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Preliminary draft guidance on alternatives to short-chain chlorinated paraffins

Note by the Secretariat

As is mentioned in the note by the Secretariat on the implementation plans (UNEP/POPS/COP.9/11), the annex to the present note sets out preliminary draft guidance on alternatives to short-chain chlorinated paraffins (SCCPs). The present note, including its annex, has not been formally edited.

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Annex

Preliminary draft guidance on alternatives to short-chain chlorinated paraffins (SCCPs)

February 2019

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List of Acronyms and Abbreviations

ATH	Aluminum trihydroxide
ATO	Antimony oxide
BBP	Butyl benzyl phthalate
BDBP	Dialkyl Dithiophosphate
BUA	Beratergremium für Umweltrelevante Altstoffe
CDP	Cresyl diphenyl phosphate
CR	Chloroprene
DEA	2:1 Di-ethanolamine
DecaBDE	Decabromodiphenyl ether
DEHP	Bis(2-ethylhexyl) phthalate
DIDP	Di-isodecyl phthalate
DIN	Deutsches Institut für Normung
DINP	Di-isononyl phthalate
DIUP	Di-isoundecyl phthalate
EALs	Environmentally adapted lubricants
EBP	Ethane, 1,2-bis(pentabromophenyl)
EC	European Commission
ECHA	European Chemicals Agency
EU	European Union
EVA	Ethylene-vinyl acetate
HBCD	Hexabromocyclododecane
HSM	High solid polymers
IPPDPP	Isopropylphenyl diphenyl phosphate
ITAP	Phenol, isopropylated, phosphate
LCCPs	Long-Chain Chlorinated Paraffins (C_{18+})
MCCPs	Medium-Chain Chlorinated Paraffins (C_{14-17})
MWF	Metalworking fluids
OSPAR	Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
POPs	Persistent organic pollutants
POPRC	Persistent Organic Pollutants Review Committee
PVC	Polyvinyl chloride
RPA	Risk & Policy Analysis
SCCPs	Short-chain chlorinated paraffins
TBP	Tributyl phosphate
TBPDPP	Tertbutylphenyl diphenyl phosphate
TBPH	Tetrabromophthalate ester
TCP	Tricresyl phosphate
TNPS	Tertiary nonyl polysulfide
TOTM	Tri-octyl trimellitate
UK	United Kingdom
UNEP	United Nations Environment Programme
US	United States
US EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds

1 Introduction

1.1 Short-chain chlorinated paraffins under the Stockholm Convention

Chlorinated paraffins (CPs), or polychlorinated n-alkanes (CA), are complex mixtures of substances with the general molecular formula CxH(2x-y+2)Cly. CPs are characterised by the carbon-chain length range of their n-alkanes and by the chlorine content of the product. According to their chain length, CPs are categorized into short-chain CPs (SCCPs, C10–C13), medium-chain CPs (MCCPs, C14–C17) and long-chain CPs (LCCPs, C17–C30) (IARC, 1990, Glüge et al, 2016).

In May 2017, by decision SC-8/11, the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants (POPs) amended Annex A to the Convention to list short-chain chlorinated paraffins (SCCPs; Alkanes, C10-13, chloro: straight-chain chlorinated hydrocarbons) with chain lengths ranging from C10 to C13 and a content of chlorine greater than 48% by weight. Additionally, a limit for the presence of SCCPs in other chlorinated paraffin (CP) mixtures was set at 1% by weight. CPs with a SCCP content >1% are therefore considered POPs.

SCCPs were listed with specific exemptions for production and the use as detailed in Table 1 below.

Table 1: Specific exemptions for short-chain chlorinated paraffins

Chemical	Activity	Specific exemption
Short-chain chlorinated paraffins (Alkanes, C_{10-13}, chloro)$^{+}$: straight-chain chlorinated hydrocarbons with chain lengths ranging from C_{10} to C_{13} and a content of chlorine greater than 48%, by weight For example, the substances with the following CAS numbers may contain short-chain chlorinated paraffins: CAS No. 85535-84-8; CAS No. 68920-70-7; CAS No. 71011-12-6; CAS No. 85536-22-7; CAS No. 85681-73-8 ; CAS No. 108171-26-2.	Production	As allowed for the Parties listed in the Register
	Use	• Additives in the production of transmission belts in the natural and synthetic rubber industry; • Spare parts of rubber conveyor belts in the mining and forestry industries; • Leather industry, in particular fatliquoring in leather; • Lubricant additives, in particular for engines of automobiles, electric generators and wind power facilities, and for drilling in oil and gas exploration, petroleum refinery to produce diesel oil; • Tubes for outdoor decoration bulbs; • Waterproofing and fire-retardant paints; • Adhesives; • Metal processing; • Secondary plasticizers in flexible polyvinyl chloride, except in toys and children's products.

On 18 December 2017, pursuant to paragraph 4 of Article 21 of the Convention, the amendments were communicated by the depositary to all Parties. On 18 December 2018, one year after the date of communication by the depository, the amendments listing SCCPs in Annexes A to the Convention entered into force for most Parties[1].

Like all POPs, the listed SCCPs have toxic properties, resist degradation, and bio-accumulate in fatty tissues. They are transported through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems.

Parties to the Convention for which the amendments enter into force have to meet the obligations under the Convention leading to the elimination of SCCPs.

[1] Amendments shall not enter into force for those Parties that have submitted a notification pursuant to the provisions of paragraph 3(b) of Article 22 of the Stockholm Convention. In accordance with paragraph 4 of Article 22, the amendment will not enter into force with respect to any Party that has made a declaration regarding the amendment to the Annexes in accordance with paragraph 4 of Article 25. Such Parties shall deposit their instruments of ratification regarding the amendment, in which case the amendment shall enter into force for the Party on the ninetieth (90) day after the date of deposit with the Depositary.

2 Objective of the guidance

This guidance document compiles chemical alternatives and non-chemical alternatives to SCCPs, mainly for the uses listed as specific exemptions in Annex A to the Convention (Table 1). Parties may wish to consider the information available in this guidance when phasing-out the use of SCCPs.

The guidance was prepared based on the information contained in the documents adopted by the POPs Review Committee (UNEP/POPS/POPRC.12/11/Add.3 and UNEP/POPS/POPRC.12/INF/7). Other reports and information on alternatives to SCCPs have been taken into account.

3 Alternatives to SCCPs

3.1 Metal working fluids in metal processing and other lubricants

3.1.1 Background

Metalworking fluids (MWFs) and other lubricant uses are listed as exemptions in the SC (Table 1). MWFs are liquids, which are supplied to a manufacturing process of a metal in a way that allows for increased productivity based on lubricating and cooling effects (Brinksmeier et al. 2015). In various manufacturing processes, MWFs are applied to ensure workpiece quality, to reduce tool wear, and to improve process productivity (Brinksmeier et al. 2015). By their lubricating and cooling properties, MWFs contribute to the avoidance of thermal damage of the workpiece material and reduce wear of the tool. In general, chlorinated paraffin lubricants and lubricants containing chlorinated paraffin additives are designed to lubricate parts that experience extreme pressures, used in deep drawing, tube bending, and cold heading (US EPA 2004).

According to DIN 51385, MWFs are classified following their composition as oil-based or water-based MWFs (DIN 2013). They can be categorized according to the manufacturing process as cutting fluid, grinding oil or forming oil.

According to the German ordinance on occupational diseases, 23% of patients with toxic, toxic-degenerative and allergic contact eczema frequently got in contact with MWFs (Bagschick et al. 1998; Barth 2003). Therefore, the selection of MWF with low toxicity is relevant for workers.

Evidence suggests that there are ample alternatives to SCCPs for use as MWFs; however, they may not be suitable for all applications. Some of these may exhibit POPs characteristics or other hazardous properties.

Lubricants are used in automotive (engine oils, transmission fluids and gear oils), industrial automotive (heavy duty vehicles; agricultural equipment, construction and other earth moving equipment; and military) rail, ships, industrial machinery (e.g. machine bearings, centrifuge, rotary compressors, air compressors), power generation (e.g. wind power facilities; electric generators), drilling in oil and gas exploration, petroleum refinery, food & beverage (European Commission 2016; UNEP 2017).

3.1.2 Alternative chemicals

Potential chemical alternatives to SCCPs in metalworking fluid applications include (Government of Canada 2009; European Commission 2002; US EPA 2004; UNEP 2016a,b, 2018):

(a) Sulphur based substitutes (for extreme pressure MWFs):

  (i) Zinc dialkyldithiophosphate;

  (ii) Sulphurized polyisobutene, polypropylene and polystyrene;

  (iii) Tertiary nonyl polysulfide (TNPS);

  (iv) Polyolefin sulphide;

  (v) Sulfonated fatty acid esters;

  (vi) Overbased calcium sulphonates;

  (vii) Polysulphides or alkyl sulphide, sulphurized alkenes/olefins, sulphurized hydrocarbons (i.e., generally di-tertiary alkyl polysulphides, in particular di-tertiary alkyl pentasulphides) - extreme pressure additive;

(b) Phosphorus compounds (forMWFs), including:

  (i) Alkyl phosphate esters;

(ii) Phosphate acid esters;

(iii) Hydrogen phosphites;

(iv) Phenol, isopropylated, phosphate (ITAP) (3:1);

(v) Tributyl phosphate (TBP);

(vi) Triaryl phosphate;

(vii) Bis(2-ethylhexyl) hydrogen phosphate;

(viii) Didodecyl phosphite;

(ix) Dimethyl hydrogen phosphite;

(x) 2-Ethylhexyl hydrogen phosphate;

(xi) Polyethoxy oleyletherphosphate;

(xii) Zinc dialkyldithiophosphates;

(c) Other non-halogenated alternatives:

(i) Mineral oils;

(ii) Alkanol amides (e.g., 2:1 di-ethanolamine (DEA) tall oil fatty acid alkanol amide);

(iii) Diisopropyl oleate;

(iv) Nitrogen compounds;

(v) Boundary acid esters;

(vi) Complex esters;

(vii) Propylene oxide;

(d) Chlorinated organics (for extreme pressure MWFs):

(i) Chlorinated fatty esters and acids;

(ii) Long-chain chlorinated paraffins (C18+) (LCCPs);

(iii) Medium-chain chlorinated paraffins (C14-17) (MCCPs).

3.1.3 Alternative materials and techniques

Available alternative techniques include the use of systems based on gases such as supercritical CO_2, which has the density and solvency of a liquid while maintaining the compressibility and viscosity of a gas (Skerlos et al. 2008).

Industry has made significant progress developing environmentally adapted lubricants (EALs), which are readily biodegradable, have low toxicity, and perform equally or better than conventional alternatives (Skerlos et al. 2008). Bio-based formulations have the potential to reduce the waste treatment costs for MWF effluents and the occupational health risks associated with petroleum oil-based MWFs (Raynor et al. 2005). Synthetic and semi-synthetic lubricants, which are often diluted with water rather than volatile organic compound (VOC) solvents, may serve as alternatives.

Other alternative materials and techniques that have been used as alternatives for the use of SCCPs in metalworking fluids and other lubricants, including the following (UNEP POPRC 2016; UNEP 2018):

(a) Material substitution with environmentally adapted lubricants (EALs) in combination with alternative technology:

(i) bio-based lubricant formulations (soybean, pine tree, rapeseed, mustard, grape seed, sunflower, coconut, canola, etc.), with or without additives;

(ii) bio-based lubricants in combination with supercritical CO_2;

(iii) oil-in-CO_2 dispersion;

(iv) gas-based lubricant system;

(b) Material substitution with HIGTO(1) (a modified triglyceride based on rape seed) with a zirconium coating;

(c) Process change to dry machining (using no cutting fluid) (Shokrani et al. 2014);

(d) Process change to cryogenic machining (using liquid nitrogen or other liquified gases) (Shokrani et al. 2014);

(e) Process change to air delivery of lubricants;

(f) Process change to oil-free, low viscosity metal-forming lubricants with high solid polymers (HSM);

(g) Using synthetic and semi-synthetic lubricants (vegetable-based methyl esters or polymers of various types), which are often diluted with water rather than VOC solvents.

3.2 Secondary plasticizers in flexible polyvinyl chloride (including tubes for outdoor decoration bulbs), except in toys and children's products

3.2.1 Background

The used of SCCPs as secondary plasticizers in flexible polyvinyl chloride has been exempted, except for the use in toys and children's products (Table 1). Flexible PVC has many applications such as cable sheeting, in plumbing, conveyor belts, imitation leather, flooring, signage, phonograph records, inflatable products or tubes for outdoor decoration bulbs.

SCCPs are used mainly as secondary plasticisers. The primary plasticisers are generally phthalates or phosphate esters (Houghton 1993). Primary plasticisers in PVC are used to increase the elongation properties and softness of the polymer. SCCPs are used in PVC manufacturing primarily where moderate plasticizing and flame retarding properties are required at low cost (Government of Canada 2009). Secondary plasticisers, when used in combination with primary plasticisers, cause an enhancement of the plasticising effect, and so are known as extenders.

3.2.2 Alternative chemical

Chemical substances that can be used to replace SCCPs in polyvinyl chloride (PVC) applications include following substances (Government of Canada 2009; UNEP 2016a,b, 2018):

(a) Inorganic substances:

(i) Alumina trihydrate;

(ii) Aluminum trihydroxide (ATH), used in conjunction with antimony trioxide;

(iii) Aluminum trioxide;

(iv) Antimony trioxide (or Antimony oxide);

(v) Zinc borate;

(b) Organophosphorus flame retardants:

(i) Cresyl diphenyl phosphate (CDP);

(ii) Tertbutylphenyl diphenyl phosphate (TBPDPP);

(iii) Isopropylphenyl diphenyl phosphate (IPPDPP);

(iv) Phosphorus based compounds (in general);

(v) Tricresyl phosphate (TCP);

(c) Organohalogen substances:

(i) Long-Chain Chlorinated Paraffins (C18+) (LCCPs);

(ii) Medium-Chain Chlorinated Paraffins (C14-17) (MCCPs);

(d) Phthalates (generally, including phthalates esters):

(i) Di-isononyl'phthalate (DINP);

(ii) Di-isodecyl phthalate (DIDP);

(iii) Bis(2-ethylhexyl) phthalate (DEHP);

(iv) Butyl benzyl phthalate (BBP);

(v) Di-isoundecyl phthalate (DIUP);

(e) Other phtalate-like alternative: Tri-octyl trimellitate

(f) Polymeric additives: Acrylic polymers

3.2.3 Alternative materials and techniques

Material substitution with other elastic polymer have been identified as alternative materials that can replace the use of PVC applications containing SCCPs (UNEP 2018):

(a) Polyethylene;

(b) Polypropylene;

(c) Rubber;

(d) Ethylene vinyl acetate (EVA).

3.3 Rubber (Spare parts of rubber conveyor belts, production of transmission belts in the natural and synthetic rubber industry)

3.3.1 Background

SCCPs are exempted as spare parts of rubber conveyor belts in the mining and forestry industries and in the production of transmission belts in the natural and synthetic rubber industry (Table 1). SCCPs have been used as flame retardants in a variety of rubber products including natural rubber, styrene and butadiene rubber, polybutadiene rubber, acrylonitrile and butadiene rubber, butadiene or isoprene rubber, and ethylene propylene diene monomer-elastomer (RPA 2010). This includes mono-ply (solid woven) conveyor belts, referred to as PVG solid woven conveyor belts, consisting of a textile core impregnated with PVC and covered in rubber (RPA 2010). Alternatives to SCCPs for use in conveyor belts are available and include alternative chemicals and alternative materials or techniques.

3.3.2 Alternative chemicals

The following substances have been identified as possible replacement for SCCPs in rubber products such as rubber conveyor belts (Dick 2001; OSPAR 2006; BiPRO 2007; ECHA 2008; RPA 2010; UNEP 2018):

(a) Phosphate esters are viable alternatives in applications where a non-flammable plasticizer is needed (Dick 2001). There are a range of organophosphorus flame retardants available.

  (i) Cresyl diphenyl phosphate (CDP);

  (ii) Tertbutylphenyl diphenyl phosphate (TBPDPP);

  (iii) Isopropylphenyl diphenyl phosphate (IPPDPP);

  (iv) Tricresyl phosphate (TCP);

  (v) Phosphorus based compounds (in general).

(b) A range of inorganic alternative additives or combination of inorganic and organic additives can be used for some application:

  (i) Antimony trioxide (ATO) (or antimony oxide);

  (ii) Aluminum trihydroxide, used in conjunction with antimony trioxide (ATO);

  (iii) Borate and phosphate esters;

  (iv) Calcium sulphonates;

  (v) Sulphonated fatty esters;

  (vi) Zinc borate;

  (vii) Acrylic polymers.

(c) Other halogenated additives:

  (i) Medium-Chain Chlorinated Paraffins (C14-17) (MCCPs);

(ii) Long-Chain Chlorinated Paraffins (C18+) (LCCPs);

(iii) Alicyclic chlorinated compounds.

(d) If only the plasticizing property are needed than Phthalates (generally, including phthalates esters) can be used as alternatives.

(i) Bis(2-ethylhexyl) phthalate (DEHP);

(ii) Butyl benzyl phthalate (BBP);

(iii) Di-isononyl phthalate (DINP);

(iv) Di-isodecyl phthalate (DIDP);

(v) Di-isoundecyl phthalate (DIUP).

3.3.3 Alternative materials and techniques

SCCPs can be avoided by using inherently flame-resistant materials or flammability barriers, or by otherwise redesigning the product such that chemical flame retardants are not needed (New York Department of Health 2013). SCCP-free alternative conveyor belts types with inherent flammability include (RPA 2010; UNEP 2016a,b, 2018)

(a) PVC solid woven and

(b) chloroprene (CR) multi-ply.

For some transmission and conveyer belt applications silicone or silicone laminated conveyor belts can be used.

3.4 Leather industry, in particular fatliquoring in leather

3.4.1 Background

SCCP have been exempted for the use in the leather industry, in particular fatliquoring in leather (Table 1). The fatliquoring step is the last stage of leather preparation. The leather industry has used SCCPs as inexpensive bulking agents in fat liquors. They are not considered critical to leather processing (RPA 1997).

3.4.2 Alternative chemicals

Alternatives include (US EPA 2009; UNEP 2016a,b, 2018):

(a) Non-halogenated alternatives:

(i) Mineral oils;

(ii) Combination of mineral oils and animal oils or vegetable oils;

(b) Nitroalkanes:

(i) Sulfonated fatty acid esters;

(ii) Alkyl phosphate;

(c) Organochlorine alternatives:

(i) Medium-Chain Chlorinated Paraffins (C_{14-17}) (MCCPs);

(ii) Long-Chain Chlorinated Paraffins (C_{18+}) (LCCPs).

3.4.3 Alternative materials

The following natural oils can be used:

(a) Vegetable oils;

(b) Natural animal oils;

(c) Combination of animal and vegetable oils.

3.5 Waterproofing and fire-retardant paints

3.5.1 Background

Waterproofing and fire-retardant paints were listed as exemptions for SCCP use (Table 1). SCCPs are used as plasticisers and flame retarding agents in paints which often function at the same time as coatings (e.g. for metals). SCCPs are used in chlorinated rubber, vinyl copolymers and acrylic based paints and coatings and intumescent paints (ECHA 2008; RPA 2010) Applications include road marking paints, anti-corrosive coatings for metal surfaces, paints/coatings for swimming pool, manure pit, water tank and fish pond coatings, decorative paints for internal and external surfaces, and textile printing inks (RPA 2010).

Alternatives to SCCPs for use in coatings and paints are readily available and include alternative chemicals and alternative materials or techniques.

3.5.2 Alternatives chemicals

MCCPs and LCCPs are potential alternatives to SCCPs in coatings and paints (BiPRO 2007; ECHA 2008; RPA 2010). Alternate plasticizers include phthalate esters, polyacrylic esters, and diisobutyrate; alternate flame retardants include phosphate and boron containing compounds (ECHA 2008; RPA 2010). Overall, the alternatives include (UNEP 2016a,b, 2018):

(a) Medium-Chain Chlorinated Paraffins (C_{14-17}) (MCCPs)

(b) Long-Chain Chlorinated Paraffins (C_{18+}) (LCCPs)

(c) Boron- and silicon-based compounds (e.g., phosphorous-boron-nitrogen compounds)

(d) Diisobutyrate compounds

(e) Other organophosphorus flame retardants

(f) Phosphate esters

(g) Phosphorus-based compounds

(h) Phthalates (generally, including phthalates esters)

  (i) Butyl benzyl phthalate (BBP)

  (ii) Di-isoundecyl phthalate (DIUP)

(i) Polyacrylate esters

3.5.3 Alternative materials and techniques

Replacing paints requiring plasticizers with epoxy-based paints eliminates the need for SCCPs (UNEP 2018). For road marking, paints can be replaced with thermoplastic products, which do not contain SCCPs and provide improved durability (RPA 2010).

3.6 Adhesives/sealants

3.6.1 Background

While for adhesives an exemption has been granted, there is no particular exemption for sealants (Table 1). SCCPs are used as plasticiser and flame retardant in the production of adhesives and sealants. Since sealants might be used as adhesives, SCCPs might still be used in the production of sealants.

Adhesives and sealants are often considered together because they both adhere and seal; both must be resistant to their operating environments; and their properties are highly dependent on how they are applied and processed (Petrie 2000). The difference between an adhesive and sealant can be difficult to define as some are used as adhesives and vice versa. Generally, sealants are considered to be materials that are installed into a gap or joint to prevent water, wind, dirt or other contaminants from passing through the joint or crack. Adhesives, on the other hand, are used to transfer loads and are typically designed with much higher tensile and shear strength than sealants (Palmer and Klosowski, 1997).

SCCPs are used as plasticizers and in some cases as flame retardants in different adhesive and sealant materials including polysulphide, polyurethane, butyl and acrylic (BUA 1992, RPA 2010).

Alternatives to SCCPs for use in sealants and adhesives are readily available and include alternative chemicals and alternative materials or techniques.

3.6.2 Alternative chemicals

The following chemicals can be used as alternative plasticizers for polysulphides (European Commission. 2002 2002; Special Chem 2003; Wypych 2004; BiPRO 2007; Mittal & Pizzi 2009; McBride 2010; UNEP 2016a,b, 2018):

(a) Medium-Chain Chlorinated Paraffins (C_{14-17}) (MCCPs);

(b) Long-Chain Chlorinated Paraffins (C_{18+}) (LCCPs);

(c) 2,2,4-trimethyl-1,3-pentanediol;

(d) Alkyl sulphonic acid esters of phenol or cresol;

(e) Di-2-ethylhexyl adipate;

(f) Glycolate esters;

(g) Hydrogenated terphenyls;

(h) Phosphate esters;

(i) Phthalates (generally, including phthalates esters):

  (i) Di-isononyl phthalate (DINP);

  (ii) Di-isodecyl phthalate (DIDP);

  (iii) Bis(2-ethylhexyl) phthalate (DOP aka DEHP);

  (iv) Butyl benzyl phthalate (BBP);

  (v) Di-isoundecyl phthalate (DIUP);

(j) Polyacrylate esters.

The following chemicals can be used as alternative plasticizers for polyurethane formulations (McBride 2010):

(a) Dibenzoate;

(b) Dipropylene glycol.

3.6.3 Alternative materials and techniques

Urethane or silicone sealants, which do not contain SCCPs, can replace polysulphide or other sealants. In silicone sealants, polydimethylsiloxanes are used as plasticizers (UNEP 2016a,b).

SCCP plasticizers in dam sealants can be replaced with high molecular weight plasticizers, which are less prone to leaking monomers and additives (Danish Ministry of Environment 2014).

4 Alternatives for uses of SCCPs not exempted by the Convention

4.1 Textiles

4.1.1 Background

As a niche application, SCCPs have been used to provide a flame-retardant, waterproof and rot-proof finish to heavy textiles, such as military tents (RPA 2010). This use has not been exempted in the SC since alternatives to SCCPs in textiles are available. Some countries might still use SCCPs in textiles. Therefore, alternatives are briefly mentioned.

4.1.2 Alternative chemicals

The substances identified as replacement for SCCPs in textiles include (UNEP 2016 a,b, 2018):

(a) Acrylic polymers;

(b) Aluminum trihydroxide (ATH), used in conjunction with antimony trioxide;

(c) Antimony trioxide (or Antimony oxide);

(d) Phosphorus based compounds:

(i) Cresyl diphenyl phosphate (CDP);

(ii) Tertbutylphenyl diphenyl phosphate (TBPDPP);

(iii) Isopropylphenyl diphenyl phosphate (IPPDPP);

(iv) Phosphorus based compounds (in general);

(v) Tricresyl phosphate (TCP);

(vi) Phosphate esters;

(vii) Other organophosphorus flame retardants;

(e) Halogenated flame retardants:

(i) Bis (tribromophenoxy) ethane;

(ii) Dibromostyrene;

(iii) Ethane, 1,2-bis(pentabromophenyl) (EBP), used in conjunction with antimony trioxide;

(iv) Ethylenebistetrabromophthalimide;

(v) Hexachlorocyclodecane;

(vi) Brominated Phthalates (generally, including phthalates esters);

a. Tetrabromophthalate ester (TBPH);

b. Tetrabromophthalate diol;

c. Tetrabromophthalic anhydride;

(vii) Tribromophenyl allyl ether;

(viii) Medium-Chain Chlorinated Paraffins (C_{14-17}) (MCCPs);

(ix) Long-Chain Chlorinated Paraffins (C_{18+}) (LCCPs).

The use of flame retardants depends to some extent on the textiles (Peter Fisc Associates 2003):

(a) Halogenated flame retardants mixed with antimony trioxide can be used on wool, cotton, polyester, polyamide fibers and blends (upholstery fabrics and roof insulating fabric);

(b) Brominated flame retardants mixed with antimony trioxide can be applied on polyester and cellulosic fibers, modacrylic fibers, non-wovens for drapery, upholstery and textile coatings;

(c) Organophosphorus compounds, such as tris(isopropylphenyl) phosphate, are suitable for cellulosic, nylon and polyester fibers (upholstery fabric, garments, flexible ducting).

4.1.3 Alternative materials and techniques

Alternative materials and techniques to the use of SCCPs in textiles include replacing the flame retarded textiles with less flammable fabrics and materials (UNEP 2016a,b, 2018).

(a) Natural fabrics and materials include:

(i) Leather;

(ii) Wool.

(b) Synthetic fabrics

(i) Modacrylics;

(ii) Aramide.

Inherently flame-resistant materials can be used for example, by designing polymer backbones with very high heat and flame resistance, or by using metal instead of textiles.

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