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Table 1. The chemical identity of Dechlorane Plus, with its *syn*- and *anti*-isomers

CAS number:	13560-89-9 (Dechlorane Plus™), 135821-03-3 (*syn*-DP), 135821-74-8 (*anti*-DP)
IUPAC name:	1,6,7,8,9,14,15,16,17,17,18,18-dodecachloropentacyclo-[12.2.1.1^{6,9}.0^{2,13}.0^{5,10}] octadeca-7,15-diene (Dechlorane Plus™), (1S,2S,5R,6R,9S,10S,13R,14R)-1,6,7,8,9,14,15,16,17,17,18,18-dodecachloropentacyclo[12.2.1.1^{6,9}.0^{2,13}.0^{5,10}]octadeca-7,15-diene (*syn*-DP), (1R,2R,5R,6R,9S,10S,13S,14S)-1,6,7,8,9,14,15,16,17,17,18,18-dodecachloropentacyclo[12.2.1.1^{6,9}.0^{2,13}.0^{5,10}]octadeca-7,15-diene (*anti*-DP)
EC number:	236-948-9
EC name:	1,6,7,8,9,14,15,16,17,17,18,18-Dodecachloropentacyclo[12.2.1.16,9.02,13.05,10] octadeca-7,15-diene
Molecular formula:	$C_{18}H_{12}Cl_{12}$
Molecular weight:	653.73 g/mol
Synonyms:	Bis(hexachlorocyclopentadieno)cyclooctane; 1,2,3,4,7,8,9,10,13,13,14,14-Dodecachloro-1,4,4a,5,6,6a,7,10,10a,11,12,12a-dodecahydro-1,4:7,10-dimethanodibenzo[*a,e*]cyclooctene; 1,4:7,10-Dimethanodibenzo[a,e]cyclooctene 1,2,3,4,7,8,9,10,13,13,14,14-dodecachloro-1,4,4a,5,6,6a,7,10,10a,11,12,12a-dodecahydro-; Dodecachlorodimethanodibenzocyclooctane; Dodecachlorododecahydrodimethanodibenzocyclooctane; Dodecachlorododecahydrodimethanodibenzocyclooctene; DDCDiMeDiBzcOb
Trade names	Dechlorane Plus; Dechlorane Plus 25 (Dech Plus); Dechlorane Plus 35 (Dech Plus-2); Dechlorane Plus 515; Dechlorane 605; Dechlorane Plus 1000; Dechlorane Plus 2520; Dechlorane A; DP; Escapeflam DK-15 (China); PyroVex SG (grade 515, 25 and 35)

Table 2. Overview of selected physicochemical properties of Dechlorane Plus, with its *syn*- and *anti*-isomers

Property	Value	Reference
Physical state at 20 °C and at 101.3 kPa	Solid white powder	ECHA, 2017b
Melting/freezing point	340-382 °C 350 °C	ECHA, 2017b OxyChem, 2004b
Vapour pressure	0.006 mm Hg ≙ 0.8 Pa (at 200 °C)	OxyChem, 2004b
Water solubility*	<1.67 ng/L (20 – 25 °C) 0.044 – 249 µg/L (insoluble)	ECHA, 2017b OxyChem, 2004b
n-Octanol/water partition coefficient, K_{ow} (log value)	9.3	OxyChem, 2004b
n-Octanol-air partition coefficient K_{oa} (log value)	12.26	OxyChem, 2004b
Sediment/water partition coefficient K_p (log value)	6.65	OxyChem, 2004b
Air-water partition coefficient K_{aw} (log value)	The following log K_{AW} values are estimated at 25 °C -3.2 (from measured water solubility and estimated vapour pressure) 0.44 (from measured water solubility and vapour pressure) -2.8 (from EPIWIN **predicted water solubility using log K_{OW} of 9 and vapour pressure) -3.5 (from HENRYWIN***v.3.20, predicted from structure using Bond Method).	ECHA, 2017b

* There is some uncertainty in the precise value for water solubility (Chou et al. (1979a). However, all available measurements and predictions agree that the substance is very poorly water soluble.

The following modelling programs are individual models in EPI Suite™:

** Estimation Program Interface Suite for Windows

*** Calculates the Henry's Law constant (air/water partition coefficient) using both the group contribution and the bond contribution methods. Since the group contribution method is not applicable to DP due to fragments missing in the database, only the result of the bond contribution method is shown.

Table 3. National regulatory processes and other related information for Dechlorane Plus and its isomers

Country/ organisation	Regulatory process
Australia	Australia has started with the evaluation of DP: Rolling Action Plan – our chemical evaluations list (AICIS, 2022).
Canada	DP is listed on Canada's Domestic Substances List (DSL) (ECCC, 2019). A final screening assessment of DP was published by Environment and Climate Change Canada (ECCC) and Health Canada in spring 2019 (Canada, 2019a). The assessment concludes that DP meets the criteria for toxicity to the environment, as it is entering or may enter 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. The proposed regulatory approach is to amend the *Prohibition of Certain Toxic Substances Regulations, 2012* to prohibit the manufacture, import, use, sale or offer for sale of DP and all products containing the substance (Canada, 2019b). A cost benefit analysis will be available following the publication of the Regulatory Impact Analysis Statement (RIAS), which will be published concurrent to proposed changes to the *Prohibition of Certain Toxic Substances Regulations, 2012*. The publication of the proposed changes to the *Prohibition of Certain Toxic Substances Regulations, 2012* and RIAS is targeted to take place in 2022 (Annex F, Canada).
China	According to Enviliance ASIA (2021), China has released a draft of the New Pollutant Management Action Plan and production, use, import and export of DP will be banned from January 1in 2026.
Egypt	DP is banned by Decree No. 55 year 1996 of the Minister of Trade (Annex E, 2021). DP is banned as a pesticide with decree no.719 in 2005. (Annex F, 2022).
European Union	The ECHA online Classification & Labelling (C&L) Inventory database, which was checked on 8 March 2021, reports a joint submission (consisting of 151 notifiers) indicating no classification according to the CLP criteria. In addition, 99 notifiers have classified the substance as Acute Toxicity Category 4, H332 Harmful if inhaled (ECHA, 2021). In 2018, based on an Annex XV dossier and Risk Management Options Analysis prepared by the United Kingdom, DP (including its *syn*- and *anti*-isomers) were identified as SVHC and added to the REACH Candidate List as they are considered to be very persistent and very bioaccumulative substances (ECHA, 2017a). Suppliers of articles containing a SVHC in a concentration above 0.1% (weight by weight) have to provide recipients of the article with sufficient information to allow the safe use of the article. As a minimum, the name of the substance in question has to be communicated. Upon request from a consumer, the supplier has to provide safety data sheet, within 45 days. Based on its intrinsic properties in combination with high volume and widespread use, ECHA recommended in October 2019 to include DP in Annex XIV of the REACH Regulation (List of Substances Subject to Authorization). However, to align risk management activities within the EU with the evaluation process under the Stockholm Convention, an Annex XV REACH restriction dossier for DP has been prepared. Norway was responsible for developing the restriction proposal (ECHA 2021). The restriction process in the EU is still ongoing (https://echa.europa.eu/da/registry-of-restriction-intentions/-/dislist/details/0b0236e184a168c4) A ban on the use of all halogenated FRs in electronic displays entered into force in the EU in 2021 (EU, 2019). This ban, adopted as part of the EU's Ecodesign Regulation, applies to all electronic displays, including TVs, monitors, and digital signage displays, with size equal or greater than 100 cm^2, or 15.5 in^2. This regulation took effect in 2021.

New Zealand	DP is listed on New Zealand's Inventory of Chemicals but does not have its own approval under the Hazardous Substances and New Organisms Act. This means it can only be used as a component of products that are covered by group standards (Annex E information, New Zealand).
Norway	In Norway, DP was added to the list of priority substances in January 2019 with a national goal to phase out the use by 2020 (Norwegian Environment Agency, 2019b).
Russian Federation	The presence of this substance in the "Unified List" is evidence of the fact of its circulation on the Russian Federation national territory, but not of its production of the Russian manufacturers. This substance supplied to the Russia by Importers or Only representatives of import manufacturers and not produced in the Russian Federation (Annex E Russian Federation, Federal State Autonomous Institute Research Institution 'Environmental Industrial Policy Center' (EIPC) (Update to Annex E information in January 2022).
Singapore	Singapore is intending to regulate five hazardous substances, including DP, under the nation's Environmental Protection and Management Act 1999 and Environment Protection and Management (Hazardous Substances) Regulations (SGS, 2022).
Thailand	DP is not yet classified under the Hazardous Substance Act B.E. 2535 (1992). However, DP is regulated under the notification of the Ministry of Industry, Thailand on Account no 5.6. Manufacturers and importers are required to report imports of chemicals/products with tonnage above 1000 kg/year. At present, there is no data on available import volumes and usage in Thailand (Annex E information, Thailand)
United States of America	DP is on the Toxic Substances Control Act (TSCA) Inventory and is subject to the TSCA Chemical Data Reporting Rule, which requires manufacturers and importers to provide the United States Environmental Protection Agency with production, import and use volumes, as well as other relevant information (US EPA, 2020). The U.S. Consumer Product Safety Commission cautioned electronics manufacturers and retailers to "eliminate the use" of halogenated flame retardants in consumer products to protect consumers and children, including the following warning: "To protect consumers and children from the potential toxic effects of exposure to these chemicals, the Commission recommends that manufacturers of children's products, upholstered furniture sold for use in residences, mattresses and mattress pads, and plastic casings surrounding electronics refrain from intentionally adding non-polymeric, organohalogen flame retardants. Further, the Commission recommends that, before purchasing such products for resale, importers, distributors, and retailers obtain assurances from manufacturers that such products do not contain organohalogen flame retardants." (govinfo, 2017).
International Chemical Secretariat	DP has been listed on the International Chemical Secretariat's ChemSec Substitute It Now (SIN) List since 2014 (SIN List, 2020). The SIN List consisting of chemicals that have been identified by ChemSec as being SVHC, based on the criteria defined within REACH, the EU chemicals legislation.

Table 4. Global production volumes for DP, in tonnes/year (Eftec, 2021)

Region	1986 - 2002	2003 - 2008	2008 - 2010	> 2011
USA	450 – 4 500[1]	450 – 4 500[2]	n/a	withheld[2]
China	0	300 – 1 000[3]	300 – 1 000[3]	n/a
Global	**450 – 4 500**	**750 – 5 500**	**4 500 – 5 000[4]**	**n/a**

Note: Global production volumes between 1986-2008 are calculated from production volumes in the USA and China.

[1] ECHA (2020b); Qiu et al. (2007)
[2] US EPA (2016)
[3] Canada (2019); ECHA (2020b); Wang et al. (2010b)
[4] Wang et al. (2010b); Feo et al. (2012); Ren et al. (2009)
Note: These references can be found in the original report (Eftec, 2021).

Table 5. Global trade volumes of DP, t/y (Eftec 2021; Annex E and F information from Republic of Korea and UK)

Region	2000	2003-2006	2008	2011	2014	2015	2016	2017	2018	2019	2020
Sweden		4 - 11[5]	0[6]								
Finland			0[6]								
Norway			0[6]								
UK*								14-40	14-40	14-40	
EU/EEA	800[6]		200[7] – 5,000[8]					100-1,000[9]	100-1,000[10]	<300[11]	10- 100[12]
Canada			1-10[13]	1-10[13]			1-10[13]				
Republic of Korea**					10		10		0.63		

Note: - Only years for which data was available are included.

- Blank cells indicate that no data on import volumes was found for the country/region in the specific year.

* Annex F information DP used per annum in the UK have been estimated based on extrapolated data from the EU registration and the estimation of imports of dechlorane plus into the UK.
** Annex E and F information
[5] IVL, 2010; ECHA, 2020a
[6] IVL, 2010
[7] EA, 2018
[8] ECHA, 2021
[9] ECHA, 2017a
[10] ECHA, 2019a
[11] ComRef, 2019C
[12] ECHA, 2020c
[13] ECCC, 2019
Note: These references can be found in the original report (Eftec, 2021).

Table 6. Summary of uses of DP found in open literature as identified in ECHA (2022b)

Industry	Sector	Article / Component
Automotive	Electrical and electronic equipment	Wires and cable plastic coatings, coil bobbins,[14] cable straps
		Switches, and small electronic appliances including cameras, computers (motherboards, chargers and hard-plastic connectors)
	Engines	2-part epoxy-void fillers
	Other	Bodywork parts
Aviation	Electrical and electronic equipment	Wires and cable plastic coatings, coil bobbins, cable straps
		Switches, and small electronic appliances including cameras, computers (motherboards, chargers and hard-plastic connectors)
	Engines	2-part epoxy-void fillers
Electrical and electronic equipment	Wire and cables	Wire and cable plastic coatings not used in the automotive or aviation industry, including cable insulation and nuclear power plant control cables
	Electronic devices	Electronic devices not used in the automotive or aviation industry, including mobile phones, lamps refrigerators, computer and washing machines
Building / manufacturing materials	Plastic products	Plastic roofing materials, wallpaper, paint, pipes, flooring, power tool housing and wall plates
Other consumer products	Plastic products	(Plastic) toys
		Food packaging
	Textiles	Clothing, mattresses, curtains, carpets and (textile) toys
	Adhesives	Adhesives and binding agents, syntactic foams and potting compounds

[14] A coil bobbin refers to the plastic containers used to keep wire enabling it to retain shape and rigidity. Additionally, coil bobbins are used to ease assembly of the windings into or onto a magnetic core.

Table 7. Uses according to REACH registrations (ECHA, 2022b)

Registered uses	End use/final product and articles (according to use descriptions explicitly listed in registration dossiers)
Formulation	Relevant chemical product categories for which Dechlorane Plus is used in pure form: PC 1: Adhesives, sealants PC 32: Polymer preparations and compounds PC 33: Semiconductors
Uses at industrial sites	Relevant sectors of end use for which Dechlorane Plus is used, whereby subsequent service life is not relevant for this use: SU 10: Formulation [mixing] of preparations and/or re-packaging (excluding alloys) SU 12: Manufacture of plastics products, including compounding and conversion SU 16: Manufacture of computer, electronic and optical products, electrical equipment
Article service life	Article category related to subsequent service life of articles at consumer use stage: AC 1: Vehicles AC 2: Machinery, mechanical appliances, electrical/electronic articles AC 3: Electrical batteries and accumulators AC 5: Fabrics, textiles and apparel AC 13: Plastic articles Article category related to subsequent service life of articles at industrial sites (by workers): AC 1: Vehicles AC 2: Machinery, mechanical appliances, electrical/electronic articles

Table 8. Information on use from stakeholders (ECHA, 2022b,c)

Sector / industry group	Use		Quantity	Reference
Aerospace and defence	Estimates of use in European Economic Area (EEA) based on preliminary responses	EEA Production	200 kg/y	Industries Association of Europe
		EEA Repair	600 kg/y	
		EEA Imported and premanufactured articles	800 kg/y	
Automotive	Vehicle including automobile, construction, machinery, agriculture etc.	Wire harness, adhesive, tape and 'diallyl phthalate prepolymer' <u>The main materials and its purpose</u>: - Polymers used in parts that require flame retardance - Greases used in parts that require seizure resistance	- 140 tons per year of the production volume of DP is used in Automobile Industries - Concentrations of DP in final products are < 0.1% - 200 g DP per vehicle in average	Japan Auto Parts Industries Association (JAPIA)
		PDAP resin		
		Spare parts		
Automotive	Motorcycle	Legacy spare parts		ACEM - The Motorcycle Industry in Europe
Automotive	Vehicle	Legacy spare parts		All-Terrain Vehicle Industry European Association
Agricultural machinery	Long-lived agricultural machinery used by farmers	Flame retardance and seizure resistance used in agricultural machinery for components such as harnesses, polymers, greases		Japan Agricultural Machinery Manufacturers Association
		Repair and spare parts		
Marine leisure		Flame retardant and anti-seize compound in products used in engines/powertrains in the marine leisure industry, including wire harnesses, adhesives, tape and grease for marine power equipment	Typical concentrations in products used are 13-20%w/w in coating of electric wires, 20-25%w/w in grease	The Marine Engine Committee (IMEC) of the International Council of Marine Industry Associations (ICOMIA)
Electrical and electronic equipment	Electric and electronic equipment including products with longer design cycle, such as	Spare parts, repaired or refurbished products		Japan Electronics and Information Technology Industries Association (JEITA)

	production machinery and infrastructure equipment			
Electrical and electronic equipment	Electrical and electronic equipment	Spare parts, refurbishment and resale of older products		DIGITALEUROPE - The association representing the digital technology industry in Europe
Electrical and electronic equipment	Electrical and electronic equipment	Additive in thermoset plastic, thermoset plastic mixtures and articles made from Dechlorane-bearing thermoset plastic mixtures	Typical concentration about 8%	Würth Elektronik eiSos GmbH & Co
		Coil forms and coil assembly mounts, such as bobbins, bases, and headers, and inductors, transformers, and other passive electromagnetic components		
Medical	Medical imaging including X-ray equipment, CT-equipment, PET/SPECT MRI-equipment, LINACs, Particle Therapy, Brachytherapy, Stereotactic body radiosurgery, Ultrasound equipment etc.	Electrical cables & ductwork, plastic in electrical wire coatings, hard plastic electrical connectors, Printed Circuit Board items, monitor/display interfaces, other plastic electronic parts		European Trade Association representing the medical imaging, radiotherapy, health ICT and electromedical industries (COCIR)

Table 9. Information on use from Annex F information

Sector / industry group	Use		Reference
Aerospace and defence	Aero engine manufacture and repair	Flame retardant in fillers; Affected parts include aircraft jet engine fan blade abradable rub strips and the use of DP includes the related void filling abradable compound for manufacturing and repair	International Coordinating Council of Aerospace Industries Associations (ICCAIA)
	Missile rocket motors	Flame retardant	
	Electrical items	Connectors, wires, cables, switches, tapes, films, power supplies, gaskets, transceivers, monitors, inductors, printed circuit boards and transformers	
	Structural panels	Epoxy adhesives, syntactic foams, potting compounds; Adhesives containing DP are used to fill honeycomb edges in panels, liners, partitions and stowage	
	Naval systems	Fire retardant in polymeric components of articles used for the manufacture and maintenance of some naval systems	
	Aircraft cabin interiors	Adhesives, syntactic foams, honeycomb core edge fillers/potting compounds	
Automotive	Automobile	Legacy spare parts	European Automobile Manufacturers' Association (ACEA)
Automotive	Automobile including motorcycles, agricultural machinery, and construction machinery	Flame retarded resins including Polydiarylphthalate (PDAP) resin, Flame retarded/Insulating/Heat resistant; Adhesive tape, Adhesive, Filler, Grease, Electric and electronic parts (Wire harness, Connector, Cable, Cable protection tube, Coil, Solenoid, Bobbin, Case, Motor, Transformer, Substrate, Sensor, Inductor, Inverter, Converter, Alternator, Thermostat, Thermistor, Noise filter, Electronic Control Unit, Gateway device, Communication terminal, Electric fan, Lump, Display, Touch panel, Power supply, Lighting device, Charger, Switch, Electromagnetic valve, IC), Gear lever, Hose/Tube, Steering shaft, Oil filter, Clutch, Starter, Antenna, Hot wire film, Car audio, Air conditioner, Heat exchanger, Scale, Water absorption sheet, USB	Japan
Railway			
Industrial machinery	Semiconductor manufacturing equipment, Automatic vending machinery, hydraulic equipment, Bearing, Machine tool, Electric equipment, Sewing machinery, Air-conditioning and Refrigerating equipment, Forming machinery, Die-casting machinery etc.		
Medical	Medical instrument		
Electrical and electronic equipment	Analytical, Measuring, Testing, Monitoring Controlling equipment, Battery, Information and communication network equipment,		

	Electronic information system, Lighting equipment, Home electronic appliance		
Construction	Housing, Construction,		
Material	Chemical and related materials		
Other	Infrastructure equipment including Wiring system, Gas alarming equipment, Gas and oil equipment, Heavy electric machinery etc.		

Table 10. Table 1 Use of DP in the automotive industry (from Eftec, 2021)

Use/application	Share of total volume
Electric wire (with wire harnesses being specifically mentioned)	80%
Plastic and rubber parts	8%
Tapes and adhesives	10%
Greases (extreme pressure agent)	2%

Table 11. Concentration of DP in thermoplastics and thermosets, based on information from 2007 and 2009 as identified in ECHA (2022b)

Type of polymeric system	Product type	Concentration of Dechlorane Plus	Reference
Thermoplastic	ABS	16.9%	OxyChem (2007)
	Natural rubber	18.7%	
	Nylon	0–35%	KemI (2007) and Weil and Levchik (2015)
	Polybutylene terephthalate	8–18%	OxyChem (2007)
	Polyester	0–16%	KemI (2007)
	Polypropylene	20–35%	OxyChem (2007)
	SBR block copolymer	30%	
Thermoset	Epoxy resins	25.5%	
	EPDM	33%	
	Neoprene	10%	
	Polyester resins, unsaturated	n/a	
	Polyethylene, cross-linked	25.5%	
	Polyurethane foam	17.5–35%	
	Polyurethane rubber	20–30%	
	Silicon rubber	18.8–40%	

Note: Other relevant polymer systems for DP referred to in OxyChem product literature as of 2007 are: Chloroprene; DAP; EEA; Phenolics; EPR; EVA; Hypalon®; Hytrel®;Kraton; High Impact Polystyrene; and TPE (ECHA, 2022b).

Table 12. Use of DP in specific polymer types

Polymer (or other substrate)	Application type	Notes on technical function, loading rate and synergist systems	Comments
Thermoplastic polymers			
Acrylonitrile butadiene styrene (ABS)	Resin	FR at 16.9% with antimony trioxide synergist (OxyChem, 2007) FR typical loading ~20% in ABS in appliances (ESD, OECD, 2004)	UV stability, high heat distortion temperature, and no blooming are particularly mentioned (OxyChem, 2007)
Natural rubber	Elastomers [Elastomer adhesives]	FR at 18.7% with antimony trioxide (OxyChem, 2007)	No further information found
Nylon	Fibre reinforced polymer	FR at 10-25% in presence of inorganic synergist (zinc, antimony, iron compounds) (OxyChem, 2007)	
Nylon	Connectors, switches, cable straps, power tool housing and wall plates	FR at 11-22% in presence of inorganic synergist (zinc, antimony, iron compounds) (OxyChem, 2007)	"The synergist selected is a very important factor in determining the physical and electrical properties of the final formulation." (OxyChem, 2007) **Confirmed and significant commercial use of DP**
Nylon coating	Wire and cable / cable coatings; cable jackets	FR at 11-22% in presence of inorganic synergist (zinc, antimony, iron compounds) (OxyChem, 2007) For 'high CTI' fibre-reinforced nylon, important for electrical insulation function: 11.2% in presence of synergist (zinc, antimony, melamine compounds) (OxyChem, 2007)	"The synergist selected is a very important factor in determining the physical and electrical properties of the final formulation." (OxyChem, 2007)
Polybutylene Terephthalate (PBT)	Connectors, switches, cable straps, power tool housing and wall plates	FR at 15.2-15.75% with antimony trioxide synergist ('high CTI') (OxyChem, 2007)	
Polybutylene Terephthalate (PBT)	Fibre reinforced polymer	FR at 8-18% with synergists (antimony trioxide) (OxyChem, 2007)	
Polyolefin Polyethylene	Wire and cable / cable coatings; cable jackets [Thermoplastic adhesives]	FR at ~25% in presence of inorganic synergist (antimony) (OxyChem, 2007)	**Confirmed and significant commercial use of DP**
Kraton	Elastomers	FR at 30% with antimony trioxide (OxyChem, 2007)	No further information found

Polymer (or other substrate)	Application type	Notes on technical function, loading rate and synergist systems	Comments
TPU, Thermoplastic urethanes	Elastomers	FR at 16% with antimony trioxide (OxyChem, 2007)	No further information found
TPU, Thermoplastic urethanes	Potting compounds		No further information found
Ethylene vinyl acetate (EVA)	Wire and cable / cable coatings; cable jackets [Thermoplastic adhesives]	FR at 25% in presence of inorganic synergist (antimony) (OxyChem, 2007)	Electrical properties, thermal stability and colourability; char formation and non-dripping, low smoke (OxyChem, 2007)
Expanded polystyrene	Foams / sound-absorbing panels		Relevance in EU is uncertain
Polyvinyl chloride (PVC)	PVC line pipes		Relevance in EU is uncertain
Thermoset polymers			
Cross-linked PE (XLPE)	Wire and cable / cable coatings; cable jackets	FR at ~25.5% in presence of inorganic synergist (antimony) (OxyChem, 2007)	Electrical properties, thermal stability, and colourability; char formation and non-dripping, extremely low smoke (OxyChem, 2007)
Epoxy	2-part Epoxy void filler / potting compound / syntactic foam [thermoset polymer adhesives]	FR at <15%	Exceptionally stringent qualification requirements apply in this sector (Rolls Royce PLC, comments received in 2019 to ECHA's Draft 9th Recommendation for DP [for inclusion of substances in Annex XIV of REACH]) **Confirmed commercial use of DP**
Epoxy resin	Resin	FR at 25.5% with synergists (antimony, zinc or iron compounds); Filler (OxyChem, 2007)	Choice of synergist can affect amount of smoke production (OxyChem, 2007)
Ethylene/propylene diene monomer elastomers (EPDM)	Wire and cable / cable coatings; cable jackets	FR at 33% in presence of inorganic synergist (antimony) (OxyChem, 2007)	Electrical properties, thermal stability, and colourability; char formation and non-dripping (OxyChem, 2007)
Ethylene/propylene diene monomer elastomers (EPDM)	Nuclear power plant control cable (Wire and cable / cable coatings; cable jackets)	FR at 33% in presence of inorganic synergist (antimony) (OxyChem, 2007)	Electrical properties and colourability; char formation and non-dripping (OxyChem, 2007)
Hypalon	Elastomers	FR at 5-6% with antimony trioxide (OxyChem, 2007)	No further information found

Polymer (or other substrate)	Application type	Notes on technical function, loading rate and synergist systems	Comments
Neoprene	Elastomers [Elastomer adhesives]	FR at 10% with antimony trioxide (OxyChem, 2007)	No further information found
Phenolic resin	Paper laminated resin [Structural adhesives]	FR at 12.9% with synergist (antimony oxide); Filler (OxyChem, 2007)	
Polypropylene Talc-reinforced PP	Moulded parts / other plastics / circuit board / motherboard & components / chargers / appliance parts	FR at 20-35% in presence of synergist (antimony, zinc compounds) (OxyChem, 2007)	Colourability and non-drip useful (OxyChem, 2007)
Polypropylene	Moulded / extruded parts / other plastics / hard plastics	FR at 20-35% in presence of synergist (antimony, zinc compounds) (OxyChem, 2007)	Colourability and non-drip useful (OxyChem, 2007)
Silicon rubber	Elastomers [Elastomer adhesives]	FR at 18.8-40% with antimony trioxide (OxyChem, 2007 manual)	No further information found
Silicon rubber	Potting compounds		No further information found
Unsaturated polyester (UPE) resin	Resin [Thermoset polymer adhesives]	FR at 20% with synergists (antimony oxide); filler (OxyChem, 2007)	
Urethane foam	Elastomers	FR at 17.5-35% with antimony trioxide (OxyChem, 2007)	No further information found
Urethane rubber	Elastomers [elastomer adhesives]	FR at 20-30% with antimony trioxide (OxyChem, 2007)	No further information found

Table 13. Use of DP in materials other than polymers (ECHA, 2022b)

Material	Application type	Technical function, loading rate and synergist systems	Comments
Adhesives	Potting, encapsulating and bonding in electronics; cladding and flooring in building/construction; bonding composite panels, flooring and other fixtures and fittings; aircraft cabin interior		Many polymer types can be used as adhesives. Where polymers for which DP may be used also have polymer uses this is noted in the rows above in square brackets. **Confirmed commercial use of DP.**
Caulk	Building materials		Potential commercial use
Greases		Dual function: FR and seizure resistance (pers comm – stakeholder consultation feedback)	**Confirmed commercial use of DP**
Cooling / coolant			No further information found. While some other polychlorinated FRs are reportedly used in coolants in electrical equipment, it is unknown whether this is a relevant use for DP in EU.
Flame resistant paint	Emulsions and coatings		No further information found. Potential commercial use of DP, but relevance uncertain; the use is not confirmed in the registration dossier
Foam	Foams / sound-absorbing panels		**Confirmed commercial use of DP .**
Foam or non-foam filling material	mattresses		Textiles is a potential commercial use of DP but further information on the nature of the coating is not available).
Non-woven wallpaper	Wall papers		Relevance in EU is uncertain
PVC/paper	Wall papers		Relevance in EU is uncertain
Explosives	Fireworks	Colour intensifier additive in pyrotechnics (Impag, 2018, US Army, 1967).	The use in explosives is recommended against by REACH registrants in the ECHA disseminated dossier. **Confirmed commercial use of DP in explosives and commercially available for the use in fireworks (Impag, 2018).**

Material	Application type	Technical function, loading rate and synergist systems	Comments
Textiles	Textile coating (i.e. finishing product) / clothing / curtains	Application of auxiliary padding liquor at normally up to 50 kg/t textile (OECD textile ESD, 2004[15]).	Further information on the nature of the coating is not available (Coated and back-coated textiles are possible.
Textiles (toys)	Textile toys		Textiles is a potential commercial use of DP but further information on the nature of the coating is not available
Textiles (military)	Military textiles		Textiles is a potential commercial use of DP but further information on the nature of the coating is not available
Tile	Building materials (e.g. roofing materials, laminate flooring)		No further information found
Wood	Building materials (e.g. panels, roofing materials, insulation board, laminate flooring)		No further information found
Unknown (plastic toys)			No further information found
Unknown (food packaging and storage)			No further information found

[15] https://echa.europa.eu/documents/10162/16908203/pt9_oecd_esd_no_7_textile_finishing_industry_en.pdf/2d6bb902-83cc-4ff1-94ef-6e8fb2aab978

Table 14. Concentration of DP in components in cars, motorcycles and explosives as reported by stakeholders (Eftec, 2021)

Stakeholder name	Product/Application	Concentration (%)	Comment
JAPIA	Wire coating	13 - 20 %	< 0.1 % in final products
Rolls Royce	Individual component articles	< 0.1 - 6.5 %	-
ACEA	Wire coating and wire printed circuit board housing. Often but not exclusively used in PA 66[16].	13 – 20 %	Average purchase price for the materials: € 6 - 11 per kg
	Plastic and rubber parts (connector, board, case, bobbin)	13 – 20 %	Average purchase price for the materials: € 6 - 11 per kg
	Grease	20 – 25 %	-
	Tape and adhesive	5 – 30 %	-
ACEM	Electric wire, where DP is contained in the wire coating	13 – 20 %	-
	Plastic and rubber parts	13 – 20 %	-
	Grease	20 – 25 %	-
	Tape and adhesive	5 – 30 %	-
Explosives (unknown)	Explosives	0.1 %	-

[16] PA 66 refers to a polyamide commonly known as Nylon 66.

Table 15. Global emissions of DP after wastewater treatment, by primary emission source (Eftec, 2021)

Use	Total releases (kg/y)		Share of total
	Low	**High**	
Manufacture of substance	33,029	110,097	52.6%
Formulation of sealants / adhesives	4	292	0.1%
Industrial use of sealants / adhesives	255	1,000	0.5%
Polymer raw materials handling, compounding and conversion	1,825	6,156	2.9%
Formulation of greases	15	50	0.02%
Widespread use of articles over their service life - indoor use	265	882	0.4%
Widespread use of articles over their service life - outdoor use	955	3,185	1.5%
Waste dismantling and recycling	19,110	83,300	37.7%
Waste incineration	30	100	0.05%
Landfill	2,640	8,800	4.2%
TOTAL	**~58,000**	**~214,000**	**100%**

Table 16. Estimated total global releases for DP after wastewater treatment (Eftec, 2021)

Releases to…	Lower estimate (kg/year)	Upper estimate (kg/year)	Share of total global releases
Air	34,600	135,000	62%
Water	6,020	20,200	10%
Agricultural soil	17,300	57,900	28%
Industrial soil	270	900	0.4%
Total	**58,100**	**214,000**	100%

Table 17. Restriction options (RO) under consideration in the EU/EEA (ECHA, 2022a,b,d)

	RO1	RO2	RO2 plus	RO3
A restriction on the manufacture, use and placing on the market in the EU of DP in concentrations > 0.1%, from entry into force + 18 months.				
(I) Derogation for aerospace and defence sector applications produced before:	None	Entry into force + 5 years	Entry into force + 5 years	Entry into force + 10 years
(II) Derogation for medical imaging applications manufactured before:	None	None	Entry into force + 7 years	None
(III) Radiotherapy devices/installations manufactured before:	None	None	Entry into force + 10 years	None
(IV) Derogation for motor vehicles produced before:	None	None	None	Entry into force + 5 years
(V) Derogation for spare parts for existing aerospace and defence equipment /vehicles:	None	Aerospace and defence sector: For equipment covered by the derogation in RO2 (I) Motor vehicles: For vehicles produced before entry into force + 18 months	Aerospace and defence sector: For equipment covered by the derogation in RO2 (I) Aerospace and defence: For applications manufactured before entry into force + 5 years Motor vehicles: For vehicles produced before entry into force + 18 months	Aerospace and defence sector: For aircrafts covered by the derogation in RO3 (I) Motor vehicles: For vehicles covered by the derogation in RO3 (II)
(V) Derogation for spare parts in other applications:	None	None	Medical imaging: For applications manufactured before entry into force + 7 years Radiotherapy: For applications manufactured before entry into force + 10 years	None

			Marine, garden and forestry machinery: For applications placed on the market for the first time + 18 months	

*Aerospace and defence applications: All applications of DP within aerospace and defence, originally RO1-RO3 only considered an exemption for aircrafts; this was later revised to aerospace and defence applications based on stakeholder input.

**Motor vehicles: Includes all applications of DP within land-based vehicles. Examples are cars, motorcycles, agriculture vehicles and industrial trucks.

Table 18. Emission reduction under each of the three restriction scenarios presented in tonnes per year as presented in the Annex to the EU restriction proposal

Sector/use	Baseline emissions (t/y)	Annual reduction (t/y)		
		RO1	**RO2**	**RO3**
Automotive	5.6 - 17.8	5.1 - 16.2	5 - 15.9	4.1 - 13
Aviation	0.9 - 2.9	0.8 - 2.6	0.6 - 2	0.4 - 1.3
Other including imported articles	2.6 - 8.1	2.3 - 7.4	2.3 - 7.4	2.3 - 7.4
All uses	**9.1 - 28.8**	**8.3 - 26.2**	**8 - 25.3**	**6.8 - 21.7**
Scenario Emission reduction capacity		**91%**	**88%**	**75%**

Note: Sums may not add up due to rounding.

Table 19. Shortlist of potential alternatives to DP (adopted from ECHA, 2022b)

CAS No.	Alternative Substance	Plastics	Coatings	Literature source*
115-27-5	Chlorendic anhydride	X		Velsicol (2020)
1003300-73-9	Mixtures of esters of phosphoric acid	X		PINFA (2010b), PINFA (2010c), PINFA (2013)
115-86-6	Triphenyl phosphate	X		KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007),Illinois EPA (2007), Troitzsch (2011), UK HSE (2012), Lowell Center for Sustainable Production, (2005), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013)
1309-42-8 13760-51-5	Magnesium hydroxide	X	X	KemI (2004, 2005, 2009), Lassen et al. (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), Illinois EPA (2007), UK HSE (2012), EFRA (2012a), EFRA (2012b), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013), Albemarle (2013), Chemtura (2011), ICL Industrial Products (2013); Stakeholder consultation
13674-87-8	Tris(1,3-dichloro-2-propyl) phosphate	X		KemI (2004, 2005, 2009), Albemarle (2013) Chemtura (2011), ICL Industrial Products (2013)
14728-39-9 68333-79-9	Ammonium polyphosphate	X	X	KemI (2004, 2005, 2009), Lassen et al. (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), Illinois EPA (2007), UK HSE (2012), EFRA (2012a), EFRA (2012b), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013)
21645-51-2 8064-00-4 1318-23-7	Aluminum hydroxide	X	X	KemI (2004, 2005, 2009), PAKALIN ET AL. (2007), US EPA (2012-2014), Illinois EPA (2007), UK HSE (2012), EFRA (2012a), EFRA (2012b), PINFA (2013, 2010a, 2010b, 2010c), ENFIRO, Albemarle (2013) Chemtura (2011) ICL Industrial Products (2013)
21850-44-2	Tetrabromobisphenol-A bis (2,3-dibromopropyl ether)	X		KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), Troitzsch (2011), UK HSE (2012), Albemarle (2013) Chemtura (2011), ICL Industrial Products (2013)
218768-84-4	Melamine polyphosphate	X	X	KemI (2004, 2005, 2009), Lassen et al. (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), UK HSE (2012), EFRA (2012a), EFRA (2012b), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013)
225789-38-8	Organic phosphinates (Diethylphosphinic acid, aluminum salt)	X		KemI (2004, 2005, 2009), Lassen et al. (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), Illinois EPA (2007), Troitzsch (2011), UK HSE (2012), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013)

CAS No.	Alternative Substance	Plastics	Coatings	Literature source*
26444-49-5	Cresyl diphenyl phosphate	X	X	KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), Illinois EPA (2007), Troitzsch (2011), UK HSE (2012), Lowell Center for Sustainable Production, (2005), EFRA (2012a), EFRA (2012b), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013), Albemarle (2013) Chemtura (2011) ICL Industrial Products (2013)
32588-76-4	Ethylene bis(tetrabromophthalimide)	X	X	KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), Troitzsch (2011), UK HSE (2012), EFRA (2012a), EFRA (2012b), Albemarle (2013) Chemtura (2011), ICL Industrial Products (2013)
37853-59-1	Bis(tribromophenoxy)ethane	X		KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), UK HSE (2012), EFRA (2012a), EFRA (2012b)
57583-54-7 125997-21-9	Resorcinol bis(diphenylphosphate) (RDP)	X		KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), Illinois EPA (2007), Troitzsch (2011), UK HSE (2012), Lowell Center for Sustainable Production, (2005), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013), (ENFIRO, 2014), Albemarle (2013), Chemtura (2011), ICL Industrial Products (2013)
5945-33-5 181028-79-5	Bisphenol-A bis (diphenyl phosphate) (BDP/BAPP)	X		KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), Illinois EPA (2007), Troitzsch (2011), UK HSE (2012), Lowell Center for Sustainable Production, (2005), EFRA (2012a), EFRA (2012b), PINFA (2010a), PINFA (2010b), PINFA (2010c), PINFA (2013), ENFIRO, Albemarle (2013), Chemtura (2011), ICL Industrial Products (2013)
66034-17-1	Substituted amine phosphate mixture (P/N intumescent systems)	X	X	US EPA (2012-2014), Troitzsch (2011), UK HSE (2012), PINFA (2013, 2010a, 2010b, 2010c)
7723-14-0	Red phosphorous (encapsulated)	X	X	KemI (2004, 2005, 2009), Lassen et al. (2006), PAKALIN ET AL. (2007), US EPA (2012), US EPA (2014), Illinois EPA (2007), UK HSE (2012), EFRA (2012a), EFRA (2012b), PINFA (2013, 2010a, 2010b, 2010c), Albemarle (2013) Chemtura (2011) ICL Industrial Products (2013)
79-94-7	Tetrabromobisphenol-A	X		KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), Troitzsch (2011), UK HSE (2012), Albemarle (2013) Chemtura (2011) ICL Industrial Products (2013)

CAS No.	Alternative Substance	Plastics	Coatings	Literature source*
84852-53-9	Ethane-1,2-bis(pentabromophenyl)	X	X	KemI (2004, 2005, 2009), Lassen et al. (2006), Washington State (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), Troitzsch (2011), UK HSE (2012), EFRA (2012a), EFRA (2012b), Albemarle (2013) Chemtura (2011) ICL Industrial Products (2013); Stakeholder consultation
88497-56-7 57137-10-7	Brominated polystyrene	X		KemI (2004, 2005, 2009), Lassen et al. (2006), PAKALIN ET AL. (2007), US EPA (2012-2014), Troitzsch (2011), UK HSE (2012), EFRA (2012a), EFRA (2012b), Albemarle (2013) Chemtura (2011) ICL Industrial Products (2013)

Note: This list is generated from the RPA (2014) report on Support to an Annex XV Dossier on Bis-(pentabromophenyl) ether (DecaBDE) and represents alternatives to flame retardants presented in the literature.

* The references can be found in the original document (ECHA, 2022b).

Table 20. Identified alternatives to DP in its function as both a flame retardant and as an extreme pressure additive in grease/lubricant (adopted from ECHA, 2022b)

Cas No.	EC No.	Alternative Substance	Commercial products and notes	Literature source*
Flame Retardant				
115-27-5	204-077-3	Chlorendic anhydride		Velsicol (2020)
14728-39-9. 68333-79-9	269-789-9	Ammonium polyphosphate	Flame retardant in many applications such as paints and coatings, and in a variety of polymers	(KemI, 2004, KemI, 2005); Lassen et al. (2006); PAKALIN ET AL. (2007); US EPA (2012-2014); Illinois EPA (2007); UK HSE (2012); (EFRA, 2012a, EFRA, 2012b); PINFA (2013, 2010a, 2010b, 2010c); ENFIRO
21645-51-2. 8064-00-4. 1318-23-7	244-492-7	Aluminium hydroxide	Aluminium Hydroxide has a wide range of applications, including a variety of polymers, paints and coatings.	(KemI, 2004, KemI, 2005, KemI, 2009); PAKALIN ET AL. (2007); US EPA (2012-2014); Illinois EPA (2007); UK HSE (2012); (EFRA, 2012a, EFRA, 2012b); PINFA (2013, 2010a, 2010b, 2010c); ENFIRO; Albemarle (2013); Chemtura (2011); ICL Industrial Products (2013)
84852-53-9	284-366-9	Ethane-1,2-bis (pentabromophenyl)		(KemI, 2004, KemI, 2005, KemI, 2009); Lassen et al. (2006); Washington State (2006); PAKALIN ET AL. (2007); US EPA (2012-2014); Troitzsch (2011); UK HSE (2012); (EFRA, 2012a, EFRA, 2012b); Albemarle (2013); Chemtura (2011); ICL Industrial Products (2013); Stakeholder consultation
Grease/Lubricant				
63449-39-8	264-150-0	Long chain chlorinated paraffins	Cereclor 42 (example)	
1330-78-5	215-548-8 809-930-9	Tricresyl phosphate	Celluflex TPP®, Disflamoll TP®, Phosflex TPP®, Phosphoric acid, triphenyl ester, Pilabrac 521®, Reofos TPP®, Reomol TPP® and TPP.	As noted in Environment Agency (2009) Some of the tradenames and trademarks may refer to older products no longer supplied to the EU, or products produced outside the EU, but these are included in the report as they are sometimes referred to in the open literature.
3232-62-0	221-775-3	Diallyl chlorendate	Only REACH pre-registered	Indicated for use as an extreme pressure additive in silicone greases - in patents literature (Google patents).

* The references can be found in the original document (ECHA, 2022b).

Table 21. Available information on the most likely alternatives to DP as a flame retardant

Flame retardant	Share of DP substituted	Price €/tonne	Loading	Price x loading compared to DP
Dechlorane Plus	-	6 000 - 10 000	17%	100%
Aluminium hydroxide	40%	964	65%	40% - 60%
Ammonium polyphosphate	30%	2 675	31%	50% - 80%
Ethane-1,2-bis (pentabromophenyl) (EBP)	30%	5 782	17%	60% - 100%

Table 22. Available information on the most common alternatives to DP used in lubricants

Flame retardant	Price €/tonnes
Dechlorane Plus	6 000 – 10 000
Long chain chlorinated paraffins (LCCPs)	4 000
Tricresylphosphate (TCP)	9 000

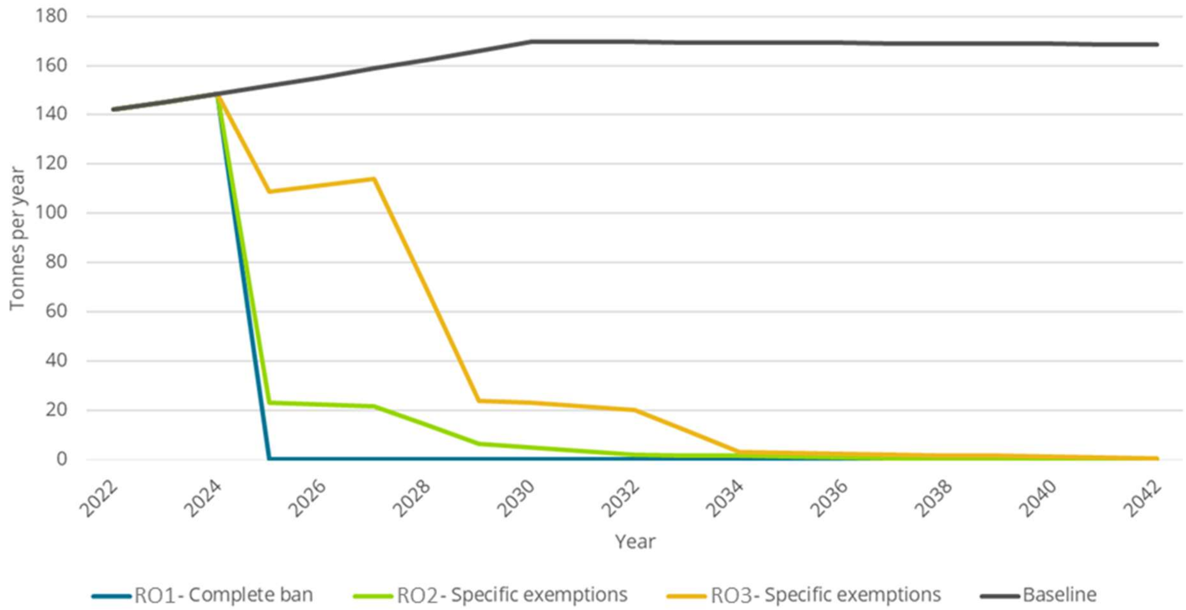

Figure 1. Continued emissions (t/y) under the baseline (central estimate) and the three restrict options (ROs) over the period 2023-2042. The figure shows the modelled emissions under the baseline (i.e. the scenario where no regulation of DP is implemented) and the three restriction options. The results show that all of the ROs will result in substantial emission reductions, and by proxy, large expected benefits, with the strictest option (RO1) achieving a 91% reduction in emissions of DP. The drivers behind the emission reductions associated with each restriction option are the entry into force of the ban and the specific exemptions (Eftec, 2021).

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