Australian Government
Department of Health and Aged Care
Australian Industrial Chemicals Introduction Scheme

Cresyl phosphates and xylyl phosphates

Evaluation statement

26 June 2023

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AICIS evaluation statement

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Cresyl phosphates and xylyl phosphates

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Reason for the evaluation

Evaluation Selection Analysis indicated a potential environmental risk.

Parameters of evaluation

This evaluation considers the environmental risks associated with the industrial uses of the organophosphate flame retardants tricresyl phosphate (TCP, CAS No. 1330-78-5), trixylyl phosphate (TXP, CAS No. 25155-23-1) and related chemicals. These chemicals are listed on the Australian Inventory of Industrial Chemicals (the Inventory) and have been assessed for their risks to the environment according to the following parameters:

- Australian introduction volume of approximately 7 tonnes per year for TCP
- Default introduction volume of 100 t/year for the remaining chemicals in the evaluation
- Industrial uses listed in the 'Summary of introduction, use and end use' section
- Expected emission to surface waters, sediment and soil due to consumer and commercial use.

These chemicals have been assessed as a group as they are structurally similar and have similar use patterns.

The following acronyms have been used in this evaluation:

- TCP (Phosphoric acid, tris(methylphenyl) ester; CAS No. 1330-78-5)
- CDPP (Phosphoric acid, methylphenyl diphenyl ester; CAS No. 26444-49-5)
- TXP (Phenol, dimethyl-, phosphate (3:1); CAS No. 25155-23-1)
- ToCP (Phosphoric acid, tris(2-methylphenyl) ester; CAS No. 78-30-8)
- TmCP (Phosphoric acid, tris(3-methylphenyl) ester; CAS No. 563-04-2)
- TpCP (Phosphoric acid, tris(4-methylphenyl) ester; CAS No. 78-32-0)
- XDPP (Phosphoric acid, dimethylphenyl diphenyl ester; CAS No. 29660-68-2)
- DCPP (Phosphoric acid, bis(methylphenyl) phenyl ester; CAS No. 26446-73-1)
- TARX (Tar acids, cresylic, C8 rich, phosphates; CAS No. 68952-33-0)
- TARC (Tar acids, cresylic, phenyl phosphates; CAS No. 68952-35-2).

Summary of evaluation

Summary of introduction, use and end use

Based on domestic and international use data, the chemicals in this evaluation may be used as flame retardants, plasticisers, lubricating agents and/or intermediates in the following products:

- plastics and polymers such as PVC, polyurethanes, polystyrene, PC/ABS blends, rubber, cellulose-based materials and resins
- construction products
- fabric, textile and leather products
- adhesives and sealant products
- paint and coating products
- lubricant and grease products
- fuel, oil, and fuel oil additives.

Australian introduction volume information is only available for TCP, with historical reported introduction volume of approximately 7 tonnes in 1998–1999.

International use information suggests that CDPP and TXP may each have worldwide annual production volume of approximately 9500–9675 tonnes/year.

No introduction volume information is available for the other chemicals in the evaluation.

Environment

Summary of environmental hazard characteristics

Based on the information presented in this evaluation and according to the environmental hazard thresholds stated in the Australian Environmental Criteria for Persistent, Bioaccumulative and/or Toxic Chemicals (DCCEEW n.d.), TCP, ToCP, TmCP, TpCP, CDPP, DCPP and XDPP are:

- Not Persistent (Not P)

- Not Bioaccumulative (Not B)
- Toxic (T)

TXP, TARC and TARX are:

- Persistent (P)
- Not Bioaccumulative (Not B)
- Toxic (T)

Environmental hazard classification

The chemicals in this group satisfy the criteria for classification according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) for environmental hazards as follows. This does not consider classification of physical and health hazards.

All isomers of TCP were classified based on the toxicity information for TCP. DCPP and XDPP were classified based on the toxicity data available for CDPP. TARC and TARX were classified based on information for TXP. Due to a lack of adequate chronic toxicity endpoints for TXP, acute endpoints were used for hazard categorisation.

TCP, ToCP, TmCP, TpCP, TXP, TARC and TARX are:

Environmental Hazard	Hazard Category	Hazard Statement
Hazardous to the aquatic environment (acute / short-term)	Aquatic Acute 1	H400: Very toxic to aquatic life
Hazardous to the aquatic environment (long-term)	Aquatic Chronic 1	H410: Very toxic to aquatic life with long lasting effects

CDPP, DCPP and XDPP are:

Environmental Hazard	Hazard Category	Hazard Statement
Hazardous to the aquatic environment (acute / short-term)	Aquatic Acute 1	H400: Very toxic to aquatic life
Hazardous to the aquatic environment (long-term)	Aquatic Chronic 3	H412: Harmful to aquatic life with long lasting effects

Summary of environmental risk

The chemicals in this evaluation are flame retardants, plasticisers and additives in a range of industrial and household products and articles. The main environmental releases are expected from leakages due to their use in hydraulic fluids, lubricants, transmission fluids and motor oils or release from articles due to their use as plasticisers and flame retardants. These releases are expected to affect surface waters, sediments and soils, predominately in areas with high human or industrial activity.

These chemicals TCP, ToCP, TmCP, TpCP, CDPP, DCPP and XDPP are not persistent in the environment. TXP, TARC and TARX are persistent in the environment. All chemicals have a low potential for bioaccumulation and are toxic to aquatic organisms. TCP may induce endocrine-related effects in some species of fish and rats, but effects are expected to occur at concentrations typically above those expected to be found in the Australian environment.

Based on measured concentrations in international surface waters and STP effluent, the chemicals are expected to be present in Australian surface waters at concentrations below levels of concern. Concentrations of concern for sediment or soil organisms could not be determined, as there were insufficient toxicity data for these environmental compartments.

As the calculated risk quotients (RQs) obtained for TCP in water are less than 1, the industrial use of the chemicals in Australia are not expected to pose a significant risk to the environment.

Conclusions

The conclusions of this evaluation are based on the information described in this statement.

The Executive Director is satisfied that the identified environment risks can be managed within existing risk management frameworks. This is provided that all requirements are met under environmental, workplace health and safety and poisons legislation as adopted by the relevant state or territory.

Note: Obligations to report additional information about hazards under *section 100* of the *Industrial Chemicals Act 2019* apply.

Supporting information

Rationale

This evaluation considers the environmental risks associated with the industrial uses of tricresyl phosphate (TCP), trixylyl phosphate (TXP) and 8 structurally similar organophosphate esters. The evaluation of these substances has been conducted as a group because they are structurally related and have known or potential applications as flame retardants and plasticisers. The compounds are often found together in commercial products, either as an active ingredient or as an impurity.

The chemicals in this group are part of the triaryl phosphate substances, which are a subgroup of organophosphate triesters. Organophosphate flame retardants (OPFRs) were developed to replace other types of additive flame retardants, such as polybrominated diphenyl esters (PBDEs) (Cristale et al. 2013; Huang Y et al. 2020; Pakalin et al. 2007).

The evaluation selection analysis (ESA) for the chemicals in this group indicated a potential concern to the environment based on high ecotoxicity and the potential to affect the endocrine system of aquatic organisms.

Environmental risks resulting from the use of other organophosphate compounds as flame retardants and plasticisers in Australia have previously been assessed by the former National Industrial Chemicals Notification and Assessment Scheme (NICNAS). A 'Priority Existing Chemical Assessment Report' for trisphosphates (No. 17) is available (NICNAS 2001).

Chemical identity

The chemicals in this evaluation are predominantly tri-aryl phosphate esters, typically manufactured by the reaction of phosphorus oxychloride with phenols, methylphenols (cresols) or dimethylphenols (xylenols). The composition of the product is dependent on the aryl feedstock used in the reaction. As the aryl feedstocks may be mixtures of various phenols, cresols and xylenols, the commercial mixtures of the chemicals in this evaluation are expected to have variable composition and be unknown or variable composition, complex reaction products or biological materials (UVCB) substances.

The chemicals in this evaluation that appear to have major industrial significance are the tricresyl phosphates, the trixylyl phosphates, and cresyl diphenyl phosphate. The other chemicals in the evaluation are expected to have similar properties, composition, and manufacturing processes.

Tricresyl phosphates (TCPs) are phosphate esters where the phosphate group is linked to three phenyl groups that are methylated at either the ortho- (o), meta- (m), or para- (p) positions. When unspecified, "cresyl" may refer to any of these methylphenyl isomers, and TCP may refer to any individual isomer or mixture of the ten different possible structural isomers.

Specific isomers of TCP with assigned CAS Nos. generally refer to pure substances. These substances are not expected to be commercial products but are often used as analytical standards that may be referred to in screening or monitoring studies. Examples of these chemicals in this evaluation are:

- Tris(2-methylphenyl) phosphate (CAS No. 78-30-8; Tris(ortho-cresyl) phosphate; ToCP)
- Tris(3-methylphenyl) phosphate (CAS No. 563-04-2; Tris(meta-cresyl) phosphate; TmCP)
- Tris(4-methylphenyl) phosphate (CAS No. 78-32-0; Tris(para-cresyl) phosphate; TpCP).

In other publications, ToCP may also be used to refer to any TCP isomer containing at least one o-cresyl group. For example, the Australian Hazardous Chemical Information System (HCIS) classifies any isomer of TCP that contains at least one o-cresyl group (i.e., o-o-o-, o-o-m-, o-o-p-, o-m-m-, o-m-p-, o-p-p- TCP isomers) under the CAS No. for ToCP (SWAa n.d.). Similarly, the CAS No. for TpCP may be used to refer to TCP mixture that does not contain any o-cresyl isomers. For example, the HCIS classifies m-m-m-, m-m-p-, m-p-p-, p-p-p- TCP isomers under the CAS No. for TpCP (SWAb n.d.).

In this evaluation, ToCP and TpCP will be used to refer to the o-o-o and the p-p-p TCP isomers only.

Commercial mixtures of TCP may contain any of the possible TCP isomers and may also include various impurities depending on the feedstock used for production. Common impurities in commercial TCP mixtures include dicresyl phosphates (DCPs), triphenyl phosphate, and trixylyl phosphates (UK EA 2009a). Available information suggests that cresol feedstocks containing significant o-cresyl content are generally avoided, resulting in reduced concentrations of o-cresyl TCPs in modern commercial mixtures (David and Seiber 1999; Sjögren et al. 2010).

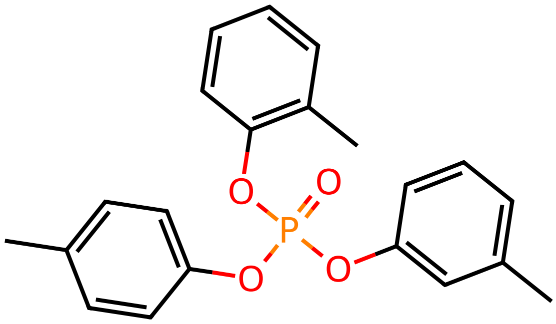
Trixylyl phosphates (TXPs) are phosphate esters where the phosphate group is linked to 3 dimethylphenyl (xylenol) groups. The term TXP may refer to any isomer or mix of TXP isomers. Impurities in commercial TXP mixtures may include phosphate esters based on various combinations of 4-ethylphenol, cresol, phenol, and trimethylphenol (Chiron n.d.; UK EA 2009b).

Methylphenyl diphenyl phosphate (cresyl diphenyl phosphate; CDPP) is a phosphate ester consisting of a cresyl group (unspecified whether o, m, or p) and 2 phenyl groups. Commercial products of CDPP are expected to also contain triphenyl phosphate, dicresyl phenyl phosphate and tricresyl phosphates as impurities in significant proportions. Levels of o-cresyl isomers in modern commercial products are expected to be low (OECD 1998; UK EA 2009c). No information is available on commercial products of dimethylphenyl diphenyl phosphate (xylenyl diphenyl phosphate; XDPP) and di(methylphenyl) phenyl phosphate (dicresyl phenyl phosphate; DCPP); however, they are expected to contain similar impurities.

These chemicals TARC and TARX are produced from the reaction of phosphorus oxychloride and tar-derived cresylic or C8-rich distillation fractions. Crude tar acid extracts generally contain various aromatic compounds such as phenols, cresols and xylenols, which can be enriched through further fractionation (Rau et al. 1967). As there is uncertainty in the proportions of these aromatic compounds in the crude tar acid extracts, it is assumed that both substances contain significant proportions of TCPs, TXPs and various other aryl phosphate esters.

Chemical name	Phosphoric acid, tris(methylphenyl) ester
CAS No.	1330-78-5
Synonyms	tricresyl phosphate (TCP) cresyl phosphate tris(methylphenyl) phosphate tritolyl phosphate
Molecular formula	C21H21O4P
Molecular weight (g/mol)	368.4
SMILES*	c1(OP(=O)(Oc2cc(C)ccc2)Oc2ccc(C)cc2)c(C)cccc1
Chemical description	A UVCB mixture corresponding to any combination of o, p, or m cresol isomers *SMILES and structure are representative of one potential isomer only

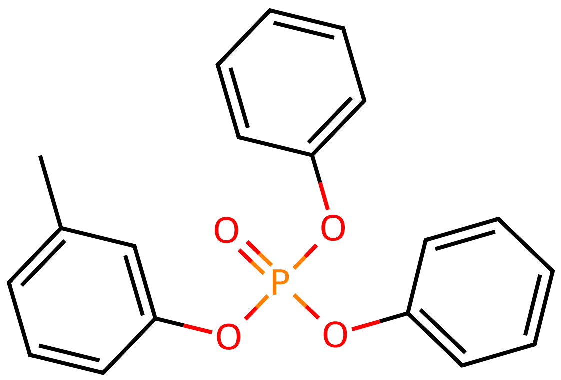
***Structural formula:**



Chemical name	Phosphoric acid, methylphenyl diphenyl ester
CAS No.	26444-49-5
Synonyms	Cresyl diphenyl phosphate (CDPP) Diphenyl tolyl phosphate
Molecular formula	C19H17O4P
Molecular weight (g/mol)	340.3

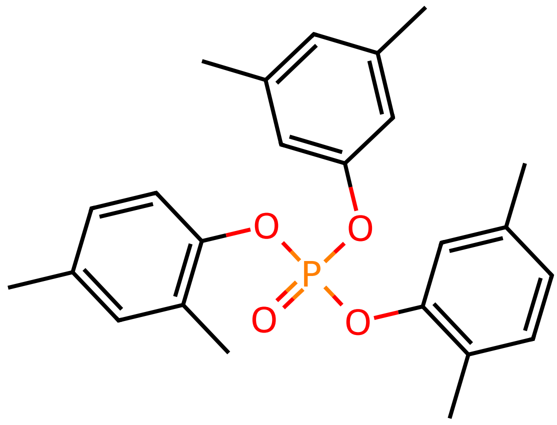
SMILES*	c1(OP(=O)(Oc2ccccc2)Oc2ccccc2)cc(C)ccc1
Chemical description	A UVCB mixture consisting of various mono-cresyl diphenyl phosphate isomers *SMILES and structure are representative of one potential isomer only

***Structural formula:**



Chemical name	Phenol, dimethyl-, phosphate (3:1)
CAS No.	25155-23-1
Synonyms	trixylyl phosphate (TXP) trixylenyl phosphate tris(dimethylphenyl) phosphate phenol, dimethyl-, 1,1',1''-phosphate
Molecular formula	C24H27O4P
Molecular weight (g/mol)	410.4
SMILES*	c1(OP(=O)(Oc2c(C)ccc(C)c2)Oc2cc(C)cc(C)c2)c(C)cc(C)cc1
Chemical description	A UVCB mixture corresponding to any potential isomer of trixylyl phosphate *SMILES and structure are representative of one potential isomer only

***Structural formula:**



Chemical name Phosphoric acid, tris(2-methylphenyl) ester

CAS No. 78-30-8

Synonyms tris(2-methylphenyl) phosphate

tri-2-tolyl phosphate

tri-o-tolyl phosphate

tri-o-cresyl phosphate (ToCP)

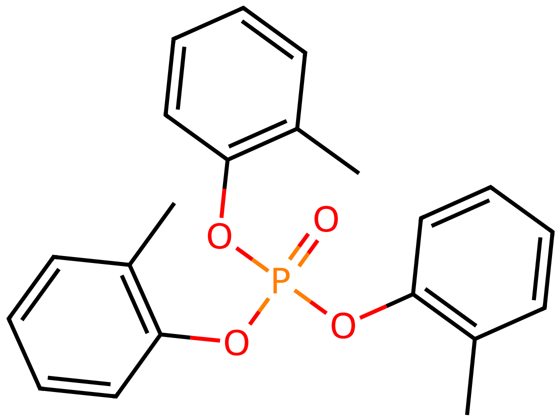
Molecular formula C21H21O4P

Molecular weight (g/mol) 368.4

SMILES Cc1ccccc1O[P](=O)(Oc2ccccc2C)Oc3ccccc3C

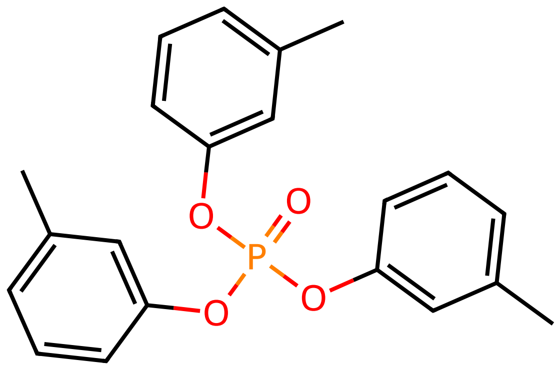
Chemical description -

Structural formula:



Chemical name	Phosphoric acid, tris(3-methylphenyl) ester
CAS No.	563-04-2
Synonyms	tris(3-methylphenyl) phosphate
	tri-3-tolyl phosphate
	tri-m-tolyl phosphate
	tri-m-cresyl phosphate (TmCP)
	phosphoric acid, tri-m-tolyl ester
Molecular formula	C21H21O4P
Molecular weight (g/mol)	368.4
SMILES	Cc1cccc(O[P](=O)(Oc2cccc(C)c2)Oc3cccc(C)c3)c1
Chemical description	-

Structural formula:

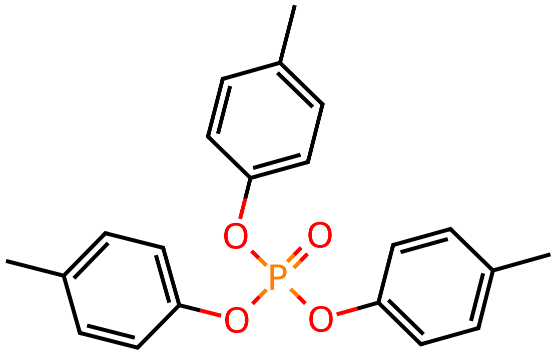


Chemical name	Phosphoric acid, tris(4-methylphenyl) ester
CAS No.	78-32-0
Synonyms	tris(4-methylphenyl) phosphate
	tri-4-tolyl phosphate
	tri-p-tolyl phosphate
	tri-p-cresyl phosphate (TpCP)
Molecular formula	C21H21O4P
Molecular weight (g/mol)	368.4

SMILES Cc1ccc(O[P](=O)(Oc2ccc(C)cc2)Oc3ccc(C)cc3)cc1

Chemical description -

Structural formula:



Chemical name Phosphoric acid, dimethylphenyl diphenyl ester

CAS No. 29660-68-2

Synonyms Xylyl diphenyl phosphate (XDPP)

Molecular formula C20H19O4P

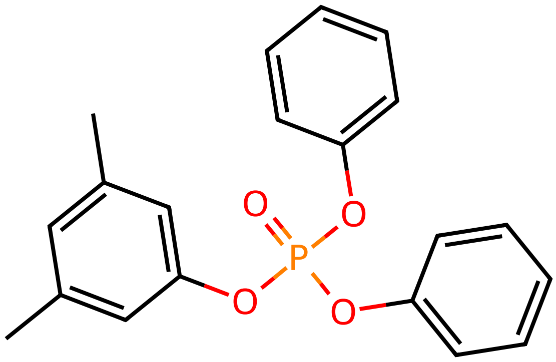
Molecular weight (g/mol) 354.3

SMILES* c1(OP(=O)(Oc2ccccc2)Oc2ccccc2)cc(C)cc(C)c1

Chemical description A UVCB mixture that corresponds to any potential isomer of mono-xylyl diphenyl phosphate

*SMILES and structure are representative of one potential isomer only

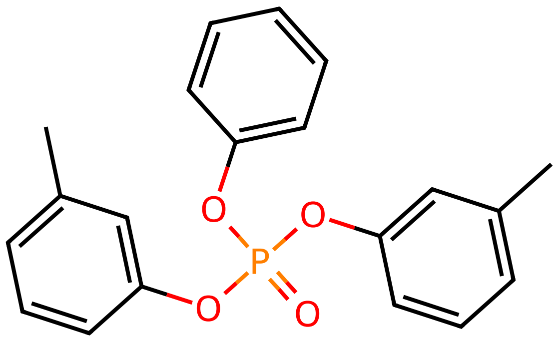
***Structural formula:**



Chemical name	Phosphoric acid, bis(methylphenyl) phenyl ester
CAS No.	26446-73-1
Synonyms	dicresyl phenyl phosphate (DCPP) bis(methylphenyl) phenyl phosphate
Molecular formula	C20H19O4P
Molecular weight (g/mol)	354.3
SMILES*	c1(OP(=O)(Oc2cc(C)ccc2)Oc2ccccc2)cc(C)ccc1

Chemical description	A UVCB mixture that corresponds to any isomer of dicresyl phenyl phosphate *SMILES and structure are representative of one potential isomer only

***Structural formula:**



Chemical name	Tar acids, cresylic, C8 rich, phosphates
CAS No.	68952-33-0
Synonyms	Phosphate esters of coal tar or petroleum derived cresylic acid (TARX)
Molecular formula	-
Molecular weight (g/mol)	-
SMILES	-

Chemical description	A complex mixture of aryl phosphates expected to contain large proportions of xylyl phosphates. Assumed to include significant proportions of TCPs and other substances in this evaluation.

Chemical name	Tar acids, cresylic, phenyl phosphates
CAS No.	68952-35-2
Synonyms	phosphate esters of coal tar or petroleum-derived cresylic acid cresylic tar acids, phenyl phosphates (TARC)
Molecular formula	-
Molecular weight (g/mol)	-
SMILES	-
Chemical description	A complex mixture of aryl phosphates expected to contain large proportions of cresyl phosphates. Assumed to include significant proportions of TXPs and other substances in this evaluation.

Relevant physical and chemical properties

The physical and chemical properties of CDPP, TCP and TXP are considered representative of all chemicals in this group and are presented below. Data for CDPP, TCP and TXP were retrieved from the respective substance registration dossier submitted under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation in the European Union (EU) (REACHa n.d.; REACHb n.d.), the relevant UK Environment Agency risk evaluation reports (UK EA 2009a; UK EA 2009b; UK EA 2009c), and the Dutch National Institute for Public Health and the Environment (RIVM) report on environmental risks of phosphate esters (Verbruggen et al. 2006). Henry's law constant values were estimated using water solubility, vapour pressure and molecular weight:

Chemical	CDPP	TCP	TXP
Physical form	liquid	liquid	liquid
Melting point	-35°C (exp.)	-30°C (exp.)	-20°C (exp.)
Boiling point	390°C (exp.)	>400°C (exp.)	394.1°C (exp.)
Vapour pressure	3.3×10^{-5} Pa (exp.)	4.7×10^{-6} Pa (exp.)	1.6×10^{-6} Pa (exp.)
Water solubility	2.4 mg/L (exp.)	0.27 mg/L (exp.)	0.11 mg/L (exp.)
Henry's law constant	0.0047 Pa m^3/mol (calc.)	0.0064 Pa m^3/mol (calc.)	0.0060 Pa m^3/mol (calc.)
Ionisable in the environment?	no	no	No
pKa	-	-	-
log K_{OW}	4.51 (exp.)	5.11 (exp.)	5.63 (exp.)

All chemicals in this group are liquids at standard room temperature and pressure except for pure isomers of TmCP and TpCP which are solid (van der Veen and de Boer 2012). They are lipophilic based on measured log K_{OW} values and very slightly volatile. The chemicals' water solubilities range from slightly soluble to very slightly soluble which indicates they are likely to partition out from surface waters to soil or sediment.

The reported solubility values for CDPP range from 2.4 mg/L (OECD 1998) to 2.6 mg/L. These varied solubility values are likely the result of different impurity components in technical mixtures of CDPP or different ratios of isomeric components in this UVCB substance. It may be likely that the true solubility of CDPP is considerably lower (UK EA 2009c).

Introduction and use

Australia

An annual use volume of approximately 7 tonnes TCP was previously reported in response to a call for information of industrial chemicals of concern conducted by NICNAS between

1998 and 1999 (Commonwealth of Australia 2000). TCP had reported Australian uses in the manufacture of PVC, rubber, nitrocellulose, coatings and resins. As TCP is also expected to be introduced into Australia in imported articles, this reported volume is likely to be an underestimate of the true volume.

While no specific Australian import or manufacturing volumes have been identified for CDPP, TXP, ToCP, TpCP and DCPP, Australian SDS indicate the following potential uses:

- use in specialised construction activities (CDPP and DCPP)
- lubricant additive (CDPP)
- anti-wear additive in jet engine oil at concentrations up to 3% (TCP)
- transmission fluid at up to 0.25% (TCP and CDPP)
- additive in sealants and insulation resins at up to 10% (CDPP and DCPP)
- component (>90% w/w) of some fire-resistant hydraulic fluids (TXP).

No specific Australian use, import or manufacturing information has been identified for TmCP, XDPP, TARX and TARC.

International

Available information indicates that the chemicals in this group are mainly used as plasticisers and flame retardants in a wide range of polymers, and within functional fluids such as lubricants and motor oils.

The annual production volume for TCP, TXP and CDPP in 2020 was estimated to be around 9500–9675 tonnes each, predominantly occurring in China (Huang et al. 2022).

The chemicals in this evaluation are commonly used as an extreme pressure additive or antiwear agents in hydraulic fluids, lubricants, transmission fluids and motor oils, and as a petrol/diesel fuel anti-preignition additive and lead scavenger (Chiron n.d.; DeLima Associates n.d.; NICNAS 2017; 2018b; van der Veen and de Boer 2012). Jet engine oil contains TCP isomers and similar substances such as phenyl and xylyl compounds at less than 5% (BP 2010; Shill et al. 2019; Winder and Balouet 2002). TCPs have been detected in engine oil samples at 0.09–1.41%, in hydraulic fluids at up to 0.0006% and in hydroelectric power station oil at 0.016% (Li et al. 2019; Marklund et al. 2005; Wei et al. 2015). TXP is present as an additive in automotive fluids such as power steering fluid at 0.1–1% w/w (Government of Canada 2020) and in power generation fluid (UK EA 2009b). CDPP was detected in four hydraulic fluids and in two engine oil samples at up to 0.001% (Li et al. 2019).

These chemicals TCP and CDPP are additives in adhesives, lacquers and coatings (UK EA 2009a; van der Veen and de Boer 2012). TpCP may have uses in paints and varnishes (Nordic Council of Ministers n.d.).

Chemicals in this evaluation have well known use as additive flame retardants and/or plasticisers for polymers such as PVC, polyurethanes, polystyrene, polycarbonate/acrylonitrile-butadiene-styrene (PC/ABS) blends, resins and rubber. These polymers are used to produce a variety of articles such as electronic products, tarpaulins, conveyor belts, air ducts, cable insulation, circuit boards, hoses, foams, food packaging, furniture upholstery, automotive interiors, synthetic leather and raincoats (Government of Canada 2019; 2020; UK EA 2009a; 2009b; van der Veen and de Boer 2012; Winder and Balouet 2002).

In polymers, effective flame retardant concentrations are usually around 10–20% (w/w) although lower loadings of <1% (w/w) may be sufficient in some systems (UK EA 2003). TCP has been detected at concentrations up to 0.45–1.43% in various electronic products (Ballesteros-Gómez et al. 2014; Kajiwara et al. 2011), in chair foam (Government of Canada 2019), in curtains and PVC wallpaper (Kajiwara et al. 2011) and in plastic mulch films (Wei et al. 2015). TCP and TpCP are additives in photographic film (NICNAS 2017; UK EA 2009a).

TCP is used as a chemical intermediate, solvent and a laboratory reagent (NICNAS 2017; 2018b).

Chemicals TCP, TmCP and TpCP may have non-industrial uses as pesticides and preservatives (NICNAS 2017; NICNAS 2018b), which are not within the scope of this evaluation.

Existing Australian regulatory controls

Environment

The use of the chemicals in this group is not subject to any specific national environmental regulations.

International regulatory status

United Nations

Chemicals in this group are not currently identified as persistent organic pollutants (POPs) (UNEP 2001), ozone depleting substances (UNEP 1987), or hazardous substances for the purpose of international trade (UNEP and FAO 1998).

OECD

The chemical CDPP is listed as an OECD High Production Volume (HPV) chemical (OECD n.d.). The substance has been sponsored for assessment by Japan and a Screening Information Data Sheet (SIDS) Initial Assessment Report (SIAR) has been published (OECD 1998).

Chemicals TCP and TXP are on the HPV list but not yet sponsored for assessment (OECD n.d.).

Canada

The chemical TCP appears on the List of Prohibited and Restricted Cosmetic Ingredients (referred to as Health Canada's Cosmetic Ingredient Hotlist) (Government of Canada 2019).

A screening assessment performed by Environment and Climate Change Canada Health Canada determined that TCP and TXP do not meet the criteria under paragraphs 64(a) or (b) of the Canadian Environmental Protection Act, 1999 (CEPA). The report found that these chemicals are not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity or that constitute or may constitute a danger to the environment on which life depends (Government of Canada 2019; 2020).

European Union

This chemical TCP is listed on EU Cosmetics Regulation 1223/2009 Annex II—List of substances prohibited in cosmetic products (EU Commission n.d.). The substance has been assessed under CoRAP (ECHAa n.d.) and concluded in 2021 with the outcome 'not PBT, not vPvB' (ECHAb n.d.).

The chemical TXP is listed on the candidate list of substances of very high concern (SVHC) (ECHAc n.d.) and was included in the Authorisation List in 2020 as it is suspected to be toxic for reproduction in humans (ECHAd n.d.).

New Zealand

The chemical TCP is listed on the New Zealand Cosmetic Products Group Standard—Schedule 4: Components Cosmetic Products Must Not Contain (NZ EPA 2019).

Asia

The chemical TCP is listed on the ASEAN Cosmetic Directive Annex II Part 1: List of substances which must not form part of the composition of cosmetic products (ASEAN n.d.).

Environmental exposure

Industrial uses of the chemicals in this group are expected to result in both diffuse and point source emissions into the environment. The chemicals in this evaluation may be released to air, water, or soil through their various uses. The main environmental releases are expected from leakages due to their use in hydraulic fluids, lubricants, transmission fluids and motor oils or release from articles due to their use as plasticisers and flame retardants.

Releases of the chemicals may occur from leakages from hydraulic systems such as those in aircraft (David and Seiber 1999; Shill et al. 2019). It has been estimated that up to 80% of trialkyl/aryl phosphate hydraulic fluid is used to replace losses from leakage (David and Seiber 1999). Releases from hydraulic systems are expected to occur at locations, such as airports, where the products containing the fluids are in use.

Chemicals in this group are also used as flame retardants and plasticisers in plastic articles. They are additives that are not chemically bonded to the materials in which they are included. This may result in release of the chemicals to the immediate environment from plastics such as PVC pipes, cladding on buildings, or microplastics (Arcadis 2011; Schmidt et al. 2021; van der Veen and de Boer 2012) due to processes such as abrasion, weathering and volatilisation (Suzuki et al. 2009; Webster et al. 2009). Additionally, the chemicals in this evaluation are routinely detected in house dust in Australia (Brommer 2014; Huang Y et al. 2020) demonstrating release of the chemicals from articles during use.

Releases from plastics are expected to be either diffuse or point source. Release during plastic article use will be diffuse and occurring predominately in urban locations, either directly releasing from the plastic article, or indirectly through the release of household dust (Marklund et al. 2003). Sites that manufacture, recycle, or dispose of plastic articles containing the chemicals are expected to be point source release sources of the chemicals in the evaluation, through direct release of the chemicals to the environment or the release of the chemical from large volumes of plastic articles.

Environmental fate

Partitioning

Chemicals in this group are expected to primarily partition to sediment and soil when released into the environment.

These chemicals CDPP, TCP and TXP are neutral organic chemicals with a low water solubility. Estimated Henry's Law constants (0.0045–0.0064 Pa m^3/mol) indicate the chemicals will be very slightly volatile from water and moist soil. All three substances are lipophilic chemicals (log K_{OW} = 4.51–5.63) with high soil adsorption coefficients (log K_{OC} = 4.31–5.08) (REACHa n.d.; REACHb n.d.) that indicate they will be immobile in different types of soil and preferentially adsorb to phases in the environment with high organic carbon content (including sediment and soil). The remaining chemicals in the group are expected to have similar physico-chemical partitioning behaviours due their structural similarity.

In aquatic environments, the chemicals in this group are expected to partition significantly to sediments. Releases to wastewater streams are treated at sewage treatment plants (STPs), where they will partition preferentially to the sludge and solids fractions, releasing a relatively minor proportion in effluent. Release to the soil compartment will likely occur through application of STP biosolids residues to land or through operation of hydraulic machinery. Fugacity calculations (Level III approach) assuming equal release to the water, soil and air compartments (1000 kg/h) predict that the substances will predominantly remain in soil (46.4–76.3%), some will partition to sediment (11.8–49.4%) and water (4.2–11.6%), and small quantities to air (0.06–0.32%) (US EPA 2017).

If chemicals in this group undergo degradation and lose an aryl group, the corresponding di-aryl degradants of the chemicals are expected to be chemicals with much higher water solubility with higher propensity to transfer to or remain in the water compartment.

Degradation

Based on available evidence, TCP and most of the chemicals in this group are not expected to be persistent in the environment. TXP is only inherently biodegradable based on a screening result and may persist in the environment. TARX and TARC may contain significant amounts of TXP and are therefore also expected to be persistent.

The typical degradation pathway for triaryl phosphates is hydrolysis, which can be either biotic or abiotic. Multiple studies show that loss of an aryl group through biotic hydrolysis is a common biodegradation pathway for various TCP isomers and unsubstituted triphenyl phosphate (TPHP) (Choi et al. 2021; Liu Y et al. 2019; Yu et al. 2022). It has been found that individual isomers of TCP have slightly different degradation rates, and that they can form mono- and di-cresyl phosphates, and various hydroxylated, formylated and carboxylated adducts (Liu Y et al. 2019). While information is lacking on the degradation pathway of TXP, the chemical is expected to follow a similar pattern during biotic degradation.

Chemicals TCP and CDPP slightly hydrolyse under neutral and basic abiotic conditions, with measured half-lives of 44–47 days at pH 7 (OECD 1998; REACHa n.d.). TCP may form cresols and dicresyl phosphates (DCPs) (Su et al. 2016). CDPP may form diphenyl phosphate (DPHP) or mixed mono-cresyl mono-phenol phosphate metabolites (Huang et al. 2020). The diaryl phosphate degradation products appear resistant to further abiotic hydrolysis (Su et al. 2016). TXP appears hydrolytically stable (REACHb n.d.). This may be a result of the higher substitution of TXP.

The chemical TCP is readily biodegradable in water. Over 28 days, the substance was shown to degrade to 80% in a biological oxygen demand (BOD) test according to OECD Test Guideline (TG) 301C (REACHa n.d.) and an experiment based on the modified Sturm method showed 82% degradation in 28 days through CO_2 evolution (UK EA 2009a). Inherent biodegradation screening tests (OECD TG 302C) conducted with ToCP and TpCP concluded with degradation rates of 65.7% and 100% according to BOD, respectively, after 28 days (NITE n.d.). All tricresyl phosphate chemicals are expected to have similar degradation timeframes due to their structural similarities.

Biodegradation of CDPP according to OECD TG 301C saw a 75% decline of the substance according to oxygen consumption after 28 days (UK EA 2009c). Using a commercial CDPP product that also contained TPHP and DCPP, a biodegradation test based on the modified Sturm method showed 84% degradation in 28 days through CO_2 evolution (UK EA 2009c).

The chemical TXP is not readily biodegradable. A test according to OECD TG 301D and using a commercial TXP product found 14% degradation through oxygen consumption over 28 days (REACHb n.d.). An OECD TG 301F study showed 29% degradation of TXP in 28 days. Extending the test run time to 68 days resulted in degradation of over 60% of the substance (UK EA 2009b). Another experiment, based on the modified Sturm method and using pre-acclimatised inoculum, showed 43% degradation after 28 days and 65% degradation after 48 days (UK EA 2009b). These results indicate that TXP is inherently capable of mineralisation through biodegradation, but the timeframe for this degradation to occur is uncertain. As such, TXP may meet Australian persistence criteria (DCCEEW n.d.).

The chemical TCP is expected to degrade in the atmosphere through reaction with photogenerated hydroxyl radicals. The rate of this degradation may be influenced by the association of the chemicals to particles in the air. Calculations performed assuming a typical hydroxyl radical concentration of 1.5×10^6 molecules/cm^3 and 12 hours of sunlight per day resulted in a half-life of 9.37 h for TCP (US EPA 2017). However, when TCP was deposited on $(NH_4)_2SO_4$ particles, the mean half-life was found to be 1.8–4.5 days) (Liu Q et al. 2019). The other chemicals in this group are expected to have similar behaviour.

Bioaccumulation

Chemicals in this evaluation generally exhibit a low potential to bioconcentrate in aquatic organisms. Experimentally determined bioconcentration factors (BCFs) in fish are below the Australian categorisation threshold for bioaccumulation (DCCEEW n.d.). TCP has been shown to undergo rapid biotransformation in fish (UK EA 2009a; UK EA 2009c) and does not biomagnify in studied food webs. While TXP may slower depuration rates than TCP, there little evidence to suggest that it will accumulate significantly.

Exposure of fish to TCP or one of its isomers typically results in BCF values below 2,000, such as for common carp (*Cyprinus carpio*), zebrafish (*Danio rerio*), bluegill (*Lepomis macrochirus*), fathead minnow (*Pimephales promelas*), rainbow trout (*Oncorhynchus mykiss*) and bleak (*Alburnus alburnus)* (Bekele et al. 2018; Muir et al. 1983; Sitthichaikasem 1978; UK EA 2009a; Verbruggen et al. 2006; Wang et al. 2017b).

The depuration rate of TpCP in zebrafish was found to be <3 days (Wang G et al. 2017b). Metabolism of TCP in fish is fast and metabolites are excreted rapidly (UK EA 2009a). However, a study involving exposure of zebrafish to TpCP under semi-static conditions (OECD TG 305) found maternal transfer of this chemical to eggs, with relatively high concentrations and slow depuration of TpCP measured in roe. This indicates a potential for the substance to be transferred to the next generation (Wang G et al. 2017b).

Values for BCF were determined for other chemicals in this group as components of a commercial phosphate ester product. A 28-day study using bleak (*A. alburnus*) determined BCF values of 100–220 L/kg for CDPP and 1300–1900 L/kg (non-steady state) for TXP. During the depuration period, the chemicals were rapidly eliminated from the fish with depuration half-life <4 days for all components. While CDPP was almost completely eliminated from the fish within 14 days, TXP components were still evident after this time (UK EA 2009b; 2009c).

A long-term dietary accumulation study that fed common minnows (*Phoxinus phoxinus*) food spiked with a commercial triaryl phosphate product found BAF values for TCP, CDPP and TXP to be much less than one (UK EA 2009a; 2009b; 2009c), indicating that the compounds may have low potential to bioaccumulate from food sources in aquatic organisms.

A study of organisms of different trophic levels in the Arctic found no biomagnification of TCP between the fish capelin (*Mallotus villosus*) and different seabirds and mammals (Hallanger et al. 2015). Trophic magnification of TCP was also not significant in a food web involving sediment, suspended matter and 12 different organisms or their eggs found in a Dutch estuary (Brandsma et al. 2015), and in a Chinese freshwater lake food web of 17 species including plankton, invertebrates and fish (Zhao et al. 2018). The observed trophic dilution during food web studies may be due to rapid metabolism (Brandsma et al. 2015; Zhao et al. 2018).

Biotransformation experiments with TpCP in fish identified six degradation products including di(para-cresyl) phosphate (DpCP), and its hydroxyl and glucuronic acid derivatives (Wang G et al. 2017a). Metabolism is thought to be mediated by cytochrome P450 (CYP) enzymes. The metabolite DpCP was also detected in urine samples from mice (Chen M et al. 2020).

Some of the chemicals in this group and their metabolites have been detected in bird eggs. Whole eggs of black-tailed gull (*Larus crassirostris*) contained 0.915–2.46 µg/kg ww CDPP, whereas no TCP could be detected (Choo et al. 2022). Australian and Belgian chicken eggs were also found to be free of TCP, but the metabolites DCP and DPHP were detected at <0.014–0.23 µg/kg ww and <0.09–34 µg/kg ww, respectively, in the Australian eggs (Li Z et al. 2020; Xu et al. 2015). It was suggested that rapid metabolism of the parent compounds and direct exposure to the metabolites may contribute to this result.

Environmental transport

Chemicals in this group may undergo long range transport by adhesion to atmospheric particles. However, some monitoring studies in remote regions have been complicated by potential local contamination sources. More information is required to determine the transport mechanisms of the chemicals over long ranges.

Studies indicate that chemicals in this group may be stabilised by particles in the air. Therefore, these chemicals may have the potential to undergo long range transport. TCP, its isomers, and TXP have been found in the particulate phase of both urban, lake and marine air (Brommer 2014; Wu Y et al. 2020). Adsorption to particles may increase resistance to degradation, resulting in longer atmospheric half-life. An experimental study of particle (ammonium sulfate) bound OPFRs determined a half-life of 1.8–4.5 days for TCP (Liu Q et al. 2019).

To date, detection of the chemicals in this evaluation in remote regions have coincided with human activity in those areas. For example, an investigation of organic contaminants in Antarctica found that the substances were present near research stations or airports (Gao X et al. 2018). Other evidence of these chemicals in remote locations has not been identified.

Predicted environmental concentration (PEC)

Based on international monitoring data, the predicted environmental concentration of TCP and its isomers is 65.2 µg/kg dw in soil, 14.4 µg/kg dw in sediment, 7.68 ng/L in STP effluent, 115 µg/kg dw in STP biosolids and 17 ng/L in surface water. While international monitoring information is available for other chemicals in this evaluation, the measured concentrations are typically below the PEC values for TCP. The highest detected values from international studies were not used as the representative PEC values as they are typically taken from highly disturbed locations and are not expected to be representative of concentrations in the environment.

No monitoring data are available for Australia.

The chemicals in this evaluation have been found in surface water samples throughout different parts of the world. Typical lake, ground and river water samples from Antarctica, Europe, Asia, North America and the Arctic regions contained on average 0–17 ng/L of the chemicals (Bacaloni et al. 2008; Chen M-H and Ma 2021; Cristale et al. 2013; Gao X et al. 2018; Gao X et al. 2020; Government of Canada 2019; Li W et al. 2019; Sim et al. 2021). Elevated concentrations of TCP and TXP, up to 13.7 µg/L and 11.7 µg/L, respectively, have occasionally been detected in surface waters impacted by landfill leachate or proximity to local industries or airports (Li W et al. 2019; Nantaba et al. 2021; Propp et al. 2021).

Average TCP concentrations in STPs vary globally but are typically in the range of 0–33 ng/L in influent and 0–7.68 ng/L in effluent (Chen M-H and Ma 2021; Government of Canada 2019; Joint Research Centre 2012; Kim et al. 2017; Martínez-Carballo et al. 2007).

Chemicals TCP, TmCP and CDPP have been found in STP biosolids samples from China, Canada, Spain and the US. TCP was detected at average concentrations of 36.5–115 µg/kg dw in biosolids, with maximum values of up to 3600 µg/kg dw. CDPP was detected in biosolids at average concentrations of 5.6–23.3 µg/kg dw (Gao L et al. 2016; Wang Y et al. 2019; Wei et al. 2015; Zeng et al. 2014).

Chemicals in this evaluation have been detected in Europe, Asia, Canada and the Arctic in river and lake sediment samples, with average concentrations generally between <0.01 and 14.4 µg/kg dw (Chen M-H and Ma 2021; Gao X et al. 2020; Giulivo et al. 2017; Government of Canada 2019; Ma et al. 2022; Matsukami et al. 2017; Ye et al. 2021). Elevated concentrations of TCP of up to 375 mg/kg have been detected in locations with suspected contamination from airports and heavy traffic (Yadav and Devi 2020), or from industrial areas and e-waste recycling centres (Chen M-H and Ma 2021).

Soil samples from different settings in China, Vietnam and the US show average concentrations of TCP, CDPP and TXP at 0.06–65.2 µg/kg, with most of the samples collected in areas of human activity (Li W et al. 2019; Matsukami et al. 2017; Wang Y et al. 2018). Higher values for TCP, up to approximately 25500 µg/kg, were observed in Nepal at locations with high human activity (Yadav and Devi 2020). Samples from three US air force bases collected between 1994–1999 showed TCP levels ranging from 30–130 000 µg/kg, with peak values taken from heavily contaminated areas (David and Seiber 1999). Detected soil concentrations varied with location in Vietnam, with the highest concentrations being detected at e-waste recycling sites (Matsukami et al. 2017).

Chemicals in this group have been detected in outdoor air in different environments around the world. In urban areas, averages were found to be in the range of 0–61 pg/m^3 (Brommer 2014; Cao et al. 2022; Wu Y et al. 2020). Maximum values ranging from 164–691 pg/m^3 have been measured for TCP, its isomers and CDPP in urban air with higher levels of pollution (Li W et al. 2019; Wu J et al. 2022; Wu Y et al. 2020). Concentrations are generally very low (≤15 pg/m^3) in remote areas (Brommer 2014; Na et al. 2020; Wu Y et al. 2020), with a peak value at 95 pg/m^3 for TmCP and TpCP at a remote location in the US (Wu Y et al. 2020).

Some of the chemicals in this group have been detected in fish. TCP was detected at 0–2.34 µg/kg ww in Mediterranean and Chinese sea and lake fish (Li J et al. 2022; Sala et al. 2022; Wang W et al. 2022; Xie et al. 2022). CDPP was found at 0–6.05 µg/kg ww in European sea fish (Sala et al. 2021; Sala et al. 2022). Fish from the Great Lakes area contained <1–1.36 µg/kg ww ToCP, <1.4–34.8 µg/kg ww TmCP and <0.2–0.462 µg/kg ww 3,4-TXP (Choi et al. 2022).

Environmental effects

Effects on Aquatic Life

Acute toxicity

The following measured median lethal concentration (LC50), effective concentration (EC50) and median effective loading rate (ErL50) values for TCP, CDPP, TXP and TpCP in model organisms that were retrieved from the literature (Wang G et al. 2017b), the registration dossier for the individual chemicals under REACH legislation (REACHa n.d.; REACHb n.d.), the National Institute of Technology and Evaluation (NITE) in Japan (NITE n.d.), the SIDS dossier on diphenyl cresyl phosphate (OECD 1998), and the UK Environmental agency risk evaluation report for tricresyl phosphate (UK EA 2009a):

Taxon	Endpoint	Method
Fish	TCP: 96 h LC50 = 0.26 mg/L	*Oncorhynchus mykiss* (rainbow trout) flow-through US EPA 1975
	CDPP: 96 h LC50 = 1.3 mg/L	*Oryzias latipes* (japanese rice fish) semi-static nominal concentration Solvent vehicle (methanol) OECD TG 203
	TXP: 96 h LC50 >1.12 mg/L*	*Pimephales promelas* (fathead minnow) flow-through, no effects observed measured concentration solvent vehicle (DMF) OECD TG 203
	TpCP: 96 h LC50 = 0.75 mg/L*	*Danio rerio* (zebrafish) OECD TG 203

Taxon	Endpoint	Method
Invertebrate	TCP: 48 h EC50 = 0.146 mg/L	*Daphnia magna* (water flea) static, mortality/mobility measured concentration at test termination OECD TG 202
	CDPP: 24 h EC50 = 3.7 mg/L*	*Daphnia magna* static, immobilisation nominal concentration solvent vehicle (DMSO:HCO-40 9:1) OECD TG 202
	TXP: 48 h EC50 = 0.060 mg/L	*Daphnia magna* static, mortality/mobility measured concentration solvent vehicle (DMF) OECD TG 202
Algae	TCP: 72 h ErL50 >2.5 mg/L*	*Raphidocelis subcapitata* (green algae) growth rate static, no effects observed nominal concentration OECD TG 201
	CDPP: 72 h EC50 = 0.99 mg/L	*Raphidocelis subcapitata* static, biomass nominal concentration solvent vehicle (methanol) OECD TG 201
	TXP: 72 h EC50 >1.01 mg/L*	*Raphidocelis subcapitata* static, no effects observed growth rate measured concentration solvent vehicle (DMF) OECD TG 201

* Toxicity endpoint above solubility limit

Chronic toxicity

The following measured no observed effect concentration (NOEC) and no observed adverse effect concentration (NOAEC) values for TCP, CDPP and TXP in model organisms across three trophic levels that were retrieved from the registration dossier under REACH legislation (REACHa n.d.; REACHb n.d.), a screening assessment for TCP performed by Environment and Climate Change Canada Health Canada (Government of Canada 2019), the SIDS dossier on diphenyl cresyl phosphate (OECD 1998), and the literature (van den Dikkenberg et al. 1989):

Taxon	Endpoint	Method
Fish	TCP: 28 d NOEC = 0.001 mg/L	*Gasterosteus aculeatus* (three-spined stickleback) semi-static, mortality nominal concentration
Invertebrates	TCP: 21 d NOEC = 0.1 mg/L	*Daphnia magna* (water flea) semi-static, reproduction measured concentration solvent vehicle (DMSO) NEN 6502
	CDPP: 21 d NOEC = 0.12 mg/L	*Daphnia magna* semi-static, reproduction nominal concentration solvent vehicle (DMSO:HCO-40 9:1) OECD TG 202
Algae	TCP: 72 h NOEC = 0.088 mg/L	*Raphidocelis subcapitata* (microalga) growth OECD TG 201
	CDPP: 72 h NOEC = 0.55 mg/L	*Raphidocelis subcapitata* biomass nominal concentration solvent vehicle (methanol) OECD TG 201
	TXP: 72 h NOAEC = 0.074 mg/L	*Raphidocelis subcapitata*, static, growth rate measured concentration solvent vehicle (DMF) OECD TG 201

Effects on terrestrial Life

A 28 d study with TXP following OECD TG 222 (nominal concentrations) reported an LC50 (mortality) of >1000 mg/kg dw soil and LOEC (growth) of 1000 mg/kg dw soil for the earth worm *Eisenia fetida* (REACHb n.d.).

In mammals and birds, toxicity of organophosphorus compounds is caused by the inhibition of esterase enzymes (mostly cholinesterases and neurotoxic esterases) through phosphorylation, leading to an accumulation of choline esters in organs or tissue (Winder and Balouet 2002). TCP can also induce a delayed neurodegenerative condition known as organophosphate-induced delayed neuropathy (OPIDN), which affects nerves of birds and mammals (Denola et al. 2011). In an experiment involving three pure isomers of TCP, it was found that ToCP inhibits cholinesterases while TmCP and TpCP have lower activity (Aldridge 1954).

The alkyl substituents at the ortho position of the aromatic rings are indicators for high neurotoxic activity and some 2-alkylphenyl phosphate isomers are more toxic than others (Denola et al. 2011). For example, unsymmetrical mono-ortho isomers of tricresyl phosphate are more toxic (in relation to OPIDN) than those with the di-ortho configuration, which in turn are more toxic than the symmetrical tri-ortho isomer ToCP. The phosphate esters of coal tar derived cresylic acids contain the more toxic ortho isomer (NICNAS 2018a). The toxicity of these substances is largely due to the ability to form cyclic metabolites in vivo that are neurotoxic (Carletti et al. 2011).

Endocrine activity

The chemical TCP shows endocrine activity in fish and rats and may cause endocrine-related effects on fish gonad development.

In vivo studies in male Japanese medaka (*Oryzias latipes*), exposed to TCP at measured concentrations up to 4 µg/L for 100 days, indicate decreased fertilisation rates (6.9%–12.8%) in all exposure groups in a dose dependent manner. Significantly reduced hatching rate and increased intersex (22% incidence) were also observed at the highest concentration (Chen R et al. 2022).

Exposure of zebrafish (*Danio rerio*) to TCP in the range 8 to 200 µg/L over 14 days (semi-static exposure, nominal concentrations) increased plasma testosterone and 17β-estradiol concentrations and significantly up-regulated transcription of steroidogenic genes in both sexes, while vitellogenin gene transcription was down-regulated in females and up-regulated in male fish. These changes were dose dependent, and in females vitellogenin gene transcription decreased at concentrations as low as 40 µg/L (Liu et al. 2012).

The chemical ToCP was found to interfere directly with spermatogenic processes and sperm motility in male rats. The threshold dose for observable testicular toxicity was 10–25 mg/kg per day (UK EA 2009a).

Predicted no-effect concentration (PNEC)

A PNEC for TCP of 0.1 µg/L (100 ng/L) was derived from the measured fish chronic ecotoxicity endpoint (35 d NOEC = 1 µg/L) using an assessment factor of 10. This assessment factor was selected as reliable chronic ecotoxicity data available over three trophic levels.

A PNEC for CDPP of 2.4 µg/L was derived from the measured fish chronic ecotoxicity endpoint (21 d NOEC = 120 µg/L) using an assessment factor of 50. This assessment factor was selected as reliable chronic ecotoxicity data available over two trophic levels.

A PNEC for TXP of 0.6 µg/L was derived from the measured invertebrate acute ecotoxicity endpoint (48 h EC50 = 60 µg/L) using an assessment factor of 100. This assessment factor was selected as reliable chronic ecotoxicity data available over one trophic level.

Categorisation of environmental hazard

The categorisation of the environmental hazards of the assessed chemical according to the Australian Environmental Criteria for Persistent, Bioaccumulative and/or Toxic Chemicals (DCCEEW n.d.) is presented below:

Persistence

Not Persistent (Not P). Based on measured degradation studies for TCP, ToCP, TpCP and CDPP, and structural similarities of TmCP, DCPP and XDPP, the chemicals TCP, ToCP, TmCP, TpCP, CDPP, DCPP and XDPP are categorised as Not Persistent.

Persistent (P). Based on measured degradation studies for TXP and structural similarities of TARC and TARX, the chemicals TXP, TARC and TARX are categorised as Persistent.

Bioaccumulation

Not Bioaccumulative (Not B). Based on low measured bioconcentration factors (BCF) in fish, and no evidence of biomagnification, the chemicals in this group are categorised as Not Bioaccumulative.

Toxicity

Toxic (T). Based on available ecotoxicity values below 1 mg/L and evidence of chronic toxicity of TCP, CDPP and TXP, and structural similarities of the remaining compounds, the chemicals in this group are categorised as Toxic.

Environmental risk characterisation

Based on the PEC and PNEC values determined above, the following Risk Quotient (RQ = PEC ÷ PNEC) have been calculated for TCP into rivers and surface waters:

Compartment	PEC	PNEC	RQ
Surface water	17 ng/L	100 ng/L	0.17

Risk quotients have not been calculated for the remaining chemicals in this group. In international monitoring studies, TCP has the highest PEC values of the chemicals in this evaluation. Additionally, TCP has the lowest PNEC value of the chemicals in the evaluation. The risk posed to environmental surface waters by the remaining chemicals in this group is therefore expected to be equal to or lower than that of TCP.

Calculated RQs less than 1 indicate that these chemicals are not expected to pose a significant risk to the aquatic environment based on estimated emissions, as environmental concentrations are below levels likely to cause harmful effects in typical environmental conditions.

While the highest environmental concentration values were found in highly disturbed areas (e.g., landfills, airports, industrial areas) they are not expected to be representative of the risk of the chemicals to the environment. Instead, average environmental concentrations from international monitoring studies have been considered for risk calculations.

While the chemicals in this evaluation are frequently found in soils and sediment, little information is known regarding the toxicity of these substances to soil or sediment dwelling organisms. As a result, no RQ for the release of the chemicals to soil or sediment has been calculated. If more information becomes available, a risk characterisation of chemicals in this group for these compartments may be possible.

The chemical TCP and related chemicals may induce endocrine effects in some species of fish, but effect concentrations are typically above those found in the environment. No endocrine activity data were available for TXP, but based on structural similarity to TCP, TXP and related chemicals are likely to exhibit similar effects. The PNEC derived in this assessment is considered protective for the endocrine effects described by currently available evidence. The risk may need to be re-evaluated if new information becomes available.

Uncertainty

This evaluation was conducted based on a set of information that may be incomplete or limited in scope. Some relatively common data limitations can be addressed through use of conservative assumptions (OECD 2019) or quantitative adjustments such as assessment factors (OECD 1995). Others must be addressed qualitatively, or on a case-by-case basis (OECD 2019).

The most consequential areas of uncertainty for this evaluation are:

- Insufficient information is available to characterise the terrestrial and sediment toxicity of the chemicals in this group. The outcomes of the evaluation may change if additional information becomes available.
- As limited information available for DCPP, XDPP, TARX and TARP, their hazard assessment has been conducted with reference to the better studied compounds in this group. The outcomes of this evaluation may change if new information becomes available to indicate that the hazard characteristics of these substances is significantly different.
- No Australian monitoring information was available for the chemicals in this group. The outcomes of this evaluation may change if new monitoring information become available to indicate that environmental concentrations of these chemicals in Australia are higher than currently assessed.

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