Dechlorane Plus

First draft risk management evaluation

Prepared for the intersessional working group on Dechlorane Plus
Persistent Organic Pollutants Review Committee

April 2022

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Executive summary

1. At its fifteenth meeting, the Persistent Organic Pollutants Review Committee concluded that Dechlorane Plus (DP, CAS No. 13560-89-9) and its *syn*-isomer (CAS No. 135821-03-3) and *anti*-isomer (CAS No. 135821-74-8) fulfilled the screening criteria in Annex D of the Stockholm Convention on Persistent Organic Pollutants (Decision POPRC-15/2). At its sixteenth meeting the POPs Review Committee considered the draft risk profile and adopted decision POPRC-16/1, by which it decided to defer its decision on the draft risk profile (UNEP/POPS/POPRC.16/INF/19). At its seventeenth meeting the POPs Review Committee completed and adopted draft risk profile (UNEP/POPS/POPRC.17/3.Add.2) and concluded that DP is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and/or environmental effects such that global action is warranted (Decision POPRC-17/2). While recognizing that the dataset on toxicity and ecotoxicity is limited, but that available short-term toxicity data indicates concern for potential adverse effects to the environment and humans at low levels, the Committee also decided to explore any further information on adverse effects, and, if appropriate, to revise the risk profile for consideration by the Committee at its eighteenth meeting. Parties and observers were invited to submit to the Secretariat the information specified in Annex F and any additional information relating to the adverse effects of DP before 14 March 2022.

2. The "Dechlorane Plus"™ technical mixture is a commercially available polychlorinated flame retardant. The technical DP mixture contains two stereoisomers, *syn*-DP and *anti*-DP, that are present in ratios of about 1:3 or 25 % *syn*-DP and 75 % *anti*-DP. Commercially available DP mixtures may also contain DP monoadducts, mono-dechlorinated DP and other substances as impurities. DP and its isomers are not known to be unintentionally produced.

3. DP is marketed as a replacement substance for decabromodiphenyl ether (decaBDE). It is used as a flame retardant in adhesives, sealants and polymers and also as an extreme pressure additive in greases to a lesser degree. The main use (around 80%) is in cables and wires and in motor vehicles. Other confirmed uses include aerospace and defence applications, electrical and electronic equipment, marine, garden and forestry machinery, consumer electronics and medical and radiotheraphy applications.

4. DP production started in the 1960s at the manufacturing plant of Hooker Chemicals and Plastics Corporation (now Occidental Chemical Company (OxyChem)) in Niagara Falls, New York. DP is a high production volume chemical in the United States. The global production of DP is estimated to be in the range of 750-6000 tonnes per year, with an estimated average of 1980 tonnes per year. Production in China started in 2003 and the annual production is reported to be 300–1000 tonnes. The Chinese manufacturer, Anpon Electrochemical Company Ltd., was recently acquired by ADAMA, and may now be the sole global manufacturer. China has announced that they are considering a proposal to ban DP in 2022, such a ban could have the implications for the global production of DP.

5. Emissions of DP to the environment occur at all its life cycle stages. Estimates suggests that around 54% of global DP emissions come from the manufacture of DP, while the next highest release to the environment comes from waste dismantling and recycling (35.9%) and landfills (4.3%). In the post manufacturing phase, polymer raw materials handling, compounding and conversion are estimated to be the the largest emission source, and overall accounts for 2.9 % of the total global emissions. Articles in service life are also an important source of emission both to the indoor and outdoor environments as evidenced by the high levels measured in indoor dust. While emissions from articles in use are estimated to account for 1.9% of the total DP emissions globally, these emissions are particularly important in relation to human exposure. In line with these estimates, monitoring data shows that DP levels are generally highest near wastewater discharges and in areas around electronic waste and recycling plants.

6. An assessment of different restriction scenarios suggests that a listing in Annex A that imposes a complete ban on production and use would be the most effective control measure and could reduce global emissions by 91% over the period 2023 – 2042, whereas listing in Annex A with time-limited exemtions according to estimates, reduce emissions by 89-88 or 75 %, depending on what exemptions are granted. A listing of DP in the Convention will also contribute to reducing emissions from waste by setting requirements for the environmentally sound management of DP containing wastes. In addition to this measure, requirements on labelling of DP containing products and waste as well as the development of guidances for Best Available Techniques/Best Environmental Practices (BAT/BEP) should be considered.

7. It is not possible to fully assess the socioeconomic impacts of listing of DP in the Convention. While the environmental benefits are expected to be highest if DP is listed in Annex A without exemptions, this is also the more costly option when compared to listing DP in Annex A with exemptions for certain critical uses. It is also anticipated that a listing in Annex A without exemptions would have more wide-ranging economic impacts, but it can nonetheless be a proportional measure considering that DP is a POP.

8. Some suitable and commercially available chemical alternatives for the substitution of DP have been identified. Furthermore, non-chemical alternatives such as non-flammable materials and physical barriers are also available, in theory. Annex F information and other available information indicates that markets are in transition away from the use of DP and that substitutions have been performed or are in progress for most, if not all, known

applications. However, the submitted Annex F information and information from the EU REACH restriction process suggests that there may be challenges for some applications and sectors, i.e., aerospace and defence sector and medical imaging devices and radiotherapy devices/installations due to long phase-in time. Time limited exemptions for applications in these sectors may be needed. In addition, time limited exemptions for use in legacy spare parts for motor vehicles, aerospace and defence applications, medical imaging- and radiotherapy devices/installations may be needed to be able to repair articles that have a long service-life. Considering also available information on emissions, time limited exemptions for these applications and sectors may be justified.

9. A restriction on production and use of DP is expected to have a positive effect on human health and the environment by reducing further emissions. DP persist in the environment for a very long time and accumulates in humans and wildlife, effects of current emissions may be observed or only be apparent in future generations.

1. Introduction

10. In May 2019, Norway submitted a proposal to include the chlorinated flame retardant (FR) Dechlorane Plus (DP, CAS No. 13560-89-9) and its *syn*- (CAS No. 135821-03-3) and *anti*- (CAS No. 135821-74-8) isomers in Annexes A, B and/or C to the Stockholm Convention on Persistent Organic Pollutants (POPs). At its fifteenth meeting, the POPs Review Committee evaluated the proposal and concluded that DP and its *syn*-isomer and *anti*-isomer met the screening criteria specified in Annex D (UNEP/POPS/POPRC.15/7, Decision POPRC-15/4).

11. In the present document, the acronym DP is used for the commercial mixture "Dechlorane Plus"^{TM} and to denote the sum of the *syn*- and *anti*-DP isomers, when reporting measured data.

1.1 Chemical Identity

12. The technical mixture Dechlorane Plus^{TM} (CAS No. 13560-89-9) is a commercially available formulation that contains two stereoisomers, *syn*-DP (CAS No. 135821-03-3) and *anti*-DP (CAS No. 135821-74-8), in concentrations of 25-35 % *syn*-DP and 65-75 % *anti*-DP (Sverko et al., 2011; OxyChem, 2013; Wang et al., 2010a).

13. As reported in the risk profile, DP is a high molecular weight molecule (653.73 g/mol) with the molecular formula $C_{18}H_{12}Cl_{12}$. The structural formula of DP and its two isomers is shown in Figure 1 below. It is a solid white powder at room temperature (20 °C and at 101.3 kPa), has limited water solubility with reported water solubility values of <1.67 ng/L (20 – 25 °C) and 0.044 – 249 µg/L (insoluble) (ECHA, 2017b; OxyChem, 2004b), and high *n*-Octanol/water partition coefficient (Kow of 9.3) and *n*-Octanol-air partition coefficients (Koa 12.26) (OxyChem, 2004b). A full overview of modelled and experimental physico-chemical properties of DP and its two isomers are given in Tables 1 and 2 in UNEP/POPS/POPRC.18/INF.xx.doc.

Dechlorane Plus (CAS No. 13560-89-9) | *Anti*- (or *exo*) Dechlorane Plus (CAS No. 1358 21-74-8) | *Syn*- (or *endo*) Dechlorane Plus (CAS No. 135821-03-3)

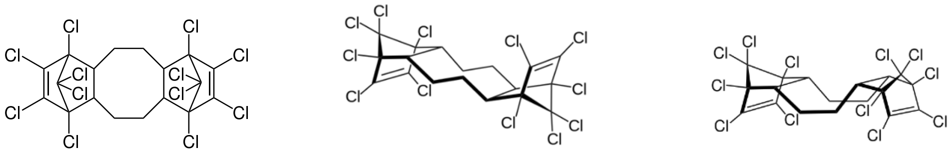

Figure 1. Structural formula of DP and its two isomers

1.2 Conclusions of the POPs Review Committee regarding Annex E information

14. The draft risk profile was discussed by the POPs Review Committee at its sixteenth meeting in January 2021, and the Committee adopted decision POPRC-16/1, by which it decided to defer its decision on the draft risk profile (UNEP/POPS/POPRC.16/INF/19) to its seventeenth meeting. In its decision, the Committee noted that, while information on persistence, bioaccumulation and the potential for long-range environmental transport was conclusive, the Committee had been unable to reach agreement that the information on adverse effects was sufficient to reach a conclusion on the risk profile. The committee also decided to establish an intersessional working group to review and update the draft risk profile and invited Parties and observers to submit to the Secretariat additional information relating to the adverse effects of DP before 1 March 2021.

15. At its seventeenth meeting the POPs Review Committee completed and adopted draft risk profile (UNEP/POPS/POPRC.17/3.Add.2) and concluded that DP is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and/or environmental effects such that global action is warranted (Decision POPRC-17/2). While recognizing that the dataset on toxicity and ecotoxicity is limited, but that available short-term toxicity data indicates concern for potential adverse effects to the environment and humans at low levels, the Committee also decided to explore any further information on adverse effects, and, if appropriate, to revise the risk profile for consideration by the Committee at its eighteenth meeting. Parties and observers were invited to submit to the Secretariat the information specified in Annex F and any additional information relating to the adverse effects of DP before 14 March 2022.

1.3 Data sources

16. The risk management evaluation has been developed using the following sources of information:

(a) The revised risk profile (UNEP/POPS/POPRC.17/3.Add.2)

(b) Annex F information submitted by the following Parties and Observers: Belarus, Canada, Egypt, Japan, Germany, Monaco, Netherland, Republic of Korea, UK, Alaska Community Action on Toxics (ACAT) and International Pollutants Elimination Network (IPEN), European Automobile Manufacturers' Association (ACEA), International Coordinating Council of Aerospace Industries Associations (ICCAIA). Information from the Society of Indian Automobile Manufacturers (SIAM) and the Aerospace Industries Association of Canada (AIAC) provided during the open commenting round of the risk profile;

(c) Reports and other grey literature as well as information from peer-reviewed scientific literature;

(d) Documents (annex, report and response to comments) supporting the Annex XV restriction proposal under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation in the European Union (EU) (ECHA 2022a-d).

(e) Screening assessment report and risk management approach from Canada (Canada, 2019a,b).

1.4 Status of the chemical under international conventions

17. DP is currently not included in any international conventions.

1.5 Any national or regional control action taken

18. As described in the risk profile and in Table 3 of UNEP/POPS/POPRC.18/INFx regulatory processes to restrict or ban DP have been initiated or are in place in several countries including Canada, Egypt, EU and and the three EFTA States Iceland, Liechtenstein, and Norway which are part of the European Economic Area (EEA).

19. China has announced that they are considering a proposal to ban DP in 2022 (ENB, 2022).

20. Certain limitations and approval, reporting and/or notification requirements for production, import and/or use also apply in New Zealand, Thailand, The Russian Federation and the United States.

2. Summary information relevant to the risk management evaluation

2.1 Production, use and emissions

21. DP was originally developed as a replacement for the FR and insecticide dechlorane, also known as Mirex (Hoh et al., 2006), and is currently marketed as an alternative/replacement for commercial decabromodiphenylether (decaBDE). Available information on the volumes of DP manufactured, imported and exported is sparse, with only a few underlying sources frequently being quoted in most studies, articles and regulatory documents as summarized in Table 4 and 5 in UNEP/POPS/POPRC.18/INF/x.

22. Globally, two manufacturing sites are known, one in the USA and one in China, but production is today assumed to only occur in China (UNEP/POPS/POPRC.17/3.Add.2; UNEP/POPS/POPRC.17/13). Manufacturing in the USA took place in Niagara Falls, New York where it begun in the 1960s at the manufacturing site of Hooker Chemicals and Plastics Corporation, that is now owned by the Occidental Chemical Corporation (OxyChem). DP has been classified as high production volume chemical (>500 tonnes per year chemical) in the USA. Since 2011, OxyChem has "withheld" their production volumes, but historic volumes manufactured by this company lie in the range of 450-5000 tonnes/year (Ren et al., 2009; Qiu et al., 2007, US EPA, 2002; Hoh et al., 2006). Production in the US declined from 2008 and ceased mid-way through 2016, however the cease of manufacture has not been formally confirmed by the US EPA (ECHA 2022a,b; Annex E IPEN). Manufacturing in China is reported to be in the range of 300–1000 tonnes per year since 2003 (Wang et al., 2010a). In China, DP is produced by Jiangsu Anpon Electrochemical Company Ltd. at manufacturing site in Huai'an. Anpon was recently acquired Adama Agriculture B.V (ADAMA, 2019). China have announced that they are considering a proposal to ban DP in 2022 (ENB, 2022). Such a ban could have implications for the global production of DP.

23. DP is used as a FR in adhesives, sealants and polymers. The main use is as a FR is in electronic wiring and cables in motor vehichles. Other confirmed FR uses include the aerospace and defence applications, electrical and electronic equipment, marine, garden and forestry machinery and medical and radiotheraphy devices/ installations (ECHA 2022b). DP is also used as a FR in construction and infrastructure (Annex F, Japan). A secondary use of DP is as an extreme pressure additive in greases, it also has a minor use as a colour intensifier in explosives in fire works (ECHA, 2022a, b) and in the thermoset resin PDAP for the purpose of electric insulation in second generation electrical vehicles (Annex F Japan; ECHA, 2022c). A detailed overview of these uses is provided in Tables 6-9 in UNEP/POPS/POPRC.18/INFx).

<u>Use in cables and wires</u>

24. Cables and wires are used in motor vehicle, aerospace and defence applications, and consumer electronics. The majority of DP is used in cables and wires in the automotive sector, which is estimated to account for 80% of the total global use in this sector (see Table 10 in UNEP/POPS/POPRC.18/INFx). In automotive applications DP is used 'in-engine' components including small and highly flexible cables that need to be able to withstand elevated

temperatures from being close to the engine (Eftec, 2021; Annex F, UK). Cables and wires containg DP may also be used in the other sectors (Table 8,9 and 12- in UNEP/POPS/POPRC.18/INFx).

Use in polymers and plastic mouldings

25. Available information confirms the use of DP in the production of polymers. KEMI (2020) have identified DP in nylon and thermoplastic polymers. Information from the manufacturer Oxychem (2007) suggests use also in other polymers such as acrylonitrile butadiene styrene (ABS), natural rubber, polybutylene terephthalate (PBT), polypropylene, and styrene butadiene rubber (SBR) block copolymer. DP may also be used in thermosets such as epoxy and polyester resins, polyurethane foam, polyethylene, ethylene propylene diene monomer rubber, polyurethane rubber, silicon rubber, and neoprene. The amount of DP in these materials ranges from 8% in PBT to up to 40% in silicon rubber (OxyChem, 2007; see Table 11,12 and 14 in UNEP/POPS/POPRC.18/INFx). DP is also used in thermoset resin for the purpose of electric insulation, e.g. in polydiarylphthalate (PDAP) resin which is used in second generation electrical vehicles (Annex F Japan; ECHA, 2022c).

26. Other uses DP containing plastic polymers and resins, include hard plastic connectors in computer monitors/TVs, and limited specific applications in the aerospace and defence sector (UNEP/POPs/POPRC.16/2; ECHA 2022b,c). DP has also been detected in other polymers used in building materials including plastic roofing materials, sound absorbing foams, expanded polystyrene panels, sealants, particle boards, paint, and wallpapers. The DP detection frequency ranged from 33% to 100% with the highest reported concentrations found in sealants, PVC, sound absorbing foams and expanded polystyrene (ECHA 2022b,c; Hou et al., 2018; see Table 13 in (UNEP/POPS/POPRC.18/INFx).

Use in two-part resins for aerospace and defence applications

27. DP is used in two-part resins for aerospace and defence applications. The uses of DP named by the aerospace and defence industry stakeholders are: epoxy adhesives, syntactic foams, potting compounds, 2-part epoxy void filler, manufactured items for the production and maintenance of aircraft and aircraft components (e.g. – aircraft engine), connectors, wire/cables and other plastic components made from polypropylene, nylon, ABS etc (See Table 9 in UNEP/POPS/POPRC.18/INFx). No tonnage estimates for the EU or global aerospace sector was provided, but Rolls Royce informed that they use 0.13 tonnes per year of DP, not including use by companies carrying out repair and maintenance for Rolls Royce (Eftec, 2021). The Aerospace and Defence Industries Association of Europe has indicated that total use in the EU is 1,600 tonnes per year and that work is underway to identify alternatives that can replace DP in the next five years or so (ECHA, 2022c).

Use in motor vehicles, other motorized vehicles, trains and industrial and household machinery

28. The Society of Indian Automobile Manufacturers (SIAM), on behalf of their members, states that DP is used as an alternative to c-decaBDE in the manufacturing of motor vehicles (SIAM, 2020). The use of DP in motor vehicles is supported by information provided by ACEA and JAPIA which confirms the use of DP in several application in the automotive sector in both Europe and Japan (Annex F, ACEA and Japan; ECHA 2022c). Confirmed used in vehicles are in polymers that require flame retardancy, and in grease requiring seizure resistance (See Table 8, 9 and 14 in UNEP/POPS/POPRC.18/INFx). Annex E information from the Netherlands further indicate that DP within this sector is used for the following parts; in powertrain, cooling, chassis and bodywork parts (Annex E, 2019). Similar information by JAPIA suggests that the main applications of DP in motor vehicle parts are fall in four categories; wire harness, adhesive, tape and PDAP resin (ECHA, 2022a,b). In addition to the use i motor vehicles, DP is in Japan also used in other motorised vehicles, railways, and industrial and household machinery (Annex F, Japan). Other identified uses in the EU are marine, garden and forestry machinery (ECHA 2022a,b,c).

Other uses

29. Other identified uses in the EU and Japan include medical imaging and radiotherapy devices (ECHA 2022, a,b,c; Annex F Japan). According to ECHA (2020a), DP may also be used in fabrics, textiles and apparels, and plastic articles, but this has not been confirmed by consulted stakeholders (Annex F; ECHA, 2022c; see Table 7, 9 and 13 in UNEP/POPS/POPRC.18/INFx).

Available information on use volmes for different sectors and uses

30. Due to conflicting information provided by different stakeholders, both at global and EU level, two different use patterns have been defined – a low and high tonnage scenario- based on information received (ECHA, 2022b, Eftec, 2021). Globally, polymers in automotive vehicles account for 57 – 75%, and aerospace for 10% of the total use, while other uses including electronics/electrical equipment, explosives and imported articles account for 15 – 33% of the total use (see Table 1 below). New information on volumes from JAPIA provided under the EU restriction process indicate that global volumes used in the automotive sector may be as high as 70 % in a high volume and 90 % in a low-volume scenario (ECHA 2022b). Stakeholders within the automotive industry reported that they use around 500 tonnes per year globally, comprising 50% of the global volume manufactured. On the other hand, using the global volumes reported by the Dutch authorities to POPRC of 300 tonnes per year, the automotive sector use about 150

tonnes per year of DP globally, i.e. less than half of what the industry itself claims to use. As explained above, some of the difference can likely be explained by stakeholders citing tonnage data from different years (Eftec, 2021). For the EU, the reported use volume was in the range of 81-161 tonnes per year for the automotive industry (ECHA, 2022a).

31. The main uses of DP mentioned by the automotive industry are: electric wire (wire harnesses specifically mentioned) (80% of total tonnage used), tape and adhesive (10% of total tonnage used); plastic and rubber parts (8% of total tonnage used), grease (2% of total tonnage used) (see Table 10 in UNEP/POPS/POPRC.18/INFx). The two key functions for the automotive sector are flame retardancy (avoids the start or slows down the growth of fire) and seizure resistance (to prevent seizure of metal parts in sliding parts). Global low- and high- volume estimates of DP per user application is provided in Table 2 below.

Table 1. Global volumes of DP per sector according to the stakeholder consultations (Eftec, 2021)

Sectors	Low volume scenario		High volume scenario	
	Share of total	**Use volume (t/y)**	**Share of total**	**Use volume (t/y)**
Motor vehicles*	75%	225	57%	565
Aerospace and defence	10%	30	10%	100
Other**	15%	45	33%	335
All	**100%**	**300**	**100%**	**1,000**

*Note: The names of the sectors have been adjusted according to ECHA, 2022a. The low- and high-volume scenarios are based on information from different sources, which is why market share as well as the tonnages of the sectors vary between the two scenarios. *Motor vehicles inclde all applications within land-based vehicles. ** Other includes all other uses apart from the two above.*

Table 2: Global volumes of DP per use application (Eftec, 2021)

Uses		**Share of total**	**Low-volume scenario (t/y)**	**High-volume scenario (t/y)**
Polymers	Wire and printed circuit board housing, other plastic and rubber parts	93%	279	930
Adhesives etc.	Tape, adhesives, sealants	5%	15	50
Greases	Lubricant	2%	6	20
All		**100%**	**300**	**1,000**

<u>Emission estimates</u>

32. Global emission estimates for DP have been developed and include direct releases to air and surface water and take into account the redistribution in the sewage treatment plants for emissions to wastewater (Eftec, 2021). These estimates suggests that around 54% of global DP emissions come from the manufacture of DP. The next highest release to the environment comes from ‘waste dismantling and recycling’ (35.9%) and ‘landfill’ (4.3%) (Eftec, 2021; Table 15 and 16 in UNEP/POPS/POPRC.18/INFx).

33. In the post manufacturing phase, polymer raw materials handling, compounding and conversion are estimated to be the the largest emission source, but overall only accounts for 2.9 % of the total global emissions. Articles in service life are also an important source of emission both to the indoor and outdoor environments as evidenced by the high levels measured in indoor dust (UNEP/POPS/POPRC.17/3.Add.2). While emissions from articles in use only account for 1.9 % of the total DP emissions globally, these emissions are particularly important in relation to human exposure. Listing DP in the Stockholm Convention with or without certain exemptions for production and use, will eventually reduce emissions of DP from both production and use. The effectiveness of the Stockholm Convention in reducing these emissions will depend on how DP is listed in the Convention (in Annex A or B, what exemptions are granted including the number of exemptions, their duration as well as the status of ratification and implementation of those measures at the national level (Eftec, 2021).

2.2 Identification of possible control measures

34. DP pose a risk to the environment and human health which is not adequately controlled. As reviewed in the DP risk profile (UNEP/POPS/POPRC.17/3.Add.2), monitoring data shows that DP is globally distributed and detected in different environmental matrices and biota at different types of locations from urban and to remote areas. The data further suggests that emissions and releases occur during all stages of the chemical's life cycle.

35. Elevated DP levels in urban, suburban, and urban industrialized areas are reported in several studies and from several global regions and include reports of DP air levels at urban sites that are 10-15 times greater than at background, rural, agricultural and sites. The highest DP levels globally have been detected in the environment, humans and wildlife near e-waste recycling sites and also landfills, and suggests that waste, and in particular e-waste, is a main source to DP emissions and releases along with production sites and products in use. The available monitoring data presented in the risk profile also suggests that diffuse emissions from articles in use are important sources, particularly in urban environments and with regard to human exposure. The highest DP levels globally have been detected in the environment, humans and wildlife near e-waste recycling sites and also landfills, and suggests that waste, and in particular e-waste, is a main source to DP emissions and releases along with production sites and products in use.

36. In line with the objective of the Stockholm Convention, the purpose of any control measures is to eliminate and/ or reduce/ minimise emissions and releases. Under the Stockholm Convention available control measures include listing in Annexes A, B and/or C to the Convention, as further detailed in Table 3 below.

Table 3. Description of available control measures for DP under the Stockholm Convention

Listing of the chemical in Annex A: This would mean elimination of the production, use, export and import of the chemical. The Conference of the Parties might decide to provide for specific exemptions. It might also add provisions that would apply specifically to the chemical (as is currently done for PCBs in Part II of Annex A). These additional provisions can cover a wide range of control measures such as restriction of certain uses, labelling requirements, additional waste management requirements or provision of information to users along with a requirement to report on progress toward elimination at certain intervals.
Listing of the chemical in Annex B: This would mean restriction of the production, use, export and import of the chemical. If it decides to list the chemical in Annex B the Conference of the Parties will also specify acceptable purposes for continued use of DP. It might also add provisions that would apply specifically to the chemical (as is currently done for DDT in Part II of Annex B). These additional provisions can include the establishment of a register, a requirement to notify the Secretariat or other intergovernmental organizations regarding intent to use the substance, and a requirement for reporting on quantities used and conditions of use. Such provisions may also require the development and implementation of an action plan that includes the implementation of suitable alternatives and covers a wide range of control measures such as labelling or the provision of information to users.
Listing of the chemical in Annex C: This Annex is applicable only to unintentionally produced chemicals. Listing in Annex C would mean that the chemical would become subject to measures to prevent, reduce or eliminate the unintentional formation and releases of the chemical. The Conference of the Parties might also include any further amendments of Annex C that would be necessary to address the chemical (e.g., additional source categories, additional process control methods or additional pollution prevention options)
Additional measures resulting from its listing in Annexes A, B and/ or C: Listing of the chemical in Annexes A, B and/or C also make the chemical subject to the control provisions of **Article 6 on stockpiles and waste**. These provisions in the Article include obligations to develop strategies for identifying products and articles in use that contain the chemical; to identify, to the extent practicable, stockpiles and waste; to manage such stockpiles safely; and to ensure that wastes are disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed.

37. Whilst in principle, DP can be listed in Annex A, B and C, only listing in Annex A or B is relevant considering that DP is not known to be unintentionally produced. DP could be listed in Annex A with or without specific exemptions or in Annex B with specific acceptable uses. Additional risk management measures could include an obligation to label new articles that contains DP to assist parties in managing articles in use and DP containing wastes.

38. It is important that any regulatory measures are effective in eliminating or reducing emissions and releases of DP. For DP the most important sources of emissions/ releases appear to be production/ manufacture, its use in plastic polymers and products, in particular in the automotive and aviation/ aerospace industry, and waste and recycling activities (UNEP/POPS/POPRC.17/3.Add.2; ECHA, 2022b), see also Section 2.1 above.

39. In the EU, different regulatory risk management options have been assessed (ECHA, 2022a,b). All considered restriction options (ROs) restrict the manufacture, use and placing on the market of DP in concentrations >0.1% by the end of a transition period of 18 months (i.e. 18 months after entry into force). Whilst the strictest restriction option (RO1) does not include any derogations, RO2 and RO3 include derogations of varying scope and length for uses in aircrafts and motor vehicles. Based on information provided by stakeholders in an open consultation the scope of restriction option RO2 was later refined to what is denoted as restriction option RO2plus which also includes an exemption for spareparts for medical imaging and radiotherapy applications as well as for marine, garden and forestry machinery. A summary of the EU derogations is provided in Table 4 below.

40. In terms of a regulation under the Stockholm Convention the proposed EU restriction options correspond to listing DP in Annex A with or without exemptions in line with the exemptions in RO1, RO2, RO2plus or RO3 in Table 4 below. A regulation in the EU would at the earliest enter into force in 2023, while a global ban or regulation on DP could at the earliest enter into force in 2024, if the Conference of the Parties were to agree in 2024 on listing DP in the Convention.

Table 4: The original restriction options (RO1-RO3) and the new restriction option RO2 plus assessed in the REACH restriction proposal (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 Marine, garden and forestry machinery: For applications placed on the market for the first time + 18 months	None

Notes:
**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.*

2.3 Efficacy and efficiency of possible control measures in meeting risk reducing goals

41. National regulatory actions are not considered adequate to manage the risks of DP due to its POPs characteristics. A ban of production and use of DP is the most effective control measure to prevent harm to human health and the environment and can be achieved by listing DP in Annex A to the Stockholm Convention with no exemptions. An alternative, but less stringent option would be to list DP in Annex A with time-limited exemptions for critical uses where substitution is currently not feasible/possible and where continued use will not significantly reduce the overall risk reduction potential. Alternatively, DP can also be listed in Annex B with or with out specific exemptions. DP is not non-intentionally produced so listing in Annex C is not relevant.

42. An assessment of different restriction scenarios suggests that a listing in Annex A that imposes a complete ban on production and use would be the most effective control measure and could reduce global emissions by 91 % over the period 2023 – 2042, whereas a global restriction of DP that lists DP in Annex A to the Convention with time-limited exemtions for certain critical uses in accordance with RO2 and RO3 of Table 4 would respectively reduce emissions by 88 % or 75 % (Eftec, 2021, see Figure 1 in UNEP/POPS/POPRC.18/INFx). It should be noted however that in these estimates of the emission reduction potential, emissions from production are not included.

43. The global emission reduction capacity of the EU restriction option RO2plus was not assessed by Eftec (2021) but is considered to have an emission reduction capacity of 89% based on baseline emissions in the EU (ECHA, 2022a,b). In the EU assessment, this is fairly similar to the effectiveness of restriction option RO2 (88%) and not very different from RO1 (91%). Based on the available information of limited use and emissions of DP from spare parts for use in medical imaging, radiotheraphy applications and marine, garden and forestry machinery, it can be assumed that RO2plus has a similar emission reduction capacity to RO2 and the EU estimates for RO2plus also at the global level.

44. In contrast to a listing in Annex A, a listing DP in Annex B will be much less effective as it allows for time-unlimited acceptable purposes. However, similar to restriction option RO2plus emission reduction capacity of listing DP in Annex B was not assessed by Eftec (2021).

45. Listing DP in the Convention implies that emissions of DP from waste dismantling and recycling will also eventually decline. From Article 6 (d) of the Convention, it follows that wastes, including products and articles upon becoming wastes shall be handled, collected, transported and stored in an environmentally sound manner and disposed; not permitted to be subjected to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of persistent organic pollutants; and not transported across international boundaries without taking into account relevant international rules, standards and guidelines. Additionally, Parties shall endeavour to develop appropriate strategies for identifying sites contaminated by chemicals listed in the Convention and if remediation of those sites is undertaken it shall be performed in an environmentally sound manner. Again, the effectiveness of the Convention in reducing these emissions will depend on the status of ratification and entry into force for the Parties, but also on the low POP content value and technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with POPs developed by the Basel Convention in close collaboration with the Stockholm Convention. Levels above the low POP value require the destruction/irreversible transformation of the POP content in wastes, including products and articles upon becoming wastes.

2.3.1 Technical feasibility

46. Technical feasibility can be understood as the ability to implement a global ban or regulation, and not only the ability to replace or substitute DP in known applications. Accordingly, technical feasibility can be very different for different sectors e.g., for industry as compared to national authorities. Technical feasibility will also depend on the nature and complexity of the task. For example, allowing more exemptions will result in a more complex regulation that can be more difficult to communicate, implement, enforce, control and monitor. This aspect could be more important for governments and national authorities than for industry. On the other hand, a greater number of exemptions could mean that a global ban or regulation could be more technically feasible for industry actors that are currently using DP and have indicated that a global ban or restriction without time-limited exemptions would be challenging.

47. The limited information and bias in the available information concerning suitable alternatives and substitution described in Section 2.3.3. below makes it difficult to fully assess the technical feasibility of the possible control measures. However, based on the information provided all available restriction scenarios discussed in Section 2.2. above appear to be technically feasible both for regulatory authorities and for industry. Nevertheless, a global ban on production and use without time-limited exemptions, although technically feasible in theory, could be challenging and result in costs and other impacts to society if exemptions are not granted for the most critical uses as discussed in Sections 2.3.2 and 2.3.3 below.

Prohibition of production, use by listing in Annex A without exemptions

48. A ban on production and use by listing in Annex A without exemptions would be the most efficient control measure to reduce emission of DP to the environment. Some countries have already imposed restriction or ban of DP (see Table 3 in UNEP/POPS/POPRC.18/INF/x), and comments received during the open consultation in EU indicate that some actors have already switched to alternatives or has ongoing substitution projects (ECHA, 2022c, Annex F Netherlands, UK, ICCIAI; ACEA). As set out in section 2.3, alternatives to the use of DP that are both technically and economically viable are available for most applications.

Restriction of production, use by listing in Annex A or B with exemptions

49. While no information has been received to indicate that listing in Annex B is justified, a restriction of production and use by listing DP in Annex A with some time-limited exemptions may be justified based on the information provided in ECHA, (2022a,b) as well as in Annex F submissions. DP is used in some sectors where substitution of substances can be challenging due to strict safety requirement and have longer phase-in times. Safety requirements mandate that when a materials' chemical property changes, a comprehensive test regime is required to ensure that durability, safety, and quality is not harmed. If control measures are implemented before phasing out is complete, the industry may require a limited time exemption. These actors have indicated that a time-limited exemption is needed to phase out use of DP, in particular in spare-parts for some products that have long service life. Labelling of articles/products containing DP can be an efficient control measure to identify these exempted products throughout their lifecycle.

Analytical methods, enforability and monitorability

50. It is expected that enforcement of a DP restriction can be carried out in parallel with enforcement of existing restrictions affecting similar products, e.g. decaBDE, so the additional costs of testing for the presence of one additional substance will likely be low (ECHA, 2022b). Analytical methods for the detection of *syn*- and *anti*-DP are reported in the literature which can be used to measure DP in both abiotic and biotic environmental media (see UNEP/POPS/POPRC.17/INF/9). For analysis of articles, products and materials, although there are no standardized analytical methods, it is possible to analytically determine DP, via suitable extraction/ cleanup procedures and establised mass spectrometric methods that combine gas chromatography with to low- or high-resolution mass spectrometry (GC-LRMS or GC-HRMS), or tandem mass spectrometry (GC-MS/MS) (Brasseur et al., 2016; Zacs et al., 2019; Hou et al., 2018).

51. Initial screening for chlorine in materials can be done using X-ray fluorescence (XRF). This rapid technique can be used as an efficient method to determine potential content of DP in waste streams. However, XRF can only be used for crude detection and separation because it only determines the elemental composition of various materials (i.e. if chlorine present) and not DP. To identify the presence of DP in material streams, XRF must be combined with more advanced analytical methods that involve mass-spectrometry as described above. Other spectroscopic techniques like Fourier Transform Infrared Spectroscopy (FTIR) will be able to distinguish polymeric bound chlorine from chlorine bound in DP. This might open up for developing a FTIR based rapid screening method to distinguish between chlorine from DP and polymeric bound chlorine in waste fractions if nessecary (Becker et al., 2017). Therefore, such method is most used as a first step for identifying materials for further assessment by more targeted approaches using mass-spectrometry or for crude sorting and separation of waste to separate out e.g., waste fractions heavily contaminated with halogenated compounds.

Waste management and clean-up of contaminated sites

52. Waste dismantling and recycling is the second major source of release, and at least landfills are likely to be so for many years to come. Measures to decrease releases at the waste stage should also be implemented to minimise releases of DP, including from articles placed on the market before the implementation of the proposed restriction. Labelling or branding requirements would facilitate the identification of articles in use and management of wastes and stockpiles. If the wastes exceed the low POP content value, they will be subject to destruction or irreversible transformation. Treatment of such wastes must be conducted according to Article 6 obligations and taking into account the Basel Convention technical guidelines and the BAT/BEP guidelines.

53. The major identified use of DP is in cable and wires in motor vehicles indicates that end-of life vehicles (ELV) and electrical and electronic waste are relevant waste streams. Thus, if DP is listed in the Convention and unless decontamination by chemical recycling methods is a possibility (Vollmer et al. 2020), material streams containing DP above the low POP limit value will have to be treated as waste and will have to be excluded from recycling by sorting and separating before being treated by recommended methods to ensure the POP content is irreversibly destroyed. To this end, a rapid on-site detection method to identify relevant objects at the recycling facility will have to be developed in analogy to the XRF method that detects bromine in plastics, and suitable waste treatment technology for separation of plastics containing DP will have to be investigated. DP can be removed either during the dismantling stage where DP-containing plastics (e.g. wire harnesses) are separated from the parts not containing DP, or after the shredding of

the vehicle where the auto shredder residue goes through post-shredder treatment. Post-shredder treatment to remove DP from the waste material can involve a number of different techniques including separation technologies, such as float-sink tanks, magnetic separation, eddy current separators, or laser and infra-red systems. Sorting technology XRF is, as opposed to laser and infra-red technology, independent of the colour of the input plastics (TOMRA, 2019) and is used to separate polymers containing halogenated FRs from halogen-free polymers. In a small study from recycler using such sorting methods it was indicated that separation methods used for separating out plastics containing high levels of bromine are highly efficient also for separation out DP. DP was detected in plastic fraction rejected from fridge and small domestic appliances, and in ELV fine- and coarse-grained plastic fraction (Rambøll and Fraunhofer, 2021).

54. According to the Bureau of International Recycling (BIR) who represents over 30,000 recyclers in more than 70 countries around the world, the main issues for recyclers in terms of hazardous chemicals in wastes are:1) a lack of knowledge on which chemicals are present in products or in wastes; and 2) a lack of economic means to identify and separate the waste containing hazardous chemicals, as well as removing the chemicals or materials containing it from the waste stream before recycling (Eftec, 2021).To ensure proper management of wastes containing DP and other POPs and clean secondary raw materials these issues needs to be addressed. As indicated above a requirement for better documentation and labelling of articles and products would be a step forward in addressing these issues and would help ensure the technical feasibility of a global regulation on DP for the waste and recycling industry as well as the effectiveness of a global regulation. In addition, technological innovation and development is important.

2.3.2 Identification of critical uses

55. The submitted Annex F information and information from the EU REACH restriction proposal for DP (ECHA 2022a,b,c) suggests that some sectors may have challenges in phasing out DP without any transition time.

56. According to Annex F information, DP is used in a a large varity of sectors and products including in motor vehicles, motorcycles, agricultural machinery, construction machinery, industrial machinery, medical instruments, infrastructure equipment, gas and oil equipment, aerospace and defence applications, as well as in railways (see Table 9 in UNEP/POPS/POPRC.18/INFx). Some of these products have long service-life and substitution may be more complex and time-consuming due to safety requirements. Exemptions for use in legacy spare parts may therefore be justified to avoid that a large number of longlived products are phased out and become waste before the end of their expected service life. According to ECHA (2022b) releases from spare parts for some of these sectors also appear to be limited.

57. As further described in Section 2.4.1-2.4.2 potentially suitable alternatives for DP both as a FR and as an extreme pressure additive has been identified (ECHA, 2022b). Only a limited number of stakeholders that provided information in the EU REACH restriction process, indicated that there were no suitable alternatives presently available. One of those stakeholders was JAPIA, who indicated that no suitable substitution for DP in PDAP-resin in automotive applications have been identified. The same submission from JAPIA indicated that inorganic FRs are available and to some extent already in use in wire harnesses and tape in the EU. However, none of the stakeholders provided information on specific technical criteria to assess whether DP could be replaced by other FRs or lubricants (ECHA, 2022a,b,c; Annex F).

58. The automotive sector generally has a high research and development (R &D) spending. This enables rapid technological changes and may have an expected accelerating effect of past regulatory in relation to DP on R&D development activities (ECHA, 2022b). European car manufacturers associations' (Society of Motor Manufacturers and Traders (SMMT) and ACEA) have provided information that the automotive industry has already started investigating its uses of DP and is aiming for a complete phase out by 2026 for motor vehicles already in production and for new models (Annex F, UK, ACEA). They have also indicated that a longer phase out time for the supply of legacy spare parts will be needed for vehicles type approved/certified before 2026 (Annex F ACEA, UK; ECHA 2022c).

59. There is limited information on use and use volumes in motor vehicles used in agriculture and forestry, other industrial machinery, infrastructure, railways and leasure boats. Some of these products may have longer service life than motor vehichles. A ban on the use of DP for those applications without time-limited exemptions for legacy spare parts could have a significant impact on the supply of spare parts and can reduce the service life the products (Annex F Japan; ECHA 2022c).

60. The aerospace and defence sector is subject to strict regulations. New materials or design changes can only be introduced to an aircraft if testing and compliance demonstrations have been approved. The approval will result in the issuance of a Supplemental Type Certificate, change approval or repair approval (ECHA, 2015). This implies that transitioning to alternatives can be more time consuming for the aerospace and defence sector than for other industries. Aerospace and defence companies, in collaboration with material suppliers, are actively investigating alternatives that can meet performance and safety requirements. However, there is a lack of available qualified substitutes for most critical aerospace and defence uses (Annex F, ICCAIA). A small share of actors in the EU aerospace industry is, however, assumed to be able to substitute DP by 2025 based on one consulted stakeholder who

reported an ongoing substitution process which is expected to be completed within five years (ECHA, 2022a,b,c). In the EU restriction proposal, it is therefore assumed that 20% of DP used in the aerospace and defence sector in the EU can be substituted with alternatives by 2025. By mid-2028, i.e. after a transition period of 5 years, substitution is expected to be feasible for most actors (70%), and 95% of the market is assumed to be able to use alternatives by 2033. It is expected that some niche applications (5%) will not be able to substitute DP before 2035.

61. For medical imaging and radiography devices it can be considered that the total number of existing and newly installed devices will be very small in comparison to electronic devices and machinery. Such devices can be considered as critical infrastructure for health. These medical devices have an expected lifetime of 10 - 20 years or more. Access to spare parts will allow repairment and avoid downtimes. In the EU restriction process it is assumed on a qualitative basis that a time-limited derogation for this use including for their spare parts will not significantly increase the emissions of DP in Europe (ECHA, 2022a).

62. The EU restriction proposal (ECHA, 2022a,b) found no critical use in the electric and electronic sector, or their spare parts as many electronic devices and electrical equipment has a short lifespan. A derogation for spare parts for specific, long-lived devices could be warranted, however, no information to base such a derogation on has been submitted. No information on the volume of DP used in the electrical and electronic equipment sector has been provided in the consultations of the EU REACH restriction proposal (ECHA, 2022a,b,c).

63. The recycling industry has indicated that they do not require any derogations for manufacturers and downstream users of DP, as this pushes problems into the future and harms the prospects of recyclers (Eftec, 2021).

64. To conclude, technical and feasible alternatives appear to be available for all uses of DP, with some uncertainty for the use in PDAP-resin. Time limited exemptions for production and use for critical applications and some applications and sectors, i.e., aerospace and defence sector and medical imaging devices and radiotherapy devices/installations due to long phase-in time may be needed. In addition, time-limited use in legacy spare parts may be justified to avoid that a large number of long-lived products are phased out and become waste before their expected service life.

2.3.3 Cost and benefits of implementing control measures

65. The impacts in terms of costs and benefits resulting from a global restriction on DP will depend on the stringency of the chosen restriction as well as the specific exemptions granted and the entry into force of any restriction or ban.

66. Quantification of benefits from a global ban or restriction on DP is challenging. For POPs like DP, the potential benefits will be linked to the environmental stock and a reduction of emissions as well as a reduction in DP contained in articles in use, stockpiles and waste that will reduce exposure in humans including workers, consumers, the general public and the environment.

67. The concentrations of DP in environmental compartments will increase over time if emissions continue. The estimated half-lives of DP in soil have been predicted to be 10 years (Zhang et al., 2016), thus for practical purposes the increasing exposure due to continued emissions may be considered irreversible. It follows that it will take considerable time before a global ban or restriction of DP under the Stockholm Convention, will lead to substantial reductions in the environmental stock. The resulting benefits associated with any reductions in environmental stock will therefore take place over a long time-period and may occur only after many years. Accordingly, a main benefit to society from a restriction of DP is the avoidance of the potential long-term impacts on the environment and human health in the future, through reductions in emissions and exposure.

68. A ban or restriction on the production and use of DP can induce several types of costs, including 1) costs accruing manufacturers of DP and potential impacts on their staff (negative), 2) substitution costs (negative), 3) costs of enforcement (negative), 4) costs to consumers of products containing DP (negative and/ or positive), 5) costs for managing stockpiles, waste disposal costs and costs of remediating contaminated sites (negative) and 6) environmental costs (e.g. increased greenhouse gas emissions) and cost-savings as a result of reducing the risk of environmental pollution and human health effects (negative and/ or positive).

69. No data has been identified or provided to calculate the scale of the possible economic losses and cost-savings at a global scale. However, a quantitative analysis of costs was performed as part of the EU restriction proposal which included a full socio-economic analysis. The EU analysis of costs includes partly quantified substitution costs and costs/lost profits associated with temporary or permanent reductions in production as well as relocation (ECHA, 2022b,d). These quantified costs may not be directly applicable at the global level, but still provides relevant insights into costs associated with a ban or restriction on the production and use of DP. The EU analysis of costs associated with a potential ban or restriction considered four different restriction options ranging from a complete ban to restricions involving time-limited exemptions for certain critical uses (RO1, RO2, RO2plus and RO3, see Section 2.3). However, due to a lack of data, it was only possible to quantify a few cost components.

70. ECHA (2022b) identifies the restriction options RO1 and RO2 as having the highest environmental and human health benefits, the EU socio-economic assessment also found that the costs in terms of profits potentially lost (i.e. at risk) under the two most stringent regulatory options (RO1 and RO2) are substantially higher than those under the least stringent restriction option (RO3). This difference is explained by the extended transition period for the use of DP in the manufacture of motor vehicles granted under RO3. Overall, RO1 is deemed the most effective restriction option as it is the only restriction option that will effectively mitigate all sources of emissions of DP. Under all scenarios, the automotive sector was found to be the largest contributor to costs in terms of lost profits. The profits potentially lost (i.e. at risk) are not linked to the tonnage of DP used but rather the value of manufactured products at risk, which is assumed to be the same regardless of the input chemical. The EU analysis further shows that RO1 is not necessarily the most cost-effective option but the inherent uncertainties in the analysis prevent a robust conclusion on proportionality of each restriction scenario. The uncertainties are primarily driven by the lack of details on the technical function(s) of DP, i.e. why DP is needed, potential alternatives and their feasibility as well as the cost of and time required for transitioning to alternatives. In absence of information needed to firmly conclude on which restriction option is most beneficial to society, it was deemed most appropriate to propose the restriction option that is most effective in minimising potential adverse effects on human health and the environment and RO1 (total ban) was therefore initially chosen as the proposed restriction. This is in line with REACH recital 70 which states that a "… substance for which it is not possible to establish a safe level of exposure, measures should always be taken to minimise, as far as technically and practically possible, exposure and emissions with a view to minimising the likelihood of adverse effects.". While the Committe for socio-economic analysis (SEAC) under REACH in their opinion on the EU restriction proposal for DP note that all the assessed restriction options (RO1, RO2, RO2plus and RO3) could be proportionate, depending on what the decision makers considers an acceptable cost to society for abating DP emissions, they also note that RO3 leads to the smallest emission reductions and will delay the emission reductions compared to the other alternative restriction options. SEAC further points to the marginal cost-effectiveness of moving from one restriction option to another.

71. As indicated above, information on substitution costs[1] was sought in the consultations of the EU REACH restriction proposal, but the information received was very limited (ECHA, 2022a,b,c). No information was provided on possible R&D activities, investments costs and other substitution costs. This limits the options of how to estimate the cost of transitioning to alternatives. Due to the lack of information, it was only possible to quantify changes in the cost of chemicals when used in FRs. Interestingly, the cost of identified chemical alternatives was found to be overall cheaper than DP (both price and loading accounted for), which means that cost savings are expected rather than cost increases. The EU assessment also showed that the differences in the cost of chemicals were found to be fairly small between the three restriction scenarios. Due to a lack of information on loading, it was not possible to quantify the change in the cost of chemicals when used as an extreme pressure additive in greases/lubricants. However, by comparing the prices, it was concluded that the loading of the substances must be considerably higher than that of DP for the cost of chemicals to be significant. Furthermore, the share of the total tonnage of DP used as an extreme pressure additive is ~2%, which means that omission of these costs or cost savings is not likely to have a major impact on the estimated total costs of the restriction options.

72. As highlighted in the socio-economic assessment performed as part of the EU restriction proposal for DP, transitioning to alternatives is usually associated with R&D and investment costs (e.g. changes in the production process) unless the alternative is a known drop-in alternative. In the case of DP, information found in literature and information received from stakeholders both indicate that there are no drop-in alternatives available. According to ECHA, 2022b, it is therefore reasonable to assume that R&D and investment costs will be incurred. Additional operational costs such as increased energy or water use may also contribute to the overall costs, however, no information has been found related to R&D investments or other operational costs. Due to a lack of information, it was not possible to quantify these other costs. A main benefit of allowing use in spare parts for complex products with a long-life time and where substitution is challenging due to stringent safety requirement and testing is that it can avoid premature replacements of those products. Premature replacements will induce costs to society both in terms of additional resource use to manufacture new vehicles and aircrafts, but also environmental costs like increased energy use and wastes. Care must however be taken to ensure that the costs and benefits are correctly balanced by considering also available information on total emissions from this use and as a proxy for environmental costs.

73. In addition to the above information from the EU, information on costs was provided by the UK, Japan and Canada (Annex F information). The UK in their Annex F submission, note that there may be significant costs associated with substituting DP from reformulation and redevelopment of technologies. As well as costs of redevelopment there will be costs from disposal of materials and articles contaminated with DP. The impact of a restriction is likely to fall on the electrical, construction and automotive sectors in which there is the primary use of DP. As use in cables has been identified as a significant use of DP, impacts will be felt in this area of industry in particular. Costs related to cables waste being redirected from recycling may be significant. As there is no production of DP in the UK, the economic impacts of a restriction are however thought to be low. The UK automotive industry

[1] Substitution costs is defined as including both any one-off or recurring costs directly associated with the substitution process, including R&D costs, investments, cost of raw materials (e.g. chemicals, water and other input materials) and energy costs.

has indicated the need for a slower phase out, but all other industries seem to be able to use alternatives. Additionally, figures on costs of waste disposal in the UK also indicate that the listing of DP as a POP with a requirement to destroy DP containing materials could significantly increase disposal costs for users of DP containing articles and materials and for local authorities. There will also be environmental costs, as much of the contaminated waste is likely to be plastics. The incineration of plastics which were previously recycled will result in higher carbon emissions and a reduction in the circular economy, increasing demand for virgin plastics.

74. In Japan, the costs of substituting DP have not been estimated yet because the influence of substitution would be huge in the broad range of industries where DP is currently still in use in Japan (Annex F Japan).

75. Canada on the other hand is in process of regulating DP nationally and has indicated that 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 cost benefint analysis is targeted to be published in 2022 (Annex F Canada).

2.4 Information on alternatives (products and processes)

76. When substituting DP, the alternatives range from a basic chemical substitution of DP with another chemical which can be used for the same application to the complete elimination of the use due to a redesign of a production process, the material used, the end product or even the way the ultimate service is provided ("system change"). When substituting DP, all these options should be considered, aiming to find the best way to substitute DP in a sustainable manner (ECHA, 2022e). FRs are generally used to meet performance-based flammability requirements. These requirements do not specify that chemical FRs need to be used; rather they may require a product or component to pass a laboratory test such as a cigarette smoulder or open flame ignition test (ASTM 2014). Using chemical FRs in their products is one means through which companies can achieve flammability requirements for their products. As indicated above, alternate technologies as well as non-chemical-based alternatives, such as barrier materials, may also be used to replace FRs in various applications (Canada 2019b).

77. More specifically, substitution of DP can occur at three different levels: 1) by substituting the FR additive; 2) the basematerial; or 3) the end-product itself. Thus, alternatives can either replace (i) the FR additive (without changing the base polymer), (ii) the base polymer with flame retardants and other additives (with another material, plastic or non-plastic, and other additives), or (iii) the product can be replaced by a different product, or the function can be fulfilled using a totally different solution (Danish EPA, 1999, Defra, 2010).

78. The alternative to DP would need to be technically and economically feasible, but also have a favourable hazard profile to avoid regrettable substitution. Given the wide range of materials that require FR and grease/lubricant properties, a universal alternative will likely not be available, and any alternative will need to be considered for each use individually.

79. Relevant information about alternatives in the open peer-reviewed literature is limited. Thus, most of the information set out in this section comes from the EU process to restrict DP (ECHA, 2022a,b).

80. This section identifies and analyses potential alternatives to DP in terms of hazards, technical feasibility, economic feasibility, and availability. Both chemical and alternative techniques/ non-chemical alternatives are discussed.

2.4.1 Alternative substances

81. ECHA (2022b) identified a shortlist of 20 chemical alternatives for DP in its function as both a FR and as an extreme pressure additive in grease/lubricant (Table 18 in UNEP/POPS/POPRC.18/INFx). All 20 alternatives were then assessed more in detail in terms of their hazard, technical feasibility, economic feasibility, and availability. Due to the limited available information in the literature and lack of information provided by stakeholders, technical feasibility could only be assessed in terms of proven or confirmed uses of DP. It may therefore be that some of the uses of DP are not covered in this analysis of alternatives. The shortlist of 20 chemical alternative substances was identified as follows:

> ***Step 1:*** As DP has been marketed as an alternative/replacement for decaBDE, a list of almost 200 alternatives substances to decaBDE developed by RPA (2014) was used as a starting point to identify possible alternatives to DP. DecaBDE has similar physico-chemical properties to DP and is used as an additive FR in many of the same applications as DP.
>
> ***Step 2:*** From the longer list of alternatives, a shortlist of 20 substances was prepared based on known uses of DP and additional information on the alternatives. Clorendic anhydride, was added to the short list based on

information from the Velsicol's website (Velsicol, 2020). Velsicol was the sole importer of DP in the EU according to information from stakeholders in 2020.

Step 3: The suitability of these alternatives was assessed based on a review of existing literature.

Step 4: To avoid regrettable substitutions, hazard criteria were used to screen out substances that are persistent, bioaccumulative and toxic (PBT) or carcinogenic, mutagenic or toxic for reproduction (CMR) in the selection of alternatives to DP as far as feasible.

82. Based on this assessment of alternatives, the EU restriction proposal indicates that there are three potentially suitable chemical alternatives for DP when used as a FR. These are ammonium polyphosphate, aluminium hydroxide and decabromodiphenyl ethane (DBDPE) or (ethane-1,2-bis (pentabromophenyl) (EBP)). Two chemical alternatives were also found to be potentially suitable for DP when used as extreme pressure additive. These were long chain chlorinated paraffins (LCCPs) and tricresyl phosphate (TCP) (ECHA 2022b). ECHA (2022b) notes however that DBDPE/EBP, LCCPs and TCP might be regrettable substitutes and that DBDPE/EBP is a suspected PBT/vPvB and has a high aggregated tonnage and wide dispersive use.

83. Available information on prices and loadings used for the identified chemical alternatives are given in Tables 20 and 21 in UNEP/POPS/POPRC.18/INFx, while the overall conclusions from the EU assessment of chemical alternatives carried out for identified and confirmed uses of DP (ECHA, 2022b) are summarized in Table 6 below (se also Table 19 in UNEP/POPS/POPRC.18/INFx). In the table, color-coding has been used to indicate the level of suitability per category (i) Availability, (ii) Hazards, (iii) Technical feasibility, and (iv) Economic feasibility, as well as for the overall suitability.

Table 6: Summary of assessment of alternatives relative to DP (net changes from the current situation)

Substance	**Availability**	**Hazards**	**Technical feasibility**	**Economic feasibility**	**Overall suitability**
Alternatives to DP as a flame retardant					
Chlorendic anhydride	Potentially similar	Potentially similar	Potentially similar	Potentially worse	**Potentially worse**
Ammonium polyphosphate	Potentially similar	Clearly better	Potentially similar	Potentially better	**Clearly better**
Aluminium hydroxide	Potentially similar	Clearly better	Potentially similar	Clearly better	**Clearly better**
DBDPE/EBP	Potentially similar	Potentially similar	Potentially similar	Clearly better	**Potentially better**
Alternatives to DP as an extreme pressure additive					
LCCPs	Potentially similar	Potentially similar	Potentially similar	Unknown	**Potentially similar**
TCP	Potentially similar	Potentially similar	Potentially similar	Unknown	**Potentially similar**
Diallyl chlorendate	Potentially worse	Potentially similar	Potentially similar	Unknown	**Potentially worse**

84. According to the ECHA (2022b), aluminium hydroxide seems to be the overall cheaper alternative to DP used as a FR, which is why it is assumed that the majority (40%) of companies affected will choose this alternative when choosing an alternative FR. However, there will likely be different technical criteria for different applications, and it is unlikely that one alternative would be suitable for all uses. This is in line with information from stakeholders indicating that there are no drop-in alternatives to DP.

85. Among the chemicals identified in ECHA (2022b) as suitable replacements for the use of DP in extreme pressure additives LCCP is the cheapest if considering price per tonne only. LCCP is therefore likely to be a favored drop in alternative to DP for this application, but there are uncertainties regarding its economic feasibility. As explained in ECHA (2022a,b) due to a lack of information on loading it is not possible to quantify the change in the

cost of chemicals when replacing DP for LCCP in extreme pressure additive in greases/lubricants. However, by comparing the prices, ECHA (2022, b) concluded that the loading of the alternative substances must be considerably higher than that of DP for the cost of chemicals to be significant. Furthermore, ECHA (2022b) also points out that the share of the total tonnage of DP used as a lubricant is ~2%, which means that omission of these costs or cost savings is not likely to have a major impact on the estimated total costs of the restriction options.

86. Alternatives will need to be commercially available and cost effective to feasibly replace current uses of DP (Annex F, UK). FRs require specific properties or requirements for these to be feasible replacements for DP. This includes, but may not be limited to, substances that are easy to incorporate into and compatible with the host polymer, without significantly altering its mechanical properties. These may also need to be colourless or at least non-discolouring, resistant towards ageing and hydrolysis, and stable to light. Based on a recent literature review the UK in their Annex F submission in proposes that that the most relevant halogenated alternatives to DP in its use as a FR are likely to be DBDPE/EBP and bis(tetrabromophthalimide) (EBTBP). Besides being a regrettable substitute as indicated above, DBDPE/EBP may be used in combination with other non-halogenated FRs to improve performance. This may present a cost issue for transition. EBTBP has been identified as a possible substitute for DP primarily in applications in electric and electronic equipment, including wire and cable insulation, switches, and conductors. However, it is only registered in the EU with an annual tonnage band in the range 100 – 1000 tonnes, suggesting use and availability may be more niche.

87. According to the UK (Annex F), non-halogenated FR alternatives can already meet many of the specifications needed to replace DP, but tend to have weaker efficacy than the halogenated alternatives, and may need to be used in greater concentrations (JRC, 2014). The key non-halogenated alternatives identified by the UK include: 1) metal hydroxides such as aluminium trihydroxide (ATH), 2) metal phosphinates and polyphosphates, inorganic metal phosphinates, 3) masteret (a non-halogenated flame retardant based on red phosphorus developed by Italmatch Chemicals), 4) polymeric non halogenated FRs such as those produced by FRX polymers, 5) NOFIA polymers (HM1100, HM9000, HM7000, HM5000) which can be used for carpet and textiles, foams, electronic connectors, wire, and cable, building and construction (e.g. decorative laminates, wall panels), 6) reactive flame retardants such as dihydro oxaphosphaphenantrene (DOPO) and phosphonate oligomers. A wide range of these non-halogenated alternatives are fully commercialized.

88. Japan notes that the feasibility of alternatives is still under investigation and has not been finalized yet, because the compatibility of flame retardancy, molding characteristics, and material properties is difficult and currently presents a challenge to substitution in many industries and sectors in Japan (Annex F, Japan).

89. ACEA in their Annex F submission state that the possible alternative substitutes for DP in motor vehicles would be brominated or phosphoric FRs or inorganic FRs, and that these alterantives are under evaluation to ensure their safety functions for all automotive applications. For PDAP resin, ACEA notes that alternatives to DP for use in PDAP resin have not been identified so far but that alternatives are under consideration to satisfy requirements of the Japanese Automobile Manufacturers Association to parts (inverters, switches, etc.) using high voltage (Annex F, ACEA).

90. In many cases, a major concern identified with chemical alternatives is that they often require higher loading levels in order to obtain equivalent flame retardant properties. However, DP is already typically used at much higher concentrations than other additive halogenated FRs (Canada 2019b).

91. In the end the choice of a chemical alternative will depend on the technical requirements and as there will likely be different technical criteria for different applications and uses, it is unlikely that one alternative would be suitable for all uses. This is also in line with information from stakeholders indicating that there are no drop-in alternatives to DP. As indictated by the UK (Annex F) several chemical alternatives identified are in use in different applications and have therefore been developed and tested for their technical feasibility. Testing may however be required to determine technical feasibility in specific applications for which DP is currently still in use (ECHA 2022c, Annex F, UK and Japan).

2.4.2 Alternative techniques

92. As described above, affected actors can move away from using DP without switching to a chemical alternative by changing the production process, by choosing an alternative material or redesigning the material used, the end product or even the way the ultimate service is provided.

93. Starting from the technical function of the substance rather than its chemical structure and the associated risks will generally allow a wider range of substitution solutions to be considered (ECHA, 2022b). Rather than focusing on similar chemical drop-in substitutes, which often have similar toxicity profiles, this approach – known as 'functional substitution' – helps to avoid regrettable substitution and can lead to process and product innovation opportunities. In the absence of detailed information on the technical function of DP, the alternative techniques for DP in its function as a FR and as as an extreme pressure grease/lubricant are only broadly described in the below text (Tickner et al., 2015).

Alternative techniques to DP in its function as a flame retardant

94. As identified in ECHA (2022b; Eftec 2021), a number of alternative techniques are available that can be used to substitute DP in its fuction as a FR, but their suitability was not assessed in detail due to the lack of detailed information about technical requirements for the use of DP in specific applications. Alternative techniques available include intumescent systems, nanocomposites, polymeric nanocomposites, expandable graphite, smoke suppressants, polymer blends, use of layering, inherently flame-retardant materials, technological developments and product redesign, and are described in more detail in Table 7 below.

Table 7. Non-chemical potential alternatives to DP in its function as a FR (ECHA, 2022b)

Alternative techniques	Technical and economic feasibility
Intumescent systems	Issues around the economic and technical viability have not been fully resolved and as substances utilised in intumescent systems often belong to nitrogen-containing or organophosphate FRs, they are not viewed as suitable alternative technologies for DP as a FR additive.
Nanocomposites	Polymeric nanocomposites have demonstrated great potential as FR materials. Nanoparticles in polymer nanocomposites have demonstrated a simultaneous reduction in heat release rate (HRR) and an increase in thermal stability (Carretier et al., 2020).
Expandable Graphite	Without further information on the precise technical function of DP additives in FRs it is not possible to assess if expandable graphite would be a suitable alternative technique although it is considered a promising material for flame retardancy for cellulosic materials (Mazela et al., 2020).
Smoke suppressants	In the event of fire these systems lead to the formation of glassy coatings or intumescent foams or dilution of the combustible material, which prevents further formation of pyrolysis products and hence smoke (KemI, 2005). Such systems are of relevance to transportation applications of DP.
Polymer blends	The more expensive polymers – in the presence of a synergist (such as a fluorinated polymer) – such as polycarbonate, PPO and PPS may also be used as a non-chemical alternative as the polymer blend can achieve an acceptable level of processability and will readily undergo recycling and exhibits a similar level of flame retardancy to that of the less expensive but more readily flammable polymer and a halogenated FR (JRC, 2007)
Use of inherently flame retardant materials	Some examples of new inherently flameretardant materials are mentioned in literature or in commercial websites, and these are often promoted as replacements for decaBDE (Albemarle, 2015, Great Lakes Solutions, 2013, UK HSE, 2012). It may be necessary to change product designs to adopt these alternative materials and their implementation would require higher level of R&D activities than the substitution of DP with an alternative flame retardant.
Technological Developments	It is possible to make components of materials that do not require additive FRs, e.g. naturally flame-retardant materials like some metals, glass, or ceramics, instead of plastics, which can reduce flammability (Shaw et al., 2010). Thermally stable polymers can be designed but may exhibit performance limitations and are often too expensive and difficult to process (SpecialChem, n.d.).
Product Redesign	To change the product design for polymers containing DP in the automotive industry, extensive research, and development into the performance of alternatives as a FR would be required to meet the strict safety criteria required. Currently, this level of R&D is not available and as such, product redesign would not be a suitable non-chemical solution to the use of DP in its flame-retardant function.

95. In relation to cables and wires, which have been identified as a main application for DP particularly in the automotive sector, the UK points out that cables need to be small and flexible while able to withstand high temperatures and that non-chemical alternatives may be limited and require significant redesign or use of alternative materials to provide physical or thermal barriers. The UK further suggest that redesign or use of alternative materials is likely to involve significant costs and redevelopment and may not be viable for specific applications of DP (Annex F, UK).

Alternative techniques to DP in its function as an extreme pressure grease/lubricant

96. According to ECHA (2022b) it is not possible to analyse the putative alternative techniques to DP in its function as an extreme pressure grease/lubricant due to the lack of data available for review (Spurlock, 2005).

97. The analysis of the availability of alternative techniques that could replace DP in extreme pressure grease/lubricants would require a high level of understanding of the function fulfilled by DP in this application and would require information such as the composition of the extreme pressure grease/lubricant, the required viscosity in relation to speed, specific additives, and lubricating regimes. This type of information is considered as confidential business information by many companies and is not available in the public domain. As the different components in the grease/lubricant provide unique properties, it is not possible to select an alternative technique as a substitute based on the available information on the application of DP for this use. More information regarding the circumstances and conditions concerning a specific application will enable further analysis of the suitability of alternative techniques for this specific application.

2.4.3 Summary and conclusion from the assessment of alternatives

98. According to the information provided above, and in ECHA (2022a,b) and Eftec (2021), alternatives to DP in its use as a FR and as an extreme pressure grease/lubricant exsist. However, identification of specific alternatives for DP, in particular for the use as an extreme pressure additive is not possible without detailed information on its technical function in existing uses and technical knowledge from the industries within which the applications are required (in this case automotive) and also from technologists within the manufacturing companies that place substances on the market (EP lubricant manufacturers). Due to limited information available in the public domain, confidentiality issues relating to known uses and limited responses from stakeholders such information has so far not been possible to gain for DP, in particular as regards it use an extreme pressure grease/lubricant. Thus, according to ECHA (2022b), there is some uncertainty as to whether the identified alternatives to DP in its use as a FR and as an extreme pressure grease/lubricant would be suitable for all applications within these use areas. Similarly, UK in their Annex F information states that the complexity and diversity of applications (particularly cabling) where DP is used means that no single non-halogenated ‘drop-in’ replacement is available, and that it may be necessary to use combinations of chemicals to achieve the correct standards. This would have implications both in terms of development to commercialise blends and costs where multiple substances are used together to replace DP. Canada highlights the potential for less effective alternatives to result in product failure and suggests that increased fire risks should be a significant concern considering that fully tested alternatives are not currently available for all critical applications. Canada also states that it is possible that alternatives could be developed in the future with time for appropriate R&D, testing and re-certification. In Japan, the feasibility of alternatives is still under investigation and has not been finalized yet, because the compatibility of flame retardancy, molding characteristics, and material properties is challenging in many different industries/ use areas (Annex F Japan).

99. Generally, if alternatives that are equally effective and/or cheaper than DP are available, there is already an economic incentive for companies to switch to these alternatives regardless of whether a restriction is implemented or not. The fact that DP is still in use may therefore indicate that there are some further technical criteria that are not fulfilled by the identified alternatives and that cannot be found by looking at the substance properties alone. Alternatively, or in addition, there could also be other costs (e.g. R&D and investments) not reflected in the cost of chemicals (price x loading) that might outweigh costs savings from purchase of chemical compounds. A third possibility is that some stakeholders have identified feasible alternatives but have not yet completed the substitution process. Furthermore, the specific functional requirements of DP as an extreme pressure additive as described above is not precisely known, and it is therefore not completely clear wether the available substitutes are technically feasible and available for use.

100. Only the affected actors have the specific information required to fully assess the alternatives to DP, it therefore relies on them to provide the necessary data to enable the public to carry out a fair assessment. Since no specific technical criteria were provided by stakeholders as part of the EU restriction process, it was assumed that the assessment of alternatives for the functions of DP as a FR and lubricant and its conclusions are valid (ECHA, 2022b).

101. The lack of information on alternatives presents a challenge in the assessment of the alternatives and critical uses. Importantly, information has been submitted by only a limited number of stakeholders and only stakeholders reporting challenges in substituting DP, while information from peer-reviewed literature and other independent sources are largely absent. Furthermore, the type of information received and in particular low level of technical details in the provided information is an issue. Overall, this implies that there is both a gap and bias in the available information that makes it difficult to fully assess the availability of alternatives, but also information on critical uses.

2.5 Summary of information on impacts on society of implementing possible control measures

102. The POP properties of DP, suggests that past and current emissions will remain in the environment for a very long time, resulting in long-term exposures to the human health and the environment.

2.5.1 Health, including public, environmental, and occupational health

103. A restriction on production and use of DP is expected to have a positive effect on human health and the environment by reducing further emissions. Since DP persists in the environment for a very long time and accumulates in humans and wildlife, effects of current emissions may be observed or only be apparent in future generations. DP has been detected in human tissue, including the cord blood and breast milk as well as in foodstuff and indoor dust (as reviewed in UNEP/POPS/POPRC.17.3.Add.2). High serum levels of DP compared to the general public has been measured in workers in both informal and formal E-waste sector (UNEP/POPS/POPRC.17/3.Add.2). The continued use of DP may present a risk to human health for workers in the E-waste and industrial sectors but also the general public being indirectly exposed via ambient air, dust, food and drinking water.

2.5.2 Agriculture, including aquaculture and forestry

104. A positive impact on agriculture, aquaculture and forestry may be expected by implementing control measures that reduces emission to the environment. DP has been detected in WWTP sludge and biosolids that in some countries is used to amend agricultural soil where concentrations will build up over time due to the persistent properties of DP. This will serve as an open emission source to air and water over time (Annex F, UK). Studies indicate that DP may be taken up from the soil, by some plant such as the peanut plant, but also from ambient air (Fan et al., 2020). DP has been detected in foodstuff both from terrestrial, and aquatic origin (UNEP/POPS/POPRC.17/3.Add.2). High levels of DP have been observed in free-land hen eggs and vegetables grown close to affected areas such as production sites and waste treatment plants in (Huang et al., 2018; Wang et al., 2013a). High levels of DP have also been observed in aquatic biota close to affected sites compared to less affected sites (UNEP/POPS/POPRC.17/3.Add.2).

2.5.3 Biota (biodiversity)

105. Pollution is one of the key drivers of biodiversity loss. The Stockholm Convention along with the Basel-, Rotterdam-, and Minamata Conventions address some of the most significant chemicals and waste pollution that has been identified over the last several decades and are contributing to the conservation of biological diversity (BRSM, 2021a,b). DP has been detected in a wide varity of species, including endangered wildlife such as polar bears and amphibians (UNEP/POPS/POPRC.17/3.Add2). Listing DP in the Convention will thus contribute to efforts to protect biodiversity.

2.5.4 Economic aspects

106. Limited data on economic aspects has been provided through the Annex F responses. Listing DP in Annex A or B of the Convention will likely have some economic impacts, but the impacts will depend on how DP is listed, and it can be assumed that the most stringent option of listing DP in Annex A without any exemptions will have the largest economic impact while lesser impacts can be anticipated if DP is listed in Annex A with exemptions.

107. Industries in some countries may already be in progress of substituting DP given that restrictions on the production and use of DP have already been underway for some time in some jurisdictions including the EU/EEA, Canada and Egypt (Annex F). Furthermore, the sole global manufacturer of DP might independently of a global restriction or ban be forced to reduce or halt its production soon due to a possible ban on DP in China in 2022. This would also mean that down-stream industrial users will have to phase-out and subsitute DP irrespectively of whether DP is listed in Annexes A or B to the Stockholm Convention.

108. Lastly, although DP is used in many different applications and likely is still in use in most countries globally, the EU assessment of costs indicate that affordable alternatives are available. Nevertheless, it is possible and likely that countries that still produce and use DP would experience some negative economic impacts of a global ban or restriction resulting e.g. from costs incurred for the management and safe destruction of any remaining stockpiles of and wastes containing DP. The exent of these impacts are hard to assess at the global level, in particular given the lack of information provided by relevant stakeholders on use, uses, technical requirements related to the known uses, alternatives and progress in substituting DP. Although negative economic impacts could occur, there are also indications to suggest that the impact of a global restriction could be limited, in particular if certain critical uses are exempted.

2.5.6 Movement towards sustainable development

109. As highlighted by two recent reports produced by the UN Secretariats of the Basel-, Minamata-, Rotterdam- and Stockholm Conventions, it is necessary to work in close collaboration and adopt a more holistic approach to improve decision-making and simultaneously address shared environmental challenges and sustainability related to biodiversity loss, climate change and hazardous chemicals (BRSM, 2021a,b).

110. Elimination of DP is consistent with the United Nations sustainable development plans that seek to reduce emissions of toxic chemicals and that link chemical safety, sustainable development and poverty reduction. Elimination of DP is also relevant to several of the United Nations Sustainable Development Goals (SDG) under the 2030 Agenda, in particular SDG 3 (good health and well-being), SDG 12 (responsible consumption and production) SDG 14 (life below water) and SDG 15 (life on land).

111. The Global Plan of Action of the Strategic Approach to International Chemical management (SAICM) contains specific measures to support risk reduction by promoting the use of safe and effective alternatives to chemicals, including non-chemical alternatives to organic chemicals that are highly toxic, persistent and bioaccumulative (UNEP, 2006). The Overarching Policy Strategy SAICM includes POPs as a class of chemicals to be prioritized for halting production and use and substitution with safer substitutes. The concept of green chemistry (also known as sustainable chemistry) can boost innovation for safe and sustainable alternatives to DP. Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.

It applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal (UNEP, 2006).

112. POPs like DP, add to the global plastic waste crisis and can result in continued emissions from waste disposal activities for many years to come. In developing countries integration of the informal sector into formal waste management, can also present a way forward to create sustainable employment while at the same time reducing the negative environmental- and health impacts of POPs and other hazardous chemicals released during waste- and recycling activities (ILO, 2012). Under the Convention sustainability in waste management is addressed by inviting the appropriate bodies of the Basel Convention, in line with Article 6 to develop technical guidelines for the environmentally sound management of DP containing waste.

113. Recycling that reduces toxic wastes and environmental pollution provides immediate benefits to both human health and the environment. However, to prevent the unintentional transfer of DP and other POPs into consumer goods and materials, like children's toys, food contact materials etc. adequate control of recycled material streams is necessary (e.g., Alghamdi et al., 2022; Arnika, 2018). Identifying DP containing articles/products and wastes can be a challenge. SAICM identified the global need for information on Chemicals in Products (CiP) throughout the whole lifecycle of the product (SAICM/ICCM.2/15) and initated a voluntary program to share information about chemicals in products in the global value chain. In a another intiative, the EU in 2020 launched the SCIP data base to provide more transparency in the EU about hazardous chemicals in products. SCIP is a database for information on substances of concern in articles and in complex objects (products), and also includes information on DP.

2.5.6 Social cost (employment, etc)

114. Social impacts are impacts which may affect workers, consumers and the general public that are not covered under health, environmental or economic impacts, including employment, working conditions, job satisfaction and education of workers and social security. There is limited information available to assess the social costs associated with the listing of DP in the Stockholm Convention, but based on the information provided in ECHA (2022,b) and Eftec (2021) a ban or restriction on production and use of DP would not expect to have substantial social impacts, besides effects on employment.

115. Impacts on employment are closely linked to what extent there might be any potential production halts, or any permanent reduction in production and relocation of production. It should also be noted that the total number of jobs lost will not be equally distributed in over time but will be concentrated in the period before most of the market has transitioned to alternatives. Furthermore, it can be assumed that human resources will be redistributed over time, i.e. that jobs lost are only temporary (ECHA, 2008). As regards the practicability of any global regulation for industry, time-limited exemptions can increase the practicability, as it increases the probability for industry actors to be able to transition to alternatives before the end of the transition period in the most cost-effective manner (ECHA, 2022b).

116. In the EU, most of the impacts associated with a ban or restriction on the production and use of DP are expected to be either small or temporary, and no further (significant) macroeconomic impacts are anticipated. Information received in the consultations of the EU REACH restriction proposal further indicates that the main sectors adversely affected by a restriction on DP production and use are the automotive and aerospace and defence industries. These are both large sectors with a strong foothold in the EU and are, as industries, likely to be resilient to small-to-moderate changes in the market. Although the industry as a whole is considered resilient, small and medium size enterprises within the supply chain might still be adversely affected, especially with a ban or a stricter regulation with more limited derogantions. A risk is that smaller companies do not have the financial means for investments needed to transition to an alternative, nor withstand periods of production halts. Larger companies may therefore become more dominant in the market. It is not known whether the aviation sector has a similar structure as the automotive sector, but according to ECHA (2022,b) it is likely that similar impacts may be seen in this sector.

117. Social impacts at the global level may be similar to those anticipated for the EU with the exeption that impacts to manufacturers were not considered in the EU assessment. For nations still manufacturing and using DP both positive and negative impacts are likely. There could for example be negative impacts related to loss of employment for workers at facilities producing DP. However, today production of DP is known to occur only at one manufacturing site globally. The direct impact of a ban or restriction on DP production is therefore anticipated to be limited primarily to this one manufacturing site, manufacturer, and country. If production at the one known production site could be switched to other products, this would limit the impact and any social costs. Production of DP appears to be only one of several chemicals produced by this manufacturer at its manufacturing site in Huai'an, China, and the negative social costs on employment may therefore be limited.

118. A ban or restriction on the production and use of DP can also affect importers/vendors as well as down-stream users in other industries and thus possibly also employment in these industries in several countries globally. However, most importers/vendors likely also import and sell other substances, including alternatives to DP. While production would cease or be reduced if DP is listed in Annexes A or B to the Convention, an increase in the production and use

of chemical and/ or non-chemical alternatives can be anticipated, and any negative economic impacts and social costs may thereby be off-set by an increase in the sales volues of DP-alternatives and non-DP containing products.

119. Eliminating or restricting the use of DP will also induce enforcement costs to national authorities. However, it is expected that enforcement can be carried out in parallel with enforcement of existing restrictions affecting similar products, e.g., decaBDE, so the additional costs of testing for the presence of one additional substance will likely be low. The enforcement costs will in all cases not be significant compared to other costs of the restriction (ECHA, 2022b).

120. A ban or restriction on the production and use of DP will also result in social benefits in terms of avoided costs associated with the negative impacts of DP on human health and the environment. However, to fully achieve these benefits, care is needed in the selection of alternatives, noting that some of the alternatives may have their own human health and environmental impacts. As discussed in more detail in Section 2.5.6 above, the social benefits in terms of avoided costs associated on human health and the environment also largely depend on wether and what exemptions for continued production and use of DP are granted and are anticipated to be highest if DP is listed in Annex A without exemptions.

121. In summary, although some information on social costs is available (ECHA, 2022b; Eftec, 2021), there is limited information on the social costs at a global scale. Based on the available evidence the negative social impacts (e.g., employment) of listing DP in the Convention are likely limited given that DP is produced by only one manufacturer that also produces a wide range of other chemicals, and that chemical and non-chemical alternatives are available.

2.6 Other considerations

122. To assist Parties in meeting their obligations under the Convention with respect to listed chemicals, the Stockholm Convention has in the past developed inventory guidance's for listed POPs, the objective of which has been to provide step-by-step guidance to enable Parties to establish inventories of newly listed POPs and develop strategies/action plans, and thereby collect national baseline data on the listed POPs, as well as other information that can be of use to the official contact points and national focal points for the Convention e.g. when revising and updating their national implementation plans. In the past guidances on best available technicques and best available environmental practices have also been developed for some POPs. Thus, if DP is listed in the Convention, the Conference of the Parties should consider the need to develop similar guidance material for DP. Furthermore, many countries seem to be facing challenges in identifying newly listed POPs in products and articles and the effectiveness evaluation recommends that the draft guidance on labelling for the newly listed POPs should be completed, and that collaboration on chemicals in products with other relevant international activities, such as the ongoing collaboration with SAICM, should be maintained as appropriate (UNEP/POPS/COP.8/22, UNEP/POPS/COP.8/22/Add.1). The Conference of the Parties must also adopt a decision whereby it invites the appropriate bodies of the Basel Convention to update or prepare technical guidelines for the environmentally sound management of POPs waste to assist Parties in fulfilling their obligations in relation to the management of POP-containing wastes.

2.6.1 Access of information and public education

123. Listing DP in Annex A without exemptions would involve control measures that are straight forward to communicate and enforce. This would be a benefit, in particular for countries that have limited chemical regulatory infrastructure and capacity. In contrast a listing in Annex A or B with specific exemptions/acceptable pourposes may not be as straight forward to communitate and enforce.

124. Access to information and public awareness are important factors for the effective implementation of the Convention. At present access to relevant information on DP in line with Article 10 of the Convention is limited. In particular, information on uses, alternatives and progress in substitution still remain scarce as open calls from information/ evidence has failed to provide sufficient information from stakeholders in the the private sector/ industry that is currently using DP (ECHA, 2022a,b). However, some information on DP is publicly available and accessible to many via the websites of the European Chemicals Agency (https://echa.europa.eu) and national authorities in some countries including e.g. the US EPA, Climate Change Canada and the official website of the UK Government.

125. The U.S. National Centre for Biotechnology Information and Environment PubChem database contains information on the physical chemical properties of DP, while PubMed provides an overview of literature on DP extracted from MEDLINE, life science journals, and online books. Information on scientific literature on DP is also available via Google Scholar. As more scientific literature in recent years is published as open access, an increasing amount peer-reviewed literature, including some on DP, is now available online without any financial, legal, or technical barriers other than gaining access to the internet, itself. The EU SCIP database contains information on DP in articles and products that could be relevant also in other countries. In addition, monitoring data on DP from some countries and regions are also available to the public via reports, websites and/or searchable databases.

2.6.2 Status of control and monitoring capacity

126. As described in Section 2.3.1 analytical methods for controlling and monitoring DP in the environment and biota, as well as in articles/products and waste are available. Available information also shows that DP is included in monitoring programs and activities in some countries, and that monitoring data are also generated through research.

127. The second cycle of the Global Monitoring Plan showed regional differences in the availability of monitoring data. For legacy POPs, data are available for several regions but long-time series providing information on changes in concentrations over time is very limited in Africa and in Latin American and Caribbean Group (GRULAC). In addition, information on changes over time in concentrations of the newly listed POPs is still limited (UNEP/POPS/COP.8/21, UNEP/POPS/COP.8/21/Add.1). The effectiveness evaluation therefore concluded that there is a need for sustained capacity building activities to strengthen national scientific and technical research capabilities in developing country Parties, and furthermore that research, monitoring, modelling, risk evaluation and data sharing should be sustained in the long term, and even enhanced in developing country Parties, including at the regional level, to advance national and regional capacities.

3. Synthesis of information

128. DP is a commercially available additive chlorinated FR. It is used as a flame retardant in adhesives, sealants and polymers and also as an extreme pressure additive in greases to a lesser degree. The main use (around 80%) is in cables and wires and in motor vehicles. Other confirmed uses include aerospace and defence applications, electrical and electronic equipment, marine, garden and forestry machinery, consumer electronics and medical and radiotheraphy applications.

129. DP is detected in the environmental samples, humans and wildlife at different locations around the globe. It is a global contaminant and has been found in remote regions far from sites of production and use. Emissions of DP to the environment occur at all its life cycle stages. Estimates suggests that around 54% of global DP emissions come from the manufacture of DP, while the next highest release to the environment comes from waste dismantling and recycling (35.9%) and landfills (4.3%). In the post manufacturing phase, polymer raw materials handling, compounding and conversion are estimated to be the the largest emission source, and overall accounts for 2.9 % of the total global emissions. Articles in service life are also an important source of emission both to the indoor and outdoor environments as evidenced by the high levels measured in indoor dust. While emissions from articles in use are estimated to account for 1.9% of the total DP emissions globally, these emissions are particularly important in relation to human exposure. Monitoring data shows that DP levels are generally highest near wastewater discharges and in areas around electronic waste- and recycling plants.

3.1 Suggested risk management measures

130. The most efficient control measure to reduce the releases of DP would be to list DP in Annex A without exemptions. Listing DP in Annex A would also mean that the provisions of Article 3 on export and import and of Article 6 on identification and sound disposal of stockpiles and waste would apply.

131. Based on the information submitted during the risk management evaluation and received during the open consultation for the restriction proposal under the REACH Regulation in EU, there may be challenges for some applications and sectors, i.e., aerospace and defence sector and medical imaging devices and radiotherapy devices/installations due to long phase-in time. Time limited exemptions for applications in these sectors may be justified. In addition, time limited exemptions for use in legacy spare parts for motor vehicles, aerospace and defence applications, medical imaging- and radiotherapy devices/installations may be justified to be able to repair articles that have a long service-life. Additional risk management measures could include an obligation to label new articles that contains DP.

132. The drivers behind the emission reductions and hence the benefits to human health and the environment are the date for entry into force of a ban or restriction and the specific exemptions and/ or acceptable purposes. If continued production and use were to be permitted at the global level, these should therefore be restricted only certain critical uses with the aim of limiting the negative impacts of continued production and use of DP to human health and the environment.

4. Concluding statement

133. Having decided that Dechlorane Plus with its *syn* and *anti*-isomer, is likely, as a result of long-range environmental transport, to lead to significant adverse effects on human health and/or the environment such that global action is warranted;

134. Having prepared a risk management evaluation and considered the management options;

135. The Persistent Organic Pollutants Review Committee recommends, in accordance with paragraph 9 of Article 8 of the Convention, the Conference of the Parties to the Stockholm Convention to consider listing Dechlorane Plus in Annex A with a specific exemption for aerospace and defence applications and for medical imaging- and radiotherapy-devices/installations, as well as for critical legacy spare parts for these applications and motor vehicles.

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