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Item 4 (b) of the provisional agenda*

Technical work: consideration of a draft risk management evaluation on short-chain chlorinated paraffins

Additional information related to the draft risk management evaluation on short-chain chlorinated paraffins

Note by the Secretariat

As referred to in the note by the Secretariat on a draft risk management evaluation on short-chain chlorinated paraffins (UNEP/POPS/POPRC.12/4), the annex to the present note sets out additional information related to the draft risk management evaluation on short-chain chlorinated paraffins. The present note, including its annex, has not been formally edited.

* UNEP/POPS/POPRC.12/1.

Annex

Short-Chain Chlorinated Paraffins

(SCCPs)

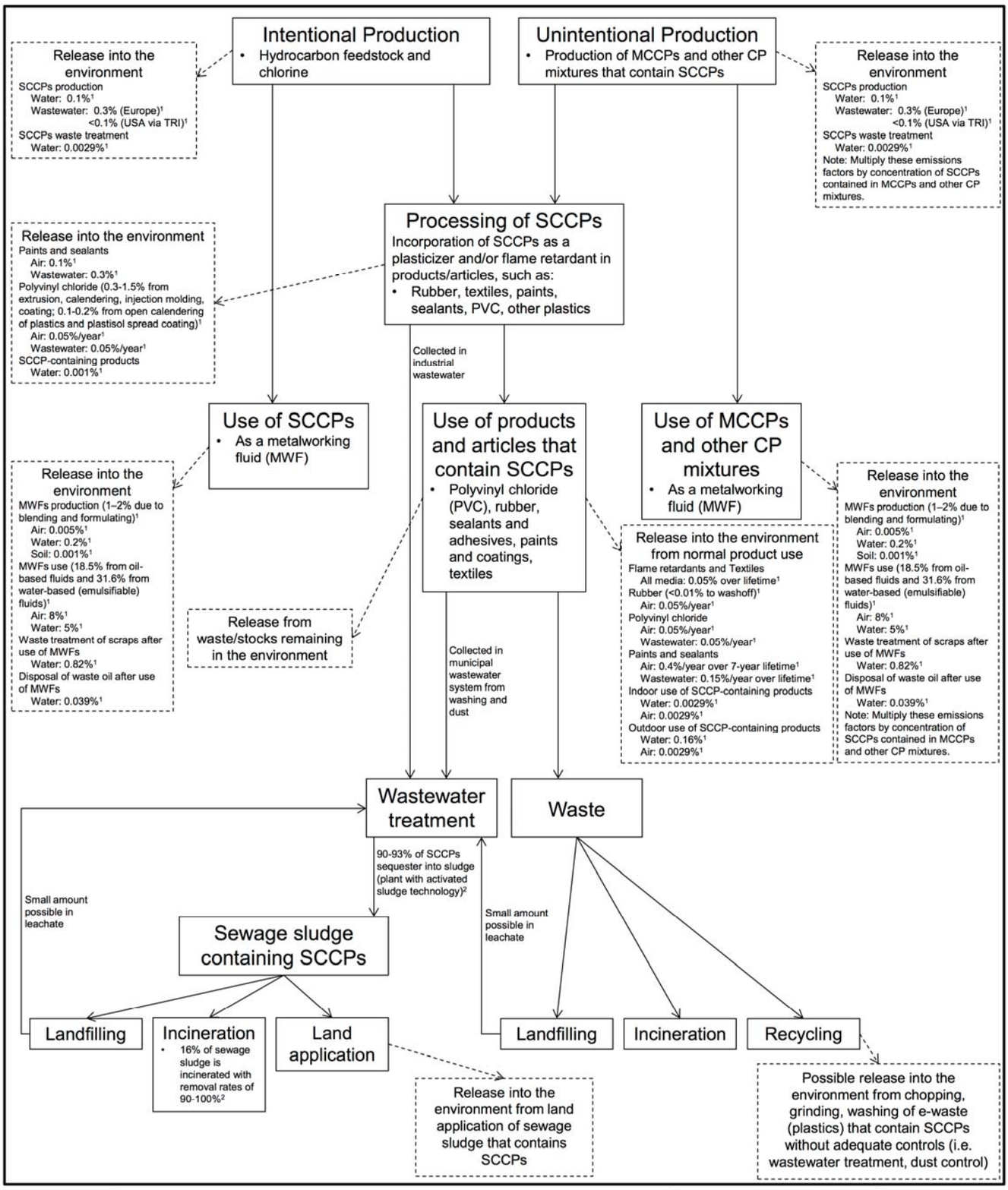
ADDITIONAL INFORMATION

Draft prepared by the intersessional working group on short-chain chlorinated paraffins under the POPs Review Committee of the Stockholm Convention

June 2016

Figure 1: Lifecycle and Estimated Releases of SCCPs

Note: Emission factors apply to annual consumption/use of SCCPs and products that contain SCCPs. The factors are expressed as percentages; therefore, to estimate the amount of a release in a specific scenario the concentration of SCCPs in the product is multiplied by the emission factor.[1]



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1. De Boer, J., El-Sayed Ali, T., Fiedler, H., Legler, J., Muir, D., Nikiforov, V.A., Tomy, G.T., Tsunemi, K. 2010. Chlorinated paraffins. The Handbook of Environmental Chemistry. Chlorinated Paraffins, vol. 10. Springer-Verlag, Berlin/Heidelberg
2. COHIBA Consortium (2011) Measures for emission reduction of short chain chlorinated paraffins (SCCP) and medium chain chlorinated paraffins (MCCP) in the Baltic Sea area, COHIBA Guidance document no. 8. http://www.cohiba-project.net/publications/en_GB/publications/_files/87107460254664293/default/SCCP-MCCP.pdf

Table 1. Potential alternative materials and processes for SCCPs

Note: "-" Denotes that no information is available

No	Potential alternatives	CAS No	Applications	Environmental and health properties	Loading	Price[2]	Economic feasibility, availability and accessibility	References
1	Material change to synthetic or semi-synthetic lubricants (vegetable-based methyl esters or polymers of various types)	-	Metalworking fluids	Less toxic - Often diluted with water rather than VOC solvents, which are used for petroleum-based lubricants (including those that contain SCCPs), to obtain the desired consistency	-	Double	Not technically feasible – water miscible and vegetable ester lubricants provide less lubricity than the petroleum-based lubricant. They do, however, serve as better coolants than the petroleum lubricant. Machines can run faster, which increases efficiency and number of parts processed Commercially available– but limited usage because they do not provide the necessary extreme pressure characteristics across the wide range of applications where chlorinated paraffins are used Not economically preferred as cost is twice as much per kilogram as chlorinated paraffins, although synthetic MWFs represent about 50% of lubricants used. Use of water miscible and vegetable ester lubricants also reduces disposal costs and cleaning requirements	US EPA (2004) Dover (2004) ECHA (2014)
2	Material substitution with environmentally adapted lubricants (EALs)	multiple	Metalworking fluids	Defined in the European Union (EU) as lubricants that have high biodegradability and low toxicity	-	-	Technically feasible - EALs performance are equal to or better than conventional alternatives	Theodori et al. (2004) Skerlos (2008)
	A oil-in-water emulsions, vegetable based	multiple	Metalworking fluids	See EALs (general)	-	-	Technically feasible - vegetable oil based (oleochemical) ingredients are already being substituted into traditional water-based formulations as alternatives to conventional fluids Commercially available - approximately 5% of all lubricants in the EU are now being sold as EAL oil-in-water emulsions, primarily as vegetable-based formulations, and their market share is growing	Norrby (2003) Clarens et al. (2004) Skerlos (2008) Theodori et al. (2004)

No	Potential alternatives	CAS No	Applications	Environmental and health properties	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	B bio-based lubricant formulations (soybean, pine tree, rapeseed, mustard, grape seed, sunflower, coconut, canola, etc),with or without additives	multiple	Metalworking fluids	Bio-based formulations could reduce the occupational health risks associated with petroleum oil based metalworking fluids due to their lower reported toxicity Soy coolants produce less mist for reduced inhalation problems, contain no chlorine or sulfur and reduces or eliminate dermatitis issues Highly biodegradable	50%	US$0.63-0.81/lb (Pine oil) US$0.26-0.30 (Soybean oil) US$0.80-0.83/lb (Rapeseed oil, over 45% erucic acid, dms) US$0.415/lb (Canola oil) US$0.48-0.56 (coconut oil)	Technically feasible − fats and oils can provide slipperiness, often much better than a mineral oil. Vegetable oils provide high strength lubricating films which interact strongly with metallic surfaces, reducing friction and wear. In some cases vegetable oils without additives have outperformed mineral oil based lubricants. Bio-based formulations perform better in manufacturing operations such as thread cutting. Genetic alternation, chemical modification and various additives can be used to counter the low oxidative stability of vegetable oil lubricants. Largely minimize the amount of cutting fluids used in machining while providing similar or even better cutting performances compared to wet cooling methods Use of soy metalworking fluids leads to less product use and less wear on tools as compared to petroleum-based metalworking fluids. Also reduces the water usage for mixing metalworking fluid by half. Mustard oil is very efficient both at high feed rate as well as at low feed rates Commercially available- would not provide fire retardancy, but vegetable oils (including rape seed, coconut, soybean, and sunflower) have higher flash points, reducing fire hazard and smoke formation. Vegetable oil based (oleochemical) ingredients are already being substituted into traditional straight-oil formulations as alternatives to conventional fluids. Fatty acid ester based oils (pine tree) have been successfully introduced in deep drawing production having good lubrication and antiwear properties, good corrosion resistance, good compatibility with paints, coating and seals Economically feasible - Soy metalworking fluids reduce retooling costs and increase productivity rates. Bio-based formulations have the potential to reduce the waste treatment costs required to meet the new MWF effluent limitation guidelines and standards published by the US EPA in the Metal Products and Machinery Rule. Their high cost relative to petroleum oils, is diminishing as petroleum prices increase	Shokrani et al. (2014) Danish EPA (2014) Boer (2010) Debnath (2014) Dover (2004) ICIS (2015) IWRC (2007) Clarens et al. (2004) Skerlos (2008) US EPA (2003) Rose and Rivera (1998) Ash and Dohlman (2005) Bay et al. (2010) Saleem et al. (2013)

No	Potential alternatives	CAS No	Applications	Environmental and health properties	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	C bio-based lubricants in combination with supercritical CO_2 ($scCO_2$) (e.g. oil-in-CO_2 dispersion)	-	Metalworking fluids	See EALs (general) See bio-based lubricant formulations (general)	-	-	Technically feasible − lubricants delivered in supercritical carbon dioxide are effective while maintaining the health and environmental advantages of air-based systems A system combining soybean oil with $scCO_2$ performs on average approximately 10% better than straight soybean oil, 20% better than the soybean oil microemulsion, and 30% better than scCO2 without oil. Also performed better than straight petroleum mineral oil and emulsions of petroleum oil Supercritical CO_2 is a convenient MWF carrier because it dissolves lubricants under pressure and carries them to the process without mixing. Supercritical CO_2 provides superior cooling to oil-in-air minimum quantity lubrication (MQL) systems. Also provides access to interstitial spaces that are inaccessible to conventional MWF oil and water jets	Skerlos (2008) Clarens et al. (2006)
	D gas-based lubricant systems	-	Metalworking fluids	Gas-based systems are somewhat higher in global warming potential (GWP)	-	-	Technically feasible − gas-based systems use less cutting fluids in machining while providing similar or even better cutting performances compared to wet cooling methods The possibility of increased GWP when switching to gas-based MWFs is a reasonable tradeoff for definite and large reductions in aquatic toxicity, water use, solid waste, and occupational health risks Gas-based systems do not require sophisticated control systems for abating fluid deterioration	Clarens et al. (2008) Skerlos (2008) Clarens et al. (2006)
3	Material substitution with HIGTO(1) (a modified triglyceride - rape seed based) with a zirconium coating	-	Metalworking fluids	Biodegradable	-	Chlorine-free fluids are approximately $1.20 per litre more expensive than those based on SCCPs	Technically feasible - exceeds the performance of chlorous deep-drawing oils	Klocke (2006) Klocke (2005) UK 2001.

No	Potential alternatives	CAS No	Applications	Environmental and health properties	Loading	Price[2]	Economic feasibility, availability and accessibility	References
4	Material substitution with other elastic polymers (i.e. Polyethylene, Polypropylene, rubber, Ethylenvinyacetate (EVA))	-	Polyvinyl chloride	-	-	-	Technically feasible, but may not be applicable to all applications Commercially available	Danish EPA (2014) PINFA (2013)
5	Material substitution with mineral products (e.g., magnesium oxide)	-	Other - Flame Retardant		Generally higher	-	Technically feasible –Lubricants for cold metal forming as well as metal cutting based on refined mineral oils with special additives of natural fatty components, synthetic esters, sulphur additives and PEP additives have had particular success in fine blanking of C-steel as well as alloyed steel and stainless steel. They have also shown very good performance in multistage deep drawing and ironing of stainless steel. Less performant than soybean oil in the tapping process Commercially available	Dufton (1995) Bay et al. (2010)
6	Process change to dry machining (no cutting fluids)	-	Metalworking fluids	-	-	-	Technically feasible – eliminates cutting fluids from machining whilst it has the potential to improve machinability. Provides similar or even better cutting performances compared to wet cooling methods Economically feasible – reduces the manufacturing costs significantly	Debnath (2014) Shokrani et al. (2014) Sreejith and Ngoi (2000)
7	Process change to cryogenic machining (liquid nitrogen)	-	Metalworking fluids	Generally considered as an environmentally friendly option Cold burns as a result of direct skin contact with super cold fluid, oxygen deprivation and nitrogen narcosis	-	-	Technically feasible - capability of enhancing the machinability of difficult-to-machine materials. Largely minimize the amount of cutting fluids used in machining while providing similar or even better cutting performances compared to wet cooling methods Additional costs given that health properties raise the requirement for personal protections for workers and oxygen monitoring facilities	Shokrani et al. (2014)

No	Potential alternatives	CAS No	Applications	Environmental and health properties	Loading	Price[2]	Economic feasibility, availability and accessibility	References
8	Process change to air delivery of lubricants	-	Metalworking fluids	Delivery of lubricants in air rather than water can reduce solid waste by 60%, water use by 90%, and aquatic toxicity by 80%, while virtually eliminating occupational health concerns The Global Warming Potential (GWP) values for the oil-in-air minimum quantity lubrication (MQL) system can drop by a factor of 10 if rapeseed oil is substituted for petroleum oil. The GWP of the rapeseed oil-in-air MQL system at least as good as the best case water-based MWF	-	Significantly lower costs	Not technically feasible −air-delivery of lubricants cannot be used for severe machining operations due to limitations of cooling and lubricant delivery	Debnath (2014) Skerlos et al. (2008) Clarens et al. (2006) Clarens et al. (2008)
9	Process change to oil free, low viscosity metal forming lubricants with high solid polymers (HSM)	-	Metalworking fluids	-	-	-	Technically feasible – they have been successfully implemented in stamping and punching of mild steel, advanced high strength steel, stainless steel, aluminium and titanium Commercially available	Bay et al. (2008) Bay et al. (2010)
10	Product substitution: Replace polysulhpide sealants by urethane sealants	-	Other: Sealants and adhesives	-	-	-	-	RPA (2010)
11	Product substitution: Replace polysulphide sealants by silicone sealants	-	Other: Sealants and adhesives	-	-	-	-	BAFU (2008) ECHA (2008) RPA (2010)

No	Potential alternatives	CAS No	Applications	Environmental and health properties	Loading	Price[2]	Economic feasibility, availability and accessibility	References
13	Product substitution: Replace flame retarded textiles with less flammable fabrics (i.e. wool, modacrylics and aramide) or leather	-	Other: Textiles	-	-	-	Technically feasible, but may not be appropriate for all applications Commercially available	PINFA (2010)
14	Product substitution: Replace flame retarded materials with inherently flame resistant materials (i.e. by designing polymer backbones with very high heat and flame resistance or by using metal)	-	Other: Textiles, flame retardants	-	-	-	Technically feasible, but may not be appropriate for all applications Commercially available	PINFA (2010) CPA (2007)
15	Product substitution: Replace paints requiring plasticizers with epoxy-based paints	-	Other: paints and coatings	-	-	-	Technically feasible, but may not be appropriate for all applications Commercially available	Subsport (2013)

Table 2. Potential alternative substances for SCCPs

Note: "-" Denotes that no information is available

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
1	Medium-Chain Chlorinated Paraffins (C_{14-17}) (MCCPs)	multiple	Metalworking fluids Polyvinyl chloride Other – rubber and plastics (other than polyvinyl chloride), paints and coatings, sealants and adhesives, textiles, flame retardant	Subject to long-range transport and detected in Arctic biota Canadian assessment concluded that MCCP (C14-17) are highly persistent and bioaccumulative and toxic to aquatic sepcies at low concentrations US EPA states that C14-17 (40-60 wt% Cl), C14-16 and Tetradecane, chloro may be very persistent; longer chain and higher chlorination can contribute to greater persistence under most environmental conditions US EPA states that C14-17 (40-60 wt% Cl), C14-16 and Tetradecane, chloro may be very bioaccumulative; but less absorption with the longer chain lengths and higher degree of chlorination. Some congener groups in MCCP products may be bioaccumulative or very bioaccumulative	Substance included in CoRAP. Registered under REACH, but is not considered a PBT substance in the EU. Substance included in the Community Rolling Action Plan (CoRAP) MCCP (C14-17) are on the List of Toxic Substances under the *Canadian Environmental Protection Act, 1999* MCCP (C14-17) were included by US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	Possibly higher use rate (~110%) in metalworking fluids MCCPs typically represent 6-15% by weight of the total compound. When used as the primary plasticizer (i.e. 40-45 parts per hundred), the increased presence of other additives restricts MCCP presence to 8-10% by weight of the total compound	Similar cost of substance with possible higher use rate, but, unit cost of MCCPs is lower by around 25% per tonne	Technically feasable, commercially available, economically feasible Possible additional one-off costs Currently in use as an alternative to SCCPs.	Germany (2015) Canada (2009) Canada (2008) US EPA (2015a)[1] US EPA (2015b)[2] US EPA (2015c)[3] ECHA (2008) RPA (2010) BiPro (2007) UK (2001) UK (2008) EC (2007) RPA (2002) ECHA (2016) Dover (2013) CoRAP (2016) Reth et al. (2006) ECHA (2014) Subsport (2013)

[1,2,3] 26 comments have been received by the US EPA on this proposed assessment. The US EPA has also requested the submission of additional information related to these substances. Additional information can be found here: https://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2015-0789-0001

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	MCCPs (continued)			US EPA states that C14-17 (40-60 wt% Cl), C14-16 and Tetradecane, chloro may present an unreasonable risk following acute and chronic exposures to aquatic organisms, and may cause long-term adverse effects in the aquatic environment Effects on liver, kidney and reproductive system. Repeated exposure may cause skin irritation. Unlikely to pose a carcinogenic hazard to humans C15 51 wt% Cl was found to be inherently degradable and possibly readily degradable in OECD 301 and 301D tests Substances with chlorine contents above 50% by weight are generally not readily biodegradable. C14 constituents with chlorine contents around 50% to 56% by weight, and C15 constituents with a ~51% chlorine content are potentially persistent and bioaccumulative and they are considered to meet the toxicity criterion. C15 to C17 constituents with a chlorine content >55% by weight are not considered bioaccumulative, but they met the persistent criterion	Harmonised classification and labelling (ATP01): very toxic to aquatic life and very toxic to aquatic life with long lasting effects Additional classification: substance may cause harm to breast-fed children				

2	Long-Chain Chlorinated Paraffins (C_{18+}) (LCCPs)	multiple	Metalworking fluids Polyvinyl chloride Other − leather, rubber and plastics (other than PVC), paints and coatings, sealants and adhesives, textiles, flame retardant	Canadian assessment concluded that LCCP (C18-20) are highly persistent and bioaccumulative and toxic to aquatic sepcies at low concentrations. However, LCCPs with more than 20 carbons were found to be persistent but not bioaccumulative US EPA states that C18-20 (40-55 weight percent chlorination [wt% Cl]) and Octadecane, chloro are likely to be persistent to very persistent; longer chain and higher chlorination can contribute to greater persistence under most environmental conditions US EPA states that C18-20 (40-55 weight percent chlorination [wt% Cl]) and Octadecane, chloro are potentially bioaccumulative; some congener groups in LCCP products may be bioaccumulative or very bioaccumulative US EPA states that C18-20 (40-55 weight percent chlorination [wt% Cl]) and Octadecane, chloro may present an unreasonable risk following acute and chronic exposures to aquatic organisms, and may cause long-term adverse effects in the aquatic environment Not found to meet toxicity criteria Not likely to be a human carcinogen. Potential to cause slight skin irritation and sensitization. Some constituents may not be readily biodegradable	CAS 63449-39-8 is registered under REACH Not classified as hazardous to human health or the environment in the EU LCCP (C18-20) are on the List of Toxic Substances under the *Canadian Environmental Protection Act, 1999* LCCP (C18-20) were included by US EPA on the 2014 updatedTSCA Work Plan Chemicals for Assessment	~110% loading when compared to SCCPs	Cost increase of 20-160 % depending on application formulation and requirements for polyvinyl chloride Additional one-off costs	Technically feasible, commercially available Likely additional one-off costs, and higher cost of substance Used in conjunction with aluminum hydroxide and brominated products (in small quantities) as an alternative to SCCPs in PVC	US EPA (2009) Canada (2008) Canada (2009) US EPA (2015a)[4] US EPA (2015b)[5] ECHA (2008) RPA (2010) Dover (2013) Danish EPA (2014)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
3	Acrylic polymers	multiple	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), textiles, flame retardant	According to the classification provided by companies to ECHA in CLP notifications, CAS no. 9065-11-6 is harmful if swallowed, is harmful in contact with skin, causes serious eye irritation, is harmful if inhaled and causes skin irritation According to the classification provided by companies to ECHA in CLP notifications, CAS no. 9003-01-4 may cause genetic defects, may cause cancer, causes severe skin burns and eye damage, causes serious eye irritation, is harmful if inhaled, causes skin irritation and may cause respiratory irritation	Pre-registered under REACH	-	-	-	Danish EPA (2014) ECHA (2016) Subsport (2013)

[4, 5] 26 comments have been received by the US EPA on this proposed assessment. The US EPA has also requested the submission of additional information related to these substances. Additional information can be found here: https://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2015-0789-0001

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
4	Alkanolamides (e.g., 2:1 diethanolamine (DEA) tall oil fatty acid alkanolamide)	multiple	Metalworking fluids	Potential health concerns for *n*-nitrosodiethanolamine contamination in heated or pressurized MWFs Certain nitrosamines, such as N-nitrosodiethanolamines (NDELA), are known to be cancer causing agents Additional classification: toxic to aquatic life with long lasting effects, causes serious eye damage, causes skin irritation and may cause an allergic skin reaction Harmonised classification and labelling (CLP00): causes severe skin burns and eye damage, is a highly flammable liquid and vapour, is harmful if swallowed, is harmful in contact with skin and is harmful if inhaled. Additional classification: toxic in contact with skin, causes serious eye damage and may cause respiratory irritation	Fatty acids, tall-oil, compounds with ethanolamine are pre-registered under REACH DEA is registered under REACH	-	The cost increase of substituting to non-chlorinated substances is estimated to be as much as $5,000 per tonne Chlorine-free fluids are approximately $1.20 per litre more expensive than SCCPs	Technically feasible; minimal information on economic feasibility and commercial availability 2:1 diethanolamine (DEA) tall oil fatty acid alkanolamide is currently used in soluble, synthetic and semi-synthetic MWFs Not considered to be a significant substitute	Canada (2009) Morpeth (2012) CCOHS 2014) Dover (2004) UK (2001) ECHA (2016)
5	Alumina trihydrate	8064-00-4	Polyvinyl chloride Other - Flame Retardant	-	-	Generally higher	Inorganic flame retardants, such as ATH, are generally less expensive	Technically feasible, commercially available, economically feasible Leading substitute for chlorinated paraffins in PVC cables	RPA (2002)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
6	Aluminum trihydroxide, used in conjunction with antimony trioxide (ATH)	21645-51-2	Polyvinyl chloride Other - rubber and plastics (other than polyvinyl chloride), textiles, flame retardant	Antimony trioxide is carcinogenic Aluminum hydroxide is readily biodegradable and non toxic Additional classification: causes serious eye irritation, causes skin irritation and may cause respiratory irritation	Registered under REACH	Combined concentration is approximately 11-15% with antimony representing 3-5% and aluminum 8-10% of the formulation	Low cost compared to SCCPs	Technically feasible in electrical equipment and as flame retardant in rubber, as long as high plasticity of the product is not vital, but may not be applicable to all applications, Commercially available Used extensively by PVC cable manufacturers, while usage of this alternative in other PVC applications is unknown	RPA (2002) Canada (2010) ECHA (2016) ECHA (2008) PINFA (2010) Subsport (2013)
7	Aluminum trioxide	1344-28-1	Polyvinyl chloride Other - Flame Retardant	Additional classification: harmful if swallowed and harmful if inhaled and may cause respiratory irritation	Registered under REACH	Variable loadings (approximately 1-15%), used in conjunction with halogenated flame retardants	-	-	Danish EPA (2014) RPA (2010) ECHA (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
8	Antimony trioxide (or Antimony oxide)	1309-64-4	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), textiles, flame retardant	Antimony trioxide is carcinogenic Additional classification: may damage fertility or the unborn child, causes damage to organs through prolonged or repeated exposure and is harmful to aquatic life with long lasting effects	Registered under REACH Harmonised classification and labelling (CLP00): suspected of causing cancer Antimony Trioxide (Antimony & Compounds on TSCA Work Plan) was included by US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	Variable loadings (approximately 1-15%), used in conjunction with halogenated flame retardants	Use would likely increase the raw material costs	Antomony trioxide is not a technically feasible alternative due to its hazardous properties	Canada (2009) Danish EPA (2014) RPA (2010) Canada (2010) ECHA (2016) Subsport (2013)
9	Animal and/or vegetable oils and/or mineral oil	multiple	Other - Leather	Highly refined mineral base oils have low acute toxicity by ingestion and skin contact Can cause slight skin and eyes irritation Crude oils contain polycyclic aromatic hydrocarbons (PAH); some are known carcinogens Bioaccumulation may be a potential concern for all base oils According to the classification provided by one company to ECHA in CLP notifications mineral oil is harmful to aquatic life with long lasting effects		-	15% more than SCCPs The higher cost is considered to be negligible	Technically feasible, commercially available, economically feasible	Danish EPA (2014) RPA (1997) Danish EPA (2005) BiPro (2007) Boer (2010) ECHA (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
10	Bis (tribromophenoxy) ethane	37853-59-1	Other – Textiles, flame retardant	Skin irritant Found in Arctic biota	Pre-registered under REACH Subject to Section 8(a) of TSCA under US EPA	-	-	-	ECHA (2008) ECHA (2016) Lewis (2004) Vorkamp (2015) Subsport (2013)
11	Boron- and silicon-based compounds Ex: Phosphorous-boron-nitrogen compounds	-	Other – Paints and coatings	According to the classification provided by companies to ECHA in CLP notifications boron is harmful if swallowed and may cause long lasting harmful effects to aquatic life	Boron is registered under REACH	-	-	Technically feasible, but does not provide plasticizing effect Not commercially available - developed relatively recently and not currently being widely used	Danish EPA (2014) Blachford (2004) ECHA (2016) Subsports (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
12	Decabromodiphenyl ether (c-decaBDE) (halogenated flame retardant), used in conjunction with antimony trioxide	1163-19-5	Other - Textiles, flame retardant	The POPs Review Committee decided that BDE-209, the main constituent of c-decaBDE 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 Neurotoxicant. Persistent. Not readily biodegradable; low to moderate bioaccumulation potential Antimony trioxide is carcinogenic Classification provided by companies to ECHA in CLP notifications: substance causes serious eye irritation, is harmful if swallowed, is harmful in contact with skin, may cause long lasting harmful effects to aquatic life, is suspected of causing genetic defects and may cause damage to organs through prolonged or repeated exposure	Registered under REACH c-decaBDE has been proposed for listing to the Stockholm Convention according to the decision of POPRC-11 decaBDE was included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	25% by weight (in conjuction with antimony trioxide)	Brominated FRs are €4.4/kg vs chlorinated FRs at €1.4/kg based (1999 value) Significantly higher substance cost than SCCPs	Technically feasible, commercially available Additional one-off costs	ECHA (2008) Canada (2010) ECHA (2016) Subsport (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
13	Dibromostyrene	31780-26-4 and 125904-11-2	Other – Textiles, flame retardant	Not readily biodegradable According to the classification provided by companies to ECHA in REACH registrations this substance is toxic to aquatic life with long lasting effects, causes serious eye irritation, causes skin irritation and may cause respiratory irritation	CAS 31780-26-4 is pre-registered under REACH CAS 125904-11-2 is registered under REACH TSCA Section 5(e) New Chemical Exposure Limit (NCEL) set at 0.3 (ppm) under US EPA and substance is identified in a SNuR under TSCA	-	-	-	ECHA (2008) ECHA (2016) Subsport (2013)
14	Diisobutyrate compounds	multiple	Other - Paints and coatings	Diisobutyrate is readily biodegradable but failing the 10-day window According to the classification provided by companies to ECHA in REACH registrations this substance is harmful to aquatic life with long lasting effects Additional classification provided by companies to ECHA in CLP notifications identifies that this substance is toxic to aquatic life with long lasting effects, causes serious eye irritation, may cause damage to organs through prolonged or repeated exposure and causes skin irritation	Registered under REACH	-	-	Technically feasible, but doest not provide plasticizing effect	Danish EPA (2014) ECHA (2008) ECHA (2016) Subsports (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
15	Isopropyl oleate	112-11-8	Metalworking fluids	Readily biodegradable	Registered under REACH	-	Chlorine-free fluids are approximately $1.20 per litre more expensive than those based on SCCPs	Not considered as a significant substitute; commonly used in the formulation of standard water miscible metalworking fluids	Canada (2009) Dover (2004) UK (2001) ECHA (2016) Eastwood (2005)
16	Ethane, 1,2-bis(pentabromophenyl) (EBP), used in conjunction with antimony trioxide	84852-53-9	Other – Textiles, flame retardant	Limited data, but likely low toxicity Not readily biodegradable, may be persistent Antimony trioxide is carcinogenic According to the classification provided by companies to ECHA in CLP notifications this substance may cause long lasting harmful effects to aquatic life	Substance included in the CoRAP Registered under REACH	Typical loading 10-30 g/m2	Comparable to decaBDE or slightly higher Significantly higher substance cost than SCCPs	Technically feasible, commercially available Additional one-off costs	ECHA (2008) Canada (2010) ECHA (2016) CoRAP (2016) Subsport (2013)
17	Ethylenebistetrabromophthalimide	32588-76-4	Other – Textiles, flame retardant	Not readily biodegradable According to the classification provided by companies to ECHA in CLP notifications this substance causes serious eye irritation	Substance included in the CoRAP Registered under REACH	-	-	-	ECHA (2008) ECHA (2016) CoRAP (2016) Subsport (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
18	Hexabromocyclododecane (HBCD) (halogenated flame retardant) in combination with antimony trioxide	25637-99-4 (3194-55-6)	Other - Textiles, flame retardant	The POPs Review Committee decided 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 Developmental effects Persistent, bioaccumulative, and of chronic and acute toxicity to aquatic organisms Antimony trioxide is carcinogenic	HBCD has been listed to Annex A of the Stockholm Convention. Substance of very high concern requiring authorisation before it is used (Annex XIV of REACH) Harmonised classification and labelling (ATP03): suspected of damaging fertility or the unborn child US EPA has included HBCD (CASRN 25637-99-4, 3194-55-6 and 3194-57-8) on the 2014 updated TSCA Work Plan Chemicals for Assessment	25% by weight (in conjuction with antimony trioxide)	Comparable to decaBDE or slightly higher Significantly higher substance cost than SCCPs	Technically feasible, commercially available Additional one-off costs	ECHA (2008) Canada (2010) ECHA (2016) Subsport (2013)
19	Hexachlorocyclodecane		Other – Textiles, flame retardant	-	-	-	-	-	Subsport (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
20	Nitrated compounds (e.g. Doverlube NCEP- Nitrogen containing compound)	multiple	Metalworking fluids	-	-	1:1 Used at 10% treat rate in soluble oil and water-based MWFs	Chlorine-free fluids are approximately $1.20 per litre more expensive than those based on SCCPs	Technically feasible - Outperforms chlorinated extreme pressure additives in machining operations, especially with hard to machine materials such as hard-chrome steels and titanium. It also outperformed chlorinated extreme pressure additives as well as phosphorous and sulphur containing additives in terms of tool life and surface finish. It also performs well with aluminum and softer non-ferrous metals to reduce chip size and scuffing Doverlube NCEP-Nitrogen containing compound is an alternative on stainless and low-ferrous alloys	Nguyen (2007) UK (2001) Dover (not dated)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
21	Other Organophosphorus flame retardants (in general)	multiple	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), paints and coatings, textiles, flame retardant	Toxicity to liver, kidney and blood Certain organophosphate flame retardants have additional toxic effects, including carcinogenicity and neurotoxicity. They are resistant to degradation, especially the chlorinated OPs. Certain OP flame retardants are subject to long-range transport and present in polar regions. TCEP and TCPP were predominating OP compounds in air samples in polar regions Another study showed sumOPE concentrations 1-2 orders of magnitude higher than the sum of BFR concentratiosn in the European Arctic, with non chlorinated and chlorinated OPs measured	-	-	300%	Technically feasible, commercially available, significantly higher substance costs Additional one-off costs Currently used in PVC belting (rather than rubber) IPPDPP is a technically feasible alternative due to its lower toxicological effect in trials when compared to CDP and TBPDPP	RPA (2002) ECHA (2008) Moller (2012) Salamova (2014) Subsports (2013)
	A Cresyl diphenyl phosphate (CDP)	26444-49-5	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride)	Toxicity to liver, kidney and blood Acts as endocrine disruptor in mouse cells Not considered to be persistent or bioaccumulative According to the classification provided by companies to ECHA in CLP notifications CDP is very toxic to aquatic life with long lasting effects, is very toxic to aquatic life and is harmful if swallowed	Pre-registered under REACH	-	See Organo-phosprorus (general)	Commercially available - used as a flame retardant in coal mine belting No information on technical feasibility - the belt material may be PVC rather than the chlorinated rubber in which SCCPs are used Additional one-off cost could be significantly high	ECHA (2008) ECHA (2016) Schang (2016) Subsport (2013)

No	Potential substance alternatives		CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	B	Tertbutylphenyl diphenyl phosphate (TBPDPP)	56803-37-3 and 68937-40-6	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride)	Possible liver, kidney and adrenal toxicity Acts as endocrine disruptor in mouse cells Accumulates in fish tissues, persistent in some ecosystems. Provisional classification as very toxic to aquatic organisms According to the classification provided by companies to ECHA in CLP notifications this substance is very toxic to aquatic life and is harmful if inhaled	Pre-registered under REACH	-	See Organo-phosprorus (general)	Commercially available - used as a flame retardant in coal mine belting No information on technical feasibility - the belt material may be PVC rather than the chlorinated rubber in which SCCPs are used Additional one-off cost could be significantly high	ECHA (2008) ECHA (2016) Schang (2016) Jarema (2015) Heitkamp (1985) Heitkamp (1986) Subsport (2013)
	C	Isopropylphenyl diphenyl phosphate (IPPDPP)	28108-99-8	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride)	Low toxicity; acute aquatic toxicity <1 mg/l Not considered to be persistent or bioaccumulative but poorly characterized Readily biodegradable	Pre-registered under REACH	-	See Organo-phosprorus (general)	Commercially available - used as a flame retardant in coal mine belting No information on technical feasibility - the belt material may be PVC rather than the chlorinated rubber in which SCCPs are used Additional one-off cost could be significantly high	ECHA (2008) ECHA (2016) Subsport (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
22	Overbased calcium sulphonates	multiple	Metalworking fluids	Potential to cause inflammatory skin changes May cause adverse effects on the lungs Vapour/mist has the potential to cause irritation of mucous membranes and respiratory tract	-	-	Chlorine-free fluids are approximately $1.20 per litre more expensive than those based on SCCPs	Technically feasible as extreme pressure additives, especially in the presence of sulphurized esters, but not for all applications These are acceptable substitutes for chlorinated paraffins in extreme pressure and temperature conditions where staining caused by oil-based fluids is not a problem	Canada (2009) UK (2008) RPA (2002) UK (2001)
23	PEP additives	multiple	Metalworking fluids	-	-	-	Chlorine-free fluids are approximately $1.20 per litre more expensive than those based on SCCPs	-	Bay (2010) UK (2001)
24	Phosphate esters		Other - Paints and coatings, sealants and adhesives, textiles, flame retardant	Certain phosphate esters are persistent and subject to long-range environmental transport	Phosphate esters were included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	-	-	Technically feasible, commercially available Where the plasticising effect is important phosphate esters can be used to replace more flammable plasticisers	Boer (2010) RPA (2010) ECHA (2008) SpecialChem (2003) COHIBA (2011) Subsport (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
25	Phosphorus based compounds (in general)	multiple	Metalworking fluids – extreme pressure additives Polyvinyl chloride Other – rubber and plastics (other than polyvinyl chloride), paints and coatings, textiles, flame retardant	Certain phosphate esters are persistent and subject to long-range environmental transport Phosphorous appears to be of low toxicity to aquatic organisms; however, its presence in the environment can cause problems if conversion to phosphates leads to eutrophication. It should be noted that a primary source of phosphorous in the aquatic environment is the use of detergents, therefore the contribution from metalworking fluids is considered minor Phosphorus' acute toxicity (eyes, skin) is marginally worse than CPs. For chronic toxicity CPs are worse than phosphorus compounds	-	-	Chlorine-free fluids are approximately $1.20 per litre more expensive than those based on SCCPs	Technically feasible, commercially available Susceptible to bacterial degradation unless biocides are added Currently used as extreme pressure additives in metalworking fluids Potential major formulation changes could entail significant costs for the manufacturer Note that alkyl phosphate esters provide better performance than aryl derivatives. Aliphatic phosphate esters provide emulsifying properties for water-based metalworking fluid formulations	Canada (2009) Morpeth (2012) RPA (1997b) Cromac (2004) Dover (2004) Byers (2006) UK (2001) RPA (2002) Subsport (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	A alkyl phosphate esters	multiple	Metalworking fluids – extreme pressure additives	See Phosphorus (general) Classification provided by companies to ECHA in CLP notifications identifies that this substance is harmful to aquatic life with long lasting effects, causes serious eye irritation, causes skin irritation and may cause allergy or asthma symptoms or breathing difficulties if inhaled	Triisobutyl phosphate is registered under REACH	-	-	See Phosphorus (general)	COHIBA (2011) ECHA (2016)
	B Phenol, isopropylated, phosphate (ITAP) (3:1)	68937-41-7	Metalworking fluids	Human health rating 1(see table note) Not irritating, sensitising or genotoxic Moderate repeated dose toxicity. No information on reprotoxicity/developmental effects/carcinogenicity According to the classification provided by companies to ECHA in REACH registrations this substance is very toxic to aquatic life with long lasting effects, is suspected of damaging fertility or the unborn child and may cause damage to organs through prolonged or repeated exposure	Registered under REACH Included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	-	See Phosphorus (general)	See Phosphorus (general)	UK (2008) Danish EPA (2005) ECHA (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	C Tributyl phosphate (TBP)	126-73-8	Metalworking fluids	Human health rating 5 (see table note) due to potential carcinogenic effect Acutely toxic by the oral route; skin irritant Initial indications are that TBP poses a risk to the environment and to top predators due to releases associated with the production and use of metalworking fluids Additionally, the classification provided by companies to ECHA in REACH registrations identifies that this substance is harmful to aquatic life with long lasting effects	Tributyl phosphate is registered under REACH Substance included in CoRAP Harmonised classification and labelling (CLP00): harmful if swallowed, is suspected of causing cancer and causes skin irritation.	-	See Phosphorus (general)	See Phosphorus (general)	Canada (2009) UK (2008) RPA (2002) Danish EPA (2005) ECHA (2016) CoRAP (2016)
	D Triaryl phosphate	-	Metalworking fluids	Human health rating 4 or 5 (see table note)	-	-	See Phosphorus (general)	See Phosphorus (general)	Danish EPA (2005)
	E bis(2-ethylhexyl) hydrogen phosphate	298-07-7	Metalworking fluids	Human health rating 3 (see table note) Readily biodegradable According to the classification provided by companies to ECHA in REACH registrations this substance causes severe skin burns and eye damage, is harmful if swallowed and causes serious eye damage. Additionally, the classification provided by companies to ECHA in CLP notifications identifies that this substance is harmful in contact with skin and causes skin irritation	Registered under REACH	-	See Phosphorus (general)	See Phosphorus (general)	Danish EPA (2005) ECHA (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	F didodecyl phosphite	21302-09-0	Metalworking fluids	Human health rating 2 (see table note) Skin irritant According to the classification provided by companies to ECHA in CLP notifications this substance causes serious eye irritation, causes skin irritation and may cause respiratory irritation	Pre-registered inder REACH	-	See Phosphorus (general)	See Phosphorus (general)	Danish EPA (2005) UK (2008) ECHA (2016)
	G Dimethyl hydrogen phosphite	868-85-9	Metalworking fluids	Human health rating 5 (see table note) due to carcinogenic potential Acutely toxic, eye and skin irritant, classified by the International Agency for Research on Cancer (IARC) as Category 3 carcinogen According to the classification provided by companies to ECHA in REACH registrations this substance is suspected of causing genetic defects, is suspected of causing cancer, is harmful to aquatic life with long lasting effects and may cause an allergic skin reaction Additionally, the classification provided by companies to ECHA in CLP notifications identifies that this substance is toxic in contact with skin, causes serious eye irritation, is a flammable liquid and vapour and causes skin irritation	Registered under REACH Substance included in CoRAP	-	See Phosphorus (general)	See Phosphorus (general)	Danish EPA (2005) UK (2008) ECHA (2016) CoRAP (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	H 2-ethylhexyl hydrogen phosphate	1070-03-7	Metalworking fluids	Human health rating 3 (see table note) According to the classification provided by companies to ECHA in CLP notifications this substance causes severe skin burns and eye damage, causes serious eye damage and is harmful in contact with skin	Pre-registered under REACH	-	See Phosphorus (general)	See Phosphorus (general)	Danish EPA (2005) ECHA (2016)
	I Polyethoxy oleyletherphosphate	39464-69-2	Metalworking fluids	Human health rating 1 (see table note) According to the classification provided by companies to ECHA in CLP notifications this substance causes severe skin burns and eye damage, causes serious eye damage, may cause long lasting harmful effects to aquatic life and causes skin irritation	Pre-registered under REACH	-	See Phosphorus (general)	See Phosphorus (general)	Danish EPA (2005) ECHA (2016)

No	Potential substance alternatives		CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	J	Zinc dialkyldithiophosphates	68649-42-3 and 84605-29-8	Metalworking fluids	Human health rating 2 or 3 (see table note) Eye and skin irritant According to the classification provided by companies to ECHA in CLP notifications 68649-42-3 is toxic to aquatic life with long lasting effects, causes serious eye damage and causes skin irritation According to the classification provided by companies to ECHA in REACH registrations 84605-29-8 is toxic to aquatic life with long lasting effects, causes serious eye damage and causes skin irritation	68649-42-3 is pre-registered under REACH 84605-29-8 is registered under REACH	-	ZDDP leaves a residue (ash) on the metal that must be removed, adding to processing time	Commercially available Partial substitute - used as extreme pressure additives especially in motor oils, but also in lubricants for metalworking	Danish EPA (2005) RPA (2002) UK (2008) ECHA (2016)
	K	Zinc Dialkyl Dithiophosphate (Zinc BDBP)	2215-35-2	Metalworking fluids	See Phosphorus (general) According to the classification provided by companies to ECHA in REACH registrations this substance is toxic to aquatic life with long lasting effects, causes serious eye damage and causes skin irritation	Registered under REACH	-	See Phosphorus (general)	See Phosphorus (general)	Canada (2009) ECHA (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	L Tricresyl phosphate (TCP)	1330-78-5	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride)	According to the classification provided by companies to ECHA in CLP notifications this substance is very toxic to aquatic life with long lasting effects, is very toxic to aquatic life, is suspected of damaging fertility or the unborn child, is harmful if swallowed, is harmful in contact with skin, may cause damage to organs through prolonged or repeated exposure and may cause an allergic skin reaction	Pre-registered under REACH Substance included in CoRAP	-	Likely an increase in cost of the raw materials	See Phosphorus (general)	Canada (2015) ECHA (2016) CoRAP (2016)
26	Phthalates (generally, including phthalates esters)	multiple	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), paints and coatings, sealants and adhesives	Readily biodegradable, generally no effects at solubility Possible developmental effects Certain phthalate esters are reproductive toxicants	Substances restricted under REACH. Listed under Annex XVI to REACH	20-30% less	€300 more per tonne of SCCPs	Phthalate esters: Technically feasible, but does not provide flame retardancy, commercially available Price of phthalates are generally significantly higher than chlorinated paraffins One-off costs could be significant DEHP, DINP and DIDP are not technically feasible alternatives due to their hazardous	Canada (2015) Canada (2015b) RPA (2002) ECHA (2008) Boer (2010) Subsports (2013) Dover (2004) Ashland (2004) TOXNET Sin List EASD IARC ECHA (2016) Danish EPA (2014) CPSC (2010) DIDP MSDS
	A Di-'isononyl' phthalate (DINP)	28553-12-0 and 68515-48-0	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), sealants and adhesives	Endocrine disruptor, Reproductive effects, Carcinogenic effects Readily biodegradable	Registered under REACH Some uses of this substance are restricted under Annex XVII of REACH Included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	20% less Additional one-off costs	C$4.15/kg in comparison to C$2.20-2.60 for chlorinated paraffins		

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	B Di'isodecyl' phthalate (DIDP)	68515-49-1 and 26761-40-0	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), sealants and adhesives	Possible reproductive effects, possible carcinogenic effects, at least some in vitro evidence of biological activity related to endocrine disruption Toxic to aquatic organisms According to the classification provided by companies to ECHA in CLP notifications this substance is very toxic to aquatic life with long lasting effects and is very toxic to aquatic life	Some uses of this substance are restricted under Annex XVII of REACH Included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	Additional one-off costs	-	properties	

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	C Bis(2-ethylhexyl) phthalate (DOP aka DEHP)	117-81-7	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), sealants and adhesives	Possibly carcinogenic to humans , may damage fertility, suspected of damaging the unborn child May not be readily biodegradable According to the classification provided by companies to ECHA in REACH registrations identifies that this substance may damage fertility or the unborn child and is very toxic to aquatic life Additionally, the classification provided by companies to ECHA in CLP notifications identifies that this substance may cause harm to breast-fed children	Substance of very high concern (SVHC) and included in the candidate list for authorisation under the EU REACH Regulation. Requires authorisation before it is used (Annex XIV of REACH). Some uses of this substance are restricted under Annex XVII of REACH Harmonised classification and labelling (CLP00): may damage fertility and may damage the unborn child Included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	-	C$3.40/kg in comparison to C$2.20-2.60/kg for chlorinated paraffins		

No	Potential substance alternatives		CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	D	Butyl benzyl phthalate (BBP)	85-68-7	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), paints and coatings, sealants and adhesives	Readily biodegradable Toxic to the reproductive system, reduces fertility and sperm quality in animal studies, increased developmental malformations, endocrine disruptions, associated with allergy and airway function changes, pancreatic adenomas and carcinomas in animal studies According to the classification provided by companies to ECHA in REACH registrations identifies that this substance may damage fertility or the unborn child	Substance of very high concern (SVHC) under the EU REACH Regulation. Some uses of this substance are restricted under Annex XVII of REACH. Requires authorisation before it is used (Annex XIV of REACH) Harmonised classification and labelling (CLP00): may damage the unborn child and is suspected of damaging fertility, is very toxic to aquatic life and is very toxic to aquatic life with long lasting effects Included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	-	C$5.10/kg in comparison to C$2.20-2.60/kg for chlorinated paraffins C$2,400/tonne of BBP compared to C$1,450/tonne for SCCPs		
	E	Di-isoundecyl phthalate (DIUP)	85507-79-5	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), paints and coatings, sealants and adhesives	Readily biodegradable but failing the 10-day window	Registered under REACH	-	C$1,950/tonne of DIUP compared to C$1,450/tonne for SCCPs		

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	F Tetrabromophthalate ester (TBPH)	26040-51-7	Other – Textiles, flame retardant	Certain phthalate esters are reproductive toxicants Brominated flame retardants have the potential to be bioaccumulative and persistent in vivo Found in Arctic biota According to the classification provided by companies to ECHA in CLP notifications this substance causes serious eye irritation	Registered under REACH Substance included in CoRAP Included by the US EPA on the 2014 updated TSCA Work Plan Chemicals for Assessment	-	-	-	ECHA (2008) TOXNET ECHA (2016) Vorkamp (2015) CoRAP (2016) Subsport (2013)
	G Tetrabromophthalate diol	77098-07-8	Other - Textiles, flame retardant	According to the classification provided by companies to ECHA in CLP notifications this substance is harmful to aquatic life with long lasting effects	Pre-registered under REACH	-	-	-	ECHA (2008) ECHA (2016) Subsport (2013)
	H Tetrabromophthalic anhydride	632-79-1	Other - Textiles, flame retardant	According to the classification provided by companies to ECHA in CLP notifications this substance may cause an allergic skin reaction	Registered under REACH	-	-	-	ECHA (2008) ECHA (2016) Subsport (2013)
27	Polyacrylate esters	multiple	Other - Paints and coatings, sealants and adhesives	Mucosal adjuvant According to the classification provided by companies to ECHA in CLP notifications polyacrylate ester based on c16-18 fatty alcohols causes serious eye irritation and may cause respiratory irritation	Pre-registered under REACH.	-	-	-	HELCOM (2002) OSPAR (2001) ECHA (2008) ECHA (2016) Hilgers (2000) Subsport (2013)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
28	Propylene oxide	75-56-9	Metalworking fluids	Readily biodegradable Eye, skin and respiratory tract irritiation, neurological effects, probable human carcinogen According to the classification provided by companies to ECHA in REACH registrations identifies that this substance is toxic if inhaled and is harmful to aquatic life	Substance of very high concern (SVHC) and included in the candidate list for authorisation under REACH Harmonised classification and labelling (CLP00): may cause genetic defects, may cause cancer, is an extremely flammable liquid and vapour, is harmful if swallowed, is harmful in contact with skin, causes serious eye irritation, is harmful if inhaled, causes skin irritation and may cause respiratory irritation	-	US$1-1.02/lb	Not considered to be a significant substitute	Dover (2004) ICIS (2015) UK (2001) ECHA (2016) US EPA (2000)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
29	Sulphur based substitutes (in general)	multiple	Metalworking fluids	Sulphur dust is irritating to skin and mucous membranes Where contact with sulphur-based fluid occurs, its use could lead to increased health risks (as compared to chlorinated paraffins)	-	-	Higher costs, chlorine-free fluids are approximately $1.20 per litre more expensive than those based on SCCPs	Not technically feasible in all applications because of dark colour, staining of yellow metals, intense odour and different temperature capabilities, although often equally efficient as CP-based products. Their suitability to serve as replacement is highly dependent on process conditions (temperature, friction, viscosity, process velocity) Might need to be used with biocides to prevent bacterial degradation as they are more easily assimilated by bacteria as compared to chlorine Commercially available - Sulfated triglyceride oils are used primarily as lubricants and emulsifiers in MWF. Sulphur-based additives are available in general	Morpeth (2012) Canada (2009) RPA (2002) RPA (1997b) UK (2008) Danish EPA (2005) UK (2001) Böhm (2003) COHIBA (2011)

No	Potential substance alternatives		CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	A	Sulphurized polyisobutene, polypropylene and polystyrene		Metalworking fluids	See Sulphur based (general) According to the classification provided by companies to ECHA in CLP notifications polystyrene causes serious eye irritation, is a flammable liquid and vapour, is harmful if inhaled and causes skin irritation	Polyisobutene is registered under REACH Polypropylene is pre-registered under REACH Polystyrene is pre-registered under REACH	-	See Sulphur based (general)	See Sulphur based (general)	UK (2008) Dover (2004) RPA (2002) ECHA (2016)
	B	Tertiary nonyl polysulfide (TNPS)		Metalworking fluids	Not biodegradable According to the classification provided by companies to ECHA in REACH registrations this substance may cause long lasting harmful effects to aquatic life Additionally, the classification provided by companies to ECHA in CLP notifications identifies that this substance causes serious eye irritation, causes skin irritation and may cause respiratory irritation	Registered under REACH	-	See Sulphur based (general)		
	C	Polyolefin sulphide		Metalworking fluids		-	-	See Sulphur based (general)		
	D	Sulfonated fatty acid esters	multiple	Metalworking fluids	According to the classification provided by companies to ECHA in CLP notifications fatty acid ester is harmful to aquatic life with long lasting effects		-	See Sulphur based (general)	Suitability of sulfur based additives is highly dependent on process conditions	COHIBA (2011) ECHA (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
	E Polysulphides or alkyl sulphide, sulphurized alkenes/olefins, sulphurized hydrocarbons (i.e.generally of the type di-tertiary alkyl polysulphides, in particular di-tertiary alkyl pentasulphides)	multiple	Metalworking fluids – extreme pressure additives	Di-(tert-nonyl) polysulphide - human health rating 4 (see table note) due to a skin sensitizing potential Di-(tert-dodecyl) polysulphide - human health rating 1(see table note) Di-(tert-dodecyl) pentasulphide - human health rating 1 (see table note) Very persistent, and may be bioaccumulative and toxic Health score of polysulphides varied from 1 to 4 (see table note) based on sparse data Data on alkyl sulphides indicate moderate toxicity by repeated exposure	Di-(tert-dodecyl) pentasulphide is pre-registered under REACH	Metalworking fluids can contain upwards of 40% (highly active) sulphur	See Sulphur based (general)	Not economically preferred or technically feasible - polysulphides are not used as much as sulphurized fats and esters in metalworking fluids, primarily due to poorer performance levels but also due to higher costs Commercially available	UK (2008) Dover (2004) RPA (2002) Danish EPA (2005) Entec (2008) ECHA (2016)
30	Tribromophenyl allyl ether	3278-89-5	Other – Textiles, flame retardant	One study found that tribromophenyl allyl ether was a potential endocrine disruptor	Pre-registered under REACH	-	-	-	ECHA (2008) ECHA (2016) Asnake (2015) Subsport (2013)
31	Tri-octyl trimellitate (TOTM)	89-04-3	Polyvinyl chloride Other - Flame Retardant	May be biodegradable under certain conditions	Registered under REACH	-	-	Technically feasible – Often used for products that are required to meet higher temperature ratings (e.g. 90-105ºC)	Domtech (2004) ECHA (2016)

No	Potential substance alternatives	CAS No	Applications	Environmental and health properties	Regulatory status	Loading	Price[2]	Economic feasibility, availability and accessibility	References
32	Zinc borate	multiple	Polyvinyl chloride Other − rubber and plastics (other than polyvinyl chloride), flame retardant in polyvinyl chloride	Considered to have lower toxic and ecotoxic potential than chlorinated paraffins and that their bioavailability is low According to the classification provided by companies to ECHA in CLP notifications this substance is very toxic to aquatic life with long lasting effects, is very toxic to aquatic life and is suspected of damaging fertility or the unborn child	CAS No. 1332-07-6 is pre-registered under REACH	-	US$1.20-2.20/lb	Not suitable for all applications Potential technical difficulties as it does not provide the same plasticizing effect Commercially available, economically feasible	Canada (2015) ICIS (2015) German UBA (2001) ECHA (2016)

Table Note:

Human Health Rating: A rating of 1 is low environmental/human health impact while a rating of 5 is a high impact. A rating of 1 indicates low acute toxicity and possible slight irritation of skin/eye. A rating of 2 indicates moderate acute toxicity, irritation to skin/eye and possible skin sensitization. A rating of 3 indicates hign acute toxicity, corrosive/irritating, probable sensitization and cumulative effects. A rating of 4 indicates very high acute toxicity, strongly corrosive, sensitizing and serious effects with repeated exposure. A rating of 5 indicates very high acute toxicity, strongly corrosive, sensitizing and serious effects with repeated exposure as well as carcinogenic, mutagenic and reprotoxic effects. (Danish EPA 2005)

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