
[23] 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.
[24] 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.

- 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 thiocol 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 on 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

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/substance 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[25,26].

A key aim of material flow analysis is to visualise 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 e.g. 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 the 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 needs to be managed and hence support decision making in regards to required treatment capacities.

In the current study the system boundary is Country A. The material included in this study are insulation foams, other plastic, sealants and wood in buildings. The substances considered in the substance flow is 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 focus 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 in

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

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

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

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 insolation 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 where 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

Information which were needed for HBCD calculation for EPS/XPS insulation foam:

- The information on the time 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 retardant were used during this time 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. Furthermore they 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 2017 (Figure B-1).
The EPS contained in average 0.8% HBCD. The XPS used contained in average 2.5% HBCD. The total stock of HBCD in 2017 in EPS/XPS insulation was 2720 t which decreased already somewhat to 2657 t for the inventory year 2022 (Figure B-2). The total amount of HBCD containing EPS in 2017 was 204,034 t which also decreased to 199,238 t in the inventory year 2022 (Figure B-4; Figure B-6). The total amount of HBCD containing XPS in 2017 was 20468,011 t 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 t (Figure B-3). The related EPS/XPS waste amount in 2050 is estimated to 5674 t EPS and 1891 t of XPS (Figure B-5). While the amount of EPS/XPS waste amount in the inventory year 2022 was 5674 t EPS and 1891 t of XPS (Figure B-5). The dynamic MFA/SFA with an estimated average service life of 50 years indicates that by 2060 still 529 t of HBCD is expected in use (Figure B-2) in 39,709 t of EPS and 13,236 t 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.

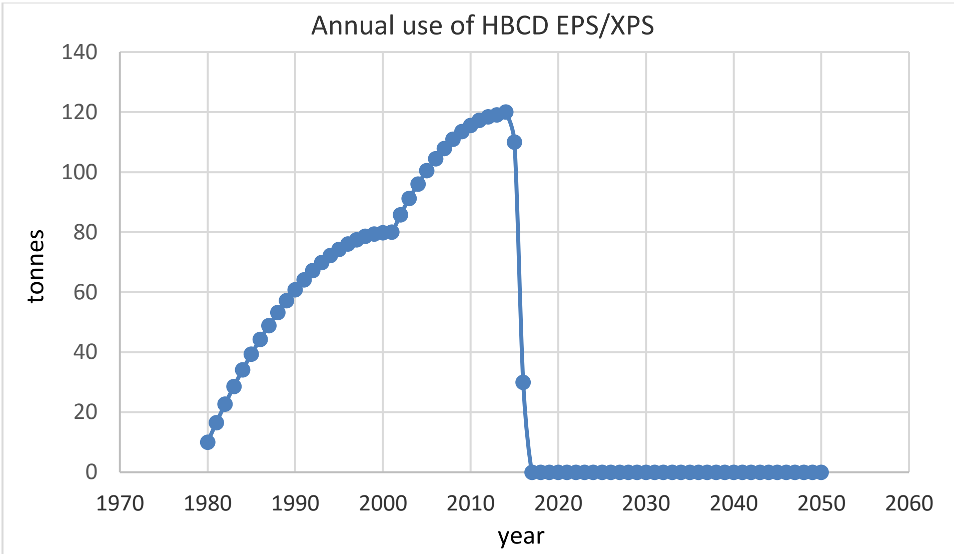

Figure B-1: Annual use of HBCD in EPS/XPS insulation foams in construction in County A

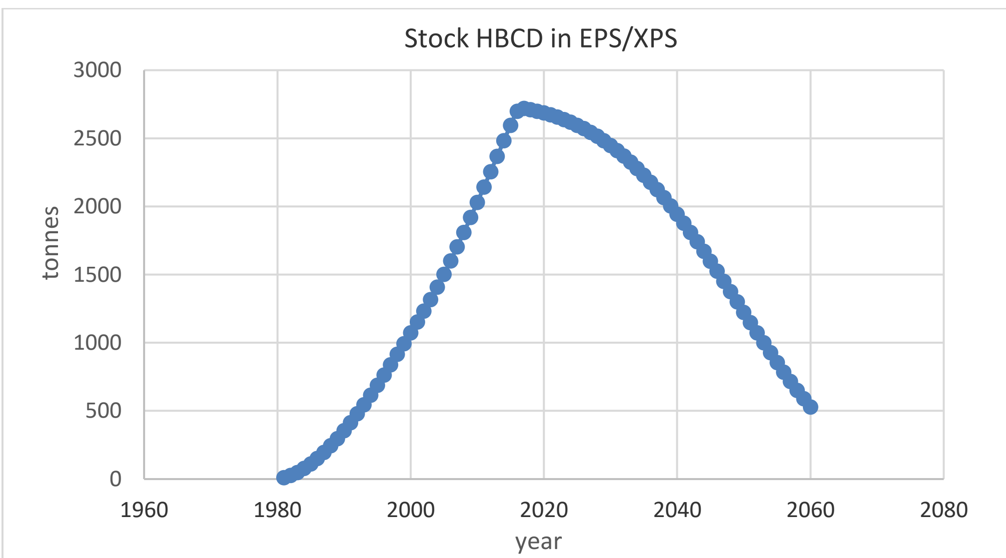

Figure B-2: In use HBCD in EPS/XPS insulation foam in construction in Country A

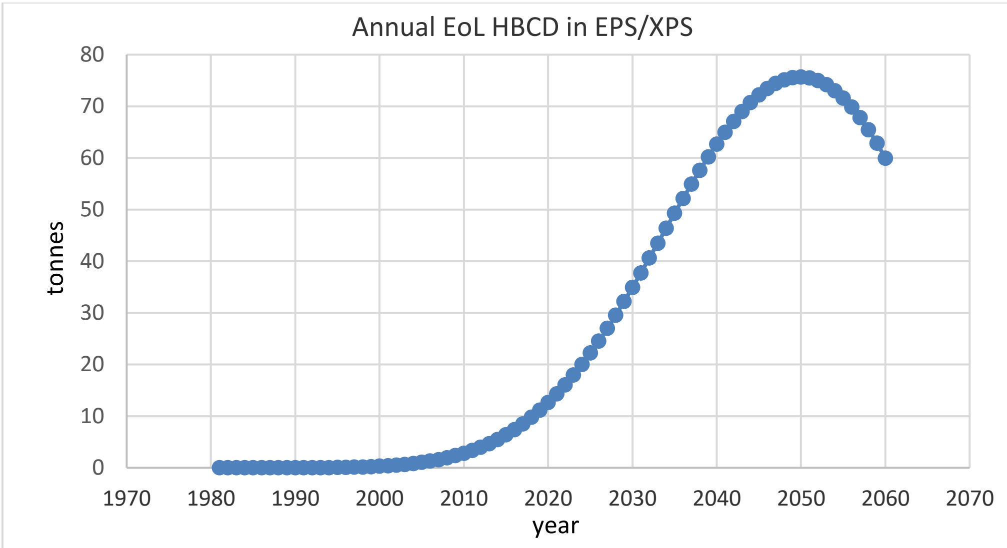

Figure B-3: Annual EoL HBCD in EPS/XPS insulation foam in Country A

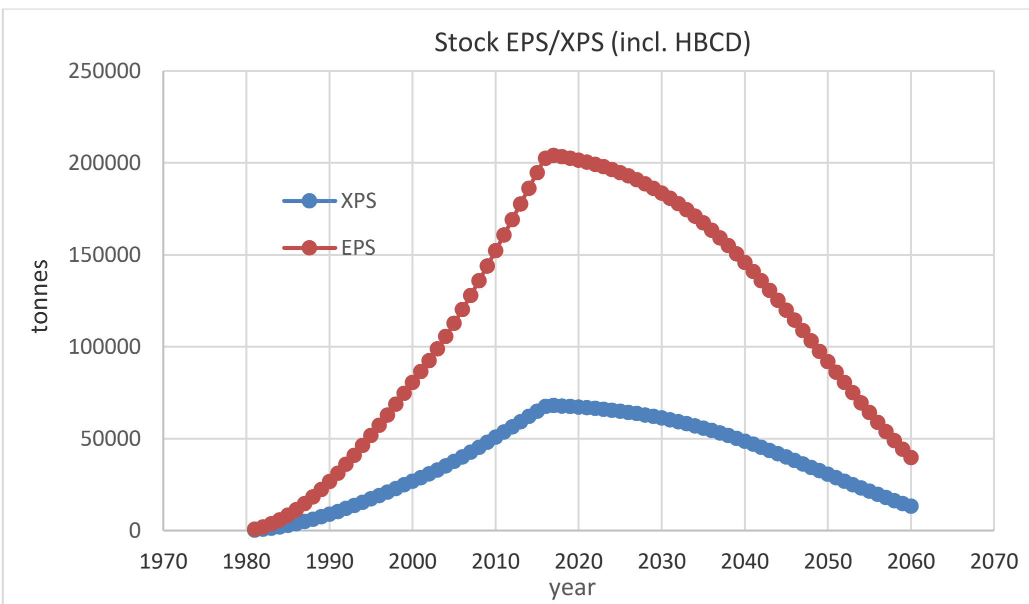

Figure B-4: Amount of in-use EPS/XPS containing HBCD in Country A

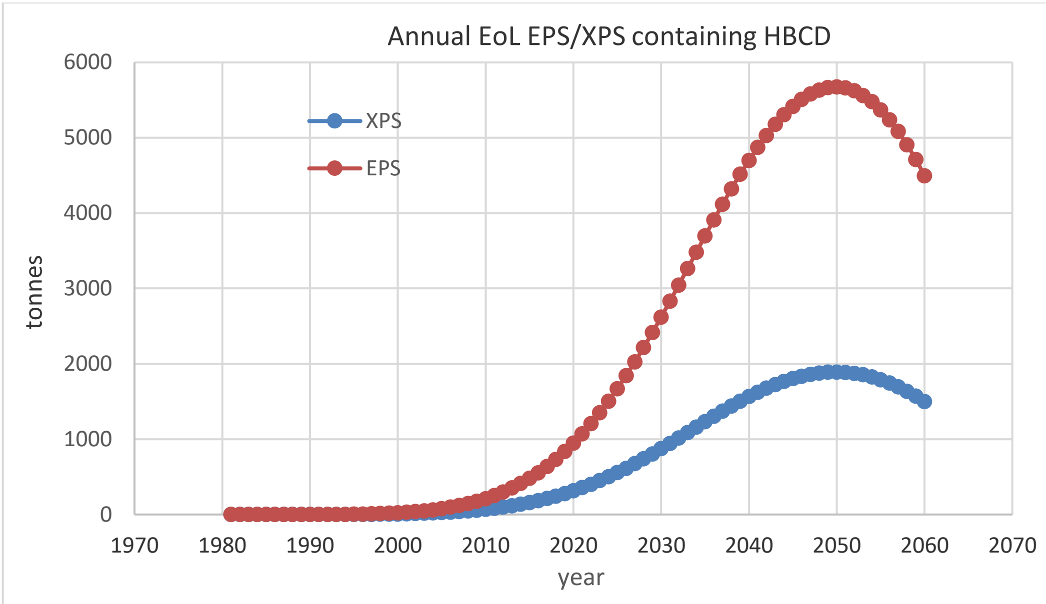

Figure B-5: Annual amount of EoL EPS/XPS containing HBCD in construction & demolition waste in Country A (Please note that EPS/XPS installed after 2017 containing other flame retardants are not included. However they need to be separated from HBCD containing EPS/XPS).

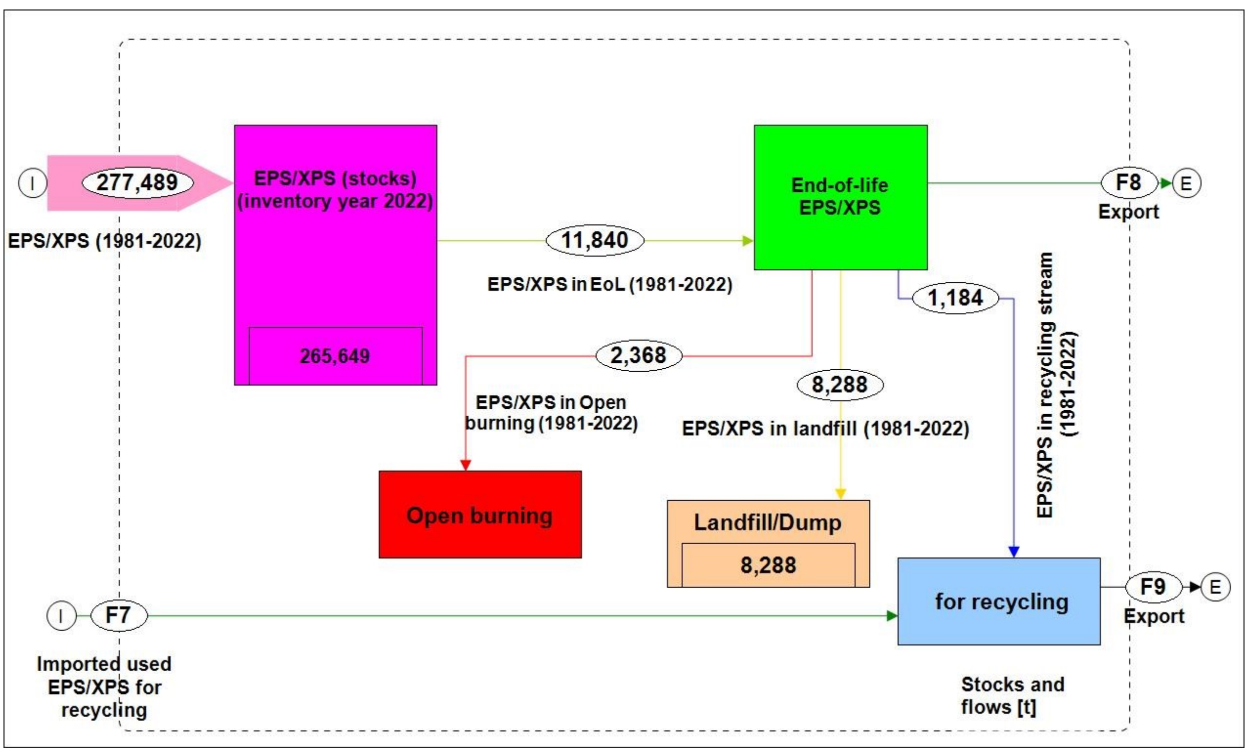

Figure B-6: Material flow analysis of EPS/XPS insulation containing HBCD in Country A (Please note that EPS/XPS installed after 2017 containing other flame retardants are not included here. However they need to be separated from HBCD containing EPS/XPS).

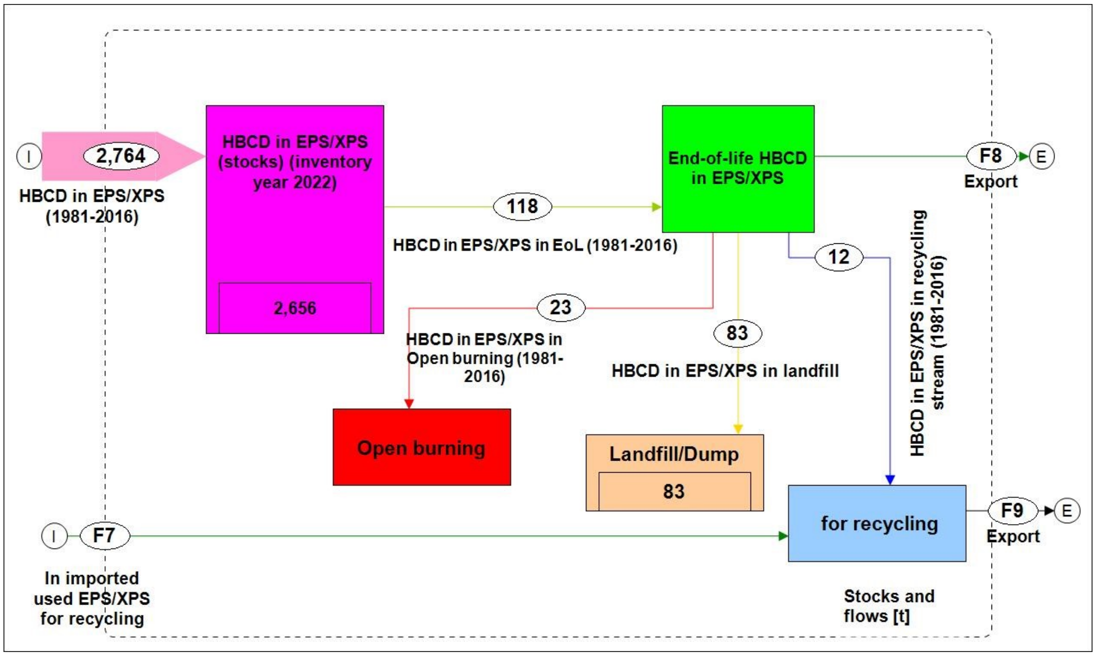

Figure B-7: Substance flow analysis of HBCD in EPS/XPS insulation in Country A.

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

DecaBDE and c-PentaBDE (containing tetraBDE/pentaBDE listed 2009) have been used in construction mainly in PUR foams and PE and PP foils.[9,10] While the production and new use of c-PentaBDE stopped in 2004, the production and use of decaBDE still continue with an exemption in the use of PUR foam insulation.[9,10] In the assessment it was found that one of the insulation foam producer also produced PUR foams containing c-PentaBDE and decaBDE as flame retardant with the phase out of c-PentaBDE in 1995 and stop of decaBDE use in 2012. Then the production changed to phosphorous flame retardants instead. Also decaBDE was used as flame retardant for PE and PP.

The information compiled for PBDEs were 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 in 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 were 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 t. This stock had already decreased somewhat to 46.4 t in the inventory year 2022. It is estimated that by 2060 almost all c-PentaBDE containing PUR foam entered EoL (Figure B-9 and Figure B-10).

DecaBDE was used in PUR foam insulation from 1980s to 2012 in Country A (Figure B-11). The total stock of decaBDE in 2012 was 6408 t in the year where new decaBDE use was stopped in Country A (Figure B-12). This stock had decreased somewhat to 6252 t in the inventory year 2022 (Figure B-12). It is estimated that 2060 618 t of decaBDE is present in PUR foams in construction (Figure B-12 and Figure B-13). In 2060 about 112 t of decaBDE is expected in EoL while for the inventory year 2022 only 30.3 t of decaBDE entered EoL with a maximum of decaBDE in PUR insulation waste of 220.5 t from construction in 2047 (Figure B-13).

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

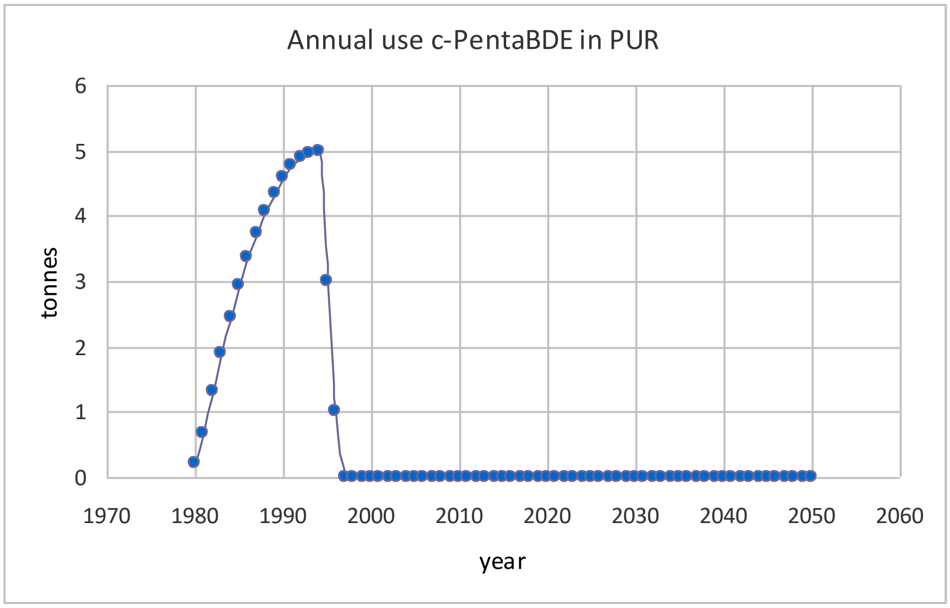

Figure B-8: Annual use of C-PentaBDE in PUR foams in construction in Country A

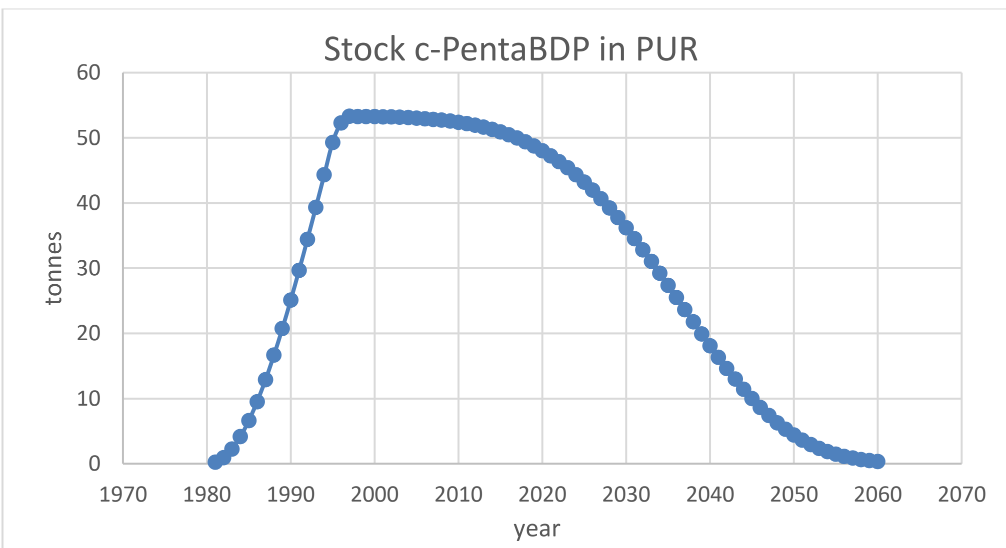

Figure B-9: Stock of c-PentaBDE in PUR foams in the construction sector in Country A

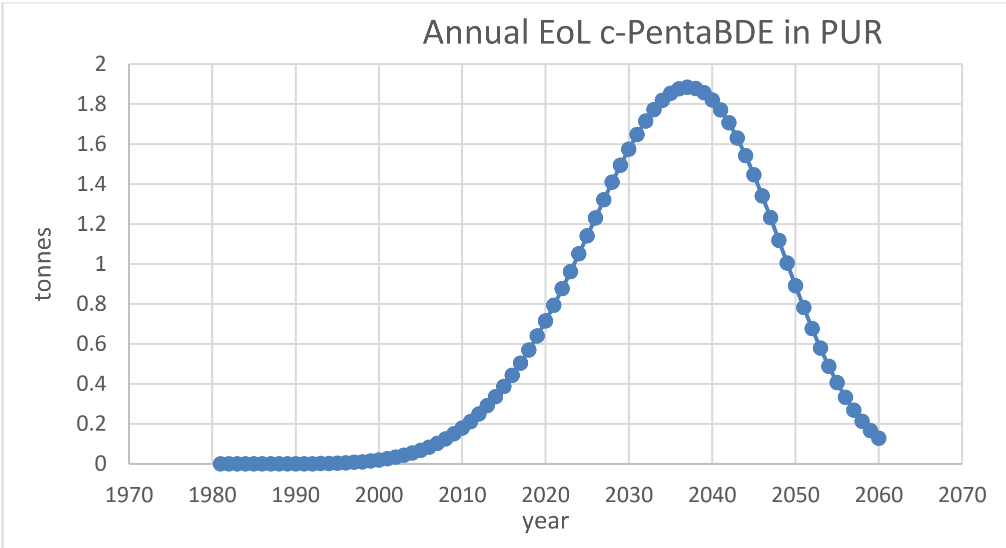

Figure B-10: Annual EoL of c-PentaBDE in PUR foam in Country A

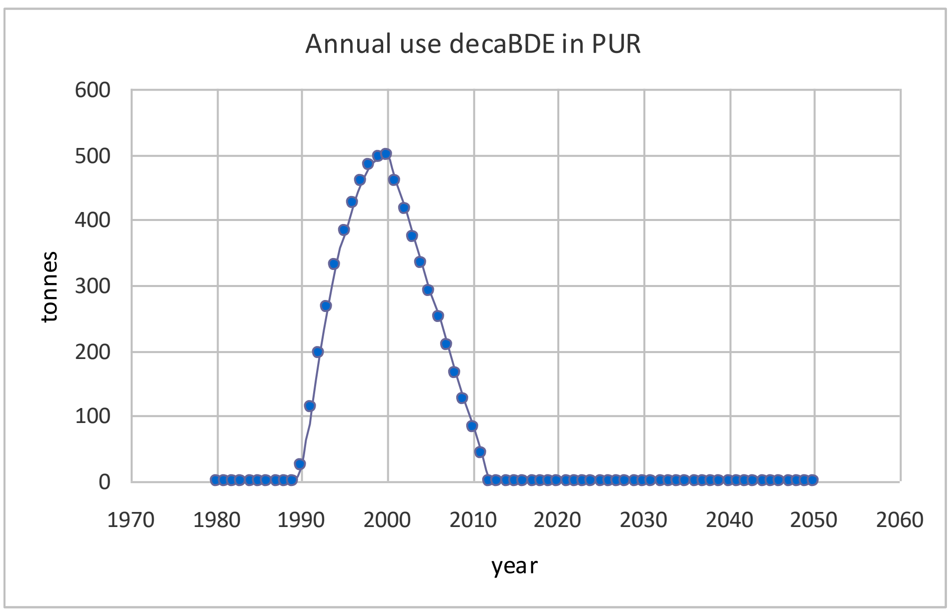

Figure B-11: Annual use of decaBDE in PUR foam in construction in Country A

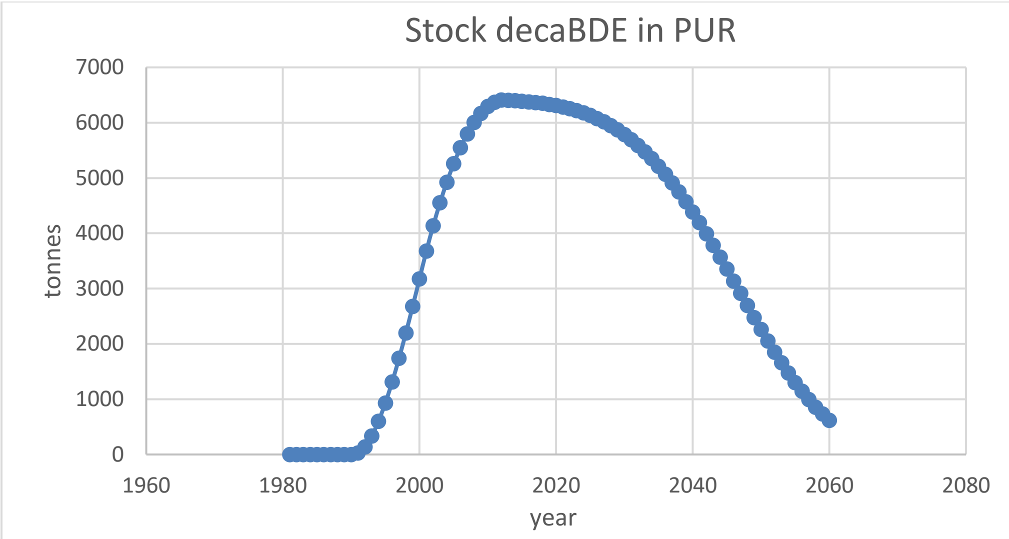

Figure B-12: In-use decaBDE in PUR foam in construction in Country A

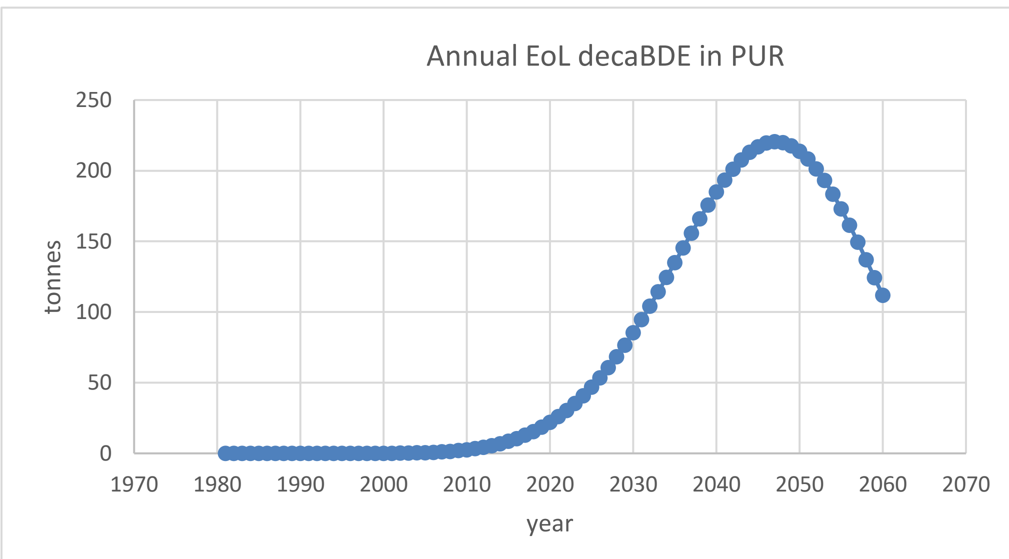

Figure B-13: Annual EoL of decaBDE in PUR foams from construction in Country A

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

PBDE have been used in PE and PP foils. The amount of PE and PP use data in construction were available from 2000 to 2020 from the national building material association. The flame retardant in the plastic sheets were however not known since these foils were imported. Since decaBDE is known to be a major flame retardant in this use it was assumed that 50% of the PE and PP plastic sheets used in construction contained decaBDE (10%) until 2017 when decaBDE was listed in the Stockholm Convention without exemption for PE and PP in construction. Before 2020 the flammability standard for buildings did not require that PE/PP in construction were flame retarded. Therefore it was assumed that PE/PP used before 2000 were not flame retarded. Based on this assumptions and an average service life of 50 years, the total amount and in-use of decaBDE in PP/PE foils were estimated (Figure B-15).

However an activity was included in the action plan of the National Implementation Plan to monitor PBDEs and other POPs and CoCs in plastic and other polymers in construction and clarify/verify former uses of POPs in construction. Based on these assessment, it was calculated that

The total amount of decaBDE in-use in PE/PP foil in construction in 2020 was 583 t in the year where new decaBDE use was stopped (Figure B-14). The amount of in-use decaBDE had slightly decreased to 582 t in the inventory year 2022 (Figure B-15). It is estimated that in 2060 173 t of decaBDE is present in PP/PE foils in construction with only 3 t remaining in 2080 (Figure B-15). In 2022 only 0.6 t of decaBDE in PP/PE were present in C&D waste while the peak amount of 20.1 t of decaBDE is expected for 2055 (Figure B-16). The related PP/PE waste amount containing decaBDE in the inventory year 2022 was only 5.8 t (Figure B-18) it increased to 201 t in 2055 (Figure B-18). The maximum stock of PE/PP containing decaBDE in construction was 5834.6 t in 2020 and 5815.8 in the inventory year 2022 (Figure B-17 and MFA in Figure B-19) with a prediction of an in-use amount of 1732 t in 2060 (Figure B-17). The total amount of PE/PP foil in-use and in EoL in C&D waste is however considerable higher since it includes PE/PP foil installed before 2000 and also PE/PP foil containing other flame retardants installed after 2017. Therefore a larger amount of PE/PP will need to be managed in C&D waste with possible separation need of PE/PP foil containing decaBDE if some of the PE/PP foil without decaBDE will 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) in Country is compiled in Figure B-20.

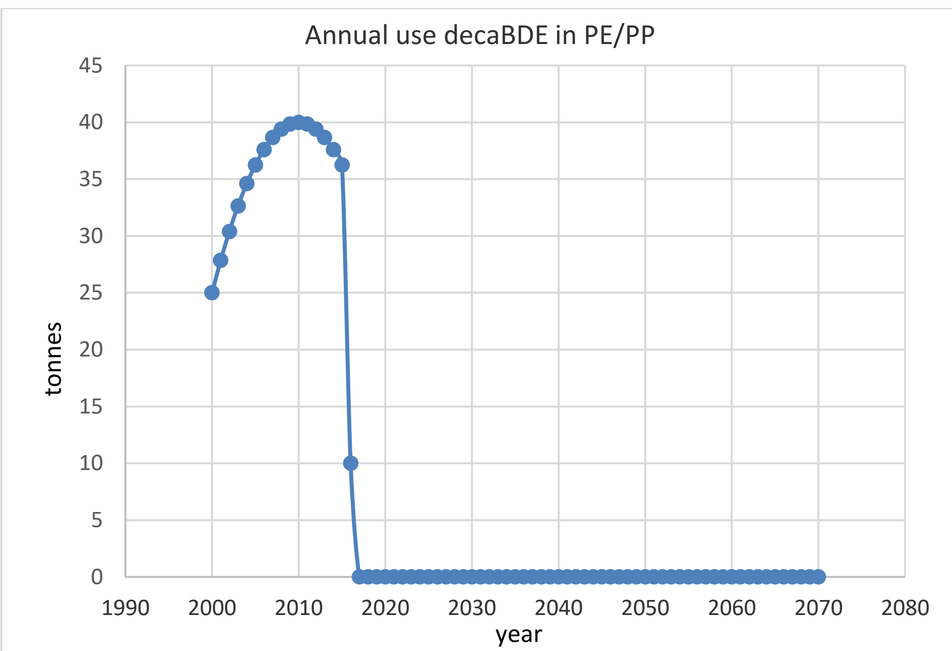

Figure B-14: Estimated annual use of decaBDE in PE/PP in the construction in Country A (The flammability standard changed in Country A in 2000 requiring flame retarded PE/PP in buildings)

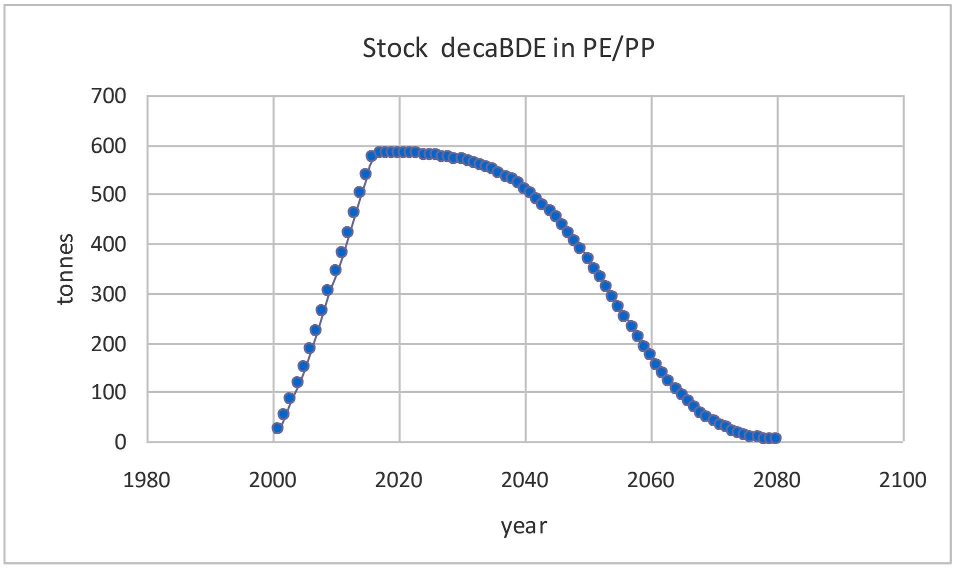

Figure B-15: In-use decaBDE in PE/PP in buildings in Country A

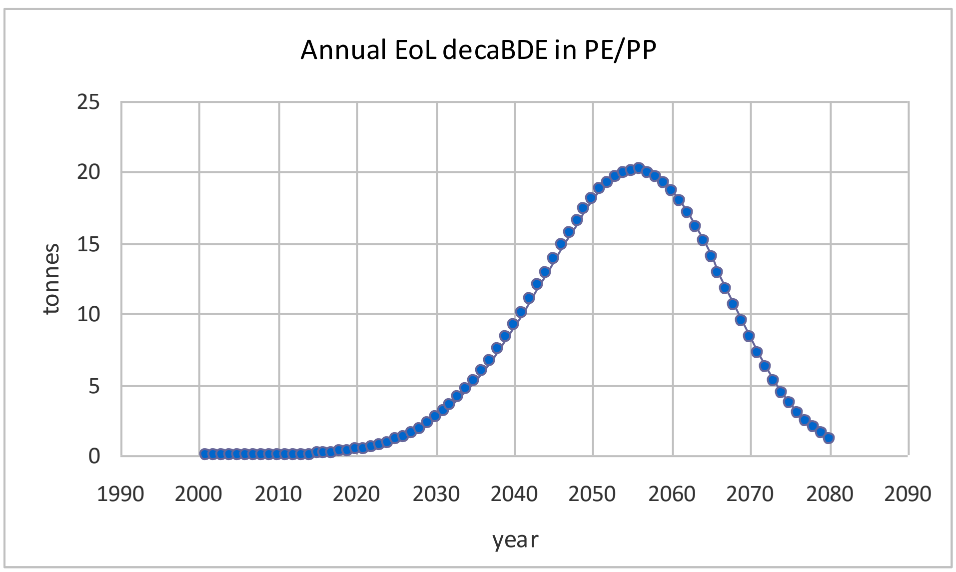

Figure B-16: Annual EoL of decaBDE in PE/PP in buildings in Country A

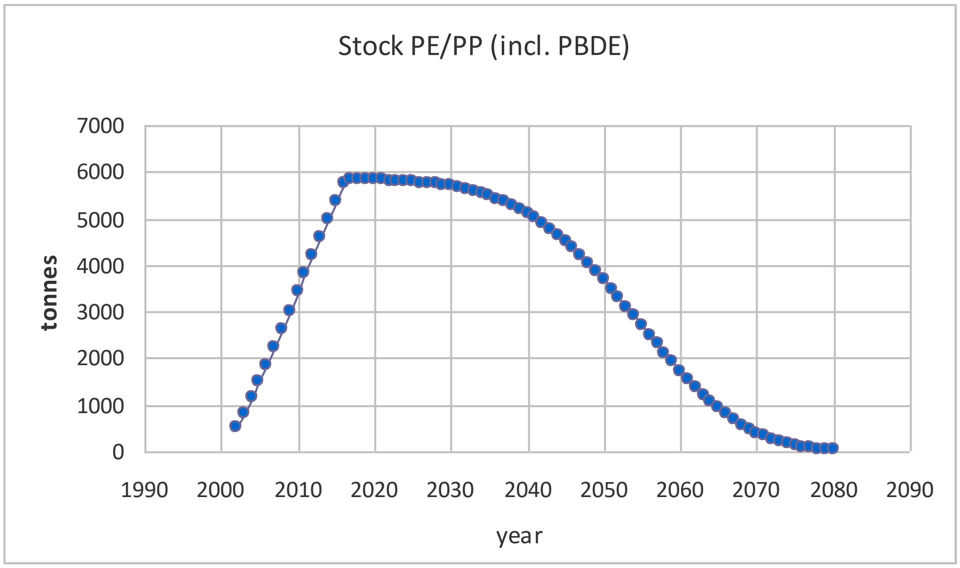

Figure B-17: In-use PE/PP containing decaBDE in construction in Country A

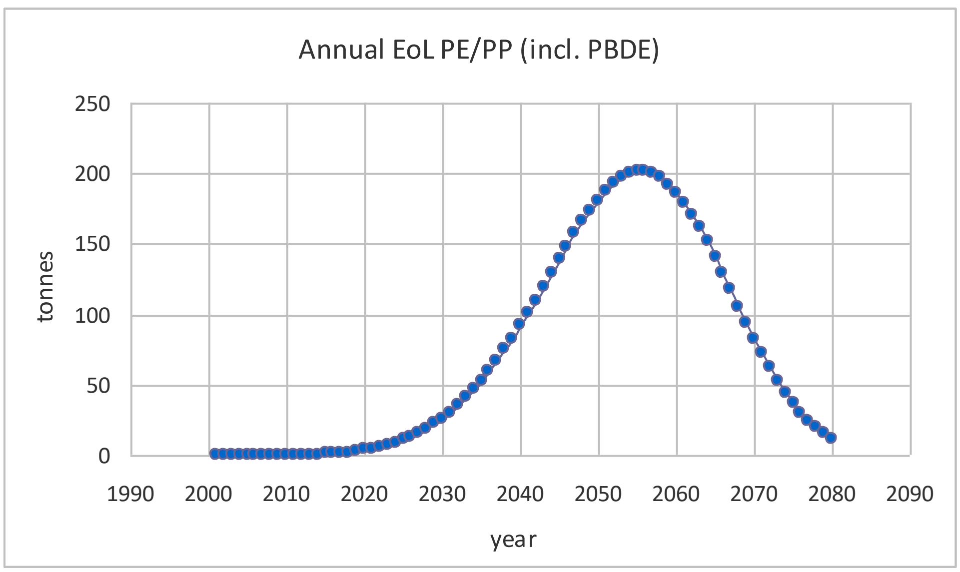

Figure B-18: Annual EoL of PE/PP containing decaBDE in C&D waste in Country A

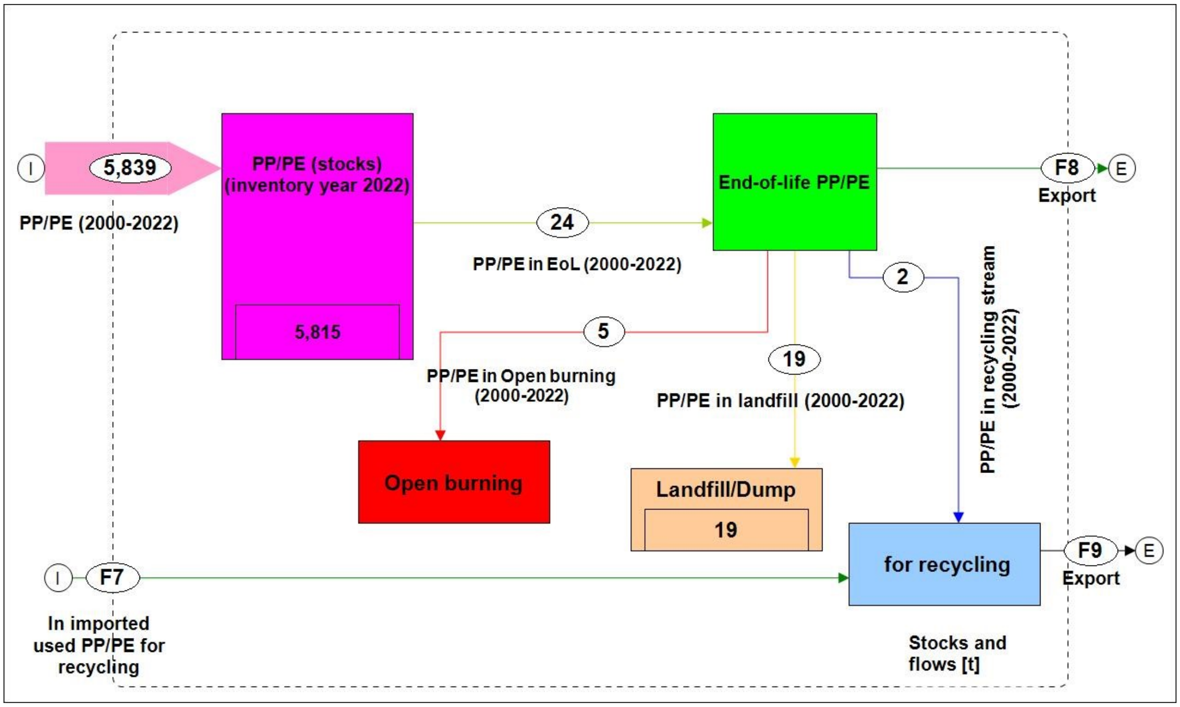

Figure B-19: MFA of PE/PP containing decaBDE in buildings in Country A

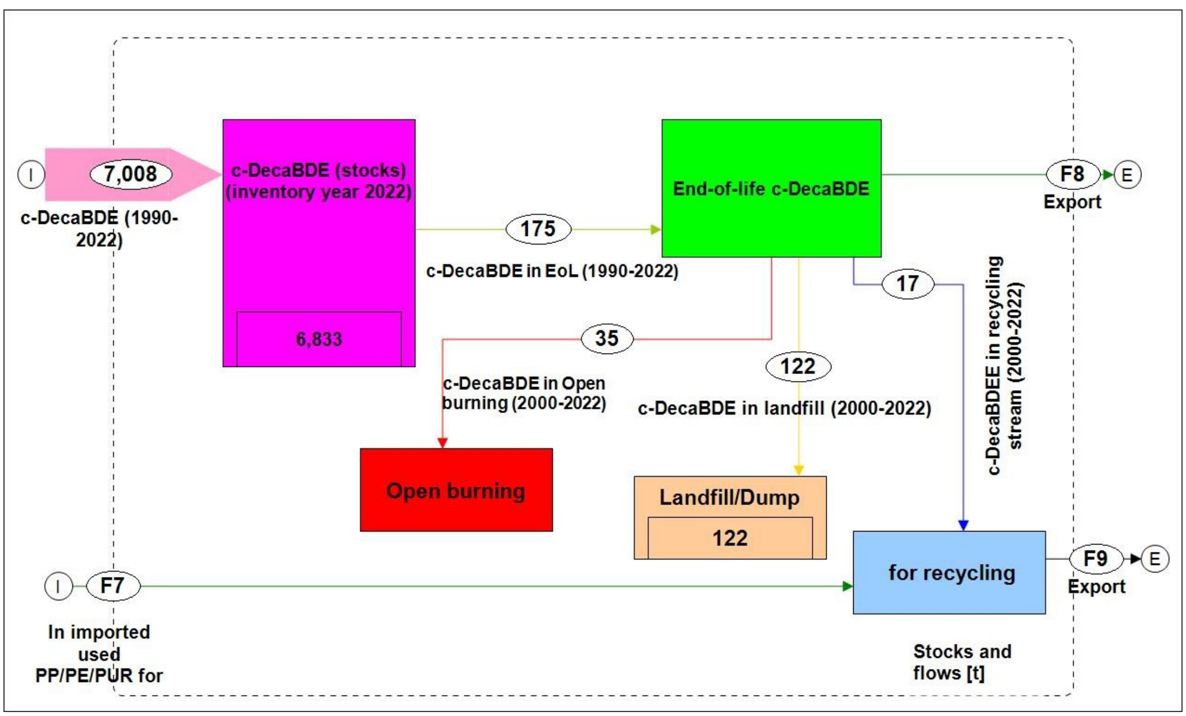

Figure B-20: SFA of decaBDE in PE/PP and PUR foam in buildings in Country A

4.2.6 Inventory of SCCP and MCCPs[17] in construction

4.2.6.1 Assessment of SCCP and MCCP[17] in PVC in construction

In the last 20 years the largest share of SCCPs and MCCPs[17] were used in PVC (ca. 70%) (Chen et al. 2022).[27] Approximately 50% of all PVC is used in construction. Since PVC containing SCCPs or MCCPs[17] are not labelled, it is difficult to estimate the share of PVC containing SCCP and MCCPs[17]. A recent study on a preliminary inventory of SCCP/MCCP[17] in Nigeria established a methodology to estimate the amount of SCCPs and MCCPs[17] imported into the country based on imports based on HS Codes of product groups potentially containing additives (Babayemi et al. 2022)[28]. For the PVC inventory the study used only HS Codes of PVC containing plasticiser[28]. As impact factor for the different PVC categories, the monitoring of SCCPs and MCCPs[17] in materials and products in China has been used (Chen et al. 2021)[29]. The same approach[28] of estimating SCCPs and MCCPs[17] 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.

Considering that more than 50% of total PVC globally are used in construction, it was considered that from the imported PVC approx. 50% were used in buildings in different applications. For the SCCPs use it was assumed for the dynamic MFA/SFA that SCCP will stop production/use in 2023 when the 5 years specific exemption will end (Figure B-21). For MCCP it is assumed that the use will continue. However MCCP is currently in the POPRC[17] and could possibly be listed in the Convention in 2025. Assuming a specific exemption for MCCP, the use of MCCP might continue until 2030. Therefore the use of MCCP in the dynamic MFA/SFA was considered to stop in 2030 for use in country A (Figure B-24).

The total amount of SCCP in-use in PVC in construction in the inventory year 2022 was estimated to 5997 t with a maximum in-use of 6358 t in 2023 (Figure B-22). The total amount of in-use MCCP in PVC in construction in 2022 was estimated to 8696 t with a maximum of 14235 t in 2030 (Figure B-25). For the inventory year 2022 it was estimated that only 28 t of SCCP was included in PVC C&D waste while a maximum of 295 t of SCCP in PVC C&D waste was predicted for 2042 (Figure B-23). For MCCP for the inventory year 2022 it was estimated that only 29 t was present in the PVC C&D waste in Country A while a maximum of 623 t of MCCP in PVC C&D waste was predicted for 2049 (Figure B-26).

[27] 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.

[28] 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

[29] 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.

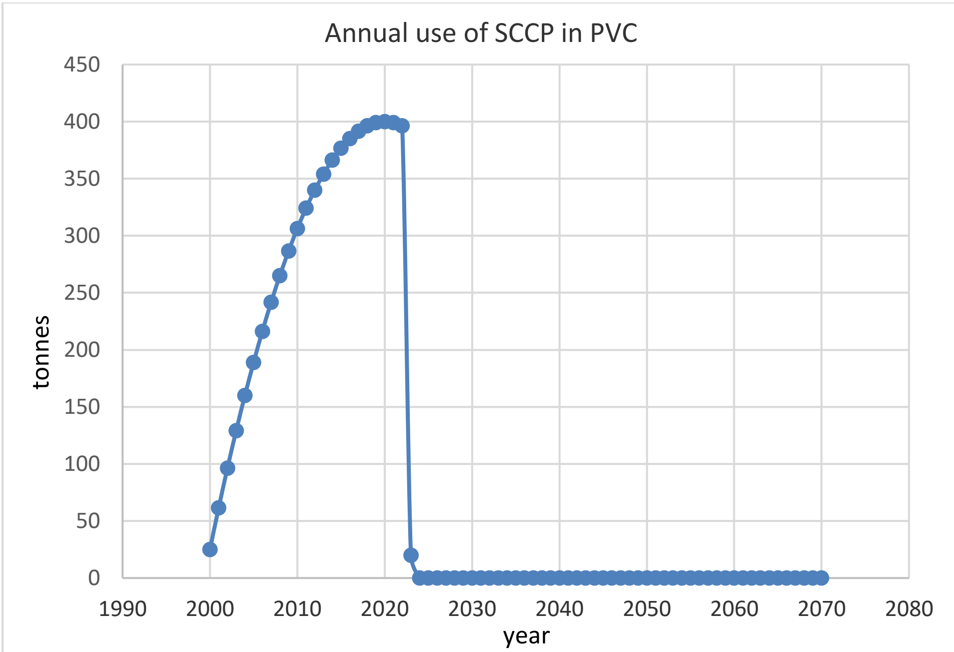

Figure B-21: Annual use of SCCP in PVC in construction in Country A

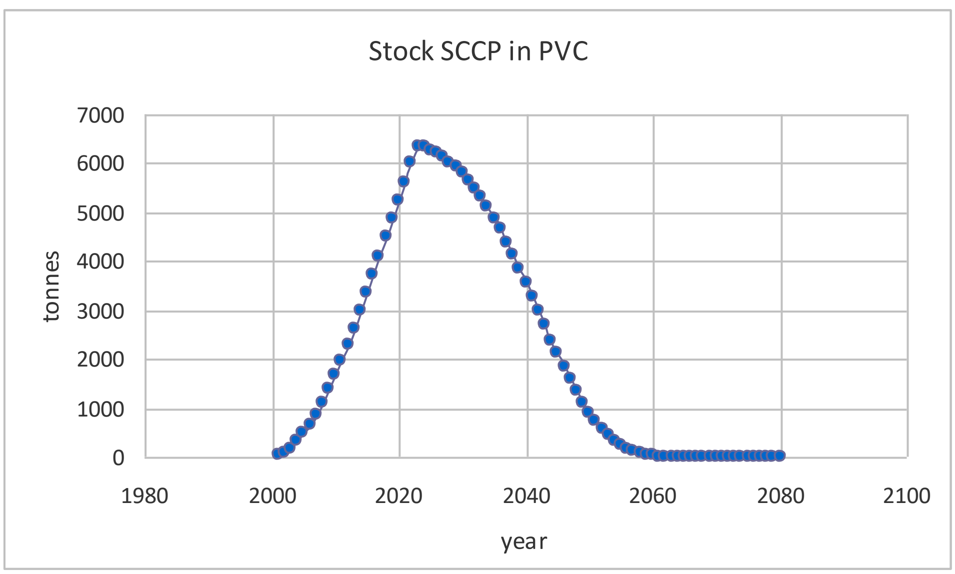

Figure B-22: SCCP in-use in PVC in construction in Country A

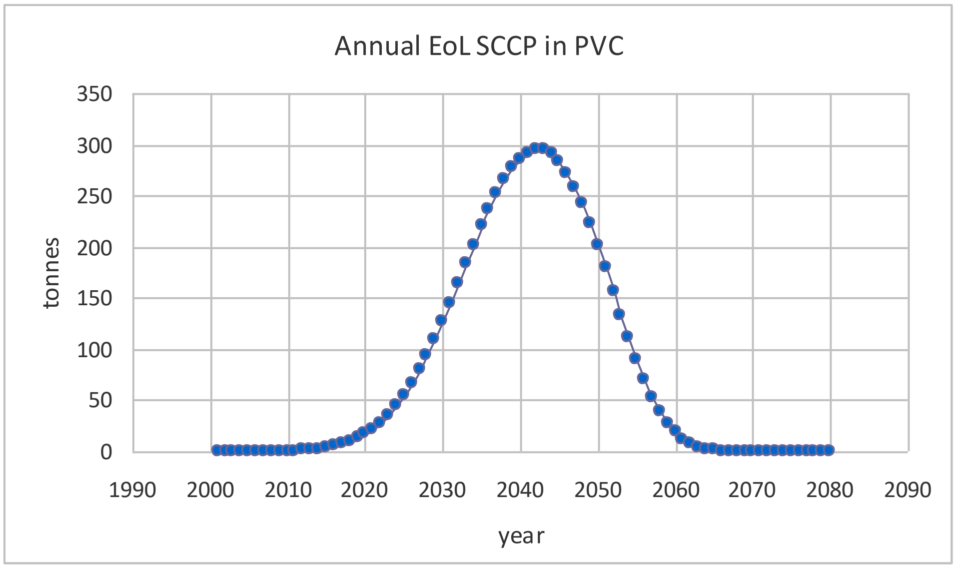

Figure B-23: Annual EoL of SCCP in PVC in construction

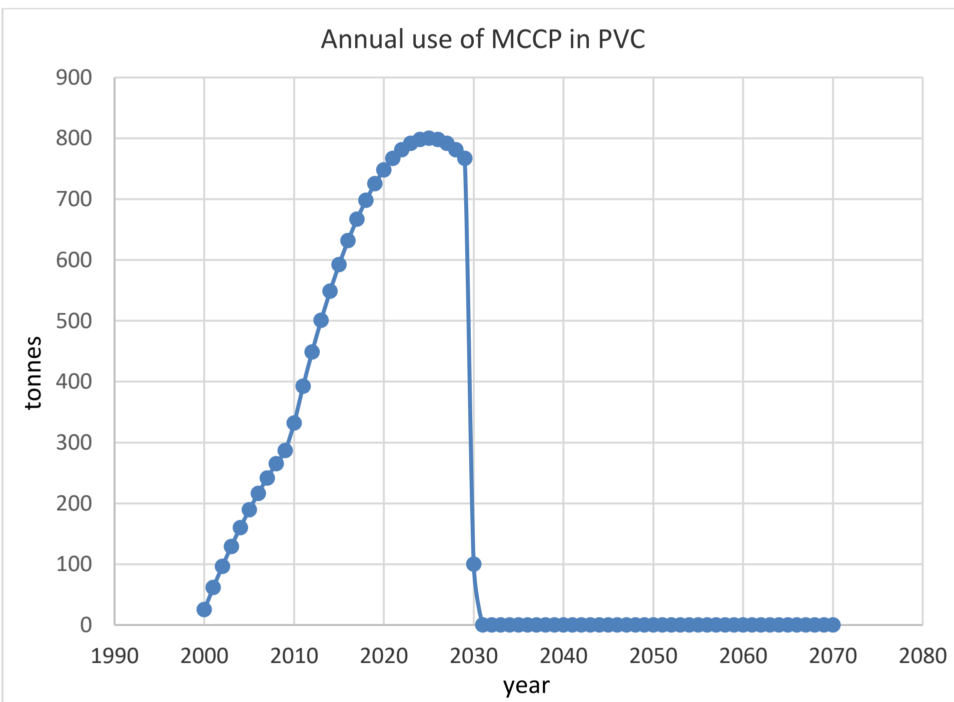

Figure B-24: Annual use of MCCP[17] in PVC in construction

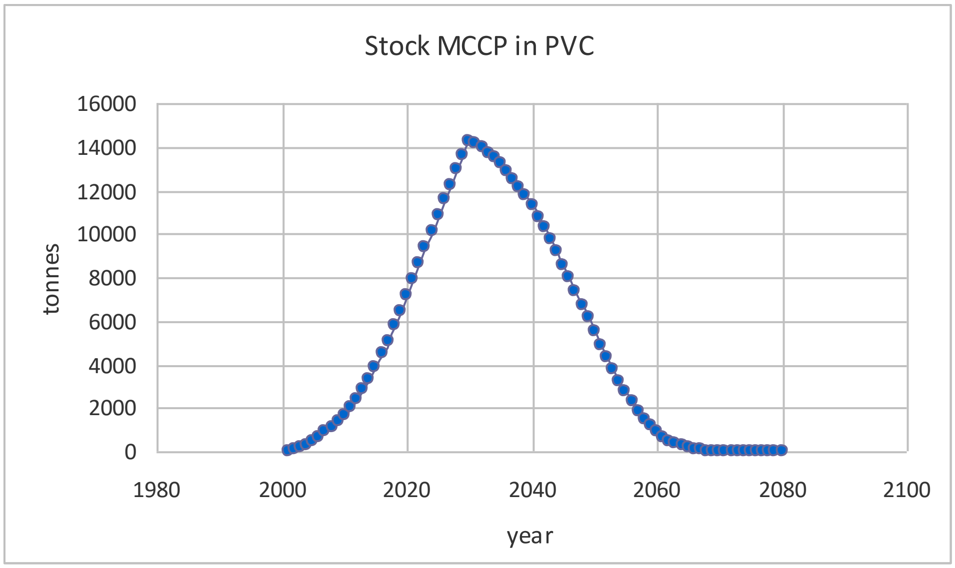

Figure B-25: In-use MCCP[17] in PVC in construction in Country A

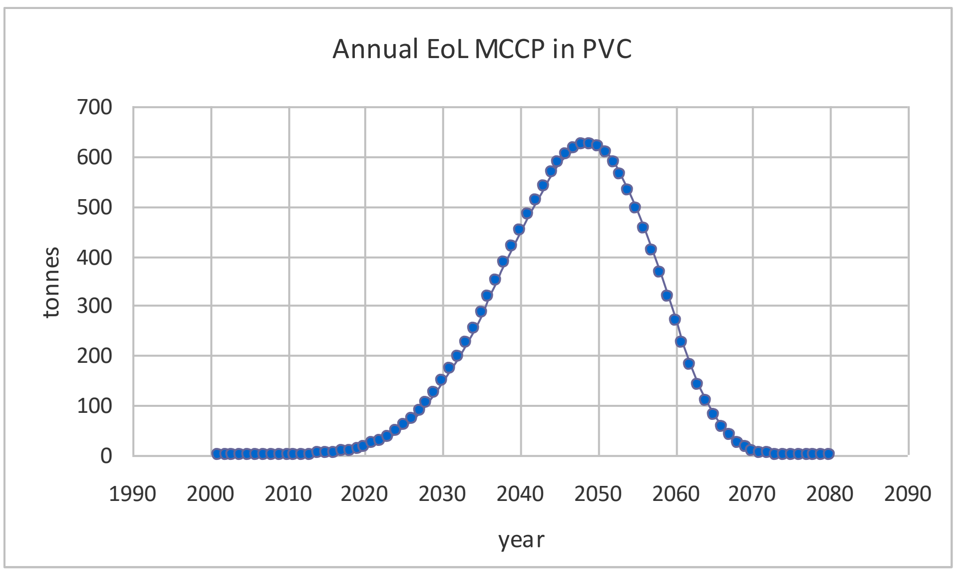

Figure B-26: Annual EoL of MCCP[17] in PVC in construction in County A

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)[27]. Also PUR spray foam in Europe contain up to 50% CPs by weight with mainly MCCP (Brandsma et al. 2021)[30].

[30] 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.

The survey with the 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 import and sales of PUR spray foam including PUR spray foams sold by retailers. However none of the companies were aware on the composition of the foam and the flame retardants they include.

Import and use data of PUR spray foam was available from 2000 to 2020. SCCPs have been exempted for the use in adhesives in the Convention which includes PUR spray foam. Since SCCP was listed in Annex A in 2017, the specific exemption ends 2023. Therefore it was assumed for the dynamic MFA/SFA that SCCPs is used in PUR spray foams until 2023 and then stop (Figure B-27). For MCCP[17] it is assumed that use continue. However MCCP[17] is currently in the POPRC and might be listed in the Convention in 2025. Assuming a specific exemption for MCCP[17] and the use of might continue until 2030 or longer. For the dynamic material and substance flow analysis it was considered that the use will stop in Country A 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 to 959 t with a maximum amount in-use of 1038 t in 2024 (Figure B-28). The total amount of MCCP in-use in PUR spray foam in construction in 2022 was estimated to 3807 t with a maximum of 5843 t in 2031 (Figure B-31). For the inventory year 2022 it was estimated that only 1.7 t of SCCP was included in PUR spray foam C&D waste while a maximum of 34 t 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 t was included in PUR spray foam C&D waste while a maximum of 174 t of MCCP in PVC C&D waste was predicted for 2065 (Figure B-31).

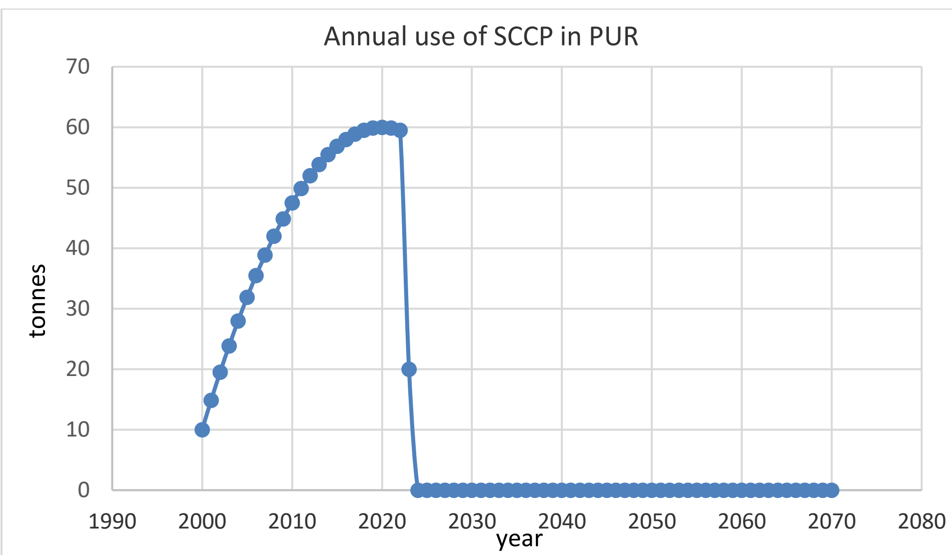

Figure B-27: Annual use of SCCP in PUR spray foam in construction in Country A

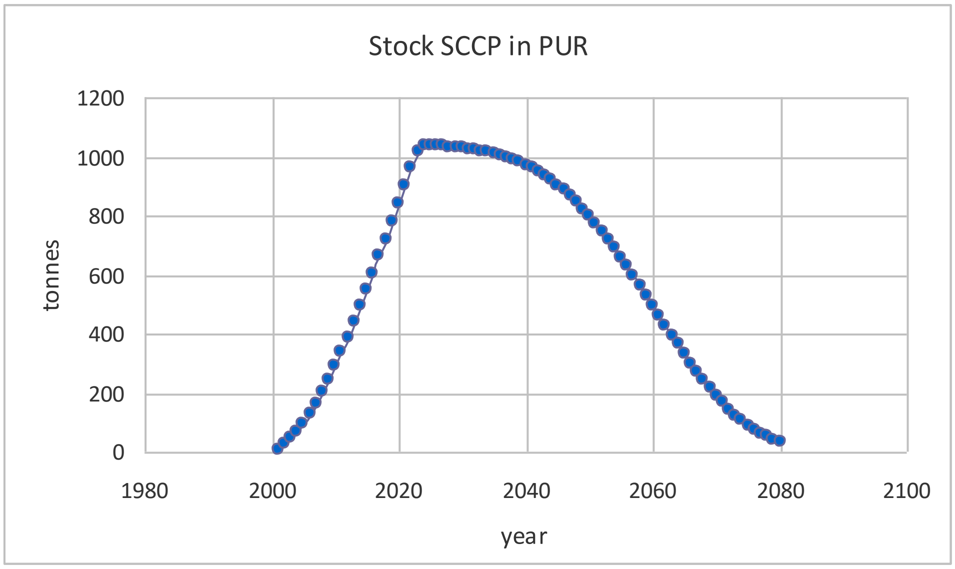

Figure B-28: In-use amount of SCCP in PUR spray foam in construction in Country A

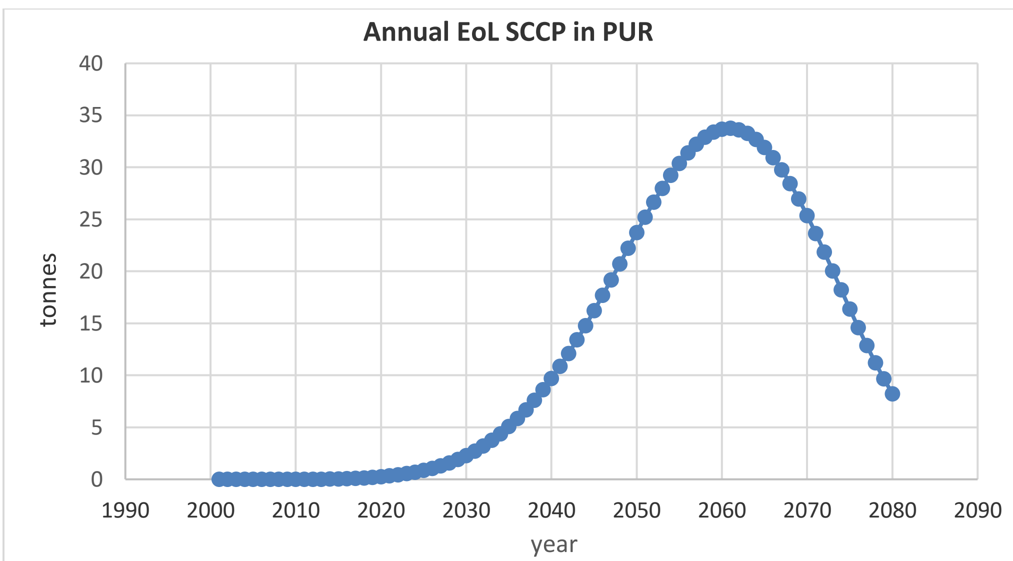

Figure B-29: Annual EoL of SCCP in PUR spray foam in construction in Country A

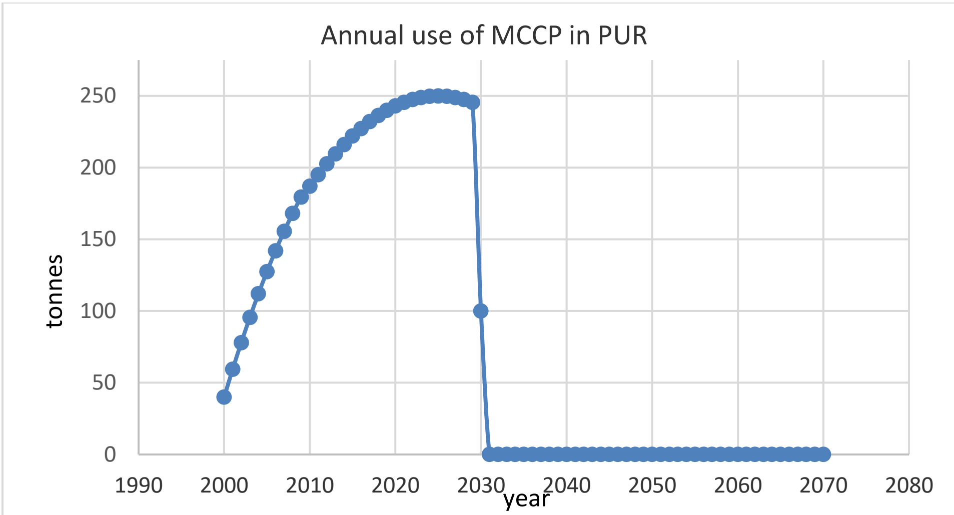

Figure B-30: Annual use of MCCP[17] in PUR spray foam in construction in Country A

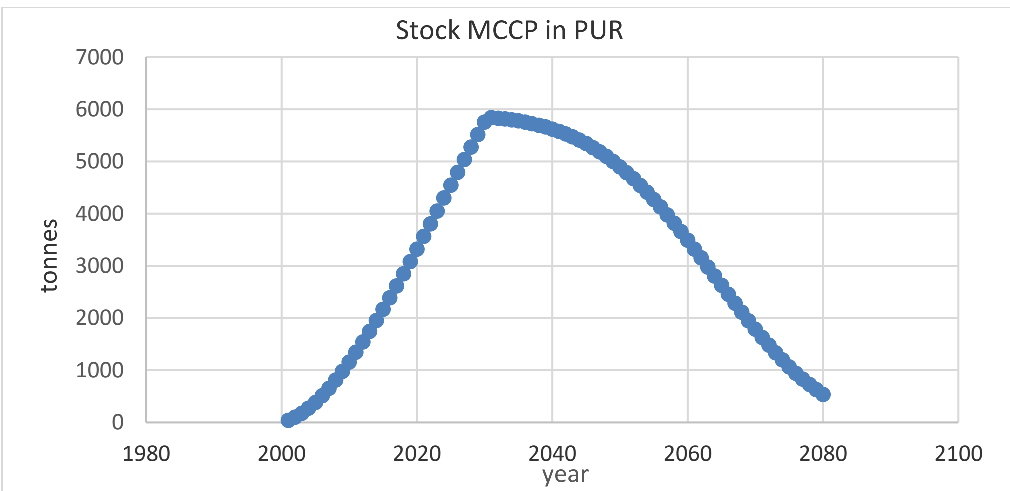

Figure B-31: Amount of MCCP[17] in-use in PUR spray foam in construction in Country A

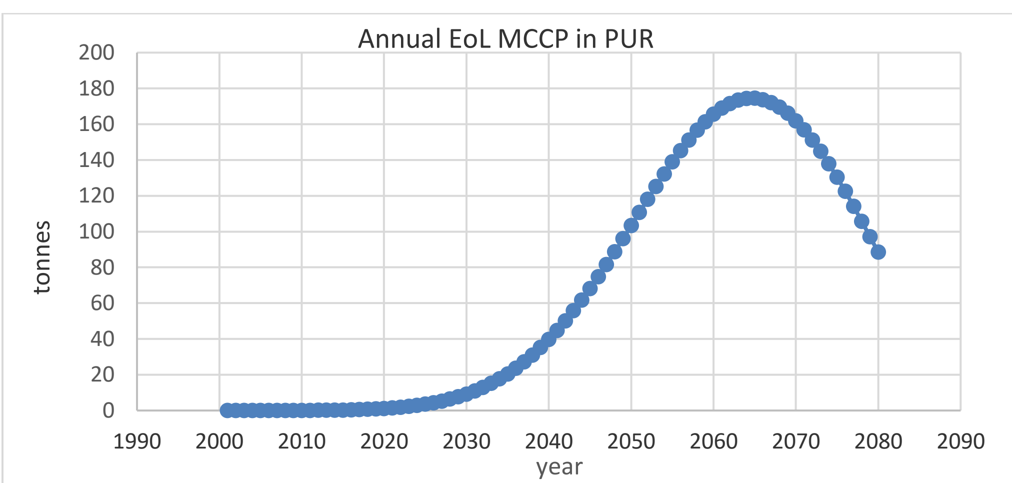

Figure B-32: Annual EoL of MCCP[17] in PUR in construction in Country A

4.2.7 Sealants in buildings and construction (PCB, PCN and SCCPs/MCCPs)

PCBs have been used in sealants, paints and cables in the construction sector from 1950s to approx. 1975[12] in particular in Thiocol sealants. The assessment of the use of Thiocol sealants in construction in the country revealed that they were not used in buildings but that two dams constructed 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 were 10%[31] 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 were 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 were not known and will be assessed in the NIP implementation.

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

According to the wood treatment companies, PCP was imported for wood treatment since 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 t) were used in 2002 (Figure B-33). In average 40% of the treated wood was used in indoor with a service life of 75 years (Figure B-34). Approx. 60% of treated wood was used for utility poles and railway sleepers with an average service life of 40 years (Figure B-35).

Considering these service life and the use data, the dynamic MFA/SFA shows that by 2002 slightly more than 1200 t of PCP had accumulated in wood in indoor use (Figure B-34) while the amount of PCP in outdoor use had accumulated to 1520 t in 2002 (Figure B-35). With the average service life of 40 years, the amount of PCP in outdoor use had decreased by 2022 to approx. 705 t 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 of waste wood was estimated to 44.6 t (Figure B-37; Table 1). For the indoor use with an average service life of 75 years, the in-use amount slowly decrease and by 2050 still 603 t of PCP remained in-use (Figure B-34). In 2022 9.9 t of PCP entered the waste stream from PCP treated indoor use of wood (Figure B-36) this is estimated to increase to 23.8 t by 2050 where PCP in wood waste from indoor use reaches is maximum (Figure B-36).

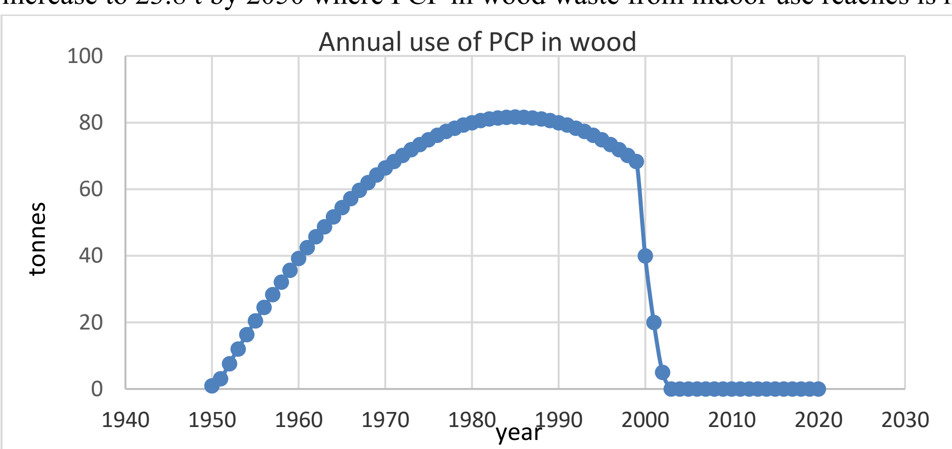

Figure B-33: Annual use of PCP in wood treatment in Country A (outdoor & indoor use)

[31] PCBs concentration in Thiocol sealants were 2.8% to 22.3% (UNEP 2021)12

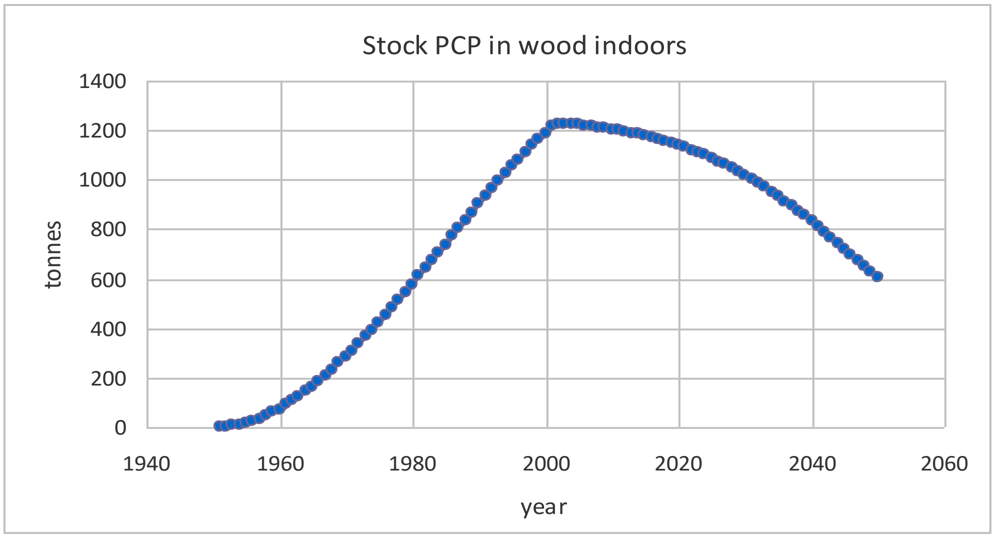

Figure B-34: Amount of PCP in-use in wood indoors in Country A

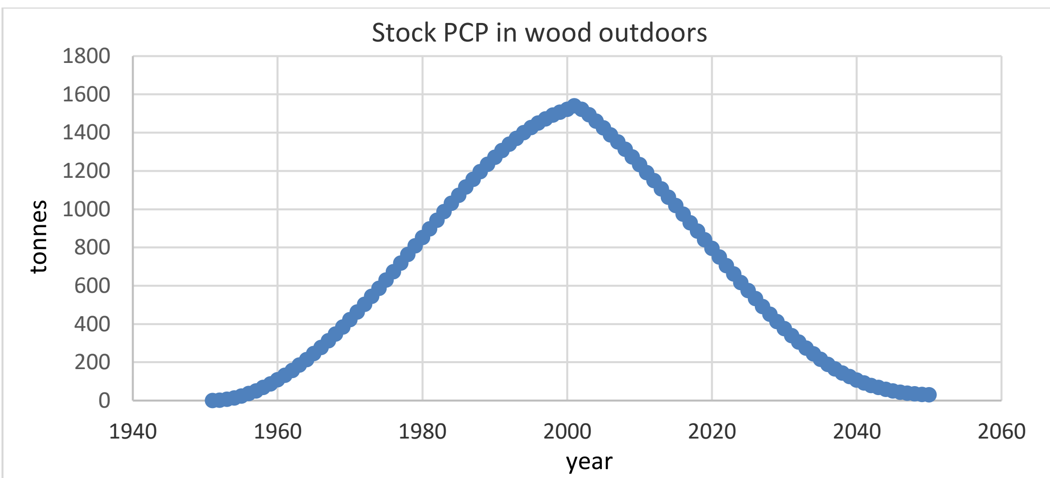

Figure B-35: Amount of PCP in-use in wood outdoor (utility poles & railway sleeper) in CountryA

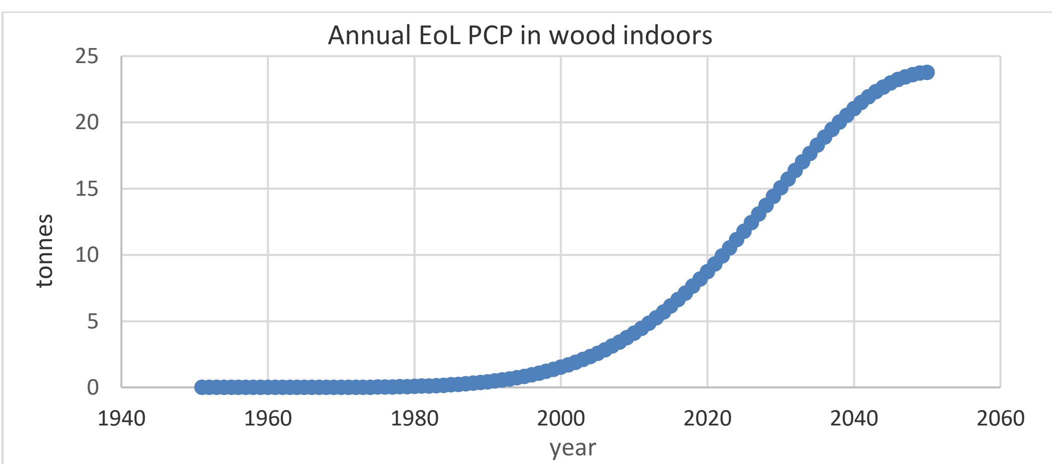

Figure B-36: Annual EoL of PCP in wood indoors in Country A

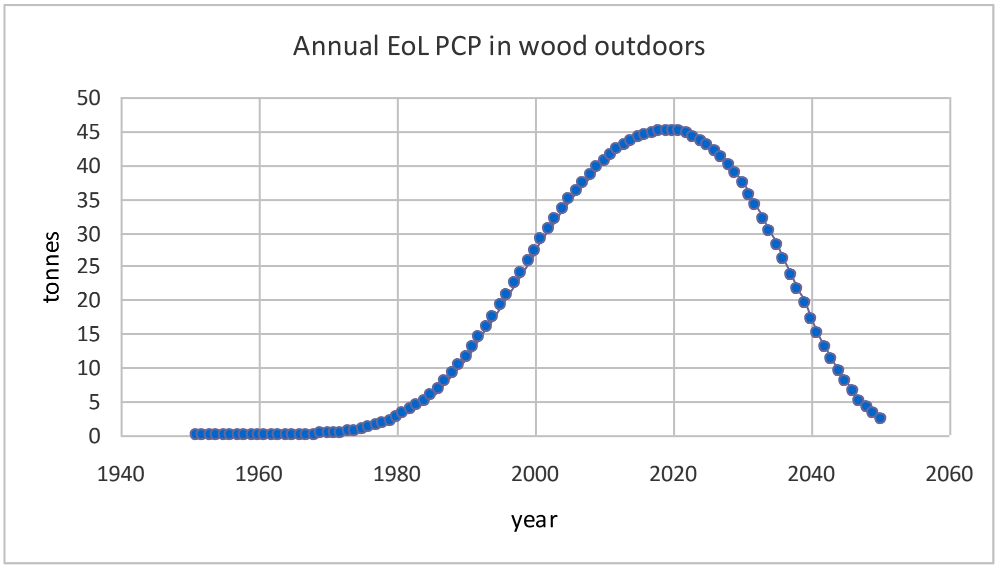

Figure B-37: Annual amount of PCP in EoL of wood outdoors (utility poles and railway sleepers)

According to information from the Agricultural Ministry no other POPs pesticides were used as wood preservatives in the country with the exemption of 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. Also these preservatives are hazardous and this wood need finally be treated as hazardous waste.

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

It is known that also PFOS and PFOA has been used in the construction sector (see Section 2.2.3 in the Sectoral POPs inventory guidance[9]). During inventory assessment no information could be found for PFOS or PFOA and related substances in the construction sector. The need for further assessment was included in the action plan of the NIP.

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[9]. 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 to landfills.[9]

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

The Table 1 below summarise the total amount of POPs in used in the life-cycle: import, current use/stock and in end-of life. The C&D waste has been disposed in the past to landfills with the exemption of wood and metals which were recovered. Therefore also the amount of POPs disposed the past 40 years have 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 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 (2022)	Accumulated POPs in construction currently in use in inventory year (2022)	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

In this first sectoral inventory of the construction sector, other chemicals of concern were not assessed such as heavy metals (e.g. lead, mercury), ODS/GHGs (CFCs, HFCs), PAHs, or PFRs (see Section 4.5 of sectoral POP inventory guidance[9]). However contacts were made to the Minamata, Basel and Rotterdam focal point as well as to the team responsible for inventory of GHG for UNFCCC to inform on the sectoral POP inventory and on interest to cooperate for a larger sectoral inventory with pollutants for different MEAs. In the Minamata initial assessment mercury in buildings were not included (only mercury lamps). It was concluded that in the next assessment, mercury in buildings should be a part of mercury inventory.

Also in the lead in paint activity in the country only regulatory activities to reduce/eliminate current lead in paints is addressed without assessing and inventory of the past use of lead paints. It was concluded that in the next inventory also lead paint in use/presence in the buildings and construction should be assessed.

Also a contact to the Montreal Protocol team was established to see if an inventory of ODS and GHG stocks in the construction sector have been developed. Since this has not been done yet it was concluded that in the refining of the POPs inventory, a 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 the 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.[32]
Also quality control
Data gaps in this study have (partly) been filled by extrapolation of data. This was This was done e.g. 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 which need to be addressed in the implementation (NIP):

- For some of the POPs it is known that they 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 but rather monitoring is needed and the labelling of products containing.
- Also 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 in PUR foam insulation was considered. Therefore the current estimate on decaBDE and c-PentaBDE in the construction sector has some uncertainty and monitoring of plastics in C&D waste and in 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 construction sector and not based on use data from the country. Therefore there is some uncertainty which is however considered relatively small. Also in the current inventory the use data of
- There is a lack of information on end-of-life management of C&D. In particular the recovery of materials by the informal sector is unknown.
- The amount of POPs used in paints used in the past and in current imported paint is unknown.
- There are hardly any data on PCNs in the construction sector

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 the information of the age of the building and the respective foil;

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

- For SCCPs and MCCP 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 restriction of SCCPs and MCCPs. Therefore impact factors pattern will likely change in 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 the two main producers (China and India) have not ratified SCCPs yet.
- DecaBDE is still produced in China but there is no information on the use pattern. Therefore there is a risk that still some DecaBDE is used in polymers in buildings.
- The service life estimates for some materials have uncertainties (e.g. wood in construction; PCB sealants in dams). Also the service life of respective materials should 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 construction sector
- materials in the construction potentially contaminated by POP and amount of insulation materials, other plastics and wood.
- POP (HBCD, PBDEs, SCCPs, MCCPs, PCB and PCP/lindane) in the related materials

These materials and POPs substances have been compiled as a material/substance flow analysis.
Since the data are valuable for the (waste) management of C&D waste and prediction of end-of-life vehicles) the data will also be made available to departments responsible for waste and resource management (Ministry of Environment and other responsible ministries). The data will be fed into and further managed within a database of the governmental body responsible for waste and resource management in cooperation with the National Statistical Office. Furthermore a mechanism will be established that when new data in particular on the current data gaps and uncertainties will be generated that these data will be integrated in the database.
Furthermore data useful for other MEAs like amount of XPS and PUR foam containing CFCs, HCFCs and HFCs. Also PUR foam contain mercury from the use of mercury catalyst.

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.