PUBLICATION

POPs in Articles and Phasing-Out Opportunities

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FOREWORD

Appropriate substitution of POPs by safer alternatives, chemical and non-chemical, is the best and most effective way to eliminate POPs from articles, products and processes and to reduce and prevent use-related environmental contamination and human health problems.

This electronic publication on POPs in Articles and Phasing-Out Opportunities aim therefore presents information on POPs in processes in identified sectors, availability and assessments of alternatives and substitutes to POPs. The publication aims at assisting Parties and others in their implementation of Stockholm Convention provisions (Art. 9 and Art. 10) by providing a compilation of information on alternatives to POPs in current uses.

The chemicals considered in this review are polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD), perfluorooctane sulfonic acid (PFOS) and related substances, DDT, lindane, endosulfan, and PCBs.

The POP Review Committee (POPRC) has already developed the main steps in assessing the safer alternatives to POPs and released guidance on such alternatives for POPs like perfluorooctane sulfonic acid, its salts, perfluorooctane sulfonyl fluoride and their related chemicals; commercial pentabromodiphenylether (c-PentaBDE); endosulfan and DDT.

Following a stakeholder's consultation process, the current document gathered information which is meant to support that, the process and steps outlined by the POPRC guidance can be better implemented in practice by the Parties by compiling related relevant information.

This electronic publication is seen as a living document where information on substitutes will be updated when it becomes available e.g. by new documents from the POPRC or by other relevant publications. Examples of good practices are compiled as case studies and could be replicated in different countries.

Parties and other stakeholders are invited to continuously submit information on substitutes and other approaches to eliminate POPs and in particular POPs in articles for possible consideration and update. Also industries and public interest NGOs are invited to suggest best practice examples for updates when they have more benign alternatives or they became available.

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ABBREVIATIONS[1]

ABS	Acrylonitrile-butadiene-styrene
AFFFs	Aqueous film forming foams
AI	Active Ingredient
APP	Ammonium polyphosphate
AR-AFFF	Alcohol-resistant aqueous film-forming foams
AR-FFFP	Alcohol-resistant film-forming fluoroprotein foams
ATH	Aluminium hydroxide
BAT	Best Available Techniques
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BCRC	Basel Convention Regional Centre for Asia and the Pacific
BDP	Bisphenol A-bis(diphenylphosphate)
BEP	Best Environmental Practices
BFRs	Brominated flame retardants
BHC	Benzene hexachloride
BRS	Basel, Rotterdam and Stockholm
CAS	Chemical Abstract Service
CEC	North American Commission for Environmental Cooperation
CEITS	Civil Engineering Industry Training Scheme
CEN	European Committee for Standardization
CETESB	Companhia de Tecnologia de Saneamento Ambiental de Brasil
CDHS	California Department of Health Services
CHA	Chemical Hazard Assessment
CLP	Classification, Labelling and Packaging
CMP	Composite Mesh Pads
c-OctaBDE	Commercial octabromodiphenyl ether
COP	Conference of Parties
c-PentaPBDE	Commercial pentabromodiphenyl ether
CRC	Chemical Review Committee
CRT	Cathode Ray Tube
CTR	California Toxics Rule
DBDPE	Decabromodiphenylethane
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	1,1,1-tricholoro-2,2-bis (4-chloroohenyl) ethane
Deca-BDEs	Decabromodiphenyl ethers
DfE	Design for the Environment
DGDs	Decision Guidance Documents
DiPAPs	Polyfluoroalkyl phosphoric acid diesters
DMPP	Dimethyl propane phosphonate
DOPO	Dihydrooxaphosphaphenanthrene

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[1] For abbreviations of the Perfluoroalkyl and polyfluoroalkyl substances the definitions of the publication “Perfluoroalkyl and polyfluoroalkyl substances in the environment: Terminology, classification, and origins. Integrated Environmental Assessment and Management 2011, 7, (4), 513-541.” was used.

DSL	Canadian Domestic Substance List
EDXRF	Energy Dispersive X-ray Fluorescence
EEE	Electrical and Electronic Equipment
ELV	End-of-Life Vehicle
EMPA	Swiss Federal Laboratories for Materials Science and Technology
EPD	Environmental Product Declarations
EPS	Expanded Polystyrene
ETFE	Ethylene tetrafluoroethylene copolymer
EtFOSA	N-Ethyl perfluorooctane sulfonamide
EU	European Union
EUR	Euro
FAO	Food and Agriculture Organization
FDA	United States Food and Drug Administration
FFFC	Fire Fighting Foam Coalition
FFFP	Film-Forming Fluoroprotein Foams
FLIS	Forward-Looking Information and Services
FRs	Flame retardants
FTOH	Fluorotelomer alcohols
GADSL	Global Automotive Declarable Substance List
GC-MS	Gas chromatography–mass spectrometry
GEF	Global Environment Facility
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
HBB	Hexabromobiphenyl
HBCD	Hexabromocyclododecane
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
Hepta-BDEs	Heptabromodiphenyl ethers
Hexa-BDEs	Hexabromodiphenyl ethers
HFFRs	Halogen-Free Flame Retardants
HIPS	High Impact Polystyrene
HP	Hewlett - Packard
IMDS	International Material Data System
IPCS INCHEM	International Programme on Chemical Safety
IPEN	International POPs Elimination Network
IPM	National Integrated Pest Management
IRS	Indoor Residual Spray
ISTAS	Instituto Sindical de Trabajo Ambiente y Salud
ITNs	Insecticide Treated Nets
IUPAC	International Union of Pure and Applied Chemistry
IUR	Inventory Update Rule
IVM	Integrated Vector Management
JAMP	Joint Article Management Promotion Consortium
JRC	European Commission Joint Research Centre
KOOP	Kooperationsstelle Hamburg IFE GmbH
LCA	Life Cycle Assessment
LCD	Liquid crystal display
LCM	Life cycle management
LLINs	Long Lasting Insecticidal Nets

LRTP	Long-Range Transport Potential
MEP	Ministry of Environmental Protection
MOA	Ministry of Agriculture
MSDS	Material Safety Data Sheet
MW	Molecular weight
NGLF	Norwegian association of electroplaters
NGOs	Non-Governmental Organisations
NILU	Norwegian Institute for Air Research
NIP	National Implementation Plan
Nona-BDEs	Nonabromodiphenyl ethers
ODS	Ozone Depleting Substances
OECD	Organisation for Economic Co-operation and Development
OH	Hydroxyl free radical
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PBDEs	Polybrominated diphenyl ethers
PBS	Packed Bed Scrubbers
PBT	Polybutylene terephthalate
PBT	Persistent, Bioaccumulative, Toxic
PC	Polycarbonate
PCBs	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzofurans
PCNs	Polychlorinated naphtalens
PCTs	Polychlorinated terphenyls (PCTs)
PeCBz	Pentachlorobenzene
Penta-BDEs	Pentrabromodiphenyl ethers
PeBBE	Pentabromo derivative
PeBBO	Pentabromobi(s)phenyl oxide
PeBDPO	Pentabromodiphenyl oxide
PET	Polyethylene terephthalate
PFAA	Perfluoroalkyl acid
PFAS	Per- and poly-fluoroalkyl substance
PFC	Perfluorocarbon
PFCA	Perfluorocarboxylic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PFOSF	Perfluorooctane sulfonyl fluoride
PFRs	Phosphorous flame retardants
PFSA	Perfluoroalkane sulfonate
PIR	Polyisocyanurate
POPs	Persistent Organic Pollutants
POPRC	Persistent Organic Pollutants Review Committee
PP	Polypropylene
PP-PE	Polypropylene–Polyethylene copolymers
ppb	Parts-per-billion
PPE	Polyphenyl ether
PPO	Poly (phenylene oxide)

PSDS	Product Safety Data Sheet
PVC	Polyvinylchloride
PUR	Polyurethane
RAPEX	Rapid Alert System for Non-Food Consumer Product
R&D	Research and Development
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RDP	Resorcinol-bis(diphenylphosphate)
RME	Risk Management Evaluation
RoHS	Restriction of Hazardous Substances
SDS	Safety Data Sheet
SFT	Norwegian Pollution Control Authority
SMILES	Simplified Molecular-Input Line-Entry System
SSC	Stockholm Convention Secretariat
SVHC	Substance of Very High Concern
T	Tonnes
TBBPA	Tetrabromobisphenol A
TBBPA-BDBPE	Tetrabromobisphenol A bis(2,3-dibromopropyl) ether
TBE	Bis (tribromophenoxy) Ethane
TBPAE	Tribromophenyl allyl ether
TCPA	Tetrachlorophthalic anhydride
TCPP or TDCPP	Tetrabromophthalic anhydride Tris(1-chloro-2-propyl) phosphate
TDCPP	tris(1,3-dichloroisopropyl) phosphate
TEQ	Toxic Equivalency Factor
Tetra-BDEs	Tetrabromodiphenyl ethers
THCP	Tetrakis hydroxymethyl phosphonium salts such as chloride
THPX	Tetrakis hydroxymethyl phosphonium salts such as ammonium
TSCA	Toxic Substances Control Act
UBA	German Federal Environment Agency
UNDP	United Nations Development Program
UNEP	United Nation Environment Programme
UPE	Unsaturated (Thermoset) polyesters
US EPA	United States Environment Protection Agency
XPS	Extruded Polystyrene
XRF	X-Ray Fluorescence
γ-HCH	gamma-hexachlorocyclohexane
ZHS	Zinc hydroxystannate
ZS	Zinc stannate
ZVEI	German Electronic Manufacturers Association
ZVO	German National Metal Plating Association
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization

1 Introduction

The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted in 2001 and entered into force in 2004. It is a global environmental treaty that aims to protect human health and the environment from a group of chemicals which persist in the environment for long periods, become widely distributed geographically, bio-accumulate in humans and wildlife, and pose risks to human health and the environment. Exposure to POPs can lead to adverse health effects including certain cancers, birth defects, dysfunctional immune and reproductive systems together with greater susceptibility to disease[2,3]. WHO and UNEP summary studies highlighted that there is still a large lack in the appropriate assessment of POPs for the global impact on diseases caused by chemicals[4,5].

Appropriate substitution of POPs by safer alternatives, chemical and non-chemical, is the best and most effective way to eliminate them from articles and products and to reduce and prevent environmental contamination and human health problems. In the Convention, and in the present document, the term "alternative" is used to denote a chemical, material, product, product design, system, production process or strategy that can replace listed persistent organic pollutants or candidate chemicals, or materials, products, product designs, systems, production processes or strategies that rely on listed persistent organic pollutants or candidate chemicals, while maintaining an acceptable level of efficacy.[6]

The Stockholm Convention contains several provisions on information related to alternatives:

- Pursuant to Article 9 each Party to the Convention is to facilitate or undertake the exchange of information relevant to "alternatives to persistent organic pollutants, including information relating to their risks as well as to their economic and social costs";
- Under Article 10 each Party, within its capabilities, is to promote and facilitate "development and implementation, especially for women, children and the least educated, of educational and public awareness programmes on persistent organic pollutants … and on their alternatives". Such programmes may include the use of safety data sheets, reports, mass media and other means of communication, and may establish information centres at the national and regional levels;

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[2] Fiedler H.(2003) Persistent Organic Pollutants. Springer Press, Heidelberg.

[3] Carpenter (Editor) (2013) Effects of Persistent and Bioactive Organic Pollutants on Human Heath. John Wiley & Sons, Inc., Hoboken, New Jersey.

[4] Üstün et al. (2011). Knowns and unknowns on burden of disease due to chemicals: a systematic review. Environmental Health 2011, 10:9.

[5] UNEP (2013) Global Chemical Outlook - Towards Sound Management of Chemicals.

[6] The word "substitute" appears once in the Convention (in paragraph (c) of article 5) and both "substitute" and the word "replacement" appear in various other relevant documents and instruments. Both words as so used have substantially the same meaning as the word "alternative" as defined above.

- According to Article 11, Parties, within their capabilities, are to “encourage and/or undertake appropriate research, development, monitoring and cooperation pertaining to persistent organic pollutants and, where relevant, to their alternatives and to candidate persistent organic pollutants”.

The use of alternative at the same time is the best approach for 2) Prevention – citing emphasised and enrolled in Article 3.3 and Article 3.4 of the Convention:

- Article 3.3: ”Each Party that has one or more regulatory and assessment schemes for new pesticides or new industrial chemicals shall take measures to regulate with the aim of preventing the production and use of new pesticides or new industrial chemicals which, taking into consideration the criteria in paragraph 1 of Annex D, exhibit the characteristics of persistent organic pollutants.”

- Article 3.4: “Each Party that has one or more regulatory and assessment schemes for pesticides or industrial chemicals shall, where appropriate, take into consideration within these schemes the criteria in paragraph 1 of Annex D when conducting assessments of pesticides or industrial chemicals currently in use.”

This report aims at assisting Parties and others in their implementation by providing a compilation of information on alternatives to POPs in current uses. The chemicals considered in this review are polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD), perfluorooctane sulfonic acid (PFOS) and related substances, DDT, lindane, endosulfan, and PCBs. The POP Review Committee (POPRC) has developed the “Guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals” elaborating the steps of the assessment of alternatives. The current document aim to compile information which supports that the process and steps outlined by the POPRC guidance can be better implemented in practice by the Parties by compiling related relevant information.

This electronic publication therefore presents information on POPs in processes in identified sectors, availability and assessments of alternatives and substitutes to POPs. A great deal of information is already available through the work of the POPRC on alternatives[7] and several other activities and this report draws upon this existing work. Further work on alternatives conducted by Parties and other governments, by the research community and by industrial stakeholders and public interest NGOs is also included. Furthermore international experts, including country representatives, regional centres and members of the POPRC contributed to this publication and took part in the development process and facilitated the expert dialogue.

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[7] http://chm.pops.int/TheConvention/POPsReviewCommittee/OverviewandMandate/tabid/2806/Default.aspx.

The information is compiled in a simple and easily searchable way to make it accessible to Parties (in particular developing countries and countries with economies in transition) and others interested in the substitution of POPs:

- To add understanding on POPs in articles and products and how to phase out POPs by appropriate substitution and elimination actions.
- To obtain a simple overview on POPs free/POPs alternatives linking to the available materials developed by the POPRC, activities of Parties, regional centres, industry, public interest NGOs and the research community.
- To assist developing country Parties and Parties with economies on transition in meeting their obligations under Articles 9 and 10.
- To provide updates on alternatives where POPRC is not updating information (e.g. on alternatives POP-PBDEs or PCB).
- To allow easy updates on POPs free/POPs alternatives information.
- To have a user-friendly easy-to-update source of information that includes POPs in processes in identified sectors, and availability and assessments of alternatives and substitutes to POPs and supply chains. Also on approaches on how to add more information on the use of POPs and alternatives in articles.
- To present a review of information for Parties to assist them in implementation of their NIPs as well as for a multi stakeholder expert dialogue.
- To contribute to the protection of workers, downstream users, consumers and the environment.

Information on POPs alternatives and on more environmentally benign solutions:

- Supports the search for the more environmentally sustainable and safer alternative.
- Acknowledges that green chemistry is increasingly important as it generates more environmentally sustainable-oriented product solutions and lays the foundations for more sustainable production. Business partners and financiers prefer safer alternatives both to comply with legislative requirements and to protect workers, consumers, downstream users and the environment whilst avoiding potentially expensive litigation and reputational damage.
- Reduces the amount of toxic chemicals in products and wastes and therefore helps promote more sustainable consumption.
- Supports the waste management hierarchy and the development of a circular economy as an important component of more sustainable production and consumption. The listing of c-PentaBDE and certain congeners of c-OctaBDE as POPs in the Convention along with the exemption for recycling has revealed the difficult challenges of POPs in global recycling flows[8] and the

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[8] UNEP (2010). Technical Review of the Implications of Recycling Commercial Pentabromodiphenyl Ether and Commercial Octabromodiphenyl Ether. 6th POPs Review Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/2).

UNEP (2010) Supporting Document for Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. 6th POPs Review Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/INF/6).

> need to substitute POPs for protection of recycling as an important step towards a circular economy. Recognising that our society has to move towards a circular economy[9] with high levels of recycling there is a particular need for substitution of POPs and other persistent toxic substances in articles and products to ensure the protection of these recycling flows.

This electronic publication is seen as a living document where information on substitutes will be updated when it becomes available e.g. by new documents from the POPRC or by other relevant publications. Examples of good practices are compiled as case studies and could be replicated in different countries.

As there are currently limitations on the information available on POPs in articles and products (see Annex 1 and Annex 2) this publication also includes approaches, strategies and recommendations on how to add more information on the use of POPs and alternatives in articles and products.

Parties and other stakeholders are invited to continuously submit information on substitutes and other approaches to eliminate POPs and in particular POPs in articles for possible consideration and update. Also industries and public interest NGOs are invited to suggest best practice examples for updates when they have more benign alternatives or they became available.

This publication is a second step of the 'POPs-free initiative'. This initiative of the Secretariat of the Stockholm Convention was intended to facilitate work on the identification of POPs-free products and to improve the exchange of information on alternatives and substitutes to POPs. An initial pilot project under the initiative engaged with companies and test products to verify the absence of POPs.

Following the completion of the project and presentation of its outcomes at the fifth meeting of the Conference of Parties to the Stockholm Convention in April 2011, UNEP/SSC sought further opportunities to engage with Parties, industries and other relevant stakeholders to promote innovative approaches in the introduction of POP alternatives and substitutes in products.

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[9] http://www.unep.org/resourceefficiency/Home/Policy/SCPPolicies/NationalActionPlansPovertyAlleviation/NationalActionPlansIntroduction/CircularEconomy/tabid/78389/Default.aspx.

2 Snapshots of information on POPs in articles and products

2.1 Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F) and PFOS-related chemicals[10]

2.1.1 Listing under the Convention

Listed under Annex B with acceptable purposes and specific exemptions

Risk profile Ar, Cn, Fr, En, Ru, Sp
Risk management evaluation (RME) Ar, Cn, Fr, En, Ru, Sp, addendum to RME Ar, Cn, Fr, En, Ru, Sp,

Perfluorooctane sulfonate (PFOS) is a fully fluorinated anion which is used as such or as salt in some applications. Perfluorooctane sulfonyl fluoride is also used to create polymers. These polymers are the precursors of PFOS and likely contain(ed) PFOS as a process impurity.
PFOS and its related substances, referred to as "PFOS precursors" which can transform or degrade into PFOS, are members of the large family of perfluoroalkyl sulfonate substances.

2.1.2 Production, uses and exemptions

A total of approximately 96,000 tonnes of PFOS have been produced[11]. Today China is considered the largest producer of PFOS with a production capacity of 100 to 200 t/y[12, 13]. The perfluorootane sulfonate (PFOS) is mainly used for metal plating, aqueous fire-fighting foams (AFFFs) and sulfluramid in China, and the use amount is about 30-40 t/y, 25-35 t/y and 4-8 t/y respectively. PFOS is also produced in Germany (approx. 5 t/y)[14] and possibly in Italy (unknown production volume).

A range of applications of PFOS and PFOS-related substances have been identified during the development of the risk management evaluation on PFOS and other POPRC activities based on information provided by Parties and observers. These uses are listed below structured as listed acceptable purposes, specific exemptions and other (former) uses not exempted under the convention. Note that the exemptions are

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[10] Many PFOS-related chemicals are not specified in Annex B. PFOS-related chemicals are chemicals that contain the structural element PFOS in their molecular structure and are or were produced with PFOSF as starting or intermediate material. These chemicals are covered through the listing of PFOSF. Therefore the present document includes descriptions of alternatives to substances which are not directly listed in the Convention but which nevertheless are covered by it.

[11] Paul AG, Jones KC, Sweetman AJ A first global production, emission, and environmental inventory for perfluorooctane sulfonate. Environ Sci Technol. 43, 386-392.

[12] Zhang Lai et. al. (2012), The inventory of sources, environmental releases and risk assessment for perfluorooctane sulfonate in China, Environmental Pollution 165 (2012) 193 – 198.

[13] Lim, Wang B, Huang J, Deng S, Yu G (2011) Emission Inventory for PFOS in China: Review of Past Methodologies and Suggestions, TheScientificWorldJOURNAL 11, 1963–1980.

[14] Podesta W (2013) Personal communication with Roland Weber, 16.10.2013.

time-limited for a period of five years. Every four years, each Party that uses and/or produces PFOS must report on progress made to eliminate it to the Conference of the Parties. The Conference of the Parties will evaluate the continued need for these exemptions and acceptable purposes in 2015 and every four years thereafter.

Acceptable purpose:
In accordance with Part III of this Annex for the following acceptable purposes, or as an intermediate in the production of chemicals with the following acceptable purposes:

- Photo-imaging
- Photo-resist and anti-reflective coatings for semi-conductors
- Etching agent for compound semiconductors and ceramic filters
- Aviation hydraulic fluid
- Metal plating (hard metal plating) only in closed-loop systems
- Certain medical devices (such as ethylene tetrafluoroethylene copolymer (ETFE) layers and radio-opaque ETFE production, in-vitro diagnostic medical devices, and CCD colour filters)
- Fire-fighting foam
- Insect baits for control of leaf-cutting ants from *Atta spp.* and *Acromyrmex spp.*

Specific exemption: For the following specific uses, or as an intermediate in the production of chemicals with the following specific uses:

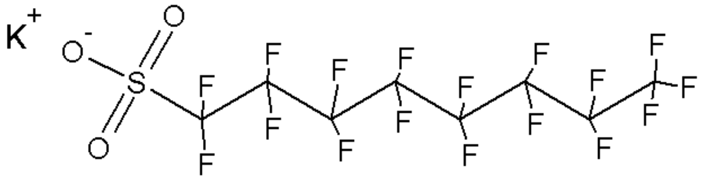
- Photo masks in the semiconductor and liquid crystal display (LCD) industries
- Metal plating (hard metal plating)
- Metal plating (decorative plating)
- Electric and electronic parts for some colour printers and colour copy machines
- Insecticides for control of red imported fire ants and termites
- Chemically driven oil production
- Carpets
- Leather and apparel
- Textiles and upholstery
- Paper and packaging
- Coatings and coating additives
- Rubber and plastics

Former uses of PFOS not allowed under the Stockholm Convention:

- Industrial and household cleaning products
- Floor polishes
- Denture cleanser
- Ski-wax
- Shampoos
- Anti-reflective coating
- Adhesion control

Note that the Conference of the Parties encourages each Party using PFOS to phase-out these uses when suitable alternatives become available. Parties, within their capabilities, are obligated to promote research on safer alternative chemical and non-chemical products, processes, methods, and strategies and take human health risks and environmental implications into account. Each Party using and/or producing PFOS must develop and implement an action plan as part of the National Implementation Plan.

2.1.3 Chemical identity and properties of PFOS

Chemical identification and physical properties	
Chemical name:	Perfluorooctane Sulfonate (PFOS); Octanesulfonate, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-
Synonyms/abbreviations:	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro; 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid; 1-Octanesulfonic acid, heptadecafluoro-; 1-Perfluorooctanesulfonic acid; Heptadecafluoro-1-octanesulfonic acid; Perfluoro-n-octanesulfonic acid; Perfluoroctanesulfonic acid; Perfluoroctylsulfonic acid
CAS registry number:	PFOS, as an anion, does not have a specific CAS number. The listing under the Stockholm Convention includes the parent sulfonic acid (CAS No. 1763-23-1), perfluorooctane sulfonyl fluoride (CAS No. 307-35-7) and some examples of its commercially important salts listed below: Potassium salt (CAS No. 2795-39-3) Diethanolamine salt (CAS No. 70225-14-8) Ammonium salt (CAS No. 29081-56-9) Lithium salt (CAS No. 29457-72-5) Tetraethylammonium perfluorooctane sulfonate (CAS No. 56773-42-3) Didecyldimenthylammonium perfluorooctane sulfonate (CAS No. 251099-16-8)
Structure:	
Molecular weight:	506.1 (potassium salt)
Molecular formula:	$C_8F_{17}SO_3$

2.1.4 POPRC recommendations

By its decision POPRC-6/2: Work programmes on new persistent organic pollutants, POPs Review Committee has developed the recommendations on risk reduction measures, in chronological order of the life cycle of PFOS and processes and materials containing PFOS to address systematically the related risks. The recommendations are provided in a short-term, medium-term and long-term framework. A number apply to both the production and usage of PFOS in various applications. Given that PFOS precursors may contribute to the overall presence of PFOS in the environment, the recommendations of POPRC (POPRC-6/2) should be considered, as appropriate for the management of PFOS and PFOS-related chemicals.

Countries in a position to do so, especially developed countries, are encouraged to take up these recommendations as soon as possible and exchange their experiences and success stories with other countries. The transfer of knowledge and technology, including capacity-building to identify PFOS in articles and applications and monitor PFOS in the environment, should be promoted to support full participation in global efforts to reduce PFOS risks.

2.1.5 POPs characteristics of PFOS

Polymers and some other substances that are made with perfluorooctane sulfonyl chemistry are both lipid- and water-repellent. Therefore, PFOS-related substances are used as surface-active agents in various applications. Due to the chemical stability and the bond strength of the carbon-fluorine bond these substances are extremely persistent and make them suitable for high-temperature applications and for applications in contact with strong acids or bases. The estimated half-life for PFOS in a hydrolysis test in water is reported as >41 years, but may be significantly longer than 41 years since no degradation was detected[15]. Biodegradation of PFOS has also been evaluated under aerobic and anaerobic conditions but no apparent degradation occurred[16].

The presence of PFOS in a wide variety of arctic biota, far from anthropogenic sources, demonstrates its capacity to undergo long-range transport[17].

Unlike other POPs, PFOS does not accumulate in fatty tissue, but binds to proteins in the blood and the liver and in this way is both bioaccumulative and biomagnifying, which results in high concentrations at high trophic levels[16,17,18].

2.1.6 PFOS Alternatives

The same as ***3.2 Alternatives to PFOS*** in Part III.

2.1.7 Guidance and useful links

Several guidance documents have been developed in the frame of the Stockholm Convention to support Parties in the implementation of Convention. Guidance with relevance to PFOS includes:

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[15] Hekster FM, de Voogt P, Pijnenburg AM Laane RW (2002) Perfluoroalkylated substances Aquatic environmental assessment Report RIKZ/2002.043. 1 July 2002.

[16] OECD (2002) Co-operation on Existing Chemicals - Hazard Assessment of Perfluorooctane Sulfonate and its Salts, Environment Directorate Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biothechnology, Organisation for Economic Co-operation and Development, Paris, November 2002.

[17] UNEP (2005) Perfluorooctane sulfonate proposal. UNEP/POPS/POPRC.1/9.

[18] UNEP (2010), Startup Guidance for the 9 new POPs (general information, implications of listing, information sources and alternatives), p.24-25.

- Guidance for the inventory of perfluorooctane sulfonic acid (PFOS) and related chemicals listed under the Stockholm Convention on POPs, (Draft, July 2012), http://chm.pops.int/Implementation/NIPs/Guidance/GuidancefortheinventoryofPFOS/tabid/3169/Default.aspx
- Guidance on best available techniques and best environmental practices for the use of perfluorooctane sulfonic acid (PFOS) and related (Draft, July 2012), http://chm.pops.int/Implementation/NIPs/Guidance/GuidanceonBATBEPfortheuseofPFOS/tabid/3170/Default.aspx
- Guidance on alternatives to perfluorooctane sulfonic acid, its salts, perfluorooctane sulfonyl fluoride and their related chemicals, (Draft, 2012), http://chm.pops.int/Convention/POPsReviewCommittee/LatestMeeting/POPRC9/POPRC9Documents/tabid/3281/Default.aspx
- Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles. Relevant to the substances listed in Annexes A, B and C to the Stockholm Convention on Persistent Organic Pollutants in 2009 and 2011 (Draft, July 2012): http://chm.pops.int/Implementation/NIPs/Guidance/tabid/2882/Default.aspx
- Stockholm Convention (2010), Startup Guidance for the 9 new POPs (general information, implications of listing, information sources and alternatives): http://chm.pops.int/Implementation/NewPOPs/Publications/tabid/695/Default.aspx ;

Other useful links:

- Acceptable purposes and Register for acceptable purposes for perfluorooctane sulfonic acid (PFOS) and related chemicals: http://chm.pops.int/Implementation/Exemptions/AcceptablePurposesPFOSandPFOSF/tabid/794/Default.aspx
- Specific exemptions and Register for specific exemptions for for perfluorooctane sulfonic acid (PFOS) and related chemicals: http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/tabid/790/Default.aspx
- Perfluorooctane sulfonic acid (PFOS) and related chemicals risk profile: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Perfluorooctane sulfonic acid (PFOS) and related chemicals Risk management evaluation: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- POPRC-6/2: Work programmes on new persistent organic pollutants: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx

2.2 TetraBDE and PentaBDE contained in commercial PentaBDE[19]

2.2.1 Listing under the Convention

TetraBDE and PentaBDE Listed under Annex A with specific exemptions.

Risk profile Ar, Cn, Fr, En, Ru, Sp
Risk management evaluation (RME) Ar, Cn, Fr, En, Ru, Sp,

Tetrabromodiphenyl ether and pentabromodiphenyl ether are dominant homologues of the commercial mixture of pentabromodiphenyl ether. Commercial pentabromodiphenyl ether (c-PentaBDE) refers to mixtures of polybromodiphenyl ether congeners in which the main components are 2,2',4,4'- tetrabromodiphenyl ether (BDE-47 CAS No. 40088-47-9) and 2,2',4,4',5-pentabromodiphenyl ether (BDE-99 CAS No. 32534-81-9), which have the highest concentration by weight with respect to the other components of the mixture.

2.2.2 Production and use

Polybrominated diphenyl ethers are a group of industrial aromatic organobromine chemicals that have been used since the 1970s as additive flame retardants in a wide range of consumer products. In total approximately 100,000 tonnes of c-PentaBDE have been produced.

It is considered that between 90% and 95% of the use of c-PentaBDE was for the treatment of polyurethane (PUR) foam. These foams were mainly used in automotive and upholstery applications. Minor uses included textiles, printed circuit boards, insulation foam, cable sheets, conveyer belts, lacquers and possibly drilling oils (UNEP, 2012[20]). The total amount of c-PentaBDE used for these minor uses is estimated to account for 5% or less of the total usage (SFT, 2009[21]; UNEP, 2010a[22],b[23]). Alcock et al. (2003)[24] estimated that 85,000 tonnes of c-PentaBDE were used overall in the United States and the remaining 15,000 tonnes in Europe. There may have been production and use in Asia but reliable data are not available.

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[19] c-PentaBDE contains also hexaBDE and heptaBDE which are also listed as POPs. Therefore all congeners/homologues contained in c-PentaBDE are listed as POPs.

[20] Stockholm Convention (2012) Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants. Draft.

[21] SFT (2009) Norwegian Pollution Control Authority (SFT). Guidance on alternative flame retardants to the use of commercial pentabromodiphenylether (c-PentaBDE). SFT, Oslo, February 2009.

[22] UNEP (2010). Technical Review of the Implications of Recycling Commercial Pentabromodiphenyl Ether and Commercial Octabromodiphenyl Ether. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/2).

[23] UNEP (2010) Supporting Document for Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. Stockholm Convention document for 6th POP Reviewing Committee meeting (UNEP/POPS/POPRC.6/INF/6) Geneva 11-15. October 2010.

[24] Alcock R.E, Sweetman, A.J, Prevedouros K, Jones, K.C. 2003. Understanding levels and trends of BDE-47 in the UK and North America: an assessment of principal reservoirs and source inputs. Environment International 29, 691-698.

c-OctaBDE has mainly been used as flame retardants, and contain significant amounts of POP-PBDEs.

Table 1: Former uses of c-PentaPBDE in polymers/resins, the applications and articles

Materials/polymers/resins	**Applications**	**Articles**
Polyurethane (PUR)	Cushioning materials, packaging, padding, construction	Furniture, transportation, sound insulation, packaging, padding panels, rigid PUR foam construction
Textiles	Coatings	Back coatings and impregnation for carpets, automotive seating, furniture in homes and official buildings, aircraft, underground
Epoxy resins	Circuit boards, protective coatings	Computers, ship interiors, electronic parts
Rubber	Transportation	Conveyor belts, foamed pipes for insulation
Polyvinylchloride (PVC)	Cable sheets	Wires, cables, floor mats, industrial sheets
Unsaturated (Thermoset) polyesters (UPE)	Circuit boards, coatings	Electrical equipment, coatings for chemical processing plants mouldings, military and marine applications: construction panels
Paints/lacquers	Coatings	Marine and industry lacquers for protection of containers
Hydraulic oils	Drilling oils, hydraulic fluids	Off shore, coal mining

Source: UNEP 2009[25]

2.2.3 Exemption

The Convention contains a time-limited exemption, for the recycling of articles that may contain c-PentaBDE and the use and final disposal of articles manufactured from such recycling. Nevertheless, recycling and final disposal have to be carried out in an environmentally sound manner and should not lead to the recovery of listed POPs for the purpose of their reuse. In addition, governments must not allow this exemption to lead to the export of articles containing TetraBDE and PentaBDE that exceed limits for sale in the country.

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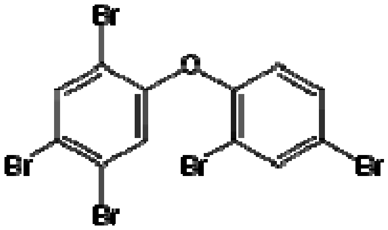
[25] UNEP. 2009. Guidance on feasible flame-retardant alternatives to commercial pentabromodiphenyl ether UNEP/POPS/COP.4/INF/24.

2.2.4 Chemical identity and properties

Information on the chemical identity, structure and physical properties of c-PentaBDE and the related TetraBDE and PentaBDE are listed in Table 2.

Table 3: Chemical identification and physical properties

Chemical identification and physical properties	
Chemical name and CAS registry number:	"Tetrabromodiphenyl ether and pentabromodiphenyl ether" means 2,2',4,4'-tetrabromodiphenyl ether (BDE-47, CAS No: 5436-43-1) 2,2',4,4',5-pentabromodiphenyl ether (BDE-99, CAS No: 60348-60-9) and other tetra- and pentabromodiphenyl ethers present in commercial pentabromodiphenyl ether.
Synonyms/ abbreviations:	Pentabromodiphenyl ether (PentaBDE and PentaBDPE), Benzene, 1,1'-oxybis-, pentabromo derivative, Pentabromophenoxybenzene, Pentabromobi(s)phenyl ether; biphenyl ether, pentabromo derivative = PeBBE, Pentabromobi(s)phenyl oxide = PeBBO, Pentabromodiphenyl oxide = PeBDPO = PentaBDPO
Trade names:	Bromkal 70, Bromkal 70 DE, Bromkal 70 5DE, Bromkal G1, Great Lakes DE 71, Great Lakes DE-60 F (85% PeBDE), FR 1205/1215, Pentabromprop, Saytex 115, Tardex 50.
Structure:	
Molecular weight:	564.69 g/mol
Molecular formula:	$C_{12}H_5Br_5O$

2.2.5 POPRC Recommendations

By its decision POPRC-6/2: Work programmes on new persistent organic pollutants, the POPRC has developed recommendations on eliminating brominated diphenyl ethers from the waste stream.

The Committee recommended eliminating brominated diphenyl ethers from the recycling streams as swiftly as possible. To meet this objective, the principal recommendation is to separate articles containing brominated diphenyl ethers as soon as possible before recycling. The POPRC noted that failure to do so will inevitably result in wider human and environmental contamination and the dispersal of brominated diphenyl ethers into matrices from which recovery is not technically or economically feasible and in the loss of the long-term credibility of recycling. Initially, the main focus should be on developed countries handling primary flame-retarded[26] articles containing higher concentrations of brominated diphenyl ethers and attention should be paid to identification and treatment of brominated diphenyl ethers in articles for both domestic use and for export. To achieve this aim a "Guidance on best available techniques and best environmental practices for the recycling and disposal of articles containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants" (Draft) have been developed which lists technologies/processes to separate PBDE containing materials.

2.2.6 POPs characteristics of c-PentaBDE

Commercial Pentabromodiphenyl ether (c-PentaBDE) is a synthetic mixture of tetraBDE, PentaBDE and minor amounts of hexaBDE and heptaBDE congeners. These PBDEs degrade slowly in the environment and can bioaccumulate and biomagnify in mammals and piscivorous birds.

Long range transport is responsible for its presence in areas such as the Arctic region, remote from sites of production and release.

Although levels of c-PentaBDE in human blood and milk, and in other environmental species, are falling in Europe, they continue to increase in North America and the Arctic region.
Based on the information in its risk profile, c-PentaBDE, due to the characteristics of its components, is likely to cause significant adverse effects on human health and the environment, such that global action is warranted.

2.2.7 C-PentaBDE (tetraBDE and pentaBDE) Alternatives

The same as ***3.3 Alternatives to POP-PBDE*** in Part III.

2.2.8 Guidance and useful links

Guidances

- Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on POPs (Draft, 2012): http://chm.pops.int/Implementation/NIPs/Guidance/tabid/2882/Default.aspx
- Guidance on best available techniques and best environmental practices for the recycling and waste disposal of articles containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on POPs (Draft, 2012): http://chm.pops.int/Implementation/NIPs/Guidance/GuidanceonBATBEPfortherecyclingofPBDEs/tabid/3172/Default.aspx
- Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles. Relevant to the substances listed in

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[26] That is articles for which the flame retardant content was added for the purposes of flame retardancy rather than articles which contain some flame retardant as a consequence of contaminants in recyclate.

Annexes A, B and C to the Stockholm Convention on Persistent Organic Pollutants in 2009 and 2011 (Draft, July 2012): http://chm.pops.int/Implementation/NIPs/Guidance/tabid/2882/Default.aspx

- Guidance on alternative flame retardants to the use of commercial pentabromo diphenyl ether (c-PentaBDE) (2009): http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC4/POPRC4documents/tabid/400/Default.aspx
- Stockholm Convention (2010), Startup Guidance for the 9 new POPs (general information, implications of listing, information sources and alternatives): http://chm.pops.int/Implementation/NewPOPs/Publications/tabid/695/Default.aspx

Other useful links:

- Specific exemption and Register for specific exemptions for tetra- and penta-BDE: http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/tabid/790/Default.aspx
- Risk profile for penta-BDE: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Risk management evaluation (RME) for penta-BDE: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx

2.3 HexaBDE and HeptaBDE contained in commercial OctaBDE

2.3.1 Listing under the Convention

Listed under Annex A with specific exemptions

Risk profile Ar, Cn, Fr, En, Ru, Sp
Risk management evaluation (RME) Ar, Cn, Fr, En, Ru, Sp,

Certain congeners of hexabromodiphenyl ether (hexaDDE) and heptabromodiphenyl ether (heptaBDE) are dominant components of the commercial octabromodiphenyl ether (c-OctaBDE). The term “c-OctaBDE” designates a commercial mixture containing polybrominated diphenyl ethers (PBDEs) with varying degrees of bromination, typically consisting of penta- to decabromodiphenyl ether isomers and containing approximately 79% (by weight) bromine.

2.3.2 Production, use and exemption

Polybrominated diphenyl ethers are a group of industrial aromatic organobromine chemicals that have been used since the 1970s as additive flame retardants in a wide range of - mainly - consumer products. In total approximately 100,000 tonnes of c-OctaBDE have been produced.

The main former use of c-OctaBDE was in acrylonitrile-butadiene-styrene (ABS) polymers, accounting for about 95% of c-OctaBDE supplied in the EU. The treated ABS was mainly used for housings/casings of electrical and electronic equipment (EEE), particularly for cathode ray tube (CRT) housings and office equipment such as copying machines and business printers.[27] Other minor uses were high impact polystyrene (HIPS), polybutylene terephthalate (PBT), and polyamide polymers. Although the majority of these polymers were used in electronics, there was also some use in the transport sector.

Other minor uses found in literature include nylon, low density polyethylene, polycarbonate, phenolformaldehyde resins, unsaturated polyesters, adhesives and coatings (UNEP, 2010a[22]; 2010b[23]). Table 4 summarizes the former uses of c-OctaBDE in various materials and applications.

Typical concentrations in the major applications were between 12 wt % and 18 wt %, with approximately 100,000 tonnes of c-OctaBDE at an application rate of 15 wt %. The primary treated polymers can be estimated at approximately 800,000 tonnes (Alaee et al. 2003[28], UNEP 2007[29]). Considering the recycling of c-OctaBDE in new plastic products (secondary contamination), the total quantity of impacted plastics is likely to be considerably higher than this. But POP-PBDE concentration in these recycled plastic is lower (Sindiku et al. 2014[30]).

Table 4: Former uses of c-OctaBDE in polymers/materials, the applications and products (ESWI 2011[31])

Polymers/materials	Application	Articles
Acrylnitrile-Butadiene-Styrene (ABS)	Polymer casings/parts in electric and electronic appliances	Computer- and TV casings (CRTs); office equipment; (other electronic equipment)
High Impact Polystyrene (HIPS)	Polymer casings/parts in electric and electronic appliances	Computer- and TV casings (CRTs); office equipment

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[27] In some regions (e.g. Europe, Japan), CRT monitor housing are normally treated separately.

[28] Alaee M, Arias P, Sjodin A, Bergman A (2003) An overview of commercially used brominated flame retardants, their applications, their use patterns in different countries/regions and possible modes of release. Environment International 29, 683– 689.

[29] UNEP (2007) Draft risk profile: commercial octabromodiphenyl ether. UNEP/POPS/POPRC.3/14. 08/2007.

[30] Sindiku, O., Babayemi, J., Osibanjo, O., Schlummer, M., Schluep, M., Watson, A., & Weber, R. (2014). Polybrominated diphenyl ethers listed as Stockholm Convention POPs, other brominated flame retardants and heavy metals in e-waste polymers in Nigeria. Environmental Science and Pollution Research, 1-13.

[31] ESWI. 2011. Study on waste related issues of newly listed POPs and candidate POPs" 25 March 2011.

	Cold-resistant layer	Refrigerator
Polybutylen-Terephtalate (PBT)	Polymer casings	Electronic appliances
	Transport sector	Connectors in vehicles
	Household	Iron
Polyamide-Polymers	Textiles	Furniture
	Construction	Pipes and plastic foil

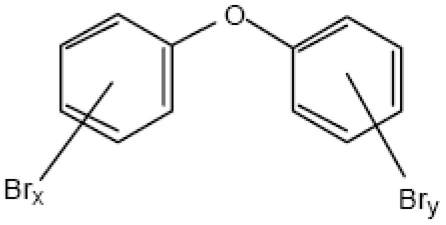
2.3.3 Exemption

The Convention contains a time-limited exemption, for the recycling of articles that may contain POP-PBDEs and the use and final disposal of articles manufactured from such recycling. Nevertheless, recycling and final disposal have to be carried out in an environmentally sound manner and should not lead to the recovery of POP-PBDEs for the purpose of their reuse. In addition, governments have to take steps to prevent exports of recycled articles containing levels of hexaBDE and heptaBDE that exceed those permitted for sale, use, import, or manufacture.

2.3.4 Chemical identity and properties

Information on the chemical identity, structure and physical properties of c-OctaBDE and the relate hexaBDE and heptaBDE are listed in Table 5.

Table 5: Chemical identification and physical properties

Chemical identification and physical properties	
Chemical name and CAS registry number:	Hexabromodiphenyl ether and heptabromodiphenyl ether” means 2,2',4,4',5,5'-hexabromodiphenyl ether (BDE-153, CAS No: 68631-49-2), 2,2',4,4',5,6'-hexabromodiphenyl ether (BDE-154, CAS No: 207122-15-4), 2,2',3,3',4,5',6-heptabromodiphenyl ether (BDE-175, CAS No: 446255-22-7), 2,2',3,4,4',5',6-heptabromodiphenyl ether (BDE-183, CAS No: 207122-16-5) and other hexa- and heptabromodiphenyl ethers present in commercial octabromodiphenyl ether
Synonyms/ abbreviations:	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro; 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid; 1-Octanesulfonic acid, heptadecafluoro-; 1-Perfluorooctanesulfonic acid; Heptadecafluoro-1-octanesulfonic acid; Perfluoro-n-octanesulfonic acid; Perfluoroctanesulfonic acid; Perfluoroctylsulfonic acid
Structure:	
Molecular	801.38 g/mol

weight:	
Molecular formula:	$C12H_2Br_8O$

2.3.5 POPs characteristics of hexaBDE and heptaBDE in c-OctaBDE

The evaluation of the human and environmental risk of commercial OctaBDE associated to its potential for long range transport must consider that the commercial OctaBDE is a mixture of congeners with different properties and profiles.

The persistence of the hexaBDEs to nonaBDEs is well documented. The main route of degradation is debromination forming other PBDEs of concern (UNEP 2010c)[32]. The potential for certain components in c-OctaBDE to bioaccumulate and also for biomagnification in some trophic chains is also sufficiently documented and confirmed by the good agreement between field observations in monitoring programmes and toxic kinetic studies.

Monitoring data in remote areas confirm the potential for long-range transport and at least for some congeners the relevance of atmospheric distribution in this process.

In addition, specific studies have reported particular hazards such as delayed neurotoxicity and immunotoxicity which may be particularly relevant in the assessment of both human health and ecosystem risks.

Based on the existing evidence, it was concluded that the hexaBDE and heptaBDE congeners of the commercial OctaBDE meet the POPs criteria.

2.3.6 POPRC recommendations

By its decision POPRC-6/2: Work programmes on new persistent organic pollutants, POPs Review Committee has developed the recommendations on elimination of brominated diphenyl ethers from the waste stream.

The Committee recommended eliminating brominated diphenyl ethers from the recycling streams as swiftly as possible. To meet this objective, the principal recommendation is to separate articles containing brominated diphenyl ethers as soon as possible before recycling. The POPRC noted that failure to do so will inevitably result in wider human and environmental contamination and the dispersal of brominated diphenyl ethers into matrices from which recovery is not technically or economically feasible and in the loss of the long-term credibility of recycling. Initially, the main focus should be on developed countries handling primary flame-retarded[33] articles containing higher concentrations of brominated diphenyl ethers and attention

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[32] UNEP (2010c) Debromination of brominated flame retardants. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/INF/20).

[33] That is articles for which the flame retardant content was added for the purposes of flame retardancy rather than articles which contain some flame retardant as a consequence of contaminants in recyclate.

should be paid to identification and treatment of brominated diphenyl ethers in articles for both domestic use and for export.

2.3.7 C-OctaBDE (hexaBDE and heptaBDE) Alternatives

The same as ***3.3 Alternatives to POP-PBDE*** in Part III.

2.3.8 Guidance and useful links

Guidances

- Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on POPs (Draft, 2012): http://chm.pops.int/Implementation/NIPs/Guidance/tabid/2882/Default.aspx
- Guidance on best available techniques and best environmental practices for the recycling and waste disposal of articles containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on POPs (Draft, 2012): http://chm.pops.int/Implementation/NIPs/Guidance/tabid/2882/Default.aspx
- Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles. Relevant to the substances listed in Annexes A, B and C to the Stockholm Convention on Persistent Organic Pollutants in 2009 and 2011 (Draft, July 2012): http://chm.pops.int/Implementation/NIPs/Guidance/tabid/2882/Default.aspx
- Stockholm Convention (2010), Startup Guidance for the 9 new POPs (general information, implications of listing, information sources and alternatives): http://chm.pops.int/Implementation/NewPOPs/Publications/tabid/695/Default.aspx

Other useful links:

- POPRC-6/2: Work programmes on new persistent organic pollutants: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Risk profile for octa-BDE: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Risk management evaluation (RME) for octa-BDE: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Specific exemption and Register for specific exemptions for hexa- and hepta-BDE: http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/tabid/790/Default.aspx

2.4 Hexabromocyclododecane (HBCD)[34]

2.4.1 Listing under the Convention

Listed under Annex A with specific exemptions

Risk profile Ar, Cn, Fr, En, Ru, Sp
Risk management evaluation (RME) Ar, Cn, Fr, En, Ru, Sp,

Hexabromocyclododecane (HBCD) is a brominated flame retardant. It consists of twelve carbon, eighteen hydrogen, and six bromine atoms tied to the ring.

2.4.2 Production and use

HBCD is used as additive brominated flame retardant. The major use (>90%) is in flame-retarded expanded polystyrene foam (EPS) and extruded polystyrene foam (XPS) insulation materials in construction (Table 6). While XPS is mostly used in insulation in a variety of applications (e.g. ground frost protection) EPS is also used for packaging (industrial and food).

However not all EPS and XPS used in construction are flame retarded. This depends on the flammability requirement of individual countries. For example in Europe some countries require flame retardant use in PS in construction (e.g. Netherlands and UK) but others do not require that EPS/XPS in construction is flame retarded (e.g. Sweden and Norway). Other countries only require for specific applications to be flame retarded (e.g. in Finland: only for wall and ceiling insulation needs to be flame retarded).

Minor uses of HBCD are in high impact polystyrene (HIPS) used in electric and electronic appliances and for back-coatings for upholstery and other interior textiles.

Table 6: Product types, products and the relevance related to the use of HBCD in the EU according to different sources

Product type	**EPS**	**XPS**	**EPS**	**XPS**	**HIPS**	**Polymer dispersion**
Products	Insulation boards for construction		Other products		Electronic products	Textile fabrics

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[34] In the Stockholm Convention including POP Review Committee documents Hexabromocyclododecane has the abbreviation HBCD. In some scientific publications the abbreviation HBCDD is used.
Bergman, Å., Rydén, A., Law, R. J., de Boer, J., Covaci, A., Alaee, M., Birnbaum, L., Petreas, M., Rose, M., Sakai, S., Van den Eede, N., van der Veen, I. (2012). A novel abbreviation standard for organobromine, organochlorine and organophosphorus flame retardants and some characteristics of the chemicals. Environment international, 49, 57-82.

<table>
<tr><td></td><td colspan="2"></td><td></td><td>and articles</td><td></td></tr>
<tr><td>ECB 2008</td><td colspan="2">< 90%</td><td>n.s.</td><td>2%</td><td>~ 10% in 2003</td></tr>
<tr><td rowspan="2">IOM 2008</td><td colspan="2">Most</td><td rowspan="2"></td><td rowspan="2">2% in EU 15 2000-2004</td><td rowspan="2">2% in 2007</td></tr>
<tr><td>48% in 2006</td><td>52% in 2006</td></tr>
<tr><td>POPRC 6/10</td><td colspan="3">Main application</td><td>2%</td><td>2%</td></tr>
<tr><td>SWEREA 2010[35]</td><td colspan="3">96.4%</td><td>1.8%</td><td>1.8%</td></tr>
</table>

2.4.3 Exemption and labelling

The production of HBCD is allowed during a time-limited period of five years for the Parties listed in the register of specific exemptions and for use in expanded polystyrene and extruded polystyrene in buildings.

Each Party that has registered for the exemption pursuant to Article 4 for the production and use of HBCD for EPS and XPS shall take necessary measures to ensure that EPS and XPS containing HBCD can be easily identified by labelling or other means throughout its life-cycle to facilitate awareness among users and proper waste handling in accordance with Article 6.

The HBCD amendment will enter into force for most Parties on 26 November 2014, except for those Parties which might opt out, or for those Parties which had submitted the declaration for opting-in to any amendments, at the time they submitted their instruments of ratification of the Convention.

2.4.4 Chemical identity and properties

Information on the chemical identity, structure and physical properties of HBCD are listed in Table 7.

Table 7: Chemical identification and physical properties

Chemical identification and physical properties	
Chemical name:	Hexabromocyclododecane and 1,2,5,6,9,10 -hexabromocyclododecane
Trade name:	Cyclododecane, hexabromo; HBCD; Bromkal 73-6CD; Nikkafainon CG 1; Pyroguard F 800; Pyroguard SR 103; Pyroguard SR 103A; Pyrovatex 3887; Great Lakes CD-75P™; Great Lakes CD-75; Great Lakes CD75XF; Great Lakes CD75PC (compacted); Dead Sea

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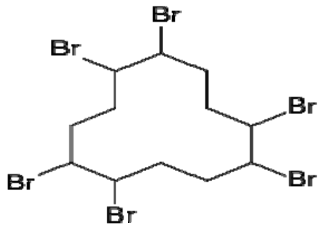
[35] Stefan Posner, Sandra Roos and Elisabeth Olsson (2010), Exploration of Management options for HBCD, Swerea IVF (2010)" http://www.unece.org/fileadmin/DAM/env/lrtap/TaskForce/popsxg/2010/Updated%20documetns_June 2010/Exploration%20of%20management%20options%20for%20HBCD.pdf

	Bromine Group Ground FR 1206 I-LM; Dead Sea Bromine Group Standard FR 1206 I-LM; Dead Sea Bromine Group Compacted FR 1206 I-CM.
CAS registry number:	25637-99-4; 3194-55-6
Structure:	
Molecular weight:	641.7 g/mol
Molecular formula:	$C_{12}H_{18}Br_6$

2.4.5 POPs characteristics of HBCD

HBCD is a synthetic substance with no known natural occurrence that continues to be used in many countries including in imported articles and products. Releases of HBCD to the environment are increasing in all regions investigated, i.e., Europe and in Asia (Japan). HBCD is persistent in the environment and bioaccumulates and biomagnifies in fish, birds and mammals. A number of measured levels in biota, including higher trophic levels such as birds and mammals, in source and remote regions are of significant concern for human health and the environment. Therefore it is concluded that HBCD is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted.

2.4.6 HBCD Alternatives

The same as ***3.4 Alternatives to HBCD*** in Part III.

2.4.7 Guidance and useful links

Guidances

- Environment Canada, Health Canada (2011), Screening Assessment Report on Hexabromocyclododecane, http://www.ec.gc.ca/ese-ees/7882C148-8AE4-4BA4-8555-668C49F91500/HBCD%20-%20FSAR%20-%20EN.pdf

Other useful links:

- Risk profile for HBCD: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Risk management evaluation (RME) for HBCD: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Specific exemptions and Register for specific exemptions for HBCD: http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/tabid/790/Default.aspx

- Arnot J et. al. (2009), An evaluation of hexabromocyclododecane (HBCD) for Persistent Organic Pollutant (POP) properties and the potential for adverse effects in the environment, http://www.unece.org/fileadmin/DAM/env/documents/2009/EB/wg5/wgsr45/Informal%20docs/An%20evaluation%20of%20hexabromocyclododecane_Final%20report.pdf
- Postle M, et al. (2011), HBCD case study: Qualitative and quantitative assessment of environmental impacts of HBCD (Annex 2), http://ec.europa.eu/environment/chemicals/reach/pdf/publications/reach_sea_part2_logicframe_final_publ.pdf

2.5 Polychlorinated biphenyls (PCBs)

2.5.1 Listing under the Convention

Listed under Annex A with specific exemptions. Also listed in Annex C.

2.5.2 Production and use

Approximately 1.3 million tonnes of PCB has been produced. Production stopped in the 1980s.

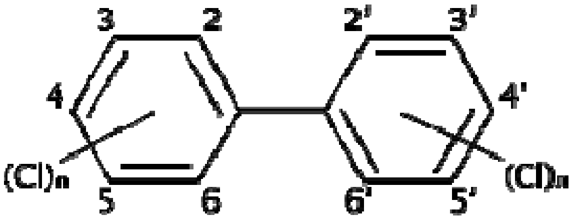
Polychlorinated biphenyls (PCBs) are a class of industrial chemicals. Since 1930 PCBs were used for a variety of industrial uses (mainly as dielectric fluids in capacitors and transformers but also as flame retardants, ink solvents, plasticizers, etc.) because of their chemical stability. PCBs are fire resistant, have a low electrical conductivity, high resistance to thermal breakdown and a high resistance to oxidants and other chemicals. There are 209 possible PCB congeners, from monochlorinated to the fully chlorinated decachlorobiphenyl isomer.

2.5.3 Chemical identity and properties

Information on the chemical identity, structure and physical properties of PCB is listed in Table 8.

Table 8: Chemical identification and physical properties of PCBs

Chemical identification and physical properties	
Chemical name and CAS registry number:	Polychlorinated biphenyls (PCBs) 1336-36-3
Trade names:	Aroclor, Pyranol, Pyroclor, Phenochlor, Pyralene, Clophen, Elaol, Kanechlor, Santotherm, Fenchlor, Apirolio, Sovol.

Structure:	
Molecular weight:	188.7 - 498.7 g/mol
Molecular formula:	$C_{12}H_{10-x}Cl_x$ (x = 1-10)

2.5.4 Exemption

Articles containing PCBs may remain in use until 2025, in accordance with the provisions of Part II of the Annex of the Convention.

2.5.5 POPs characteristics of PCBs

The degradation of PCBs in the environment depends largely on the degree of chlorination of the biphenyl, with persistence increasing as the degree of chlorination increases. Half-lives for PCBs undergoing photodegradation range from approximately 10 days for a monochlorobiphenyl to 1.5 years for a heptachlorobiphenyl.

The persistence of PCBs, combined with the high partition coefficients of various isomers (log KOW ranging from 4.3 to 8.26) provide the necessary conditions for PCBs to bioaccumulate in organisms. Bioconcentration factors of 120,000 and 270,000 have been reported in fathead minnow.

Concentration factors in fish exposed to PCBs in their diet were lower than those for fish exposed to PCBs in water, suggesting that PCBs are bioconcentrated (taken up directly from the water) as opposed to being bioaccumulated (taken up by water and in food).

The chemical properties of PCBs (low water solubility, high stability, and semi-volatility) favour their long range transport, and PCBs have been detected in arctic air, water and organisms.

2.5.6 PCB Alternatives

The same as ***3.5 PCB*** in Part III.

2.5.7 Guidance and useful links

Guidances

- Guidance Documents on PCBs (Stockholm Convention Website) http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx

- Basel Convention (2003), Preparation of a National Environmentally Sound Management Plan for PCBs and PCB-Contaminated Equipment - Training Manual, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- Basel Convention (2007), Updated technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls (PCBs), polychlorinated terphenyls (PCTs) or polybrominated biphenyls (PBBs), http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- Basel Convention (2007), Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs), http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- Intergovernmental Forum on Chemical Safety (2001), Framework for the management of PCBs, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- UNEP Chemicals (1999), Guidelines for the identification of PCBs and materials containing PCBs Guidelines for the identification of PCBs and materials containing PCBs; http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- Basel Convention (2002), Destruction and decontamination technologies for PCBs and other POPs wastes under the Basel Convention – Volume A, B and C http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- Basel Convention (2002), Destruction and decontamination technologies for PCBs and other POPs wastes under the Basel Convention – Volume B, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx

Other useful links:

- Stockholm Convention (2010), PCBs Elimination Network (PEN) magazine, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- IPEN (2009), Open systems uses of PCBs, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- L. Ritter et al., Persistent Organic Pollutants. An Assessment Report on: DDT Aldrin Dieldrin Endrin Chlordane Heptachlor Hexachlorobenzene Mirex

Toxaphene Polychlorinated Biphenyls Dioxins and Furans, The International Programme on Chemical Safety (IPCS) ; http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx

- UNEP Chemicals (2002), PCB Inventory Form; http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- UNEP Chemicals (2002), PCB Transformers and Capacitors - From Management to Reclassification and Disposal, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- UNEP Chemicals (2004), Inventory of World-wide PCB Destruction Capacity, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx
- UNEP Chemicals (2000), Survey of Currently Available Non- Incineration PCB Destruction Technologies, http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665/Default.aspx

2.6 Technical endosulfan and related isomers

2.6.1 Listing in the Convention

Listed under Annex A with specific exemptions

Risk profile Ar, Cn, Fr, En, Ru, Sp
Risk management evaluation (RME) Ar, Cn, Fr, En, Ru, Sp,

Endosulfan is an insecticide that has been used since the 1950s to control crop pests, tsetse flies and ectoparasites of cattle and as a wood preservative. Endosulfan has been banned or restricted in a number of countries but it is still extensively used in other countries. As a broad-spectrum insecticide, endosulfan is still used to control a small range of pests on a variety of crops including coffee and cotton. It has been listed with a number of crop-pest of time-limited exemptions for five years.

2.6.2 Production and use

According to the Draft Risk Profile for Endosulfan[36], prepared by the POPRC in 2009, Endosulfan is synthesized via the following steps: Diels-Alder addition of hexachloro-cyclopentadiene and cis-butene-1,4-diol in xylene. Reaction of this cis-diol with thionyl chloride forms the final product.

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[36] UNEP (2009), Draft risk profile: endosulfan. UNEP/POPS/POPRC.5/3.

Endosulfan was developed in the early 1950s. Global production of endosulfan was estimated to be 10,000 tonnes annually in 1984. Current production is judged to be significantly higher than in 1984. In 2007- 2008 India was regarded as being the world’s largest producer (9900 tonnes per year (Government of India 2001-2007)) and exporter (4104 tonnes to 31 countries (Government of India[37])); followed by Germany (approximately 4000 tonnes per year); China (2400 tonnes), Israel and South Korea.

The same Draft Risk Profile describes endosulfan as an insecticide used to control chewing, sucking and boring insects, including aphids, thrips, beetles, foliar feeding caterpillars, mites, borers, cutworms, bollworms, bugs, white fliers, leafhoppers, snails in rice paddies, earthworms in turf, and tsetse flies.

Also, endosulfan is used on a very wide range of crops. Major crops to which it is applied include soy, cotton, rice, and tea. Other crops include vegetables, fruit, nuts, berries, grapes, cereals, pulses, corn, oilseeds, potatoes, coffee, mushrooms, olives, hops, sorghum, tobacco, and cacao. It is used on ornamentals and forest trees, and has been used in the past as an industrial and domestic wood preservative.

The use of Endosulfan is now banned in at least 60 countries[38] with former uses replaced by less hazardous products and methods.

2.6.3 Chemical identity and properties

Information on the chemical identity, structure and physical properties of technical endosulfan and its isomers is listed in Table 9.

Table 9: Chemical identification and physical properties of Endosulfan

Chemical identification and physical properties		
Chemical name:	Endosulfan 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide 6,9-methano-2,4,3-benzodioxathiepin-6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9-hexahydro-3-oxide	
Trade name:	Thiodan® , Thionex, Endosan, Farmoz, Endosulfan, Callisulfan	
CAS registry number:	alpha (α) endosulfan	959-98-8
	beta (β) endosulfan	33213-65-9
	technical endosulfan *	115-29-7

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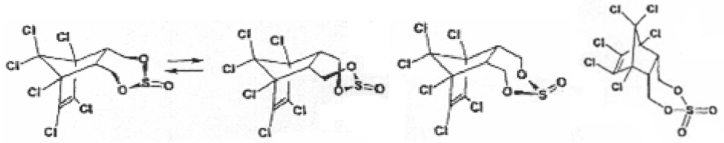
[37] Government of India, Ministry of Commerce & Industry, Department of Commerce Export Import Data Bank. Export: Commodity-wise all countries. Commodity 38081018. Endosulfan technical., http://commerce.nic.in/eidb/Default.asp.

[38] Austria, Bahrain, Belgium, Belize, Benin, Bulgaria, Burkina Faso, Cambodia, Cape Verde,Chad, Colombia, Cote d’Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Estonia, Finland, France, Gambia, Germany, Greece, Guinea Bissau, Hungary, Indonesia, Ireland, Italy, Jordan, Kuwait, Latvia, Lithuania, Luxembourg, Malaysia, Mali, Malta, Mauritania, Mauritius, Netherlands, New Zealand, Niger, Nigeria, Norway, Oman, Poland, Portugal, Qatar, Romania, Saudi Arabia, Senegal, Singapore, Slovakia, Slovenia, Spain, Sri Lanka, St Lucia, Sweden, Syria, the United Arab Emirates, United Kingdom.

	Endosulfan sulfate: * stereochemically unspecified	1031-07-8
Structure:	 α-endosulfan β-endosulfan endosulfan sulfate	
Molecular weight:	406.96 g·mol^{-1}	422.96 g·mol^{-1}
Molecular formula:	$C_9H_6Cl_6O_3S$	$C_9H_6Cl_6O_4S$

* Technical endosulfan is a 2:1 to 7:3 mixture of the α- and the β-isomer.

2.6.4 POPs characteristics of Endosulfan

Endosulfan has been reported throughout the atmosphere of northern Polar Regions. Concentrations of endosulfan (isomers unspecified) from Arctic air monitoring stations increased from early to mid-1993 and remained at that level through the end of 1997. Unlike most other organochlorine pesticides that have decreased over time, average concentrations of endosulfan in the Arctic have not changed significantly during the last five years.

The rapid field dissipation of the endosulfan isomers is related to volatility and it is then subject to atmospheric long-range transport. Persistence, in particular in colder regions, and bioaccumulation potential are confirmed through the combination of experimental data, models and monitoring results. Endosulfan is highly toxic to the environment and there is evidence suggesting the relevance of some effects on humans. However, the information on its genotoxicity and potential for endocrine disruption is not fully conclusive. Based on the inherent properties, and given the widespread occurrence in environmental compartments and biota in remote areas, together with the uncertainty associated with the insufficiently understood role of the metabolites which maintain the endosulfan chemical structure, it is concluded that endosulfan is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted.

2.6.5 Exemptions

By its decision SC-5/3, the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants (COP) decided to amend part I of Annex A to the Convention to list therein technical endosulfan and its related isomers, with specific exemptions:

Production

As allowed for the Parties listed in the Register of Specific Exemptions

Use

Crop-pest complexes as listed in accordance with the provisions of part VI of Annex A.

2.6.6 Endosulfan alternatives

The same as ***3.6 Alternatives to Endosulfan*** in Part III.

2.6.7 Guidance and useful links

Guidances

Several guidance documents have been developed in the frame of the Stockholm Convention to support Parties in the implementation of Convention. Guidance with relevance to Endosulfan is:

- Report on the assessment of chemical alternatives to endosulfan and DDT (2012), http://chm.pops.int/Convention/POPsReviewCommittee/POPRCMeetings/POPRC8/POPRC7WorkingDocuments/tabid/2801/Default.aspx
- Report on the assessment of non-chemical alternatives to endosulfan (2012), http://chm.pops.int/Convention/POPsReviewCommittee/POPRCMeetings/POPRC8/POPRC7WorkingDocuments/tabid/2801/Default.aspx
- Endosulfan - An introduction to the chemical added to the Stockholm Convention at the fifth meeting of the Conference of the Parties (2011), http://chm.pops.int/Default.aspx?tabid=3013

Other useful links:

- Specific exemptions and Register for specific exemptions for technical Endosulfan and related isomers: http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/tabid/790/Default.aspx
- Risk profile for technical Endosulfan and related isomers: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Risk management evaluation (RME) for technical Endosulfan and related isomers: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx

2.7 DDT (1,1,1-tricholoro-2,2-bis (4-chloroohenyl) ethane)

2.7.1 Listing under the Convention

Listed under Annex B with acceptable purposes

Risk profile Ar, Cn, Fr, En, Ru, Sp
Risk management evaluation (RME) Ar, Cn, Fr, En, Ru, Sp,

DDT (dichlorodiphenyltrichloroethane) is an organochlorine insecticide which is a colorless, crystalline, solid, tasteless and almost odorless chemical compound.

Technical DDT has been formulated in almost every conceivable form including solutions in xylene or petroleum distillates, emulsifiable concentrates, water-wettable powders, granules, aerosols, smoke candles, and charges for vaporisers and lotions[39].

2.7.2 Production and use

According to the Report of the expert group on the assessment of the production and use of DDT and its alternatives for disease vector control[40], the global production of DDT in 2009 was estimated at 3314 tonnes (expressed in active ingredient; a.i.), which was a reduction of 43% relative to production in 2007. India was the only reported producer. China, the other major producer of DDT until 2007, has confirmed to have stopped the production of DDT.

China and India have both exported DDT. China exported DDT as a technical product whereas India exported 75% WP formulation. In 2008, China exported a record 1,500 tonnes (a.i.) from existing stocks. India exported 465 tonnes (a.i.) in 2008 and 124 tonnes in 2009. Export from India was mainly to Mozambique with minor quantities exported to Gambia and Eritrea.

Three counties were formulating DDT: South Africa, Ethiopia and the Democratic People's Republic of Korea. DDT was formulated with technical product imported from China. Ethiopia has stopped formulation of DDT in 2009 and has switched the formulation plants to production of deltamethrin instead. South Africa has notified its export of formulated product to Swaziland and Zambia. The Democratic People's Republic of Korea had formulated 160 tonnes of DDT per year in 2007.

Regarding the use, the report states that reported use of DDT in 2009 from India, Ethiopia, Zambia, and Mauritius combined was 4783 tonnes.

India remains the largest user of DDT by far, reporting 3415 tonnes used in 2009. Ethiopia reported 1350 tonnes used in 2009 and it has stopped using DDT after 2009, switching to deltamethrin for use in indoor residual spraying.

DDT was mainly used for malaria control. In India, an estimated 1100 tonnes (active ingredient) of DDT was used for the control of leishmaniasis.

2.7.3 Chemical identity and properties

Information on the chemical identity, structure and physical properties of DDT is listed in Table 10.

Table 10: Chemical identification and physical properties

Chemical identification and physical properties	
Chemical name:	DDT 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane

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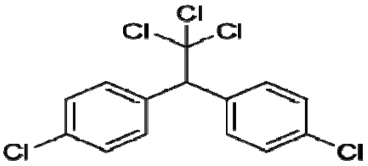
[39] DDT and its Derivatives. Geneva: World Health Organisation. 1989. p. 83. ISBN 92-4-154283-7.

[40] UNEP (2010), Report of the expert group on the assessment of the production and use of DDT and its alternatives for disease vector control. UNEP/POPS/COP.5/5.

Trade name:	Anofex (Geigy Chemical Corp.), Cezarex, Chlorophenothane, Clofenotane, Dicophane, Dinocide, Gesarol (Syngenta Crop.), Guesapon, Guesarol, Gyron (Ciba-Geigy Corp. – now Novartis), Ixodex, Neocid (Reckitt & Colman, Ltd), Neocidol (Ciba-Geigy Corp. – now Novartis), and Zerdane
CAS registry number:	50-29-3
Structure:	
Molecular weight:	354.49 g/mol
Molecular formula:	$C_{14}H_9Cl_5$

2.7.4 POPs characteristics of DDT

DDT is a persistent organic pollutant that is readily adsorbed to soils and sediments, which can act both as sinks and as long-term sources of exposure contributing to terrestrial organisms[39]. Depending on conditions, its soil half life can range from 22 days to 30 years. Routes of loss and degradation include runoff, volatilization, photolysis and aerobic and anaerobic biodegradation. Due to hydrophobic properties, in aquatic ecosystems DDT and its metabolites are absorbed by aquatic organisms and adsorbed on suspended particles, leaving little DDT dissolved in the water itself. Its breakdown products and metabolites, DDE and DDD, are also highly persistent and have similar chemical and physical properties[41]. Because of its hydrophobic properties, DDT has a high potential to bioaccumulate, especially in predatory birds[42].http://en.wikipedia.org/wiki/DDT - cite_note-41#cite_note-41 DDT, DDE, and DDD magnify through the food chain, with apex predators such as raptor birds concentrating more chemicals than other animals in the same environment. They are very hydrophobic and are stored mainly in body fat. DDT and DDE are very resistant to metabolism; in humans, their half-lives are 6 and up to 10 years, respectively.

2.7.5 Specific exemption and acceptable purpose

DDT is listed in Annex B with the following Acceptable purposes and specific exemptions for production and use.

Chemical	Activity	Acceptable purpose or specific exemption
DDT (1,1,1-trichloro-2,2-bis(4-chrlorophenyl) ethane) CAS No 50-29-3	Production	Acceptable purpose: Disease vector control use in accordance with Part II of this Annex

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[41] Toxicological Profile: for DDT, DDE, and DDE. Agency for Toxic Substances and Disease Registry, September 2002.

[42] Connell, D. et al. (1999). Introduction to Ecotoxicology. Blackwell Science. p. 68. ISBN 0-632-03852-7.

		Specific exemption: Intermediate in production of dicofol Intermediate
	Use	Acceptable purpose: Disease vector control use in accordance with Part II of this Annex Production of dicofol Intermediate

2.7.6 DDT Alternatives

The same as ***3.7 Alternatives to DDT*** in Part III.

2.7.7 Guidance and useful links

Guidance

- Report on the assessment of chemical alternatives to endosulfan and DDT (2012): http://chm.pops.int/Convention/POPsReviewCommittee/POPRCMeetings/POPRC8/POPRC7WorkingDocuments/tabid/2801/Default.aspx
- Report of the Expert Group on the Assessment of the Production and Use of DDT and its Alternatives for Disease Vector Control (2012): http://chm.pops.int/Implementation/DDT/Meetings/DDTEG42012/tabid/2942/mctl/ViewDetails/EventModID/874/EventID/338/xmid/9462/Default.aspx

Other useful link:

- Acceptable purposes and Register for acceptable purposes for DDT: http://chm.pops.int/Implementation/Exemptions/AcceptablePurposesDDT/tabid/456/Default.aspx

2.8 Lindane

2.8.1 Listing under the Convention

Listed under Annex A with specific exemptions

Risk profile Ar, Cn, Fr, En, Ru, Sp
Risk management evaluation (RME) Ar, Cn, Fr, En, Ru, Sp,

Lindane, also known as *gamma*-hexachlorocyclohexane, (γ-HCH), gammaxene, Gammallin and erroneously known as benzene hexachloride (BHC)[43], is an isomer of

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[43] Brandenberger, Hans; Maes, Robert A. A. (1997). Analytical toxicology: for clinical, forensic, and pharmaceutical chemists. Berlin: Walter de Gruyter. p. 243. ISBN 978-3-11-010731-9.

hexachlorocyclohexane that has been used both as an agricultural insecticide and as a pharmaceutical treatment for lice and scabies[44,45].

2.8.2 Production and use

According to the Draft Risk Profile for Lindane[46] prepared by POPRC and the assessments of the International HCH and Pesticide Association, the global lindane usage from 1950 to 2000 for agricultural, livestock, forestry, human health and other purposes amounts to around 600 000 tonnes[47].

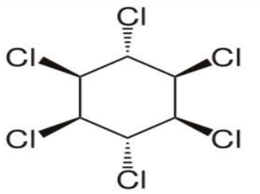
Lindane productions operated in Austria, Brazil, China, Czech Republic, France, Germany, Hungary, India, Italy, Japan, Macedonia, Nigeria, Poland, Romania, Slovakia, South Africa, Spain, Switzerland, The Netherlands, UK, United States, and former USSR. The last Lindane production was operated in India and also stopped production.

Lindane has been used as a broad spectrum insecticide, which acts by contact, for both agricultural and non-agricultural purposes. Lindane has been used for seed and soil treatment, foliar applications, tree and wood treatment and against ectoparasites in both veterinary and human applications (WHO, 1991)[48].

2.8.3 Chemical identity and properties

Information on the chemical identity, structure and physical properties of lindane is listed in Table 11.

Table 11: Chemical identification and physical properties of Lindane

Chemical identification and physical properties	
Chemical name:	Lindane
CAS registry number:	58-89-9
Structure:	

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[44] Drugs.com Professional Drug Information: Lindane.

[45] Commission for Environmental Cooperation. The North American Regional Action Plan (NARAP) on Lindane and Other Hexachlorocyclohexane (HCH) Isomers. 2005. Available at: http://www.cec.org/files/PDF/POLLUTANTS/Lindane-NARAP-Public-Comment_en.pdf.

[46] UNEP (2006), Draft Risk Profile: Lindane. UNEP/POPS/POPRC.2/10.

[47] Vijgen J, Abhilash PC, Li Y-F, Lal R, Forter M, Torres J, Singh N, Yunus M, Tian C, Schäffer A, Weber R (2011) HCH as new Stockholm Convention POPs – a global perspective on the management of Lindane and its waste isomers. Env Sci Pollut Res. 18, 152-162.

[48] WHO (1991). Environmental Health Criteria 124 Lindane

Molecular weight:	290.83 g/mol
Molecular formula:	$C_6H_6Cl_6$

2.8.4 POPs characteristics of Lindane

Lindane has been the subject of numerous risk assessment reports by different agencies, diverse country regulations and international initiatives, indicating the general concern raised by this organochlorine compound and indicating global action has already been undertaken.

The information provided in the risk profile document, as well as the information contained in the numerous risk assessment reports published on lindane, indicate that lindane is persistent, bioccumulative and toxic, and is found in environmental samples all over the world as well as in human blood, human breast milk and human adipose tissue in different studied populations, especially impacting Arctic communities that depend on subsistence foods. These findings indicate that lindane is likely as a result of its long-range environmental transport to lead to significant adverse human health and environmental effects such that global action is warranted.

2.8.5 Specific exemption

Use as human health pharmaceutical for control of head lice and scabies as second line

2.8.6 Lindane Alternatives

The same as ***3.8 Alternatives to Lindane*** in Part III.

2.8.7 Guidance and useful links

Guidances

- FAO Pesticide Disposal Series Environmental Management Tool Kit for Obsolete Pesticides Volume 3 http://www.fao.org/fileadmin/templates/obsolete_pesticides/Guidelines/EMTK3web_nov_small.pdf
- FAO Pesticide Disposal Series Environmental Management Tool Kit for Obsolete Pesticides Volume 4 http://www.fao.org/fileadmin/templates/obsolete_pesticides/Guidelines/EMTK4xweb_nov_small.pdf
- IPEN (2009) NGO Guide to Hazardous Pesticides and SAICM http://www.ipen.org/documents/ngo-guide-hazardous-pesticides-and-saicm
- Stockholm Convention (2010), Startup Guidance for the 9 new POPs (general information, implications of listing, information sources and alternatives): http://chm.pops.int/Implementation/NewPOPs/Publications/tabid/695/Default.aspx

Other useful links:

- FAO Prevention and Disposal of obsolete pesticides: http://www.fao.org/agriculture/crops/obsolete-pesticides/en/
- Risk profile for Lindane: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Risk management evaluation (RME): http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx
- Specific exemptions and Register for specific exemptions for Lindane: http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/tabid/790/Default.aspx
- Vijgen J (2006a) The legacy of lindane HCH isomer production. Main report. http://www.ihpa.info/docs/library/reports/Lindane%20Main%20Report%20DEF20JAN06.pdf
- Vijgen J (2006b) The legacy of Lindane HCH isomer production. Annexes. IHPA, Holte, January 2006 http://www.clu-in.org/download/misc/Lindane_AnnexesDEF20JAN06.pdf

3 POPs-free/POPs alternatives – overview and case studies

According to the "Guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals", (UNEP 2009)[49] prepared by the POPs Review Committee, the objective of promoting the use of alternatives under the Convention is to protect human health and the environment. Unlike the original POPs, and particularly dioxins and POPs pesticides the major exposure pathway for some of the more recently listed POPs such as polybrominated diphenyl ethers may not be mainly from exposure via the food chain. Significant exposures can now include other pathways arising from releases of POPs from furniture, pillows, carpet paddings or polyurethane-filled baby products. In these cases, POPs may contaminate the indoor environment including house dust which can be ingested, particularly by children and infants (Stapleton et al. 2004[50]; Harrad et al. 2006[51]; Stapleton et al. 2008[52]; Johnson et al. 2010[53]; Imm et al. 2009[54]). High POP-PBDE levels in gymnasts who have significant contact with polyurethane foam mats (Carignan et al 2013)[55] or carpet installers (Stapleton et al. 2008)[56] demonstrate contamination from exposure to POP-PBDEs in articles. Even after 40 years, people in housing containing PCBs have considerably higher body burdens compared to the general population (Meyer et al. 2014[57]). In Switzerland approximately 20% of the public swimming pool areas are contaminated from former use of PCB paints and renovations (Knechthofer 2009)[58]. The Swiss regional governments are requested now

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[49] UNEP (2009) Guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals. UNEP/POPS/POPRC.5/10/Add.1.

[50] Stapleton, H M, Dodder NG, Offenberg JH, Schantz MM, Wise SA. 2004. Polybrominated diphenyl ethers in house dust and clothes dryer lint. *Environ Sci Technol* 39, 925-931.

[51] Harrad S, Hazrati S, Ibarra C. Concentrations of polychlorinated biphenyls in indoor air and polybrominated diphenyl ethers in indoor air and dust in Birmingham, United Kingdom: implications for human exposure. Environ Sci Technol 40, 4633–4638.

[52] Stapleton HM, Kelly SM, Allen JG, McClean MD, Webster TF (2008) Measurement of PBDEs on hand wipes: estimating exposure from hand- to-mouth contact. Environ Sci Technol, 42:3329–3334.

[53] Johnson PI, Stapleton HM, Sjodin A, Meeker JD (2010) Relationships between polybrominated diphenyl ether concentrations in house dust and serum. *Environ Sci Technol* 44: 5627-5632.

[54] Imm P, Knobeloch L, Buelow C, Anderson HA (2009) Household exposures to polybrominated diphenyl ethers (pbdes) in a wisconsin cohort. *Environ Health Perspect* 117 (12): 1890-5. Imm et al found that the bromine content in the participant's sleeping pillow (p-value = 0.005) and primary vehicle seat cushion (p-value = 0.03) were the strongest predictors of PBDE blood concentrations.

[55] Carignan CC, Heiger-Bernays W, McClean MD, Roberts SC, Stapleton HM, Sjödin A, Webster TF. (2013) Flame Retardant Exposure among Collegiate United States Gymnasts. Environ Sci Technol. 47:13848-13856.

[56] Stapleton HM, Sjödin A, Jones RS, Niehüser S, Zhang Y, Patterson DG Jr. (2008) Serum levels of polybrominated diphenyl ethers (PBDEs) in foam recyclers and carpet installers working in the United States. Environ Sci Technol. 42:3453-3458.

[57] Meyer HW, Frederiksen M, Göen T, Ebbehoj NE, Gunnarsen L, Brauer C, Kolarik B, Müller J, Jacobsen P (2013) Plasma polychlorinated biphenyls in residents of 91 PCB-contaminated and 108 non-contaminated dwellings—An exposure study, International Journal of Hygiene and Environmental Health 216, 755– 762.

[58] Knechtenhofer L (2009) Ein Fünftel der Bäder ist mit PCB belastet. Kommunalmagazin, Bauen und Bauten, Nr. 2 2009.

to develop inventories of PCB contaminated swimming-pool areas by 2017 (Agir 2013)[59].
These exposure situations of POPs in articles and products and long term management problems, including the contamination of large material flows and recycling schemes, reinforce the pressing need to substitute POPs in consumer articles with sustainable alternatives. This is an important contribution for the protection of human health and cleaner recycling flows as a basis for a circular economy.

In this section alternatives to the individual POPs, having an exemption for continuing use under the Convention or being otherwise present in products and articles and which can be reduced through substitution by better alternatives or reduced by other means to get products and articles free or virtually free of POPs, are compiled.
In the Convention, and in the present document, the term “alternative” is used to denote a chemical, material, product, product design, system, production process or strategy that can replace listed persistent organic pollutants or candidate chemicals, or materials, products, product designs, systems, production processes or strategies that rely on listed persistent organic pollutants or candidate chemicals, while maintaining an acceptable level of efficacy.

3.1 POPs Review Committee considerations on identification and evaluation of alternatives and developed guidance

The POPs Reviews Committee agreed at its fourth meeting that a guidance document should be prepared, describing the issues related to alternatives and indicated the considerations related to persistence, bioaccumulation, and potential for long-range environmental transport and adverse effects that should be taken into account when dealing with possible alternatives.
At its fifth meeting, the Committee adopted the document ”Guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals” (UNEP 2009)[49] on the basis of a draft developed by an inter-sessional working group.
The document is intended to provide general guidance on the identification and evaluation of alternatives to the chemicals listed in the annexes to the Stockholm Convention or proposed for listing in the annexes.

The General guidance highlights that simply replacing POPs with other hazardous chemicals should be avoided and safer alternatives should be pursued. A “safer alternative” is an alternative that either reduces the potential for harm to human health

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Kohler, M., Tremp, J., Zennegg, M., Seiler, C., Minder-Kohler, S., Beck, M., ... & Schmid, P. (2005). Joint sealants: an overlooked diffuse source of polychlorinated biphenyls in buildings. Environmental science & technology,39(7), 1967-1973.

[59] AGIR (2013) Schweizer Arbeitsgruppe lnterventionswerte und Risikobeurteilung der Fachstellen Bodenschutz der Kantone Faktenblatt „Belastungen des Bodens durch PCB in Freibädern“ 23.01.2013.

or the environment or that has shown not to meet the Annex D screening criteria for listing a chemical under the Convention as a persistent organic pollutant. To ensure that a potential alternative leads to the protection of human health and the environment, a risk profile for the chemical being considered should be developed to assess whether it is safer than persistent organic pollutants. In case a comprehensive risk assessment may be impossible, due to the lack of information on its hazardous properties or exposure data, at minimum, a simple analysis of risk should be performed, taking into account the weight of available evidence.

Even if the alternative does not contain, use or lead to the formation of other chemicals with the characteristics of a persistent organic pollutant, it may lead to increased risk to human health and the environment depending on its hazardous properties and exposure conditions. Efforts should be made to collect information to ensure that:

- The alternative chemical does not have hazardous properties that raise serious concern, such as mutagenicity, carcinogenicity or adverse effects on the reproductive, developmental, endocrine, immune or nervous systems;
- The risk resulting from the use of the alternative is considerably lower than that resulting from the use of persistent organic pollutants, in view of its known hazardous properties and exposure conditions.

The guidance provides a general description of the issues to be considered in identifying and evaluating alternatives to listed persistent organic pollutants and candidate chemicals. The steps in the identification and evaluation of alternatives are shown in the figure below and the individual steps are described in individual chapters of the guidance document.

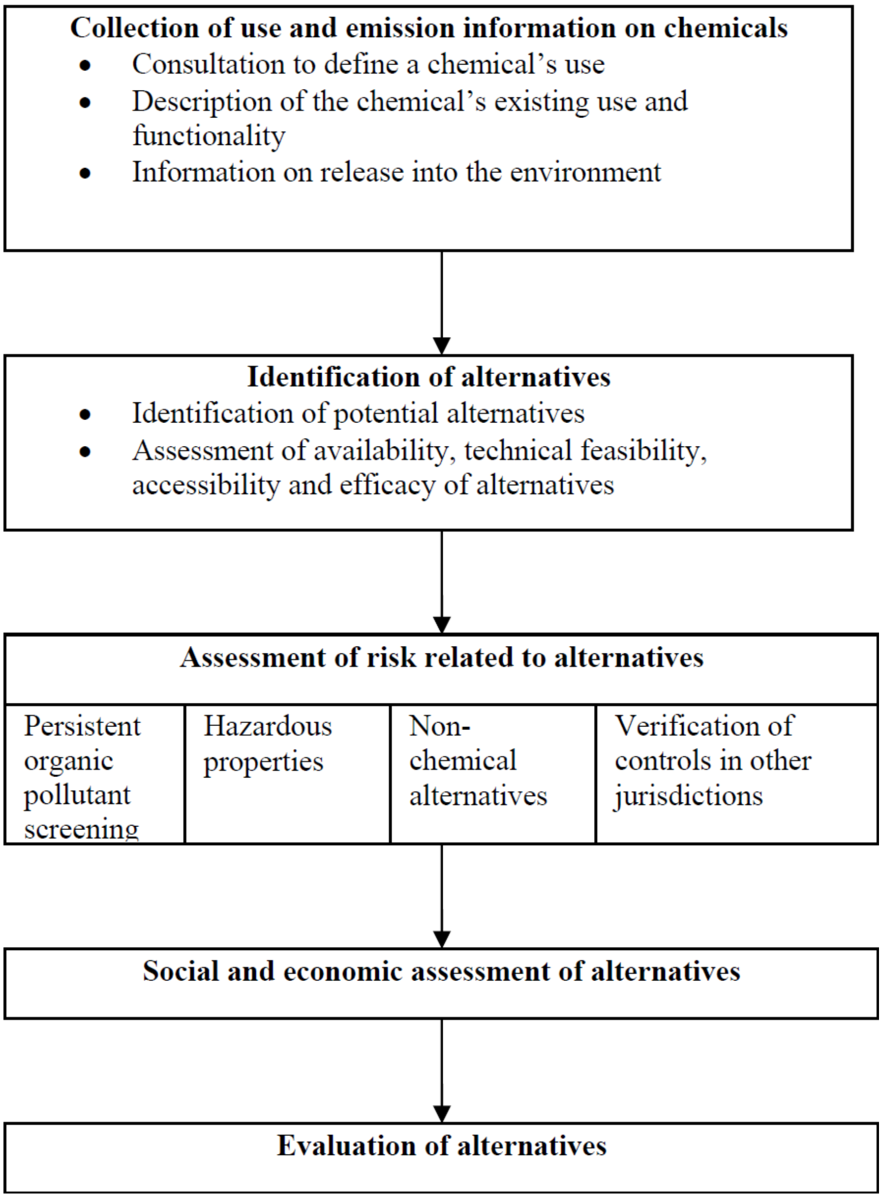

Figure 1: Steps in the identification and evaluation of alternatives

Foremost attention should be also paid to the potential for harm under actual conditions of use by consumers and to indications that the processing or manufacturing conditions of the alternative might increase health risks of factory workers. Finally, all exposures and risks must be seen in a product life cycle perspective to avoid burden shifting and to ensure an overall net benefit from substituting POPs chemicals in products and articles.

Key conclusions and recommendations of this guidance can be summarized as follows:

- It is essential to identify the precise use and functionality of listed persistent organic pollutants and candidate chemicals, which requires information to be collected from various sources, mainly through consultations with industry and other stakeholders. The availability of alternative chemicals, products or processes can be determined by conducting a survey on which specific alternatives are feasible for what use;

- Although it may be difficult to implement fully risk assessment on alternatives, Parties should at least confirm that persistent organic pollutants are not substituted by others POPs-like chemicals or by chemicals with concern of significant risk;
- Although it is difficult to estimate precisely costs and benefits of alternatives, Parties should make every effort to collect information on social and economic impacts to evaluate cost-effectiveness for a particular use;
- Cooperative efforts are helpful to facilitate further dissemination of better and safer alternatives worldwide. The development of the present guidance under the auspices of the POPs Review Committee is one example.

Other alternative assessment approaches have been compiled in this publication (***4.3Alternative assessment approaches for chemical alternatives***)

3.2 Alternatives to PFOS

At its forth meeting the Conferences of Parties to the Stockholm Convention decided to list perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF) in Annex B (Restriction) of the Convention with the following acceptable purposes and specific exemptions for production and use, as listed in Part III of Annex B (Annex 3). Alternatives to PFOS are addressed in this publication to provide information that may permit Parties to substitute PFOS with safer alternatives.

The reasons for addressing selected exempt uses of PFOS in this publication are:

- Those which today are thought to be the major uses
- Those where countries have applied for exemptions and industries in certain countries are considering to need exemptions (Annex 3)
- Those were POPRC information is thought to be missing and were POPRC requested Parties and observers to provide information on use of PFOS or its alternatives and on quantities of PFOS:
    - Aviation hydraulic fluid;
    - Chemically driven oil production;
    - Electric and electronic parts for some colour printers and colour copy machines
    - Insect baits for the control of leaf-cutting ants from the Atta and Acromyrmex species. Peer reviewed studies and pilot projects would be useful to evaluate the feasibility of alternatives to PFOS within an integrated pest management approach.

Where countries have asked for exemptions Parties might need particular support on information on alternatives. According to the Convention, Parties using PFOS and related substances need to first register for the necessary acceptable purposes and/or

specific exemptions. They will afterwards need to take action to phase out uses when suitable alternatives substances or methods are available.
The specific exemptions and/or acceptable purposes which have been registered by some Parties are compiled on the BRS Website.

A UNIDO report[60] on PFOS concluded that while developing countries might use PFOS in many sectors, industrial countries are likely restricted only to a smaller number of specific industrial uses. According to the report, China was by far the largest producer and user between 2003 and 2008. Industrial countries such as Japan and Germany were also producers and users of PFOS among developed countries in the period of 2003-2008.

China is considered the largest producer of PFOS with a production capacity of 100 t/y[61, 62]. The perfluorootane sulfonates (PFOS) are mainly used for metal plating, aqueous fire-fighting foams (AFFFs) and sulfluramid in China, and the use amount is about 30-40 t/y, 25-35 t/y and 4-8 t/y respectively.

3.2.1 POPRC Compilation of information and POPRC activities

After the listing of PFOS, its salts and PFOSF in the Convention, the POPs Review Committee came to support the Parties in their actions on switching to alternatives. The working group on guidance on alternatives to perfluorooctane sulfonic acid, its salts, perfluorooctane sulfonyl fluoride and their related chemicals constituted under POPs Review Committee prepared for its 9th meeting the "Revised draft guidance on alternatives to perfluorooctane sulfonic acid, its salts, perfluorooctane sulfonyl fluoride and their related chemicals"[63]
The guidance summarizes the most recent information about alternatives to PFOS, its salts, PFOSF and their related chemicals in order to enhance the capacity of developing countries and countries with economies in transition to phase out PFOS, its salts and PFOSF taking into account the need for longer phase-in schedules for alternatives for some uses and the fact that for certain uses alternatives may not be currently readily available in all countries.
The document concludes that fluorinated or non-fluorinated alternatives exist for nearly all current uses of PFOS and that, importantly, they will normally be less hazardous.
It should be noted that perfluorohexane sulfonate (PFHxS), a homologue of PFOS, has been determined by POPRC to have the same POP characteristics (persistence, bioaccumulation, toxicity, long-range transport) as PFOS (UNEP, 2008) and therefore

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[60] Carloni D. (2009) Perfluorooctane Sulfonate (PFOS). Production and Use. Past and current evidence.

[61] Zhang Lai et. al. (2012), The inventory of sources, environmental releases and risk assessment for perfluorooctane sulfonate in China, Environmental Pollution 165 (2012) 193 – 198.

[62] Lim, Wang B, Huang J, Deng S, Yu G (2011) Emission Inventory for PFOS in China: Review of Past Methodologies and Suggestions, The Scientific World JOURNAL 11, 1963–1980.

[63] UNEP/POPS/POPRC.9/INF/11.

the POPRC concluded that PFHxS and its related substance are not acceptable alternatives to PFOS.[64]

The most common PFOS alternatives in use are fluorotelomers, which are precursors for PFCA. Formerly, C8-fluorotelomers were a frequent choice; they have been shown, however, to degrade into PFOA, which also has hazardous properties. For that reason some producers of fluorochemicals in the EU, Japan, and US have agreed to commit to working toward the elimination of PFOA, chemicals that breakdown to PFOA, and related higher homologues by 2015. As a result, there has been a shift by producers to C6-, C4- and C3-perfluoroalkylated chemicals, and subsequent concerns about some of the properties of these substitutes have been raised[65]. Some alternatives may eliminate PFOS or other fluorinated or chemical alternatives completely. Sometimes, but not always, there is enough information to determine whether they are suitable from both, a functionality and environmental health and safety perspective.

Table 12: Availability of information used for the assessment of alternatives to the use of PFOS in open applications

Type of open use	Existence of alter-natives	Chemical identity and properties	Trade names	Producers	Traders	Quantity of use	Risks	Other information used for the assessment
Aviation hydraulic fluids	Exists	Not available	Available	Available	Available	Not available	Not available	Not available
Fire-fighting foam	Exists	Available	Available	Available	Available	Not available	Generally available	Available
Insecticides	Exists	Available	Available	Available	Available	Not available	Generally available	Limited information on cost effectiveness
Hard metal plating	Exists	Available	Available	Available	Available	Not available	Generally available	Available in general
Decorative metal plating	Exists	Available	Available	Available	Available	Not available	Generally available	Available in general
Electric and electronic parts for some colour printers and colour copy machines	Exists	Not available	Not available	Not available	Not available	Not available	Not available	Not available
Chemically driven oil production	Exists	Available	Available	Available	Available	Not available	Generally available	Not available

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[64] UNEP/POPS/POPRC.8/10.

[65] Scheringer M, Trier X, Cousins IT, de Voogt P, Fletcher T, Wang Z, Webster TF (2014) Helsingør Statement on poly- and perfluorinated alkyl substances (PFASs). Chemosphere. 2014 Jun 14. doi: 10.1016/j.chemosphere.2014.05.044.

Carpets, leather, apparel, textiles and upholstery	Exists	Available	Available	Available	Available	Not available	Generally available	Available
Paper, packaging, rubber and platics	Exists	Available	Available	Available	Available	Not available	Generally available	Not available
Coatings and coatings additives	Exists	Available	Available	Available	Available	Not available	Generally available	Not available

3.2.2 PFOS in textiles

PFOS and related substances have been used as surface coatings to increase the oil and water repellency of textiles. A number of alternatives to PFOS and related substance are now available for these uses.

A distinction needs to be made between the uses for hydrophobing[66]and for increasing oil repellency for specific application. There are a wider range of approaches for hydrophobing as this can be achieved by less chemically aggressive approaches compared to oil repellency.

3.2.2.1 Per and Poly-fluoroalkyl alternatives

Side-chain fluorinated polymers are used extensively by the textile industry and by consumers for the treatment of all-weather clothing, umbrellas, bags, sails, tents, parasols, sunshades, upholstery, leather, footwear, rugs, mats, carpets etc, to repel water, oil and dirt (stains).

PFOS derivatives have been banned in many countries and replaced with either shorter-chain analogues, fluorotelomers or with non-fluorinated chemicals.

The POPRC guidance includes the following alternatives for the impregnation of textile fabrics, leather, carpets, rugs and upholstery and similar articles:

(a) Other polyfluorinated compounds with shorter alkyl chain length such as:
    (i) Substances based on perfluorobutane sulfonate (PFBS);
    (ii) fluorotelomer-based substances, including polymers;

(b) Flurorotelomer triethoxy silane such as polyfluorooctyl triethoxy silane (1H,1H,2H,2H-perfluorooctyl triethoxy silane, a NanoCover® product) used in a bathroom floor spray product. This and similar substances were banned in Denmark in April 2010 because of toxic effects on mouse lungs[67].

For example 3M launched a product called Scotchgard® Protector containing 1–5% of a perfluorobutane sulfonyl urethane (the identity of the chemical has not been provided by the company), which has also been suggested as an alternative for stain-repellent impregnation of textiles, leather and carpets. DuPont has introduced a new

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[66] Increasing water repellency.

[67] www.mst.dk/Nyheder/Pressemeddelelser/Nanospray.htm.

brand name, Capstone®, for a series of alternative products for various applications based on short-chain fluorotelomers, mainly involving C6 chemistry. Other companies such as Daikin, Asahi and Clariant (and maybe others) have introduced short-chain fluorotelomers as well. Bluestar Silicones markets some silicone-based PFOS alternatives for textile applications under the trade name Advantex®[68]. The technology offers long-lasting water repellence, quick drying, waterproofness and breathability[69]. The environmental persistence of these replacements is uncertain and is the subject of ongoing research[70].

3.2.2.2 Fluorocarbon-free silicon-based alternatives

Fluorocarbon free alternatives based on:

(a) Silicone-based products[71];

(b) Mixtures of silicones and stearamidomethyl pyridine chloride, sometimes together with carbamide (urea) and melamine resins;

are available on the market.

3.2.2.3 Fluorocarbon-free hydrocarbon-based alternatives

A) F**luorocarbon-free, water-repellent finishing agent**

There is a fluorocarbon-free, water-repellent finishing agent for textiles produced available which is marketed by a German company[72]. Several known brands are utilizing this advanced technology for their hydrophobic outdoor wear. It is the ecological alternative to conventional durable hydrophobic finishes based on perfluorinated polymers.

In another product, also no perfluorinated compounds are used in the manufacturing process[73] which is the corresponding finishing product used in the textile mills for producing the aforementioned product. The latter product is composed of special waxes and star-shaped, hyper-branched polymers also called dendrimers. It can be applied to all types of substrates but is mainly used for outdoor textiles.

This PFOS/PFAS-free waterproofing agent has according to the producer a range of advantages:

- The aforementioned finishing agent[1] is based on a fluorine-free recipe. The chemical basis of it is more environmentally friendly than conventional durable water-repellent finishes containing perfluorinated polymers.
- It does not have soil- and water-repellent properties to textiles only, but also a soft handle.

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[68] High molecular weight siloxanes are normally used.

[69] www.advantex-textiles.com/.

[70] See, for example: Liu, Jinxia and Sandra Mejia Avendaño. 2013. Microbial degradation of polyfluoroalkyl chemicals in the environment: A review. *Environ Int* 61 (0): 98-114.

[71] High molecular weight siloxanes are normally used.

[72] The commercial name of the product concerned is BIONIC-FINISH®ECO marketed by Rudolf Chemie Ltd., Geretsried/Germany.

[73] The commercial name of this product is RUCO-DRY® ECO which is also marketed by Rudolf Chemie Ltd., Geretsried/Germany.

- It has a high abrasion resistance and an excellent washing durability.
- No temperature activation is required after washing.
- It improves the sewabilty of textiles during confectioning.
- The product is bluesign® approved (http://www.bluesign.com/).

According to the OECD test methods, the product is not easily biodegradable but eliminable.

The second product can be easily eliminated from the effluent (> 80%) and is considered harmless regarding water toxicity (EC-50 (bacteria) > 100 mg/l, LC-50 (fish) > 100 mg/l) as well as oral toxicity (LD-50 (rat) > 5000 mg/kg).

B) Functional finishing agent

New textile finishing products from another producer[74] are the result of an interdisciplinary development project. Experience with the textile industry, polymer processing and surface technology was combined to develop a new solution for the functional finishing of textiles. The new products include:

1. A water-repellent[75]: Water-based, aliphatic polyurethane emulsion, reactive, one- or two-component, hydrophobic.
2. A water attracting agent[4]: Water-based, aliphatic polyurethane emulsion, latent reactive, one-component, hydrophilic.
3. An abrasion protection agent[4]: Water-based, aliphatic polyurethane emulsion, reactive, one- or two-component.

According to the producer, the fluorocarbon-free waterproofing agent has a range of properties to improve the performance of textiles:

Efficiency: It offers textile finishers advantages. In addition to the desirable performance properties it also reduces manufacturing, chemical stocking and disposal costs. It does not require retooling for application purposes. It can be applied using all known textile wet finishing processes. With a solid content up to 70 percent, it makes it possible to achieve high add-ons in a single pass. Less water needs to be evaporated, and fewer stabilising agents are required. This is primarily an economic advantage for textile manufacturers resulting in better machine utilisation and reduced logistical and energy costs. In addition, because the emulsifiers are easily degradable, wastewater requires no treatment, further reducing costs. With this new product, multiple functions can be achieved through a single treatment, meaning that textile finishers can dispense with many of the chemicals they would otherwise need.

Versatility: The different handling and surface properties the product provides to textiles makes it suitable for a wide range of applications, e.g. outdoor and sportswear, workwear, protective clothing, interior of vehicles, fabrics for furniture and the home.

Compliance: The product conforms to all international laws and standards and meets or exceeds all applicable legal and regulatory standards, as well as the RSL (Restricted Substances List) guidelines of leading brands and retailers. It complies

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[74] The commercial name is Purtex® and the producer is the Freudenberg Group, Weinheim/Germany.

[75] Purtex® WR, Purtex® WA, Purtex® AP marketed by the Freudenberg Group, Weinheim/Germany.

with legal requirements for the sale within the EU (REACH), as well as individual country requirements, such as the Consumer Product Safety Improvement Act (CPSIA) in the U.S. The fact that the product is 100% solvent-free and safe to use is critical in meeting these regulations. It contains nothing but polyurethane (PUR) and does not contain substances that have been classified as toxic, harmful or non-biodegradable. The emulsifiers used for the product are readily biodegradable.

The properties of this finishing agent are neither new nor unique in themselves. It achieves a durable water repellent effect in a cost-effective product without needing to use persistent chemicals and does not contain substances that are considered in any way dangerous, either to humans or to the environment.

C) Water and dirt repellence

There is another new finishing agent that ensures a high level of water and dirt repellence (mud) on textile produced by a Swiss company[76]. The technology is environmentally sound, free from fluorocarbons and biodegradable[77].

This finishing agent consists of paraffin chains that wrap themselves around the individual fibres of a fabric. This reduces the surface tension of the textile so that water and mud with a considerably higher surface tension run off simply.

According to the producer:

- The technology is successfully applied in clothing (particularly sports and outdoor wear), as well as in other areas.
- The new product offers an alternative to finishes containing fluorocarbons while at the same time providing extremely strong performance in terms of water, dirt and abrasion resistance. E
- Applying the product, the fabrics acquire a high level of water and dirt repellence (watery dirt). In addition, thanks to the high level of abrasion resistance, the finish is permanently retained, even with heavy-duty use,
- It can be applied without difficulty to almost all types of textiles and yarn compositions. Prior to production, testing is usually carried out in order to confirm the effectiveness of this product.
- The new finishing agent is not suitable for industrial laundering, but textiles finished with it withstand professional wet laundering without difficulty.
- The fabrics finished with this product are breathable; the breathability is being retained as the paraffin chains wrap themselves around the individual fibres. The fibre interspaces are retained, and breathability therefore remains intact.

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[76] The commercial name of the product is ecorepel® marketed by Schoeller Techologies AG, Sevelen/Switzerland.

[77] in accordance with OECD 302 B (80 – 100%).

3.2.3 PFOS Alternatives in Chromium Plating

In chromium plating PFOS can be substituted by per and poly-fluoroalkyl alternatives as well as fluorocarbon-free alternatives.

The German national metal plating association (ZVO) describes the availability of PFOS-free alternative products from 10 German suppliers[78]. While information is lacking about the exact identity of several of these chemical compounds, three were fluorinated chemicals and seven were fluorine-free. The non-fluorinated alternatives were not stable enough in the hard chrome plating bath. It is stated that all 10 products could be used for decorative chrome plating, for which alternative Cr-III processes seem to exist already in many cases[78].

3.2.3.1 Per and Poly-fluoroalkyl alternatives

Reported PFOS alternatives used in chromium plating are for example perfluorobutane sulfonate (PFBS) (CAS RN 29420-49-3; CAS RN 45187-15-3) based chemicals[79] and H4PFOS (1H,1H,2H,2H-Perfluorooctanesulfonic acid; CAS-Nr.: 276-19-97-2)[80]. PFBS are rapidly eliminated from the body with a relatively low bioaccumulation potential. The toxicity and ecotoxicity of H4PFOS is less clear. The use and release of H4PFOS is higher compared to PFOS. The German Federal Environmental Agency consider H4PFOS not a good alternative substance for PFOS since it is still highly fluorinated and persistent and since it is more difficult to remove from the waste water resulting in higher quantities emitted to waste water treatment plants and ultimately into surface waters compared to PFOS[80].

In China additionally available PFOS alternatives used for chrome plating are F-53 (1,1,2,2-tetrafluoro-2-(perfluorohexyloxy)ethane sulfonate, CAS RN 756426-58-1) and F-53B (potassium 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate, CAS RN 73606-19-6)[81]. The persistence, the potential to bio-accumulate and the fish toxicity has been assessed and found similar to that of PFOS[82] and therefore a recommendation or the use of this alternative cannot be given (see ***4.7 Case study: Scientific assessment of a PFOS alternatives in chromium plating***)

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[78] Personal communication from Christoph Matheis, Zentralverbandes Oberflächentechnik e. V. (ZVO), 6 March 2009.

[79] Environmental Canada (2014) Format for the collection of information on alternatives to the use of perfluorooctane sulfonic acid, its salts, perfluorooctane sulfonyl fluoride and their related chemicals. 31.01.2014.

[80] German Federal Environmental Ministry (2014) Format for the collection of information on alternatives to the use of perfluorooctane sulfonic acid, its salts, perfluorooctane sulfonyl fluoride and their related chemicals.14.02.2014.

[81] Presentation by Jun Huang, Tsinghua University, at the national workshop on nine new persistent organic pollutants and the implementation of the Stockholm Convention in China, Beijing, 1–2 July 2010.

[82] Wang et al (2013) First Report of a Chinese PFOS Alternative Overlooked for 30 Years: Its Toxicity, Persistence, and Presence in the Environment. Environ. Sci. Technol., 47, 10163–10170.

3.2.3.2 Fluorocarbon-free based alternatives

Non-fluorinated alternatives for hard chrome plating are available on the European market. However these are rather new and some are still being tested. These alternatives appear functional with some slight process changes including stirring the chromium bath[83].

The experiences with alkylsulfonates in recent years show that alternative substances for PFOS in bright chrome plating are available. This substitution is also possible for hard chrome plating, according to the statements of the specialist companies. However, here the practical experience and transferability of existing alternatives to other hard chrome platers are lacking[84]. According to the published patent application, the mixture contains unbranched and branched long chained alkylmonosulfonic acids and alkyldisulfonic acids.[85] According to the product safety datasheet the product is biodegradable.[86]

Another possible non-fluorinated surfactant alternative for decorative plating may be Enthone® (ethoxylated oleyl amine, CAS no. 26635-93-8). Alternatives to the PFOS derivatives are less stable and durable in the chrome bath than PFOS since they degrade through oxidation.

The Norwegian association of electroplaters (Norsk Galvanoteknisk Landsforening, or NGLF) has reported that the industry has already started to phase out the use of PFOS-containing wetting/anti-mist agent by using the Cr-III process instead of the Cr-VI process where possible[87].

The use of control devices, such as Composite Mesh Pads (CMP) or Packed Bed Scrubbers (PBS), to catch aerosols from chromium plating baths offers an alternative to the use of PFOS. CMP are currently considered to be maximum achievable control technology of chrome VI aerosols, but these installations cost more than current operations. Closed tanks with increased ventilation have been suggested as alternative solutions to CMP and PBS for applications where use of chromium-III is not yet possible. However, such systems need further improvement to be as effective as control devices in getting rid of chromium emissions. There is some concern that increased ventilation will also result in increased energy consumption and loss of some chromium from baths[88]. Other methods such as using physical covers (netting, balls) for baths to diminish hydrogen burst and reduce misting currently do not work but should be further investigated[89].

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[83] www.freepatentsonline.com/6319423.html and www.freepatentsonline.com/WO2006138081.html.

[84] German Federal Environmental Agency (2013) Progress report ‘‘Replacement of PFOS with halogen-free substitute materials in galvanisation’ December 2013. Submission to POPRC 9.

[85] Bundesrepublik Deutschland Deutsches Patent-und Markenamt (2008) Offenlegungsschrift DE102006042076A12008.03.20.

[86] TIB Chemicals (2011) TIB SUACT CR-H, Sicherheitsdatenblatt gemäß 1907/2006/EG, Artikel 31. 25.07.2011.

[87] Information from Norwegian Pollution Control Authority (former Statens Forurensningstilsyn), 2009.

[88] http://eippcb.jrc.es/reference/BREF/stm_bref_0806.pdf.

[89] Poulsen et al. *Substitution of PFOS for use in nondecorative hard chrome plating*, 2011, Environmental Project No. 1371 2011, Danish Ministry of Environment.

3.2.4 PFOS alternatives for paper impregnation

PFOS derivatives have been used in food contact applications including plates, food containers, popcorn bags, pizza boxes and wraps as well as in non-food contact applications such as folding cartons, containers, carbonless forms and masking papers. Before 2000 about 32% of the total use of PFOS in the European Union was for paper coating but the use of PFOS for this purpose is no longer allowed.

3.2.4.1 Fluorinated alternatives

Historic PFOS use in the production of waterproof and greaseproof papers has been replaced mainly by other fluorinated chemicals. The alternative chemical surfactants for paper and cardboard use in packaging are short-chain telomer-based substances and perfluoropolyethers, and poly (dimethyl siloxane).

3.2.4.2 Non-fluorinated alternatives

Grease-proof paper existed before PFOS technology was introduced to the market, and so it is clear that other technologies are available as substitutes.

A 2006 survey by the Norwegian Food Safety Authority concluded that no fluorinated substances were used in fast-food packaging in Norway. Nordic Paper, a Norwegian paper manufacturer, uses mechanical processes to produce extra-dense paper that inhibits leakage of grease through the paper without the use of any additional chemical[90].

3.2.5 PFOS alternatives in firefighting foam

A number of different types of fire-fighting foams which included PFOS have been produced:

(a) Fluoro-protein foams used for hydrocarbon storage tank protection and marine applications;

(b) Aqueous film-forming foams (AFFF) developed in the 1960s and used for aviation, marine and shallow spill fires;

(c) Film-forming fluoroprotein foams (FFFP) used for aviation and shallow spill fires;

(d) Alcohol-resistant aqueous film-forming foams (AR-AFFF), which are multi-purpose foams;

(e) Alcohol-resistant film-forming fluoroprotein foams (AR-FFFP), which also are multipurpose foams, developed in the 1970s;

Fire-fighting foams containing PFOS have been very effective for extinguishing highly flammable liquid fuel fires (e.g. at airports, oil refineries or storage facilities). However, they represent a direct release of PFOS to the environment. Fire-fighting foam production is still a major use of PFOS in China.

3.2.5.1 Fluorine-containing fire-fighting foam alternatives

Today most AFFF fire-fighting foams are manufactured with fluorochemicals/telomers based on a perfluorohexane (C6) chain.

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[90] Information from Norwegian Pollution Control Authority (former Statens Forurensningstilsyn), 2009.

Manufacturers, distributors and users of AFFF fire-fighting agents and their chemical components have formed a trade association, the Fire Fighting Foam Coalition (FFFC), whose stated aim is to ensure that accurate industry information about PFOS alternatives, including telomer-based products, is disseminated to appropriate audiences.

The alternatives to the use of PFOS fluorosurfactants in fire-fighting foams are:

(a) Non-PFOS-based fluorosurfactants with shorter chain length such as:

  (i) C6-fluorotelomers such as perfluorohexane ethyl sulfonyl betaine, often used in combination with hydrocarbons such as ®Capstone® products (DuPont);
  (ii) Dodecafluoro-2-methylpentan-3-one (3M).

3.2.5.2 Non-fluorine containing fire-fighting foam

There are fluorine-free alternatives on the market,

Examples include:

  (i) Silicone-based surfactants;
  (ii) Hydrocarbon-based surfactants,
  (iii) Synthetic detergent foams, often used for forestry and high-expansion applications and for training ("Trainol"); new products with glycols (Hi Combat ATM from AngusFire)[91];
  (iv) Protein-based foams (e.g. Sthamex F-15), which are less effective for flammable liquid fuel fires and are mainly used for training but also have some marine uses.

In some applications these foams are less effective than fluorine-containing AFFF foams (POPRC Draft guidance PFOS Alternatives).

The Norwegian producer Solberg Scandinavian AS states that the performance of the fluorine-free Arctic Re-Healing Foam™ RF is close[92] to that of AFFF and that it is a good alternative for a range of uses. It has been approved for the control and extinguishing of class B flammable liquid hydrocarbon and polar fuel fires. Arctic Re-healing Foam RF meets the requirements of parts 3 and 4 of the European Committee for Standardization (CEN) EN 1568 specifications[93].

Solberg foams can also be used for Foam/Water Sprinkler System. The company has an upgrade program utilising RE-HEALING™ Foam (RF), the first UL-listed and FM-approved fluorine-free foam concentrate. This contains no fluorine or other organ halogens - whether surfactant or polymer based.

Customers with foam/water sprinkler systems containing fluorine based foam concentrates, and particularly those with older technology foams including PFOS and

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[91] www.kiddecanada.com/utcfs/Templates/Pages/Template-50/0,8061,pageId%3D2587&siteId%3D463,00.html.

[92] Due to the lower effectiveness compared to AFFF this foam is e.g. not used as alternative at offshore installations or for the petroleum industry.

[93] Information from Norwegian Pollution Control Authority (former Statens Forurensningstilsyn), 2009.

PFOA, can substitute to the non-fluorine containing alternative. The Program facilitates upgrades by users of fluorine containing Aqueous Film Forming Foam (AFFF) to the fluorine-free RE-HEALING Foam while maintaining the existing system compliance certification by NFPA 11.

Fluorine-free alternatives to fire-fighting foams in the United Kingdom were approximately 5–10% more expensive than fluorosurfactant-based foams (Risk and Policy Analysts and Building Research Environment. 2004). The price should fall as the market size increases and a major shift towards fluorine-free fire-fighting foam alternatives would probably eliminate the difference in cost.

3.2.6 PFOS alternatives in Aviation Hydraulic Fluids

According to the POPRC PFOS alternative report, there is uncertainty about alternative substances in this area. Aviation hydraulic fluids can be based on, for example, phosphate esters and fluorinated chemicals other than PFOS.

POPRC is currently gathering information from Parties on alternatives for this application and this will be included in an update of this publication.

3.2.7 PFOS alternatives for Pesticide use

N-Ethyl perfluorooctane sulfonamide (EtFOSA; sulfluramid; CAS no. 4151-50-2) is both a surfactant and a pesticide used in tropical areas against termites, cockroaches and other insects and in Brazil for control of leaf-cutting ants from the *Atta spp.* and *Acromyrmex spp*. The 2006 OECD survey indicates that sulfluramid was used in insecticides at a concentration of 0.01-0.1% with an annual volume of up to 17 tonnes. Fluorosurfactants may also be used as “inert” surfactants[94] in pesticide products. These substances are released directly to the environment.

PFOS is no longer used to manufacture ant bait or insecticides against beetles and ants in the European Union, and the United States Environmental Protection Agency cancelled the registration of sulfluramid in May 2008[95] and PFOS is no longer used to manufacture ant baits or insecticides against beetles and ants in the European Union.

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[94] Enhancers used in pesticide formulation but not consisting active ingredients.

[95] www.epa.gov/fedrgstr/EPA-PEST/2008/May/Day-16/p10919.htm.

Information submitted to the secretariat of the Stockholm Convention indicates that sulfluramid had been used to control cockroaches, white ants and fire ants) in China and is used in Brazil in more than 95% of baits for the control of leaf cutting ants. The quantity of PFOS used was not reported. Since sulfluramid is degraded to PFOS this use represents a direct release of PFOS to the environment[96].

The active ingredients currently registered in Brazil for producing bait to control leaf-cutting ants are sulfluramid, fipronil and chlorpyrifos. The latter two, however, are considered more acutely toxic to humans and the environment than sulfluramid[97]. Furthermore, the effectiveness of these substances has been questioned[97] and alternatives are now being reviewed in Brazil. According to the Brazilian Annex F information, sulfluramid cannot currently be efficiently replaced in Brazil by any other registered products commercialized for the same purpose. However, ant baits containing S-methoprene and pyriproxifen are registered in New Zealand for the control of exotic ants by aerial and ground applications[98]. In the EU, PFOS-related substances are not used in the manufacture of pesticides[99].

There are many differences between leaf-cutting ants and exotic ants (urban ants), including in alimentary behaviour and these differences explain why some active ingredients are effective for controlling urban ants but not for controlling leaf-cutting ants. Since 1958, over 7,500 chemical compounds for ant control have been studied in many countries. According to the industry association, the Leaf-Cutting Ant Baits Industries Association, less than 1% of those 7,500 compounds have shown promise[100].

Studying the adaptation mechanisms of leaf-cutter ants is recommended to improve effectiveness of strategies for their ecological management. Several mechanical, cultural, biological and chemical methods have been studied since the 1950's for controlling leaf-cutting ants. The management of the ants using resistant plants toxic plants, and by manipulating predators, parasitoids and micro-organisms, has had inconsistent results[101]. However, diversification of crop systems, including the conservation of undergrowth and strips of native vegetation offers some potential for management.[102] Biological control can be effective. In laboratory studies, the entomopathogenic *Metarrhizium anisopliae* can cause the decline and ultimate death of small colonies and research indicates that the entomopathogenic fungi *Beauveria*

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[96] UNEP (2007) Addendum Risk management evaluation on perfluorooctane sulfonate UNEP/POPS/POPRC.3/20/Add.5

[97] UNEP (2007), Draft risk management evaluation: perfluorooctane sulfonate. UNEP/POPS/POPRC.3/13.

[98] Environmental Risk Management Authority of New Zealand (ERMA NZ) (2007), Decision, 2007-11-11.

[99] http://archive.defra.gov.uk/environment/quality/chemicals/documents/pfos-riskstrategy.pdf.

[100] UNEP-POPS-POPRC-SUB-F08-PFOS-LEAF-N1.English

[101] Jaccoud DB, Hughes WOH, Jackson CW (1999) The epizootiology of a Metarhizium infection in mini-nests of the leaf-cutting ant Atta sexdens rubropilosa, ENTOMOLOGIA EXPERIMENTALIS ET APPLICATA, Volume 93, Number 1, 51-61, DOI: 10.1023/A:1003830625680.

[102] Della Lucia TMC, Gandra LC, Guedes RNC. (2014) Managing leaf-cutting ants: peculiarities, trends and challenges. Pest Manag Sci 70(1):14-23.

bassiana and *Aspergillus ochraceus* both show a high degree of control with 50% mortality within 4-5 days[101,103]. Effective natural products include limonoids extracted from the roots of the endemic South Brazilian plant *Raulinoa echinata*.[104]. Biological, mechanical and cultural control methods, besides plant resistance, can reduce the quantity of chemicals applied in the plantations[105]. Mixing compostable materials with ant nests (Atta cephalotes) in a Columbian study caused a rapid decrease of ant nests (73%) within three months.[106] The results of this study indicate that composting treatment might be used as an alternative method to control leaf-cutting ants (A. cephalotes).

3.3 Alternatives to POP-PBDEs

Substitution of flame retardants such POP-PBDEs can take place at three levels (UBA 2008[107]):

A. Chemical Substitution: This approach involves identifying a "drop-in" chemical substitute for the BFR. It is the simplest approach because it typically does not require changes to the polymer material or to the design of the product.

B. Resin/Material Substitution: This approach involves changing the resin system, while also changing the flame retardant chemicals. This is a more complex approach than simple flame retardant substitution because it has a greater effect on overall product cost and performance.

C. Product Redesign: This approach involves changes to the product design to minimise or eliminate the need for flame retardant chemicals. Examples of product redesign include using fire barrier material; increased separation; or reduction of the source of heat from the product and/or the use of alternative materials.

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[103] Myriam M. R. Ribeiro,1 Karina D. Amaral, Vanessa E. Seide, Bressane M. R. Souza,1 Terezinha M. C. Della.

Lucia, Maria Catarina M. Kasuya,2 and Danival J. de Souza, Diversity of Fungi Associated with Atta bisphaerica (Hymenoptera: Formicidae): The Activity of Aspergillus ochraceus and Beauveria bassiana, Psyche Volume 2012, 2012, Article ID 389806, 6 pages, doi:10.1155/2012/389806.

[104] Maique W. Biavatti*, I; Rosângela WesterlonI; Paulo C. Vieira; M. Fátima G. F. da Silva; João B. Fernandes; M. Fernanda G. V. Peñaflor; Odair C. Bueno; Javier Ellena, *Leaf-cutting ants toxicity of limonexic acid and degraded limonoids from Raulinoa echinata.* X-ray structure of epoxy-fraxinellone, Journal of the Brazilian Chemical Society *Print version* ISSN 0103-5053. Chem. Soc. vol.16 no.6b São Paulo Nov./Dec. 2005.

[105] Zanetti R, Zanuncio JC, Santos JC, da Silva WLP, Ribeiro GT, Lemes PG (2014) An Overview of Integrated Management of Leaf-Cutting Ants (Hymenoptera: Formicidae) in Brazilian Forest Plantations. Forests 2014, 5, 439-454.

[106] I. Armbrecht, M. Montoya, M. C. Gallego y J. Montoya (2012) Composting to control the leaf-cutting ant Atta Cephalotes L (Hymenoptera:Formicidae). Revista de Ciencias Volume 16, December 2012.

[107] UBA. 2008. Brominated Flame Retardants: Guardian angels with a bad streak? German Environmental Agency, April 2008.

3.3.1 POPRC document(s) on POP-PBDE alternatives

3.3.1.1 Commercial pentabromodiphenyl ether (containing tetraBDE and pentaBDE)

Information on alternatives has been compiled in the **Guidance on alternative flame retardants to the use of commercial pentabromodiphenylether (c-PentaBDE)**[108]**.**
In which the alternatives to c-PentaBDE have been compiled for the polymers/resin of major applications and the related commercial commodities. The flame retardant alternatives have been categorised as: inorganic alternatives; phosphorous/nitrogen organic alternatives; halogen organic alternatives; and inherently flame-retarded material alternatives (Table 13). Moreover new flame retardant solutions are being introduced while others disappear from the market for a number of reasons. Therefore these technologies are changing over time and this can be regarded only as a snap-shot and a rough guide to illustrate the variety of chemical systems available to c-PentaBDE rather than as a complete and contemporary listing.
Furthermore each flame retardant application is specific and unique - there is no single universal solution for fire protection of materials and applications. Design and material substitution should be considered in the achievement of flame retardancy.

Table 13: Overview of use of alternative flame retardants to c-PentaBDE in several materials and applications compiled in the POPRC document (UNEP 2008)[109]

Materials /polymers /resins	**Inorganic alternatives to PentaBDE**	**Phosphorous/ nitrogen organic alternatives to PentaBDE**	**Halogen organic alternatives to PentaBDE**	**Alternative flame inherent materials**	**Applications**	**Commercial commodities for the applications**
Epoxy resins	Aluminium hydroxide (ATH) Magnesium hydroxide Ammonium poly phosphate Red phosphorous	Metallic phosphinates Reactive nitrogen anc phosphorous constituents (unspecified) DOPO[110]	Tetrabromobisphenol A (reactive) Ethylene bis (tetrabromo) phthalimide	Polyethylene sulphide	Circuit boards, protective coatings	Computers, ship interiors, electronic parts.

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[108] UNEP/POPS/POPRC.4/INF/13.

[109] UNEP/POPS/POPRC.4/INF/13.

[110] DOPO=Dihydrooxaphosphaphenanthrene oxide.

	Zinc hydroxystannate (ZHS), Zinc stannate (ZS) & ZHS/ZS-coated ATH					
Polyvinylchloride (PVC)	Aluminium hydroxide (ATH); Zinc borate; Zinc-molybdenum compounds (together with phosphate esters); Zinc hydroxystannate (ZHS), Zinc stannate (ZS) & ZHS/ZS-coated ATH	Tricresyl phosphate (also plasticiser)	Tris (dichloropropyl) phosphate Vinylbromide	Rigid PVC is flame inherent itself	Cable sheets	Wire end cables, floor mats, industrial sheets.
Polyurethane (PUR)	Ammonium poly phosphate Red phosphorous Reofos (non-halogen flame retardant)	Melamine (nitrogen based) Dimethyl propane phosphonate (DMPP)	Bromoalkyl phosphates Tetrabromophthalic anhydride Tris(1-chloro-2-propyl) phosphate (TCPP) (together with brominated polyols or red phosphorous)	Intumescent systems	Cushioning materials, packaging, padding	Furniture, sound insulation packaging, padding panels, wood imitations, transportation.

Materials /polymers /resins	**Inorganic alternatives to PentaBDE**	**Phosphorous /nitrogen organic alternatives to PentaBDE**	**Halogen organic alternatives to PentaBDE**	**Alternative flame inherent materials**	**Applications**	**Commercial commodities for the applications**
Unsaturated (Thermoset) polyesters (UPE)	Ammonium polyphosphate Aluminium hydroxide (ATH) Magnesium hydroxide Zinc	Triethyl Phosphate Dimethyl propane phosphonate (DMPP)	Dibromostyrene Tetrabromophthalic anhydride based diol, Tetrabromophthalic anhydride	Intumescent systems	Circuit boards, coatings	Electrical equipment, coatings coatings for chemical processing plants mouldings, military and marine applications:

	hydroxystannate (ZHS), Zinc stannate (ZS) & ZHS/ZS-coated ATH		Bis (tribromophenoxy) Ethane (TBE)			construction panels.
Rubber	N/A	Alkyl diaryl phosphates (nitrile rubber)	N/A	Intumescent systems	Transportation	Conveyor belts, foamed pipes for insulation.
Paints/lacquers	N/A	Triaryl phosphates (unspecified)	Tetrabromo phthalate diol; Tetrabromophthalatic anhydride based diol; Bis (tribromophenoxy) Ethane	Intumescent systems Silicone rubber	Coatings	Marine and industry lacquers for protection of containers
Textiles	Aluminium hydroxide Magnesium hydroxide Ammonium compounds (unspecified) Borax	Tetrakis hydroxymethyl phosphonium salts such as chloride (THCP) or ammonium (THPX) Dimethyl phosphono (N-methylol) propionamide; Diguanidine hydrogen phosphate; Aromatic phosphates (unspecified)	Trichloropropyl phosphate	Intumescent systems Aramide fibres (certain protective applications) Wool Modacrylic	Coatings	Back coatings and impregnation for carpets, automotive seating, furniture in homes and official buildings, aircraft, underground.

3.3.1.2 Commercial octabromodiphenyl ether (hexaBDE and heptaBDE)

Production of c-OctaBDE stopped worldwide in 2004 and according to the 2008 risk management evaluation document for commercial octabromodiphenyl ether (c-OctaBDE), prepared by the POPs Review Committee, the phase out of c-OctaBDE was already well advanced. In light of this the availability of practicable and economically viable substitutes has already been well established.

Furthermore design changes are increasingly being used to eliminate the need for flame retardants by using alternative materials or designs that remove the need for chemical flame retardants.

a) Chemical substitutes for c-OctaBDE in ABS plastic

The report "Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Octabromodiphenyl Ether" (RPA, 2002)[111] preceding the EU level control measures contains an analysis on the suitability of various alternatives to c-OctaBDE in terms of technical performance, health and environmental risks and cost implications. Alternatives identified included tetrabromobisphenol-A, 1,2-bis(pentabromophenoxy) ethane, 1,2-bis(tribromophenoxy) ethane, triphenyl phosphate, resourcinol bis (diphenylphosphate) and brominated polystyrene.

In ABS, TBBPA and brominated epoxy oligomers are used as additive flame retardants meaning that they are not bound to the polymer and therefore have a greater tendency to be released to the environment. TBBPA is a cytotoxicant, immunotoxicant, and thyroid hormone agonist with the potential to disrupt estrogen signalling (Birnbaum & Staskal, 2004)[112]. TBBPA is classified as very toxic to aquatic organisms and is on the OSPAR Commission's List of Chemicals for Priority Action due to its persistence and toxicity (RPA, 2002[111]; OSPAR, 2005[113]). To avoid their use in ABS applications, poly (phenylene oxide) / high impact polystyrene (PPO / HIPS) blends flame retarded with resorcinol diphosphate (RDP) have been proposed (Morose, 2006)[114].

Bisphosphate and its derivatives include RDP and are used in "Blue Angel" printers and PCs with PC / ABS casings (Leisewitz et al., 2000)[115]. The US EPA DfE report lists triaryl phosphate and an isopropylated derivative as having moderate

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[111] Risk & Policy Analysts Limited (RPA) for DEFRA (2002). Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Octabromodiphenyl Ether Final Report Prepared for Department for Environment, Food and Rural Affairs Contract Reference: 16/13/33 June 2002.

[112] Birnbaum L, Staskal D (2004) Brominated flame retardants: Cause for concern? Environ Health Persp 112, 9-17.

[113] OSPAR (2005) Convention for the Protection of the Marine Environment of the Northeast Atlantic, Tetrabromobisphenol-A. OSPAR Commission Update, 2005.

[114] Morose G. (2006). An overview of alternatives to tetrabromobisphenol A (TBBPA) and hexabromocyclododecane (HBCD). Lowell Center for Sustainable Production, University of Massachusetts – Lowell, March 2006.

[115] Leisewitz A, Kruse H, Schramm E (2000) Substituting environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000.

bioaccumulation properties based on structure activity relationships (US EPA, 2005)[116]. Bis (tribromophenoxy) ethane is poorly characterised. Studies by its manufacturer indicate low toxicity, but the substance tends to persist and bioaccumulate (Washington State, 2006)[117].

b) Chemical substitutes for c-OctaBDE in synthetic textiles

Reactive-type flame retardants are usually used in thermosetting material (e.g. polyester resins, epoxy resins, polyurethanes). Chemical substitutes for c-OctaBDE in textiles include reactive phosphorous alternatives. Specific reactive phosphorous alternatives were not identified in a Danish report though polyglycol esters of methyl phosphonic acid (CAS 676-97-1) have been used for flame retardants in polyurethane foam (e.g. CAS 294675-51-7) (Danish Environmental Protection Agency, 1999)[118].

Hexabromocyclododecane (HBCD) is a listed POPs and was used as an additive flame retardant. As a POPs, HBCD is bioaccumulative, persistent, and contaminates the environment via long range transport. HBCD causes neurobehavioral alterations in vitro (Birnbaum & Staskal, 2004)[112].

c) Chemical substitutes for c-OctaBDE in thermoplastic elastomers

Additive-type flame retardants are usually used in thermoplastic material (e.g. Polypropylen, Polyethylen, Ethylen-Vinylacetate, and PVC).

Chemical substitutes for c-OctaBDE in thermoplastic elastomers include bis (tribromophenoxy) ethane, discussed above, and tribromophenyl allyl ether (TBPAE) (Danish Environmental Protection Agency, 1999)[118]. Very little information was available for TBPAE though it is on a list of flame retardants considered “deferred” for testing by the interagency testing committee of US EPA (IPCS, 1997)[119]. Based on the partitioning properties of TBPAE alone the compound has been judged in SFT research[120] to have the potential to undergo long-range transport. However, estimated short atmospheric half-life indicates that it is more likely to pose a problem in the near source environment[121].

d) Chemical substitutes for c-OctaBDE in polyolefins

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[116] US EPA (2005) Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam.

[117] Washington State (2006) Washington State Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Final Plan. January 16 2006.

[118] Danish Environmental Protection Agency (1999). Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999.

[119] IPCS (1997) Environmental Health Criteria 192. Flame retardants: A general introduction 1997.

[120] Harju, Mikael,, Eldbjørg S, Heimstad, Dorte Herzke Torkjel, Sandanger, Stefan, Posner, and Frank, Wania. 2008. *Current State of Knowledge and Monitoring Requirements Emerging “new” Brominated Flame Retardants in Flame Retarded Products and the Environment December 2008.* Oslo: Statens forurensningstilsyn.

[121] Harju, Mikael,, Eldbjørg S, Heimstad, Dorte Herzke Torkjel, Sandanger, Stefan, Posner, and Frank, Wania. 2008. *Current State of Knowledge and Monitoring Requirements Emerging “new” Brominated Flame Retardants in Flame Retarded Products and the Environment December 2008.* Oslo: Statens forurensningstilsyn.

Chemical substitutes for c-OctaBDE in polyolefins include polypropylene-dibromostyrene, dibromostyrene, and tetrabromobisphenol A (TBBPA) (Danish Environmental Protection Agency, 1999)[118]. TBBPA is described above in chemical substitute alternatives for c-OctaBDE in ABS plastic. Few data are available for polypropylene-dibromostyrene. For dibromostyrene an EU assessment found insufficient information on toxicity, no bioaccumulation based on a low BCF value, and overall persistence of 49 days based on modelling (Pakalin et al., 2007)[122].

e) Technical feasibility

All above described alternatives to c-OctaBDE are technically feasible and have been used in commercial applications.

The EU RPA concluded already in 2002 that, "based on consultation with industry, it is evident that most companies have already replaced octabromodiphenyl ether in their products with other flame retardants and some companies utilise design measures, rather than flame retardants, for certain types of products. Overall, there does not appear to be any major technical obstacle to replacement of the substance, although some of the flame retardant/polymer combinations considered in this section may have inferior technical performance in certain applications" (RPA, 2002)[111].

3.3.2 Overview on availability of flame retardant alternatives from industry

The Phosphorous, Inorganic & Nitrogen Flame Retardants Association has developed an online tool to seek and assess alternatives for the entire range of flame retardant applications including all applications to c-PentaBDE and c-OctaBDE. With the online product selector the entire range of individual applications can be screened for alternative flame retardants available. Information is provided for GHS labelling, REACH registration and CAS number.

For brominated and chlorinated alternatives such a detailed and continuously updated overview is not available from industry[123] or the Bromine Science and Environmental Forum. Arcadis/EBRC (2011) compiled a report on "Evaluation of data on flame retardants in consumer products" for the European Commission. This covers a range of contemporary brominated, chlorinated and non-halogenated flame retardants and aimed to present up-to-date information on flame retardant substances currently used in consumer products in the home. The report however does not consider the entire life cycle of flame retarded products where brominated and chlorinated flame retardants have unresolved challenges in the end-of-life phase such as the challenges

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[122] Pakalin S, Cole T, Steinkellner J, Nicolas R, Tissier C, Munn C, Eichenreich, S. (2007) Review on production processes of decabromodiphenyl ether (DecaBDE) used in polymeric applications in electrical and electronic equipment, and assessment of the availability of potential alternatives to DecaBDE). European Chemicals Bureau, Institute of Health and Consumer Protection, Joint Research Centre, European Commission. (EUR 22693 EN).

[123] BFRs including PBDE alternatives from product portfolio of e.g. Albermare, Chemtura, ICL,EBFRIP, UNIBROM Corp.

with global recycling flows or the end of life treatment in developing countries (Shaw et al. 2010)[124].

3.3.3 Case study: Assessment of alternatives to c-PentaBDE in PUR foam

The US EPA Design for the Environment (DfE) completed an assessment of alternatives to c-PentaBDE in PUR in 2005 (US EPA, 2005)[125]. The agency had established a Furniture Flame Retardancy Partnership with a broad set of stakeholders to assess environmentally safer chemical alternatives to c-PentaBDE and to investigate other technologies for improving furniture fire safety.

Within this project the US EPA has compiled Environmental Profiles Chemical Flame-Retardant Alternatives for Low-Density Polyurethane and their Chemical Hazard Reviews.

In January 2013, US EPA DfE began updating its alternatives assessment for flame retardants used in polyurethane foam for furniture issued in 2005 and published a draft update of the previous alternatives assessment on flame retardants used in flexible polyurethane foam[126]. The goal of this draft update, developed with stakeholders' input, is to present a review of both new and older flame retardants in this category and to help manufacturers of flexible foam products make informed decisions on flame retardants by providing a detailed comparison of the potential human health and environmental effects of chemical alternatives.

3.3.3.1 Chemical substitution

Leading US flame-retardant chemical manufacturers identified 14 chemical formulations that are viable substitutes for c-PentaBDE in large-scale production of low-density flexible polyurethane foam (see Table 13 below). The identified alternatives are drop-in replacement chemicals for c-PentaBDE, compatible with existing process equipment at foam manufacturing facilities, and therefore cost-effective. Some chemicals other than these fourteen formulations are currently used for other types of foam and in niche markets for low-density polyurethane foam. The chemicals are used to flame retard high-density, flexible polyurethane foam.

Three of the most commonly used chemicals that have been substituted for c-PentaBDE are: melamine, tris (1,3-dichloro-2-propyl) phosphate (TDCPP) and ammonium polyphosphate (APP). APP, an additive flame retardant, is currently used to provide flame retardancy in flexible and rigid polyurethane foams, as well as in intumescent laminations, moulding resins, sealants and glues. However, chemical manufacturers and foam manufacturing trade groups do not consider it to be an alternative for c-PentaBDE on a large scale. Flame retardants based on melamine are

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[124] Shaw SD, Blum A, Weber R, Kannan K, Rich D, Lucas D, Koshland CP, Dobraca D, Hanson S, Birnbaum LS. (2010) Halogenated Flame Retardants: Do the Fire Safety Benefits Justify the Risks? Reviews on Environmental Health 25, 261-305.

[125] US EPA (2005) Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam. Volume 1 and Volume 2.

[126] US EPA (2014) Flame retardants used in flexible polyurethane foam: An alternative assessment update. Draft June 2014, EPA 744-D-14-001.

currently used in flexible polyurethane foams, intumescent coatings (those which swell on heating and thus provide some measure of flame retardancy), polyamides and thermoplastic polyurethanes. They are effectively used in Europe in high-density flexible polyurethane foams but require 30 to 40 per cent melamine per weight of the polyol. TDCPP is a chlorinated phosphate ester that is often used in polyurethane foam formulations. It is used in high-density foam and has been used in low-density foams when light scorching (discoloration) is not a primary concern. However, TDCPP was identified as likely to be bioaccumulative and persistent and it is linked to cancer in animals, and studies indicate it is neurotoxic, endocrine disruptor, and reproductive toxicant[127, 128, 129, 130]. The Office of Environmental Health Hazard Assessment of California EPA compiled evidence on carcinogenicity of TDCPP[131].This shows the need on a detailed assessment of the toxicity of the alternatives. Further assessment of toxicity and general hazard evaluation of alternative flame retardants in flexible polyurethane foam has been compiled by the US EPA Design for the Environment in the recent draft document.

Table 14: Alternative Flame-Retardant Chemical Formulations (US EPA, 2005)

Albemarle Corporation	**Ameribrom, Inc. (ICL Ind. Products)**	**Great Lakes Chemical Corporation**	**Supresta (Akzo Nobel)**
SAYTEX® RX-8500 *Proprietary reactive brominated flame retardant, proprietary aryl phosphate, triphenyl phosphate* *CAS 115-86-6*	FR 513 *Tribromoneopentyl alcohol* *CAS 36483-57-5*	Firemaster® 550 *Proprietary halogenated aryl esters, proprietary triaryl phosphate isopropylated, triphenyl phosphate*	Fyrol® FR-2 *Trs(1,3-dichloro-2-propyl) phosphate* *CAS 13674-87-8*
SAYTEX® RZ-243 *Proprietary tetrabromophthalate, proprietary aryl phosphate, triphenyl phosphate*		Firemaster® 552 *Proprietary halogenated aryl esters, proprietary triaryl phosphate isopropylated, triphenyl phosphate*	AB053 *Tris(1,3-dichloro-2-propyl) phosphate*
ANTIBLAZE® 195			AC003

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[127] Dishaw LV, et al. (2011) Is the PentaBDE replacement, tris (1,3-dichloropropyl) phosphate (TDCPP), a developmental neurotoxicant? Studies in PC12 cells. Toxicol Appl Pharmacol 256(3):281–289.

[128] Xiaoshan Liu, et al. (2012) Endocrine disruption potentials of organo phosphate flame retardants and related mechanisms in H295R and MVLN cell lines and in zebrafish Aquat Toxicol 114–115:173–181.

[129] .van der Veen I, de Boer J. Phosphorus flame retardants: properties, production, environmental occurance, toxicity, and analysis. Chemosphere 88(10):1119–1153 (2012).

[130] Betts (2013) Exposure to TDCPP Appears Widespread. Environ Health Perspect 121:A150.

[131] Reproductive and Cancer Hazard Assessment Branch Office of Environmental Health Hazard Assessment California Environmental Protection Agency (2011) Evidence on the carcinogenicity of tris (1,3-dichloropropyl) phosphate.

Tris(1,3-dichloro-2-propyl) phosphate *CAS 13674-87-8*			*Proprietary organic phosphate ester, triphenyl phosphate*
ANTIBLAZE ® 205 *Proprietary chloroalkyl phosphate, aryl phosphate and triphenyl phosphate*			AC073 *Proprietary aryl phosphates, triphenyl phosphate*
ANTIBLAZE® 180 *Tris(1,3-dichloro-propyl) phosphate* *CAS 13674-87-8*			
ANTIBLAZE® V-500 *Proprietary chloroalkyl phosphate, aryl phosphate and triphenyl phosphate*			
ANTIBLAZE® 182 *Proprietary chloroalkyl phosphate, aryl phosphate and triphenyl phosphate*			

3.3.3.2 Non-flame retardant alternatives to c-PentaBDE in PUR foam

Non-chemical alternatives have also been identified by the US EPA (2005). Three currently available, alternative technologies for flame retarding furniture include barrier technologies, graphite impregnated foam and surface treatment.

Graphite impregnated foam and surface treatments have limited commercial uses. Barrier technologies are predominantly used in mattress manufacturing rather than residential upholstered furniture, but may have further applications. In most countries having no specific flame retardant requirement for PUR foam in furniture (Shaw et al. 2010)[124] the barrier technology is the preferred technique to guarantee appropriate fire safety of PUR foam containing furniture.

In addition, it should be noted that some furniture designs exclude the use of filling materials, and even fabric altogether. Design therefore, should be considered when evaluating alternative means for achieving flame retardancy in furniture.

3.3.4 Case study: Suggested ecological priorities for the use of flame retardants

The German environmental agency (UBA) has published a brochure on PBDE and other brominated flame retardants including a suggestion of ecological priorities for the use of flame retardants in products (UBA 2008)[132].

UBA proposes the following hierarchy for the use of flame retardants based on ecological priorities (UBA 2008 with adjustment)[133]:

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[132] UBA. 2008. Brominated Flame Retardants: Guardian angels with a bad streak? April 2008.

[133] *In the UBA list priorities were numbered 1 to 6. However, there have been no full life cycle assessments of the individual FR additives and so prioritising of options 4 to 6 is difficult given the challenges which may arise from recycling products containing some of the phosphorous based flame retardants. Therefore options 4 to 6 are categorised all in category 4 and need to be assessed for the individual substances considering their life cycle.

1. Design measures aimed at reducing the use of flame retardants
(E.g. use of flame resistant materials; integration of barrier layers; adjusting flame retardant use to device voltage)
2. Inorganic flame retardants
(Aluminium hydroxide, magnesium hydroxide, micro-encapsulated red phosphorus and, ammonium polyphosphate)
3. Reactively bonded, halogen-free organic nitrogen and phosphorus compounds
4a.* Additive halogen-free organic nitrogen and phosphorous compounds that are not persistent or bioaccumulative and that are not toxic to humans or the environment in the long term.
4b.* Reactively bonded, halogenated flame retardants
4c.* Additive halogenated flame retardants that are not persistent or bioaccumulative and also not toxic to humans and the environment in the long term.

These ecological priorities are subject to the following conditions (UBA 2008):

- The relevant properties of all flame retardants used must have been adequately investigated (see e.g. the assessment under US EPA Design for the environment assessment).
- Product manufacture and disposal should not give rise to environmental or health risks.
- In specific cases, additional organisational and technical measures may allow alternative prioritisation.

The approach to flame retardancy and the choice of the flame retardants should be based on effectiveness, ecological priorities and consideration of health risks. One important aspect which has largely been ignored in the past is the effect on the recyclability of the polymers and other flame retarded materials. The global assessment of the challenges with the global recycling flow of materials containing c-PentaBDE and c-OctaBDE (e.g. plastic from electronics or polyurethane foam which are key flame retarded material flows) (UNEP 2010 a[22], b[23]) demonstrates that significant improvement in the management of these material flows is needed. In future it is important to take into account the whole life cycle of flame retarded materials and articles.

In the publication, the German Federal Environment Agency lists five objectives for a sustainable substance policy in accordance with the precautionary principle.

1. No irreversible emissions of persistent and/or bioaccumulative xenobiotics into the environment, irrespective of their toxicity.
2. No emissions of xenobiotics that are carcinogenic, mutagenic or toxic to reproduction into the environment.
3. No anthropogenic release of natural substances that exhibit the properties mentioned in items 1 and 2 into the environment, if such release increases the natural background burden.
4. Reduce emissions of other toxic or ecotoxic substances to the technically feasible minimum.

5. Minimise the emissions of substances whose potential effects are unknown, if these substances cannot be removed from the environment.

Some alternative flame retardants for the main applications of PBDEs are listed in Table 15.

An overview on alternatives to flame retardants are shown in Figure 2.

Table 15: Main use areas of c-PentaBDE and c-OctaBDE and alternative halogenated flame retardants and non-halogenated alternatives (derived from UBA 2008 with additions)

Main use area of POP-PBDEs	**Alternative BFR or CFR**	**Non-halogenated alternatives**
Casings of EEE (c-OctaBDE)	DecaBDE, DBDPE (ABS, HIPS); HBCD (HIPS) Additive TBBPA (ABS) FR 245 and S-8010 including brominated polymers	Phosphorous based halogen-free flame retardants: RDP, BDP (PC, PC/ABS, PPE/HIPS)
Small components in EEE (c-OctaBDE)	DecaBDE, DBDPE (PBT, PET, PA) Brominated polymers	Microencapsulated red phosphorus, magnesium hydroxide, melamine, metal phosphinate (PA) Metal phosphinate (PBT, PET)
Printed circuit boards (c-PentaBDE))	Reactive TBBPA (epoxy resin) Additive TBBPA (phenol resin)	Phosphorus based halogen free flame retardants: DOPO/aluminium hydroxide (epoxy resin) Metal phosphinate/DOPO/silica dioxide (epoxy resin) Polymer phosphonate (epoxy resin) Flame resistant thermosets Flame resistant thermoplastics (under development)
Textile coatings (c-PentaBDE)	DecaBDE (various fibres) HBCD (various fibres) Halogenated PFRs	Inherently flame resistant synthetic fibres with integrated flame retardants (PP, PE); Flame resistant synthetic fibres (polyaramide); glass fibres; Long term integration of phosphonium compounds (cellulose); Intumescent systems (various fibres)

Polyurethane foam (c-PentaBDE)	Firemaster 550 and 600 Halogenated PFRs	Various barrier technologies Substitution of PUR foam in certain applications
ABS: acrylonitrile-butadiene-styrol BDP: bisphenol A-bis(diphenylphosphate) DOPO: dihydrooxaphosphaphenanthrene EPS: expanded polystyrene HIPS: high impact polystyrene PC: polycarbonate		PET: polyethylene terephthalate PP: polypropylene PPE: polyphenyl ether RDP: resorcinol-bis(diphenylphosphate) XPS: extruded polystyrene

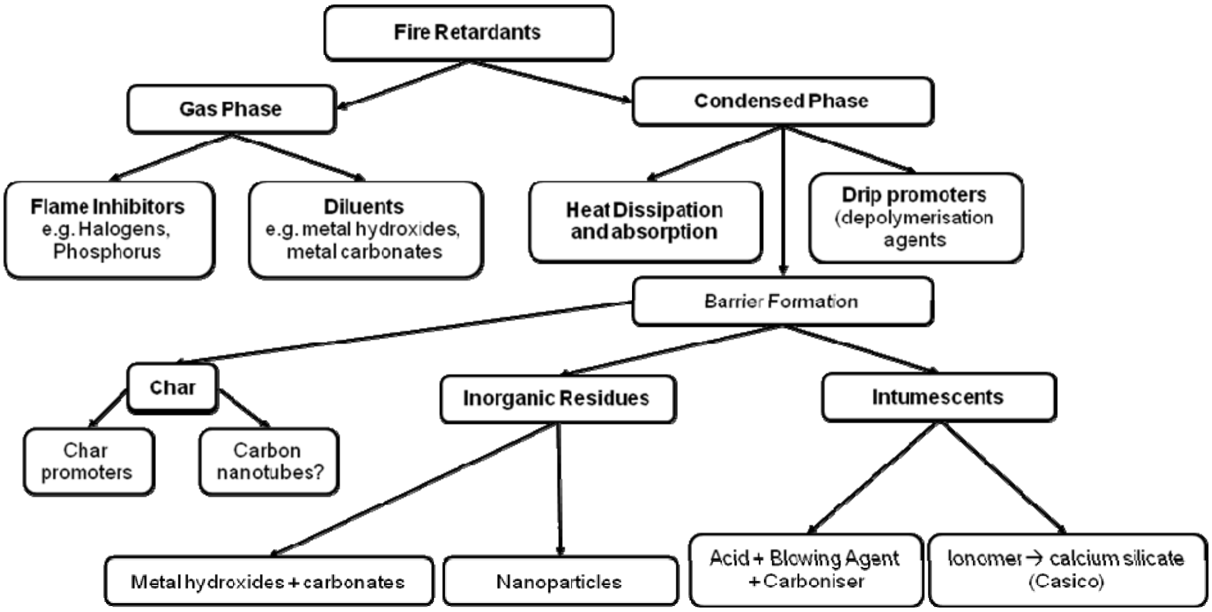

Figure 2: Overview on the mode of action for flame retarding materials which can be alternatively utilized to substitute flame retardants/inhibitors (Hull 2010).

3.3.5 Case study: Role of flammability standards

Policy makers need to ensure that flammability standards are appropriate and according to national legislation in order to guarantee that full consideration has been given to policy measures to ensure fire safety. The difficulties associated with POP-PBDEs in the recycling of PUR foam in the US (Luedeka 2011 [134]; UNEP

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[134] Luedeka R.J. (2011) Flexible Polyurethane Foam Waste Management & Recycling. Polyurethane Foam Association. Guidance Document Submission, United Nations Industrial Development Organization, 29.11.2011:

2010a[135],b[136]) and associated occupational exposure of PUR foam recyclers and carpet installers working with carpet paddings from recycled PUR foam (Stapleton et al. 2008)[137], for example, arises largely from the Californian 1975 furniture flammability standard Technical Bulletin 117 (TB117). This has only very recently been updated.[138]. This, and similar, 'open flame' standards for foam (e.g. in the UK for furniture) led to use of high levels of use of flame retardants in PUR foam in furniture, vehicles and other consumer goods. In the United States this has resulted in increased exposure to PBDEs amongst the respective population in blood and human milk (Figure 3, Imm et al. 2009[54], Shaw et al. 2010[124]). The development of flammability standards has however not always been driven only by scientific and safety considerations but to some extent by industry interests: This has been documented by an article series in the Chicago Tribune, documenting how flammability standards and flame retardant usage have been increased in the US, which has in some cases been in response to industry lobbying rather than reasonable requirements for safety standards (Chicago Tribune 2011/2012). Recently, the California furniture flammability standards in the "Technical Bulletin 117″ have been reviewed and updated so that flame retardants are no longer needed to meet it[139].

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[135] UNEP (2010). Technical Review of the Implications of Recycling Commercial Pentabromodiphenyl Ether and Commercial Octabromodiphenyl Ether. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/2).

[136] UNEP (2010) Supporting Document for Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/INF/6).

[137] Stapleton HM, Sjödin A, Jones RS, Niehüser S, Zhang Y, Patterson DG Jr. (2008) Serum levels of polybrominated diphenyl ethers (PBDEs) in foam recyclers and carpet installers working in the United States. Environ Sci Technol. 42:3453-3458.

[138] http://www.latimes.com/business/money/la-fi-mo-furniture-standards-remove-retardants-20131126,0,2126854.story#axzz2mR7Su54f.

[139] Scientific America (2013) Cancer-Linked Flame Retardants Eased Out of Furniture in 2014. December 31, 2013.

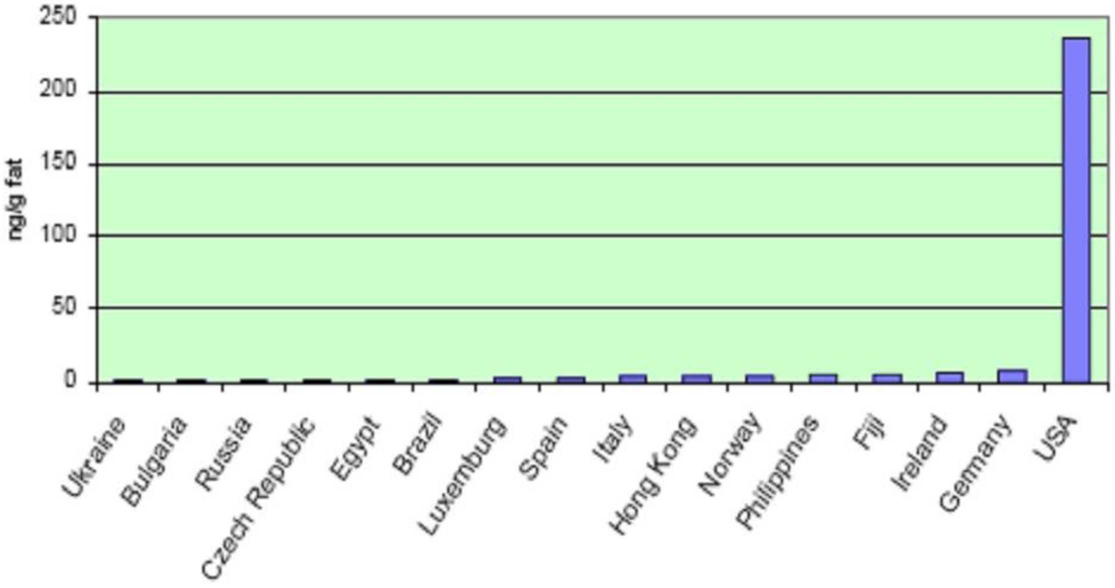

Figure 3: Levels of PBDE in human milk from the third WHO human milk survey (Kotz et al 2005; Malisch & van Leeuwen 2003)[140]

3.3.6 Case study: Paxymer^{TM} Flame retarded polymer system without flame retardants

The Paxymer^{TM} flame retardant system has been assessed in the POPs free pilot project and is a non-toxic flame retardant system developed for polyolefins. The polymer contains no classified substances and is completely POPs, antimony and halogen free.

The system is designed to address the full range of challenges of fire safety of polymers.

Fire fighters and rescue workers have vast problems in dealing with burning plastic materials which emitted toxic smoke, reignited other materials and caused material damage through soot. The burning process of Paxymer^{TM} has low smoke, low dripping and soot generation and by this increase the safety for both rescue workers and victims and minimize the fire spread.

The Paxymer^{TM} system is based on functional polymers that give the system its properties for excellent processing and very low impact on mechanical properties.

Paxymer is a thermoplastic and can therefore be recycled. The recycling process does not result in loss in flame retarding capacity if it is not mixed with other plastic.

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[140] Kotz A, Malisch R, Kypke K, Oehme M, (2005) PBDE, PBDD/F and mixed chlorinated-brominated PXDD/F in pooled human milk samples from different countries. Organohalogen Compounds 67, 1540-1544.

Malsch R, van Leeuwen R (2004) Levels of PCDDs, PCDFs and PCBs in human milk – Third round of WHO-coordinated exposure study. International Conference on Environmental and Public Health Management "PERSISTENT TOXIC SUBSTANCES Kowloon Tong, Hong Kong November 17-19, 2004.

3.4 Alternatives to HBCD

HBCD is used as a flame retardant in a variety of materials, such as a flame retardant in expanded polystyrene foam (EPS) and extruded polystyrene foam (XPS) as well as textiles and in high-impact polystyrene (HIPS) in electronics housings. The major use is in EPS and XPS used as rigid foam insulation in the building and construction industry.

3.4.1 Case study: Alternative HBCD EPS insulation materials in construction

The study "Chemicals in products - Alternatives to the use of flame retarded EPS in buildings"[141], was the contribution from the Norwegian government to the POPs Review Committee assessment process for HBCD. The study was limited to the alternatives to flame retarded EPS used mainly as insulation materials for the building and construction sector.

The study identified alternative insulation materials marketed for all applications of flame retarded EPS in buildings.

The study focused on two main aspects: identification of alternatives to flame retarded EPS and a comparison with the alternative materials selected.

Among the alternative materials identify it can mention the followings:

a) Stone wool (representing mineral wool materials), which is marketed for the same application areas as flame retarded EPS although some minor changes in the construction may be required;
b) The PUR/PIR foams (representing plastic foams), which can substitute for flame retarded EPS for nearly all applications;
c) Wood fibre boards (representing natural fibre-based insulation), which may be used for some of the same applications as flame retarded EPS, although the material's vulnerability to moisture may restrict its uses for some applications;
d) Cellular glass, which has a very high resistance to compression compared to EPS and can reduce dimensions of a load bearing insulated walls in some cases.

The comparison with alternative materials was made against the following criteria: technical feasibility, fire safety, human health and ecotoxicological impact, other environmental impacts and resource consumption, recyclability and price of material.

The study concluded that alternatives are available for all the applications of flame retarded EPS assessed. It is anticipated that the flame retarded EPS would be replaced by different insulation materials depending on the application, as no alternative assessed would substitute for all EPS applications, if the use of flame retarded EPS is restricted. Also - and most importantly - that the alternatives typically have better fire performance and contain less problematic chemical substances.

Prices of the cheapest alternatives ranged from approximate equivalence to flame retarded EPS to approximately 30% more. There are also alternatives with significantly higher prices, but these are typically used because they have some desired technical advantages and would, probably not be the first choice substitutes for general application. For some applications, where flame resistance is not needed,

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[141] COVI (2011), Chemicals in products. Alternatives to the use of flame retarded EPS in buildings.

non-flame retarded EPS would probably take over, to the extent national regulation allows.

3.4.2 US-EPA report on alternatives to HBCD

In August 2010, EPA issued an action plan for hexabromocyclododecane (HBCD) under its enhanced chemical management program. As part of the Agency's efforts to manage chemical risks, the action plan called upon the Design for the Environment (DfE) program to conduct an alternatives assessment for HBCD.

The scope of this project is limited to HBCD's primary uses in EPS and XPS foam and only examined alternatives to HBCD for these uses.

The alternatives assessment compares potential human health and environmental impacts of HBCD and its alternatives and provides a basis for informed decision-making.

EPA, through its Design for the Environment (DfE) program, released a draft Alternatives Assessment report titled "Flame Retardant Alternatives for Hexabromocyclododecane (HBCD)" on September 24, 2013.

3.4.2.1 Chemical alternatives in EPS/XPS foam

The alternatives assessment considered two alternatives to HBCD. One of the alternatives, a butadiene styrene brominated copolymer, is a polymer with a molecular weight (MW) much greater than 10,000 daltons. The other, a tetrabromobisphenol A (TBBPA)-bis brominated ether derivative, is a large molecule with a MW close to 1,000 daltons. Both of these chemicals incorporate bromine as the mechanism for fire retardation. The limited number of alternatives is, at least in part, due to the requirement that flame retardants for expanded polystyrene (EPS) and extruded polystyrene (XPS) foam

(1) allow the material to comply with fire safety codes,
(2) not compromise the physical properties of the foam, and
(3) be compatible with its manufacturing processes and formulas.

These alternatives were evaluated against the following criteria: (1) human health hazard, (2) ecotoxicity, (3) persistence, (4) bioaccumulation potential, and (5) exposure potential.

When selecting alternative insulation materials, there are several insulation characteristics that should be considered, such as environmental considerations, material safety considerations, performance considerations, and economic considerations.

3.4.2.2 Material substitution of EPS/XPS foam

Rigid Board Alternatives

The alternative insulation materials identified are available as rigid board and therefore can be used in many of the same applications as EPS and XPS. The materials readily available as board insulation include polyisocyanurate foams, perlite insulation, and mineral wool/rockwool insulation.

Alternatives for Certain Functional Uses

The alternative insulation materials which may be used for certain functional uses of EPS and XPS are generally not available as rigid board insulation, but may be used in certain applications where the properties such as dimensional stability or compressive strength are not integral to the performance of the insulation material. Alternative insulation materials that may be used for certain functional uses of EPS and XPS are: cellulose, cementations foam, cotton insulation, fiberglass and polyurethane.

Specialty and Emerging Alternative Materials

There are also insulation materials that may be functional alternatives to EPS and XPS, but are not considered to be currently viable for large scale building applications, and so are constrained to specialty applications or limited geographic areas. This information is intended to provide context in case changes in manufacturing processes or economies of scale allow these products to become viable in the future. Speciality and emerging alternative insulation materials identified include: aerogel, carbon foam, foamglas, phenolic foam, reflective insulation and agrifiber insulation.

3.4.3 Case study from SUBSPORT: Specific substance alternative assessment HBCD

A study on "Specific Substances Alternatives Assessment – Hexabromocyclododecane" was developed in 2013 within the SUBSPORT project (see ***4.3.5 SUBSPORT – internet portal on safer alternatives***).

The study concluded that alternative chemical substances and materials have been identified for the major HBCD use in EPS and XPS insulation foams, in HIPS and in textile back coating applications.

With the exception of triphenyl phosphate for HIPS application, the substances that were considered in this alternatives assessment all passed the Substance Database according to SUBSPORT Screening Criteria (SDSC)[142].

The chemicals and material alternatives identified for EPS and XPS, HIPS and textiles back coating applications are judged to be technically feasible and commercially available. They can therefore be assumed to be economically feasible as the material alternatives, particularly, are currently in use in some countries in Europe. Non-flame

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[142] The Substance Database according to SUBSPORT Screening Criteria (SDSC) contains substances that are known to be carcinogens, mutagens or toxic for reproduction – CMR, (very) persistent, (very) bioaccumulative or toxic – (v)P(v)BT, endocrine disruptors, neurotoxicants or sensitization agents taken from the following sources:
CMR: CLP Regulation cat. 1A, 1B (Dir. 67/548, categ. 1 and 2); IARC group 1, 2A, 2B
(v)P(v)BT: EC PBT Working Group; OSPAR List of substances of possible concern
Endocrine disruptors: EU Endocrine disruptors database cat. 1, 2 ; SIN list database
Neurotoxicants: Vela, Laborda, Garcia Study, 2003, cat. 2-4
Sensitization agents: CLP Regulation for H334, H317 (Dir. 67/548, for R42, R43).

retarded EPS and XPS with thermal barriers are used in countries where regulation does not specify the use of flame retarded EPS and XPS insulation foams without any reduction in the fire safety performance of construction and rock wool is marketed for most applications where EPS is traditionally used. Alloys of PPE/HIPS treated with halogen-free flame retardant are used by major European TV set manufacturers.

From a safety perspective, no definite safer alternatives for the various HBCD applications were identified. Some of the chemical and material alternatives are associated with hazard characteristics of concern. Other alternatives lack data to allow for a final assessment of their hazards.

However, according to the Risk Management Evaluation for HBCD prepared by the POPRC, the current building practice from Sweden and Norway, where most of the EPS and XPS used is HBCD-free, suggests that fire-safety of building materials and buildings can be obtained at a reasonable cost without the use of HBCD and without altering traditional building and construction techniques to a great extent [143]. According to an analysis on alternatives to flame retardant EPS made in Norway, a change from flame retarded EPS to the alternative insulation materials would consequently not compromise fire safety and the alternatives would in general be able to meet the same requirements, or higher, as the flame retarded EPS. The alternatives, including non-flame retarded EPS in combination with thermal barriers, typically have better fire performance and can compete with regard to the insulation properties and moisture resistance required in most applications in both cold and warm climates[144]. According to Climate and Pollution Agency in Norway (KLIF) the price of the cheapest alternatives ranges from more or less the same price as for flame retarded EPS to approximately 30 % more[144].

There is limited data available to assess the life cycle impacts of the alternative chemical substances and materials. Only non-flame retarded EPS and XPS with thermal barriers and rock wool which are both material alternatives for HBCD in flame retarded EPS and XPS insulation foams application have some information describing their respective life cycle impacts.

3.5 PCB

PCBs have been used in closed applications as dielectric fluids in transformers and capacitors, heat transfer fluids and as hydraulic lubricants (primarily in the mining sector).

Open applications of PCBs have included sealants, paints, speciality coatings, pesticide extenders, plasticizers, adhesives, dedusting agents, cutting oils, flame retardants and carbonless copy paper. Open uses were phased out in the early 1970s.

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[143] UNEP (2011), Risk management evaluation on hexabromocyclododecane. UNEP/POPS/POPRC.7/19/Add.1.

[144] Climate and Pollution Agency in Norway (2011). Alternatives to the use of flame retarded EPS in buildings. A report by COWI AS Denmark. Authors: Lasses C, Maag J, Hoibye L, Vesterlykke M, Lundegaard T. 97 p.

Since widespread production bans in the late 1970s and early 1980s alternatives have been substituted for all uses of PCBs. Substitution of PCBs has, however, not always been based on an adequate assessment of the alternatives.

3.5.1 PCB-Alternatives in closed applications

Some alternatives which were used to replace PCBs include polychlorinated terphenyls (PCTs), alkyl-substituted chlorodiphenyls and PCNs. These substitutes are also persistent and PCN has been evaluated as POPs by the POP Reviewing Committee. The historic substitution of PCB is therefore an example highlighting the need for a better evaluation and an environmentally sound substitution of POPs.

Alternatives to PCBs in closed applications have been evaluated by The Nordic Council of Ministers and those they considered to be less hazardous than PCBs are listed in table 15 below (Norden 2000)[145].

The major use of PCBs was as dielectric fluids. The most frequently used alternatives for transformers are mineral oils, silicone oils and ester fluids (both synthetic and natural). Mineral oils, silicone oils and ester-based materials all are preferable from an environmental perspective. Natural ester based dielectric has become available which is less costly and has the added advantage that, like the synthetic esters, it is entirely biodegradable. Alternative engineering designs such as encapsulated transformers equipped with air cooling have been recommended for PCB substitutes that are not biodegradable.

Technology to replace PCB oil with alternative oils in larger transformers, called retro-filling, is available. However, most transformers contain a variety of components, including materials that retain the PCB-oil, such as wood. Depending on the size and structure of the transformer this increases the time taken to effectively empty the transformer and replace the oil. In some cases it may be necessary to carry out several retro-filling operations over several months. If all the PCB-containing oil is not removed there will be a gradual leaching of residual PCBs from the porous components which will contaminate the new oil (Norden 2000).

Replacement oils offered on the market today are all suitable for use in electrical equipment. But they may not be suitable for a particular use, e.g. transformers used in certain conditions. Transformers with an expansion chamber outside the transformer can accommodate temperature changes. In this kind of transformers it is possible to use oil with a relatively high coefficient of thermal expansion. In sealed transformers the replacement oil must have the same thermal expansion coefficient as the original oil (Norden 2000).

Alternative fluids used for retro-filling are mineral oils, silicone fluid and ester materials – both synthetic and natural. Synthetic ester materials are more expensive but are well established replacements with good properties. Natural ester based

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[145] Norden (2000) A survey of alternatives to 12 persistent organic pollutants DIVS 2000:825.

dielectric has become available which is less costly and has the added advantage that, like the synthetic esters, it is entirely biodegradable. The fluid has marked technical advantages over many other alternatives including: no de-rating factor after conversion; good electrical properties; and suitable for up-grading oil transformers to become classified as less flammable.

Mineral oils have a greater flammability than PCB oil but in many environments this risk is not an over-riding factor and the necessary fire safety performance can often be achieved. Also silicone oil is used in transformers. The transformers are then designed to match the properties of silicone oil. It will therefore be necessary to modify existing transformers to take account of these different properties, and particularly the thermal expansion coefficient, if silicone oils are used as replacements for PCBs (Norden 2000).

Table 16: Alternatives to PCB in closed application (NORDEN 2000)

Uses	PCB-substitutes	Alternative solution
Dielectric fluid in transformers	Mineral oil	Alternative design
	Silicone oil	
	Tetrachlorbenzene	
	Chloroalkylene	
	Biphenyl	
	Chlorinated diphenylethane	
Dielectric fluid in capacitors	Mixture of Methyl (phenyl-methyl) benzene and Methylbis (phenylmethyl) benzene	Alternative design for small capacitors
	Phenylxylethane	
Heat exchange fluid	Mineral oil	
	Silicone oil	
	Biphenyl	
	Diphenyl oxide	
Hydraulic fluid	A vegetable based oil (turnip oil)	

3.5.1.1 Case study: Substitution of PCB transformer oils in Russia

The Arctic Council initiated a project on the phase-out of PCB use and the management of PCB-contaminated wastes in the Russian Federation (www.amap.no). The *Multilateral Co-operative Project on Phase-out of PCB Use and Management of PCB contaminated Wastes in the Russian Federation* was initiated in 1998 under the Arctic Council's Action Plan for Elimination of Pollution in the Arctic. In the project, costs are calculated for more environmentally sound solutions, including a feasibility study with an evaluation of alternative dielectric fluids for use in larger capacitors and transformers. Two alternatives were recommended: AZI-3 (1,1-phenyl xylyl ethane or PXE or S oil) and DON (mixture of 70-75% of mono-benzyl-toluene and 20-25% of dibenzyltoluene). Further testing of AZI-3 was recommended since the toxicity and the environmental properties of this compound were unknown. These alternatives can be based on Russian raw materials and production technology, and they could potentially keep costs in an acceptable range. The utilisation of the vacant process facilities and a part of existing equipment substantially reduces costs. The technology of storage and filling of transformers have been slightly adjusted due to combustibility of the applied liquid dielectrics and fire safety measures have been intensified. Technologies involving the production of power capacitors and transformers may be applied without any updating. Capacitors and transformers using the alternative dielectric fluids have got electric properties and service life comparable with units filled with PCB and will be less expensive to dispose in an environmentally sound manner (AMAP 2003[146]).

3.5.2 Alternatives in open applications

There is currently no comprehensive compilation on the alternatives available for PCBs in open applications (sealants, paints, ink, lubricants, waxes, adhesives, surface coatings, insulating material, pesticides, dyes, condensate form pipelines, plasticizers[147]). As alternatives have now been used for more than forty years their technical suitability for all applications is no longer an issue. However it is not known to which extent environmental performance of the alternatives has been assessed and there is no compilation what alternatives are used. One major substitute of PCB in open application were/are chlorinated paraffins (e.g. in sealants, paints, flame retardant). Currently short chain chlorinated paraffins (SCCP) is evaluated by the POP Reviewing Committee for listing in the Stockholm Convention and has been listed in the Long-Range Transboundary Air Pollution Convention.

3.6 Alternatives to Endosulfan

By its decision SC-5/3, the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants (COP) decided to amend part I of Annex A to the Convention to list therein technical endosulfan and its related isomers, with specific exemptions. Therefore alternatives to a wide range of applications were needed.

Chemical and non-chemical alternatives to endosulfan are available in many geographical situations both in developed and developing countries. Some of these alternatives are being applied in countries where endosulfan has been banned or is being phased-out. However, in some countries, it may be difficult and/or costly to replace endosulfan for specific crop-pest complexes.

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[146] AMAP (2003) PCB in the Russian Federation: Inventory and Proposals for Priority Remedial Actions. Executive Summary of the report of Phase 1: Evaluation of the Current Status of the Problem with Respect to Environmental Impact and Development of Proposals for Priority Remedial Actions of the Multilateral Cooperative Project on Phase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation. AMAP Report 2000:3

[147] UNEP Chemicals (1999), Guidelines for the Identification of PCBs and Materials Containing PCBs, http://www.chem.unep.ch/Publications/pdf/GuidIdPCB.pdf.

The Persistent Organic Pollutants Review Committee (POPRC), at its seventh meeting, was requested to assess the alternatives to endosulfan in accordance with the general guidance on considerations related to alternatives and substitutes to listed persistent organic pollutants and candidate chemicals[148]. It subsequently provided to the 6th Conference of the Parties (COP) two documents, one on non-chemical alternatives and one on chemical alternatives to endosulfan. The POPRC recommended, and the COP agreed, to give priority to ecosystem approaches (essentially non-chemical) to pest control when replacing endosulfan.

3.6.1 Chemical Alternatives and their assessment

An ad hoc working group on assessment of alternatives to Endosulfan and DDT constituted under the POPs Review Committee prepared in July 2012 the report on the assessment of chemical alternatives to endosulfan and DDT[149]. The report is addressed to Parties as a primary source of information when choosing chemical alternatives to Endosulfan or to DDT.

The report lists in Annex II 110 chemical alternatives for the different exempted application areas.

The report provided hazard-based information on the alternatives with respect to the POP criteria in Annex D of the Stockholm Convention and other relevant hazard criteria.

For the 1st screening the POPRC developed following categorization with data analysis:

a) Category 1: High potential to be persistent organic pollutants – BCF >5000, persistence:DT50 for whole water-sediment system >60 days
b) Category 2: Candidates that could be POPs substances – BCF >1000, persistence: DT50 soil or whole water-sediment system >60 days and/or a PB–score >1 (P–score >0.5)
c) Category 3: Candidates that are difficult for prioritization; log Kow >3.5 (in absence of an experimental BCF value), DT50 soil or whole water-sediment system >60 days and/or a PB-score >1 (P-score >0.5).
d) Category 4: Unlikely to be persistent organic pollutants; BCF <1000 or log Kow <3.5), DT50 water-sediment or soil<60 days

According to the report, out of the 110 chemical alternatives 84 are unlikely to be a POP on basis of screening against the criteria described above. Two substances were deemed to be potential POP candidates, whereas 18 were classed as candidates for further assessment and 6 as candidates for further assessment with limited data. The category IV substances were not further analysed. Substances in category I, II and III were further assessed, results of which presented in section IV and Annex IV of the report.

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[148] UNEP/POPS/POPRC.5/10/Add.1;

[149] UNEP/POPS/POPRC.8/INF/12.

The report stated that no monitoring data or other evidence as provided for in Annex D of the Convention had been analysed. Furthermore, the report mentioned that the substances deselected for further assessment (category IV) may exhibit other characteristics that should be considered in the authorization of the substance as an insecticide by Parties, such as carcinogenicity or neurotoxicity (cf. section 4). The prioritization should be seen as only a screening analysis of persistence (P) and bioaccumulation (B) properties of the alternatives.

It is important to note that the assessment is not a comprehensive and an in depth assessment of all available information as only a limited number of databases have been consulted and degradation products were not covered.

The screening also only focuses on POP characteristics. The report strongly recommends that further assessment needs to be carried out within the national frameworks of authorization. In addition, substances which have been identified in the report as not likely to be a POP, may still exhibit hazardous characteristics that should be assessed by Parties before considering such substances as a suitable alternative. Therefore national authorities should be aware of other hazardous characteristics when authorizing these substances.

Some examples of chemical alternatives:

- malathion (used in the Sahel region against the cotton bollworm on cotton);
- cyromazin (used in Canada against the Colorado potato beetle (*Leptinotarsa decemlineata*) on potato);
- bifenthrin (used in China against white fly on tea).

3.6.2 Non-Chemical Alternatives

In October 2012, at its eighth meeting, the POPRC presented the report on the evaluation of non-chemical alternatives to endosulfan. This technical document is meant to assist Parties to find non-chemical alternatives to endosulfan for the listed exemptions.

The document evaluates the non-chemical alternatives in two parts: the first-part is an evaluation of ecosystem approaches to management of pests in the listed crop/pest complexes, and the second part is an evaluation of non-chemical alternatives that are used within the existing chemical input-based agricultural approach as simple substitutes for endosulfan.

The ecosystem approach to pest management is now the internationally preferred option, as in FAO’s calls their ecosystem approach ‘sustainable crop production intensification, in which emphasis is placed on improving soil health, conserving natural enemies of pests, a preventative approach, and cultural and management techniques, with pesticides used as a last resort.

Ecosystem approaches, or agroecology, includes organic agriculture and some traditional, and improved traditional, approaches such as Community Managed Sustainable Agriculture. Such approaches have shown increased or similar yields, greater returns to farmers, and improvement in social and environmental indicators.

The focus is on managing the agro-ecosystem to avoid build-up of pests, using wherever possible cultural, biological, and mechanical methods instead of synthetic materials.

Practices include using resistant varieties better adapted to ecologically based production than those bred for high-input agriculture, crop diversity, crop rotation, intercropping, optimized planting time and weed management, conserving natural enemies, and managing crop nutrient levels to reduce insect reproduction.

It is difficult to provide a prescription for a particular crop/pest complex in these systems as the entire interwoven management process is crucial to protecting crops from pests. Each crop/pest complex needs to be looked at within the specific agroecosystem, taking into account many aspects, including climatic and geographical variables, presence of natural enemies and availability of biological controls, the structure and function of the particular farm, and microclimatic variations within it.

The report also concluded that there is a large range of discrete non-chemical options that can be used in ecosystem, IPM, or in chemical-input based agriculture as simple substitutes. These include natural plant extracts, attractant lures and traps, and biological controls such as pathogens, predators, and parasitoids. The availability and technical feasibility of these may differ between countries.

Selected examples of non-chemical alternatives:

- *Bacillus thuringiensis* (bacterium used in Canada against the diamondback moth on cauliflower);
- *Metarhizium flavoviride* (fungus used in West Africa against locusts on rice and wheat);
- *Phymastichus coffea* (wasp used in Mexico and Costa Rica against the coffee berry borer on coffee).

In 2008, PAN Germany have developed a field guide to non-chemical pest management in banana, cabbage and other crucifers, cassava, citrus, coffee, corn, cotton and other fiber crops, cowpea, eggplant, forage crops, forest trees, garlic, lettuce, mango, mungbean, onion, ornamentals, peanut, pepper, pigeon pea, oil crops, ornamentals, potato, rice, sesame, sorghum, soybean, squash and other cucurbits, string bean, sweet potato, tea, tomato, and wheat production, namely “How to Grow Crops without Endosulfan”. The content of this publication is based on the information provided at www.oisat.org. It enables to provide farmers with practical guides to avoid the use of Endosulfan. The recommended practices are scientifically based. Most of the farm practices described in this publication, the farmers can do by themselves.

Also IPEN have published the booklet “Alternatives to Endosulfan in Latin America” that illustrates the variety of alternatives to endosulfan beyond the chemical substitution approach that means go beyond chemical pesticides that are less toxic and less persistent, but also agroecological and organic agricultural practices used in growing soybeans, coffee, vegetables, flowers and tobacco in Latin American countries.

3.6.3 Project/Case study Endosulfan substitution in Uganda and Mozambique

A guidance to assist countries to undertake an assessment of continued need of endosulfan and of potential alternative chemical and non-chemical option has been developed and is available in the Stockholm Convention website. The guidance includes tools and information gathered by POPRC and other scientific bodies and allows countries to determine main crops and related pests where endosulfan is used at national level, but most importantly it provides a method towards its sustainable substitution. Currently a project on substitution of endosulfan is conducted in Uganda and Mozambique.

3.7 Alternatives to DDT

Every three years, Parties that produce or use DDT are obliged to report the conditions of such use to the Secretariat using a DDT questionnaire that was adopted by the COP. Assessment of scientific, technical, environmental and economic information related to DDT and a report is provided to the COP with recommendations so that they are able to evaluate the continued need for DDT for disease vector control. Since a range of countries are still using DDT the compilation of information on DDT alternatives and integrated vector control approaches are important to communicate.

3.7.1 Alternatives: work/document of POPs Review Committee

By its decision SC-5/6 on DDT, the COP requested the POPRC, beginning at its eighth meeting, to assess the alternatives to DDT in accordance with the general guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals on the basis of factual information provided by Parties and observers.

An ad hoc working group on assessment of alternatives to Endosulfan and DDT was constituted under the POPs Review Committee of the Stockholm Convention. This working group prepared in July 2012 the report on the assessment of chemical alternatives to endosulfan and DDT[150].

The insecticides recommended by the World Health Organization for disease vector control in indoor residual spraying as alternatives to DDT were assessed for persistent organic pollutant characteristics and other hazard endpoints.

A total of 11 chemical alternatives to DDT, of which 9 were also possible alternatives to endosulfan, were assessed for persistent organic pollutant properties and other hazard indicators. The outcome of the assessment of the alternatives to DDT and of the alternatives to endosulfan is presented in annex IV to the report. In summary, the alternatives were classified as follows:

- Class 1. Substances that are likely to meet all Annex D criteria (b), (c), (d) and (e): None;
- Class 2. Substances that may meet all Annex D criteria but have equivocal or insufficient data: Bifenthrin;

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[150] UNEP/POPS/POPRC.8/INF/12.

- Class 3. Substances that are not likely to meet all Annex D criteria (b), (c), (d) and (e): alpha-cypermethrin, bendiocarb, cyfluthrin, lambda-cyhalothrin, deltamethrin, etofenprox, fenitrothion, malathion, pirimiphos-methyl and propoxur.

It is important to note that the assessment of the persistent organic pollutant characteristics and other hazard indicators of the alternatives should not be seen as a comprehensive and detailed assessment of all available information, because only a limited number of databases have been consulted, as indicated in section III of the report. In addition, substances that are not likely to be considered as persistent organic pollutants in the report, on the basis of the numerical criteria in Annex D, might still exhibit hazardous characteristics that should be assessed by Parties before considering such substances as a suitable alternative. Furthermore degradation products have not been considered in the assessment.

3.7.2 Work/report UNEP global alliance for DDT alternatives - chemical alternatives

As presented in the 2012 report of the Expert Group on the Assessment of the Production and Use of DDT and its Alternatives for Disease Vector Control[151], many countries have already started introducing alternative products and strategies. However, information on the applicability and cost-effectiveness of alternatives has been limited, thus, not allowing the countries to effectively design application of alternatives in local environmental, epidemiological and socio-economic settings.

According to the report, there is in some countries a continued need for DDT for disease vector control in accordance with WHO recommendations and guidelines on the use of DDT, until locally appropriate and cost-effective alternatives are deployed for a sustainable transition away from DDT.

Long Lasting Insecticidal Nets (LLINs) is one of the effective alternative methods to Indoor Residual Spray (IRS) in vector control programmes when optimum coverage, use and effectiveness are achieved.

Insecticide resistance is one of the major threats to global malaria and leishmaniasis control and elimination efforts. There is a lack of new active ingredients with new modes of action and long lasting efficacy to replace DDT.

A number of new formulations of insecticides, such as alpha-cypermethrin, pirimiphos-methyl and deltamethrin, are in the WHO evaluation process and are potential alternatives to DDT. Research is on-going on non-chemical alternatives, methods and strategies for disease vector control but these are yet to be established as tools in disease vector control programmes.

Inadequate technical, managerial and institutional capacity exists to translate international policies, tools, best practices and guidelines on pesticide management and alternatives to DDT based vector control into locally appropriate programmes.

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[151] UNEP/POPS/DDT/EG.4/2.

The Global Alliance for development and deployment of alternatives to DDT serves as one of the important mechanisms for providing assistance to countries in strengthening their capacity towards reducing reliance on DDT.

3.7.3 Non-chemical DDT alternatives for vector control

An "Overview on the global status of DDT and its alternatives for use in vector control to prevent disease"[152] has been prepared as background document for the preparation of the business plan for a global alliance giving an overview on chemical and non-chemical methods for malaria vector control (Table 17).

The publication emphasize that for an integrated approach to malaria control a broadened scope of malaria control would cover a wider set of determinants of disease, some outside the working domain of the health sector thus calling for inter-sector collaboration. Various studies have demonstrated that integration and localized targeting of vector control methods resulted in significant reductions in transmission and morbidity rates of malaria.

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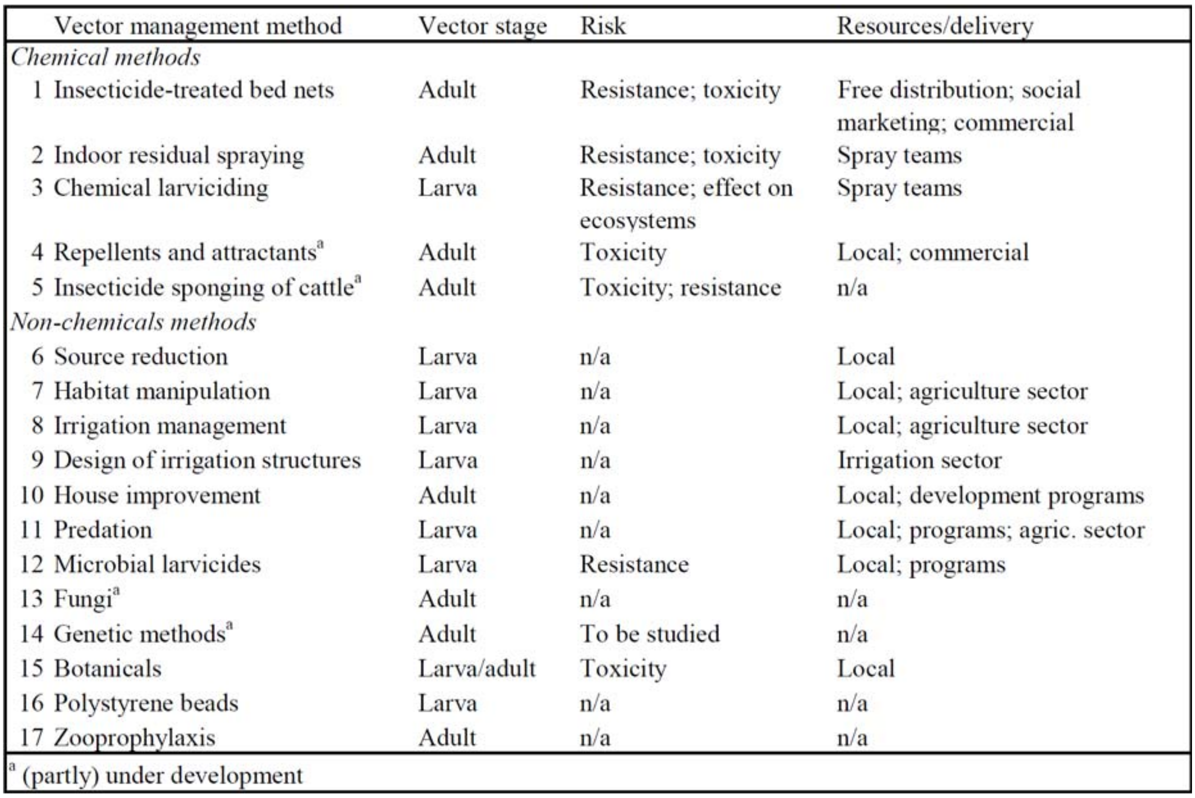
[152] UNEP (2008) Global status of DDT and its alternatives for use in vector control to prevent disease UNEP/POPS/DDTBP.1/2.

Table 17: Alternative methods for malaria vector control, indicating the targeted vector stage, the potential risk, and required resources and delivery mechanisms (UNEP 2008)[152]



Vector management method	Vector stage	Risk	Resources/delivery
Chemical methods			
1 Insecticide-treated bed nets	Adult	Resistance; toxicity	Free distribution; social marketing; commercial
2 Indoor residual spraying	Adult	Resistance; toxicity	Spray teams
3 Chemical larviciding	Larva	Resistance; effect on ecosystems	Spray teams
4 Repellents and attractants[a]	Adult	Toxicity	Local; commercial
5 Insecticide sponging of cattle[a]	Adult	Toxicity; resistance	n/a
Non-chemicals methods			
6 Source reduction	Larva	n/a	Local
7 Habitat manipulation	Larva	n/a	Local; agriculture sector
8 Irrigation management	Larva	n/a	Local; agriculture sector
9 Design of irrigation structures	Larva	n/a	Irrigation sector
10 House improvement	Adult	n/a	Local; development programs
11 Predation	Larva	n/a	Local; programs; agric. sector
12 Microbial larvicides	Larva	Resistance	Local; programs
13 Fungi[a]	Adult	n/a	n/a
14 Genetic methods[a]	Adult	To be studied	n/a
15 Botanicals	Larva/adult	Toxicity	Local
16 Polystyrene beads	Larva	n/a	n/a
17 Zooprophylaxis	Adult	n/a	n/a

[a] (partly) under development

3.7.4 Framework for strengthening IVM in malaria control programmes

A guidance document for a "Framework for strengthening Integrated Vector Management in malaria control programmes" has been published by the Pesticide Action Network (PAN et al. 2013)[153].

The document presents a decision making framework to assist malaria control programme funders achieve a significant reduction in malaria morbidity and mortality through cost-effective, ecologically sound and sustainable Integrated Vector Management (IVM) interventions. The framework is a tool to assess whether new and on-going malaria project applications incorporate least toxic, effective and participatory disease control measures and focuses particularly on three key elements of a holistic IVM strategy (PAN et al 2013)[153]:

a) evidence-based decision making at community level by community members;
b) social mobilization to support communities becoming primary stakeholders in IVM;

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[153] PAN Africa, PAN Germany, PAN North America, ICIPE, KEMRI (2013) Framework for strengthening Integrated Vector Management in malaria control programmes.

c) use of non-chemical approaches to vector control within community-guided IVM.

The framework presents questions that funders can request applicants to respond to and is based on literature from disease control programme planning and incorporates lessons from on-the-ground activities that adopt sustainable IVM-based controls (PAN et al 2013)[153].

3.7.5 UNEP/WHO global program sustainable alternatives to DDT

In 2008, UNEP, together with WHO and GEF has launched the Global Programme "Demonstrating and Scaling-up of Sustainable Alternatives to DDT in Vector Management (Global DSSA Programme)". The Global Programme aims at the protection of human health and the environment through the reduction of emission of DDT into the global environment by means of decreasing the use of DDT through introduction, demonstration and scaling-up of sustainable alternatives to DDT in disease vector management, for example for malaria (UNEP 2008)[154].

For Africa, 5 projects including 18 countries will be involved. The Global Programme aims in a yearly reduction of DDT application in vector management of about 4000 tonnes by the end of the Programme period (2014).

According to this programme one global project was implemented and three regional projects are under the implementation, out of which one in Africa region, one in Middle East and Africa regions and one in Southern Caucasus and Central Asia region

The Africa and Middle East regional project, with September 2013 as end date, is the project "Demonstration of Sustainable Alternatives to DDT and strengthening of National Vector control Capabilities in Middle East and North Africa". The participating countries are Djibouti, Egypt, Jordan, Morocco, Islamic Republic of Iran, Sudan, Syria, Yemen. The overall development objective of the project is the reduction of DDT use and avoiding the use of DDT in future as well as the sound management of DDT stocks through strengthening of malaria vector control practices in 8 project countries. The project objective is to demonstrate cost effective, environmentally sound, and locally appropriate alternatives to DDT use in malaria control, ensuring their sustainable application through strengthened national and local capacity as well as sustainable management of POPs stocks.

The Africa's regional project, which is currently under implementation, is "Demonstrating Cost-effectiveness and Sustainability of Environmentally Sound and Locally Appropriate Alternatives to DDT for Malaria Vector Control in Africa" project. The project started in 2009 and will run until 2014 having as participating countries Ethiopia, Eritrea and Madagascar. This project will demonstrate cost-effective, environmentally sound, and locally appropriate alternatives to DDT for

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[154] UNEP (2008) Demonstrating and Scaling - up of Sustainable Alternatives to DDT in Vector Management (DSSA - Global Programme)

malaria vector control, ensuring their sustainable use through strengthened national and local capacity for malaria control. The project strategy is to enhance the capacity of the participating countries to effectively plan, implement, monitor and evaluate vector control interventions, which are not relying on DDT. The project activities will be implemented in a number of demonstration districts in the three project countries. In this project the following alternatives to DDT will be demonstrated based on the Integrated Vector Management (IVM) approach: - Residual house spraying with insecticides alternative to DDT; - Insecticide Treated Nets (ITNs); - Environmental management (including management of groundwater, irrigation schemes, dams, roads and building construction); and Mosquito larviciding[155].

The Southern Caucasus and Central Asia regional project, called "Demonstrating and Scaling Up Sustainable Alternatives to DDT for the control of vector borne diseases in Southern Caucasus and Central Asia", is currently under implementation, having as end date December 2014. The participating countries within the project are Georgia, Tajikistan, Kyrgyzstan. The long-term developmental objective of the project is to reduce potential threads from POPs to humans and to the environment. The project objective is to eliminate the possibility to apply DDT in vector management without increasing the occurrence of Vector Borne Diseases, while at the same time to promote appropriate vector control management practices through strengthened capacities of countries and to sustain scaled-up implementation of environmentally sound alternatives.

3.7.6 PAN: Case studies and success stories on non-chemical alternatives

The 2nd extended edition of the "Environmental strategies to replace DDT and control malaria" concluded that new low-risk insecticides, drugs and vaccines are not likely to become available in the near future, and consequently alternative approaches have to be strengthened. The report emphasizes and describe that a broad range of non-chemical malaria control approaches are known to be effective. These vary from multiple malaria control interventions, which relied strongly on environmental management strategies (Zambia) to bioenvironmental malaria control (Kenya, Sri Lanka and India).

The report stresses that successful switching to alternatives should be accompanied by community participation, awareness raising, surveillance, decentralization, local capacity building, inter-sectoral collaboration, improvement of public health system, income generation, involvement of civil society organizations, support by local research and regional cooperation.

The publication on "Phasing in Alternatives to DDT" presents examples of success stories in controlling malaria without DDT from Asia (Sri Lanka and Vietnam), Africa (Kenya) and Latin America (Mexico) and synthesizes the available alternatives

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[155] where an insecticide is specifically targeted against the larval life stage of an insect.

to DDT including environmental management, non-chemical personal protection, and biological control.

The PAN publication “Combating Malaria without DDT: An ecosystem and community approach in Beer, Senegal”, presents the results of the pilot project to raise awareness of the causes of malaria and initiate non-chemical methods and activities for its prevention.

3.7.7 Best practice case studies on Integrated Vector Management for Malaria Control

Biovision Foundation, recipient of the “Alternative Nobel Prize” in 2013, is funding a comprehensive malaria programme which is implemented by icipe and Kemri. The program promotes and supports the implementation of Integrated Vector Management (IVM) at community and district level at 3 sites in Ethiopia and Kenya[156,157], and currently runs research on the different components effectiveness on larvae and mosquito reduction and hence malaria control. As insecticide treated bed nets are distributed and IRS carried out regularly through the ministry of health, the contribution of the programme lies in entomological surveillance, environmental management of breeding sites and biological larviciding with Bacillus thuringiensis israelensis (bti)[156,157,158]. Research and formulations on new local biopesticides such as neem oil is ongoing and is being tested in field trials.

The effectiveness and importance of biological larvae control alongside other IVM tools has been observed at different project sites with a significant reduction in the vector. Community based organizations and health officers are trained in detecting, eliminating and monitoring breeding sites by covering up open water sources and eliminate littering, reclamation of land, stocking of fish ponds[159] and applying bti[156,157] to open water bodies such as swimming pools in touristic areas or large water bodies in the community environment with the effect of reducing larvae and adults mosquitos drastically. As the challenge of these methods lies in its labor intensive activities, linkages of environmental management and larviciding activities with income generating activities at community level as well as up-taking of these regular activities through the public health system are crucial.

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[156] Kibe LW. et al. (2006) Community based vector control in Malindi, Kenya, African Health Sciences 6(4): 240-247.

[157] Mwangangi JM et al. (2010), Wide-scale application of Bti/Bs biolarvicide in different aquatic habitat types in urban and peri-urban Malindi, Kenya, Parasitol Res (2011) 108:1355–1363.

[158] Tusting LS et al. (2013), Mosquito larval source management for controlling malaria (Review), The Cochrane Library 2013, Issue 8.

[159] Imbahale SS et al. (2013), Conflict between the Need for Income and the Necessity of Controlling Endemic Malaria, J Ecosys Ecograph 2013, 3:4.

3.7.8 WHO training module on malaria control

WHO developed a “Training module on malaria control: Entomology and vector control” to improve the knowledge and skills of entomologists and vector control staff as well as of managers/senior health officers involved in malaria vector control at programme level.

The module consists of two parts, the Guide for participants and the Guide for tutors, and provides guidance on relevant aspects of malaria entomology and vector control including identification and sampling of malaria vectors, incrimination of malaria vectors, selection between different vector control options, and monitoring and management of insecticide resistance.

The tool offers to a limited extent training on the non-chemicals alternatives but does not include yet training on a framework for strengthening the IVM in malaria control and related alternatives (WHO 2013)[160].

3.8 Alternatives to Lindane

The Draft risk management evaluation for Lindane prepared by POPRC[161]compiled information on the chemical and non-chemical alternatives for the pharmaceutical uses of Lindane and reviewed e.g. the North American Regional Action Plan on Lindane and Other HCH Isomers developed by the North American Commission for Environmental Cooperation (CEC 2006[162]; O’Reilly & Yarto 2013[163]).

3.8.1 Alternative for head lice treatment

3.8.1.1 Chemical alternatives

In the United States, approved chemical treatments for pharmaceutical uses for head lice include: *Malathion, Permethrin, Ivermectin, Pyrethrum/Piperonyl butoxide*, and *Spinosat topical suspension* (Table 18).

Canadian chemical alternatives for pharmaceutical uses of Lindane for head lice include: *Permethrin* (1% cream), *Bioallethrin* and *piperonyl butoxide*, *Pyrethrin* and *piperonyl butoxide*, and for scabies *Permethrin* (5% cream), *Precipitatedisulphur 6% in petrolatum* and *Crotamiton* 10% (*Eurax*) (Table 17). In Mexico also Sulfur soap and Permithrin soap is used for head lice and Ivermectin und Benzyl Benzoate for scabies (Table 18).

In Sweden, *Malation*, *Permethrin* and *Disulfiram* with bezylbenzoate have been used as chemical alternatives against scabies and lice in humans (Annex F information provided by Sweden, 2007).

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[160] WHO (2013) Training module on malaria control: Entomology and vector control. August 2013

[161] UNEP (2007), Draft risk management evaluation: lindane. UNEP/POPS/POPRC.3/12.

[162] Commission of Environmental Cooperation (2006), The North American Regional Action Plan (NARAP) on Lindane and Other Hexachlorocyclohexane (HCH) Isomers. 30. November 2006.

[163] O’Reilly J, Yarto M (2013), North American Regional Action Plan on Lindane and Other Hexachlorocyclohexane Isomers. Final Evaluation Report. September 2013.

In Thailand, chemical alternatives for the treatment of head lice and scabies include: P*ermethrin*, C*abaryl*, S*temona* root extract and benzyl benzoate.
Chemical alternatives for use head lice treatment in the Republic of Zambia include: *Nix* (Annex F information provided by the Republic of Zambia, 2007).

Table 18: Available chemical Alternatives to the Pharmaceutical Uses of Lindane in Canada, Mexico and the United States of America (O'Reilly & Yarto 2013[163])

Use	Canada*	Mexico	US
Head Lice Treatment	Permethrin (1% cream) Bioallethrin and piperonyl butoxide Pyrethrin and pyperonyl butoxide	Permethrin Sulphur soap Pyrethrin soap	Malathion lotion (5%) Benzoyl alcohol lotion (5%) Spinosad topical suspension (0.9%) Sklice (ivermectin) lotion (0.5%) Permethrin cream rinse (1%) Pyrethrum/piperonyl butoxide Nit comb: Combing is desirable to accompany all treatments
Scabies Treatment	Permethrin (5% cream) Precipitated sulphur 6% in petrolatum Crotamiton (10%) (Eurax)	Permethrin Ivermectin Benzyl benzoate Crotamiton (10%) (Eurax)	Permethrin Crotamiton (Eurax)

3.8.1.2 Non-chemical alternatives

There are also non-chemical methods for the treatment of head lice. A study in the journal Pediatrics describes hot air as an effective non-chemical method for the treatment of head lice that resulted in nearly 100% mortality of eggs and 80% mortality of hatched lice. The author's findings demonstrate that one 30-minute application of hot air has the potential to eradicate head lice infestations and that hot air is an effective and safe treatment to which lice are unlikely to evolve resistance.

There were no adverse effects of treatment.[164] This article demonstrates that treatment without the use of pediculicides[165] can exceed the efficacy of pediculicidal treatments. The National Pediculosis Association®, Inc., a non-profit organization from the United States, submitted the LiceMeister® comb. The comb is an U.S. Food and Drug Administration cleared medical device to screen, detect and remove head lice and their eggs (nits). This combing tool is used instead of applying pesticides to the hair and scalp. Of particular relevance to the Convention, the LiceMeister® comb could be considered as an alternative to pharmaceutical applications containing lindane, listed under annex A of the Convention with a specific exemption.

Also the documentation on "The NPA's Ten Tips for Head Lice & Nit Removal" provided by the National Pediculosis Association supports mechanical removal with the approach of using a wet combing method with the specialized LiceMeister™ comb.[166] The LiceMeister™ comb was included in the first POPs free pilot project. The results of the analysis of the first POP-free pilot project determined that the LiceMeister™ comb is POPs-free according to the definitions applied in the project.

3.8.1.3 Factsheet from Informa Inc on Lindane-Free Head Lice Prevention & Treatment

INFORM Inc. has published a Factsheet on Lindane-Free Head Lice Prevention and Treatment (INFORM Inc. 2003[167]) within their Purchasing for Pollution Prevention Factsheet series

3.8.2 Alternative scabies treatment

3.8.2.1 Chemical alternatives

According to the information provided by the risk management evaluation, in the United States *Permethrin* and *Crotamiton* (*Eurax*) are approved chemical treatments for scabies (Annex F information provided by the United States of America, 2007).

In Thailand, chemical alternatives for the treatment of head lice and scabies include: *Permethrin*, *Cabaryl*, *Stemona* root extract and benzyl benzoate.

In Sweden, *Malation*, *Permethrin* and *Disulfiram* with bezylbenzoate have been used as chemical alternatives against scabies and lice in humans (Annex F information provided by Sweden, 2007).

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[164] Goates, B. M., Atkin, J. S., Wilding, K. G., Birch, K. G., Cottam, M. R., Bush, S. E., et al. (2006). An effective nonchemical treatment for head lice: A lot of hot air.. Pediatrics 118(5):1962-1970.

[165] *Pediculicides* are substances used to treat lice.

[166] The National Pediculosis Association. The NPA's Ten Tips for Head Lice and Nit Removal. Accessed November 22, 2013 www.headlice.org/downloads/tipsremoval.htm .

[167] INFORM Inc. (2003) Purchasing for Pollution Prevention Lindane-Free Head Lice Prevention and Treatment.

Some of these chemical alternatives have also been highlighted as superior compared to lindane by a review article in the renounce Lancet magazine. In particular Permethrin, a synthetic pyrethoid, is used in many countries as first-line therapy and it is judged to have low toxicicity. Since permethrin is adulticidal and ovicidal, it is highly effective after a single application. In a study in 467 patients, a single application of 5% permethrin was as effective as 1% lindane, and it has been successfully used in outbreaks of lindane-resistant scabies (Purvis & Tyring 1991; Judd 1991).[168]

3.8.2.2 Non-chemical alternatives

There are also non-chemical methods for the treatment of scabies. Some authors highlight that the use of these methods exceed the efficacy of pediculicidal treatments. For scabies treatment some authors suggest that essential oils have shown positive effects against mites in vitro and in field studies. Tea tree oil (*Melaleuca alternifolia*) and a paste made from extracts of neem (*Azadirachta indica*) and tumeric (*Curcuma longa*) are considered highly effective. In a clinical trial in Nigeria, bush tea (*Lippia multiflora*) essential oil showed similarly high cure rates. A randomized control study in Brazil showed a commercially available repellent containing coconut oil and jojoba was highly effective (IPEN, 2009)[169].

3.8.2.3 Factsheet from Informa Inc on Lindane-Free Scabies Prevention & Treatment

INFORM Inc. has published a Factsheet on Lindane-Free Scabies Prevention and Treatment within their Purchasing for Pollution Prevention Factsheet series

3.8.3 Case Studies: Ban of lindane pharmaceutical use

There are many countries that have banned Lindane’s pharmaceutical use.

3.8.3.1 Regional ban of lindane in the Mediterranean countries and the EU

The 21 countries of the Barcelona Convention for the protection of the Mediterranean Sea have banned its use with no exemptions in the framework of the “Regional Plan on the phasing out of Lindane and Endosulfan“ adopted in 2012 within one regulatory frame.

Also the EU Member States in accordance with the Regulation (EC) 850/2004 on persistent organic pollutants have banned all uses of lindane without exemptions.

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[168] Purvis RS, Tyring SK (1991) An outbreak of lindane-resistant scabies treated successfully with permethrin 5% cream. J Am Acad Dermatol 25: 1015–1016.

Judd LE. (1993) Gamma benzene hexachloride resistant scabies. N Z Med J 106: 61–63.

[169] IPEN (2009) Lindane:Pharmaceutical and Agricultural Alternatives, April 2009.

3.8.3.2 Lindane ban in California, USA (IPEN, 2009)[169]

In the United States, the State of California took regulatory action to ban the pharmaceutical use of lindane in 2002 due to concerns over impacts from water pollution. A scientific assessment on the "Outcomes of the California Ban on Pharmaceutical Lindane: Clinical and Ecologic Impacts" published in the journal Environmental Health Perspectives concluded: "The California experience suggests that elimination of pharmaceutical lindane produced environmental benefits, was associated with a reduction in reported unintentional exposures, and did not adversely affect head lice and scabies treatment. The ban serves as a model for governing bodies considering limits on the use of lindane or other pharmaceuticals. Given the recognition of lindane and other HCH isomers as toxic and persistent chemicals with health consequences, coupled with the ethical issues of manufacturing in developing countries for use elsewhere, the harms of use and production may outweigh any residual benefit from maintaining it as a second-line therapy."

The following study provides the strong evidence that pharmaceutical uses of lindane can be replaced with safer alternatives. The case study is excerpted from the North American Regional Action Plan for Lindane and Other HCH Isomers[162]:

“In May 2000, the California Toxics Rule (CTR) established a new water quality criterion of 19 ppt (parts per trillion) lindane in existing or potential drinking water supplies for protection of public health based on potential cancer risk to humans. Studies conducted of water exiting the Los Angeles County Sanitation Districts’ treatment facilities found both peak and mean levels in many cases to be higher than the new (state) effluent standards. These standards were equal to the US national water quality criterion for water bodies that are existing or potential drinking water sources. As available treatment technology was unable to adequately remove lindane from the water, a preventive strategy to allow compliance was required.”

“The Los Angeles County Sanitation Districts calculated that a single treatment for head lice, when rinsed down the drain, contributed enough lindane to the water entering treatment facilities to bring 6 million gallons of water over the CTR standard. Based on a review of California pesticide applicator records and physician surveys conducted by these same districts, there were no significant agricultural sources identified in the region, indicating that nearly the entire load was the result of pharmaceutical use. Initially, an education campaign with pharmaceutical lindane providers was started to discourage use. While this appeared to decrease the inflow levels of contamination, it was inadequate to comply with the new standards. A bill was then sponsored in the California assembly, which passed without opposition, to ban the sale of all pharmaceutical lindane in the state of California beginning in Jan 2002.”

“A review of medical and public health authorities conducted by the Los Angeles County Sanitation Districts noted no difficulties or concerns that have been raised by the ban after over two years in a population of over 30 million. Lindane concentrations in wastewater exiting these Districts’ treatment plants have declined from non‑attainment of the 19 ppt goal to almost non‑detectable following the 2002 institution of the ban on pharmaceutical sales. From 2000 ‑ 2004, four scabies outbreaks were reported by four counties to the California Department of Health Services (CDHS) Surveillance and Statistics Section. Statewide the number of scabies outbreaks decreased the first yea following the ban with a slight increase the second and third year. A 2005 random survey of California pediatricians (135 responded) indicated that 98.5% of them had not seen any increase in scabies since the ban. Since 1999, CDHS has recommended against the use of lindane for scabies and against its use for head lice since 1987. Prior to the ban, CDHS issued guidelines to all physicians to use malathion instead of lindane.”

> *"Outbreaks of scabies in healthcare facilities, particularly acute care hospitals, are not uncommon in California, and can last for months if not promptly recognized and managed aggressively. To address this problem, the CDHS developed and distributed to healthcare facilities a guideline for the management of scabies outbreaks (www.dhs.ca.gov/ps/dcdc/disb/disbindex.htm). In it, CDHS recommends the use of ivermectin to treat patients with severe (e.g. keratotic) scabies that are likely to be refractory to cutaneous medication, and that are the source for outbreaks in healthcare facilities. Although not recommended by CDHS for typical scabies or prophylaxis, ivermectin has also been used in outbreaks for treatment of symptomatic cases and for mass prophylaxis because of its ease in application and probable greater compliance and efficacy compared to permethrin. It should be noted that ivermectin has not been approved by the FDA for use for scabies. Institution of mass prophylaxis has always been successful in terminating the outbreak. CDHS has received no reports of adverse effects from any of these uses. However, it is not known how adverse effects were monitored for and controlled studies have not been conducted."*

Two case studies involving large institutional settings indicate that treatments for head lice and scabies are effective without the use of lindane products. The California Department of Corrections, with a population of over 150,000 inmates per year has treated head lice and scabies without lindane, instituting alternative treatments two years prior to the ban on the use of pharmaceutical lindane enacted by the California legislature in 2002. The corrections system has effectively treated both lice and scabies through the use of Elimite cream (5% permethrin) for scabies and several non-lindane products for head lice. The Department of Corrections recommends the use of combs to treat head lice. Dr. Evalyn Horowitz, Chief of Public Health at the California Department of Corrections, advised against the use of lindane because its use was ineffective and unnecessarily increased pesticide exposure and resistance.

3.9 Case studies on reduction and phase out unintentional POPs in products

The production of certain organochlorine chemicals results in the unintentional production of POPs by-products including polychlorinated dibenzo-p-dioxin (PCDD) and polychlorinated dibenzofurans (PCDF), PCB, hexachlorobenzene (HCB) or pentachlorobenzene (PeCBz)[170]. Depending on the production and purification process, some of these unintentionally produced POPs can finally contaminate the marketed chemical and articles containing these chemicals. By optimising production processes and the purification of the chemicals or by substitution, low POPs or POPs-free products can be produced and marketed for further use in formulations or in consumer goods.

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[170] UNEP (2013) Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs under Article 5 of the Stockholm Convention on Persistent Organic Pollutants. January 2013.

For a range of chemicals the UNEP Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs (UNEP 2013)[170] has compiled emission factors included also those in the product. For some of these chemicals BAT/BEP levels have been defined.

3.9.1 Case study: Production and purification of TCPA and certain pigments

According to the information provided by the Toolkit, tetrachlorophthalic anhydride (TCPA) is the primary feedstock for the production of a range of pigments (UNEP 2013)[170]. Japan has informed the Conference of Parties of the Stockholm Convention of the high HCB content in TCPA (up to 3,000 ppm have been detected) and suggested BAT levels for HCB in TCPA product and related pigments (Government of Japan 2006[171], 2007[172]),. TCPA-derived pigments include e.g. Pigment Yellow 110 (CAS 5590-18-1), Pigment Yellow 138 (CAS 30125-47-4), Solvent Red 135 and Solvent Red 162 (CAS 20749-68-2 and 71902-17-5). With TCPA use, unintentional HCB is transferred to pigments and residues (Government of Japan 2006[171], 2007[172]). However, BAT levels of less than 200 ppm and below 50 ppm can be achieved by modification of production processes and re-crystallization (Government of Japan 2006[171]; Table 19). For the different pigments individual BAT levels have been compiled by the Stockholm Convention Toolkit (Table 18; UNEP 2013[170]).

Some of these and other pigments also contain unintentional produced polychlorinated biphenyls (PCBs) as unintentional produced POPs[173,174]. Testing of consumer products such as newspaper and magazine papers, food packaging, and plastic bags colored or printed with inks and pigments associated with PCB by-products has also confirmed the presence of these PCBs[175].

Recent testing of pigments in Japan by the Japan Dyestuff and Industrial Chemicals Association has found traces of PCBs in 57 out of 98 organic pigments tested. Some of these pigments were found to contain PCBs at concentrations above 50 ppm. Considering the Stockholm Convention, Japan has banned those pigments which had levels above 50 ppm.[176] Information on achievable levels and related BAT/BEP in production has not been compiled yet.

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[171] Government of Japan (2006) Submission to COP3: Assessment Committee on BAT Levels for Reduction of a Specified Chemical as a Contaminant By-product November 2006.

[172] Government of Japan (2007) Submission to COP3: Assessment Committee on BAT Levels for Reduction of a Specified Chemical as a Contaminant By-product. April 2007.

[173] Grossman E (2013) Nonlegacy PCBs Pigment Manufacturing By-Products Get a Second Look Focus. Environmental Health Perspectives 121, A87-A93 http://ehp.niehs.nih.gov/pdf-files/2013/Mar/ehp.121-a86_508.pdf.

[174] Anezaki K, Nakano T (2014) Concentration levels and congener profiles of polychlorinated biphenyls, pentachlorobenzene, and hexachlorobenzene in commercial pigments. Environmental science and pollution research international 21, 998-1009.

[175] Stone A (2014) Polychlorinated Biphenyls (PCBs) in General Consumer Products. Department of Ecology State of Washington. June 2014.

[176] METI. Summarized Results of the Second Investigation into the Presence of Polychlorinated Biphenyls (PCBs) as By-Products in Organic Pigments [press release]. Tokyo, Japan: Japanese

Table 19: HCB emission factors for Stockholm Convention Toolkit source category 7d: TCPA and related pigments (UNEP 2013[170])

7d	**TCPA and related pigments**	**Emission Factors (g/t product)**				
Classification		**Air**	**Water**	**Land**	**Product**	**Residue**
1	Tetrachlorophthalic acid (CAS 632-58-6)	ND	ND	ND	**2000**	ND
2	Tetrachlorophthalic acid (BAT)	ND	ND	ND	**200**	500
3	Solvent Red 135 (CAS 20749-68-2)	ND	ND	ND	**200**	ND
4	Solvent Red 135 (BAT) (CAS 20749-68-2)	ND	ND	ND	**10**	ND
5	Pigments Yellow 110 (CAS 5590-18-1) & 138 (CAS 30125-47-4)	ND	ND	ND	**200**	ND
6	Pigment Green 7[177] (CAS 1328-53-6)	ND	ND	ND	**200**	ND
7	Pigment Green 7 (BAT) (CAS 1328-53-6)	ND	ND	ND	**10**	ND
8	Pigment Green 36 (CAS 14302-13-7)	ND	ND	ND	**10**	ND
9	Pigment Green 36 (BAT) (CAS 14302-13-7)	ND	ND	ND	**1**	ND

Source: Stockholm Convention (2013), Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs under Article 5 of the Stockholm Convention

3.9.2 Case study: Production of certain pesticides containing unintentional POPs

A range of chlorinated pesticides contain PCDD/PCDF and other unintentional POPs as impurities[170,178,179]. For those pesticides where sufficient data on PCDD/PCDF content were available dedicated emission factors are listed in source group 7d of the updated UNEP toolkit[170]. Other pesticides were contamination with PCDD/PCDF was reported but where information to develop emission factors was not sufficient are have been listed in Annex 2 of UNEP toolkit[170] until more data is available for assigning emission factors.

For some pesticides like 2,4-D and derivatives the level of contamination strongly depends on the applied technology and refining steps (table 19) making it possible to phase out POPs contaminated 2,4-D products and substitute it by formulations produced according to BAT/BEP.

Ministry of Economy, Trade, and Industry (30 Aug 2012). Available: http://www.meti.go.jp/english/press/2012/0830_01.html; accessed 10.08.2014.

[177] Due to its stability, Pigment Green 7 is used in inks, coatings, and many plastics. In application, it is transparent. The pigment is insoluble and has no tendency to migrate in the material. It is a standard pigment used in printing ink and packaging industry. It is also allowed in cosmetics except those used around the eyes, and is used in some tattoos.

[178] Holt E, Weber R, Stevenson G, Gaus C (2010) Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans (PCDD/Fs) Impurities in Pesticides: A Neglected Source of Contemporary Relevance. Environ. Sci. Technol 44, 5409–5415.

[179] Ambrus A, Hamilton D, Kuiper H, Racke K (2003) Significance of impurities in the safety evaluation of crop protection products (IUPAC technical report). Pure and applied chemistry 75: 937-973.

For other pesticides like pentachloronitrobenzene (PCNB; Quintozene) the difference between different technology levels are less pronounced with still relatively high PCDD/PCDF emission factors at high end BAT/BEP production (table 20). In this case the pesticide is best substituted by less contaminated alternatives or integrated pest management measures. Therefore for PCNB which in addition have been found to contain high levels of dioxin-like PCBs and HCB and finally degrading to pentachlorobenzene to some percentage[180,181,182] - many governments have decided to ban the use resulting in the use of more benign alternatives and alternative approaches.

Table 20: PCDD/PCDF emission factors for 2,4-D and Derivatives (UNEP 2013)[170]

7d	**2,4-D and Derivatives**	**Emission Factors ((µg TEQ/t product)**				
Classification		**Air**	**Water**	**Land**	**Product**	**Residue**
1	Low-end production technologies	ND	ND	ND	**5688**	ND
2	Mid-range production technologies	ND	ND	ND	**170**	500
3	High-end production technologies	ND	ND	ND	**0.1**	ND

Table 21: PCDD/PCDF emission factors for Pentachloronitrobenzene Production (UNEP 2013)[170]

7d	**Pentachloronitrobenzene Production**	**Emission Factors ((µg TEQ/t product)**				
Classification		**Air**	**Water**	**Land**	**Product**	**Residue**
1	Low-end production technologies	ND	ND	ND	**5600**	ND
2	Mid-range production technologies	ND	ND	ND	**2600**	500
3	High-end production technologies	ND	ND	ND	**260**	ND

3.9.3 Case study: Production/purification of chloranil

p-Chloranil (2,3,5,6-tetrachloro-2,5-cyclohexadiene-1,4-dione; CAS 118-75-2) is used as an intermediate in the production of medicines, pesticides, and dioxazine dyes. It is also used as a fungicide and for seed treatment, although such uses are prohibited in some countries. PCDD/PCDF contamination in chloranil is transferred to dyestuffs, pigments, inks, etc. and other products made from chloranil. PCDD/PCDF in chloranil-derived materials are further transferred into the production processes of

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[180] Huang, J., Gao, J., Yu, G., Yamazaki, N., Deng, S., Wang, B., & Weber, R. (2014). Unintentional formed PCDDs, PCDFs, and DL-PCBs as impurities in Chinese pentachloronitrobenzene products. Environmental Science and Pollution Research, 1-9.

[181] Masunaga S, Takasuga T, Nakanishi J (2001) Dioxin and dioxin-like PCB impurities in some Japanese agrochemical formulations. Chemosphere 44: 873-885.

[182] UNEP (2010) Additional consideration of new persistent organic pollutants: pentachlorobenzene. Persistent Organic Pollutants Review Committee Sixth meeting, 11-15 October 2010, Geneva, Switzerland. UNEP/POPS/POPRC.6/INF/21.

textiles, polymers/plastics, and packaging materials (paper, tin cans, etc.) and released in process outputs (UNEP 2013)[170].

The levels in chloranil from production have been compiled in the "Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs under Article 5 of the Stockholm Convention on Persistent Organic Pollutants" (Table 22, UNEP 2013)[170]. Liu *et al.* (2012)[183] determined PCDD/PCDF concentrations in chloranil samples from three Chinese factories, each of which used a production process involving the chlorination of hydroquinone. However, at each facility, the chloranil was purified to a different extent because of different intended uses. Chloranil produced for use as an intermediate in pharmaceutical products was most stringently purified and had a PCDD/PCDF concentration of 163 pg TEQ/g. A PCDD/PCDF concentration of 26,368 pg I-TEQ/g was measured in moderate quality chloranil. PCDD/PCDF was found at 1,540,200 pg TEQ/g in the chloranil intended for use as an intermediate for dyes and pesticides. Total PCB levels in the three chloranil samples ranged from 1,179.4 to12,413.7 pg/g (1.9-3.3 pg WHO-TEQ/g); pentachlorobenzene (PeCBz) ranged from 12.1 to 31.8 ng/g; and HCB from 3.8 to 391.5 ng/g (Liu et al. 2012)[183].

Ni *et al.* (2005)[184] analyzed chloranil produced by two Chinese facilities and found PCDD/PCDF concentrations of 13 and 126 ng TEQ/kg. The disparity in their results was attributed to the use of different production methods, which were not described. Based on this and former findings, emission factors were selected for the Stockholm Convention Toolkit for *p*-chloranil and are compiled in Table 22. The case study shows that chloranil produced from hydroquinone and from phenol contain PCDD/PCDF above the Basel provisional low POPs content (15 ng TEQ/g) for waste (Table 22). Low POPs contaminated chloranil can be produced by purification (Table 22).

Table 22: PCDD/PCDF emission factors for source category 7d p-Chloranil production (UNEP 2013)[170]

7d	***p*-Chloranil Production**	**Emission Factors (µg TEQ/t product)**				
Classification		**Air**	**Water**	**Land**	**Product**	**Residue**
1	Direct chlorination of phenol	ND	ND	ND	**400,000**	ND
2	Chlorination of hydroquinone with minimal purification	ND	ND	ND	**1,500,000**	ND
3	Chlorination of hydroquinone	ND	ND	ND	**26,000**	ND

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[183] Liu W, Tao F, Zhang W, Li S, Zheng M (2012) Contamination and emission factors of PCDD/Fs, unintentional PCBs, HxCBz, PeCBz and polychlorophenols in chloranil in China. Chemosphere. 86, 248-251.

[184] Ni Y, Zhang Z, Zhang Q, Chen J, Wu Y, Liang X. (2005) Distribution patterns of PCDD/Fs in chlorinated chemicals. Chemosphere 60, 779-784.

	with moderate purification					
4	Chlorination of hydroquinone with advanced purification	ND	ND	ND	**150**	ND

4 How can we add more understanding on the use of POPs and alternatives in products and articles?

Several of the more recently listed POPs have been used or are still used in products and articles including e.g. PFOS in carpets, paper, textiles or fire fighting foam or HBCD in insulation foam or textiles. In addition, although production of other POPs has stopped, they are still present in consumer articles in use and in the end of life and recycling flows (e.g. listed polybrominated diphenyl ethers (POP-PBDEs) as flame retardants in electrical and electronic equipment (EEE) or the transport sector). Their use and presence in these material flows, including the waste stream, need to be managed.

Information on the presence of POPs in articles and products is essential for controlling and eliminating these POPs, for preventing POPs from entering recycling schemes and for the implementation of the national implementation plans. However, Parties to the Convention are now facing challenges in monitoring these substances due to the lack of information on POPs in products and articles and their presence in the recycling streams. Detailed information on POPs in articles and products is needed in order to prevent the POPs contamination of products produced from recycling; however, this information is often not available due to the lack of labelling of POPs in products.

Monitoring of chemicals and products by authorities is largely conducted by control of, for example, import papers and other information documents, chemical names, product names, CAS number, GHS labels or HS codes. These and other tools and regulatory frameworks for monitoring of POPs (and other hazardous chemicals) in products and articles are described in Annex 1. However, a range of gaps for the monitoring and management of POPs (and other hazardous chemicals) in articles and products exists for all these tools and regulatory frameworks (see Annex 1). In addition there are a range of voluntary schemes for identification of chemicals in articles to regulate and facilitate the control of chemicals (including POPs) in articles and products (Annex 2). However, these voluntary schemes also have gaps in respect to monitoring of POPs in articles and products (Annex 2).

Due to the limitations of these tools and of voluntary schemes (see Annexes 1 and 2) for monitoring newly listed POPs in articles and products, the improvement of some of these schemes and additional regulatory frames for disclosing information on chemicals in products are needed.

In addition a complementary analytical monitoring approach is needed for those POPs which are currently in articles/products where information on their presence and distribution is missing. Also analytical monitoring is needed for recycling flows where POPs containing articles may end up and in the articles and products made from these recycling flows.

Therefore, in this chapter information is compiled on existing systems which are already used to gather more information on chemicals in articles and products and on guidance and case studies on monitoring of POPs in articles.

The chapter also contains information on regulatory systems for improving information on POPs (***4.1 Approaches for better information and monitoring of POPs in articles***) in articles. Finally, the chapter briefly introduces tools and approaches that may be useful in evaluating and selecting POPs alternatives.

4.1 Approaches for better information and monitoring of POPs in articles

Improved disclosure of POPs (and other hazardous chemicals) in products would make it possible both to reduce the risk of exposure and to track the movement of these chemicals through the economy and into recycling flows which could then better be protected, Also, it would help consumers to make informed choices of safer but sometimes more expensive alternatives and help to drive the market towards greener products containing sustainable chemicals.

For HBCD, a labelling scheme will be developed for the exempted use in XPS/EPS insulation material to control the end of life management of XPS/EPS and to protect and support the recycling of XPS/EPS. For other POPs, such a labelling scheme has not been developed yet; however, considerations on labelling of POPs in articles have been compiled in the Stockholm Convention document "Labelling of products or articles that contain POPs – Initial considerations".

Some countries have developed specific information schemes for hazardous chemicals which might in a modified way be applied for POPs or POPs-like chemicals:

4.1.1 Better information on hazardous chemicals by disclosure initiatives

There are a range of laws in different countries that require disclosure of certain information about chemicals in products/articles. POPs as one of the most hazardous groups of chemicals should be foremost addressed if countries have or develop such systems on disclosure of information.

4.1.1.1 Notification of chronic health effects and Toxics Information Clearinghouse (California; United States)[185]

California's Safe Drinking Water and Toxic Enforcement Act of 1986 (commonly referred to as Proposition 65) provides for the annual publication of a list of chemicals that are "known to the state of California to cause cancer or reproductive toxicity." The list includes approximately 775 chemicals.[186]

Under Proposition 65, businesses must provide a 'clear and reasonable' warning when a product or workplace will expose people to listed chemicals. This warning can be

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[185] Text largely excerpted from Massey RI, Hutchins JG, Becker M, Tickner J (2008) Toxic Substances in Articles: The Need for Information. TemaNord 2008:596.

[186] California Office of Environmental Health Hazard Assessment, Proposition 65 in Plain Language, accessed at http://www.oehha.org/prop65/background/p65plain.html and Proposition 65, accessed at http://www.oehha.org/prop65.html

provided through a label, signs posted at a workplace, "distributing notices at a rental housing complex, or publishing notices in a newspaper."

Notification is not required if the exposure is below a scientifically established "no observable effect level" (NOEL), divided by 1,000. Where a NOEL has not been established for a chemical, this provision creates an incentive for firms to generate data that could serve as the basis for establishing a NOEL.

Because of the requirements of Proposition 65, some products sold in California bear a label stating that "This product contains chemicals known to the state of California to cause cancer or reproductive toxicity." These labels make it possible for consumers in California to make informed choices about the products they purchase. This information makes it possible for consumers, in turn, to send clear market signals up the supply chain. If a similar requirement were adopted elsewhere in the world as well, the market signals could be further reinforced.

In 2008, California adopted two new laws that increase the state's ability to manage information on toxic chemicals, including those found in articles.[187] Moving beyond the approach of legislation that focuses on one or a few chemicals at a time, the new laws provide a broad approach to all chemicals in commerce. The state is directed to create a Toxics Information Clearinghouse to identify the chemicals of highest concern, inventory comprehensive information on these chemicals, and provide information to the public. In 2014, California's Department of Toxic Substances Control (DTSC) issued its first proposed list of priority chemical-product pairs (a chemical of concern as used in a specific product). Once these designations are finalized, companies selling these products in California will be subject to a number of requirements, including a requirement to develop an alternatives assessment.[188]

4.1.1.2 Notification of toxics in children's products[189,185]

In 2008, the states of Maine and Washington (United States) adopted toxics legislation that requires submission of toxics data to the state, among other provisions.

- Maine's Act to Protect Children's Health and the Environment from Toxic Chemicals in Toys and Children's Products[190] provides for the creation of a list of chemicals of high concern. Once this list is created, manufacturers and distributors will be required to provide written notification to the state if they use a listed chemical in a "children's product" for sale in the state.

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[187] California AB 1978, accessed at http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1851-1900/ab_1879_bill_20080929_chaptered.html, and SB 509, accessed at http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0501-0550/sb_509_bill_20080929_chaptered.html.

[188] DTSC. "*Frequently Asked Questions: DTSC Draft Initial Priority Products*." Retrieved from https://dtsc.ca.gov/SCP/upload/PP_FAQs.pdf, viewed July 20, 2014.

[189] Text largely excerpted from Massey RI, Hutchins JG, Becker M, Tickner J (2008) Toxic Substances in Articles: The Need for Information. TemaNord 2008:596.

[190] Act to Protect Children's Health and the Environment from Toxic Chemicals in Toys and Children's Products, accessed at http://www.chemicalspolicy.org/legislationdocs/Maine/ME_1691.pdf.

- Washington's Children’s Safe Products Act[191] provides for a phase-out of the use of lead, cadmium, and phthalates in “children’s toys and other products” as well as a comprehensive approach to toxics in children’s products. In addition, the legislation provides for the state to “identify high priority chemicals that are of high concern for children." Manufacturers must provide notice to the state of any product that contains a chemical designated as a high priority.

Both of these laws have the potential to increase significantly the amount of information available to state governments, and to the public, regarding toxic substances in children's articles.

Establishing the necessary databases to manage this information can be a large undertaking for a state government. This includes creating the information infrastructure, as well as defining rules as to what entities must comply, and providing for enforcement. Maine and Washington, along with other states, have entered into discussions to create a new interstate entity called the Interstate Chemicals Clearinghouse, through which states can pool resources, share data collected on different product types, collect information from initiatives in other countries, and share the burden of conducting assessments of safer substitutes. These states have collaborated on the creation of a harmonized database on mercury in products, and this model could be used for other chemicals as well. Washington has created a database of chemicals in children’s products, which provides substantial information to the state and to the public.

4.1.2 Management of Information on Chemicals in Articles under REACH[192]

The European Union (EU) chemicals regulation, REACH, is designed to improve information flow and enhance chemicals management in multiple dimensions. It mandates information sharing about both chemical hazards and chemical uses.

The information requirements under REACH make it necessary for firms to obtain and disclose to their supply chains, and to some degree the public, significantly more information about chemicals in articles. As a result, REACH is leading to greater information flow up and down the supply chain. For gaps in respect to POPs in articles see Annex 6.1.7.

Substances in articles: Registration and notification requirements:

Article 7 of REACH includes two requirements that apply specifically to substances in articles: registration and notification.

- Registration. If an article contains a substance that is intended to be released "during normal and foreseeable conditions of use" and is manufactured or imported at more than 1 tonne per year per manufacturer or importer, then that substance is subject to registration requirements. This means that the

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[191] Children's Safe Products Act, accessed at http://www.ecy.wa.gov/programs/swfa/cspa/.

[192] Text largely excerpted from Massey RI, Hutchins JG, Becker M, Tickner J (2008) Toxic Substances in Articles: The Need for Information. TemaNord 2008:596 with additions and update.

manufacturer or importer must submit information to the European Chemicals Agency on toxicity and other inherent properties of the substance, as well as its expected uses, including the use in the article in question.

- Notification. In addition, there is notification requirements for articles that contain substances of very high concern (SVHCs) included on the candidate list for authorization. This means that the manufacturer or importer must notify the European Chemicals Agency of the presence of that substance in the article. This requirement applies when the substance is present in a concentration above 0.1% (w/w) and the substance is present at more than 1 tonne per year per producer or importer.

The notification requirement is waived if "the producer or importer can exclude exposure of the substances to humans or the environment during normal or reasonably foreseeable conditions of use including disposal," or if the substance has already been registered for the use in question.

According to article 33 of the REACH regulation, any supplier of an article containing substances of very high concern (SVHC) included on the candidate list for authorization in a concentration above 0.1% (w/w) has to provide the recipient of the article with sufficient information, available to the supplier, to allow safe use of the article.

To facilitate consumer information, Denmark has introduced an app that allows consumers to test whether products contain any substances of very high concern (SVHCs) by scanning the article's barcode. The tool is part of the "Check chemistry" campaign created by the Danish Environmental Protection Agency and the Think Consumer Council.

This requirement to communicate information applies at any quantity; there is no annual tonnage threshold below which it does not apply. This requirement cannot be waived based on exclusion of exposure, or based on the substance already having been registered for the use in question.

The Environmental Agency of Germany has developed an electronic guidance for manufacturers and importers of articles describing their information tasks under REACH. The “REACH SVHC Communicator” tool is publicly available under http://svhc-in-articles-communication.de/.

In addition to the information disclosure requirements that refer specifically to articles, other requirements under REACH will also lead to greater availability of information about substances in articles.

In completing a registration for a chemical product, the manufacturer or importer is required to determine, and document, how that chemical will be used downstream, requiring communication with the supply chain to determine such uses. This means that if the chemical will be incorporated into an article downstream, this information must be provided to the European Chemicals Agency.

Further, if the chemical is produced or imported in quantities from ten tonnes per year, the manufacturer or importer must produce a Chemical Safety Report which will provide information on the risks the substance poses in different use/exposure scenarios.

In summary, the information requirements under REACH are likely to ensure better data about how substances are used in articles. They should also ensure greater information about the flow of chemicals, from initial manufacture through incorporation in a final product and eventual disposal of that product.

4.1.3 Voluntary schemes

There are a range of initiatives by some industrial sectors (e.g. electronics industry and auto industry) or by some pro-active companies to track and disclose information on chemicals in the products they produce or sell which could be used for POPs and are in some cases used for POPs in articles an products. Some examples are listed in Annex 2. These schemes mainly aim to provide information within supply chains but in some cases, the information is also made available for non-industrial stakeholders such as consumers or policy makers (see Annex 2).

4.1.4 UNEP project on chemicals in products[193]

In May, 2009, the second session of the International Conference of Chemicals Management (ICCM2) adopted a resolution agreeing to implement a project on Chemicals in Products with the overall objective of promoting the implementation of paragraph 15 (b) of the Overarching Policy Strategy of the Strategic Approach to International Chemicals Management. The Conference invited UNEP to lead and facilitate the project. The Conference agreed that the following tasks be undertaken:

- to collect and review existing information on information systems pertaining to chemicals in products including but not limited to regulations, standards and industry practices;
- to assess that information in relation to the needs of all relevant stakeholders and identify gaps;
- to develop specific recommendations for actions to promote implementation of the SAICM with regard to such information, incorporating identified priorities and access and delivery mechanisms.

These UNEP-led activities are in support of SAICM emerging issue on chemicals in products. The resolution recommended that proposals for cooperative actions should take into account the Globally Harmonized System of Classification and Labelling of Chemicals and avoid any duplication of efforts under that system.

Up to now a range of useful documents from the Chemicals in Products project have been published:

- An "overview of systems for providing information regarding chemicals in products and of stakeholders' needs for such information" (11/2010)[194],

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[193] Text largely excerpted from the UNEP project website and documents therein

- The "CiP Project synthesis report" (02/2011),

including developed sector case studies for:

- Electronics (2011)[195],
- Toys (2011)[196],
- Building products - February, 2011,
- Textiles (02/2011)[197].

At ICCM3 (September, 2012 - Nairobi, Kenya) a side event on "The Need for Chemicals in Products information" was held. ICCM3 reviewed the findings and generally endorsed UNEP's proposed recommendations for future actions. More specifically, the Conference invited UNEP to continue to lead the CiP project and mandated the project (in the next intersessional period 2012-2015 prior to ICCM4) to develop a proposal for an international CiP programme.
At ICCM3 a resolution on CiP for the 2012-2015 was mandated to UNEP CiP project.

4.2 Monitoring of POPs in articles and products

Since products and articles containing POPs are not labelled as such, a certain extent of monitoring is needed. In addition to articles/products on the market, this includes the monitoring and management of articles in use, stockpiles, and at end-of-life including recycling. A range of these articles/products can return to the market either as used goods (e.g. electronics, cars, carpets, furniture) or as material in the recycling flow (e.g. polymers from electronics; polyurethane foam from furniture; material recycling of textiles, paper, or synthetic carpets). Therefore, information on monitoring data from these materials is also crucial to get an overall picture of POPs in the material flows including product/article and related recycling flows.

4.2.1 Monitoring guidance to screen POPs in articles

In order to help countries overcome the challenges regarding monitoring of new listed POPs in products and articles, as well as in the recycling streams, the Secretariat of the Stockholm Convention, with financial support from Norway has developing a "Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles" (Draft).
This document provides guidance on monitoring (sampling, screening and analysis) of the POPs content in articles and products in use and in the recycling streams for those POPs listed in 2009 and 2011.

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[194] Kogg B, Thidell A (2010) Chemicals in Products: An Overview of Systems for Providing Information Regarding Chemicals in Products and of Stakeholders' Needs for Such Information".

[195] Nimpuno N, Scruggs C (2011) Information on Chemicals in Electronic Products. TemaNord 2011:524.

[196] Dannwolf U, Ulmer F, Cooper J, Hartlieb S (2011) Chemicals in Products Toys Sector Case Study for UNEP.

[197] UNEP DTIE (2011) The Chemicals in Products Project: Case Study of the Textiles Sector.

Guidance is provided on:

- articles and products possibly containing the POPs listed in 2009 and 2011;
- developing strategies for monitoring of POPs in articles/products and recycling streams;
- inventory development aspects such as determining emission/impact factors;
- import control and possible monitoring at customs or at consumer protection level;
- assessment of human exposure through articles in use and through recycled materials.

The guidance addresses to the types of major articles, products and other material, which may contain POPs listed in 2009 and 2011 (Annex 1).

The guidance is to:

- refer to international standards where they are available and sufficient for the analysis of respective articles and mention their limitations for articles/products;
- describe some standard methodologies used by laboratories experienced in the analysis of POPs listed in 2009 and 2011 contained in certain articles and products;
- describe case studies with links to reports where monitoring or analytical procedures for a certain matrix are described.

New analytical standard procedures for specific matrices and other case studies can be considered in the finalization and updating of the draft guidance.

4.2.2 Best practice case studies on screening and analysis of POPs in articles

There has already has been a range of activities of monitoring of POPs in articles and products by research institutions or by governmental entities in different countries/regions. An overview of existing studies gives an insight on the current presence of POPs in articles. Some of the case studies reveal that many former applications of PFOS are no longer relevant. Recent surveys detected no PFOS or related substances in coated paper in Germany, for example (Schlummer et al. 2011)[198] . Also for PBDE only specific categories of plastics from E-waste appear to contain POP-PBDEs at significant levels (Waeger et al. 2010)[199].

Case studies provide information on methodologies and approaches for monitoring POPs in articles and products and how such monitoring could be performed. These case studies can therefore be assessed with the view of selecting the most appropriate approaches and methodologies (sampling and analysis).

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[198] Schlummer M, Gruber L, Fengler R, Fiedler D, Wolz G (2011) How Poly- And Perfluoroalkyl Substances (PFAS) May Enter Our Food From Food Contact Materials (FCM). Perfood Newsletter, Issue 2: November 2011.

[199] Waeger P, Schluep M, Müller E. (2010) RoHS substances in mixed plastics from Waste Electrical and Electronic Equipment. Final Report September 17, 2010.

4.2.2.1 Monitoring project of PFOS/PFAS[200] in consumer products in Norway and Sweden

The Norwegian Pollution Control Authority (SFT) has commissioned a survey on PFOS/PFCs in consumer products (Herzke et al. 2009).[201] It was carried out by Swerea IVF (Sweden) together with Norwegian Institute for Air Research (NILU) and aimed to identify and quantify possible sources of PFAS in Norway in industrial manufacturing and applications used by the Norwegian population in daily life.

The study included waterproofing agents (5), paint and inks (5), impregnated products: paper, textiles, leather and carpets (2/2/2/2), non-stick ware (6), electronics (5) and fire fighting agents (5).

PFOS has been banned in Norway since 2007 but was still detected in 47% of samples in low concentrations. However, concentrations in only 4 of the 34 products analysed were close to or exceeding the regulations.[202] These products were all within the leather or carpet product groups: The two leather samples had the highest concentrations of PFAS: Office furniture leather; (pool of 3) and black shoe, leather, showed PFOS levels of 38 and 21 µg/m^2, exceeding the EU regulation of 1 µg/m^2. Carpets were around the regulation of 1 µg/m^2. The relatively low levels detected indicate that PFOS were not applied as major performance chemical but rather as by-product or contaminant of other PFAS or treatment procedure. Only five of the 34 analysed industrial materials and consumer products contained none of the 29 polyfluorinated substances for which the samples were tested.

4.2.2.2 Case study: PFOS/PFAS monitoring Baking and Muffin papers

As a contribution to the European Perfood project (http://www.perfood.eu/; KBBE-227525), 154 paper-based food contact materials (Baking papers and Muffin cups) were collected and screened for fluorinated contaminants (Schlummer et al. 2011)[198]. 47 fluorine-positive samples were identified und subjected to a detailed analysis for PFOS and other perfluorinated sulfonates (PFSA), fluorotelomer alcohols (FTOH), and perfluorinated carboxylates (PFCA). In this study, PFOS and other perfluorinated sulfonates (PFSA) were not detected in any sample at levels above 1 ng/g. Instead 6:2 FTOH, 8:2 FTOH and 10:2 FTOH were identified in all fluorine-positive samples at levels ranging from 9 to 39,500 ng/g. Concentrations of PFCA were considerably lower and ranged from LOD (<1) to 619 ng/g PFOA, LOD (<1) to 1,500 ng/g PFNA, and LOD (<1) to 390 ng/g PFDA[198]. This strongly indicates a switch from PFOS/FOSE-based coatings for paper to FTOH containing macromolecules in industrial practise.

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[200] Recommendation for further reading on PFAS analysis::Trace analysis of per- and polyfluorinated alkyl substances in various matrices-How do current methods perform? Journal of Chromatography, A 2009, 1216, (3), 410-421. Challenges in perfluorocarboxylic acid measurements. Analytical Chemistry 2007, 79, (11), 3966-3973.

[201] Herzke D, Posner S, Olsson E (2009) Survey, screening and analyses of PFCs in consumer products. TA-2578/2009; Swerea IVF Project report 09/47.

[202] Regulation EC No 552/2009 of 22 June 2009 amending Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards Annex XVII , p.53.

It needs to be highlighted that in the first phase of the study performed in 2009/2010, most baking paper and muffin cups purchased in super markets were fluorine positive and had significant FTOH and PFCA levels (no PFOS). However, in a second screening in 2010/11 of baking and muffin papers newly purchased in super markets, most samples were fluorine negative in the screening (detection limit approx. 0.1%), meaning that most of the investigated brand marks had changed for the European market their coating in recent years towards non-organofluorine coatings and already some years earlier moved away from PFOS precursor based coatings.

4.2.2.3 Monitoring of paper packaging for food (Denmark)

PFOS and related chemicals in food packaging are of particular concern due to possible direct human exposure. In an (on-going) survey for the Danish Food Administration[203] approximately 85 food packaging samples were taken by food inspectors in food packaging businesses (samples with no previous contact with food) and by DTU-Food in retail stores (samples in contact with foods). Only four samples contained perfluorinated sulfonates (PFSAs), and only two of these contained PFOS but in low levels (< 10 ppb). The other samples contained FTOH based PFAS in 57 % of the samples. Also this study revealed/conformed with the pattern of detected PFAS that industry for the European market already have shifted away from PFOS-derived coatings to diPAPs and now towards FTOH containing coatings. PFCA impurities/breakdown products were often seen in the paper extracts/migrates.

4.2.2.4 Non-analytical screening of PFOS/PFAS in products on the Danish market

In the first steps of monitoring of newly listed POPs in a country other approaches (including) import statistics, product registers, company survey and audits should be considered and compiled before any instrumental screening and analysis is done. One documented survey on of PFOS/PFAS in consumer products in the Danish market with non-analytical means has been conducted and published from the Danish Ministry of Environment (2008)[204].

Approaches of the Danish market survey of PFOS/PFAS on the national market were:

- Compilation of information from the Danish Product Register.
- Information from different companies such as producers, importers, suppliers and stores. Producers of fluorinated substances have been identified by Internet survey.
- The most important companies within the most relevant sectors were contacted by phone (not by questionnaires). This approach only gave sparse information (either companies did not know the chemical content of their

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[203] Danish Veterinary and Food Administration (2012) Danish Technical University Report (not published).

[204] Danish Ministry of Environment (2008) Survey and environmental/health assessment of fluorinated substances in impregnated consumer products and impregnating agents. Survey of Chemical Substances in Consumer Products, No. 99, 2008.

products or they did not want to give information about the use of fluorinated substances (the survey was performed by a consultancy and not by a competent authority).

- Stores and companies marketing and selling consumer products with a content of fluorinated substances have been identified initially by identifying the different products that contain fluorinated substances, and then secondly identifying the sectors in which the products are sold or produced.
- Information found on the Internet search about the content of fluorinated substances in different products was combined with statistics of sales of products in Denmark in order to estimate the use of fluorinated substances in Denmark in different product categories.

4.2.2.5 Monitoring of PBDEs in WEEE plastic in EU

The largest and most relevant transboundary substance flow of POP-PBDEs and BFR containing materials are plastic fractions from WEEE recycling, followed by polyurethane foam in car/transport, furniture, construction, mattresses or baby products[205,206]. The Swiss national material testing institute EMPA developed a standardized methodology for sampling of WEEE for a survey of RoHS regulated substances in WEEE plastic in Europe including c-OctaBDE (Wäger et al. 2010)[207]. Specific features of EMPA's case study on PBDE and other RoHS relevant substance screening in WEEE plastics are:

- In the study a sampling methodology and a sampling protocol has been developed and is described in detail of Annex 1 and Annex 2 of EMPA study. This sampling strategy and protocol can be applied (in a modified way) in other countries and regions having shredder plants for processing of WEEE.
- The study gives a broad overview on the current POP-PBDE content of the polymer fractions of WEEE categories (for Europe).
- The study further gives an overview on other critical RoHS relevant pollutants which might be relevant today for other regions too.

4.2.2.6 Determination of POPs-PBDE and BFRs in WEEE plastics in Nigeria

The largest POP-PBDE share within EEE/WEEE is casings of Cathode Ray Tubes (CRTs) (see *PBDE Inventory Guidance*[3]). In a monitoring study of POP-PBDEs in Nigeria the two major CRT categories (TVs and computers) were monitored (Sindiku

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[205] Stockholm Convention (2011) Work programmes on new persistent organic pollutants. 5th Conference of Parties meeting. UNEP/POPS/COP5/15.

[206] Stapleton MH, Klosterhaus S, Keller A, Ferguson PL, van Bergen S, Cooper E, Webster TF, Blum A (2011) Identification of Flame Retardants in Polyurethane Foam Collected from Baby Products. Env. Sci. Technol. 45. 5323-5331.

[207] Wäger P, Schluep M, Müller E. 2010. RoHS substances in mixed plastics from Waste Electrical and Electronic Equipment. Final Report September 17, 2010.

et al. 2011[208] and 2012[209]). In this case study 382 single housings of computer and TV Cathode Ray Tubes (CRTs) were sampled at WEEE storage sites in Nigeria (Sindiku et al. 2011, 2012). Furthermore the recycling of the plastic of these appliances is of interest from an economic perspective.

The samples were specifically selected from waste storages, electronics workshops, roadsides, dumpsites and dismantling sites. The labels on the TVs and computer monitor plastic housings were examined for information on the manufacturer, brand, model, serial number, year and origin (production or assembly). About 250 cm^2 sizes were cut from each sample.

Small parts of these sub-samples were subjected to a screening with EDXRGF aiming at the semi-quantification of bromine, chlorine but also of inorganic compounds listed in the RoHS directive. Bromine positive samples were then selected for GC/ECD and GC/MS analysis and the type and amount of PBDE and other major BFR determined.

4.2.2.7 Monitoring of BFRs in polymers of electronics on Swiss market

The Swiss competent authorities monitored brominated flame retardants in 2000 in consumer products currently in sale including electrical devices, building materials and lighting equipment (Bantelmann et al. 2010)[210]. The aim of the survey was to evaluate the compliance of commercial articles with the provisions of the Swiss restrictions on BFRs: In Switzerland, the placing on the market and use of c-PentaBDE, c-OctaBDE and PBBs in preparations with contents of each of these BFRs equal to or exceeding 0.1% by mass is prohibited. Also placing of articles on the market of articles that contain these substances in concentrations equal to or exceeding 0.1% by mass is banned as well.

Only 2 of the approximately 2000 samples contained c-OctaBDE above the 0.1% RoHS threshold. The study gives an insight on POP-PBDE and other BFRs used in electronic products present/imported to the European market. The study shows that the POP-PBDE content in current products on the Swiss (and therefore European) market is small.

The results of the third screening level of unknown BFRs in the samples by EMPA revealed that some of these samples contained e.g. hexabromobenzene or pentabromobenzene where the chlorinated analogues (HCB & PeCBz) are prohibited by the Stockholm Convention.

4.2.2.8 Monitoring POP-PBDEs in carpet rebond from recycled PUR foam

PUR foam is recycled to carpet rebond in some regions in particular North America. In a monitoring project of POP-PBDEs in recycled carpet padding samples from

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[208] Sindiku et al. (2011) Screening E-waste plastic in Nigeria for BFR using XRF – towards a methodology for assessing POPs PBDE in Ewaste exports. Organohalogen Compounds 73. 785-788.

[209] Sindiku O, Babayemi JO, Osibanjo O, Schlummer M, Schluep M, Weber R (2012) Assessing POP-PBDEs and BFRs in E-waste polymers in Nigeria. Organohalogen Compounds 74, 1320-1323.

[210] Bantelmann E, Ammann A, Näf U, Tremp J. (2010) Brominated flame retardants in products: Results of the Swiss market survey 2008. BFR 2010, April 7-9, Kyoto, Japan.

different word regions have been screening with XRF for bromine content and 26 samples were analysed for PBDE content by GC/MS analysis (DiGangi et al. 2011)[211]. The study showed that carpet padding/rebond in the US and Canada was impacted with high levels of PBDEs but that the levels in samples from developing countries were low.

4.2.2.9 Monitoring of POP-PBDEs and other flame retardants in baby products

For the first time a wide range of polyurethane baby products were sampled, screened and analysed for POP-PBDEs and other flame retardants. In total 101 commonly used baby products from the United States containing polyurethane foam were monitored for POP-PBDEs and other flame retardants (Stapleton et al. 2011)[212]. The study combined bromine screening methodology with confirmation analysis (as suggested in this guidance document). A portable X-ray fluorescence (XRF) analyser was used to estimate the bromine and chlorine content of the foams.

From these products:

- A significant correlation was observed for bromine with quantitative analysis of BFRs.
- Five samples contained POP-PBDE congeners commonly associated with c-PentaBDE, suggesting that such products are still in-use in sensitive use areas although production of c-PentaBDE is widely believed to have stopped in 2004.
- 80% of the PUR foam baby products contained an identifiable flame retardant additive, and all but one of these was either chlorinated or brominated compounds.
- The most common flame retardant detected was tris(1,3-dichloroisopropyl) phosphate (TDCPP; detection frequency 36%), followed by polybrominated aromatic compounds typically found in the Firemaster550 commercial mixture (detection frequency 17%).

The study revealed that flammability standard[213] in a country can result in high levels of flame retardant in sensitive products with critical exposure to vulnerable groups like infants. Based on exposure estimates conducted by the US Consumer Product Safety Commission, the study predict that infants may receive TDCPP from these products higher than acceptable daily intake levels of TDCPP set by the US Consumer Product Safety Commission (Stapleton et al. 2011)[212]. This highlights that the selection of alternative flame retardants is crucial for the safety of vulnerable groups

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[211] DiGangi J, Strakova J, Watson A (2011) A Survey of PBDEs in Recycled Carpet Padding. Organohalogen Compounds 73, 2067-2070.

[212] Stapleton MH, Klosterhaus S, Keller A, Ferguson PL, van Bergen S, Cooper E, Webster TF, Blum A (2011) Identification of Flame Retardants in Polyurethane Foam Collected from Baby Products. Env. Sci. Technol. 45. 5323-5331.

[213] Baby products containing PUR foam must meet California state furniture flammability standards, which likely affects the use of flame retardants in baby products throughout the U.S and possibly North America.

and that in monitoring studies the alternative flame retardants used should be measured and assessed for their risk and toxic flame retardants excluded from the substitution process.

4.2.2.10 Monitoring of POP-PBDE in children's toys

A Chinese research group assessed the presence of PBDEs and other BFRs in children's toys in South China (Chen et al. 2009)[214]. In all samples PBDE or other BFRs were detected. The median BFR concentrations in the hard plastic toys were notably higher than values in other toys. The PBDE concentrations were below the threshold limit (1000 ppm) required by the European Commission's Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) directives in all of the toys, except for one hard plastic toy with a total PBDE concentration of 5,344 ppm. Several samples made from hard plastic were above POP-PBDE concentrations of 50 ppm, while the major contaminant was DecaBDE responsible for exceedance of RoHS limit for some samples The BFR profiles in the toys were therefore consistent with the patterns of their current production and consumption in China, where PBDEs, specifically DecaBDE, were the dominant BFR, followed by the emerging DBDPE used as alternative for commercial DecaBDE and commercial OctaBDE (Chen et al. 2009)[214].

The study revealed the broad use of recycled WEEE plastic in sensitive use areas like children toys and that recycling of polymers seems uncontrolled and that monitoring of polymers in these sensitive uses for POP-PBDEs and other BFRs are important to control the recycling flow and control exposure.

4.2.2.10 Monitoring of PBDEs/BFRs in thermo cups and selected kitchen utensils

A market survey on black plastic food-contact articles (FCA) was conducted in order to screen for the presence of recycled polymer from waste electric and electronic equipment (WEEE) (Samsonek & Puype 2013)[215]. Thermo cups and selected kitchen utensils where screened with XRF spectrometry to discover bromine-containing samples. In a second step the bromine-positive samples were analysed by thermal desorption GC-MS. A large share of thermo-cups contained brominated compounds. The flame retardants detected contained mainly commercial decabromodiphenyl ether (decaBDE) currently evaluated from the POPs review committee. Also tetrabromobisphenol A (TBBPA), tetrabromobisphenol A bis(2,3-dibromopropyl), ether (TBBPA-BDBPE) and decabromodiphenylethane (DBDPE) were detected. However the samples did not contain POP-PBDEs. The results indicate that polypropylene–polyethylene copolymers (PP-PE) and mainly styrene-based food-

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[214] Chen S-J, Ma Y-J, Wang J, Chen D, Luo X-J, Mai B-X (2009) Brominated Flame Retardants in Children's Toys: Concentration, Composition, and Children's Exposure & Risk Assessment. Environ Sci Technol 43, 4200- 4206.

[215] Samsonek J., Puype F. (2013): Occurrence of brominated flame retardants in black thermo cups and selected kitchen utensils purchased on the European market, Food Additives & Contaminants: Part A, DOI: 10.1080/19440049.2013.829246

contact materials, such as acrylonitrile-butadiene-styrene (ABS) have the highest risk of containing BFRs.

4.3 Alternative assessment approaches for chemical alternatives

While the guidance document from the POPs Review Committee has been specifically developed for the assessment of POPs alternatives, several reports, projects and methodologies for the assessment of chemical alternatives have been developed and are publicly available. These chemical alternative assessment approaches and tools can also support the assessment of the alternatives to POPs chemicals and help to ensure that alternatives are not other POPs or POPs-like chemical.
Some of the most helpful materials and approaches are compiled in this section.

4.3.1 Common Principles of Alternatives Assessment

Assessing the relative hazard of alternatives to chemicals of concern has become an increasingly powerful and robust approach to implementing changes to promote safer chemicals and materials that are technically and economically feasible. The Toxics Use Reduction Institute (TURI) is a leading organization promoting this approach and has conducted a number of formal alternatives assessments[216]. According to TURI, an alternatives assessment looks comprehensively at the uses of chemicals of concern, and the availability of safer, technically feasible and affordable alternatives. These alternatives may include chemical substitutions, process modifications, product redesigns, or other changes that facilitate the shift to safer processes and products.

TURI has contributed to the development of a harmonized set of principles for alternatives assessment methodology. The Commons Principles of Alternatives Assessment, designed to guide any alternatives assessment project. The Commons Principles are:

- Reduce Hazard;
- Minimize Exposure;
- Use Best Available Information;
- Require Disclosure and Transparency;
- Resolve Trade-Offs;
- Take Action;

Useful resources for information related to hazard assessment and reduction include:
A) Available screening methods for more quickly identifying preferable chemicals:

- Clean Production Action's GreenScreen for Safer Chemicals.
- EPA's Design for the Environment process - DfE Screens for Safer Chemicals Ingredients.

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[216] Formal alternative assessments were conducted for perchloroethylene for dry cleaning and for 5 other selected chemicals.

- Cradle to cradle guidelines.
- Swedish KemI PRIO model - The criteria for the “PRIO substances” have been selected based on the Swedish Environmental Quality Objective for a Non-Toxic Environment (Government Bill 2000/01:652), and in consideration of the EU chemicals legislation REACH (Registration, Evaluation and Authorisation of Chemicals).
- German Institute for Occupational Safety Column Model - The Institute (IFA) has developed the Column Model to provide industry with a practical aid for the identification of possible substitutes. The model uses risk-phrases to quickly characterize the "employee risk" associated with a chemical being assessed.
- Healthy Building Network Pharos Project - a tool to evaluate building materials.
- Pollution Prevention Options Assessment System (P2OASys), created and maintained by TURI, guides users in assessing key criteria, from EH&S data to process performance and occupational safety issues.

B) Methods for displaying data to facilitate decision making on alternatives:

- EPA's Design for the Environment process. The DfE program released "Alternatives Assessment Criteria for Hazard Evaluation" in November 2010. This guidance goes through the step-by-step process that DfE is using in conducting alternatives assessments for chemicals as part of the EPA's Chemical Action Plans.
- TURI's method for assessing alternatives, including their 2006 review of five chemicals of concern in Massachusetts and their 2012 review of alternatives to perchloroethylene in dry cleaning applications. TURI’s method presents distinguishing criteria for all alternatives as well as the chemical of concern, to facilitate informed substitution choices.

4.3.1.1 Case study: The Massachusetts Toxics Use Reduction Act (TURA)

Under the Massachusetts Toxics Use Reduction Act (TURA), companies that use toxic chemicals above a specified threshold are required to report on their use of the chemical each year and conduct Toxics Use Reduction Planning every two years. The law is designed as a complement to other environmental and occupational safety laws. It is intended to encourage companies to reduce toxics as a means to comply with other laws, and to reduce total use of toxic chemicals while enhancing company performance.[217]

A Toxic Use Reduction Plan must establish two- and five-year goals for by-product reduction of listed chemicals used in that facility/company. Plan documents are

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[217] Massey RI, Tenney H, Harriman E (2011) “Higher Hazard Substances Under the Massachusetts Toxics Use Reduction Act: Lessons from the First Four Years.” *New Solutions* 21:3, 457-476.

maintained at the facility, and a plan summary is submitted to the State. Plans may be inspected by a governmental official on request. Plans are formally updated every two years, including an assessment of the implementation schedule and Toxic Use Reduction commitments.

In the Toxics Use Reduction Planning process, companies are required to identify opportunities for reducing or eliminating the chemical of concern; analyze any hazards of alternatives they identify; and conduct a technical and economic feasibility analysis. Based on the results of this required analysis, companies choose which options to implement.

Use reporting includes total amount of the chemical manufactured, processed, or otherwise used; amount generated as byproduct; and amount "shipped in product" (included in the final product), as well as information on waste emitted or transferred offsite. The requirement to track the amount generated as by-product helps to highlight inefficiencies in industrial processes and can motivate businesses to improve production processes. The requirement to track the amount shipped in product makes it possible to determine what chemicals are incorporated into a final product or article. All this information is made available to the public, except in cases in which the Massachusetts Department of Environmental Protection grants a company a trade secret exemption.

Over the first ten years of TURA, from 1990 to 2000, companies subject to the law reduced their use of toxic chemicals by 40%, by-product by 58%, and emissions by 90%. From 2000 to 2012, companies continued to make progress, reducing use by 23%, by-product by 42%, and emissions by 73%. These reductions were achieved largely by adopting more efficient manufacturing methods that in turn saved the firms money.

A survey of companies subject to TURA found that 51% experienced improved worker health and safety; 41% achieved financial savings; 33% achieved improved compliance with other state or federal regulations; 29% achieved improvements in production efficiency; and 21% achieved improved product marketing.[218]

The Toxics Use Reduction Act defines several activities that can qualify as toxics use reduction. These include: input substitution, product reformulation, production unit redesign and modification, production unit modernization, improved operations and maintenance, and "integral recycling" (re-use of a material that occurs strictly within a single, hard-piped production process). In any case in which a company considers substituting one chemical for another, the TURA process requires a thorough evaluation of the environmental health and safety characteristics of the alternative.

The development of a common set of principles for alternatives assessment by the Toxics Use Reduction Institute and other institutions has contributed to this reduction by facilitating the introduction of safer alternatives.

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[218] Massey RI (2011) Program assessment at the 20 year mark: experiences of Massachusetts companies and communities with the Toxics Use Reduction Act (TURA) program. Journal of Cleaner Production 19, 2012, 505-516.

4.3.2 Lowell Center for Sustainable Production Alternative Assessment framework

The Lowell Center for Sustainable Production has developed its Alternatives Assessment framework with the goal of creating an open source framework for the relatively quick assessment of safer and more socially just alternatives to chemicals, materials, and products of concern and guidance have been developed. Within their activities they have assessed alternatives for HCBD.

4.3.3 EPA's Design for the Environment process.

The EPA's Design for the Environment (DfE) program is using a step-by-step process for conducting alternative assessment for enabling substitution to safer chemicals[219]. The "Alternatives Assessment Criteria for Hazard Evaluation" guidance goes through the step-by-step process that DfE is using in conducting alternatives assessments for chemicals as part of the EPA's Chemical Action Plans.

Practical example of EPA's Design for the Environment (DfE) program related to POPs are the US EPA approach for use of alternatives in Printed Circuit Boards and assessment of alternatives to c-PentaBDE in PUR foam (***3.3.3 Case study: Assessment of alternatives to c-PentaBDE in PUR foam***).

4.3.3.1 Case study: US EPA approach for use of alternatives in Printed Circuit Boards[220]

C-PentaBDE and HBCD have been used to a smaller extent in printed circuit boards. Within the USEPA program on "Design for the Environment" the electronics industry formed a partnership to develop information that will improve their understanding of the environmental and human health impacts of new and current materials that can be used to meet the fire safety requirements for circuit boards (US EPA 2008). One aim of the work was that the information from the partnership will allow industry to consider these impacts along with cost and performance of circuit boards as they review alternative materials and technologies. Participation of all interest groups was aimed at ensuring that the full range of views was considered from the start of the project and that they were incorporated appropriately into the project objective and methodology.

The partnership incorporated life cycle thinking into the project as it explored the potential hazards associated with flame retardants and potential exposures throughout the life cycle of flame retardants as used in FR-4 printed circuit boards. The scope included aspects of the life cycle where public and occupational exposures could

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[219] Lavoie ET; Heine LG; Holder H; Rossi MS; Lee REI; Connor EA; Vrabel MA; DiFiore DM; Davies CL (2010) Chemical Alternatives Assessment: Enabling Substitution to Safer Chemicals. Environmental Science & Technology 45, 1747-1747.

[220] US EPA (2008) Partnership to evaluate flame retardants in printed circuit boards. Draft November 2008. (The text is largely taken from project website)

occur. For example, consideration of exposures from incineration or burning at end-of-life was included, as were exposures from manufacturing and use.

The initial hazard assessment was conducted using EPA's criteria for the New Chemicals Program under the Toxic Substances Control Act (TSCA) to evaluate hazard concerns for each flame retardant formulation. The analysis explored hazard data associated with potential exposure scenarios. The partnership did not conduct a full risk assessment. The project is not a life cycle assessment, which inventories inputs and outputs from all (or most) processes throughout the life cycle and evaluates the environmental impacts associated with those inputs and outputs.

This partnership report provides objective information that will help members of the electronics industry more efficiently factor human health and environmental considerations into their decision-making when selecting flame retardants for printed circuit board applications (US EPA 2008)[220]

4.3.4 GreenScreen approach[221]

Regulatory actions such as chemical or material restrictions can drive the need for alternatives assessment and the use of chemical hazard assessment methods such as the GreenScreen™ for Safer Chemicals. GreenScreen is a method for comparative Chemical Hazard Assessment (CHA) that can be used for identifying chemicals of high concern and safer alternatives. It is being used by industry, governments and NGOs as part of alternatives assessment to meet regulatory requirements and to support product design and development and materials procurement.

The GreenScreen™ can also be used to support environmentally preferable product procurement tools including standards, scorecards and ecolabels. It can be used to:

a) Help prioritize chemicals for further review and/or phase out;
b) Help companies identify safer alternative chemicals for use in formulations;
c) Meet client specifications for eliminating chemicals of high concern;
d) Support chemical management through environmental management systems;
e) Support corporate reporting on chemical uses;
f) Communicate materials goals and criteria to suppliers;
g) Serve as a resource for pollution prevention and technical assistance programs;
h) Guide internal product development processes.

To apply the GreenScreen for safer chemical alternatives, chemicals in products are screened against 18 human and environmental health hazard endpoints in order to identify any substance of very high concern and to differentiate among safer alternatives.

Four benchmark scores, ranging from 1-4, are possible in the GS method, with benchmark 4 representing the lowest hazard to humans or the environment. It is also possible for a chemical to receive an "unspecified (U)" Benchmark.

Both the GreenScreen hazard criteria and benchmarking system were developed to align with national and international precedents including the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), OECD testing protocols

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[221] Text has mainly taken from the Greenscreen™ webpage http://www.greenscreenchemicals.org/

and the European REACH legislation, while also ensuring that new and emerging science can be incorporated into the hazard assessment process.

4.3.5 SUBSPORT – internet portal on safer alternatives

The goal of the Substitution Portal (SUBSPORT) project is to develop an internet portal (http://subsport.eu) that constitutes a state-of-the-art resource on safer alternatives to the use of hazardous chemicals including POPs. It is a source of not just information on alternative substances and technologies, but also of tools and guidance for substance evaluation and substitution management.

A range of case studies related to POPs (POP-PBDE, PFOS and HBCD) are included and can be retrieved on the web-page. Some key case studies (e.g. on HBCD) are also mentioned and linked in this publication in the paragraphs of the related POPs.

The SUBSPORT web-site also refers to key POPRC documents related to substitution of POPs. The webpage is continuously updated.

At the European Union level a consortium comprising of Kooperationsstelle Hamburg IFE GmbH (KOOP), "Instituto Sindical de Trabajo Ambiente y Salud" (ISTAS), Madrid, International Chemical Secretariat (ChemSec), Gothenburg and Grontmij A/S, Copenhagen implemented for a 3 years period (Jan 2010 – March 2013) the SUBSPORT project[222], with financial support from the LIFE+ Programme of the European Union, Federal Institute for Occupational Safety and Health, Germany and Federal Ministry of Agriculture, Forestry, Environment and Water Management, Austria. The goal of the SUBSPORT project is to develop an internet portal that constitutes a state-of-the-art resource on safer alternatives to the use of hazardous chemicals. It should be a source of not just information on alternative substances and technologies, but also of tools and guidance for substance evaluation and substitution management.

The portal is intended to support companies in fulfilling substitution requirements of EU legislation, such as those specified under the REACH authorisation procedure, the Water Framework Directive or the Chemical Agents Directive. Furthermore other stakeholders like authorities, environmental and consumer organisations as well as scientific institutions will benefit from the portal. The internet portal SUBSPORT makes publicly available in four languages the information on:

- a structured presentation of legal information on substitution throughout the European Union and, in part, on an international and national level;
- a database of hazardous substances that are legally or voluntarily restricted or subjects of public debates;
- a compilation of prevalent criteria for the identification of hazardous substances;
- a description of existing substitution tools to compare and assess alternative substances and technologies;

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[222] SUBSPORT project webpage: http://www.subsport.eu/.

- a database comprising case stories from companies and literatures with general information on alternatives to the use of hazardous substances and detailed alternative assessment reports for 10 substances or substance groups of high concern each including up to 5 essential applications;
- concepts and materials for substitution training programmes;
- interactive elements for discussion, networking, exchange of information and experience as well as for portal updates.

In addition, the project created a network of experts and stakeholders who are active in substitution. The network assisted in content development and promotion of the portal as well as ensuring sustainable updates and maintenance. This contributed to the project's goal of raising awareness and promoting safer alternatives. Furthermore, training on substitution methodology and alternatives assessment was provided.

4.4 Screening of potential POPs in chemical databases

Research groups assessed in available chemical databases with different POPs assessment tools the chemicals for their POPs and likely-POPs properties.

4.4.1 Assessment of potential POPs chemicals with Annex D criteria

Scheringer et al. (2012)[223] assessed a set of 93,144 organic chemicals for their potential POPs properties. The chemicals were selected from a dataset of approximately 122,000 chemicals for which correct CAS numbers and unique SMILES codes were available. From these approximately 20,000 inorganic and metal organic substances and salts were removed because the chosen property estimation method could not be applied to these substances. Also another 10,000 organic substances were removed because they were outside the applicability domains of the property estimation methods. In addition several 100 individual congeners of PCBs, PCNs, PCDD/PCDF and PBDE were merged to single homologues (Scheringer et al. 2012)[223].

For the screening and assessment process for persistence, bioaccumulation and long-range transport potential the criteria defined in Annex D of the Stockholm Convention were applied. As toxicity threshold the threshold of REACH, the chemicals regulation of the European Union, were used because no toxicity threshold is currently defined under the Stockholm Convention.

To identify potential POPs, two groups of chemicals were defined, one "POP group" consisting of chemicals that exceed a biodegradation half-life in water of 60 days, a BCF or BAF of 5000, a half-life for reaction with OH radicals in air of 2 days, and have toxic effect concentrations below 0.1 mg/L (acute) or 0.01 mg/L (chronic), and a second group ("very-POP") defined by a biodegradation half-life in water exceeding

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[223] Scheringer M, Strempel S, Hukari S, Ng CA, Blepp M, Hungerbuhler K (2012), How many persistent organic pollutants should we expect, Atmospheric Pollution Research 3 (2012) 383-391, http://www.atmospolres.com/articles/Volume3/issue4/APR-12-045.pdf.

180 days, a BCF or BAF exceeding 20,000, and a half-life in air exceeding 10 days; the toxicity thresholds are the same as in the POP group[223].

The outcome of the screening revealed that 510 chemicals exceeded all four criteria and can be considered potential POPs. Ninety-eight percent of these chemicals are halogenated; frequent types of chemicals are halogenated aromatic compounds, including polychlorinated diphenylethers, tetrachloro benzyltoluenes, brominated and fluorinated naphthalenes and biphenyls; and highly or fully chlorinated and fluorinated alkanes (cyclic, linear, branched). Non-halogenated substances are highly branched alkanes and nitroaromatic compounds. Ten substances are high-production volume chemicals and 249 are pre-registered in the EU. The group used also uncertainty ranges of the chemical property data to estimate a lower and upper bound of the number of potential POPs; these bounds range from 190 to 1200 chemicals.

4.4.2 Assessment of potential POPs chemicals in commerce and degradation products

Researchers from Environment Canada assessed a large range of chemical within chemical databases for "Identifying New Persistent and Bioaccumulative Organics Among Chemicals in Commerce" (Howard & Muir 2011)[224]. The goal of this study was to identify commercial chemicals that might be persistent and bioaccumulative (P&B) and that were not being considered in current Great Lakes, North American, and Arctic contaminant measurement programs. The researchers combined the Canadian Domestic Substance List (DSL), a list of 3059 substances of "unknown or variable composition complex reaction products and biological materials" (UVCBs), and the U.S. Environmental Protection Agency (U.S. EPA) Toxic Substances Control Act (TSCA) Inventory Update Rule (IUR) database for years 1986, 1990, 1994, 1998, 2002, and 2006 yielding a database of 22263 commercial chemicals. From that list, 610 chemicals were identified by estimates from U.S EPA EPI Suite software and using expert judgment. This study has yielded some interesting and probable P&B chemicals that should be considered for further study.

Studies, following up the initial reports on this assessment work, have confirmed the presence of many of the chemicals identified in the environment.

In a second study on "Identifying New Persistent and Bioaccumulative Organics Among Chemicals in Commerce III: By-products, Impurities, and Transformation Products[225]" the researcher focus on chemicals that are not on commercial chemical lists such as U.S. EPA's Inventory Update Rule but may be found as by-products or impurities in commercial chemicals or are likely transformation products from commercial chemical use. The study evaluated the 610 chemicals from an earlier publication as well as high production volume chemicals and identified 320 chemicals

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[224] Howard PH, Muir DC (2013) Identifying new persistent and bioaccumulative organics among chemicals in commerce. III: by-products, impurities, and transformation products. Environ Sci Technol. 47, 5259-5266.

[225] Howard PH, Muir D (2013) Identifying new persistent and bioaccumulative organics among chemicals in commerce. III: by-products, impurities, and transformation products. Environ Sci Technol. 47(10):5259-5266.

(39 by-products and impurities, and 281 transformation products) that could be potential PB chemicals. Four examples were discussed in detail; including information on the commercial synthesis and by-products and impurities that might be found in the commercial product. Unfortunately for many of the 610 chemicals, as well as the transformation products, little or no information was available. Use of computer-aided software to predict the transformation pathways in combination with the biodegradation rules of thumb and some basic organic chemistry has allowed 281 potential PB transformation products to be suggested for some of the 610 commercial chemicals; more PB transformation products were not selected since microbial degradation often results in less persistent and less bioaccumulative metabolites[225].

4.5 Tools for the assessment of POPs properties of chemicals

4.5.1 US EPA PBT Profiler[226]

The PBT Profiler (http://www.pbtprofiler.net/) was designed to be an easy to use, widely available, no-cost tool to screen chemicals lacking experimental data in order to help identify pollution prevention (P2) opportunities. It is a continuation of the Office of Chemical Safety and Pollution Prevention (OCSPP, U.S. Environmental Protection Agency) Pollution Prevention (P2) Assessment Framework - a collection of screening models and methods to help promote the design, development, and application of safer chemicals and processes. The methodology the PBT Profiler uses has been developed by government, academic, and private-sector researchers over the past 20 years and represents some of the best techniques currently available. The P2 Framework uses computerized methods, such as structure/activity relationships (SARs) and standard scenarios, to predict risk related data (physical/chemical properties, bioconcentration, environmental fate, carcinogenicity, toxicity to aquatic organisms, worker and general population exposure, and other information) on chemicals lacking experimental data.

Purpose. The PBT Profiler uses a subset of P2 Assessment Framework computer-based tools to help identify chemicals that potentially may persist, bioaccumulate, and be toxic to aquatic life, i.e., PBT chemicals. The release of even small amounts of persistent, bioaccumulative, and toxic chemicals to the environment is of concern because they can accumulate over time to higher concentrations and, therefore, have a higher potential to adversely impact human health and the environment. The overwhelming majority of known chemical substances do not have experimental persistence, bioaccumulation, and toxicity data available. Only a small fraction of chemicals currently in commerce, including the 2,000 new chemicals introduced each year, have sufficient data available to perform a thorough evaluation of potential risks. The PBT Profiler was designed to help interested parties voluntarily screen chemicals for persistence, bioaccumulation, and aquatic toxicity characteristics when no experimental data are available.

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[226] Text is largely taken from the PBT profiler Website (http://www.pbtprofiler.net/)

Limitations. It is important to stress that the PBT Profiler is a screening level predictive tool and cannot be used for all chemical substances. Nevertheless, the PBT Profiler is a tool that, like all tools, has strengths, weaknesses, and limitations. These limitations should be considered before using this model. For example, predicted data should never be used in place of experimental data. Additional model limitations are described on this web site. When properly applied, the PBT Profiler can provide a straight-forward estimate of persistence, bioaccumulation, and aquatic toxicity based on widely accepted criteria. This information can help interested parties to identify pollution prevention initiatives and aid in their chemical selection processes.

Advantages. Many chemicals can be profiled in one on-line session. The PBT Profiler provides three integrated levels of output for each chemical including (1) easy to read color-coded comparisons of predicted values to PBT criteria; (2) predicted values for P, B, and T; and (3) narrative descriptions of pollution prevention considerations for each chemical. For rapid recognition of the estimated results, the "P", "B", and "T" designators (corresponding to persistence, bioaccumulation, and toxicity, respectively) are shaded orange or red if a chemical exceeds the defined thresholds for each criteria; if the thresholds are not exceeded, the designators are shaded green. Numeric estimates in a tabular format are also provided for persistence (in air, water, soil, and sediment), bioaccumulation, and toxicity. To put these results in perspective, pollution prevention considerations for each chemical profiled are also provided in narrative available by clicking on the “P2 Considerations” link on the Results page. More information on interpreting the PBT Profiler estimates is available on the PBT web site.

A case study on the assessment of alternatives to a POP (PFOS related substance as pesticide) using the PBT profiler can be found in 4.5.2.

4.5.2 Case study: Use of PBT Profiler for assessing sulfluramide alternative pesticides

The Stockholm Convention Regional Centre for Capacity-building and the Transfer of Technology in Asia and the Pacific at Tsinghua University (Beijing/China) has assessed alternative pesticides to sulfluramide using the PBT profiler.

Background

Sulfluramid (N-ethyl perfluorooctane sulphonamide, CAS No.: 4151-50-2) is a perfluorinated active ingredient (AI) in insecticides commonly used to control the insects with highly social behaviour patterns, such as termite[227], red fire ant[228], and

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[227] Su NY, Scheffrahn RH, Ban PM (1995) Effects of sulfluramid-treated bait blocks on field colonies of the Formosan subterranean termite (*Isoptera: Rhinotermitidae*). J Econ Entomol 88: 1343-1348.

[228] Banks WA, Las AS, Adams CT, Lofgren CS (1992) Comparison of several sulfluramid bait formulations for control of the red imported fire ant (Hymenoptera, Formicidae). J Entomol Sci 27(1): 50-55.

cockroach[229]. These insecticides use sulfluramid at a certain concentration (e.g. 3 g/kg), mixed with citric fruit pulps and soybean oil. The mixture of these materials is extruded to form pellets of the insecticide, which are usually called baits[230]. Since 1990s, sulfluramid has been adopted as AI in some commercial bait products, e.g. FirstLine® termite defense system from FMC Corporation[231], Mirex-S bait from Aracruz Celulose S.A. Company, Brazil[232].

China is still producing and using sulfluramid now, about 4-8 t/y of PFOSF was used to formulate in sulfluramid manufacture according to the survey in 2008[233]. Currently there are five sulfluramid containing pesticide products from two producers legally registered in China. These products are mainly for the control of termite and cockroach. Among them, Yekang bait for cockroach control has been successfully recommended by the organization committee of both Beijing 2008 Olympic Games and Shanghai Expo2010 China, with the annual sale of about 5 million USD. On August 30, 2013, China's Standing Committee of the National Congress ratified the amendments to Annexes A, B and C to the Stockholm Convention to list nine new persistent organic pollutants, including perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride. Chinese Government submitted the ratification to the Depositary of the Stockholm Convention on December 26, 2013, and the amendments entered into force for China from March 26, 2014. A 12-ministry joint announcement was issued on March 25, 2014. There are 7 acceptable purposes and 6 specific exemptions out of Annex B for PFOS that have been verified and registered at the Secretariat of the Stockholm Convention by the Chinese Government. However the pest control using sulfluramid has not been registered. Therefore as a Party to the Convention, China has to find cost-effective and environmentally sound alternatives to replace the sulfluramid as soon as possible.

Alternatives on the Chinese market

There are many competitive insecticide products on the Chinese market; however their environment related properties have not been reviewed comprehensively. Therefore in a research study conducted at the Stockholm and Basel Convention Coordination Center at Tsinghua University (Beijing/China), the sulfluramid substitutes contained in registered bait products available in Chinese market were reviewed. A preliminary assessment on their PBT (i.e. persistence, bioaccumulation and toxicity) profiles was conducted using a screening-level tool (PBT profiler)

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[229] Appel AG, Abd-Elghafar SF (1990) Toxicity, sublethal effects, and performance of sulfluramid against the German cockroach (*Dictyoptera: Blattellidae*). J Econ Entomol 83(4): 1409-1414.

[230] Bergamasco RC, Zanin GM, Moraes FF (2005) Sulfluramid Volatility Reduction by -Cyclodextrin. J Agric Food Chem 53, 1139-1143.

[231] Grace J K, Yamamoto R T, Tome CHM (2000) Toxicity of sulfluramid to Coptotermes formosanus (Isoptera : Rhinotermitidae). Sociobiol 35(3): 457-466.

[232] Machado-Neto JG, Queiroz MEC, Carvalho D, Bassini AJ. Risk of intoxication with sulfluramid in a packing plant of Mirex-S. Bull Environ Contam Toxicol. 1999 May;62(5): 515-519.

[233] Zhang L, Liu J, Hu J, Liu C, Guo W, Wang Q, Wang H (2012) The inventory of sources, environmental releases and risk assessment for perfluorooctane sulfonate in China. Environ Pollut 165: 193-198.

developed by the Environmental Health Analysis Center under contract to the Office of Chemical Safety and Pollution Prevention, U.S. Environmental Protection Agency. Also the WHO recommended classification of pesticides by hazard was used for comparison.

Review of existing sulfluramid substitutes

According to China's Regulation on Pesticide Administration (RPA), all pesticide products should be registered before their production and sale in the Chinese market. There's an official database of registered pesticide products in China, which is maintained by the Institute for Control of Agrichemicals at the Ministry of Agriculture (ICAMA). This database can be accessed via internet (http://www.chinapesticide.gov.cn/, in Chinese). Defining the search keywords as "bait" for "formulation", "termite" and "cockroach" for "target pest species", all records of registered bait products for termite and cockroach control can be obtained.

According to the database search results, there are 3 bait products for termite control using 2 AIs other than sulfluramid registered in China; also there are 133 bait products for cockroach control using 20 AIs other than sulfluramid registered in China (including 1 inorganic chemical, 16 organic chemicals, 3 biogenic substances).

Assessment of persistence, bioaccumulation and toxicity of the alternatives

The assessment of persistence, bioaccumulation and toxicity was conducted using the PBT Profiler (http://www.pbtprofiler.net/, Version 2.000, last updated September 4, 2012) developed by U.S. EPA, which is a screening-level tool that provides estimates of the persistence, bioaccumulation, and chronic fish toxicity potential of chemical compounds. The PBT Profiler employs methodologies that calculate or otherwise estimate PBT characteristics based on an analysis of chemical structure. According to EPA, PBT estimations rendered by the PBT Profiler are not sufficient for definitive PBT determinations. The PBT Profiler is rather a research, not regulatory, tool to identify chemicals that may need further evaluation for potential Persistence, Bioaccumulation and Toxicity characteristics (http://www.pbtprofiler.net/notice.asp).

Considering the principle of the PBT profiler, inorganic AI (boric acid) and biogenic AIs (i.e. emamectin benzoate, metarhizium anisopliae, periplaneta fuliginosa desovirus (PfDNV)) were excluded in the assessment. The results for the other 16 AIs obtained from PBT profiler are summarized in table 22.

Both persistence and toxicity of all AIs are labeled as either Orange or Red, which mean moderate or high concern (for toxicity) and persistent or very persistent (for persistence). However, most AIs are of low overall PBT concern since they belong to the category of "not bioaccumulative" (Green) (table 22). Only three organofluorine AIs (i.e. flufiprole, hexaflumuron and chlorfluazuron) are classified into the category of "considered bioaccumulative" (Orange) (table 22). Therefore the PBT profiles of these three AIs are very similar with that of sulfluramid, as they have the same colors: red for persistence and toxicity and orange for bioaccumulation. Therefore according to the PBT profiler it is necessary to further investigate the safety of these AIs.

Table 23. Classification and criteria used by PBT Profiler and the WHO hazard classification

No.	Name	Half-life (d)			Percent in Each Medium (%)			BCF	Fish ChV (mg/L)	PBT	WHO Classification*
		Water	Soil	Sediment	Water	Soil	Sediment				
	Sulfluramid	180	360	1,600	2	7	90	2,300	0.0018	**PBT**	II
1	Acephate	38	75	340	35	65	0	3.2	0.021	**PBT**	II
2	Imidacloprid	60	120	540	9	90	1	3.2	5.2	**PBT**	II
3	Propoxur	38	75	340	20	79	0	4.7	0.65	**PBT**	II
4	Fipronil	180	360	1,600	5	92	3	200	0.00016	**PBT**	II
5	Chlorpyrifos	180	360	1,600	6	89	5	870	0.011	**PBT**	II
6	Hydramethylnon	180	360	1,600	1	40	59	16	0.000175	**PBT**	II
7	Fenitrothion	38	75	340	18	81	1	70	0.11	**PBT**	II
8	Chlorbenzuron	60	120	540	10	90	1	420	0.012	**PBT**	III
9	Tetramethrin	38	75	340	18	81	1	34	0.00011	**PBT**	U
10	Permethrin	60	120	540	6	55	40	500	0.0000096	**PBT**	II
11	Cypermethrin	180	360	1,600	3	74	23	970	0.000057	**PBT**	II
12	Deltamethrin	60	120	540	6	62	32	320	0.000086	**PBT**	II
13	Azamethiphos	60	120	540	37	63	0	2.3	0.021	**PBT**	II
14	Flufiprole	180	360	1,600	4	95	1	2,200	0.000294	**PBT**	NA
15	Hexaflumuron	180	360	1,600	5	92	3	2,600	0.004	**PBT**	U
16	Chlorfluazuron	180	360	1,600	2	66	31	3,100	0.003	**PBT**	U

* Note: II = Moderately hazardous; III = slightly hazardous; U = Unlikely to present acute hazard in normal use; NA = Not available

Further discussion about the hazard of pesticide AIs in us

According to the WHO recommended classification of pesticides by hazard (WHO 2010)[234], most of the alternative AIs are classified as "II" (i.e. moderately hazardous), as shown in the table above. As the exception, three AIs are of "U" (i.e. unlikely to present acute hazard in normal use), including chlorfluazuron, hexaflumuron and tetramethrin; also chlorbenzuron is classified as "III" (i.e. slightly hazardous). Compared with sulfluramid which is also classified as "II", the existing AIs seem to be at the same level or lower level in terms of hazard.

One AI (flufiprole) is labelled as "NA" (Table 22) since this AI is China-specific and rarely used in other countries and therefore not covered by the WHO guideline. Flufiprole was developed by Dalian Raiser Pesticides Co., Ltd in 2002 (Patent No. PCT/CN03/00343) is a new fipronil derivative[235]. The 0.2% flufiprole-based bait product for cockroach control obtained its full registration in 2013 (Certificate No.: WP20130225), which was labelled as "slightly toxic". It has been well accepted due to its low toxicity to fish, shrimp and crabs[236]. The acute toxicity of technical material of flufiprole for male/female rat is as below: LD50>=4640 mg/kg (oral), LD50>=2150 mg/kg (dermal)[237].

Conclusion

In the present study, the existing baits for termite and cockroach in Chinese market were reviewed by searching the official Chinese database of registered pesticides. Twenty AIs have been identified in totally 136 registered bait products, among which 16 chemogenic organic AIs were further assessed for their persistence, bioaccumulation and toxicity using the U.S.EPA's online software - PBT profiler. Also the WHO recommended classification of pesticides by hazard was used for comparison.

Combining the PBT profiles and classification by hazard, the existing AIs seem to be better in terms of environmentally soundness. The results from this preliminary assessment confirmed that none of sulfluramid AIs adopted by currently registered bait products for termite and cockroach belong to the POPs group. However, that it is necessity to further evaluation the PBT quality of the used organofluorine. Overall the applicability of the U.S. EPA PBT profiler as a useful screening tool has been illustrated.

4.5.3 OECD assessment of overall environmental persistence and long range transport

OECD provides the so called "OECD *P*OV and LRTP Screening Tool" whose purpose is to estimate overall environmental persistence (*P*OV) and long-range transport potential (LRTP) of organic chemicals at a screening level, and to provide context for making comparative assessments of environmental hazard properties of different chemicals. The Tool requires estimated degradation half-lives in soil, water and air, and partition coefficients between air and water and between octanol and water as chemical specific input parameters. From these

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[234] WHO (2010) The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009.

[235] Jiang D, Zheng X, Shao G, Ling Z, Xu H (2014) Discovery of a novel series of phenyl pyrazole inner salts based on fipronil as potential dual-target insecticides. J Agric Food Chem 62: 3577-3583.

[236] Han SY (2013) New agrochemicals invented in China in recent years. ARGROW World Crop Protection News (660): V-IX.

[237] Li YL (2014) A novel insecticide flufiprole. Agrochemicals 53(2): 126-128 (in Chinese).

inputs The Tool calculates metrics of *P*OV and LRTP from a multimedia chemical fate model, and provides a graphical presentation of the results.

The tool is accompanied by a description manual, which includes 3 sections. Section 1 is an introduction to ‘The Tool’ software, instructions for performing different types of calculations and for customizing the presentation of results. Section 2 provides guidance for interpreting results from ‘The Tool’, including definitions of the *P*OV and LRTP metrics. Section 3 presents a brief history of ‘The Tool’ that describes its development and relationship to other multimedia chemical fate models.

4.6 Toxicity assessment of alternatives

The assessment of the toxicity of the alternatives is a crucial, but complex, factor for the appropriate selection of alternatives. Currently the Stockholm Convention does not have a specific benchmark for assessment of toxicity (Scheringer et al. 2012)[223].

Furthermore many of the alternatives to POPs are either protected by commercial confidentiality regimes and not identified by a CAS number, and/or do not have available toxicological data as has been discovered in the assessment of PFOS alternatives (POPRC Draft report on PFOS alternatives).

Therefore, case studies where a comprehensive assessment has been made or has been compiled are highly desirable for further progress in the assessment of alternatives.

4.6.1 Case study: compilation of toxicity assessment information of non-halogenated flame retardants

For the selection of appropriate alternative to the listed brominated flame retardants PBDEs, PBB or HBCD (POP-BFRs) and assessment of the alternative flame retardants needs to be compiled and gaps of information be highlighted and further studied to close these gaps.

A review on the “Persistence, Bioaccumulation, and Toxicity of Halogen-Free Flame Retardants” has been performed including an inventory of the available data that exists (up to September 2011) on the physical–chemical properties, production volumes, persistence, bioaccumulation, and toxicity (PBT) of a selection of HFFRs that are potential replacements for POP-BFRs in polymers (Waaijers et al. 2013)[238].

Data gaps were identified for the physical–chemical and the PBT properties of the reviewed HFFRs. The review concluded that APP, Mg(OH) 2, ZHS, and ZS are to be the most promising among alternative HFFRs. To assess whether the presently reviewed HFFRs are truly suitable alternatives, each compound should be examined individually by comparing its PBT values with those of the relevant halogenated flame retardant. Until more data are available, it remains impossible to accurately evaluate the risk of each of these compounds, including those which are already extensively marketed.

4.6.2 Life Cycle thinking approach for assessing alternatives

The challenge of managing PBDE in the recycling and end of life phase and also, PCB from closed and open applications, are highlighting the need of Life Cycle Thinking when using a

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[238] Waaijers et al., (2013) Persistence, bioaccumulation, and toxicity of halogen-free flame retardants Rev Environ Contam Toxicol. 222, 1-71.

chemical in articles, products or technical processes considering the entire life cycle. Life cycle management (‘LCM’) has been defined as an integrated concept for managing the total life cycle of goods and services towards more sustainable production and consumption, building on the existing procedural and analytical environmental assessment tools and integrating economic, social and environmental aspects and has together with Life Cycle Assessment (LCA) been listed in the Stockholm Convention BAT/BEP guidance as Guidance principles and cross-cutting considerations (Stockholm Convention 2007). It normally involves a cradle to grave approach although other system boundaries can be defined in specific cases. Considering that decision have to be made on the recycling of large POP-PBDE containing material flows, LCA and LCM for these flows have to be considered for appropriate science based decisions for their management (Secretariat Stockholm Convention 2012). For a comprehensive assessment of alternative chemicals to POPs finally also LCA and LCM approaches are needed to select the most appropriate and most sustainable alternative considering the entire life cycle: production, use and end of life phase including recycling of articles containing the chemical and their behaviour in different destruction or disposal scenarios.

Life Cycle Assessment (LCA) is a comprehensive technique that quantifies ecological and human health impacts of a product or system over its complete life cycle (UNEP 2011, European Commission JRC 2010). While the main applications of LCA include the analysis of the origins of problems related to a particular article; the comparison of improvement variants of a given article; the design of new articles; and the choice between existing comparable products and chemicals it can also be applied for comparing recycling and end-of-life scenarios.

Some projects on POPs alternatives have already included Life Cycle Assessment or Life Cycle Management approaches.

4.6.2.1 Chemical footprint[239] development

According to recent definitions, a “footprint” is a quantitative measure of the appropriation of natural resources by humans (Hoekstra 2008)[240] and may be used to describe how human activities impose different types of burdens on the environment and thus impact the global sustainability (UNEP/SETAC 2009)[241].

A recent review article presented and discussed the need and relevance of developing a methodology for assessing the chemical footprint, coupling a life cycle-based approach with methodologies developed in other contexts, such as environmental risk assessment and sustainability science. Two different approaches and steps to chemical footprint were envisaged, applicable at the micro‐ as well as at the meso‐ and macro-scale:

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[239] “Chemical Footprint" has also been used to defined the total mass of chemicals of high concern (CoHCs) in products sold by a company and used in its manufacturing operations. If it's not possible to determine the total mass of CoHCs, a company may be able to report on the number of CoHCs that are in the products it sells and are used in its manufacturing operations. http://www.cleanproduction.org/chemical-footprint.

[240] Hoekstra AY. 2008. Water neutral: Reducing and offsetting the impacts of water footprints. Value of Water Research Report Series No. 28. Delft, the Netherlands: UNESCO‐IHE.

[241] UNEP/SETAC (2009) Life cycle management: How business uses it to decrease footprint, create opportunities and make value chains more sustainable.

- The first step (step 1) is related to the account of chemicals use and emissions along the life cycle of a product, sector, or entire economy, to assess potential impacts on ecosystems and human health.
- The second step (step 2) aims at assessing to which extent actual emission of chemicals harm the ecosystems above their capability to recover (carrying capacity of the system). This latter step might contribute to the wide discussion on planetary boundaries for chemical pollution[242] (were POPs and POPs-like chemicals play a particular role): the thresholds that should not be surpassed to guarantee a sustainable use of chemicals from an environmental safety perspective.

Further work by the science community is necessary for further developing of this concept before it can be used for policy making.

4.6.2.2 ENFIRO Project – substitution approach for flame retardants considering LCA

A European Commission-funded project (ENFIRO), that offers a prototypical case study on substitution options for specific brominated flame retardant (BFRs) application including several applications where POP-PBDEs have been used, was conducted from 2009 to 2013. The study involved small and medium size commercial and industrial enterprises (SME's) and universities covering a wide variety of scientific disciplines.

The project outcomes included delivering a comprehensive dataset on viability of production and application, environmental safety, and a life cycle assessment of the alternative flame retardants (FRs) and recommending certain flame retardant/product combinations for future study based on LCA, LCC and risk assessment studies.

During the project implementation a practical approach was followed, based on the chemical substitution cycle (Figure 4) in which the alternative flame retardants were evaluated regarding their environmental and toxicological properties, their flame retardant properties, and their influence on the function once incorporated in the product.

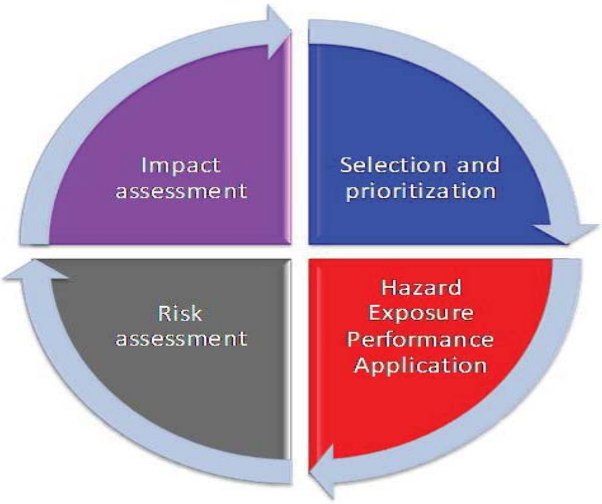

Figure 4: Chemical substitution cycle (Source: ENFIRO Project Newsletter 1)[243]

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[242] The definition of what the planetary boundaries for chemical pollution are and how the boundaries should be identified is an on - going scientific challenge for ecotoxicology and ecology.

[243] http://www.enfiro.eu/Newsletter%201.pdf.

This was achieved by performing case studies, which gather a comprehensive set of information on environmental behaviour and toxicological impact as well as an assessment of the performance of the FR in a specific application. They also included recommendations for industrial and governmental stakeholders.

ENFIRO started with a prioritization and selection phase when the most promising three FR/product combinations were defined for further detailed studies on: hazard characterization, http://www.enfiro.eu/appr_exposure.htmlexposure and fate, FRs emissions and fire retarding information (FR capability studies), technical suitability of the FRs when used as such or as mixtures in specific applications (PCBs, coatings, etc.).

The selection and prioritization phase showed that only limited information exists on fire performance, toxicity, physico-chemical properties, exposure and economic aspects of alternative FRs. In total, 15 commercially available halogen-free FRs (HFFRs) were selected from the groups of inorganic, organophosphorus & salts, nitrogen, nanoclay, and intumescent FRs. These FRs cover five major applications: printed circuit boards, electronic components, injection-moulded products, textile coatings, intumescent paint[244].

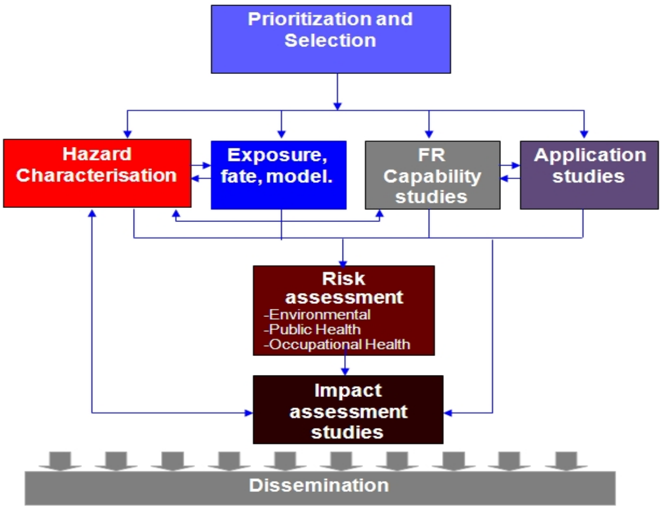

Figure 5: ENFIRO Project Phases (ENFIRO Project Newsletter 1)

The information was collected and analysed in a risk assessment. After collection of socio-economic information on the FR/product combinations together with the risk assessment the outcome was digested in a life-cycle assessment, including an analysis of costs and socio-economic aspects. This finally resulted in a recommendation of certain FR/product combinations (e.g. three FR/product combinations: metal-based FRs, phosphorous-based and nanoclay-based FRs in printed circuit boards, paints and foam).

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[244] The Norman Network Bulletin (2011): http://www.norman-network.net.

4.6.3 RiskCycle and Forward-Looking Information and Services

The recycling and recovering of materials and elements from wastes is of crucial importance for sustainable production and for the path towards a circular economy (European Commission 2012[245]; The Ellen MacArthur Foundation 2012, 2013)[246].

Considering the urgent need for resource efficiency and reduction of wastes the material flows need to be closed and recovery and recycling considerably improved towards moving to a circular economy.

There is, however, a high risk of exposure to humans and the environment if POPs or other toxic substances are recycled as demonstrated by, for example, the assessment for POPRC of the global material flow of POP-PBDE and POP-PBDE containing materials (UNEP 2010a,b)[247]. Although the art. 6(d)(iii) prohibits the disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of POPs, this assessment demonstrated that this recycling of e.g. POP containing consumer products such as WEEE plastic is largely uncontrolled in many regions and results in the contamination of particularly sensitive products such as children toys (Chen et al. 2010)[248] and food contact materials (Samsonek & Puype 2013)[249].

Recently the Basel Convention has changed its policy towards recovery and recycling of wastes. At the tenth meeting of the Conference of the Parties to the Basel Convention in Cartagena, (Colombia; 2011), the Parties adopted the Cartagena Declaration on the Prevention, Minimization and Recovery of Hazardous Wastes and Other Wastes. Through this Declaration Parties committed to actively promote and implement more efficient strategies and measures to achieve prevention, minimization and recovery of hazardous waste and other wastes and their disposal with the final aim of reducing the risk for human health and the environment from the dangers posed by such wastes.

If in the frame of moving towards cycle economies the recovery and recycling become more important then, in particular initiatives to evaluate and minimize the risk from recycling of hazardous materials and hazardous chemicals in recycling flows are of major importance. In particular the control of hazardous chemicals such as POPs present in worldwide trade of recyclables (such as PBDEs in plastic, HBCD in textiles or PFOS in synthetic carpets or the

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[245] European Commission (2012) Manifesto for a resource-efficient Europe. European Commission - MEMO/12/989 17/12/2012.

[246] The Ellen MacArthur Foundation (2012) Towards the Circular Economy vol. 1: Economic and business rationale for an accelerated transition. 2013.

The Ellen MacArthur Foundation (2013).Towards the Circular Economy vol. 2: opportunities for the consumer goods sector. 2013.

[247] UNEP (2010a). Technical Review of the Implications of Recycling Commercial Pentabromodiphenyl Ether and Commercial Octabromodiphenyl Ether. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/2).

UNEP (2010b) Supporting Document for Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/INF/6).

[248] Chen S-J, Ma Y-J, Wang J, Chen D, Luo X-J, Mai B-X (2009) Brominated Flame Retardants in Children's Toys: Concentration, Composition, and Children's Exposure and Risk Assessment. Environmental Science and Technology 43: 4200- 4206.

[249] Samsonek J, Puype F (2013) Occurrence of brominated flame retardants in black thermo cups and selected kitchen utensils purchased on the European market. Food Additives & Contaminants. Part A, Chemistry, Analysis, Control, Exposure & Risk Assessment. DOI: 10.1080/19440049.2013.829246.

other hundreds of POPs-like chemicals in current use (Scheringer et al. 2012)[223] possibly ending up in recycled products need to be controlled and omitted. In particular, sensitive uses with high exposure risk need to be protected.

Therefore as chemicals and additives in products being produced, marketed, used and recycled globally, it makes an international harmonised assessment and management essential. Chemical testing, research on risks, impacts and management options are carried out globally mainly on national or regional levels but the activities are quite fractionated and often focus to certain areas and sectors and much too often with little linkages between the different scientific communities.

The EU project "RISKCYCLE" is aimed to establish and co-ordinate a global network of European and international experts and stakeholders to define together future needs of R+D contributions for innovations in the risk-based management of chemicals and products in a circular economy of global scale leading to alternative strategies to animal tests and reduced health hazards. The partners joining this action seek to explore the synergies of the research carried out within different programmes and countries of the EU, in Asia and overseas.

The primary aim of “RISKCYCLE” is to identify future R&D needs required to establish a risk-based assessment methodology for chemicals and products, especially additives used in consumer and industrial products, that will help reduce animal testing while ensuring the development of new chemicals and product management pattern leading to minimized risks for health and the environment.

“RISKCYCLE” focuses on the fate and behaviour of these additives in six sectors: textile, electronics, plastics, leather, paper and lubricants. In textile industry the use of additives is being studied, in the electronic industry and also in textile industry the use of flame retardants, specially brominated flame retardants such as PBDEs und HBCD is being analysed. In the leather industry, heavy metals such as chromium are taken into account. The use of biocides in the paper industry is another main concern of co-ordinated activities.

Another RISKCYCLE related and supportive approach is described by the Forward-Looking Information and Services (FLIS) report developed by the European Environmental Agency.

Policymakers need knowledge about possible future developments to inform their decision-making in order to avoid taking unsustainable decisions also concerning chemicals production and management which can lead to the worst consequences on human health and the environment. The late lessons from early warnings (Part 1 and Part 2) show case studies on decision failures on chemicals in the past and their consequences highlighting that decisions making need to consider the precaution approach and need forward looking information for sustainable long-term planning. A knowledge base for Forward-Looking Information and Services developed by the European Environment Agency aims to support such long-term planning. FLIS currently has six components, including scenarios and forward-looking indicators. A FLIS brochure describes the six components of FLIS and lists some of the information generated so far. In the future, additional components may be added, for example horizon scanning and early warning signalling. A report "Catalogue of scenario studies" contributes to the FLIS knowledge base. The scenario report brings together a review of available scenarios studies relevant to environmental assessment and decision-making at the European scale (263 studies), and facts sheets of selected 44 studies using common description categories, which enables the user to review existing scenario studies that may be of relevance to their particular interest.

4.7 Case study: Scientific assessment of a PFOS alternatives in chromium plating

The Stockholm Convention Regional Centre for Capacity-building and the Transfer of Technology in Asia and the Pacific at Tsinghua University (Beijing/China) has conducted an assessment of an alternative substance for PFOS used in chromium plating in China[250]

Background

The electroplating industry in China is well developed, with an estimated >15,000 factories, >500,000 employees, >5,000 production lines and a production capacity of >300 million m^2. A recent survey by a China market research centre revealed the total industrial output value to be almost 13,000 million USD in 2008.[251] During the electroplating process, especially in 'hard chrome plating', mist suppressants are indispensable for the protection of employees from exposure to the airborne, highly toxic form of chromium (Cr(VI)). The most commonly used mist suppressants are based on perfluorooctane sulfonate acid and its salts (PFOS, $C_8F_{17}SO_3^-$). For example, the United Nations Industrial Development Organization (UNIDO) estimated that up to 10,000 kg/yr of PFOS-containing mist suppressants were being used for this purpose in Europe in 2004.[252] Similarly, among the three major mist suppressants used in the Chinese market (Table 23), two of them are PFOS salts. According to the Chinese Electroplating Association, the estimated annual consumption of PFOS in China for electroplating was 30-40 t in 2007,[253] which appears to be stable in recent years.[254]
Perfluoroalkyl ether potassium sulfonate (F-53, $C_8F_{17}O_4SK$) was first developed as a mist suppressant for the hard chrome plating industry, by the Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences in 1975.[255] After successful demonstrations in four local electroplating plants in Shanghai, F-53 was found to be excellent in performance but high in synthesis cost. F-53B is the modified version of F-53, with the replacement of one fluorine atom by chlorine (Table 24). This modification was made to simplify the production process (see Figure S1) and reduce the cost where chlorination is used in the last step, and

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[250] Wang S, Huang J, Yang Y, Hui Y, Ge Y, Larssen T, Yu G, Deng S, Wang B, Harman C (2013) First Report of a Chinese PFOS Alternative Overlooked for 30 Years: Its Toxicity, Persistence, and Presence in the Environment. Environmental Science & Technology 47, 10163–10170

[251] Dong, X.; Li, C.; Li, J.; Wang, J.; Huang, W., A game-theoretic analysis of implementation of cleaner production policies in the Chinese electroplating industry. *Resources, Conservation and Recycling (in Chinese)* 2010, *54* (12), 1442-1448.

[252] Carloni, D., Perfluorooctane Sulfonate (PFOS) production and use: past and current evidence. United Nations Industrial Development Organization (UNIDO), Vienna, Austria, 2009, http://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Stockholm_Convention/POPs/DC_Perfluorooctane%20Sulfonate%20Report.PDF.

[253] Lin, A.; Li, X., Reduction and alternative of POPs in electroplating industry. *Technology & New Process (in Chinese)* 2008, *12* (12), 10-13.

[254] Zhang, L.; Liu, J. G.; Hu, J. X.; Liu, C.; Guo, W. G.; Wang, Q.; Wang, H., The inventory of sources, environmental releases and risk assessment for perfluorooctane sulfonate in China. *Environ. Pollut.* 2012, *165*, 193-198.

[255] Shanghai Guangming Electroplating Plant; Shanghai Institute of Organic Chemistry at Chinese Academy of Sciences; Jiangsu Taizhou Electrochemical Plant, Preparation of F-53 and its application in chrome mist suppression. *Material Protection (in Chinese)* 1976, *3* (3), 27-32.

prevent the use of toxic and expensive chemicals (e.g. $SbCl_5$ and SbF_3). Therefore the commercialized product was F-53B instead of F-53. For several years, this compound had remained as the only available mist suppressant in the Chinese electroplating industry, until the emergence of PFOS related substances FC-80 ($C_8F_{17}O_3SK$) in 1982, and FC-248 ($C_{16}H_{20}F_{17}O_3NS$) later[256] (see Table 24).

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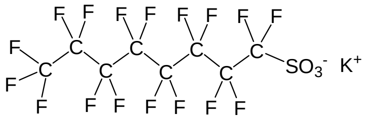
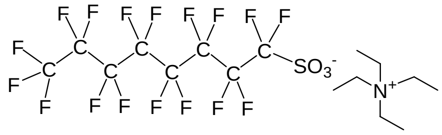
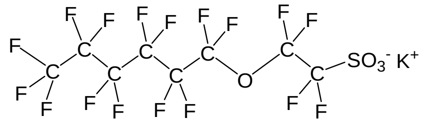
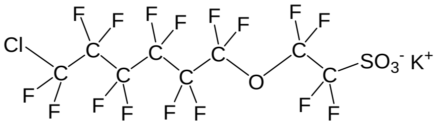
[256] Zhu, C., FC-80 Chrome Mist Suppressant. *Plating & Finishing (in Chinese)* 1985, *2* (2), 28-30.

Table 24. Main mist suppressants on the Chinese market

Product Name	Chemical	CAS Number	Chemical Formula	Structure
FC-80	Potassium perfluorooctane sulfonate	2795-39-3	$C_8F_{17}O_3SK$	
FC-248	Tetraethylammonium perfluorooctane sulfonate	56773-42-3	$C_{16}H_{20}F_{17}O_3NS$	
F-53	2-[(1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluorohexyl)oxy]-1,1,2,2-tetrafluoroethanesulfonic acid potassium salt	Not available	$C_8F_{17}O_4SK$	
F-53B	2-[(6-Chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyl)oxy]-1,1,2,2-tetrafluoroethanesulfonic acid potassium salt	73606-19-6	$C_8ClF_{16}O_4SK$	

As the main PFOS manufacturing country, there has been growing pressure on China to reduce production, which appears to have peaked in 2006. Therefore, F-53B as a PFOS alternative may be expected to obtain a larger market share and potentially expand from being solely used by the metal plating industry to other industries which currently use PFOS.

There is ample evidence that PFOS is environmentally persistent, bioaccumulative, and toxic to human and animals. The similarity in chemical structures between F-53B and PFOS makes it reasonable to assume that these chemicals possess similar physicochemical properties and environmental behaviour. However, data were lacking, with no information available on the environmental presence and potential impact of F-53B. Therefore in a research study conducted at the Stockholm and Basel Convention Coordination Center at Tsinghua University (Beijing/China), F-53B was firstly evaluated for its persistence, bioaccumulation and toxicity (PBT)[257] to give further recommendation on substitution.

B) Biodegradation test

Laboratory tests of "ready biodegradability" have been used as conservative surrogates for the assessment of biodegradation in actual or simulated environmental matrices, which can indicate the propensity for a chemical to be degraded in the aquatic environment. Amid of them, the Closed Bottle Test (CBT, OECD 301D) is recommended as a first, simple test for the assessment of the biodegradability of organic compounds in the environment. The degradation process of the test substance is tracked by analysis of the demand of oxygen in a mineral medium inoculated with micro-organisms from a mixed population. In the testing, F-53B was added to make a final concentration of 3 mg/L. The demand of oxygen was

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[257] Wang S, Huang J, Yang Y, Hui Y, Ge Y, Larssen T, Yu G, Deng S, Wang B, Harman C (2013) First Report of a Chinese PFOS Alternative Overlooked for 30 Years: Its Toxicity, Persistence, and Presence in the Environment. Environmental Science & Technology 47, 10163–10170.

measured in two vessels at 0, 7, 14, 21 and 28 d, and the results were used to calculate the biological oxygen demand (BOD) according to OECD Guideline 301D.[258]

F-53B was classified as not readily degradable in the CBT, which implies that it is probably not biodegraded efficiently in wastewater treatment plants. Considering the stringency of the OECD 301 test pass criteria, this result does not necessarily demonstrate that F-53B is not degradable in the environment.

C) Advanced oxidation process (AOP) stability test

In addition, the stability of F-53B under various advanced oxidation process (AOP) conditions was tested as described in detail by Schröder and Meesters (2005).[259] Briefly, the original analyte concentration was 45 mg/L, made in ultrapure water, with a reaction vessel volume of 250 mL, in all cases. Tests proceeded for 120 min, with samples taken every 20 min, in which F-53B was determined using the analytical method described below, after dilution. The following tests were carried out.

(i) UV photodegradation: F-53B water solution was added into the reactor chamber and irradiated with a high pressure mercury lamp (220V, 300W) in the XPA-2 photochemical reactor (Nanjing Xujiang Electromechanic Plant, Nanjing, China).

(ii) UV/H_2O_2 oxidation: 4.0 mL of 30% H_2O_2 was added into the reaction system of (i).

(iii) O_3 oxidation: the dosage of O_3 was 3.0 g/h; and the pH of solution was 11, using the reaction system of (i).

(iv) O_3/H_2O_2 oxidation: 4.0 mL of 30% H_2O_2 was added into the reaction system of (iii).

(v) Fenton oxidation: 250 mg/L $FeSO_4$, 30% H_2O_2, pH=3.

Under all AOP test conditions (i)-(v), the degradation of F-53B was very low. For test conditions (i) and (v), no concentration change could be found. After 2 hr reaction, the degradation of F-53B was observed as less than 5% under test condition (ii), about 10% under test condition (iii), and 25% under test condition (iv). These results clearly demonstrated that F-53B is very refractory even under the rigorous AOP conditions.

D) Estimation of bioaccumulation

It is difficult to predict the bioconcentration factor (BCF) or bioaccumulation factor (BAF) of PFOS and F-53B as their non-standard partitioning behaviour prevents meaningful Log K_{ow} values being derived.[260]

Due to the similarity in chemical structure it may be assumed that F-53B will bioaccumulate in the same order as PFOS and potentially more because of its larger size due to the replacement of one fluorine atom with chlorine. To test this assumption and in the absence of empirical data for F-53B, physicochemical properties were derived using EPI Suite 4.11. The

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[258] Organisation for Economic Cooperation and Development (OECD), (301D) Guideline for Testing of Chemicals (closed bottle test), **1992**b, http://www.oecd-ilibrary.org/test-no-301-ready-biodegradability_5lmqcr2k7qmw.pdf?contentType=/ns/Book&itemId=/content/book/9789264070349-en&containerItemId=/content/serial/2074577x&accessItemIds=&mimeType=application/pdf.

[259] Schröder, H. F.; Meesters, R. J., Stability of fluorinated surfactants in advanced oxidation processes—A follow up of degradation products using flow injection–mass spectrometry, liquid chromatography–mass spectrometry and liquid chromatography–multiple stage mass spectrometry. *J. Chromatogr. A* **2005,** *1082* (1), 110-119.

[260] Liu, C.; Gin, K. Y. H.; Chang, V. W. C.; Goh, B. P. L.; Reinhard, M., Novel Perspectives on the Bioaccumulation of PFCs – the Concentration Dependency. *Environ. Sci. Technol.* **2011**, *45* (22), 9758-9764.

results are shown in Table 24. Accepting the uncertainty associated with these estimations, then F-53B had a log K_{ow} value of 5.24 compared to 4.49 for PFOS, and also had an associated higher BAF (3.81 and 3.28, respectively).

Table 25. Estimated BAF, BCF and physicochemical properties of F-53B and PFOS

Property	[a] F-53B (anion)	PFOS (anion)	Software programs
log *K*ow	5.24	4.49	KOWWIN v1.68 (EPI Suite 4.11)
pKa	-5.01	-5.08	ACD Labs 6.00/pKa DB
Vapor pressure (Pa, 25 °C)	0.0268	0.853	MPBPWIN v1.43 (EPI Suite 4.11)
[b] log BAF	3.81	3.28	BCFBAF v3.01 (EPI Suite 4.11)
[b] log BCF	3.53	3.23	BCFBAF v3.01 (EPI Suite 4.11)

[a] The water solubility of F-53B (potassium salt) was higher than 200 mg/L in pure water at a room temperature of 25 °C. The water solubility of potassium salt of PFOS was measured at 570~910 mg/L [261-262].

[b] Both the BAF and BCF values were estimated for the fish in the upper trophic level based on Arnos-Gobas (2003) model.

E) Acute toxicity test

Toxicity tests were carried out at the Key Laboratory of Ecological Effect and Risk Assessment of Chemicals, the Chinese Research Academy of Environmental Sciences, in Beijing. Fish acute toxicity was tested according to Organisation for Economic Cooperation and Development (OECD) Guideline[263] using zebrafish (*Brachydanio rerio*) as the test species.

The LC_{50} (96 h) of F-53B for *Brachydanio rerio* was just over 15 mg/L. This is less than 100 mg/L, but larger than 10 mg/L, which means that F-53B should be classified as a Category III chemical in terms of acute toxicity (harmful to aquatic life), according to the Globally Harmonised System (GHS) criteria for classification of chemicals.[264] The same test was carried out for PFOS along with F-53B. F-53B seems to be similar to PFOS in terms of acute fish toxicity, belonging to the same toxicity class as PFOS according to the GHS definition. The acute toxcity for F-53B is close to the 10 mg/L EC_{50} limit for Class II "moderate toxicity". The LC_{50} value is similar to the LC_{50} (96 h) values of PFOS acute toxicity for zebrafish (*Danio rerio*) from literature studies with 22.2 mg/L[265] and 71 mg/L[266].

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[261] Brooke, D.; Footitt, A.; Nwaogu, T.; Britain, G., *Environmental risk evaluation report: Perfluorooctanesulphonate (PFOS).* Environment Agency UK: 2004.

[262] Inoue, Y.; Hashizume, N.; Yakata, N.; Murakami, H.; Suzuki, Y.; Kikushima, E.; Otsuka, M., Unique Physicochemical Properties of Perfluorinated Compounds and Their Bioconcentration in Common Carp Cyprinus carpio L. *Arch. Environ. Contam. Toxicol.* **2012,** *62* (4), 672-680.

[263] Organisation for Economic Cooperation and Development (OECD), (203) Guideline for Testing of Chemicals (fish, acute toxicity test), **1992**a, http://www.oecd.org/dataoecd/17/20/1948241.pdf

[264] United Nations, Globally Harmonized System of Classification and Labelling of Chemicals (GHS), ST/SG/AC.10/30/Rev.4, 4th revised edition, **2011**, http://www.unece.org/fileadmin/DAM/trans/danger/publi/ghs/ghs_rev04/English/ST-SG-AC10-30-Rev4e.pdf.

[265] Sharpe, R. L.; Benskin, J. P.; Laarman, A. H.; MacLeod, S. L.; Martin, J. W.; Wong, C. S.; Goss, G. G., Perfluorooctane sulfonate toxicity, isomer-specific accumulation, and maternal transfer in zebrafish (Danio rerio) and rainbow trout (Oncorhynchus mykiss). Environ. Toxicol. Chem. 2010, 29 (9), 1957-1966.

F) Conclusion

F-53B, a China-specific chrome mist suppressant widely used for over 30 years, is very similar to PFOS in respect to the PBT profiles. Therefore its appropriateness as a PFOS alternative is questionable and need further assessment.

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[266] Ye, L.; Wu, L.; Jiang, Y.; Zhang, C.; Chen, L., Toxicological study of PFOS/PFOA to zebrafish (Danio rerio) embryos. Chinese Journal of Environmental Science (in Chinese) 2009, 30 (6), 1727-173.

5 Conclusions and recommendations

Recommendations and conclusions on further progressing on POPs alternatives and POPs phase-out and related challenges have been gathered from POP Reviewing Committee activities and during the development of this guidance and the stakeholder consultation.

As for the case studies also these conclusions and recommendations will be further developed in the process of updating this publication.

5.1 General Recommendations and Conclusions

5.1.1 Key conclusions and recommendations of the POPRC guidance on alternative

Some key conclusions and recommendations of the POPRC guidance on alternative assessments are

- It is essential to identify the precise use and functionality of listed persistent organic pollutants and candidate chemicals, which requires information to be collected from various sources, mainly through consultations with industry and other stakeholders. The availability of alternative chemicals, products or processes can be determined by conducting a survey on which specific alternatives are feasible for what use;
- Although it may be difficult to perform full risk assessments on alternatives, Parties should at least confirm that persistent organic pollutants are not substituted by other POPs-like chemicals or by chemicals with concern of significant risk;
- Although it is difficult to estimate precisely costs and benefits of alternatives, Parties should make every effort to collect information on social and economic impacts to evaluate cost-effectiveness for a particular use;
- Cooperative efforts are helpful to facilitate further dissemination of better and safer alternatives worldwide. The development of the present guidance under the auspices of the POPs Review Committee is one example.

5.1.2 Updating and exchange of information on POPs alternatives and POPs free

There is abundant information on alternatives to POPs. Currently available publications and some of the current knowledge have been compiled in this publication. However, there are undoubtedly more alternatives chemicals and alternative products available, which are currently not considered in this publication. Also the performance of some products or approaches might change future, which will then need to be included in any updated publication. Therefore it is recommended to continue to gather information on POPs alternatives and POPs free products and articles and to encourage all stakeholders to submit best practice case studies and suggestions for POPs alternatives and POPs free products/articles as they become available.

This information can be forwarded to the Secretariat to ta@brsmeas.org.

It is also recommended that information exchange between stakeholders including industry, governmental institutions, regional centres, the research community and NGOs is facilitated.

5.1.3 Confidential business information and the need of disclosing relevant information

On many alternatives data and information has been generated by the respective producers and the industries using these alternatives. However a considerable share of this information is considered confidential business information and is not disclosed. The challenge with confidential business information has e.g. been discovered by the POPRC within the work on PFOS alternatives resulting in difficulty with the PFOS alternatives document. This negatively impacts correct decision-making and has negative impact on appropriate health and safety information. Improved communication and information exchange between these stakeholders and a better sharing of information is needed in particular those data which help to better protect human health and the environment considering the Overarching Policy Strategy paragraph 15c „information on chemicals relating to the health and safety of humans and the environment should not be regarded as confidential“[267].

5.1.4 Information need on POPs in products and articles

There is a lack of information of the presence and fate of POPs in articles and products. The detailed former and current use of some POPs in articles and products are unknown. It is not known, for example, which particular article is affected (i.e whether a particular TV or car contains PBDE, which synthetic carpet contain PFOS or which textile contains HBCD) since a variety of chemicals have been used in different ways and possibly at different rates. Getting more information on chemicals in products from industrial stakeholders in possession of this information is crucial. Also here the industry should consider the relevance to appropriately manage POPs in products and articles and take into account the extended producer responsibility and be more flexible in respect to what they consider confidential business information.

The need for information exists at every stage of the supply chain, including manufacturers/OEMs, retailers, consumers, waste handlers, and others. It is important to create disclosure requirements at the national and international levels to ensure this information is available to all stakeholders.

In addition further activities on screening of articles/products where POPs might have originally been used or nave been transferred by recycling are called for from the science community.

The situation is complicated by recycling of POPs containing articles where even less is known about the presence of POPs since the use of materials from recycling can contaminate products and articles where there was no original use of POPs.

Therefore it is recommended that more information is generated/gathered in which original products/articles and in which recycling flows POPs are present and to which extent they are present. In particular the knowledge base is weak in developing countries and countries with economies in transition. It is also recommended that the information is made available then to other Parties.

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[267] UNEP (2006) Strategic approach to international chemical s management. SAICM texts and resolutions of the International Conference on Chemicals Management.

These activities can be linked where appropriate to UNEP's on-going work related to information flow for Chemicals in Products Project and the UNEPs' Chemical Information Exchange Network (CIEN) and possibly stimulate activities of CIEN.

For some articles/products and for material flows in recycling possibly be impacted by POPs more well planned monitoring activities are needed. For this screening/monitoring of POPs in articles a guidance has been developed ("Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles" (Draft), ***4.2.1 Monitoring guidance to screen POPs in articles***) and it is recommended that the guidance is studied when planning monitoring projects of POPs in articles and considered where appropriate.

It is further recommended that monitoring of POPs in articles is not done in isolation by individual country projects but that where possible regional projects to monitor POPs in articles and products are developed possibly coordinated or supported by the work of the regional centres.

It is recommended that coordinated monitoring of POPs in products and articles is conducted by regional studies possibly coordinated by regional centres to minimize efforts and maximise outcomes. Such monitoring might be supported by South-North or South-South cooperation with experienced institutions or research groups.

5.1.5 Need of dissemination of information and education

Information about POPs in products and articles is essential in order to make it possible for all stakeholders to make informed decisions. While stakeholders working closely with Stockholm Convention issues might easily get access to information on POPs alternatives and POPs free products (such as this publication and related resource materials) other stakeholders normally not exposed to the Stockholm Convention implementation will usually not be exposed to such information. For instance, there are a number of stakeholders e.g. those working in recycling of materials and of producing new products from recycled materials which may not be aware on the possible contamination with POPs chemicals. Also industries where POPs are or have been used might not be aware of all POPs alternatives.

The recommendation is that stakeholders for which information on POPs and POPs alternatives and POPs free might be relevant need as first step to be discovered and then contacted. In a second step information materials should be provided or possibly workshops organized informing on best practice of substitution of POPs in articles, products and processes. Such activities might be integrated with for instance cleaner production activities on chemical management or substitution of hazardous chemicals.

5.1.6 Prioritising non-chemical methods and avoidance of problematic substitutes

The recommendation by POPRC, and the subsequent decision by the COP, that priority should be given to ecosystem approaches to pest management when replacing endosulfan, is a good model for assessing alternatives for other POPs. Wherever a POP is to be replaced priority should be given to looking at non-chemical methods, approaches and products, to avoid creating further downstream problems with hazardous properties of chemicals. This would include analysis of ways in which products or processes could be changed slightly to prevent the need for a replacement chemical.

If the phase-out of a particular chemical identified as hazardous takes place, the substitution process may result in just an incremental rather than a fundamental change of the type of chemical used. On the one hand, this is plausible because it is this chemical structure that generates the desired properties and performance of the chemicals. On the other hand, this incremental change constitutes a problem because also the unwanted properties of the chemicals being replaced may show up in the replacements. For this type of substitution process, where the basic chemical structure is maintained, the term "lock-in" problem was proposed[268].

Alternatives to known POPs should for a first screening possibly be assessed/considered in classes based on chemical structure and/or functional use. For example, it would be logical to create groupings of halogenated hydrocarbons, and to examine their likely persistence/bioaccumulation potential before considering them as viable alternatives. It is important to avoid regrettable substitutions, in which other potential POPs are adopted as substitutes for POPs that have already been identified. In this sense the POPs research community has developed statements addressing PFAS (Helsingör statement[269] and Madrid statement) and halogenated flame retardants (San Antonio statement)[270].

To assure appropriate substitution the manufacturers of the replacements should generate the information that is required for a detailed and comprehensive hazard and risk assessment of the replacements.[271] This is in principle the intention of the European chemicals regulation, REACH. The information should not only be shared with regulatory bodies, but also be made publicly accessible.

If chemical substitution is used it need to be assured that the most benign alternative are used by applying the available assessment tools and approaches (see chapter 4). By utilizing these tools and by providing comprehensive hazard and risk assessments it can be confirmed that the alternative does not have POPs and POPs-like properties and to a reasonable extent excluded that the alternative has otherwise properties of significant risk.

5.1.7 Approach of using and promoting Green Chemistry/Sustainable Chemistry

Green chemistry and sustainable chemistry refers to a set of principles designed to reduce or eliminate the use or generation of hazardous substances in the design, manufacture and application of chemical products[272].

Green Chemistry is used in two main ways:

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[268] Scheringer M, Fantke P, Weber R (2014) How can we avoid the lock-in problem in the substitution of hazardous chemicals used in consumer products? Organohalogen Compound 76.

[269] Scheringer M, Trier X, Cousins IT, de Voogt P, Fletcher T, Wang Z, Webster TF (2014) Helsingør Statement on poly- and perfluorinated alkyl substances (PFASs). Chemosphere. 2014 Jun 14. Doi: 10.1016/j.chemosphere.2014.05.044.

[270] Birnbaum LS, Bergman A (2010) Brominated and Chlorinated Flame Retardants: The San Antonio Statement Environ Health Perspect. 118, A514–A515.

[271] Stieger G, Scheringer M, Ng CA, Hungerbühler K (2014) Assessing the persistence, bioaccumulation potential and toxicity of brominated flame retardants: Data availability and quality for 36 alternative brominated flame retardants. Chemosphere. Doi: 10.1016/j.chemosphere.2014.01.083.

[272] UNEP (2013) Global Chemical Outlook - Towards Sound Management of Chemicals p.210.

(1) Green Chemistry refers to a specific approach to the science of chemistry using the key principles developed by Anastas and Warner[273]; and

(2) Green Chemistry refers to more generally to an approach that takes toxicity and environmental impacts into account e.g. in order to reduce it.
It involves pulling together tools, techniques and technologies that can help chemists and chemical engineers in research, development and production to develop more eco-friendly and efficient products and processes, which may also have significant financial benefits. Green Chemistry aims to improve the way that chemicals are both produced and used in chemical processes in order to reduce any impact on man and the environment[274].
Sustainable Chemistry needs to have as a major aim a transformation to 'better' alternatives that are compatible with human health and the environment "Benign by design[275,276].
Sustainable Chemistry is recognized as an important innovation in achieving sustainability, and encapsulates or enables the principle of substitution in sound management of chemicals that can be transferred from developed to emerging and developing economies[277].
The right policy frame needs to be set to strengthen the competitiveness of those chemical companies which invest in research and development of safer alternatives. While currently most regulatory approaches work with negative lists, a complementary approach could be to develop and compile lists with chemicals of no or minor concern.

To reach the goal of Green Chemistry the green design of chemicals need to be improved. Generally, a life-cycle perspective on chemicals and the products and processes the chemicals are involved in, needs to be introduced. This is important especially in green product design involving chemical substitution in order to avoid burden shifting from one undesired property to another between substituted and replacement chemicals, but also to avoid burden shifting from specific environmental impacts (e.g. bioaccumulation in the food chain) to other impacts (e.g. groundwater contamination) and from one location to another if the replacement chemicals involve different manufacturing or processing steps[278].
Overall it is important to establish new strategies for introducing novel types of chemical structures in markets that are dominated by a certain type of chemistry. A first aspect of this is that more research into new types of chemical structures that are in agreement with the principles of Green Chemistry, in particular: low toxicity and no persistence, is needed[279]. Chemical research needs to investigate systematically to what extent it is possible to reconcile

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[273] Anastas P, Warner J (1998) Green Chemistry: Theory and Practice. New York: Oxford University Press

[274] Royal Society of Chemistry (2002) Note on: Green Chemistry. Version: 5 April 2002.

[275] Benign by Design Alternative Synthetic Design for Pollution Prevention. Editor(s): Paul T. Anastas, Carol A.Farris, ACS Symposium Series Volume 577, 1994 ISBN13: 9780841230538 eISBN: 9780841214989.

[276] Klaus Kümmerer (2007) Sustainable from the very beginning: rational design of molecules by life cycle engineering as an important approach for green pharmacy and green chemistry. Green Chem. 9, 899–907.

[277] Discussed in Wilson, M.P. and Schwarzman, M.R. (2009). Green Chemistry: Wilson and Schwarzman Respond Environmental Health Perspectives, 2009 September, 117(9): A386. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2737034/.

[278] Scheringer M, Fantke P, Weber R (2014) How can we avoid the lock-in problem in the substitution of hazardous chemicals used in consumer products? Organohalogen Compound 76.

[279] Clark JH. (2006) Green chemistry: today (and tomorrow) Green Chem. 8: 17-21.

the needs for technical performance in defined applications with the requirement that, according to the principles of Green Chemistry, chemical products should be degradable and not highly toxic.

More guidance needs to be developed on how a comprehensive comparative assessment of various environmental aspects can be incorporated into chemical substitution design. Additionally the existing substantial data gaps and uncertainties for such an assessment need to be overcome. This requires an integrated approach of all stakeholders involved including the chemical industry, industrial downstream users of chemicals, regulatory authorities, the research community, and related Non-Governmental Organizations.

5.1.8 Need of protection of recycling flows as a basis for a circular economy

Considering the urgent need for resource efficiency and reduction of wastes, the material flows need to be closed and recovery and recycling considerably improved to move towards a circular economy. Therefore recycling will in future become more important or even become a necessity considering the limit of resources. Recently the Basel Convention has changed its policy towards recovery and recycling of wastes by adopting the Cartagena Declaration on the Prevention, Minimization and Recovery of Hazardous Wastes and Other Wastes. Through this Declaration Parties committed to actively promote and implement more efficient strategies and measures to achieve prevention, minimization and recovery of hazardous waste and other wastes and their disposal with the final aim of reducing the risk for human health and the environment from the dangers posed by such wastes. When now such recovery activities are emphasised which are useful for resource recovery then initiatives to evaluate and minimize the risk from recycling of hazardous materials are of major importance. This needs to specifically control hazardous chemicals such as POPs present in worldwide trade of recyclables (such as PBDEs in plastic, HBCD in textiles or PFOS in synthetic carpets) possibly ending up in recycled products. The recycling of PBDEs and other hazardous chemicals into sensitive uses like plastic toys, household equipment and food contact materials highlights the necessity to better plan and control recycling flows in respect to human exposure (UNEP 2010 a,b)[280].

Therefore it is recommended

- To assess recycling flows of POPs in respect to their risk and to evaluate how materials can be separated that products made from recycling are POPs free.
- To assess current use of POPs in articles/products and evaluate their future risks for recycling flows and in the entire life cycle.
- That when selecting POPs alternatives also to take in account risks for the recycling flows and in the entire life cycle.

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[280] UNEP (2010a). Technical Review of the Implications of Recycling Commercial Pentabromodiphenyl Ether and Commercial Octabromodiphenyl Ether. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/2).

UNEP (2010b) Supporting Document for Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. 6th POP Reviewing Committee meeting Geneva 11-15. October 2010 (UNEP/POPS/POPRC.6/INF/6).

5.1.9 Extended producer responsibility and extended product responsibility

The manufacture of safe products, the protection of the recycling flows and the end of life management is a particular responsibility of the industry. Extended producer responsibility (EPR) recognizes that product manufacturers must take on new responsibilities for the life cycle of their products and to minimize the environmental impact of their products. However, real change cannot always be achieved by producers acting alone: retailers, consumers, and the existing waste management infrastructure need to help to provide the most workable and cost-effective solutions. Solutions and roles will vary from one product system to another. Product stewardship is a product-centered approach to environmental protection. Also known as extended product responsibility, product stewardship calls on those in the product life cycle—manufacturers, retailers, users, and disposers—to share responsibility for reducing the environmental impacts of products.

All industrial stakeholders (producers and users of chemicals as well as the recycling sector) should take up their responsibility and jointly work together for the development of more sustainable products and sustainable chemical and non-chemical alternatives. The industry should be proactive about safer chemical alternatives. The past few decades have seen some bad examples of regrettable substitution of POPs – taking out a harmful chemical and substituting one that turns out to e have similar or other drawbacks. This is extremely costly for down-streamers, governments, and consumers.

Policy makers have their responsibility to develop appropriate regulatory frame for extended producer and product responsibility and that the right incentives are given to promote sustainable chemical and non-chemical alternatives to POPs and POPs-like chemicals.

On the other hand also consumers, NGOs working on chemical have their responsibility to contribute by more sustainable consumption and support of sustainable products containing the most benign alternatives.

The individual roles and responsibilities for sustainable production and consumption need to be better defined that the individual stakeholders know their responsibilities and options and that cooperation and communication between the stakeholders is facilitated as best frame for promoting safer alternatives.

5.1.10 Recommendation for improvement of current approaches for controlling POPs in articles

There are certain gaps for all current approaches of controlling and monitoring POPs in articles and products (e.g. HS codes; GHS; MSDS, REACH) (see Annex 1 and Annex 2). Therefore it is recommended to assess how these gaps can be addressed and closed and how such an improvement can be implemented in practice. This effort should include guidance on disclosure of the presence of POPs in articles and products.

5.1.11 Recommendation for development of a guidance for a regulatory framework for POPs in articles and products

While industrial countries have developed some legislation to control chemicals in articles and products, such control is weak in developing countries and countries with economies in transition. Therefore it is recommended to develop a guidance document which gives some support to develop or strengthen regulatory frames for the control of POPs in articles and products. This should include guidance on disclosure requirements, restrictions and prohibitions of POPs in articles and products, among other topics.

5.1.12 Green/Sustainable (Public) Procurement as a driver for sustainable products

During the Rio+20 Conference, held in Rio de Janeiro in June 2012, a new international initiative to fast track a global transition to a green economy by harnessing the market-shifting power of government and local authority spending was launched by the UN Environment Programme (UNEP) and partners. Supported by over 30 governments and institutions, the International Sustainable Public Procurement Initiative (SPPI) aims to scale-up the level of public spending flowing into goods and services that maximize environmental and social benefits.

The new SPP initiative seeks to back the worldwide implementation of sustainable public procurement by promoting a better understanding of its potential benefits and impacts and facilitating increased cooperation between key stakeholders.

UNEP has developed significant expertise and a successful track-record in implementing sustainable public procurement policies and action plans across 7 pilot countries in cooperation with the Swiss-led Marrakech Task Force on SPP. This has allowed the accumulation of experience and know-how in regards to the design of SPP policies in emerging and developing countries.[281]

Considering the challenges of developing countries and countries with transition economies with the end of life management of POPs and POPs-like chemicals[282], the use of chemicals in products should become a criterion for sustainable public procurement and support the global effort to move to products with sustainable alternative to POPs and other hazardous chemicals. The inclusion of chemicals in green public procurement is already mentioned in the Handbook on Green Public Procurement from the EU.

5.1.13 Promotion of the Sustainable Consumption Approach – “less is more”

There is a vital need for more sustainable consumption patterns and an overall reduction of resource use. The overall reduction and avoidance of products containing hazardous chemicals is an alternative approach which should be promoted more frequently in particular in industrial countries in which levels of consumption are already far above a sustainable ecological footprint.

For certain product groups the question could be asked if an application is needed at all.

5.2 Recommendations and conclusions for individual chemicals

5.2.1 Recommendation from POPRC on PFOS

The work of POPRC provides recommendations on PFOS phasing out:

- Recommendation on specific Applications;

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[281] http://unep.org/newscentre/Default.aspx?DocumentID=2688&ArticleID=9188&l=en.

[282] Weber R, Aliyeva G, Vijgen J. (2013), The need for an integrated approach to the global challenge of POPs management. Environ Sci Pollut Res Int. 20, 1901-1906.

- Recommendation regarding Information Gaps;
- Recommendation on Future Work.

Recommendation on specific Applications

One important recommendation stressed by POPRC was that Parties are encouraged to stop using PFOS for the following applications:

- (i) Fire-fighting foams;
- (ii) Insecticides for the control of red imported fire ants and termites;
- (iii)Decorative metal plating;
- (iv) Carpets;
- (v) Leather and apparel;
- (vi) Textiles and upholstery;

Because information is available on the commercial availability and effectiveness of safer alternatives to PFOS, Parties are encouraged to restrict the use of PFOS in hard metal plating to closed-loop systems only.

POPRC requests Parties and observers to provide information on use of PFOS or its alternatives and on quantities of PFOS for:

  - (i) Aviation hydraulic fluid;
  - (ii) Chemically driven oil production;
  - (iii) Electric and electronic parts for some colour printers and colour copy machines

In case of insect baits for the control of leaf-cutting ants from Atta spp. and Acromyrmex spp., it should be considered the need for peer reviewed studies, such as pilot projects, in close cooperation with the national authorities in any country that still uses PFOS for this application, to evaluate the feasibility of alternatives to PFOS within an integrated pest management approach.

Recommendation Regarding Information Gaps

- Encourage Parties and stakeholders, such as industry and academia, to continue to identify and assess chemical and non - chemical alternatives to PFOS;
- Encourage Parties to collect information to fill the gaps in information on alternatives to PFOS identified through the Committee’s work;
- Encourage Parties and industry to identify ways to make information on the properties of alternatives to PFOS publicly available;
- Invite Parties to make additional information available for:
  - Revision of the guidance on alternatives to PFOS and its derivatives;
  - Evaluation of the continued need for PFOS, its salts and PFOSF for the various acceptable purposes and specific exemptions.

Recommendation on Future Work

- Consider the need for further evaluation of certain alternatives identified in the technical paper that indicates that they might be of concern with regard to their health and environmental effects;
- Need to:

- Revise the guidance on alternatives to PFOS to incorporate the information contained in the technical paper on alternatives to PFOS in open applications;
- Participate in the assessment of information on alternatives to PFOS made available to the Conference of the Parties.

5.2.2 POPRC and COP Recommendation on risk reduction for PFOS and PBDE

The POPRC have developed "Recommendations on the elimination of brominated diphenyl ethers from the waste stream and on risk reduction for PFOS, its salts and PFOSF (Decision POPRC-6/2)".

Some of these recommendations might have relevance for other newly listed POPs used or present in articles and products. It is recommended to further assess these recommendations in respect to recommendations which are of general nature or which can be translated to other POPs and to evaluate what recommendation could be in a modified way be utilized for HBCD or Endosulfan and other POPs with potential relevance to articles and products.

5.2.3 Conclusions, Recommendations and future tasks (PFOS alternative document 2013)

Need for incentives

There is a need for incentives to develop safe, affordable and technologically feasible alternative substances and processes and to identify the driving forces for their development. The international requirements applying to all Parties to the Stockholm Convention, which must be implemented in national law, constitute one such incentive. Article 3 of the Stockholm Convention states that Parties with regulatory and assessment schemes for new chemical substances shall take measures to regulate with the aim of preventing the production and use of substances that exhibit characteristics of POPs. The development of national law is an important tool for promoting incentives to identify and use alternative substances and processes. Postponing the development of national law until perfect alternatives are available is not wise because manufacturers may not develop alternatives if they are not forced to do so.

Need for more public data and information on alternatives

Too few data are currently available publicly on the alternatives than to PFOS. Much of the information is from patent literature, and the identities of actual chemicals used are often not disclosed. This reinforces the need for implementation of paragraph 1 of Article 9 on the information exchange regarding alternatives to persistent organic pollutants.

Chemicals with structures similar to those of the listed PFOS substances could cause concerns similar to those related to the latter substances. This should be considered in evaluating alternatives.

Increasing effort will be needed to study the toxicological and environmental properties of alternatives and to make the resulting information public and trustworthy by publishing it in peer-reviewed scientific journals.

A strategic integrated approach to testing is needed to speed development of the data required to understand the issues and concerns relating to the various types of alternatives. The private sector/industry has a key responsibility in this regard.

Need for better communication in the value chain

It is important that the issues associated with PFOS as a globally recognized persistent organic pollutant, including the health and environmental risks, be made fully known to suppliers and industries at every step of the supply chain (including workers). Producers need to have better knowledge about the use of PFOS in processes, products and articles. It is also important to provide information to customers, workers and consumers so that they can develop informed opinions about the possible need to change products or processes. Industries that are proactive in phasing out the use of a very hazardous chemical such as PFOS are likely to reap future market advantages.

Need for more international cooperation

PFOS and its substitutes are being studied and evaluated in parallel by authorities in many countries. More international cooperation and private sector transparency can save resources and speed up processes. The OECD Parallel Process for the Notification of New Chemicals is one useful approach (for new chemicals) to consider in developing international collaboration on assessing potential alternatives to PFOS and other polyfluorinated chemicals of concern.

6 Annexes

6.1 Annex 1: Tools and legal frameworks for the identification of chemicals and related gaps for monitoring of products and articles possibly containing newly listed POPs

6.1.1 Trade names of chemicals and mixtures and related gaps

Systematic names are often long, complicated, and difficult to read for marketing and trade of chemical substances, mixtures, and articles. Therefore, generic names, proprietary or trade names, and trivial (common) names are used. A trade name is given to a chemical, a mixture or an article by the company that markets/supplies it. The trade name normally specifically identifies the chemical, mixture or article and sometimes gives information on the company.

One model for how to use trade names in the control of banned chemicals is the "UNEP Inventory of trade names of chemical products containing ozone depletion substances and their alternatives".[283] Related to this, the establishment of import and export licensing systems is mandatory for all Parties to the Montreal Protocol. Because those systems determine the accuracy and completeness of national ODS consumption data, by extension they are key tools to help measure and ensure compliance with the Protocol.

If trade names of all currently used chemicals and products of all newly listed POPs would be available and compiled, a similar system could be established. However, the available information differs for the different newly listed POPs. For example:

- For PFOS, its salts, PFOSF, and PFOS-related chemicals, there is very limited information available on trade names, and what is available is generally obsolete, e.g. information from the company "3M", which stopped the supply of these chemicals by 2002. For commercial PentaBDE (c-PentaBDE) and commercial OctaBDE (c-OctaBDE), only some common names are available from the work of the POPRC.
- Only for lindane, endosulfan, and DDT is there an abundance of information on trade names available from the Chemical Abstract Service (CAS), INCHEM, and the Decision Guidance Documents (DGDs) of the Rotterdam Convention. From CAS, only trade names, common names, generic names, and synonyms are available for all three chemicals, but not company information. INCHEM PIM provides common names, synonyms, trade names, and company information not related to the trade names for endosulfan; common names, synonyms and trade names, but no company information for DDT; and, for lindane, common names, synonyms and trade names and company information not related to the trade names. For mixtures containing lindane, trade names with related company names for mixtures including information of the concentration of the active ingredient are provided.
- For endosulfan, the DGD from the Rotterdam Convention provides trade names, company (basic manufacturers) names not related to the trade names, and a general description of mixtures containing endosulfan as an active ingredient. For DDT and lindane, trade names, company (basic manufacturer) names not related to the trade names, and a general description of mixtures containing DDT or lindane as an active ingredient are available.

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[283] http://www.unep.fr/ozonaction/information/mmcfiles/3328-e.pdf.

Available information is compiled in a document prepared as part of national implementation plans supporting documents a publication which provides the common name, chemical name, CAS number, HS code chemical, HS code mixture, trade names with source (POPRC, CRC, CAS, INCHEM; for PFOS: Environmental working group), trade name mixtures from INCHEM, information about mixtures from CRC, and company names from CRC/POPRC and INCHEM/Environmental working group.

As the different sources sometimes provide the same trade names for lindane, DDT, and endosulfan, the trade names were put into the database and the duplications and other mistakes, such as UN numbers, were removed. The resulting database, which includes more than 200 names for lindane, more than 100 for DDT, and almost 100 names for endosulfan, allows users to search the trade names for the three chemicals. The great number of trade names is also due to the fact that common names, synonyms, and trade names are collected together, that different forms of writing the same name were accepted, and that the same names are given in different languages. Except for endosulfan, the information sources are from 2000 onwards for lindane and from the 1990s for DDT.

Regarding lindane, many manufacturers are from countries that have long banned the chemicals and the company related trade names are expected to not be very useful for customs control or other control purposes. Therefore, it would be useful to collect additional information on trade names and companies for the other newly listed chemicals.

The only specific actual information for PFOS, its salts, PFOSF and PFOS-related chemicals is through internet search. In addition, through direct contact with the German company Lanxess, one PFOS-related chemical with trade name was identified. Information have been compiled as supporting information for the Stockholm Convention Guidance for the control of the import and export of POPs[284].

6.1.1.1 Gaps regarding trade names and mixtures

Information on trade names, companies, and HS codes for POPs as substances and in mixtures is mostly lacking for the totally banned newly listed POPs and PFOS, its salts and PFOS-related chemicals. For DDT and lindane, if such information is available, it is typically outdated.

Some trade names for PFOS have been compiled and listed. There is still a need to collect further information through other processes.

Such gaps might be addressed together with Rotterdam Convention activities: The Chemical Committee of the Rotterdam Convention decided at its seventh meeting (CRC7) in March 2011 to recommend the POPs chemicals endosulfan, PFOS, its salts and precursors, c-PentaBDE, and c-OctaBDE, for which two notifications met the criteria of Annex II of the Rotterdam Convention for listing in Annex III of the Convention. Meanwhile these substances have been listed.

The experience with the DGD for endosulfan from CRC6 shows that trade-related information, such as trade names, common names, and companies, is collected extensively in this process and documented in the DGD. Therefore, it is expected that the DGDs for the other POPs proposed for listing will also contain information on trade names, common names,

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[284] http://chm.pops.int/Implementation/NIPs/Guidance/NIPGuidanceSupportingDocuments/tabid/2941/Default.aspx

and companies which could be used for the Stockholm Convention.

6.1.2 Trade names of articles containing newly listed POPs and related gaps

Trade names of articles and the time frame that contain POPs such as c-PentaBDE or c-OctaBDE and articles containing PFOS for exempted uses or acceptable purposes would be helpful for enforcement/control purposes. For example, regarding articles where specific trade names are used, such as for vehicles from a specific brand containing c-PentaBDE (here brand name; type and production year would be needed), or for electronic goods (e.g. TVs or computers) containing c-OctaBDE in the polymer. These might be gathered from monitoring studies.

Two POPs monitoring studies have recently presented monitoring data for POP-PBDEs/brominated flame retardants (BFR) in articles using bromine screening:

- BFRs in electronics: BFR have been screened with XRF in 382 plastic samples in Nigeria[285,286] in a project implemented by the Basel Convention Regional Coordinating Centre for the African Region (Ibadan/Nigeria). Information on products (producer, year, area of origin, and BFR content and type) has been compiled. The articles were analysed with GC/ECD for the individual BFRs. From these activities, a first data set on product names and POP-PBDE content were developed.
- POP-PBDE in carpet rebond: Recently, a monitoring project of POP-PBDE in carpet rebond was performed with XRF for bromine screening and 26 samples were analysed for POP-PBDE by GC/MS analysis. The levels of contamination and the names of products with higher levels have been published.[287]

6.1.2.1 Gaps regarding trade names of articles containing newly listed POPs

The recent activities on identifying these articles (see work program on newly listed POPs proposed by POPRC and agreed by COP5) show that little information is available regarding trade names of articles. There is only very limited information available on POP-PBDE or PFOS in articles. The European Automobile Manufacturers Association has undertaken a survey on former c-PentaBDE and c-OctaBDE use in vehicles, but did not collect information for use before 2000 (after 2000 c-PentaBDE and c-OctaBDE has not been used in European vehicle production).[288]

Producers of electronics have also not revealed if and for which years they have used POP-PBDEs in their products. Such information would therefore first need to be retrieved from the producers or generated by measurements.

Similarly, information on trade names of articles currently on the market and formerly sold (for articles still on the market for used goods, such as used vehicles or electronics) needs to

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[285] Sindiku O, Babayemi JO, Osibanjo O, Schlummer M, Schluep M, Weber R (2012) Assessing POP-PBDEs and BFRs in E-waste polymers in Nigeria. Organohalogen Compounds 74, 1320-1223 http://www.dioxin20xx.org/pdfs/2012/1338.pdf

[286] Sindiku O, Babayemi J, Osibanjo O, Schlummer M, Schluep M, Watson A, Weber R (2014) Polybrominated diphenyl ethers listed as Stockholm Convention POPs, other brominated flame retardants and heavy metals in E-waste polymers in Nigeria. Env Sci Pollut Res. DOI: 10.1007/s11356-014-3266-0 (and supporting information).

[287] DiGangi J, Strakova J, Watson A (2011) A Survey of PBDES in Recycled Carpet Padding. Organohalogen Compounds 73, 2067-2070. http://www.dioxin20xx.org/pdfs/2011/4511.pdf.

[288] ACEA (2010) Personal communication ACEA - European Automobile Manufacturers Association, 2010.

be retrieved from the producers or otherwise be collected.

Emphasis has been given to collecting information about PFOS, its salt, PFOSF and PFOS-related chemicals (e.g. POPs name, CAS number, trade names, and uses). Also, the former use of POP-PBDE in the transport sector (company, model, and year) would be valuable. This information could also be requested from the electronic sector (company, model, and year).

While such information might be useful for monitoring the imports of vehicles, it likely would have only limited practical use for controlling used electronics since such electronics are often imported as mixed bulk in containers. To assess producer and product names for custom control seems impractical for electronics.

Published results for articles from recycled products, such as carpet padding studies, also have limitations. For example, some uncertainty exists when applying the results to other products from the same company with the same specifications since the POP-PBDE levels in recycled products might have fluctuation. Nevertheless, such studies are still useful for information on which companies are recycling POP-PBDE-containing materials as a first indication of possible POP-PBDE-containing goods.

It is also important to note that some articles have been found which formerly contained newly listed POPs (e.g. lindane for head lice treatment), but the producers have since changed formulation, yet kept the product name.

6.1.3 Custom codes (Harmonised System Codes) and related gaps

The HS codes for chemicals listed in Annex III of the Rotterdam Convention are available from the World Customs Council through the website of the Rotterdam Convention[289]:

- substance specific (for one or two substances): aldrin 2903.52, DDT 2903.62, dieldrin 2910.40, heptachlor 2903.52, hexachlorobenzene 2903.62, lindane (same as technical HCH) 2903.51, toxaphene (none)
- generic code (for ANNEX III entry) for mixtures containing these substances: 3808.50- generic code for polybrominated biphenyls (PBB) (hexa- CAS 36355-01-8, octa- CAS 27858-07-7, deca- CAS 13654-09-6) mixture 3824.84

For the other newly listed POPs, the following HS codes are available from the European Union (EU) Customs database ECICS[290]:

- Chlordecone: 2914.70 Ketones and quinones, whether or not with other oxygen function, and their halogenated, sulphonated, nitrated or nitrosated derivatives
- Hexabromobiphenyl 2903.69 Halogenated derivatives of hydrocarbons, other
- Pentachlorobenzene 2903.69 Halogenated derivatives of hydrocarbons, other
- PFOS acid 2904.90 Sulphonated, nitrated or nitrosated derivatives of hydrocarbons, whether or not halogenated, other
- PFOS potassium salt 2904.90 Sulphonated, nitrated or nitrosated derivatives of hydrocarbons, whether or not halogenated, other

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[289] http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals/HarmonizedSystemCodes/tabid/1159/language/en-US/Default.aspx

[290] http://ec.europa.eu/taxation_customs/dds2/ecics/chemicalsubstance_consultation.jsp?Lang=en&Cas=29457-72-5&Cus=&CnCode=&EcCode=&UnCode=&Name=&LangNm=en&Inchi=&Characteristic=&sortOrder=1&Expand=true&offset=0&range=25.

- Endosulfan: 2920.90 specific

The HS code, if chemical specific, can be used to identify the imported chemical. The HS code relates to a group of chemicals that also includes a POP might be used for the customs risk analysis but can not be used for inventory purpose[291].

6.1.3.1 Gaps regarding custom codes (Harmonised System Codes)

For most newly listed POPs, the custom code is not specific yet. Therefore, currently for these substances, custom codes have limited use[291]. PFOS and POP-PBDEs have also not yet received a custom code.

6.1.4 GHS classification and labelling for chemicals and mixtures and related gaps

The report of UNEP on chemicals in products[292] states: “while currently there is no single global information system for management of information about chemicals in products, the GHS is an international standardized system for communicating chemical hazards. It addresses classification of chemicals by types of hazard and proposes harmonized hazard communication elements, including labels and safety data sheets. Its limiting factor is that it applies solely to chemicals and chemical compositions and not to products in general” – that is, articles.

According to the GHS, for a hazardous chemical or mixture the label should, inter alia, contain a product identifier for the hazardous chemicals and supplier identification. As a product identifier, the identity of a substance is to be provided by its common chemical name. The “common chemical name” may, for example, be the CAS name or IUPAC name, as applicable.

The CAS registry number provides a unique chemical identification and should be provided when available. Supplier identification consists of the name, address, and telephone number of the manufacturer or supplier of the substance or mixture.

For a mixture, the chemical identity, identification number (CAS number), and concentration or concentration ranges of all hazardous ingredients, which are hazardous to health or the environment within the meaning of the GHS, and are present above their cut-off levels, should be provided.[293]

All POPs are hazardous chemicals and their chemical name and CAS number, together with supplier information, should appear on the label. There is no internationally agreed list of GHS classification and labelling of the newly listed POPs. To facilitate the customs control, the GHS classification and labelling as used by the EU has been integrated in Annex 1L of the *POPs Labelling Considerations Document*. The original data can be found in a database of

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[291] Korucu MK, Gedik K, Weber R, Karademir A, Karakus PBK (2014) Inventory development of perfluorooctane sulfonic acid (PFOS) in Turkey: challenges to control chemicals in articles and products. Environ Sci Pollut Res Int. DOI 10.1007/s11356-014-3924-2

[292] A Synthesis of Findings Under the UNEP/IOMC Project on Information on Chemicals in Products, UNEP / DTIE Chemicals Branch February, 2011 http://www.chem.unep.ch/unepsaicm/cip/Documents/CiP%20Project%20synthesis%20report__Final.pdf.

[293] Table 3.1 in 1.4 GLOBALLY HARMONIZED SYSTEM OF CLASSIFICATION AND LABELLING OF CHEMICALS (GHS), *Fourth revised edition,* UNITED NATIONS, New York and Geneva, 2011.

the European Commission Joint Research Centre[294] and the data for chlordecone, DDT, endosulfan, lindane, c-OctaBDE, c-PentaBDE, PeCBz, PFOS and its salts are available in Annex 1L of the *POPs Labelling Considerations Document* with explanations regarding the hazard classcodes, hazard statements codes, and label information. Therefore, the EU has developed labelling for all of the POPs except HBB.[295] The GHS might be useful to some extent for controlling POPs in articles.

6.1.4.1 Gaps regarding GHS classification and labelling

While the GHS is an international standardized system for communicating chemical hazards, it is not yet the single global information system for the management of information about chemicals in products. Currently, 67 countries are listed as implementing GHS and many other countries are preparing for implementation. Many developing countries in particular might need additional support for preparation and implementation.

Concentration levels below 0.1% are normally not covered in the GHS label. However, there are possibilities to lower this generic value. For POPs, such levels would need to be defined.

6.1.5 Safety data sheets and related gaps

A Material Safety Data Sheet (MSDS), Product Safety Data Sheet (PSDS), or Safety Data Sheet (SDS), is a form that provides data on the properties of a particular substance. SDSs are a widely used system for cataloguing information on chemicals, chemical compounds, and chemical mixtures. The chemical supplier (e.g. manufacturer, importer, or formulator) should be able to provide detailed information about the chemical in an SDS. In certain countries, the supplier is obligated to provide information in an SDS on the chemicals' health and environmental hazards, labelling, safe use and handling, among other things. SDSs have been prepared on many dangerous substances and preparations.

An SDS should go together with the product to the user in the workplace. It should provide comprehensive information about a chemical substance or mixture for use in a workplace setting. It can be used by both employers and workers as a source of information about hazards, including environmental hazards, to obtain advice on safety precautions, and most importantly to identify appropriate risk reduction messages for the related uses. Advice by the supplier on the safe use of the chemical by the user requires information on the workplace situation of the user and expected exposures. The information in an SDS acts therefore as a reference source for the effective management of hazardous chemicals in the workplace.

The SDS is product related and, sometimes, may not be able to provide specific information that is relevant for a specific use. In other cases, the SDS may be specific and detailed for a particular use. The SDS is a resource that enables an employer to undertake worker and environmental protection activities, including training that are specific to the individual workplace.

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[294] http://esis.jrc.ec.europa.eu/index.php?PGM=cla.

[295] Production of HBB stopped in 1976 and therefore has no relevance as a traded chemical.

6.1.5.1 Gaps regarding safety data sheets

The SDS is an essential component of the GHS framework. It does not provide more information for identification than the GHS label. As with the GHS, chemicals at concentrations below 0.1% are not listed in SDSs. Often only the main compounds are listed.

One experience, within the newly listed POPs project in Nigeria, was that no SDSs were provided with imported fire-fighting foams since there is no requirement for SDSs in the country. This might be the case for many developing countries.

6.1.6 Specific labelling of articles (RoHS certificates; POPs label) and related gaps

6.1.6.1 Certificate for RoHS compliance

For compliance with RoHS Directive, a compliance certificate/label exists. This covers PBDEs (c-PentaBDE, c-OctaBDE, and c-DecaBDE) and HBB as well as certain heavy metals (lead, mercury, cadmium, and hexavalent chromium). Although RoHS was developed for the EU, companies comply worldwide with the standard due to import requirements of the EU and the development of similar regulations in other countries.

The RoHS standard can be seen as success story. There are also several countries with RoHS-like legislation (including Australia, Canada, China, Japan, Republic of Korea, and the United States (US)) making RoHS a “global legislation”. The EU RoHS Directive has recently been updated and extended.

6.1.6.2 Gaps regarding the RoHS certificate

The RoHS limit is 0.1% for POP-PBDEs and HBB and therefore about an order of magnitude above the low POPs content of PCB (50 ppm) or POPs pesticide (50 ppm). Furthermore, the definition and measurement of PBDEs in RoHS differ somewhat from the Stockholm Convention. In RoHS, for example, the OctaBDE homologue is also included, but not considered as a POP in the Stockholm Convention, and therefore the total content is calculated slightly different. Also, DecaBDE (by far the most abundant PBDE in articles) is included in RoHS, but not in the Stockholm Convention.[296]

6.1.6.3 Labels for articles based on the POPs content

Dedicated labels for articles with a specific material exist for plastic and asbestos. A more general labelling requirement is included in California’s Proposition 65 (the Safe Drinking Water and Toxic Enforcement Act of 1986) which requires “clear and reasonable warning” about chemicals in products that are associated with cancer or reproductive toxicity.

A specific label might also be developed for POPs. For the listing of HBCD a labelling of products containing HBCD will be required from 26 November 2014 on. For POPs as substances or in mixtures or articles, the label could contain the name of the POP if the concentration is above a certain cut off value.

Countries could also consider dedicated labels for POPs in articles which are not covered by

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[296] DecaBDE degrades over time to the lower brominated PBDE including POPs PBDEs (UNEP/POPS/POPRC.6/INF/20).

the GHS. In principle, this could be applicable to all articles manufactured that contain a regulated POP. (Also see the *POPs Labelling Considerations Document of the Stockholm Convention.*)

Key stakeholders and resources required for implementation include:

- Manufacturers to identify the POPs and label the article.
- User industries, workers, farmers, and the public, using the information to protect human health and the environment.
- Governments to provide awareness raising, training, as well as monitoring the obligation to label.
- An efficient customs monitoring system to identify unlabelled imported articles and to control manufacturers producing the regulated articles.

6.1.6.4 Gaps regarding a "POPs label"

A "POPs label" has not yet been developed and would require considerable time and effort to establish. Furthermore, it is questionable whether development of a label only for POPs is justified considering the relatively small amount of goods to be labelled and the related effort. Additional resources would also be required to educate and train customs staff and other competent authorities and to motivate them to consider such labels.

6.1.7 REACH and related gaps regarding POPs monitoring and control

The European chemicals legislation REACH[297] was developed and implemented in order to overcome some of the core problems in the EU's chemicals management, such as the lack of information on hazardous properties for the majority of substances on the market, the unequal treatment of substances marketed before and after 1991 (existing substances and new substances), the slow progress of authorities in the risk assessment of prioritised substances, and the patchwork of different pieces of legislation (lack of coherence). The requirements of the Stockholm Convention are implemented in a separate regulation[298] at the EU level. The main aim of REACH is to ensure the safe handling and use of substances on the market while enhancing innovation and competitiveness by different mechanisms.

The core REACH process of registration requires all manufacturers and importers of substances, in mixtures, and in articles from which they are intended to be released to submit a registration dossier to the European Chemicals Agency (ECHA), if these are manufactured or imported in amounts exceeding 1 t/a. For substances registered in amounts exceeding 10 t/a, a chemicals safety report must be compiled; for substances fulfilling the classification criteria as hazardous, an exposure and risk assessment for all lifecycle stages must also be compiled.

ECHA may carry out an evaluation of industries' dossiers and both ECHA and the EU Member State authorities conduct evaluations of substances which are suspected of being of concern.[299] The authorisation process consists of several steps, at the end of which the use of

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[297] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

[298] Regulation (EC) No 850/2004 on persistent organic pollutants.

[299] This process corresponds to the former EU risk assessment under the Existing Substances Regulation however with defined responsibilities and timelines aimed at ensuring an efficient work process.

substances of very high concern (SVHC)[300] may be prohibited, except where the user has been granted an authorisation. The formal identification of substances as SVHCs and their inclusion in the candidate list for authorisation[301] triggers communication requirements for article producers and distributors. The restrictions process aims to regulate substances posing a risk to human health or the environment at the EU level by restricting or banning the manufacture, import, and use of specific substances, in mixtures, or in articles.

The scope of REACH excludes active substances in biocide and pesticides, as well as substances which are not intentionally manufactured (e.g. dioxins). Furthermore, wastes are outside its scope.[302] Therefore, some of the current and potentially future POPs are not regulated by REACH.

REACH does explicitly regulate the export of substances; i.e. substances manufactured for export neither have to be registered nor can they be subject to authorisation. Only the ban of manufacturing would be effective (e.g. by a restriction).

POPs which can be legally manufactured and traded in the EU as such and in mixtures may be registered in the EU.[303] The identified uses will be reported as part of the chemical safety report if one is required and recommendations on adequate control of risks from their use will be forwarded with the SDSs. The information will be published in the ECHA dissemination database.

The basis for registering substances is the definition of the substance identity. Detailed rules on how to name and characterise different substance types are provided in a guidance document by ECHA, which inter alia sets thresholds for identifying impurities and additives of a substance. Consequently, the POP content in substances may be reported by registrants; although part of the database, it is not published because the substance identity is considered confidential business information.

If a persistent bioaccumulative toxic substance (PBT) or a very persistent very bioaccumulative (vPvB) (such as POPs) or substances transforming into one are contained in a substance above 0.1%, a PBT-specific risk characterisation should be performed, according to the ECHA guidance on PBT assessment (exemptions possible if total amount below 1 t/a), potentially resulting in specific information to be forwarded with the SDS (emission minimisation).

PBT/vPvBs (such as POP) have to be identified in SDSs if they are contained in substances or mixtures above the thresholds for consideration according to the classification, labelling and packaging (CLP-) regulation. This information is available in the supply chains. Mixtures and their content are not registered or reported under REACH.

POPs may be identified as SVHC and included in the candidate list for authorisation[304], if

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[300] The criteria for “very high concern” are set out in REACH Article 57 and are hazard based. The following substances properties are listed: CMRs category 1a and 1b, PBTs, vPvBs and substances with similar properties or potential adverse effects.

[301] http://echa.europa.eu/web/guest/candidate-list-table.

[302] Substances recovered as such or contained in recovered materials are however regarded as “manufactured” and fall under the scope. Exemptions from registration may be claimed based on Article 2.7(d).

[303] Registration of substances in articles is only required if they are intended to be released. This is a specific case and not further discussed here. For details refer to the ECHA guidance on substances in articles: http://echa.europa.eu/documents/10162/13632/articles_en.pdf.

[304] Currently HCBD is on the list.

they fulfil the criteria of Article 57. Article 57(f) in principle could be used to identify substances as SVHC because of their transformation products being SVHC or because of their content of SVHC(s).

For all substances on the candidate list, the article producers and importers are to report to ECHA the content of these substances in their articles, if the total amount of any individual SVHC in concentrations above 0.1%[305] exceeds 1 t/a[306]. They can claim exemptions to that if the substance is already registered for the use or if they can prove that there is not exposure of humans or the environment from the article.

Apart from reporting to ECHA, article producers and importers are to communicate to their commercial customers[307] information on the content of SVHC(s) on the candidate list in their articles if they contain above 0.1% and forward information necessary to ensure safe use. This requirement applies regardless of the total tonnage. This information could be a starting point for monitoring SVHC in articles and for targeting inspection and control campaigns.

POPs which may become subject to authorisation (as such or as impurity in substances on the list for authorisation) will be particularly controlled because they only may be used by companies which have an authorisation. All users of substances subject to authorisation have to report their use of the substance to ECHA. ECHA maintains a register of respective downstream users and grants access to Member State authorities. This mechanism allows identification of all companies which use an authorised substance. This is also an entry point to identify where they are included in articles.

The restriction process is useful to limit the manufacture and/or use of substances inside the EU and from imports. However, no monitoring instruments are available, except those stemming from the enforcement of the requirements (e.g. see RAPEX).

6.1.7.1 Gaps regarding REACH

Chemical safety reports only contain generic use patterns, and no specific information on who uses a substance for/in which specific product. Hence, it is possible to use that information to target monitoring or inspection programmes, but it does not provide direct information on the occurrence of POPs on the market.

Registration of substances and related identification of potential POPs contained in them only starts at concentrations above 0.1% and volumes of 1 t/a per registrant; i.e. substances manufactured or imported in smaller volumes are not assessed. Importers of substances contained in mixtures are not likely to obtain or generate that detailed information on the substance content as to be able to identify whether or not POPs are contained.

The registration information for a (POP-containing) substance is not linked to any specific products or uses, but rather only generic use patterns are provided for substances for which a

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[305] There are different interpretations as to the reference unit of 0.1% “in the article“. The European Commission, ECHA, and the majority of Member States use the article “as placed on the market” as reference for the threshold whereas the so called “dissenting Member States” relate the 0.1% threshold to the component or article part, which became an article according to the REACH definition for the first time.

[306] The article producer is to sum up all individual amounts of each SVHC separately which is contained above 0.1% in any of the articles the producers produces or imports. SVHC in concentrations below 0.1% are not considered.

[307] This information is to be provided to consumers upon their request free of charge and within 45 days.

chemical safety assessment and exposure assessment must be carried out.

As substances are only registered as such, even if they are imported in mixtures, no information on that mixture will be reported to the ECHA database. Consequently, although the supply chain actors may be aware of a POP in a mixture, that information is not structurally available for monitoring or controlling POPs at the EU level.

Reporting the content of candidate substances to ECHA would in principle be a helpful tool to monitor the flow of POPs (those which are included on the candidate list) on the markets. However, it is already clear that only limited information will be obtained via this track because of several reasons. These are, inter alia: tonnage and the concentration thresholds for SVHCs in articles (0.1% in articles for reporting and communication) are too high and only in a few cases, the reporting requirement applies; the exemption from the reporting obligation will apply to many potential reporting cases; and the sanctions for breaching either article related requirement (reporting to ECHA and communicating to customers) are very low and not likely to motivate in particular the importers of articles to conduct extensive testing to identify SVHCs.

REACH is a substance-oriented regulation, primarily aiming at ensuring the safe handling and use of substances on the market by generating and disseminating hazard, exposure, and risk information. The specific processes of candidate listing, authorisation, and restrictions aim at controlling risks from the most hazardous substances could also be used for POPs. It is not likely, however, that major changes to the regulation will be made to include product- or article-related requirements, which would also facilitate the monitoring and control of POPs, before the end of the last registration period in 2018.

6.1.8 RAPEX and related gaps

RAPEX (Rapid Alert System for Non-Food Consumer Products) is the EU rapid alert system for all dangerous consumer products, with the exception of food[308] and medical devices. Meanwhile, the alert system also covers pharmaceutical products and in this respect is also reporting to an international UN body (WHO). The system allows for the rapid exchange of information between Member States via central contact points and the European Commission on measures taken to prevent or restrict the marketing or use of products posing a serious risk to the health and safety of consumers, which may be available in more than two Member States. RAPEX covers reporting on measures ordered by national authorities, and measures taken voluntarily by producers and distributors.

Hazardous chemicals are addressed within RAPEX and chemical risk is ranked as the fifth category within RAPEX notification and has a relevant share (13%) (European Commission, 2007). Each Member State has designated competent market surveillance authorities and granted them with the necessary powers to take measures in order to prevent or restrict the marketing or use of dangerous products. More specifically, the national authorities are competent to take samples of consumer products placed on the market, to test them in laboratories, and – in cases where these products pose risks to consumers – order producers and distributors to stop their sale, withdraw them from the market, and/or recall them from

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[308] For example, the Rapid Alert System for Food and Feed (RASFF) is used to exchange information about dangerous food and feed.

consumers.

6.1.8.1 Gaps regarding RAPEX

Currently, POPs are not specifically addressed under RAPEX. RAPEX is mainly an instrument within the EU. However, as with pharmaceutical products, it is already linked to the UN (WHO). In addition, RAPEX China indicates that such a system has the potential for extension beyond the European region.

6.2 Annex 2: Voluntary schemes for the identification of chemicals in articles and related gaps in facilitating the monitoring of articles possibly containing newly listed POPs

There is already quite a diverse range of instruments for communication on substances in articles from industry. Within the feasibility study “Reporting Format on SVHC in Articles” from the German Federal Environmental Agency[309], voluntary instruments have been assessed regarding their capability for reporting on SVHC under the REACH regulation. Some of these instruments include reporting on (new) POPs or have the potential for newly listed POPs to be included.[310]

These instruments have different aims and scope and can, according to Kogg and Thidell (2010), be classified into the following groups:

- Instruments for communication within the supply chain
- Instruments for producer to consumer communication
- Instruments for producer to end-of-life management communication
- Instruments for communication from external stakeholders to consumers and the general public
- Initiatives for communication between external stakeholders and supply chain actors

The best developed systems with a wide coverage of chemicals are within the supply chains. Their potential use for other purposes could be assessed.

6.2.1 The Joint Article Management Promotion Consortium (JAMP)

JAMP[311] builds on standardised MSDS and MSDSplus, which are information transmission sheets for information on chemical substances contained in products. The chemical contained in products/articles is reported in standardized Article Information Sheets (AIS) for the information transfers further down the supply chains. This system offers a way to systematically list all substances of a chemical or product, including name, CAS number, and concentration. Warnings are displayed on the AIS when a certain substance and concentration

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[309] Project No. (FKZ) (37112 65 409) Feasibility Study “Reporting Format on SVHC in Articles”, Consultancy for the German Federal Environment Agency (UBA), Draft Report on Work Package 1, Andreas Manhart, Dirk Bunke.

[310] If a system(s) would be developed or adapted, it should be structured as simple as possible with a unified reporting format to facilitate communication. Currently, the German Federal Environmental Agency assesses options for such reporting formats.

[311] http://www.jamp-info.com/english.

falls under one of the following regulations: Japanese Chemical Substance Control Law, Japanese Industrial Safety and Health Act, Japanese Poisonous and Deleterious Substance Control Law, RoHS Directive, End-of-Life Vehicle (ELV) Directive, CLP Regulation (Annex VI Table 3.2 CMT-cat. 1,2), REACH (Annex XVII), and REACH SVHC.

6.2.1.1 Gaps

The use of the common web-based platform for data sharing and exchange (JAMP-IT) is based on payment and membership. Therefore developing countries will have challenges to use this platform.

6.2.2 The Global Automotive Declarable Substance List (GADSL)

GADSL was compiled by representatives from the automotive industry (including its supplier base in the chemicals and plastics industries) who are organised in the Global Automotive Stakeholders Group. The aim of this group was to harmonise the various substance lists that were formally used in the industry, which resulted in the globally harmonised GADSL. The list covers substances that are addressed by any substance-specific legislation worldwide and that are expected to be present in materials and parts in vehicles at point-of-sale. The list currently encompasses 139 substances which are either classified as D (“duty-to declare”) or P (“prohibited”).

The intent of GADSL is to become the principal company-specific list for declaration of parts composition within the automotive industry. It provides a definitive list of substances requiring declaration with the target to minimize individual requirements and ensure cost-effective management of declaration practices along the complex supply chain. The scope covers declarable substances in the flow of information relevant to parts and materials supplied throughout the automotive value chain, from production to the end-of-life phase. This approach is a voluntary industry initiative designed to ensure integrated, responsible, and sustainable product development by automobile manufacturers and their supply chain.

Several newly listed POPs are already covered by the substance list: PFOS, POP-PBDEs (by listing c-PentaBDE and c-OctaBDE), HBB, pentachlorobenzene (PeCBz), and lindane.

6.2.2.1 Gaps

GADSL is specific to vehicles and the list only covers regulated substances relevant to the automotive industry. Regulated substances of other sectors and applications are not covered exhaustively.

6.2.3 International Material Data System (IMDS)

IMDS[312] is a system that enables the communication, collection, and analysis of the materials used in vehicles and their parts. In contrast to most other intra-supply-chain communication systems, IMDS is not restricted to regulated substances, but aims to collect and manage the total material composition of vehicle parts to ultimately enable the calculation and tracking of the total material composition of vehicles. In addition, the system is also linked to the GADSL

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[312] https://www.mdsystem.com/magnoliaPublic/en/public/news.html.

to support the proper management of regulated substances. Therefore, POPs are also listed in this system.

6.2.3.1 Gaps

IMDS is currently a pure supply chain tool and only free of charge for suppliers.[313] Vehicle manufacturers pay an annual fee ranging between 100,000 to 500,000 EUR. In addition, vehicle manufacturers pay a one-time fee of 100,000 EUR when they join the system. The applicability might be extended to other industries in future: HP had made efforts to sell the system to other industries such aircraft, toy, and electronics manufacturing. Nevertheless, applying the system to other industries will need adjustments in all modules (e.g. list of materials, data entry template, and online database).

6.2.4 The Joint Industry Guide for Material Composition for Electronics Products

This guide[314] applies to products that are supplied to manufacturers of electrotechnical products, for incorporation into their products. It covers materials and substances that may be present in the supplied product. It does not apply to process chemicals (i.e. chemicals used and consumed during manufacture) unless those process chemicals constitute part of the finished product, nor does it apply to packaging (e.g. cardboard, plastic trays).

This guide represents industry-wide consensus on the relevant materials and substances that shall be disclosed by suppliers when those materials and substances are present in products that are incorporated into electrotechnical products.

6.2.4.1 Gaps

This guide only covers regulated substances relevant for the electronics industry. Regulated substances of other sectors and applications are not covered exhaustively.

6.2.5 BOMcheck

BOMcheck[315] is a declaration tool that covers restricted and declarable substances relevant for electrical and electronic equipment. It comprises a “restricted and declarable substances list” and a data entry template that is linked to an online database. The system is usually used to communicate on regulated substances.

6.2.5.1 Gaps

BOMcheck only covers regulated substances relevant to the electronics industry. Regulated substances of other sectors and applications are not covered exhaustively.

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[313] http://www8.hp.com/us/en/services/services-detail.html?compURI=tcm:245-823413&pageTitle=international-materials-data-system#.

[314] http://www.ce.org/Standards/browseByCommittee_6365.asp.

[315] http://www.bomcheck.net/.

6.2.6 Umbrella Specifications

Umbrella Specifications[316] are datasheets that provide information on the total material composition of electronics parts such as semiconductors, passive components, and connectors. The datasheets are compiled according to a format specified by the German Electrical and Electronic Manufacturers Association (ZVEI).

6.2.6.1 Gaps

Umbrella Specifications are currently only used for the electronic industry, but an extension seems possible.

6.2.7 Environmental Product Declarations (EPDs)

Environmental Product Declarations (EPDs)[317] aim to provide relevant, verified, and comparable information about the environment impacts from goods and services. EPDs are available for all types of products and services and give quantitative information derived from lifecycle assessments and other product specific assessments.

6.2.7.1 Gaps

It is up to the producer to include specific information on hazardous substances. The currently available EPDs are not uniform regarding chemicals in products.

6.2.8 Ecolabels

A wide variety of ecolabelling systems have been developed, in part to compensate for the lack of internationally standardized information systems. Ecolabels are voluntary systems and typically do not contain specific information on the chemical content of a product, but might indicate what the article does not contain. Several types of ecolabels exist: those that indicate overall environmental preferability of one brand of product within a product sector and that is based on life-cycle considerations; those that are self-declarations by manufacturers that mostly apply to a single attribute of a product; and those that provide quantified environmental data of a product under preset categories of parameters set (including the absence of, or within specified limits for, certain chemicals), verified by a third party, and based on a lifecycle assessment.

Eco-labelling systems exist in the following countries:

- Americas: Canada, the US, Brazil;
- Asia Pacific: Australia, China (including Hong Kong and Taiwan), India, Israel, Japan, New Zealand, Republic of Korea, Philippines, Singapore, Thailand;
- Europe: Austria, Czech Republic, Croatia , the EU[318], France, Germany, Hungary, The Netherlands, Scandinavia, Slovakia, Spain.

Related to this, the Global Ecolabelling Network is an association of national ecolabelling organizations from around the world. It serves as a platform for the exchange of information

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[316] Examples are available online at: http://www.zvei.org/index.php?id=1158.

[317] http://www.environdec.com/en/.

[318] http://ec.europa.eu/environment/ecolabel.

and knowledge. It assists newly established ecolabelling organizations in developing structures and in matters of organization and quality assurance of processes.

An example of an ecolabelling system, the German Blue Angel, which is the first and oldest environment-related label for products and services in the world, is outlined below.[319]
Status, concept, aim:

- Initiative of the German ministry responsible for environment in 1978;
- Voluntary system, used in Germany by companies producing chemical products and articles;
- Preventive system to highlight the positive environmental features of products and services and to promote, through information, both environmental and consumer protection;
- The protection goals are environment and health, climate, water, and resources.

Scope, impact:

- The ecolabel is awarded to products and services;
- Information communicated through the label is provided from the manufacturer to the distributor to the user;
- Proposals for new ecolabels for products are submitted by industry, with decisions made by an independent Environmental Label Jury based on technical criteria developed by German Federal Environmental Agency;
- Target audiences are industrial and public users that can consider the label when buying products;
- Benefits due to the absence of certain hazardous chemicals in articles through the Blue Angel that have relevance for POPs include:
  - wooden toys being free from synthetic fragrances, flame retardants, and wood preservatives
  - composite wood panels with no alarming release of pollutants, and being free from halogenated organic compounds
  - mobile phones with pollutant-free plastic cases.

The German Blue Angel ecolabel restricts the presence of PBDE and HBB (and chlorinated paraffins) in imaging equipment.

6.2.8.1 Gaps

POPs are only addressed to some extent in current ecolabel schemes. Low POPs contents are not defined.

6.2.9 IEEE Standard – United States

Similar to ecolabel schemes, the IEEE Standard intends to provide a clear and consistent set of performance criteria for the design of products, and to provide an opportunity to secure market recognition for efforts to reduce the environmental impact of these products. The US Environmental Protection Agency manages this activity.

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[319] http://www.blauer-engel.de/en/blauer_engel/index.php.

6.2.9.1 Gaps

The label is based on self-declaration and when the product enters into the market a third party verification system is foreseen. Since such verification systems are only within the US, international application is questionable.

6.2.10 Product/article-related consumer information in the internet

A range of governmental and private initiatives have developed information systems on the internet on articles specifically for consumers. Chemicals are often a prominent part of the information. The following are some good examples.[320]

- Household Products Database: http://hpd.nlm.nih.gov;
- GoodGuide: http://www.goodguide.com/;
- HealthyStuff: http://www.healthystuff.org/;
- Skin Deep: http://www.cosmeticdatabase.org;
- ToxFox: http://www.edc-free-europe.org/smart-fox-toxfox-app-helps-consumers-detect-edcs-in-cosmetics/;
- Restricted Substance List and Toolkit of the American Footwear and Apparel Association: https://www.apparelandfootwear.org/ Resources/RestrictedSubstances.asp;
- US EPA Design for Environment Program: http://www.epa.gov/dfe/index.htm;
- State of Washington: Database of chemicals in children's products: https://fortress.wa.gov/ecy/cspareporting/;
- NEWMOA Mercury-Added Products Database: http://www.newmoa.org/prevention/mercury/imerc/notification/.

6.2.10.1 Gaps

Newly listed POPs are mostly not specifically addressed in these databases.

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[320] Kast and Bunke, Project No. (FKZ) (37112 65 409) Feasibility Study "Reporting Format on SVHC in Articles". Consultancy for German environment agency (UBA).