Ministry of Environment of Denmark

Update of the National Implementation Plan (NIP) for the Stockholm Convention on Persistent Organic Pollutants (POPs)

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Summary

The Stockholm Convention
The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted in May 2001 and entered into force on 17 May 2004. The purpose of the Convention is to protect human health and the environment against the harmful properties of POPs.

The Convention initially included 12 substances or groups of substances (sometimes referred to as "the dirty dozen") and has subsequently been amended, adding 22 additional substances or groups of substances. Of these, 6 substances or groups of substances have been added since the previous implementation plan in 2018:

- Dicofol,
- Perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds,
- Perfluorohexanesulfonic acid (PFHxS), its salts and PFHxS-related compounds,
- Methoxychlor,
- Dechlorane Plus, and
- UV-328

Substances under the Stockholm Convention are divided into three groups. Each group is listed in its own annex to the Stockholm Convention:

- Annex A: Substances, which Parties must ban
- Annex B: Substances, which Parties must restrict
- Annex C: Substances, which are formed unintentionally, the formation of which Parties must restrict or, if possible, eliminate

The six most recently added POPs are all included under Annex A of the Convention.

Implementation plans
Denmark’s first NIP was published by the Danish Ministry of Environment in May 2006 and was updated in 2012 and 2018. The current NIP update focusses on the six new substances/substance groups as well as new, relevant information for several of the previously recognized POPs.

This updated implementation plan was prepared by the Danish Ministry of Environment (Miljøministeriet, MIM). The work was followed by an advisory group comprising representatives from the following organisations:

- Ministry of Environment of Denmark (MIM)
- Danish Environmental Protection Agency (DK EPA)
- Danish Health Authority (SST)
- Danish Ministry of Defence – Estate Agency (FES)
- The Danish Regions
- Green Transition Denmark (NGO, Rådet for Grøn Omstilling)
- Circular Denmark (Brancheforeningen Cirkulær, interest organisation consisting of municipal waste companies
- Aarhus University, Danish Centre for Environment and Energy (DCE)
- Holbæk Hospital, Occupational Medicines
- Confederation of Danish Industry (Dansk Industri)
- Danish Chambre of Commerce (Dansk Erhverv)
- Association of environmental, planning and nature employees in the public sector (EnviNa)

Relevant regulation in Denmark and the EU
As the EU is a contracting party to the Stockholm Convention, the EU is obliged to implement the Convention. This is done by Regulation (EU) 2019/1021 of 20 June 2019 on persistent organic pollutants. It should be noted that the EU POP Regulation does not translate all requirements and exemptions from the Stockholm Convention into Union law. In many cases the EU POP Regulation is more stringent than the Stockholm Convention requirements. As the POP Regulation is a binding legislative act, it is applied in its entirety across the European Union and does not need to be transposed into national law.

Annex I of the POP Regulation contains the substances listed in Annexes A and B of the Stockholm Convention together with their unintentional trace contaminants concentration limits above which a substance, mixture or product may not be placed on the market. It also contains specific exemptions for each substance or substance group, if available.

The waste-related concentration limits are stated in Annex IV and V of the Regulation. The limits in Annex IV are general POP-waste limits above which the waste must be treated in such a way that the containing POP substances are “destroyed or irreversibly transformed so that the remaining waste and releases do not exhibit the characteristics of POPs”. The Annex V limit values are derogations from this allowing higher concentrations in selected waste streams and different waste operations to be performed.

The Regulation was recast in 2019, replacing the previous EU POP Regulation 850/2004.

Of the new POPs in focus of this NIP only Dicofol, PFOA and PFHxS are listed in the POP Regulation as of December 2023.

Dicofol
Dicofol is an organochloride insecticide, specifically it is an acaricide to control mites in a range of food and ornamental crops. Dicofol is neither produced nor used in EU Member States due to various prohibitions in place. It has never been produced in Denmark.

Dicofol has been used as an insecticide in fruit farming, horticulture, and plant nurseries in Denmark. The earliest known sale is registered in 1958. Last selling of pesticides containing dicofol occurred in 1993. During the whole period, it is estimated that ca. 36 tons dicofol have been sold in Denmark.

The limited historical use and existing environmental data indicate that the environmental presence of dicofol is unlikely to pose a major concern. Exposure to dicofol in the Danish population can occur due to dietary intake of crops of foreign origin, however detections in food items are rare. Overall, there is no risk of adverse health effects following dietary exposure to dicofol.

Therefore, it is assessed that no additional initiatives in relation to dicofol are necessary.

Methoxychlor
Methoxychlor is an organochlorine pesticide which has been used as a replacement for DDT. As an insecticide, methoxychlor was commonly applied on field crops, vegetables, fruits, stored grain, livestock, and domestic pets.

Methoxychlor has been phased out in the EU since 25 July 2003, with some Member States ceasing the use also prior to this date. There are no existing producers nor importers of methoxychlor in Europe.

The earliest sale of Methoxychlor in Denmark is registered in 1956 and the last selling of pesticides containing methoxychlor occurred in 1991. During the whole period, it is estimated that ca. 123.5 tons methoxychlor have been sold in Denmark.

Since 2004, methoxychlor has not been detected in any of the samples within the analysed food groups in Denmark (fruit and vegetables; grain, flour, groats, etc., unprocessed; dairy and meat products; babyfood, honey).

Environmental concentrations of Methoxychlor appear generally to be low or under detection limits. Available data indicate that human exposure to methoxychlor is low and unlikely to pose concerns for human health in Denmark.

Therefore, it is assessed that no additional initiatives in relation to methoxychlor are necessary.

Perfluorooctanoic acid (PFOA), its salts and PFOA related compounds
PFOA (perfluorooctanoic acid), its salts and PFOA related compounds belong to the group of per- and polyfluorinated substances (PFAS).

PFAS, and thus PFOA, its salts and PFOA related compounds, have never been produced in Denmark, however, they have been imported from other countries and used in e.g. manufacturing facilities of consumer products and in firefighting foam. However, while the placing on the market of PFOA is forbidden, the substances is most probably still present in certain products on the Danish market e.g. firefighting foams.

Historically, PFOA has been used in numerous applications in Denmark. These include for example cardboard and paper, chemical industry, electronics, paints, textile and leather and wood and furniture.

PFOA is ubiquitously present in the Danish environment with measured concentrations in both water, soil and air compartments. Numerous human biomonitoring studies investigating the presence of PFOA in humans confirm an exposure of the Danish population to PFOA. Overall, a strong decline of PFOA exposure starting from around year 2000 in Denmark and other European countries can be observed, most likely due to the phase-out of PFOA by the producing company 3M and regulation of the substance.

Due to increased national and international attention towards, and regulation of PFAS in general, numerous activities regarding monitoring environmental and human exposure are ongoing to close knowledge gaps and assess risks from potential PFAS exposure. The MIM will follow the work and initiatives set out by the Danish Environmental Protection Agency’s PFAS task force and assess whether the actions taken based on this work sufficiently address the knowledge gaps identified for PFOA, its salts and related compounds.

Perfluorohexane sulfonic acid (PFHxS), its salts and PFOA related compounds
Similar to PFOA, PFHxS, its salts and related substances belong to the group of PFAS. The substance was never produced in Denmark. Historically, PFHxS has been used in numerous applications in Denmark. These include for example cardboard and paper, chemical industry, dry cleaners, textile and leather and wood and furniture.
Under the POP Regulation, there are no use exemptions for PFHxS, its salts and related substances.

PFHxS is ubiquitously present in the Danish environment with measured concentrations in both water, soil and air compartments.

The presence of PFHxS in humans confirms that the Danish population is exposed to this substance, however, the human biomonitoring data show that the trend is declining. Some of the measures and initiatives as described for PFOA, its salts and PFOA related compounds, do also apply for PFHxS, its salts and related substances.

Dechlorane Plus

Dechlorane Plus (DP) is a man-made substance mainly used as a polychlorinated flame retardant. The technical DP mixture consists of two stereoisomers, syn-DP and anti-DP. Dechlorane Plus is not manufactured in Denmark or the EU, but only imported as a substance, in mixtures or in articles. DP has been commercially in use since the 1960s. It was developed as an alternative for the brominated flame retardant decaBDE and the organochlorine insecticide Mirex.

Numerous studies conducted in Denmark and other European countries indicate DP is widely distributed in the environment, even though only few data are available for the Danish environment. Studies conducted in other European countries indicate that also humans are exposed to DP, however, the exposure routes are not well understood.

The MIM will therefore follow-up on data availability regarding environmental exposure as well as assess the need of defining environmental quality criteria.

UV-328

UV-328 belongs to the group of substituted benzotriazole UV-absorbers. It can absorb the entire spectrum of UV light without being destroyed. It is no longer produced nor used in Europe and Denmark.

It was used in applications which are typically used outdoors. In Europe, ~50% of UV-328 was used in car coatings and special industrial wood coatings. Another 40% was used for the protection of plastics and rubbers, which includes e.g. PVC, polycarbonates, polyacrylates and polyester. A survey of unwanted substances in building materials identified uses of UV-328 in Denmark in paint and lacquers, ABS-, epoxy-, and fibre-resins, in PVC, and in binders in 2012.

Few data on the presence of UV-328 in the Danish and Nordic environment are available. Some biota data are available, at concentrations below levels of concern. Monitoring data in water and sediment are lacking.

Limited data on human exposure to UV-328 in Denmark or the EU are currently available, and the available data do not allow for conclusions on human exposure.

As an initial step, the MIM will follow-up on data availability regarding environmental exposure.

New initiatives
In the following table the new initiatives for the new POPs are listed:

POP	Initiative	Description	Responsible	Time-frame
Dicofol	None	-	-	-
Methoxychlor	None	-	-	-
PFOA, its salts and PFOA related compounds	Follow the work of the PFAS taskforce	Follow and assess the work of PFAS taskforce with focus on: • The presence of PFOA precursors in the environment, especially regarding a potential increase in PFOA concentration in various media. • Knowledge generation regarding presence and removal of PFOA in leachate from landfills.	MIM	2024-2029
	Follow-up on waste incineration	Knowledge generation regarding waste incineration	MIM	2024-2029
	Follow-up on stockpiles	Remind stakeholders of their information and management obligations, if they are holders of a stockpile.	MIM	2024-2026
PFHxS, its salts and PFHxS related compounds	Follow-up on waste incineration	Knowledge generation regarding waste incineration	MIM	2024-2029
	Follow-up on stockpiles	Remind stakeholders of their information and management obligations, if they are holders of a stockpile.	MIM	2024-2026
Dechlorane Plus	Follow-up on data availability	Screening of DP in the environment as a part of NOVANA.	MIM	2024-2029
	Assess the need of environmental quality criteria for the water environment	Assess whether an EQS for biota (and possibly sediment) to assess environmental exposure data is needed – pending the outcome of the NOVANA screening.	MIM/ DK EPA	2024-2029
UV-328	Follow-up on data availability	Screening of UV-328 in the environment as a part of NOVANA.	MIM	2024-2029

Follow-up on initiatives identified in the previous NIP
DecaBDE and other PBDEs – The presence of brominated flame retardants has been and currently is investigated in consumer product surveys by the Danish EPA. PBDE have not been detected in gaming equipment or textiles with electronic parts.
In 2020, PBDE´s (and other hazardous substances) were included in the Danish Statutory Order on Waste, meaning buildings must be screened for PBDE prior to demolition and waste must be handled accordingly. Waste from the demolition containing or contaminated with hazardous substances must be separated from the rest.
A study on destruction of POPs (including PBDE) in MSW incinerators was published in 2019 but could not provide definite conclusions on destruction efficiency. The work to assess the destruction efficiencies therefore continues.

SCCPs – MIM has since 2019 worked with initiatives to increase better sorting of building waste to increase recycling and at the same time prevent POP and other hazardous materials from re-entering in new products. The work is ongoing.

HBCDD – A study on destruction of POPs (including HBCDD) in MSW incinerators was published in 2019 but could not provide definite conclusions on destruction efficiency. MIM has since 2019 worked with initiatives to increase better sorting of building waste to increase recycling and at the same time prevent POP and other hazardous materials from re-entering in new products. The work with assessment of the destruction efficiencies and building waste management continues.

PCB – The study on PCB in transformers and capacitors in Denmark has been finalised and the results do not warrant further initiatives.
Regarding the human health the risk assessment of low-chlorinated PCBs, results from several human cohort studies are available. According to the Danish Health Authority, the results need further corroboration in other studies to draw consolidated conclusions and potential subsequent regulatory actions. Furthermore, experimental investigations on the hazardous properties of the low-chlorinated, non-dioxin-like PCBs are also necessary.

PFOS – Denmark has informed about the phase out of PFOS for non-decorative chrome plating and the switch to alternatives for this application in the national reports under the Stockholm Convention and POPs Regulation.
In the import data retrieved from Statistics Denmark, some irregularities regarding volumes of imported PFOS-related substances were observed. The MIM will follow up on this information and take action as appropriate.

Dioxins and other unintentionally formed POPs – Several campaigns have been carried out by the Danish EPA to inform users of wood stoves about measures to reduce emissions. Updated information for HCBD and PCNs in the emission inventories is not available and it has to be further evaluated to what extent it is possible to include these substances in a screening survey. Regarding the content and handling of dioxins and other unintentionally formed POPs in flue gas cleaning residues, MIM will assess whether further activities should be initiated and whether changes to the legislation regarding the disposal of flue gas cleaning products should be made.

Updated information about selected previously added POPs
Within this NIP, selected POPs that have been added previously under the Convention are listed either with respect to availability of new data and/or because their regulation under the POP Regulation has been updated. These POPs were PFOS, its salts and PFOS-F, PCP, PBDE, dioxins, DDT, lindane, PCB, SCCP and HBCDD.

Waste limit values under Annex IV and V were either updated or introduced for PCP, PDBE, dioxins, SCCP and HBCDD. Additionally, for the following POPs new information was considered:

PCP – Some new relevant data are available regarding the presence of PCP in the food on Danish market and the overall environmental and human health exposure. Overall, the new data on PCP are limited and do not change the conclusion from the previous NIP, i.e. that no further actions needed in order to comply with the requirements of the Stockholm Convention and the POP Regulation.

PBDE – In the recent OSPAR assessment, PBDE concentrations were measured in sediment and biota from several monitoring sites in the North Sea and showed that concentrations of

PBDE in the OSPAR assessment area are either stable or decreasing. As a result, PBDE concentrations are not expected to have harmful effects on marine organisms.

Dioxins – In a study by the Danish EPA, the concentration of dioxins and furans in ash and soot from the combustion of biomass for heat and energy was studied in order to reconsider use and handling of the combustions waste (bottom ash, fly ash/soot). The study comprised both wood-burning stoves (approx. 5 kW) and larger biomass boilers (1-40 MW). The measured concentrations are all below the Annex IV waste limit values for dioxins in the POP Regulation.
In the NIP from 2018, an initiative was to follow the results of the HALOSEP projects, aiming at providing a local management method for fly ash from waste incineration, instead of exporting flue gas residues for landfilling/depositing in underground mines. Hazardous substances are stabilised in a residual treatment product of the HALOSEP process. The process has been in full-scale application at the MSW incineration plant Vestforbrænding in Copenhagen since 2021. Currently, the flue gas cleaning residue at Vestforbrænding is classified as non-hazardous waste. However, it is currently exported for landfilling in Sweden, as none of the Danish waste recipients are approved to receive this comparatively new waste fraction and guidelines regarding possible use of the waste, e.g., for building purposes, are lacking.

DDT – is one out of the 12 initial POPs recognized under the Convention. The first NIP (MIM, 2006) concluded that as a result of the low or non-existent occurrences of DDT in foodstuffs, waste products, the environment and the groundwater, no further initiatives would be necessary.
The Environmental Protection Agency informs that there is currently no evidence available that causes the soil quality criterion for DDT to be raised. A cut-off criterion, indicating the level of a substances above which soil must be remediated before it may be used for housing or other sensitive use, is not defined for DDT.
Updated results (2010-2019) from the Danish food monitoring indicate that human exposure via food uptake of DDT continues to decrease.

Lindane – In the NIP from 2012, where the substance was originally presented, it was concluded that no further initiatives are needed for lindane in Denmark. This was due to low or non-existent presence of this substance in food, waste, the environment, and groundwater. Since, a systematic inventory of sites that are potentially impacted by HCH/lindane has become available. The sites are included in the Danish regions' general action on soil contamination, and at the sites where lindane has been detected, it is not considered to pose a risk. Therefore, further initiatives on lindane are not needed.

PCB – One of the initiatives identified in the 2018 NIP was to follow the results of the HESPERUS project, which assesses the risk of low-chlorinated PCB in the indoor environment. The Danish Health Authority and the Danish Patient Safety Authority collaborate on health effects of exposure to PCBs with the register-based 'Health Effects of PCBs in Indoor Air' (HESPAIR) cohort. According to the Danish Health Authority, the human observational study results need further corroboration in other studies to draw consolidated conclusions and potential subsequent regulatory actions. Furthermore, experimental investigations on the hazardous properties of the low-chlorinated, non-dioxin-like PCBs are also necessary.

In the recent OSPAR assessment, PCB concentrations were measured in sediment and biota from several monitoring sites in the North Sea. While concentrations are decreasing in many sub-regions, there is one sub-region (in biota from the Southern North Sea) that shows an increasing trend. With the exception of the most toxic form (PCB-CB118), concentrations of all PCB congeners in sediment and biota are below the threshold at which they might pose an unacceptable risk to the environment. Mean concentrations of PCB-CB118 in sediment are at or above this threshold in two of the six areas assessed, and in biota, this is the case for seven out of thirteen areas assessed. The OSPAR assessment concludes that PCBs continue to enter the environment through secondary sources such as leachate from waste disposal sites, thus indicating further research is needed to better define and quantify these inputs.

Sammenfatning

Stockholm-konventionen
Stockholm-konventionen om persistente organiske miljøgifte (POP-stoffer) blev vedtaget i maj 2001 og trådte i kraft den 17. maj 2004. Formålet med konventionen er at beskytte menneskers sundhed og miljøet imod POP-stoffers skadelige egenskaber.

Konventionen omfattede oprindeligt 12 stoffer eller grupper af stoffer (”det beskidte dusin”) og er senere blevet ændret, så der er tilføjet yderligere 22 stoffer eller grupper af stoffer. Af disse er seks stoffer eller grupper af stoffer blevet tilføjet siden den forrige implementeringsplan i 2018:

- Dicofol,
- Perfluoroctansyre (PFOA), salte heraf og PFOA-beslægtede forbindelser,
- Perfluorhexansulfonsyre (PFHxS), salte heraf og PFHxS-beslægtede forbindelser,
- Methoxychlor,
- Dechloran Plus og
- UV-328

Stoffer under Stockholm-konventionen er opdelt i tre grupper. Hver gruppe er opført i sit eget bilag til Stockholmkonventionen:

- Bilag A: Stoffer, som parterne skal forbyde
- Bilag B: Stoffer, som parterne skal begrænse
- Bilag C: Stoffer, som dannes utilsigtet, og hvis dannelse parterne skal begrænse eller om muligt eliminere.

De seks senest tilføjede POP-stoffer er alle inkluderet i bilag A til konventionen.

Implementeringsplaner
Danmarks første nationale implementeringsplan (NIP) blev udgivet af Miljøministeriet i maj 2006 og blev opdateret i 2012 og 2018. Den nærværende opdatering af NIP fokuserer på de seks nye stoffer/stofgrupper samt ny, relevant information for flere af de tidligere anerkendte POP-stoffer.

Denne NIP er blevet udarbejdet af det danske Miljøministerium (MIM). Arbejdet er blevet fulgt af en følgegruppe bestående af repræsentanter fra følgende organisationer:

- Miljøministeriet (MIM)
- Miljøstyrelsen (MST)
- Sundhedsstyrelsen (SST)
- Forsvarsministeriet – Forsvarets Ejendomsstyrelse (FES)
- Danske Regioner
- Rådet for Grøn Omstilling
- Brancheforeningen Cirkulær (interesseorganisation bestående af kommunale affaldsselskaber)
- Aarhus Universitet, Nationalt Center for Miljø og Energi (DCE)
- Holbæk Sygehus, Arbejds- og Socialmedicinsk Afdeling
- Dansk Industri
- Dansk Erhverv
- Foreningen af miljø-, plan- og naturmedarbejdere i det offentlige (EnviNa)

Relevant regulering i Danmark og EU
Da EU er part i Stockholmkonventionen, er EU forpligtet til at implementere konventionen. Dette er sket ved forordning (EU) 2019/1021 af 20. juni 2019 om persistente organiske miljøgifte (POP-forordningen). Det skal bemærkes, at EU's POP-forordning ikke omsætter alle krav og undtagelser fra Stockholm-konventionen til EU-lovgivning. I mange tilfælde er POP-forordning strengere end kravene i Stockholm-konventionen. Da POP-forordningen er en bindende retsakt, anvendes den i sin helhed i alle EU's Medlemslande, og den behøver ikke at blive omsat til national lovgivning.

Bilag I til POP-forordningen indeholder de stoffer, der er opført i bilag A og B til Stockholm-konventionen, sammen med deres respektive koncentrationsgrænser for utilsigtede sporforureninger. Er denne koncentrationsgrænse overskredet, må en blanding eller et produkt ikke markedsføres. For stoffer eller stofgrupper, hvor specifikke undtagelser er gældende, er disse også angivet i Bilag I.

Koncentrationsgrænser for stoffer, der er omfattet af forordningens bestemmelser om affaldshåndtering, er angivet i bilag IV og V til POP-forordningen. Grænseværdierne i bilag IV er generelle POP-affaldsgrænseværdier, over hvilke affaldet skal behandles på en sådan måde, at indholdet af POP-stoffer "destrueres eller omdannes irreversibelt, således at restaffaldet og udslip ikke udviser egenskaber, der er karakteristiske for POP". Bilag V-grænseværdierne er undtagelser fra dette, og tillader højere koncentrationer i udvalgte affaldsstrømme og forskellige affaldsbehandlinger.

Forordningen blev revideret i 2019 og erstattede den tidligere POP-forordning 850/2004.
Af de nye POP-stoffer, som denne NIP fokuserer på, er det kun dicofol, PFOA og PFHxS, som er opført i POP-forordningen (status december 2023).

Dicofol
Dicofol er et organochlorid-insekticid, nærmere bestemt et acaricid, som anvendes til bekæmpelse af mider i en række afgrøder og prydplanter. Dicofol bliver hverken produceret eller anvendt i EU's medlemslande. Det har aldrig været produceret i Danmark.

Dicofol har været brugt som insekticid i frugtavl, gartnerier og planteskoler i Danmark. Det tidligste kendte salg er registreret i 1958. Det sidste salg af sprøjtemidler indeholdende dicofol fandt sted i 1993. I hele perioden anslås det, at der er blevet solgt ca. 36 ton dicofol i Danmark.

Den begrænsede historiske anvendelse og de eksisterende miljødata indikerer, at tilstedeværelsen af dicofol i miljøet sandsynligvis ikke vil udgøre et væsentligt problem. Eksponering for dicofol i den danske befolkning kan stamme fra indtag af afgrøder af udenlandsk oprindelse – dog er påvisninger i fødevarer sjældne. Samlet set er der ingen risiko for sundhedsskadelige effekter ved eksponering for dicofol gennem kosten.

Det vurderes derfor, at der ikke er behov for yderligere initiativer i forhold til dicofol.

Methoxychlor
Methoxychlor er et organochlor-pesticid, der har været brugt som erstatning for DDT. Som insekticid blev methoxychlor almindeligvis anvendt på afgrøder på friland, grøntsager, frugt, oplagret korn, husdyr og kæledyr.

Methoxychlor har været udfaset i EU siden 25. juli 2003, og i nogle medlemslande ophørte anvendelsen før denne dato. Der er ingen eksisterende producenter eller importører af methoxychlor i Europa.

Det tidligste salg af methoxychlor i Danmark er registreret i 1956, og det sidste salg af sprøjtemidler, der indeholder methoxychlor, fandt sted i 1991. I hele perioden anslås det at ca. 123,5 ton methoxychlor er blevet solgt i Danmark.

Siden 2004 er methoxychlor ikke blevet påvist i nogen af prøverne af de analyserede fødevaregrupper i Danmark (frugt og grønt; korn, mel, gryn og andre uforarbejdede fødevarer; mejeri- og kødprodukter; babymad, honning).

Miljøkoncentrationerne af methoxychlor ser generelt ud til at være lave eller under detektionsgrænserne. Tilgængelige data indikerer, at menneskers eksponering for methoxychlor er lav og sandsynligvis ikke udgør et problem for menneskers sundhed i Danmark.

Derfor vurderes det, at der ikke er behov for yderligere initiativer i forhold til methoxychlor.

Perfluoroctansyre (PFOA), salte heraf og PFOA-beslægtede forbindelser
PFOA, dets salte og PFOA-beslægtede forbindelser tilhører gruppen af per- og polyfluorerede stoffer (PFAS).

PFAS, og dermed PFOA, dets salte og PFOA-beslægtede forbindelser, er aldrig blevet produceret i Danmark, men de er blevet importeret fra andre lande og brugt i f.eks. produktionsfaciliteter af forbrugerprodukter og i brandslukningsskum. Selvom det er forbudt at markedsføre PFOA, er stoffet sandsynligvis stadig til stede i visse produkter på det danske marked, f.eks. brandslukningsskum.

Historisk set har PFOA været brugt i mange sammenhænge i Danmark. Det gælder f.eks. pap og papir, kemisk industri, elektronik, maling, tekstil og læder samt træ og møbler.

PFOA er allestedsnærværende i det danske miljø med målte koncentrationer i både vand, jord og luft. Talrige humane biomoniteringsstudier, der undersøger tilstedeværelsen af PFOA i mennesker, bekræfter at den danske befolkning er eksponeret for PFOA. Generelt kan der observeres et kraftigt fald i PFOA-eksponeringen fra omkring år 2000 i Danmark og andre europæiske lande, hvilket sandsynligvis kan tilskrives udfasningen af PFOA fra producentfirmaet 3M og regulering af stoffet i lovgivningen.

På grund af den øgede regulering, samt den nationale og internationale opmærksomhed på PFAS generelt, er der mange aktiviteter i gang vedrørende overvågning af miljømæssig og menneskelig eksponering. Formålet med dette er at afdække manglende viden og vurdere risici fra potentiel PFAS-eksponering. MIM vil følge arbejdet og initiativerne fra Miljøstyrelsens PFAS-taskforce og vurdere, om de tiltag, som vedtages på baggrund af dette arbejde, i tilstrækkelig grad afdækker den manglende viden, der er identificeret for PFOA, dets salte og relaterede forbindelser.

Perfluorhexansulfonsyre (PFHxS), salte heraf og PFHxS-beslægtede forbindelser
I lighed med PFOA tilhører PFHxS, dets salte og relaterede stoffer gruppen af PFAS. Stoffet er aldrig blevet produceret i Danmark. Historisk set har PFHxS været brugt i mange sammenhænge i Danmark. Disse omfatter for eksempel pap og papir, kemisk industri, renserier, tekstil og læder samt træ og møbler.
I henhold til POP-forordningen er der ingen undtagelser for brugen af PFHxS, dets salte og relaterede stoffer.

PFHxS er allestedsnærværende i det danske miljø med målte koncentrationer i både vand, jord og luft.

Tilstedeværelsen af PFHxS i mennesker bekræfter, at den danske befolkning er udsat for dette stof. Dog viser de humane biomonitoreringsdata, at tendensen er faldende. Nogle af foranstaltninger og initiativer, som beskrevet for PFOA, dets salte og PFOA-relaterede forbindelser, gælder også for PFHxS, dets salte og relaterede stoffer.

Dechloran Plus

Dechloran Plus (DP) er et menneskeskabt stof, der hovedsageligt bruges som flammehæmmer. Den tekniske DP-blanding består af to stereoisomerer, syn-DP og anti-DP. Dechloran Plus fremstilles ikke i Danmark eller EU, men importeres kun som stof, i blandinger eller i artikler. DP har været anvendt kommercielt siden 1960'erne. Det blev udviklet som et alternativ til den bromerede flammehæmmer decaBDE og det organiske chlorinsekticid Mirex.

Talrige undersøgelser foretaget i Danmark og andre europæiske lande tyder på, at DP er vidt udbredt i miljøet, selvom der kun er lidt data tilgængelig for det danske miljø. Undersøgelser foretaget i andre europæiske lande tyder på, at mennesker også udsættes for DP, men eksponeringsvejene er ikke velkendte.

MIM vil derfor følge op på tilgængeligheden af data vedrørende eksponering af miljøet samt vurdere behovet for at definere miljøkvalitetskriterier.

UV-328

UV-328 tilhører gruppen af substituerede benzotriazol UV-filtre. Stoffet kan absorbere hele spektret af UV-lys uden at blive nedbrudt. Det produceres og anvendes ikke længere i Europa og Danmark.

Stoffet blev anvendt på produkter, som typisk bruges udendørs. I Europa blev ~50% af UV-328 brugt i lak til biler og specielle industrielle træbelægninger. Derudover blev 40% brugt til beskyttelse af plast og gummi, herunder PVC, polycarbonater, polyacrylater og polyester. En undersøgelse af uønskede stoffer i byggematerialer i Danmark fandt at UV-328 blev anvendt i maling og lakker, ABS-, epoxy- og fiberharpikser, i PVC og i bindemidler i 2012.

Der findes kun lidt data om tilstedeværelsen af UV-328 i det danske og nordiske miljø. De tilgængelige data om biota viser at koncentrationerne ikke giver anledning til bekymring. Der mangler overvågningsdata i vand og sediment.

Der findes i øjeblikket begrænsede data om menneskers eksponering for UV-328 i Danmark og EU, og de tilgængelige data giver ikke mulighed for at konkludere hvad menneskers eksponering er.

MIM vil derfor følge op på tilgængeligheden af data vedrørende eksponering af miljøet, som et indledende tiltag.

Nye initiativer

Den følgende tabel viser relevante initiativer for de nye POP-stoffer:

POP	Initiativer	Beskrivelse	Ansvarlig	Tids-periode
Dicofol	Ingen	-	-	-
Methoxy-chlor	Ingen	-	-	-
PFOA, salte heraf og PFOA-beslægtede forbindelser	Følge og vurdere arbejdet i PFAS-taskforce	Følge og vurdere arbejdet i PFAS-taskforcen med fokus på: • Tilstedeværelsen af PFOA-precursors i miljøet, især med hensyn til en potentiel stigning i PFOA-koncentrationen i forskellige matricer. • Generering af viden om tilstedeværelse og fjernelse af PFOA i perkolat fra deponeringsanlæg.	MIM	2024-2029
	Opfølgning på affaldsforbrænding	Generering af viden om affaldsforbrænding	MIM	2024-2029
	Opfølgning på lagerbeholdninger	Påminde interessenter om deres informations- og håndteringsforpligtelser, hvis de er indehavere af et lager.	MIM	2024-2026
PFHxS, salte heraf og PFHxS-beslægtede forbindelser	Opfølgning på affaldsforbrænding	Generering af viden om affaldsforbrænding	MIM	2024-2029
	Opfølgning på lagerbeholdninger	Påminde interessenter om deres informations- og håndteringsforpligtelser, hvis de er indehavere af et lager.	MIM	2024-2026
Dechloran Plus	Opfølgning på datatilgængelighed	Screening af DP i miljøet som en del af NOVANA.	MIM	2024-2029
	Vurdere behovet for miljøkvalitetskriterier for vandmiljøet	Vurdere om der er behov for et EQS for biota (og evt. sediment) til vurdering af miljøeksponeringsdata – afventer resultatet af NOVANA-screeningen.	MIM/ DK EPA	2024-2029
UV-328	Opfølgning på datatilgængelighed	Screening af DP i miljøet som en del af NOVANA.	MIM	2024-2029

Opfølgning på initiativer identificeret i den foregående NIP fra 2018

DecaBDE og andre PBDE'er – Forekomsten af bromerede flammehæmmere er blevet og bliver i øjeblikket undersøgt i Miljøstyrelsens kortlægning af forbrugerprodukter. PBDE er ikke blevet påvist i spilleudstyr eller tekstiler med elektroniske dele.
I 2020 blev PBDE (og andre farlige stoffer) inkluderet i den danske affaldsbekendtgørelse, hvilket betyder, at bygninger skal screenes for PBDE før nedrivning, og at affald skal håndteres i overensstemmelse hermed. Affald fra nedrivningen, der indeholder eller er forurenet med farlige stoffer, skal sorteres fra resten.
En undersøgelse af destruering af POP-stoffer (herunder PBDE) i husholdningsaffald i forbrændingsanlæg blev offentliggjort i 2019, men kunne ikke give endelige konklusioner om effektiviteten af destrueringen. Arbejdet med at vurdere effektiviteten fortsætter derfor.

SCCP – MIM har siden 2019 arbejdet med initiativer til at øge sorteringen af byggeaffald for at øge genanvendelsen og samtidig forhindre POP-stoffer og andre farlige materialer i at blive recirkuleret med nye produkter. Arbejdet er igangværende.

HBCDD – En undersøgelse af destruering af POP-stoffer (herunder HBCDD) i et affaldsforbrændingsanlæg blev offentliggjort i 2019, men kunne ikke give endelige konklusioner om effektiviteten af destrueringen. MIM har siden 2019 arbejdet med initiativer til bedre sortering af byggeaffald for at øge genanvendelsen og samtidig forhindre POP-stoffer og andre farlige stoffer i at blive recirkuleret med nye produkter. Arbejdet med vurdering af effektiviteten af destrueringen samt håndtering af byggeaffald fortsætter.

PCB – Undersøgelsen af PCB i transformatorer og kondensatorer i Danmark er afsluttet, og resultaterne giver ikke anledning til yderligere initiativer.
Med hensyn til sundhedsrisikovurderingen af de lavchlorerede PCB'er, foreligger der resultater fra flere humane kohortestudier. Ifølge Sundhedsstyrelsen skal resultaterne dog bekræftes yderligere i andre undersøgelser, før der kan drages entydige konklusioner og udarbejdes potentielle lovgivningsmæssige tiltag. Desuden er der behov for eksperimentelle undersøgelser af de farlige egenskaber af de lavchlorerede, ikke-dioxinlignende PCB'er.

PFOS – Danmark har i de nationale rapporter under Stockholm-konventionen og POP-forordningen informeret om udfasningen af PFOS til ikke-dekorativ forkromning og skiftet til alternative stoffer i denne anvendelse.
Der blev der observeret nogle uregelmæssigheder med hensyn til importmængden af PFOS-relaterede stoffer i data, der er indhentet fra Danmarks Statistik. MIM vil følge op på disse oplysninger og vurdere behovet for yderligere foranstaltninger.

Dioxiner og andre POP-stoffer som dannes utilsigtet – Miljøstyrelsen har gennemført flere kampagner for at informere brugere af brændeovne om foranstaltninger til at reducere emissioner. Der foreligger ikke opdaterede oplysninger om HCBD og PCN i emissionsopgørelserne, og det skal vurderes nærmere, i hvilket omfang det er muligt at inkludere disse stoffer i en screeningsundersøgelse. Med hensyn til indhold og håndtering af utilsigtet dannede dioxiner og andre POP-stoffer i restprodukter fra røggasrensningen vil MIM vurdere, om der skal iværksættes yderligere aktiviteter, og om der skal foretages ændringer i lovgivningen vedrørende bortskaffelse af restprodukter fra røggasrensningen.

Opdaterede oplysninger om udvalgte tidligere tilføjede POP-stoffer
I denne NIP er udvalgte POP-stoffer, der tidligere er blevet tilføjet under konventionen, opført enten med hensyn til tilgængelighed af nye data, og/eller fordi deres regulering under POP-forordningen er blevet opdateret. Disse POP-stoffer er PFOS, dets salte og PFOS-F, PCP, PBDE, dioxiner, DDT, lindan, PCB, SCCP og HBCDD.

Affaldsgrænseværdierne i bilag IV og V blev enten opdateret eller indført for PCP, PDBE, dioxiner, SCCP og HBCDD. For følgende POP-stoffer blev der desuden taget hensyn til nye oplysninger:

PCP – Der foreligger nye relevante data om tilstedeværelsen af PCP i fødevarer på det danske marked, samt om den samlede eksponering af miljøet og menneskers sundhed. Samlet set er de nye data om PCP begrænsede og ændrer ikke konklusionen fra den tidligere NIP, dvs. at der ikke er behov for yderligere tiltag for at overholde kravene i Stockholm-konventionen og POP-forordningen.

PBDE – I den seneste OSPAR-vurdering blev PBDE-koncentrationer målt i sediment og biota fra flere overvågningssteder i Nordsøen hvilket viste, at koncentrationerne af PBDE i OSPAR-vurderingsområdet enten er stabile eller faldende. Som følge heraf forventes PBDE-koncentrationer ikke at have skadelige virkninger på marine organismer.

Dioxiner – I en undersøgelse foretaget af Miljøstyrelsen blev koncentrationen af dioxiner og furaner i aske og sod fra forbrænding af biomasse til varme og energi undersøgt med henblik på at genoverveje brugen og håndteringen af forbrændingsaffaldet (bundaske, flyveaske/sod). Undersøgelsen omfattede både brændeovne (ca. 5 kW) og større biomassekedler (1-40 MW).

De målte koncentrationer ligger alle under bilag IV-grænseværdierne for dioxiner i POP-forordningen.
I NIP fra 2018 var et initiativ at følge resultaterne af HALOSEP-projekterne, der sigter mod at tilvejebringe en lokal håndteringsmetode for flyveaske fra affaldsforbrænding i stedet for at eksportere restprodukter fra affaldsforbrænding til (overjordisk) deponi eller deponering i underjordiske miner. I HALOSEP-processen stabiliseres farlige stoffer i et restbehandlingsprodukt fremstillet i processen. Processen har kørt i fuld skala på forbrændingsanlægget Vestforbrænding i København siden 2021. I øjeblikket er restproduktet fra processen på Vestforbrænding klassificeret som ikke-farligt affald. Det eksporteres dog til deponering i Sverige, da ingen af de danske affaldsmodtagere er godkendt til at modtage denne forholdsvis nye affaldsfraktion, og fordi der mangler retningslinjer for mulig anvendelse af affaldet, f.eks. til byggeformål.

DDT – DDT er et af de 12 oprindelige POP-stoffer, der er optaget under Stockholm-Konventionen. Den første NIP (MIM, 2006) konkluderede, at som følge af de lave eller ikke-eksisterende forekomster af DDT i fødevarer, affaldsprodukter, miljøet og grundvandet, ville der ikke være behov for yderligere initiativer.
Miljøstyrelsen oplyser, at der på nuværende tidspunkt ikke foreligger dokumentation, der giver anledning til at hæve jordkvalitetskriteriet for DDT. Der er ikke defineret et afskæringskriterium for DDT, som angiver det niveau af et stof, over hvilket jorden skal oprenses, før den kan bruges til boliger eller anden følsom anvendelse.
Opdaterede resultater (2010-2019) fra den danske fødevareovervågning viser, at menneskers eksponering for DDT via fødevarer fortsat er faldende.

Lindan – I NIP fra 2012, hvor stoffet oprindeligt blev beskrevet, blev det konkluderet, at der ikke er behov for yderligere initiativer for lindan i Danmark. Det skyldtes den lave eller ikkeeksisterende forekomst af stoffet i fødevarer, affald, miljø og grundvand. Siden er der kommet en systematisk opgørelse over lokaliteter, der potentielt er påvirket af HCH/lindan. Lokaliteterne indgår i de danske regioners generelle indsats overfor jordforurening. På de grunde, hvor der er påvist lindan, vurderes det ikke at udgøre en risiko. Derfor er der ikke behov for yderligere initiativer over for lindan.

PCB – I den seneste OSPAR-vurdering blev PCB-koncentrationerne målt i sediment og biota fra flere overvågningssteder i Nordsøen. Mens koncentrationerne er faldende i mange subregioner, er der én subregion, som viser en stigende tendens (biota fra den sydlige del af Nordsøen). Med undtagelse af den mest toksiske form (PCB-CB118) er koncentrationerne af alle typer af PCB i sediment og biota under tærskelværdien for hvornår, de kan udgøre en uacceptabel risiko for miljøet. Gennemsnitskoncentrationerne af PCB-CB118 i sediment er på eller over denne tærskelværdi i to af de seks vurderede områder, og i biota er dette tilfældet i syv ud af 13 vurderede områder. OSPAR-vurderingen konkluderer, at PCB fortsat kommer ud i miljøet gennem sekundære kilder såsom perkolat fra affaldsdeponier. Dette viser, at der er behov for yderligere forskning for bedre at definere og kvantificere disse tilførsler.

1. Introduction

1.1 Background

Persistent organic pollutants (POPs) are chemical substances that remain in the environment for a long time after their release, accumulate strongly via food chains and can eventually reach concentrations that have harmful effects on human health and the environment. POPs also have the potential for long-range transport and can spread globally. Thus, they pose not only local or regional risks, but also threaten regions far from emissions.

POPs are the subject of the Stockholm Convention on POPs and the POPs Protocol under the Convention on Long-Range Transboundary Air Pollution (LRTAP) from the United Nations Economic Commission for Europe (UNECE). Both international conventions recognize the above-mentioned problematic nature of POPs and the need to undertake international activities with the overarching goal of reducing or eliminating production, use and releases of the substances as far as possible. In this sense, the Conventions set targets for the Parties on intentionally produced POPs, unintentionally released POPs and wastes and stockpiles containing POPs. The Parties are thus obliged to implement and put into practice measures that prevent or minimize the release of POPs into the environment.

Substances under the Stockholm Convention are divided into three groups. Each group is listed in its own annex to the Convention:

- Annex A: Substances, which Parties must ban
- Annex B: Substances, which Parties must restrict
- Annex C: Substances, which are formed unintentionally, the formation of which Parties must restrict or, if possible, eliminate

The implementation of the obligations of the Stockholm Convention is recorded by the contracting parties in so-called National Implementation Plans (NIPs). In the NIPs, the respective contracting Parties are to outline their specific national strategies and programs for shaping the contents of the Convention, appoint responsible bodies for sub-areas and finally submit the plan to the Secretariat of the Stockholm Convention. The NIPs are then published on the Convention's website and thus made available to all contracting parties and the public.

The Stockholm Convention on Persistent Organic Pollutants was adopted in May 2001 and entered into force on 17 May 2004. Upon ratification of the Stockholm Convention on 17 December 2003, Denmark had notified the Secretary-General of the territorial exclusion in respect of the Faroe Islands and Greenland. By a communication received on 10 February 2012, the Government of Denmark informed the Secretary-General that it had decided to withdraw the declaration, made upon ratification, regarding the territorial exclusion in respect of the Faroe Islands. On 22 November 2022, the Government of Greenland has decided that the territorial reservation for Greenland in relation to the Stockholm Convention can be lifted. Denmark has sent this declaration to the UN Secretary-General and is awaiting an acknowledgement of final deposit of the declaration.

Denmark submitted its first, comprehensive NIP in May 2006, which was updated in 2012 and 2018, respectively with the inclusion of new POPs under the Stockholm Convention. Since 2019, six new substances/substance groups have been added to the Convention. The current document provides the 2024 update of the NIP including those six new substances/substance groups. The update contains, among other things, a survey of which and how much of these newly added POPs are currently still in use, which products containing the POPs are still in use, and whether there are releases of the substances to the environment.

The Kingdom of Denmark placed a reservation with regard to the Stockholm Convention for the Faroe Islands and Greenland when ratifying the Convention. The Faroe Islands lifted their reservation to the Stockholm Convention on 10 February 2012 and the reservation will be lifted for Greenland in 2024. Separate National Implementation plans will be developed for The Faroe Islands and Greenland.

1.2 Objectives

The general objectives of the NIP are:

- To inform the Stockholm Convention secretariat about Denmark's implementation of its obligations under the Convention;
- To provide background information for authorities and other stakeholders in Denmark about the current issues regarding POPs in Denmark;
- To facilitate public participation in the process of developing activities, strategies and actions for further reducing any environmental and health risks from POPs in Denmark;
- To inform the European Commission and other EU Member States as well as other parties to the Convention about the POPs situation in Denmark and measures for risk reduction

The specific objective of the current NIP update is to describe the POPs situation and risk reduction measures for six newly added substances/substance groups under the Stockholm Convention, as well as provide new, relevant information for several of the legacy POPs, which have been addressed in earlier NIPs.

1.3 The newly added POPs

At the 9th Conference of the Parties in 2019, the following substances were included in Annex A.

- Dicofol and
- Perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds.

The 10th Conference of the Parties in 2021 decided to include the following substances in Annex A:

- Perfluorohexanesulfonic acid (PFHxS), its salts and PFHxS-related compounds

At the 11th Conference of the Parties held in 2023, three more substances were included in Annex A:

- Methoxychlor,
- Dechlorane Plus and
- UV-328

The Danish situation in terms of production, use, presence in waste, presence in the environment and human exposure is described for each of these substances in chapters 2-7.

1.4 Previous NIP and preparation of current update

Denmark's first NIP was published by the Danish Ministry of Environment in May 2006 (MIM, 2006) and was updated in 2012 (DK EPA, 2012) and 2018 (MIM, 2018).

The current NIP update focusses on the six new substances/substance groups as well as new, relevant information for several of the previously recognized POPs.

For additional information about the Stockholm Convention, earlier added POPs, EU, and national implementation of obligations under the Stockholm Convention, please refer to the earlier NIPs.

This updated implementation plan was prepared by the Danish Ministry of Environment (Miljøministeriet, MIM). The work was followed by an advisory group comprising representatives from the following organisations:

- Ministry of Environment of Denmark (MIM)
- Danish Environmental Protection Agency (DK EPA)
- Danish Health Authority (SST)
- Danish Veterinary and Food Administration (DVFA)
- Danish Ministry of Defence – Estate Agency (FES)
- The Danish Regions
- Green Transition Denmark (NGO, Rådet for Grøn Omstilling)
- Circular Denmark, interest organisation consisting of municipal waste companies
- Aarhus University, Danish Centre for Environment and Energy (DCE)
- Holbæk Hospital, Occupational Medicines
- Confederation of Danish Industry (Dansk Industri)
- Danish Chambre of Commerce (Dansk Erhverv)
- Association of environmental, planning and nature employees in the public sector (EnviNa)

The work was managed and coordinated by a steering group from the Department of the Ministry of Environment. Assistance with the drafting was provided by the consulting company Rambøll A/S.

1.5 Brief review of relevant regulation

As the EU is a contracting party to the Stockholm Convention, the EU is obliged to implement the Convention. This is done by Regulation (EU) 2019/1021 (hereinafter referred to as the EU POP Regulation) of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants. It should be noted that the EU POP Regulation does not translate all exemptions and acceptable purposes from the Stockholm Convention into Union law. In many cases the EU POP Regulation is more stringent than the Stockholm Convention requirements. As the POP Regulation is a binding legislative act, it is applied in its entirety across the European Union and does not need to be transposed into national law.

Article 3 of the EU POP Regulation imposes a general ban on the production, placing on the market and use of substances as such, in mixtures or in articles, which are listed in Annex I of the Regulation. According to Article 4 (1), only small quantities (laboratory scale) of the substances for research purposes and unintentional trace contaminants are exempted from this. Annex I contain the substances listed in Annexes A and B of the Stockholm Convention together with their unintentional trace contaminants concentration limits above which a substance, mixture or product may not be placed on the market. It also contains specific exemptions for each substance or substance group, if available.

Furthermore, article 7 sets out requirements for the handling of waste containing POPs above a certain concentration limit. The waste-related concentration limits are stated in Annex IV and V of the Regulation. The limits in Annex IV are general POP-waste limits above which the waste must be treated in such a way that the containing POP substances are “destroyed or irreversibly transformed so that the remaining waste and releases do not exhibit the characteristics of POPs”. The Annex V limit values are derogations from this, allowing higher concentrations in selected waste streams and different waste operations to be performed.

The Regulation was recast in 2019, replacing the previous EU POP Regulation 850/2004.

TABLE 1-1 lists the requirements for the six newly added POPs.

TABLE 1-1. Legal status of new POPs under the EU POP Regulation

Substance	Specific currently valid exemptions	Unintentional trace contamination	Limit value in waste in Annex IV	Limit value in waste in Annex V
Dicofol	None	None	50 mg/kg	5,000 mg/kg
Methoxychlor	Not yet listed			
Perfluorooctanoic acid, its salts and related substances	(a) photolithography or etch processes in semiconductor manufacturing, until 4 July 2025; (b) photographic coatings applied to films, until 4 July 2025; (c) textiles for oil- and water-repellency for the protection of workers from dangerous liquids that comprise risks to their health and safety, until 4 July 2023; (d) invasive and implantable medical devices, until 4 July 2025. (e) manufacture of polytetrafluoroethylene and polyvinylidene fluoride (PVDF) for production in certain applications, until 4 July 2023 (f) Use in foams from already installed fire fighting foam systems for liquid fuel fires, subject to certain conditions, see Annex 1, Part A, PFOA entry no. 6. a) - c). (g) the use of perfluorooctyl bromide containing perfluorooctyl iodide for the purpose of producing pharmaceutical products (e) Articles placed on market before Juli 4. 2020.	0.025 mg/kg (PFOA and its salts) 1 mg/kg (for individual PFOA-related compounds or a combination of PFOA-related compounds) 20 mg/kg (for related compounds to be used as a transported isolated intermediate) 1 mg/kg (for PFOA and its salts present in PTFE micro powder), until 18 August 2023	1 mg/kg (PFOA and its salts) 40 mg/kg (sum of related compounds)	50 mg/kg (PFOA and its salts) 2,000 mg/kg (sum of related compounds)
Perfluorohexanesulfonic acid, its salts and related substances	None	0.025 mg/kg (PFHxS or its salts) 1 mg/kg (for sum of related substances) 0.1 mg/kg (for PFHxS, its salts and PFHxS-related compounds in concentrated firefighting foams that are to be used or are used in the production of other firefighting foam mixtures)	1 mg/kg (PFHxS and its salts) 40 mg/kg (sum of related compounds)	50 mg/kg (PFHxS and its salts) 2,000 mg/kg (sum of related compounds)
Dechlorane Plus	Not yet listed			

UV-328	Not yet listed

2. Dicofol

Dicofol is an organochloride insecticide with CAS No. 115-32-2 and EC No. 204-082-0. It is an acaricide to control mites in a range of food and ornamental crops.

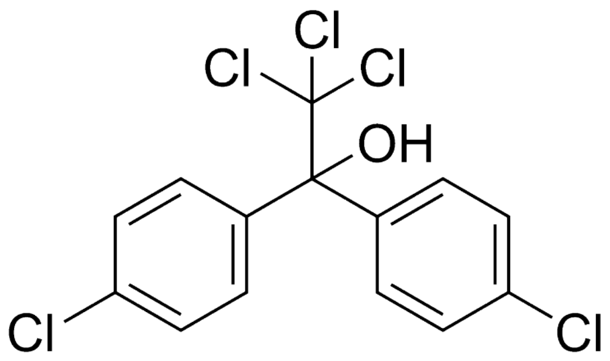

Figure 2-1 The chemical structure of dicofol with CAS No. 115-32-2.

Dicofol is structurally similar to another Stockholm Convention POP, DDT. It differs from DDT by the replacement of the hydrogen on C-1 by a hydroxyl (OH) functional group. DDT is an intermediate in dicofol production and may be present as an impurity in commercial mixtures of dicofol. Commercial mixtures contain two isomers of dicofol, o,p'dicofol (15-20%) and p,p'dicofol (80-85%).

2.1 Production in Denmark

Dicofol is neither produced nor used in EU Member States due to various prohibitions in place. Dicofol has never been produced in Denmark. For a long time, Spain was the only manufacturer and main consumer of dicofol in Europe (Li et al., 2014).

In 2000, around 1,500 tons of dicofol were produced in the EU, primarily in Italy and Spain where the use ceased in 2009 due to the Commission Decision on the non-inclusion of this substance to the Annex I of the Plant Protection Products Regulation. This means that manufacture, and use of dicofol in the EU has not been allowed for at least a decade (European Commission, 2021a). Additionally, from 2020, the POP Regulation prohibits its manufacture and use in another substance, mixture, or article.

2.2 Current use and supply in Denmark

Dicofol is neither produced nor used in EU Member States due to various regulations in place.

2.3 Historical use and supply in Denmark

Dicofol has been used as an insectide in fruit farming, horticulture, and plant nurseries in Denmark with the trade names Kelthane Emulsion, Kelthane SP, Kelthane WP, Kelthane E 30, Dicofol M12, Lindinger Dicofol M12, and Dicofol (DK EPA, 2000). The earliest known sale is registered in 1958. Last selling of pesticides containing dicofol occurred in 1993. During the whole period, it is estimated that ca. 36 tons dicofol have been sold in Denmark (DK EPA, 2022a).

2.4 Presence in waste, stockpiles, and contaminated areas

No stockpiles of dicofol in Denmark have been identified.

There is a possibility, similar to other POPs pesticides, that limited remaining stockpiles exist within the European Union. However, given the significant period of time that has passed since legal use has ceased, it is expected that quantities are rather small, if such stockpiles exist at all (European Commission, 2021a).

2.5 Presence in food and drinking water

2.5.1 Presence in food

Dicofol is regularly monitored in the Danish Pesticide Residues in Food on the Danish Market control programme by the National Food Institute of the Technical University of Denmark.

Within the control analyses, samples are usually taken from the food groups fruit and vegetables, cereals, flour, groats and similar, animal products (incl. milk), baby food and honey. Since 2010, dicofol has only been detected in a few samples within the groups fruit and vegetables, including herbs, but not in the other groups (see TABLE 2-1). Measured concentrations were well below the allowed maximum residue levels (MRL) in the respective crops, as defined by Regulation (EC) No 396/2005 on MRLs in food and feed.

TABLE 2-1. Dicofol results in the Danish Pesticide Residues in Food monitoring.

Sampling period	n dicofol detected / n total[1]	Max. concentration (mg/kg)	Crops with dicofol detected	Crop origin	Reference
2021	1 / 916	0.006	Avocado	non-DK	DTU Food, 2023
2020	1 / 880	0.007	Chervil	non-DK	DTU Food, 2022
2019	0 / 1228	-	Not detected	-	DTU Food, 2021
2018	0 / 1281	-	Not detected	-	DTU Food 2019a
2012-2017	7 / 8080	Not reported	Beans with pods Grapefruit Lemons Melons Oranges	non-DK	DTU Food 2019
2010-2014	1/ 10		Herbs	non-DK	DTU Food 2016

[1] Number of samples with dicofol detected / number of samples within fruit and vegetables.

In the 2013 European Union report on pesticide residues in food published by EFSA, dicofol was detected in 0.15% of analysed samples across the EU with the highest mean concentrations in mandarins (0.02 mg/kg ww) and highest concentrations in strawberries (0.04 mg/kg ww) (UNEP, 2016). These levels are at or above the MRL defined for those crops (0.02 mg/kg).

In the 2017 European Union report on pesticide residues in food published by EFSA, dicofol was quantified in 14 out of 58,672 samples (quantification rate of 0.02%) taken for analysis from 28 European countries (EFSA, 2019). Concentrations, type of food and country of origin were not specified.

In the 2021 European Union report on pesticide residues in food published by EFSA, dicofol was detected in sweet/bell pepper, but additional data about the dicofol analysis are not provided. EFSA concludes that acute dietary exposure to dicofol would not be expected to be of concern to consumer health (EFSA, 2023).

2.5.2 Presence in drinking water

The EU Directive on the quality of water intended for human consumption[1] defines the maximum concentration allowed in drinking water as 0.1 µg/l for a single pesticide or relevant metabolite, and 0.5 µg/l for the total sum of pesticides. This Directive was implemented in Danish law as the Statutory Order on Drinking Water (Drikkevandsbekendtgørelsen, BEK no. 1023 of 29/06/2023), including a list of pesticides for mandatory surveillance. Dicofol is not comprised by the list.

In a period between 1990 and 2006, dicofol was analysed in waterworks drillings (n=22) but not detected in any of the samples (DK EPA, 2007). Additionally, analysis data of dicofol from 40 foreign groundwater monitoring programmes was reviewed. Dicofol was detected in only one sample out of 1,634 at a concentration ≥ 0.1 µg/l (DK EPA, 2007). Additional data on the presence of dicofol in drinking water in Denmark have not been identified.
Since dicofol is practically insoluble in water and has strong adherence to organic matter (log K_{ow} 3.5-6.06), it partitions primarily to soil and sediment in the environment. Therefore, the occurrence of dicofol in drinking water is not likely.

2.6 Release of the substance and presence in the environment

Dicofol is included in Directive 2013/39/EU as a priority hazardous substance in the field of water policy with the following environmental quality standards (EQS):

- 1.3×10^{-3} µg/l in inland surface waters,
- 3.2×10^{-5} µg/l in other surface waters
- and 33 µg/kg wet weight in biota.

The EU-derived EQS are implemented in Denmark with the Statutory Order no. 796 of 13/06/2023. EQS for the sediment and biota compartment are not defined for dicofol.

In addition, due to being identified as a priority hazardous substance, the Water Framework Directive (Directive 2000/60/EC) makes it obligatory to cease all discharges to the environment which go beyond the EQS target thresholds (European Commission, 2021a).

Primary sources of environmental releases can stem from the production processes, professional or private use, or from the subsequently generated waste (UNEP, 2016). Since dicofol is no longer produced nor imported in Denmark, releases from production and use of dicofol can be excluded.

Few data on environmental exposure in Denmark are available from "Miljødata – Danmarks Miljøportal"[2] which provides raw data from environmental surveys in seas, lakes, and streams. The presence of dicofol was investigated in sediments of nine river basins located in the Central Denmark Region and Region of Southern Denmark (hereunder the Giber/Odder streams, the Gudenå, Odense stream and more). A total of 14 sediment samples were taken from the water bodies during 2022. The detection limits varied between 0.02 and 0.1 mg/kg dry weight. None of the samples displayed concentrations above the detection limit. It is noted that the detection limits are quite high in relation to anticipated environmental concentrations. Data for marine sediments were not available.

In the Danish National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA), dicofol is mentioned but has not been analysed in any environmental samples during the period 2008-2019 (Boutrup et al., 2021). Due to the ceased use of dicofol, the Danish Centre For Environment and Energy (DCE) decided that future

[1]

[2] Available at https://miljoedata.miljoeportal.dk/, chemistry search parameter "898 – p,p'-Dicofol" (accessed October 11, 2023).

monitoring of the substance in the Danish environment would not be relevant (Boutrup et al., 2021).

There is a lack of studies investigating the presence of dicofol in the environment in Denmark, while a few are available for other European countries. Boström 2015, for example, conducted a study with the aim to investigate the presence of pesticides in Sweden in surface waters. Sampling took place from 1983 to 2014. Dicofol was not detected in any of the 256 analysed surface water samples.

Vulliet et al., (2014) conducted a national investigation in France during 2012 on the presence of organic contaminants in the environment and dicofol was not detected in any of the 154 analysed sediment samples (124 watercourse sediments, 18 lake sediments and 12 coastal sediments) (LOQ was 15.0 ng/g = 0.015 mg/kg).

Iakovides et al., (2023) measured presence of dicofol in atmospheric samples collected in Cyprus in 2018. Six atmospheric samples (gaseous and particulate phase) were collected separately for 24 hours. Average concentration of dicofol in gas phase was 11.16±1.15 pg/m^3 and in particulate phase 128±24 pg/m^3. Being on the crossroad of three continents, the Island of Cyprus has a specific geographic location where approximately 70% of the air masses originate from the Etesian winds. These winds transport pollutants primarily from Eastern Europe and Turkey. Additionally, noteworthy contribution also comes from air masses from north-eastern Africa and the Arabian Peninsula. Large atmospheric input indicates persistence and long-range transport potential of this substance.

UNEP, 2016 concluded dicofol and/or its transformation products can be atmospherically transported to areas far away from local sources, indicating the substance could appear also in Denmark. However, due to prohibitions in place regarding its manufacture and use as well as significant time that has passed since its legal use in Europe, its releases and subsequent presence in Danish environment are expected to be low.

2.7 Assessment of environmental and human exposure

2.7.1 Environmental exposure

Dicofol is practically insoluble in water and adheres strongly to organic matter (log K_{ow} 3.5-6.06) and partitions therefore primarily to soil and sediment in the environment.

Few data for the Danish environment exist. In Danish sediments, the substance was not detected at concentrations above detection limits. EQS for sediments are not available.

Few European data with measured sediment and water concentration are available, all with concentrations being below detection or quantification limits.

The limited historical use and existing environmental data indicate that the environmental presence of dicofol is unlikely to pose a major concern.

2.7.2 Human exposure

Exposure to dicofol in the Danish population can occur due to dietary intake of crops of foreign origin. Generally, the number of crops containing dicofol residues as well as concentrations of dicofol in the crops appear to be low. The health risk resulting from chronic dietary exposure was compared to the toxicological reference value, ADI, for dicofol based on the findings in the Danish food monitoring. Both for children (4-6 years) and adults, the hazard quotients were well below 0.1 (0.06% and 0.02%, respectively), indicating that there is no risk of adverse health effects following dietary exposure to dicofol (Jensen et al., 2019a).

The conclusion is supported by a study by Jensen et al., (2015), who measured cumulative risk assessment after chronic dietary exposure to all monitored pesticides in fruit, vegetables, and cereals for different consumer groups in Denmark. They estimated that dicofol is among 20 pesticides that contribute most to the hazard index used to estimate the risk from pesticide exposure via food. However, calculated hazard quotients (HQ) for the individual pesticides range from 0.0000001 to 0.024 (HQ of dicofol: 0.0086), with 98% of the HQs being below 0.01. This indicates there is no risk of adverse effects following dietary exposure to these pesticides, including dicofol (Jensen et al., 2015).

Dicofol is regularly sampled in the Danish Pesticide Residues in Food on the Danish Market control programme. Since 2010, dicofol has only been detected in a few samples within the groups fruit and vegetables, including herbs, but not in the other groups (for more details see section 2.5.1.). Furthermore, measured concentrations were well below the allowed maximum residue levels (MRL) in the respective crops. This indicates dicofol occasionally appears in food on the Danish market, however, the risks from exposure to dicofol seems to be well controlled.

3. Methoxychlor

Methoxychlor is an organochlorine pesticide with CAS No. 72-43-5 which has been used as a replacement for DDT. The name methoxychlor refers to any possible isomer of dimethoxydiphenyltrichloroethane or any combination thereof. Correspondingly, several CAS No. are available for the substance. As an insecticide, methoxychlor was commonly applied on field crops, vegetables, fruits, stored grain, livestock, and domestic pets.

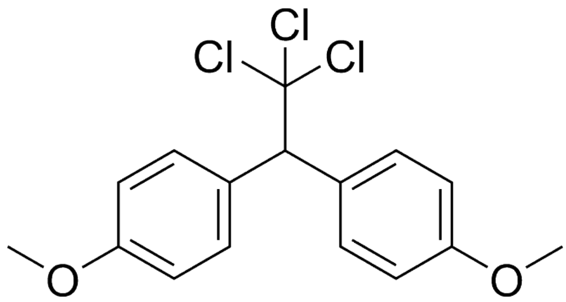

Figure 3-1. The chemical structure of methoxychlor (CAS No. 72-43-5).

3.1 Production in Denmark

There are no existing producers nor importers of methoxychlor in Europe (UNEP, 2021).

3.2 Current use and supply in Denmark

Methoxychlor has been phased out in the EU since 25th of July 2003, with some Member States ceasing the use also prior to this date (UNEP, 2021).

There are several regulations in place that prohibit the use of methoxychlor in the European Union. Commission Regulation (EC) No 2076/2002 does not approve use of methoxychlor as a plant protection product in the EU with all authorisations being withdrawn by 25th of July 2003. Regulation (EC) No 276/2004 does not approve its use in veterinary medicinal products in the EU.

3.3 Historical use and supply in Denmark

Methoxychlor is an organochlorine pesticide that has been used as a replacement for DDT. As an insecticide it was applied on field crops, vegetables, fruits, and stored grain.

Methoxychlor has been used in Denmark in pesticides with the trade names Metodion 270 and PLK-Methoxychlor 30 (DK EPA, 1991). The earliest sale is registered in 1956 and last selling of pesticides containing methoxychlor occurred in 1991. During the whole period, it is estimated that ca. 123.5 tons methoxychlor have been sold in Denmark (DK EPA, 2022a).

3.4 Presence in waste, stockpiles, and contaminated areas

No stockpiles of methoxychlor in Denmark have been identified.

The substance has been approved for disposal in landfills until 1990 (DK EPA, 2022a) however, there are no data about the presence, leaching or leaking of the substance from landfills in Denmark.

3.5 Presence in food and drinking water

3.5.1 Presence in food

Methoxychlor is regularly monitored in the Danish Pesticide Residues in Food on the Danish Market control programme by the National Food Institute of the Technical University of Denmark.

Since 2004, methoxychlor has not been detected in any of the samples within the analysed food groups (fruit and vegetables; grain, flour, groats, etc., unprocessed; dairy and meat products; babyfood, honey) (DTU Food, 2016, 2021, 2022, 2023; Jensen et al., 2019b; Jensen et al., 2019a).

In the 2018 European Union report on the pesticide residues in food published by EFSA, methoxychlor was quantified in 0.01% of analysed samples (5 out of 56,428 food samples from 30 countries) (EFSA, 2020). More specifically, methoxychlor was quantified in one sample of animal fat and four coffee bean samples imported from Brazil, Ethiopia, Peru, and Uganda at a concentration range of 0.01-0.05 mg/kg (LOQ of 0.01 mg/kg) (UNEP, 2021).

MRL for methoxychlor are defined for several vegetable, herbs and fruit in Regulation (EC) No 396/2005 on maximum residue levels of pesticides (0.01 mg/kg). The available data show that exceedance of the MRL is rare but may occur.

3.5.2 Presence in drinking water

In the period from 1990 to 2012, methoxychlor was analysed from nine waterworks drillings but not detected in any of the samples (GEUS, 2013). For the following groundwater monitoring period from 2012-2021, methoxychlor (and isomers) were analysed in 248 samples without any detections (GEUS, 2023). Detection or quantification limits were not provided in the studies but must be <0.01 µg/l based on how the data are presented.

In France, methoxychlor was detected in 30 of the 118,563 (0.025%) groundwater samples taken between 1990 and 2018. In total, 19,428 sites were monitored with majority of them coming from tap water survey network. Highest concentration was measured in 2010, after phasing out of methoxychlor, at a concentration of 0.089 µg/l (LOD: 0.00001–100 µg/l) (UNEP, 2021).

3.6 Release of the substance and presence in the environment

Methoxychlor does not occur naturally in the environment and its release is mainly related to its application to crops and livestock (UNEP, 2021). Since methoxychlor is not produced nor imported in Denmark, releases from production and use of methoxychlor can be excluded.

Danish environmental exposure data are available for sediments.

Sediment data from Denmark are available from "Miljødata – Danmarks Miljøportal".[3] The presence of methoxychlor was investigated in nine river basins located in the Central Denmark Region and the Region of Southern Denmark (hereunder the Giber/Odder streams, the Gudenå, Odense stream and more). A total of 14 sediment samples were taken from the water bodies. The detection limits varied between 0.02 and 0.1 mg/kg dw. None of the samples displayed concentrations above the detection limit.

A study by the DK EPA, (2001) investigated the contamination of harbour sediments with organic pollutants at seven industrial harbours and five fishing/yacht harbours. Methoxychlor

[3] Available at https://miljoedata.miljoeportal.dk/, chemistry search parameter "565 – Methoxychlor" (accessed October 24, 2023).

was not detected in any of the samples in concentrations above the limit of detection (40 µg/kg dw).

The substance is not included in the Danish National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA).

Environmental data for water, soil or biota compartments are not available for Denmark, but for a few other EU Member States.

In Portugal, methoxychlor was detected in sediment core collected in 2013 from the upper part of Óbidos lagoon in Portugal. The upper part of the lagoon receives most of the inputs from surface runoff of the surrounding agricultural fields and from small tributaries. Methoxychlor was found in concentration range of 21.8 to 89 ng/g dw (between 16 and 40 cm depth), indicating that agricultural use of the substance leads to environmental presence (UNEP, 2021).

In Italy, methoxychlor was detected in topsoil samples (n=148; 0-20 cm top layer) collected in 2016 in urban and rural areas in Italy (methoxychlor was banned in plant protection products since 2003 and in biocidal products since 2006). Methoxychlor was found in a concentration range of n.d. - 53 ng/g in urban areas and n.d. - 522 ng/g in rural areas (LOD of 0.025 ng/g). It is not known whether the findings originate from agricultural use or as a result of its long-range transport (UNEP, 2021) but provide some evidence for the substance’s persistence in aerobic soils.

In Austria, authorization of plant protection products containing methoxychlor has ceased in 1993. Groundwater (n=13) and lower surface water (n=9) samples collected in 2014 and 2018 were below the limit of detection (UNEP, 2021).

In France, methoxychlor was detected in 73 out of 202,923 (0.036%) surface water samples taken between 2000 and 2018 with measured concentrations being in range of 0.005-0.269 µg/l (LOD: 0.001–0.3 µg/l). The highest measured concentration of 0.269 µg/l was measured in 2013 (UNEP, 2021).

3.7 Assessment of environmental and human exposure

3.7.1 Environmental exposure

Environmental quality standards are not defined for methoxychlor.

Environmental concentrations of methoxychlor appear generally to be low or under detection limits. The presence of methoxychlor in the environment cannot be excluded due to limited data for the Danish environment and due to its historical use (123.5 tons during a 36-year period) and the substance’s apparent persistence in anaerobic and anaerobic environments.

3.7.2 Human exposure

The most probable route of exposure to methoxychlor would occur from occupational handling of the substances (manufacture, handling or application), which is of no relevance for Denmark, since the substance has not been sold since 1991.

Exposure of the general population takes place by consumption of contaminated food and drinking water, by respiratory uptake of dust and aerosols containing methoxychlor and through oral intake of dust and soil.

In a study performed in Finland and Denmark from 1997 to 2001, methoxychlor was detected in human breast milk samples (detection rate 26.9%) in the range of 0.06-1.12 ng/g lipid (milk of mothers of boys with cryptorchidism, n=62, 29 Danish and 33 Finnish) and 0.05-0.41 ng/g lipid (milk of mothers with healthy boys, n=68, 36 Danish and 32 Finnish) (Damgaard et al., 2006). Shen et al., (2007) investigated exposure levels of placenta and paired breast milk samples to selected organochlorine compounds and pesticides from Danish and Finnish samples in order to determine the more suitable monitoring medium. Methoxychlor was generally accumulated more in placenta compared to breast milk samples.

Methoxychlor may have been used in cotton production, which is why the substance was included in a screening of organochlorine pesticides in tampons in a consumer product survey in 2001 by the DK EPA. Methoxychlor was not detected in any of the 5 samples (DK EPA 2002).

DTU Food, (2019b) concluded that based on the monitoring of the substance in imported food stuff, the acute dietary exposure to this pesticide would not be expected to pose a concern to consumer health. The chronic dietary exposure to methoxychlor residues in the food commodities analysed, is unlikely to pose concerns for consumer health.

In summary, detection of methoxychlor in humans indicates humans are exposed to this substance in Denmark. Detection of methoxychlor in sediment, soil, and water samples on various locations in Europe several years after methoxychlor was banned in Europe, indicate that methoxychlor is still present in the environment and humans may be exposed via the environment and/or consumption of contaminated water or food grown on contaminated soils. Available data indicate that human exposure to methoxychlor is low and unlikely to pose concerns for human health in Denmark.

4. PFOA, its salts and PFOA related compounds

PFOA (perfluorooctanoic acid), its salts and PFOA related compounds belong to the group of per- and polyfluorinated substances (PFAS). PFOA has the CAS number 335-67-1.

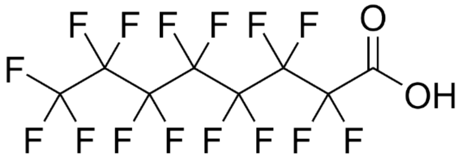

Figure 4-1 The chemical structure of PFOA (CAS no.: 335-67-1)

Similar to other POP substances, the restriction on PFOA in the POP-Regulation does not only include PFOA itself, but also its salts and PFOA related compounds. In this chapter when mentioning PFOA, the term only refers to PFOA. In case data are available for other substances belonging to the group, either the specific substances or the group name will be mentioned.

The following substances are comprised by the group PFOA, its salts and PFOA related compounds:

1. Perfluorooctanoic acid, including any of its branched isomers;
2. its salts;
3. PFOA-related compounds which, for the purposes of the Convention, are any substances that degrade to PFOA, including any substances (including salts and polymers) having a linear or branched perfluoroheptyl group with the moiety $(C_7F_{15})C$ as one of the structural elements.

The following compounds are not included as PFOA- related compounds:

1. C_8F_{17}-X, where X = F, Cl, Br
2. fluoropolymers that are covered by $CF_3[CF_2]_n$-R’, where R’ = any group, n > 16;
3. perfluoroalkyl carboxylic acids (including their salts, esters, halides and anhydrides) with ≥ 8 perfluorinated carbons;
4. perfluoroalkane sulfonic acids and perfluoro phosphonic acids (including their salts, esters, halides and anhydrides) with ≥ 9 perfluorinated carbons;
5. perfluorooctane sulfonic acid and its derivatives (PFOS)

4.1 Production in Denmark

PFAS, and thus PFOA, its salts and PFOA related compounds, have never been produced in Denmark, however, they have been imported from other countries and used in e.g. manufacturing facilities of consumer products and in firefighting foam (DK EPA, 2016).

Data was received from the Danish Product Registry in December 2023. The data contained information on import of PFOA and related compounds for the years 2014 - 2022. Based on the information received, relatively small amounts of PFOA and related substances have been imported (0-16.5 kg/year) (Danish Working Environment Authority, 2023).

The data entered in the Product Registry provide an indication of the amounts imported, but due to uncertainty the numbers are not exact. The uncertainties arise because only products and substances that are hazardous according to the criteria defined in statutory order no. 1794 of 18/12/2015 have to be registered. Many of the PFOA related substances may not fulfil these criteria.

4.2 Current use and supply in Denmark

PFOA, its salts and PFOA-related compounds, were included in Annex I of the POP Regulation in 2020 with few exemptions (see TABLE 1-1), effectively banning the substance in most products. However, while the placing on the market of PFOA is forbidden, the substances is most probably still present in certain products on the Danish market.
PFOA was used in firefighting foams, specifically aqueous film-forming foams (AFFF) for firefighting. Such foams and other firefighting equipment have been used extensively at airports, marine applications, military and firefighting training sites (ECHA, 2023). While Copenhagen Airport already transitioned to fluorine free foam in 2008, the situation varies for other airports and firefighting use sites in Denmark. As the use of PFOA in firefighting was only recently banned, it might still be present in stock AFFF. For example, the Ministry of Defence stated that the ministry has initiated a systematic inspection of all stocks of firefighting foam in all areas of the ministry to investigate whether there may still be firefighting foam in stock containing PFOS and PFOA, and if so, destroy it (DK parliament, 2023).

In the EU rapid alert system for dangerous non-food substances, SafetyGate[4], products screened by national authorities for various hazards are collected and results are publicised. SafetyGate includes both chemical and other types of hazards (e.g. fire safety, energy consumption, choking etc.). One entry is available for PFOA, which was measured in muffin forms with a concentration of 0.054 mg/kg (legal limit 0.025 mg/kg) in 2022. The muffin forms originated from China, which indicates that while the substance is banned in Europe, imported products may still contain the substance and be available on the Danish market.

The DK EPA's database about chemical substances in consumer products holds information about in which consumer products, PFOA has been found.[5] Product categories with detections of PFOA comprise textiles for children (in seven out of eight products, study from 2015), cosmetic products (in two out of 22 products, study from 2018), bicycle helmets (in one out of three products, study from 2018) and children's carpets (five out of five products, study from 2016).

Ten handheld foam extinguishers were tested by the DK EPA in 2022, and all were found to be free from PFOS and PFOA (DK EPA, 2022b). However, nine out of ten foam extinguishers contained other PFAS, which are not regulated.

In 2021, the DK EPA tested the content of PFAS in face masks made from textile (DK EPA, 2021b). Neither PFOA, 8:2 FTOH nor 10:2 FTOH were detected (LOD <0.1 mg/kg).

4.3 Historical use and supply in Denmark

PFOA has been used in numerous applications in Denmark. The Danish Regions developed a number of industry descriptions as a basis for mapping potential soil contamination sites in Denmark. Based on data from the industry descriptions, the former use of 52 PFOA-related substances was identified in 17 different industries (Danish Regions Environment and resources, 2023). The industries and the use of PFOA are listed in TABLE 4-1.

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[4] Safety Gate: the EU rapid alert system for dangerous non-food products (europa.eu)

[5] DK EPA Chemical substances in consumer products – Database https://vidensbank.mst.dk/v2/, Search for CAS no. 335-67-1 (14.12.2023)

TABLE 4-1. List of industries in Denmark where PFOA, its salts and PFOA related compounds have been used based on industry descriptions by (Danish Regions Environment and resources, 2023).

Industry / activity area	Use of PFOA, its salts and PFOA related substances
Cardboard and Paper	Surface treatment of cardboard and paper packaging, and food contact paper
Carpets	Surface treatment to add dirt- and water-repellent properties
Car Washes	Used in waxes and car wash products, i.e. polishes and conditioners
Chemical Industry/Soap	Manufacture of soap, detergents, cleaning and polishing preparations, waxes, polishes, paints, varnishes and similar coatings, printing ink etc., and sealing materials.
Chrome Plating	May be added to the tyre fluid (anti-fog) used in chrome baths in chrome plating.
Dry Cleaners	Cleaning fluids may contain a number of additives, including impregnating agents
Electronics	Surface treatment and as solvents, binders and in paints or colours
Fire Drill Site	Firefighting foam
Iron and Metal	Surface treatment of metals
Landfills	Old landfill sites may contain products treated with or containing the substances
Oil Depots	Firefighting foam
Paint	Additive in paints and varnishes to improve paint flow and levelling/smoothing, as well as to improve gloss and can promote the antistatic properties of products
Plastics	Release agents in plastic and rubber moulds
Printing Companies	In printer ink, in printer heads for ink-jet printers, in the printing paper and in lithographic printing plates
Textile and Leather	Impregnation agents for water-repellent breathable membranes such as rain and outdoor clothing, sportswear and workwear for hospital staff, pilots, the military and firefighters, dyeing and bleaching of textiles, antifoam agents, surface treatment of cotton, production of leather goods, including tanning of the hides and for finishing with water and dirt-repellent treatments of the tanned leather product
Varnish	Additive in paints and varnishes to improve paint flow and levelling/smoothing, as well as to improve gloss and can promote the antistatic properties of products
Wood and Furniture	Manufacture of construction timber and joinery, straw and wicker materials, bleaching of wood fibres with chemicals, weather-resistant coating of wood products, manufacture of furniture, treatment of wooden floors with floor wax, furniture refinishing and furniture deacidification, and manufacture of kitchen equipment

4.4 Presence in waste, stockpiles, and contaminated areas

4.4.1 Waste

PFOA, its salts and PFOA related compounds have been used in a wide variety of applications (see sections 4.1, 4.2 and 4.3) and because of their persistence, PFOA, its salts and PFOA related compounds are expected to be found in many waste types. However, specific data on the concentration of PFOA, its salts and PFOA related compounds in different waste types in Denmark are lacking.

PFAS content in waste has been assessed in the PFAS restriction proposal. Five European Countries are currently (as of December 2023) preparing to restrict the entire group of PFAS in the EU. The restriction dossier covers the entire lifetime from production to waste phase of

PFAS in Europe (ECHA, 2023). It also mentioned PFAS tonnages entering the waste stage for several waste streams. In Appendix A in Table A.67 of the restriction proposal, it is stated how many tons of PFAS enter a certain waste stream, however, these numbers are not further divided into individual PFAS or PFAS groups (see data from the restriction proposal (ECHA, 2023) in TABLE 4-2 below).

By assuming that each European country emits the same amount per capita, the amount of PFAS entering the waste stream for an individual country can be estimated. In total in 2023 448,387,872 people live in the EU27 and 5,932,654 in Denmark, meaning that the Danish population constitutes 1.32% of the European population. This factor can then be used to estimate the amount of PFAS entering the waste stream in Denmark.

TABLE 4-2. Table A.67 of Annex A of the PFAS restriction proposal showing the amounts of PFAS entering the waste stage for certain product groups and calculated shares for Denmark based on population size (ECHA, 2023).

Use	Tonnages which enter solid waste stage in the EEA (t/y)	Calculated share for Denmark (t/y)
TULAC***	50,853	673
FCM**** & packaging	24,565	325
Manufacturing of metal products and metal plating	984	13
Consumer mixtures	**	
Cosmetics	**	
Ski wax	1	0.013
HVACR***** decommissioning	19,724	261
Medical devices	8,500	112
Transport	6,410	85
Electronics and semiconductors	3,752	50
Energy*	2,995	40
Lubricants	1,447	19
Petroleum and mining	1	0.013

*: Waste from the energy sector is expected to sharply increase as many of the first windmills from 20-25 years ago are currently replaced. Amount of accruing blade material from stripping down wind turbines in Germany alone: 20 000 t/y (windmill blades are often coated with fluoropolymers). For solar panels the same is applicable: Sharply increasing waste volumes (solar panels front- and backsheet are often coated with fluoropolymers) (ECHA, 2023).
**: Waste stage emissions of lesser importance (use phase emissions of most importance)
***: TULAC: Textiles, Upholstery, Leather, Apparel and Carpets
****: FCM: Food Contact Materials
*****: HVACR: Heating, ventilation, air conditioning and refrigeration

From the data in TABLE 4-2, it is expected that the waste streams with the largest PFAS content in Denmark are TULAC (Textiles, Upholstery, Leather, Apparel and Carpets), and FCM and packaging. However, it is noted that specific Danish legislation banning PFAS in FCM exist (compare section 4.5.2), therefore the quantity of PFAS in FCM and packaging is likely to be overestimated. It is likely that PFOA is present in low amounts in waste from products developed after 2020.

4.4.1.1 Waste incineration

A literature review of the fate of PFAS in waste incineration has been performed for the DK EPA (2023b). The literature review includes a description of investigations in two Danish waste incineration plants in 2022. Both plants incinerate municipal household waste as well as some industrial wastes and were operated according to the terms of the Industrial Emissions Directive (Directive 2010/75/EU). The investigations included sampling and analysis of flue gas, gypsum from flue gas cleaning, cleaned wastewater, fly ash and slag. Additionally, at plant 2, groundwater was sampled, as it is used in the scrubber for flue gas cleaning. During the flue gas sampling, the temperature was in the range 860 – 1,030°C, and in the main part of the measurement period, the temperature was approx. 1,000°C. The concentrations in the different compartments are reported in TABLE 4-3.

TABLE 4-3. Results of concentrations in flue gas, cleaned wastewater, and residues from two Danish incineration plants (DK EPA, 2023b).

	Incineration plant 1			Incineration plant 2		
	PFOA	Sum of PFAS 4	LOD (PFAS 4)	PFOA	Sum of PFAS 4	LOD (PFAS 4)
Flue gas (µg/m^3)	<LOD	<LOD	<0.006	<LOD	<LOD	<0.006
Gypsum (µg/kg dw)	<LOD	<LOD	3	<LOD	<LOD	< 3.0
Fly ash (µg/kg dw)	-	-	-	<LOD	<LOD	< 0.1
Groundwater at inlet to remediation plant (ng/l)	-	-	-	<0.3 – 2.9	0.5 – 9.2	<1
Cleaned wastewater (ng/l)	-	<LOD	1	0.9 – 1	1.5 – 1.8	1
Slag (µg/kg dw)	-	-	-	0.04	0.04	<0.1

PFAS concentrations were reported to be <LOD in many of the samples from the two incinerations plants. This may indicate that PFAS compounds, including PFOA, are destroyed in the incineration process (DK EPA, 2023b). However, it may be discussed whether the detection limits are sufficiently low to report concentrations at relevant levels (see TABLE 4-3).

PFAS are found in the groundwater at the inlet to a remediation plant and wastewater from the flue gas cleaning. PFAS are also found in the slag, indicating its presence in the waste and that it is not completely destroyed during the incineration process.

Additionally, several waste incineration plants in Denmark have conducted their own measurements of PFAS in waste residue fractions. These data are not available in a comprehensive format. A collection, review and analysis of these data would strengthen the conclusion on PFAS fate in Danish waste incinerators.

In 2022, the Danish EPA initiated a screening project aimed to increase knowledge of both content and leaching of PFAS in slag from Danish waste incineration plants. 13 samples of slag from incineration plants were analysed for PFAS compounds. The PFAS content was analysed in the dry matter of the samples as well as in the slag eluates from batch leaching tests.
PFOA was not detected in any of the dry matter samples, but in all 13 eluates from the leaching test (TABLE 4-4). A conclusion regarding the potential impact on groundwater related to the use of slag according to the Danish Statutory Order on Residual Products[6] was not possible based on this screening study.

[6] Danish: Restproduktbekendtgørelsen, BEK no. 1672 of 15/12/2016

TABLE 4-4. Results of PFOA concentrations in slag from Danish incineration plants (DK EPA, 2023d).

Sample	Concentration	LOQ	Number of samples (n)
Dry matter, µg/kg dw	<LOQ	0.5	13
Batch leaching test, µg/l	Min: 0.0057 Max: 0.036	0.0050	13
Amount leached (liquid/solid ratio =2 l/kg), ng/kg dw	Min: 11 Max: 72	n.d.[1]	13

[1] n.d. no data.

A Swedish study by Awad et al., (2021) sampled bottom ash, fly ash and condensate water from 27 incineration plants in Sweden and analysed the matrices for their PFAS-27 (27 individual PFAS) content. Incineration temperatures were between 850°C and 1,125°C, with most facilities incinerating both household and industrial waste at the same time. The report does not provide analytical data for any individual PFAS compounds, only for PFAS groups. In the samples from 5 out of the 27 incineration plants, PFAS could not be detected above the limit of detection (LOD ~0.1-0.5 µg/kg in ash and 0.1-0.5 ng/l in condensate water).

In bottom ash samples, 9 out of 27 facilities had concentrations above the LOD with PFAS-27 concentrations between 0.22 to 12.76 µg/kg. The group of perfluoro carboxylic acids (PFCA), to which PFOA belongs, had an average concentration of 0.9 µg/kg in bottom ash. In fly ash for PFAS-27, 15 out of 27 facilities had concentrations above the LOD ranging from 0.18 to 37.71 µg/kg, with an average PFCA concentration of 2.5 µg/kg. Lastly, in the scrubber condensate water, 13 out of 27 facilities had PFAS-27 concentrations above the LOD ranging between 0.28 to 182.95 ng/l, with an average PFCA concentration of 22 ng/l. The authors could not find a correlation between PFAS concentration and incineration temperature, nor between PFAS concentration and incinerated waste type (household or industrial), indicating that higher temperature does not lead to lower PFAS concentration in the residues. However, other studies show that a complete destruction of other PFAS, e.g. PFOS, requires the use of temperatures above 1100 to 1200 °C (Nordic council of Ministers, 2019).

In a similar study by Björklund et al., (2023) analysed bottom ash, flue gas cleaning residues, treated process water, and flue gas for 18 PFAS from a waste-to-energy incineration facility in Sweden. The authors describe the incineration plant as state of the art. It incinerates ~60% household waste and ~40% industrial waste at temperatures above 850°C and up to 1,100°C. During one sampling campaign, sewage sludge was added to the waste input at 5-8%. The authors state that as the waste input on a given day is unknown, the addition of sewage sludge provided a case where PFAS containing material is known to be included in the fuel mix. In total 6 samples were taken, three with the addition of sewage sludge and three without. PFOA was detected in all flue gas samples with concentrations ranging between 0.16 ng/m³ and 0.79 ng/m³, and concentrations being significantly higher when the sewage sludge was added to the input. It is noted that the lower concentration range is below the LOD in the flue gas analyses from the Danish study (6 ng/m³, see TABLE 4-3). Similarly, in the effluent water, the PFOA concentration ranged between 1.7-6.6 ng/l and was detected in all samples, with higher concentrations in the samples stemming from the incineration with addition of sewage sludge. In the bottom ash, however, PFOA could only be detected in one out of the six samples with a concentration of 0.54 ng/g. The sample stems from a fuel mix without sewage sludge. In the air pollution control residue (a mixture of fly ash and sludge from the water treatment) and in the gypsum, PFOA could not be detected in concentrations above the LOD (0.17 ng/g dw and 0.16 ng/g dw, respectively) in the samples. The total annual release of PFAS during waste incineration was estimated to be between 7 and 20 g, or 0.07−0.1 µg/kg of incinerated waste for the facility.

The results indicate that while PFAS (incl. PFOA) are not completely destroyed during waste incineration, the total amount of PFAS emitted via the residues is in the gram per year range. It is not clear from the results whether PFOA and related compounds are emitted to the air via the flue gas. They may be present in the air in the gaseous phase or attached to particulate matter. The suitability of the LOD in samples from waste incineration was not assessed. The results also confirm that PFOA is emitted into air via the flue gas.

4.4.1.2 Waste and sludge pyrolysis

The literature review by the DK EPA, (2023b) summarized available information about the fate of PFAS during pyrolysis. Pyrolysis of PFAS-contaminated waste and sludge typically takes place at lower temperatures than incineration and without the presence of oxygen.

Pyrolysis of dried sludge at 300-500°C produces a biochar and pyrolysis gas. The authors conclude that the biochar contains PFAS levels below detection limits and can be used for agricultural purposes or landfilled[7] (DK EPA, 2023b).

The gas contains most of the PFAS from the sludge. The gas should subsequently be incinerated at >1000°C to ensure that PFAS are completely broken down into the gases HF, CO_2 and CF_4 (<1%). During flue gas cleaning in a wet scrubber, HF is removed and dissolved as fluoride and some CO2 is removed as carbonate. Consequently, water vapour, some CO_2 and CF_4 are emitted to the air (DK EPA, 2023b).

The authors conclude that pyrolysis can convert and/or degrade PFAS to some degree, but it requires higher temperatures to completely destroy PFAS. The latest research, knowledge and experience shows that complete destruction of PFAS requires technology involving temperatures of 1000°C or higher (DK EPA, 2023b).

Conclusions specifically on the fate of PFAS during pyrolysis of other waste fractions, e.g. plastic waste, were not available.

4.4.1.3 Landfills

There is limited information about the concentrations of PFAS in waste (section 4.4.1) and also in landfills. However, the concentration of PFOA in landfill leachate has been reported in a number of studies (TABLE 4-5).

TABLE 4-5. Mean and range of PFOA concentrations in ng/l in landfill leachate in Denmark and Sweden.

Mean (min. – max.)	Sample size (n)	Country, comment	Reference
1223 (range not reported)	1	Sweden	IVL, (2016)
1270 (38 - 4200)	5	Sweden, median value	IVL, (2016)
226 (<LOD - 1800)	17	Sweden	IVL, (2016)
140 (<LOD - 370)	9	Sweden	IVL, (2016)
137 (<LOD - 290)	20	Sweden	IVL, (2016)
44.6* (<LOD-115)	8	Denmark, LOD = 2 ng/l	DMU, (2007)

* Samples comprise leachate from industry, landfill and wastewater

[7] The conclusion does not account for other substances than PFAS. For example, dioxin and PAH formation during pyrolysis processes can occur, which may impact the applicability of biochar.

In addition to the figures in TABLE 4-5, the DK EPA (2017) reported concentrations of PFOA between 22.0 to 560.0 ng/l in six landfill leachates, and PFOA was reported in the leachate at five sites.

4.4.1.4 Sewage sludge

The presence of PFOA in sewage sludge has been reported in several studies, the concentration was in the range of 0.38 – 4.19 µg/kg dw (TABLE 4-6).

TABLE 4-6. Concentrations of PFOA in waste water sludge and the quality criteria for sum of PFAS4 in sludge from municipal wastewater treatment plants.

PFOA Concentration (µg/kg dw)	PFAS4 Concentration (µg/kg dw)	Sample size (n)	Comment	Reference
Median 0.9, Max. 2.8	-	12	Median for PFOA in wastewater sludge in NOVANA data from 2004-2009. Range <LOQ – 2.8 µg/kg dw. 75% of the PFOA concentrations were <LOQ.	Boutrup et al., (2015)
0.38	4.3	1	Wastewater sludge with a dry matter content of 18.6 % and with standardized sludge without knowledge of potentially increased PFAS content in 2022	DK EPA, (2023b)
1.1	1.1	1	Wastewater sludge with a dry matter content of 16 % and with sludge from an area with increased PFAS content in 2022.	DK EPA, (2023b)
0.48	5.6	1	Wastewater sludge with a dry matter content of 18,6 % and with sludge without knowledge of potentially increased PFAS content in 2022.	DK EPA, (2023b)
<LOD - 4.19	4.4 – 72.5	12	12 samples of wastewater sludge from the period between 2003-2022. There is a decrease in PFOA concentrations with time for the reported period.	Draborg & Tsitonaki, (2023)
0.85	-	215	Median value for PFOA in sludge used in the derivation of cut-off values for PFAS in waste water sludge. Min. concentration 0.085 and max. 19 µg/kg dw. N > LOQ 154.	Jensen et al., (2023)
	10		**Quality criteria (indicative)**	**DK EPA, (2023a)**

The studies in TABLE 4-6 report content of PFOA in sludge, however, several precursors that may transform into PFOA under certain circumstances have also been frequently detected (Eriksson et al., 2017). Precursors may exceed the level of perfluoroalkyl carboxylic acids (PFCAs) in some sludge samples. This may change the composition of PFAS compounds in the sludge, leading to an increase in e.g., PFOA and other PFAS compounds over time (Eriksson et al., 2017).

Sewage sludge is used as organic fertilizer on arable land. A recent Danish study by Draborg & Tsitonaki, (2023) investigated the transport and fate of PFAS in field soils amended with municipal sewage sludge at plots with different sludge application rates at the CRUCIAL experimental site[8]. In the highly sludge loaded plots, the load corresponds to 75 years of a typical Danish sludge load. In the accelerated plots, the load corresponds to more than 200

[8] Closing the Rural-Urban nutrient Cycle—Investigations through Agronomic Long-term experiments, https://plen.ku.dk/english/research/plant_soil/sf/crucial/

years of typical sludge loads in Denmark. PFAS4 concentrations measured in the applied municipal sewage sludge (from the Avedøre plant) were markedly decreasing in the period 2003 to 2022, ranging from concentrations exceeding the sludge quality criterion by a factor of 7 in 2003 to a concentration below the sludge quality criterion in 2022.

PFAS has also been reported in the effluent from wastewater treatment plants. Mean values of PFOA concentrations in two comprehensive studies were 0.017 and 0.019 µg/l DK EPA, (2021a) and Boutrup et al., (2015), respectively; TABLE 4-7).

TABLE 4-7. Concentrations of PFOA in the effluent from wastewater treatment plants.

Concentration µg/l	Sample size (n)	Comment	Reference
0.019	159	Mean value in data from 2008-2012. 91 samples were <LOD. Concentration 10th percentile: 0.0025 µg/l Concentration 90th percentile: 0.031µg/l	Boutrup et al., (2015)
0.017	105	Mean value in data from 1998-2019. 93 % samples were <LOD. Concentration 10th percentile: 0.004 µg/l Concentration 90th percentile: 0.027 µg/l	DK EPA, (2021a)

Rothenborg and Nielsen, (2022) reviewed data on concentrations of PFAS in several Danish waste water treatment plants. A general increase in the concentration of PFAS through wastewater treatment plants has been observed, meaning that for some PFAS compounds the effluent concentrations are higher than the influent concentrations (Rothenborg & Nielsen, 2022). The reason for the increase in concentration is most likely caused by the transformation of precursors into stable compounds like PFOA.

4.4.2 Stockpiles

4.4.2.1 Firefighting foams

As described in chapter 4.2, PFOA has been widely used in firefighting foams. Several precursors to PFOA, such as 8:2 FTCA, have also been used in AFFF (aqueous film-forming foams). While the use is gradually being prohibited, it cannot be excluded that PFOA is still present in existing firefighting foams systems and equipment.

According to the exemption no. 6 in the Annex I of the POP regulation, PFOA in firefighting foam that has already been added to existing systems can be used until 4 July 2025 under certain conditions. Use sectors include the chemical industry, municipal fire brigades, marine applications, airports and the military (ECHA, 2023). Since the ban of PFOS in AFFF in 2006/2011, many AFFF manufacturers started using alternative PFAS, including PFOA and its precursors, however, fluorine-free alternatives are already available on the market. PFOA may still be present in AFFF concentrate in Danish facilities and as such, AFFF could represent a stockpile of PFOA and its precursors (and other PFAS) in Denmark. Estimates on the amount of AFFF stockpiles in Denmark have not been identified. The conclusion is supported by a study the DK EPA conducted in 2022. The study found that 10% of firefighting foams used for training in Denmark contains PFAS (DK EPA, 2023e). ECHA has submitted an EU restriction proposal for PFAS in firefighting foams which is currently under evaluation by the scientific committees in ECHA (ECHA, 2023).

4.4.3 Contaminated areas

Currently, about 15,000 sites are suspected to be contaminated with PFAS (Danish Regions, 2023). The five regions are responsible for the investigation of contaminated sites in Denmark. Every year they asses the risk of contamination at a number of sites. In 2021, 1,092 sites were investigated by the five regions for PFAS contamination (Danish Regions, 2021). At 746 sites, groundwater concentrations of the sum PFAS4 (PFOS, PFOA, PFHxS and PFNA) exceeded the quality criteria for groundwater of 2 ng/l (Danish Regions, 2021). The five regions investigate for 22 PFAS, but the study only reported the sum of PFAS4, and therefore concentrations for PFOA are not presented.

4.5 Presence in food and drinking water

4.5.1 Presence in drinking water

Quality standards (QS) for drinking water at the consumers' water tap are established in Denmark. For PFAS22, the standard is 0.1 µg/l and for the sum of 4 PFAS (PFOA, PFOS, PFNA and PFHxS) it is 0.002 µg/l (BEK no. 1023 of 29/06/2023). Until 2022, the standard of 0.1 µg/l applied to the sum of 12 PFAS (BEK no. 1383 of 03/10/2022).

From the 21st of November 2022, there has been a requirement for all 1,744 waterworks in Denmark to analyse drinking water for PFAS4. This requirement has made it common for results regarding drinking water to be reported as the concentration of the sum of PFAS4. The sum of PFAS4 includes PFOA, but often the PFOA concentration is not specified. Therefore, in the following, data for the sum of PFAS4 in drinking water are reported.

The Geological Survey of Denmark and Greenland (GEUS) sampled 1,304 drinking water wells from 2017 to 2021 for PFAS. The sum of PFAS12 substances did not exceed the quality standard of 0.1 µg/l in any of the samples, but the sum of PFAS4 was found above the standard of 0.002 µg/l in 53 wells, equivalent to 4.1% of all sampled wells (GEUS, 2023). The results from the 1/10-2022 to 30/9-2023 PFAS control of the drinking water wells in Denmark are listed in TABLE 4-8 and results specifically for PFOA are available. PFOA is the most frequently detected of the substances included in PFAS4 (GEUS, 2023a).

TABLE 4-8. Data for PFOA in drinking water wells from the period 2022-2023 (GEUS, 2023a).

LOD µg/l	QS for drinking water µg/l	Sample size			PFOA detections %	
		N	>LOD	>QS	>LOD	>QS
0.0001-0.01	0.002	917	122	42	13.3%	4.6%

4.5.2 Presence in food

As reported by EFSA, contamination of food with PFOA occurs via two different mechanisms. The first involves the accumulation of PFOA in the aquatic and terrestrial food chains. The second arises from the transfer of PFOA and PFOA precursors to the food from materials used in food processing and packaging (EFSA CONTAM, 2018).

At a European level, the Commission Regulation (EU) 2023/915 provides maximum levels for several food types for 4 PFAS substances (PFOS, PFOA, PFNA, and PFHxS). Maximum levels allowed per type of substance and type of food are summarized in the table below (TABLE 4-9).

TABLE 4-9. Maximum level of PFAS for several food types (µg/kg) (Commission Regulation (EU) 2023/915).

Food type	PFOS	PFOA	PFNA	PFHxS	∑PFAS
Meat of bovine animals, pig and poultry	0.30	0.80	0.20	0.20	1.3
Meat of sheep	1.0	0.20	0.20	0.20	1.6
Offal of bovine animals, sheep, pig, and poultry	6.0	0.70	0.40	0.50	8.0
Meat of game animals, except for bear meat	5.0	3.5	1.5	0.60	9.0
Offal of game animals, except for bear offal	50	25	45	3.0	50
Muscle meat of fish, except fish listed below. Muscle meat of fish listed in below in case it is intended for the production of food for infants and young children*	2.0	0.20	0.50	0.20	2.0
Muscle meat of the following fish, in case it is not intended for the production of food for infants and young children: Baltic herring, bonito, burbot, European sprat, flounder, grey mullet, Horse mackerel, pike, plaice, sardine and pilchard, seabass, sea catfish, sea lamprey, tench, vendace, silverly lightfish, wild salmon and wild trout, wolf fish*	7.0	1.0	2.5	0.20	8.0
Muscle meat of the following fish, in case it is not intended for the production of food for infants and young children: anchovy, babel, bream, char, eel, pike-perch, perch, roach, smelt, whitefish*	35	8.0	8.0	1.5	45
Crustaceans and bivalve molluscs	3.0	0.70	1.0	1.5	5.0
Eggs	1.0	0.30	0.70	0.30	1.7

* In case the whole fish is intended to be eaten, maximum level applies to the whole fish.

The maximum levels in food are provided in the unit µg/kg, corresponding to the unit ng/g, which is commonly used in studies reporting concentrations in food.

There are few studies available that measured PFOA in food available in Denmark.

Since 2011, the Danish Veterinary and Food Administration (DVFA) measured PFAS in selected food item, mostly fish and food of animal origin.
In 2011, PFOA was measured in fish and meat (n=43). For this, four samples of land-based trout farms, four samples from marine trout farms, four samples from beef, three samples from chicken and 28 samples from pork were collected. PFOA was not detected in any of the samples (LOD: 0.5 ng/g wet weight meat) (DK EPA, 2013).

In the measurements of PFAS in wild fish, during 2020 – 2022, each year 18 – 21 samples of 10 - 11 fish species were analysed for eight PFAS substances, hereunder PFOA and PFOS. PFOA was not detected in any of the samples (LOQ 0.5 µg/kg), while PFOS was detected in 5 - 13 out of 18 - 21 samples at concentrations of 0.4 – 2.2 µg/kg. PFOS was only detected in bottom-dwelling fish (DVFA, 2021, 2023a, 2023b).

The findings are in line with the general observation by the DVFA that out of the eight PFAS analysed in food items, usually only PFOS is found (DVFA, 2023).

In 2021, the DVFA also conducted several measurements of PFOA in fish, fruit and vegetables at a firefighting training site near Korsør, after it became known that former use of PFOS-containing firefighting foam had led to a contamination of the surrounding environment, including cattle and fish.[9] The investigations focussed on detections of PFOS due to the substance's former use, and only few data are available for PFOA. Results in eel and eelpout were below LOQ (0.5 ng/g) from the adjacent water body Korsør Nord. Results in samples of 5 vegetables and 5 fruit/berry samples were also below LOQ (0.9 ng/g) (Slagelse Municipality, 2023).

In 2022, the Technical University of Denmark (DTU) measured PFAS in eggs from Denmark. In this regard, whole eggs and egg yolks were sampled from barn eggs, free range eggs, and organic eggs. Granby, (2023a) demonstrates that there is an increased level of measured PFAS substances in yolks of organic eggs compared to eggs from other productions. When compared to the other three main PFAS substances (PFOS, PFHxS, and PFNA), PFOA concentrations appear to be in a similar range as PFHxS concentrations, lower when compared to PFNA and significantly lower when compared to branched PFOS.

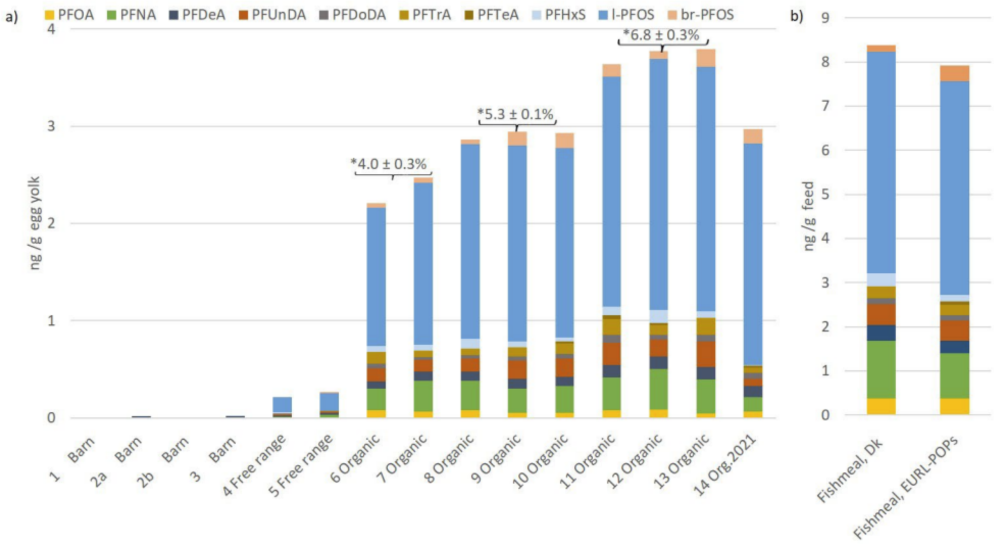

Figure 4-2 PFAS content of egg yolks from different farm types sampled in 2021-2022 and amount of PFAS in fishmeal for hen feed (Granby, 2023a)

DTU found the source of the PFAS to be the hen feed made with fishmeal. Both fishmeal samples were from the same Danish producer and consisted of herring collected from the Baltic Sea, the Bothnian Sea and Southern Central Baltic. Granby, (2023a) measured the PFAS content of the two types of fishmeal used as hen feed in Denmark. A very similar distribution of PFAS substances in fishmeal and analysed organic egg samples confirm that the substances are most likely transferred from the fishmeal given as a feed to the hens (Granby, 2023a). The whole case of detecting PFAS in eggs produced in Denmark was followed by a press conference presenting the results to the public. After 2 months, farmers voluntarily phased-out fishmeal given as a feed to hens ultimately resulting in no to very low concentrations of PFAS in organic eggs (Granby, 2023a).

Another way for PFOA to end up in food is via contact with food contact materials (FCM).

[9] Analytical reports available at the municipality's homepage: https://www.slagelse.dk/da/service-og-selvbetjening/bolig-og-byggeri/vand-og-kloak/spildevand/pfos-forurening-i-korsoer/ (accessed 09/11/2023)

In 2020, the Danish Veterinary and Food Administration banned the marketing of PFAS containing paper and cardboard food contact materials (FCM) in Denmark[10]. At the same time, an indicator value of 20 µg total organic fluorine/gram of paper was established. Concentrations below this value are considered as unintentional background contamination. Additionally, if there is a functional barrier preventing the migration of PFAS from packaging, the use of PFAS in paper and cardboard packaging is allowed[11].

The migration of PFOA and other PFAS from FCM has been extensively studied, and Lerch et al., (2022) provide a recent publication on the topic.

Lerch et al., (2022) report that migration is a process dependent on various conditions, such as contact time, temperature, food matrix properties (water content, presence/absence of emulsifiers), as well as the migrant properties (e.g., different PFAS have different volatility). To better understand the extent of the migration of PFAS from FCMs to food, a total of 6 paper based FCMs were bought on the Scandinavian market in 2017 and 2019. Sampled FCMs included three types of microwave disposable paper plates and three types of muffin cups (muffin cups A and B originated from China while cup C originated from Europe). The investigation was performed both on real food samples (e.g., muffins were prepared in muffin cups, oatmeal porridge and tomato soup were prepared on paper plates) as well as on the food simulants (solutions of ethanol). Detected concentrations in food samples and food simulants are given in TABLE 4-10 and TABLE 4-11, respectively. Generally, concentrations of PFOA in the food simulants was significantly higher than in the real foods.

TABLE 4-10. Concentration of PFOA (ng/g food) in real food samples (oatmeal porridge, tomato soup, and muffins) due to migration from disposal paper plates or muffin cups after microwaving (1 min at 800 W) or baking (13 min at 200 °C) (Lerch et al., 2022).

FCM type	Type of food prepared	PFOA
Paper Plate A	Oatmeal Porridge	< LOQ
	Tomato Soup	n.d.
Paper Plate B	Oatmeal Porridge	< LOQ
	Tomato Soup	0.04 ± 0.00
Paper Plate C	Oatmeal Porridge	n.d.
	Tomato Soup	< LOQ
Muffin Cup A	Muffin	0.03 ± 0.01
Muffin Cup B	Muffin	0.13 ± 0.03
Muffin Cup C	Muffin	0.03 ± 0.02

[10] DVFA, 2020, Ban on fluorinated substances in food contact materials (FCM) made of paper and cardboard (in Danish)
https://foedevarestyrelsen.dk/Media/638188046476275772/Fakta%20ark%20fluorerede%20stoffer.pdf

[11] BEK no. 681 of 25/05/2020, Bekendtgørelse om fødevarekontaktmaterialer og om straffebestemmelser for overtrædelse af relaterede EU-retsakter

TABLE 4-11. Concentrations of PFOA (ng/g food) detected in food simulants (20% ethanol and 50% ethanol) after migration tests on disposable paper plates (2 h at 70 °C) (Lerch et al., 2022).

FCM type	Type of food simulant	PFOA
Paper Plate A	50% ethanol	< LOQ
	20% ethanol	< LOQ
Paper Plate B	50% ethanol	0.33 ± 0.03
	20% ethanol	0.30 ± 0.03
Paper Plate C	50% ethanol	< LOQ
	20% ethanol	< LOQ
Muffin Cup A	50% ethanol	0.54 ± 0.06
Muffin Cup B	50% ethanol	0.69 ± 0.07
Muffin Cup C	50% ethanol	n.d.

The study conducted by Lerch et al., (2022) confirms that PFOA (see tables above) and other measured PFAS substances (data not shown) do migrate from paper based FCMs to food. The authors also conclude on a risk arising from dietary exposure of PFOA and PFAS in general. Further details on the estimated dietary exposure and risk assessment from the same study is given in section 4.7.2.

It is noted that the study by Lerch et al., (2022) was conducted with samples acquired in 2017 and 2019. The samples were thus acquired before PFOA was added to the POP Regulation in 2020[12]. Since 2020, PFOA, its salts and PFOA related substances may not occur in concentrations exceeding the defined concentration limit for unintentional trace contaminations (UTC, 0.025 mg/kg and 1 mg/kg, respectively) according to the POP Regulation. Additionally, since 2020, the indicator value of 20 µg total organic fluorine/gram packaging material established by the DVFA has been in force.

In addition to the POP regulation and ban of PFAS in FCM made of paper and cardboard, other regulations regarding PFOA in FCM apply. The PFOA salt APFO and several other PFAS are listed in Commission Regulation (EU) No. 10/2011 on plastic materials and articles intended to come into contact with food. The PFAS substances are usually intended to be used as an additive or polymer production aid or as a monomer for the FCM. Specific migration limits, defining the allowable amount of substance migrating to the food, are not defined for any of the PFOA-related substances. For APFOA (a PFOA salt), a restriction is defined in the Regulation as APFOA is “Only to be used in repeated use articles, sintered at high temperatures”. The sintering is expected to remove residual APFOA content and thus eliminate the risk of migration to food products (DVFA, 2023). For several of the other PFAS, specific migration limits and/or other restrictions are defined for plastic FCM. For FCM made of paper or cardboard, specific migration limits or concentration limits are not defined at EU level.

In 2021, the Danish Food Agency Nielsen & Holm, (2022) conducted a study in which 28 samples were analysed for total organic fluorine in food contact materials. Analysed samples included different cardboard and paper food packaging. The highest content value of total organic fluorine was found in bags for microwave popcorn, muffin liners and popcorn cups. Other than that, high values were also found in pizza boxes and disposable cups. The results are listed in TABLE 4-12. Obtained results showed contents above the indicator value of 20 µg/g for 8 out of 28 food contact materials. It is emphasized that the analyses only comprised total organic fluorine and no conclusions regarding PFOA content can be drawn based on

[12] Commission Delegated Regulation (EU) 2020/784 of 8 April 2020 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32020R0784

these results. The DVFA made a case-by-case assessment of each of the samples exceeding the indicator value. Some samples were assessed as illegal due to the content of organic fluor, while others had a functional barrier, allowing for the use of PFAS in FCM.

TABLE 4-12. Results of total organic fluorine content in food packaging (Nielsen & Holm, 2022)

Sample type	Total organic fluorine µg/g	Sample type	Total organic fluorine µg/g
Pizza box	4	Muffin liners	2
Pizza box	15	Muffin liners	480
Pizza box	11	Muffin liners	<1
Pizza box	26	Muffin liners	4
Pizza box	37	Mug	88
Pizza box	5	Mug	39
Plate	3	Mug	77
Plate	3	Baking sheet	1
Plate	4	Popcorn Cup	255
Plate	3	Cardboard box	2
Plate	5	Döner box	<1
Plate	11	Hot Dog tray	6
Plate	2	Cup	16
Plate	7	Popcorn bag	610

Additional data are available regarding the presence of organic fluorine in FCM and migration/extraction of PFAS to food (e.g. Granby, (2020); Granby & Håland, (2018) and additional references in Granby & Håland, (2018)). However, no studies were identified that provide clear relationships between concentration levels of PFOA in FCM and resulting concentrations in food due to migration.

4.6 Release of the substance and presence in the environment

PFOA is present globally in the environment today and may originate from many different sources, including:

- Emission from the manufacture of the substance or industrial processes where the substance is included in the process directly or as an impurity.
- From the use and disposal of mixtures and articles that intentionally include the substances
- From use and disposal of mixtures and articles that may contain them as an impurity
- From the abiotic or biotic degradation of precursors

The following sections provide available data of the substance's release and presence in the water environment, in air and soil, respectively. The environmental presence of PFOA is relatively well-investigated, as monitoring data either comprise PFOA as a single substance and/or PFOA in included in PFAS groups comprising the 4, 12 or 22 PFAS, corresponding to the environmental limit values defined.

4.6.1 Release and presence in water

PFOA, its salts and PFOA related compounds may be released to water from a number of sources depending on the water body. Releases to water resources, are, for example, from sewage sludge on fields, wastewater discharge, contaminated sites, uncontrolled landfills and landfill leachate, rain, sea spray and atmospheric deposition (wet or dry). The concentration of PFOA in rain may have many sources, such as evapotranspiration, dust particles in the atmosphere and precursors in the form of volatile PFAS such as 8-2 FTOH.

Quality criteria for the surface water are currently not established for PFOA. However, for bathing water, an indicative quality criterion of 40 ng/l for PFAS4 has been developed for use in the assessment of bathing water quality[13].

The presence of PFOA is reported in many different water bodies in Denmark, see TABLE 4-13. Water samples are commonly analysed for 22 PFAS compounds in Denmark including PFOA and the PFOA precursor PFOSA.

TABLE 4-13. PFOA (or PFAS4, if indicated) concentrations in different water bodies in Denmark.

Concentration	Comment	Sample size (n)	Reference
Groundwater			
5 ng/l	Mean, samples > LOD 7 %	57	Boutrup et al., (2015)
>0.3->1 ng/l	Detected in 43 of 686 samples (6.3 %) Exceeds groundwater quality criterion in 16 of 686 samples (2.3 %)	686	GEUS, (2023)
Streams			
<LOD	Mean LOD was 2 ng/l, Number of samples <LOD 88 %, 10th percentile <LOD, 90th percentile 2.9	125	Boutrup et al., (2015)
2.3 ng/l	Median for sum of PFAS4. LOD was in the range 0.3-15 ng/l. Number of samples <LOD 619 (18.6 %), 10th percentile 0.6 ng/l, 90th percentile 10.7 ng/l.	3322	Miljøportalen, (2023)[1]
0.2 µg/kg	Sediment, median for sum of PFAS4, without <LOD. LOD was in the range 2-10 µg/kg. Number of samples <LOD 438 (61.7 %), 10th percentile 0.1 µg/kg, 90th percentile 5.1 µg/kg	710	Miljøportalen, (2023)[1]
Lakes			
1.90 ng/l	Median for sum of PFAS4.	3	Miljøportalen, (2023)[1]
<10 µg/kg	Sediment 19 lakes sampled in 2009. LOD was 10 µg/kg.	19	Boutrup et al., (2015)
Rain			
<LOD	LOD below 2 ng/l.	7	DMU, (2007)
Sea water			
1.15 ng/l	Median for sum of PFAS4, without <LOD. LOD was not specified. Number of samples <LOD 43 (15.5 %), 10th percentile 0.35 ng/l, 90th percentile 8.50 ng/l	321	Miljøportalen (2023)[1]

[1] Data extracted from Danmarks Miljøportal Miljoeportalen.dk , accessed 10/11/2023.

[13] Letter from the Danish EPA, 2023: https://edit.mst.dk/media/eplbfs0z/graensevaerdier-ved-miljoestyrelsen.pdf

According to data available at Miljoeportal.dk, the median concentrations of PFOA in streams and lakes are relatively similar. Lower concentrations are observed in sea water, and markedly lower concentrations in groundwater. The low concentrations of PFOA in groundwater could partly be due to adsorption of PFOA in the soil matrix, as well as dilution in groundwater aquifers.

A total release of PFOS and PFOA to the Baltic Sea from the surrounding countries in 2010 was estimated at 300-600 kg/year (DK EPA, 2013). The contribution of emissions from municipal wastewater treatment plants to the total load was estimated to be in the range of 30% for PFOS and 40% for PFOA. These amounts included direct emissions to water via treatment plant effluent, as well as emissions from (agricultural) land via sewage sludge. Releases of PFOA due to transformation of fluorotelomers was estimated to account for 30% of all releases. In the analysis, it was estimated that firefighting foams accounted for 70% of the total PFOS/PFOA emissions, while accounting for 20% of the PFOA emissions, however, it is also noted that the estimates are subject to high uncertainty (Cohiba 2011a and b, as cited by DK EPA, (2013)). It can be anticipated that current amounts are lower based on environmental monitoring data. The PFOA concentration in Baltic grey seal has been observed to decline 1997-2008, although an increasing concentration has been observed in Swedish otters 2002-2011 (Johansson & Undeman, 2020).

In a study from the Region of Southern Denmark, groundwater and surface water samples in a coastal area were analysed along a ca. 3 km transect inland from the coast. The highest concentrations of PFAS were found in the samples closest to the coast, which points towards sea spray being the primary source of PFAS in the surface and groundwater. In the groundwater, intrusion of PFAS-containing sea water may be a source as well. In the groundwater samples (n=14), the overall trend was decreasing concentration with increasing distance to the sea. PFOA concentration ranged from a maximum of 38 ng/l (ca. 100 m distance to sea) to a minimum of 10 ng/l (ca. 2000 m distance to sea) and 18 ng/l (ca. 3000 m distance to sea). In surface water sampled from waterholes (n=7), the relationship between distance to the sea and PFOA concentration was approximately exponentially decreasing, with the highest concentration of 57 ng/l (ca. 50 m) and lowest concentration of 5.7 ng/l (ca. 3000 m) (Niras, 2023).

De Wit et al., (2020) investigated the occurrence of several PFAS including PFOA in Baltic Sea biota. Most of the samples were collected in 2015 and 2016, except for harbour seal (2012-2016), grey seal (2006-2010), porpoise (2006-2012) and one pooled herring sample (2014). Species collected for chemical analysis consisted of blue mussel, eelpout, common eider, Atlantic herring, common guillemot, white-tailed eagle, grey seal, harbour seal, and harbour porpoise. As reported in TABLE 4-14, PFOA was detected in nearly all biota samples. The highest concentration was found in harbour seal liver sampled in 2014-2015 (1.9 ng/g lw).

TABLE 4-14. Concentrations of PFOA (ng/g lw) measured in different species and tissues collected from the Baltic Sea (De Wit et al., 2020).

Species	Tissue	n	Location, year	PFOA
Eelpout	Muscle	47	Darßer Ort, 2015, DE	<0.05
Herring	Liver	38	Byxelkrok, 2016, SE	1.3
Herring	Liver	40	Byxelkrok, 2014, SE	0.81
Grey seal	Liver	5	Baltic Proper, 2009-2010	0.54
Grey seal	Liver	4	Baltic Proper, 2006-2009	1.0
Harbour seal	Liver	5	Baltic Proper, 2014-2015	1.9

Harbour seal	Liver	4	Baltic Proper, 2012-2016	0.62
Harbour porpoise	Liver	2	SW Baltic Proper, 2008	0.30
Harbour porpoise	Liver	4	SW Baltic Proper, 2006-2012	0.19
Common eider	Egg	5	Christiansø, 2015, DK	0.22
Common eider	Egg	5	Christiansø, 2015, DK	0.21
Common eider	Liver	5	Christiansø, 2015, DK	<0.3
Common eider	Liver	5	Christiansø, 2015, DK	<0.3
Common guillemot	Egg	4	St. Karlsö, 2016, SE	0.36
Common guillemot	Egg	5	St. Karlsö, 2016, SE	0.32
White-tailed eagle	Egg	5	Baltic Sea, 2015	0.85
White-tailed eagle	Egg	4	Baltic Sea, 2015	0.83

4.6.2 Release and presence in air

According to previous sections, PFOA may be released to the air from a number of sources, including incineration of waste, sea spray aerosols, the use and disposal of products containing the substances and in the form of dust from landfills.

PFOA and precursors will be released from the air to soil and water bodies, through rain, snow and dust particles. Studies show that PFAS compounds can be transported over long distances, and thus the release of PFAS compounds from air to the environment in Denmark may not originate solely from Danish emissions, just as Danish emissions may be transported to other countries (Cousins et al., 2022).

Due to the physical and chemical properties of PFOA, it is not expected in the gas phase, but rather sorbed to dust (particulate matter). However, a number of PFOA precursors, especially the fluorotelomer alcohols, will be found in the gaseous phase and are therefore potentially present in both indoor air and outdoor air, where they may transform into more stable PFAS compounds like PFOA (Danish Regions Environment and Resources, 2022).

PFOA and precursors are found in the indoor air and the atmosphere in studies from countries surrounding Denmark (TABLE 4-15), where a similar demography and environment would be expected. There has only been one study in Denmark investigating PFOA and related substances' concentrations in indoor air (Rambøll, 2023). PFOA was not included in the analysis, but three fluorotelomer alcohols were analysed and concentrations were reported for two precursors to PFOA. The concentration of PFOA in the atmosphere is significantly lower than concentrations of the fluorotelomer alcohols reported in the indoor air.

TABLE 4-15. PFOA and PFOA precursors in the air in Denmark and neighbouring countries.

Concentration (pg/m³)	Comment	Sample size (n)	Reference
Outdoor			
1.54-552	PFOA concentration in the particulate phase of outdoor air. Samples were collected from 4 field sites in Europe: Hazelrigg, UK (semi-rural), Manchester, UK (urban), Mace Head, Ireland (rural), Kjeller, Norway (rural).	21	Barber et al., (2007)
~0.3	Average concentration of PFOA in time series in air from two sites. The concentration is in the particulate phase. Both sites were in in the vicinity of Hamburg, Germany.	-	Dreyer et al., (2009)
1.10 - 1.23	PFOA concentration in the particulate phase of atmospheric air from Råö in Sweden.	2	Kärrman et al., (2019)
<LOQ <LOQ-1000	Concentration of respectively 8:2 FTOH and 10:2 FTOH. Outdoor references for a study at a contaminated site in Jutland, Denmark. Both compounds are precursors to PFOA.	2	Rambøll, (2023)
Indoor			
14.000	Median. 8:2 FTOH, min 1.1 and max 209 pg/m³. Concentrations of other precursors were reported. Indoor air samples were taken in April-May 2009 and March 2010 in and around Hamburg, Germany at 16 locations.	17	Langer et al., (2010)
~1000	Approximate concentrations of 8:2 FTOH and 10:2 FTOH. Study of indoor air at a contaminated site in Jutland, Denmark. Both compounds are precursors to PFOA.	4	Rambøll, (2023)
4.4	Mean concentration in particulate phase in indoor air from 1 field site in Tromsø, Norway.	4	Barber et al., (2007)

4.6.3 Release and presence in soil

Main sources of releases to soil are rain (TABLE 4-13) and atmospheric deposition (TABLE 4-15). The application of sewage sludge is a main source for agricultural land, as described in section 4.4.1.4.

At agricultural test plots operated by the University of Copenhagen (CRUCIAL experimental site[14]), soil samples were taken from plots applied with sewage sludge corresponding to either 75 (high load plot) or 200 (accelerated plots) years of legal operation (TABLE 4-16). Increased soil concentrations were identified in the accelerated plots compared to control and highly sludge loaded plots. PFOA concentrations ranging from LOD – 1.9 µg/kg dw (n=5) were found in the accelerated plots, and PFOA concentrations in the highly sludge loaded soils ranged from LOD-1.1 µg/kg dw (n=7). The highest PFOA concentration and generally the highest PFAS concentrations in soil were found in the topsoil (upper 0.3 m). Neither sludge application rate resulted in exceedances of the Danish soil quality criterion for sum of 4 PFAS – 10 µg/kg dw, the detected highest concentration being 6.5 µg/kg for PFAS4 (Draborg & Tsitonaki, 2023). It is noted that the study only describes the impact of one type of sewage sludge to one type of soil, limiting the applicability of the results to other environmental settings.

[14] Closing the Rural-Urban nutrient Cycle—Investigations through Agronomic Long-term experiments, https://plen.ku.dk/english/research/plant_soil/sf/crucial/

In a study from the Region of Southern Denmark, soil samples from a coastal area were analysed in a ca. 3 km transect from coast into the land. The highest concentrations of PFAS were found in soil samples from 0-0.1 m below ground, which is consistent with PFAS deposited over land and seeping into the unsaturated zone. In one of these samples, the concentration of sum of 4 PFAS (32 µg/kg) exceeded the soil quality criterion of 10 µg/kg. None of the concentrations of soil samples from 0.4-0.5 m below ground exceeded the quality criterion, the maximum detected concentration being 5.3 µg/kg (TABLE 4-16). The highest detected concentration of PFOA was 2.6 µg/kg and was found in a sample from 0-0.1 m below ground (Niras, 2023).

TABLE 4-16. Concentration of PFOA and sum of 4 PFAS in soil. Bold = exceeds soil quality criterium. Bg = below ground.

PFOA concentration µg/kg dw	PFAS4 concentration µg/kg dw	Sample size (n)	Comment	Reference
-	10		Danish soil quality criterion	
<LOD-1.1	0.08-3.6	8	Soil, agricultural testplot (0.3-1.0 m bg). Treated with sewage sludge corresponding to 75 years of operation	Draborg & Tsitonaki, (2023)
<LOD-1.9	<LOD-6.5	5	Soil, agricultural testplot (0.3-1.0 m bg). Treated with sewage sludge corresponding to 200 years of operation	Draborg & Tsitonaki, (2023)
0.041-2.6	0.19-**32**	6	Soil, coastal area (0-0.1 m bg). Forest/heath/mashland, 103-765 m from the sea	Niras, (2023)
<0.030-0.13	0.15-5.3	5	Soil, coastal area (0.4-0.5 m bg). Forest/heath/mashland, 103-765 m from the sea	Niras, (2023)

4.7 Assessment of environmental and human exposure

4.7.1 Environmental exposure

PFOA is ubiquitously present in the Danish environment with measured concentrations in both water, soil and air compartments.

The presence of PFOA in sewage sludge from Danish municipal wastewater treatment has been documented in numerous studies. A sludge quality criterion for PFOA alone is not defined, but for the sum of PFAS4, including PFOA. Generally, PFOA constitutes a substantial fraction of the measured PFAS4. An investigation of PFOA and PFAS concentrations in sludge from a municipal wastewater treatment plant showed markedly decreasing concentrations over the period from 2003-2022, with concentration from 2022 being below the sludge quality criterion for PFAS4. Field-scale sludge application experiments corresponding to 75 and 200 years of sludge application at an experimental site close to Copenhagen indicate that application of sludge with increased level of PFOA and other PFAS does not lead to exceedance of soil quality criteria. The authors of the study encourage additional studies with several types of soil and several types of sewage sludge to strengthen the conclusions of the study (Draborg & Tsitonaki, 2023).

Sea spray is a relevant source of PFOA in soils, groundwater and surface water of coastal areas. In the Region of Southern Denmark, elevated concentrations of PFOA and concentrations of PFAS4 exceeding the soil quality criterion have been determined in the topsoil close to the sea (< 765 m; Niras, 2023). The study area was confined to a limited area at the Danish west coast, but similar conditions can be found along other coastal areas, especially along the Danish west-facing coasts with high wind impact and high wave intensity (Niras, 2023a). Coast-near surface waters have been considered to pose a risk to wildlife that predominantly reside in coastal areas and drink from the waterholes in the coastal areas (Niras, 2023).

Currently, about 15,000 sites are suspected of soil contamination with PFAS based on knowledge about industries and activities where PFAS have been used in the past (Danish Regions, 2023). In 2021, 1,092 sites were screened for PFAS contamination by the five regions (Danish Regions, 2021).). At 746 sites, concentrations of the sum PFAS4 (PFOS, PFOA, PFHxS and PFNA) exceeded the quality criteria for groundwater of 2 ng/l (Danish Regions, 2021). The 1,092 sites were screened as they were already part of the regional investigation program and activities indicating PFAS use were registered at the sites (see section 4.3).

4.7.2 Human exposure

There are several pathways for human exposure to PFOA. Hull et al., (2023) report that a major contribution comes from the consumption of contaminated food and drinking water. This is followed by inhalation of e.g., dust and airborne volatiles, while dermal absorption is considered only as a minor contributor (Hull et al., 2023).

In March 2018, EFSA's panel on contamination of food (CONTAM) revised the tolerable weekly intake (TWI) for PFOA and PFOS. The panel commented that there was still insufficient data on concentrations within food, but toxicological data were sufficient to lower the values. For PFOA, the original limits set in 2008 of 1,500 ng/kg bw per week (214 ng/kg bw per day) were proposed to be lowered to 6 ng/kg bw per week (EFSA CONTAM, 2018). Additionally, a new TWI was set in 2020 for the sum of 4 PFAS (PFOA, PFOS, PFNA, PFHxS) at 4.4 ng/kg bw/week (0.63 ng/kg bw/day) (Lerch et al., 2022).

Numerous studies have been conducted in Denmark that investigated the presence of PFOA in the Danish population, as well as human exposure and accompanying health risks. Based on these studies, Hull et al. (2023), recently published a review study with temporal trends of PFAS concentrations in the Danish population. This review study is based on a total of 29 reports published between 2008 and 2022, with PFAS being measured in any type of biological specimen, including plasma, serum, urine, seminal fluid, amniotic acid, breast milk, placenta, or adipose tissue. All biological specimens were collected in the period between 1988 and 2021. In total, included reports were based on 18,231 individuals (58% pregnant women) from 19 Danish study populations. Reports from Greenland and Faroe Islands were excluded.

Concentrations of PFOA were measured in all study populations and in all plasma and serum samples (n=18,321). The median blood concentrations of PFOA ranged between 0.8 ng/ml to 9.7 ng/ml with the lowest median concentration measured in serum samples collected in 2020 from adults and highest median concentration measured in plasma samples collected in 1997 from randomly selected 9-year-old boys (Figure 4-3). As stated in the study, similar results regarding time trends were observed for pregnant women, children, and adults. Furthermore, the highest median concentrations in the Danish population were reported especially for PFOA and PFOS with a similar concentration trend in the observed period. More specifically, there was an overall increase in concentrations of the measured PFAS over the period from 1988 until late 1990s followed by a decrease until 2021. The study concludes that the strong decline of PFOA around year 2000 in Denmark and other European countries is very likely due to the phase-out of PFOA and PFOS by the producing company 3M in 2002. Hull et al., (2023) also note in their conclusion that only a few PFAS substances, hereunder PFOA, were part of the study, and that the conclusion cannot be applied to other PFAS or PFAS in general.

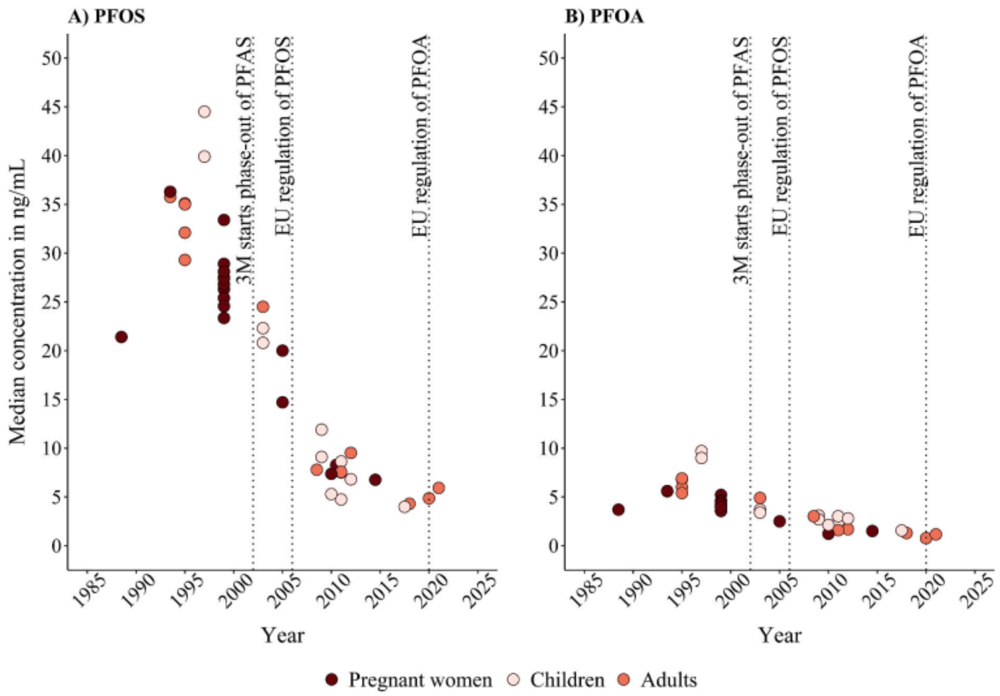

Figure 4-3. Median concentration of PFOA in ng/ml measured in the Danish population, 1988–2021 (Hull et al., 2023).

The studies described here confirm that the Danish population is exposed to PFOA, but the main exposure pathways are not clear. As reported also by other studies, food consumption (contaminated either directly or indirectly) is certainly one of the main contributors (EFSA CONTAM, 2018; Hull et al., 2023). However, only few studies have been identified that investigate the presence of PFOA in the food available on the Danish market. PFOA is generally not detected in fish and meat samples, and it was quickly phased out from the organic eggs once it was detected in significant concentrations (see section 4.5.2).

In regard to indirect contamination of food, both the French Food Safety Agency (DK EPA, 2013) and the Norwegian Institute of Public Health (Jensen et al., 2008) analysed cookware for PFOA residue in non-stick coatings to assess the exposure of humans to indirectly contaminated food, by e.g., cross contamination during storage and preparation. However, both studies concluded on the non-significance of this exposure route for consumer health. It is also noted that human exposure to PFOA present in food due to preparation of food in Teflon coated pans can occur only if consumers use old Teflon coated pans.

With regard to exposure via food contact material (FCM), Lerch et al., (2022) conducted a study with the aim to investigate the migration of PFAS (including PFOA) from paper based FCMs into food products as well as potential health risks for the Danish population (see section 4.5.2 for more details). For this, an estimation of dietary exposure for each product type was performed (TABLE 4-17).

TABLE 4-17. Estimated dietary exposures per serving [ng/kg bw/day] for PFAS migration from paper based FCMs in real food (oatmeal porridge, tomato soup, and muffins) (Lerch et al., 2022).

		Sum of PFOA and PFNA*		Total PFAS		Relative potency factor (RPF)**	
		Adult	Child	Adult	Child	Adult	Child
Paper Plate A	Oatmeal Porridge	0.06	0.18	14.3	43.4	0.46	1.39
	Tomato Soup	0.00	0.00	10.4	31.5	0.66	1.99
Paper Plate B	Oatmeal Porridge	0.06	0.18	11.0	33.3	0.35	1.06
	Tomato Soup	0.12	0.36	10.5	31.8	0.87	2.63
Paper Plate C	Oatmeal Porridge	0.00	0.00	15.1	45.9	0.36	1.09
	Tomato Soup	0.15	0.45	41.9	127	1.87	5.67
Muffin Cup A	Muffin	0.03	0.10	1.75	5.30	0.41	1.24
Muffin Cup B	Muffin	0.11	0.32	3.10	9.38	1.34	4.07
Muffin Cup C	Muffin	0.04	0.11	3.65	11.1	0.46	1.38

* Only sum of PFOA and PFNA since PFOS and PFHxS were not measured.

** RPF larger then 1 indicates a risk.

For the sum of PFOA and PFNA, estimated dietary exposure per serving for adults ranged from 0 to 0.15 ng/kg bw/day and for children from 0 to 45 ng/kg bw/day with none of the values exceeding the TDI of 0.63 ng/kg bw/day for sum of 4 PFAS (PFOA, PFOS, PFNA, PFHxS). However, most exposure estimates were in the same order of magnitude as the TDI, indicating that the added consumption of several contaminated servings may lead to an exceedance of the TDI from PFOA and PFNA consumption.

The exposure estimates obtained for the total PFAS where significantly higher compared to the exposure estimates for PFOA and PFNA, resulting in estimated dietary intakes in the range of 0.35 to 1.87 ng/kg bw/day for adults, and in the range of 1.06 to 5.67 ng/kg bw/day for children. Due to high differences in detected sum concentrations, the RPF approach was applied in which the concentration of each PFAS was converted to a PFOA equivalent. When compared to TDI for the sum of 4 PFAS, all estimated dietary PFAS exposures for children exceed the threshold by up to nine times. Lerch et al. (2022) concluded there is a need for further investigation on PFAS migration from FCMs and subsequent exposure to humans to ensure a better understanding of the overall human exposure and associated health risks of the Danish population.

It is emphasized that the FCM samples, on which the risk assessment by Lerch et al., (2022) was based on, were acquired at a time before PFOA UTC limits were established in the POP Regulation in 2020, and before Denmark implemented a national ban on the use of PFAS in certain FCMs with a maximum limit of 20 µg organic F/g FCM. Both measures are expected to contribute to a decrease of PFOA and total fluorine in FCMs and subsequent human exposure. Therefore, the contribution via FCM to total PFOA exposure is not anticipated to be a significant concern.

Additionally, human exposure to PFOA can occur through the consumption of drinking water. According to the recently performed investigation (in the period of 10/2022 to 09/2023) on the presence of PFOA in drinking water wells in Denmark, of the 4 main PFAS substances, PFOA was the most frequently detected (GEUS, 2023). In measurements from previous years (2017 – 2021, n=1304) the sum of 4 PFAS substances (PFOS, PFOA, PFHxS and PFNA) was found above the limit of 0.002 µg/l in 4.1% of the investigated wells (GEUS, 2023). As drinking water may account for a significant contribution of PFOA to the total human exposure, the identification of wells contaminated with PFAS is imperative. Therefore, since 2022, the measure of analysing for PFAS substances has become mandatory for all waterworks in Denmark. Special attention should be paid to locations along the Danish West coast, were groundwater in close vicinity to the coast is at higher risk to be impacted by PFAS via sea spray and sea water intrusion. Groundwater with concentrations of PFOA and other PFAS above the quality criterion cannot be used for drinking water extraction. The use of PFAS impacted groundwater for livestock should also be considered.

In addition to dietary exposure, humans can also be exposed to non-dietary sources such as to PFOA contaminated air or dust (EFSA CONTAM, 2018; Hull et al., 2023). Fromme et al., (2009), (as cited in DK EPA, 2013) estimated adult exposure to dust potentially as significant as dietary exposure (see TABLE 4-18). However, exposure via indoor and outdoor air did not appear significant compared to the other routes. Due to regulations put in place after this period, the current exposure in Denmark is expected to be lower. Recent studies investigating the presence of PFOA in indoor/outdoor air and household dust in Denmark have not been identified.

TABLE 4-18. Estimated adult daily intake (pg/kg bw) of PFOA for the general population (DK EPA, 2013, based on Fromme et al., 2009).

Source of exposure	PFOA	
	Mean	High
Indoor air	4.7	4.7
Outdoor air	0.1	1.0
House dust	31.7	4,217
Diet	1,500	4,483
Drinking water	23.3	130
Overall intake	1,560	8,836

Note: Mean intake is based on mean or median concentrations. High intake is based on upper percentile or maximum concentrations.

Human exposure to PFOA and PFOA precursors can also occur through dermal contact with consumer products. There are several studies conducted in other European and non-European countries that identified PFOA in various products such as carpets, textiles, paints, FCMs, etc. While some studies have been identified regarding the presence of PFOA and other PFAS substances in FCMs and non-stick cookware in Denmark, there is a lack of studies investigating the presence of PFOA in other consumer products in Denmark. It is also important to note that due to a ban on PFOA, human exposure through dermal contact is likely to occur only via contact with products produced while PFOA was still in use.

Furthermore, workers could be exposed to PFOA contained in waste and stockpiles such as firefighting foams. Section 4.4.1 highlights TULAC (Textiles, Upholstery, Leather, Apparel and Carpets), FCMs, and packaging to be the largest source of PFAS in waste streams. However, it is likely that PFOA is present in low concentrations in waste from products developed after 2020. Regarding firefighting foams, it can be assumed that PFAS and PFOA are still present in firefighting foams in stockpiles despite the decline in the use of PFAS in AFFF in recent years.

Overall, numerous studies investigating the presence of PFOA in humans from Denmark confirm an exposure of the Danish population to PFOA. However, the extent to which each source contributes to the overall human exposure is not clear.

5. PFHxS, its salts and PFHxS related compounds

PFHxS (perfluorohexane sulfonic acid), its salts and PFHxS related compounds also belong to the group of PFAS (see chapter 4). PFHxS has the CAS number 355-46-4.

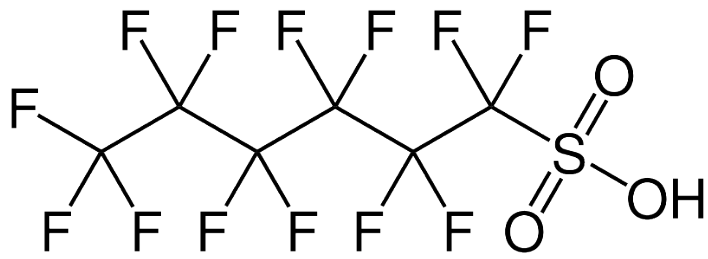

Figure 5-1 The chemical structure of Perfluorohexane-1-sulphonic acid (CAS no.: 355-46-4)

Similar to other POP substances, the restriction on PFHxS in the POP-Regulation does not only include PFHxS itself but also its salts and PFHxS-related compounds. This includes specifically:

1. Perfluorohexane sulfonic acid, including any of its branched isomers;
2. its salts;

PFHxS-related compounds which, for the purposes of the Convention, are any substance that contains the chemical moiety $C_6F_{13}S$- as one of its structural elements and that degrades to PFHxS. In this chapter when mentioning PFHxS, the term only refers to PFHxS.

5.1 Production in Denmark

Similarly to PFOA and other PFAS compounds, PFHxS has not been produced in Denmark.

Data was received from the Danish Product Registry in December 2023. The data contained information on import of PFHxS and related compounds for the years 2014 - 2022. Based on the information received, relatively small amounts of PFHxS and related substances have been imported (0.005-17.3 kg/year) (Work Environment in Denmark, 2023).

The data entered by in the Product Registry provide an indication of the amounts imported, but due to uncertainty the numbers are not exact. The uncertainties arise because only products and substances that are hazardous according to the criteria defined in statutory order no. 1794 of 18/12/2015 have to be registered. PFHxS, its salts and many of the PFHxS related compounds may not fulfil these criteria.

5.2 Current use and supply in Denmark

PFHxS and related substances were included in Annex I of the POP Regulation in May 2023 without any use exemptions. However, while the manufacturing, placing on the market and use of PFHxS is forbidden, the substances are most probably still present in certain products on the Danish market.

PFHxS was for example extensively used in firefighting foams, specifically aqueous film-forming firefighting foams (AFFF). Foams based on fluorinated C6 technology have been used as substitutes for the earlier restricted foams based on C8 technology. As PFHxS was only recently restricted to be used, it is likely that the substance is still present in AFFF stock in Denmark.

5.3 Historical use and supply in Denmark

PFHxS has been used in numerous applications in Denmark. Based on data from the industry descriptions developed by the Danish Regions, the former use of 19 PFHxS-related substances was identified in 11 different industries (Danish Regions Environment and resources, 2023). The industries and the use of PFHxS are listed in TABLE 5-1.

TABLE 5-1. List of industries in Denmark where PFHxS and related substances have been used based on industry descriptions by (Danish Regions Environment and resources, 2023).

Industry/ activity area	Use of PFHxS and related substances
Cardboard and Paper	Surface treatment of cardboard and paper packaging, and food contact paper
Carpets	Surface treatment to add dirt- and water-repellent properties
Car Washes	Used in waxes and car wash products, i.e. polishes and conditioners
Chemical Industry/Soap	Manufacture of soap, detergents, cleaning and polishing preparations, waxes, polishes, paints, varnishes and similar coatings, printing ink etc., and sealing materials.
Dry Cleaners	Cleaning fluids may contain a number of additives, including impregnating agents
Fire Drill Site	Firefighting foam
Iron and Metal	Surface treatment of metals
Oil Depots	Firefighting foam
Plastic	Release agents in plastic and rubber moulds
Textile and Leather	Impregnation agents for water-repellent breathable membranes such as rain and outdoor clothing, sportswear and workwear for hospital staff, pilots, the military and firefighters, dyeing and bleaching of textiles, antifoam agents, surface treatment of cotton, production of leather goods, including tanning of the hides and for finishing with water and dirt-repellent treatments of the tanned leather product
Wood and Furniture	Manufacture of construction timber and joinery, straw and wicker materials, bleaching of wood fibres with chemicals, weather-resistant coating of wood products, manufacture of furniture, treatment of wooden floors with floor wax, furniture refinishing and furniture deacidification, and manufacture of kitchen equipment

5.4 Presence in waste, stockpiles, and contaminated areas

5.4.1 Waste

As described in section 4.4.1, PFAS in solid waste and municipal/industrial wastewater can derive from many different product groups. See TABLE 4-2 for the amounts of PFAS entering the waste stage for various product groups estimated for Denmark.

The emissions of PFHxS and other PFAS from Danish incineration plants were presented in a literature study by the Danish EPA (DK EPA, 2023b). Samples were obtained from several process steps in two Danish incineration plants, as presented in TABLE 4-3, including flue gas, gypsum and treated wastewater. Aside from PFOA, as described in section 4.4.1.1, the samples were also analysed for PFHxS. The concentration was below the detection limit in all samples from both incineration plants, indicating that PFHxS may be destroyed during the incineration process along with other PFAS.

In a Swedish study by Björklund et al., (2023), samples of bottom ash, flue gas cleaning residues, gypsum, treated process water, and flue gas from a waste-to-energy incineration facility in Sweden were analysed for 18 PFAS compounds. The authors describe the incineration plant as state of the art. It incinerates ~60% household waste and 40% industrial waste at temperatures above 850°C and up to 1100°C. During one sampling campaign, sewage sludge was added to the waste input at 5-8%. The authors state that as the waste input on a given day is unknown the addition of sewage sludge provided a case where PFAS containing material was included in the fuel mix. A total of six samples were taken, three without the addition of sewage sludge and three with. PFHxS was not detected in any sample, indicating that the compound is destroyed during incineration. However, the exact fate of PFHxS is unknown. The authors state that PFHxA (analogue carboxylic acid) was the most detected individual PFAS compound, which could indicate that PFHxS is desulfurized and converted into PFHxA during incineration. In general, the results indicate that while PFHxS is completely destroyed during waste incineration, the exact fate of the compound is unknown, and it might be transformed into other persistent PFAS.

Sampling of influent, effluent, and sludge from nine Danish wastewater treatment plants was carried out as part of the NOVANA programme in 2007. PFHxS was found in measurable concentrations in the effluent from municipal wastewater treatment plants. The removal efficiencies in the wastewater treatment plants are relatively low. The concentration of PFHxS in sewage sludge was 1.8 µg/kg dry matter (DK EPA, 2013).

Another study by Bossi et al. (2008) found concentrations of 0.4-10.7 ng/g dry matter of PFHxS in sludge from wastewater treatment plants in Denmark. In the influent of the treatment plants there was a concentration of up to 32.8 ng/l and in the effluent up to 2.7 ng/l of PFHxS. This indicates a relatively high removal rate, however, in the review of international data in the same publication such removal of PFHxS in wastewater treatment plants is not demonstrated. It is also noted that even though a removal of PFHxS in Danish wastewater treatment plants is indicated, higher effluent concentrations are observed for several other PFAS, e.g., PFOA (Bossi et al., 2008). Overall, the study does not provide information about the differences in concentrations between influent and effluent, nor allows for general conclusions about the fate of PFHxS in wastewater treatment plants.

5.4.2 Stockpiles

As described in chapter 4.3, PFHxS has been widely used in firefighting foams, including its precursor 6:2 FTS, especially after the ban of PFOS in 2009. While the use of PFAS in general in AFFF has declined in recent years, PFAS and PFHxS may still present in firefighting foams on the market. Use sectors include the chemical industry, municipal fire brigades, marine applications, airports and the military (ECHA, 2023). PFHxS and its precursors may still present in AFFF concentrate in Danish facilities, and could represent a stockpile of PFHxS in Denmark.

5.4.3 Contaminated areas

See section 4.4.3.

5.5 Presence in food and drinking water

5.5.1 Presence in drinking water

PFHxS is included in the quality standard for drinking water for the sum of 4 PFAS (PFOA, PFOS, PFNA and PFHxS) of maximum 0.002 µg/l at the consumers' tap (BEK no. 1023 of 29/06/2023).

The results from the 1/10-2022 to 30/9-2023 PFAS control of the drinking water wells in Denmark are listed in TABLE 4-8 and results specifically for PFOA are available. PFOA is the most frequently detected of the substances included in PFAS4 (GEUS, 2023a).

TABLE 5-2. Data for PFOA in drinking water wells from the period 2022-2023 (GEUS, 2023a).

LOD µg/l	QS for drinking water µg/l	Sample size			PFOA detections %	
		N	>LOD	>QS	>LOD	>QS
0.0001-0.01	0.002	915	103	8	11,3%	0,9%

5.5.1 Presence in food

See section 4.5.2 about 4 PFAS in different food substances.

5.6 Release of the substance and presence in the environment

The sources of PFHxS in the environment are similar to those of PFOA, that is:

- Emission from the manufacture of the substance or industrial processes where the substance is included in the process directly or as an impurity.
- From the use and disposal of mixtures and articles that intentionally include the substances.
- From use and disposal of mixtures and articles that may contain them as an impurity.
- From the abiotic or biotic degradation of precursors.

5.6.1 Release and presence in water

Concentrations of PFHxS in Danish water bodies are presented in TABLE 5-3. Since there are overlaps in the use of PFHxS and PFOA (sections 4.2, 4.3, 5.2 and 5.3), the sources of PFHxS release to surface waters are most likely similar to those of PFOA. That is, municipal wastewater and firefighting foam are probably among the main sources.

Quality criteria for surface water are currently not available for PFHxS. Similarly, to PFOA, PFHxS is included in the indicative quality criterion for bathing water of 40 ng/l for PFAS4[15].

PFHxS concentrations have been mapped in the Danish groundwater monitoring programme, GRUMO, conducted by GEUS (GEUS, 2023). PFHxS was detected in 4.7% of the 686 samples obtained in 2017-2021. The detection limit was reduced from 1 ng/l to 0.3 ng/l in 2021. The wells sampled in the GRUMO programme are distributed across all of Denmark with the objective to assess the effect of regulation on diffuse groundwater contamination (point sources are avoided).

PFHxS concentrations are also reported for Danish surface water, including streams and lakes. Concentrations in sea water are reported as PFAS4 (see section 4.6.1). Surface water is monitored as part of the national NOVANA programme, the latest survey being conducted in 2011-2015 (Boutrup et al., 2015). PFHxS was not detected in the 19 samples obtained from lake sediment, although it should be noted that the detection limit was rather high (10 µg/kg). Lake water concentrations are only available as PFAS4. In stream water, the mean PFHxS concentration was 0.77 ng/l, <LOQ values not included (Boutrup et al., 2015). PFHxS was detected in 7.2% of the 125 samples.

[15] Letter from the Danish EPA, 2023: https://edit.mst.dk/media/eplbfs0z/graensevaerdier-ved-miljoestyrelsen.pdf

Rainwater samples for monitoring of PFAS were collected from seven stations across Denmark in 2004. PFHxS was detected just above the LOQ in one sample from Southern Jutland. The concentration in rainwater was lower than the highest concentrations detected in groundwater and stream water.

TABLE 5-3. PFHxS (or PFAS4, if indicated) concentrations in different water bodies in Denmark.

Concentration (ng/l)	Comment	Sample size (n)	Reference
Groundwater			
>0.3->1	Detected in 32 of 686 samples (4.7 %) Exceeds groundwater quality criterion in 8 of 686 samples (1.2 %)	686	GEUS (2023)
Streams			
0.77	Mean, 10th percentile <LOD, 90th percentile 0.72, samples above LOD 7.2 %	125	Boutrup et al., (2015)
	PFAS4: See TABLE 4-13		
Lakes			
<0.010 mg/kg	Sediment 19 lakes sampled in 2009	19	Boutrup et al., (2015)
	PFAS4: See TABLE 4-13		
Rain			
<LOD-0.3	Detected in 1 of 7 samples. LOD is below 0.2 ng/l for rainwater.	7	DMU, (2007)
Sea water			
	PFAS4: See TABLE 4-13		

De Wit et al., (2020) investigated the occurrence of PFHxS in Baltic Sea biota from 9 different locations. Most of the samples were collected in 2015 and 2016, except for harbour seal (2012-2016), grey seal (2006-2010), porpoise (2006-2012) and one pooled herring sample (2014). Species collected for chemical analysis consisted of blue mussel, eelpout, common eider, Atlantic herring, common guillemot, white-tailed eagle, grey seal, harbour seal, and harbour porpoise. Obtained concentrations are given in TABLE 5-4.

TABLE 5-4. Concentrations of PFHxS (ng/g lw) measured in different species and tissues collected from the Baltic Sea (De Wit et al., 2020).

Species	Tissue	n	Location, year	PFHxS
Eelpout	Muscle	47	Darßer Ort, 2015, DE	<0.075
Herring	Liver	38	Byxelkrok, 2016, SE	<0.62
Herring	Liver	40	Byxelkrok, 2014, SE	<0.62
Grey seal	Liver	5	Baltic Proper, 2009-2010	1.1
Grey seal	Liver	4	Baltic Proper, 2006-2009	<0.62
Harbour seal	Liver	5	Baltic Proper, 2014-2015	2.0
Harbour seal	Liver	4	Baltic Proper, 2012-2016	<0.62
Harbour porpoise	Liver	2	SW Baltic Proper, 2008	0.89
Harbour porpoise	Liver	4	SW Baltic Proper, 2006-2012	<0.62

Species	Tissue	n	Location, year	PFHxS
Common eider	Egg	5	Christiansø, 2015, DK	0.91
Common eider	Egg	5	Christiansø, 2015, DK	0.89
Common eider	Liver	5	Christiansø, 2015, DK	<0.62
Common eider	Liver	5	Christiansø, 2015, DK	<0.62
Common guillemot	Egg	4	St. Karlsö, 2016, SE	1.2
Common guillemot	Egg	5	St. Karlsö, 2016, SE	1.2
White-tailed eagle	Egg	5	Baltic Sea, 2015	1.1
White-tailed eagle	Egg	4	Baltic Sea, 2015	1.1

5.6.2 Release and presence in air

No data for PFHxS in Danish atmospheric air were found. However, in a study by Barber et al., (2007), 21 samples of outdoor air were obtained from four sampling stations in neighbouring countries (UK, Ireland and Norway). See TABLE 5-5. The purpose was to map PFAS in air in NW Europe. Also, two samples were obtained in Sweden by Kärmann et al., (2019), who had the purpose of mapping PFAS in various media in the Nordic environment. In both cases, the particulate phase was analysed, since PFHxS is not considered volatile.

PFHxS concentrations in indoor air in or near Denmark has only been reported by Barber et al., (2007), who obtained 4 samples from one field site in Tromsø, Norway. Unfortunately, the LOQ was rather high, and the result was <4.1 pg/m^3. It is therefore possible that the indoor concentration was at the level or even higher than the measured outdoor concentrations.

TABLE 5-5. PFHxS in neighbouring countries to Denmark. No data were found for PFHxS precursors.

Concentration (pg/m^3)	Comment	Sample size (n)	Reference
Outdoor			
0.07-1.0 <5.9 (Hazelrigg, Feb-Mar 2005)	PFHxS concentration in the particulate phase of outdoor air. Samples were collected from 4 field sites in Europe: Hazelrigg, UK (semi-rural), Manchester, UK (urban), Mace Head, Ireland (rural), Kjeller, Norway (rural).	21	Barber et al., (2007)
1.10 - 1.23	PFHxS concentration the particulate phase of atmospheric air from Råö in Sweden.	2	Kärrman et al., (2019)
Indoor			
<4.1	Concentration in particulate phase in indoor air from 1 field site in Tromsø, Norway.	4	Barber et al., (2007)

5.6.3 Release and presence in soil

Concentrations of PFHxS in Danish coastal soil were below the detection limit of 0.030 µg/kg, except in one sample from 0-0.1 m bg, where the concentration was 0.43 µg/kg (TABLE 5-6). Values were also reported for PFAS4 in agricultural soil treated with sludge, see TABLE 4-16.

TABLE 5-6. Concentration of PFHxS and sum of 4 PFAS in soil. Bold = exceeds soil quality criterium. Bg = below ground.

PFHxS Concentration µg/kg dw	PFAS4 Concentration µg/kg dw	Sample size (n)	Comment	Reference
-	10		Danish soil quality criterion	
<0.030-0.43	0.19-**32**	6	Soil, coastal area (0-0.1 m bg). Forest/heath/marshland, 103-765 m from the sea	Niras, (2023)
<0.030	0.15-5.3	5	Soil, coastal area (0.4-0.5 m bg). Forest/heath/marshland, 103-765 m from the sea	Niras, (2023)

5.7 Assessment of environmental and human exposure

5.7.1 Environmental exposure

See section 4.7.1 regarding the exposure of PFAS4 in the environment.

5.7.2 Human exposure

In general, human exposure to PFAS, including PFHxS, can occur through consumption of contaminated water or food and through inhalation of contaminated air (Ode et al., 2013). Additionally, inhalation of household dust and dermal exposure can also occur. Exposure of workers during the waste handling processes cannot be excluded either.

PFHxS as an individual substance does not have a safety threshold but is included in the TWI set in 2020 given for the ∑ PFAS4 (PFOA, PFOS, PFNA, PFHxS), and currently is set at 4.4 ng/kg bw/week (0.63 ng/kg bw/day) (Lerch et al., 2022).

In a review study from Hull et al., (2023) (for more details on the study please refer to section 4.7.2), the temporal trend of PFHxS concentrations in the Danish population is given. Concentrations of PFHxS were measured in plasma and serum samples in 20 study populations between 1988 and 2021. According to the temporal trend shown in Figure 5-2, concentrations of PFHxS have decreased from mid-1990s until 2021, with the exception in year 2003, when significantly higher concentrations were measured in one of the individual studies (up to 6.6 ng/ml). Hull et al., (2023) expected a steeper decline in concentrations of PFHxS due to the cease of PFHxS production by the main producer in 2000-2002. In the end, a conclusion was made that overall lower values might have mitigated the impact of the ceased production.

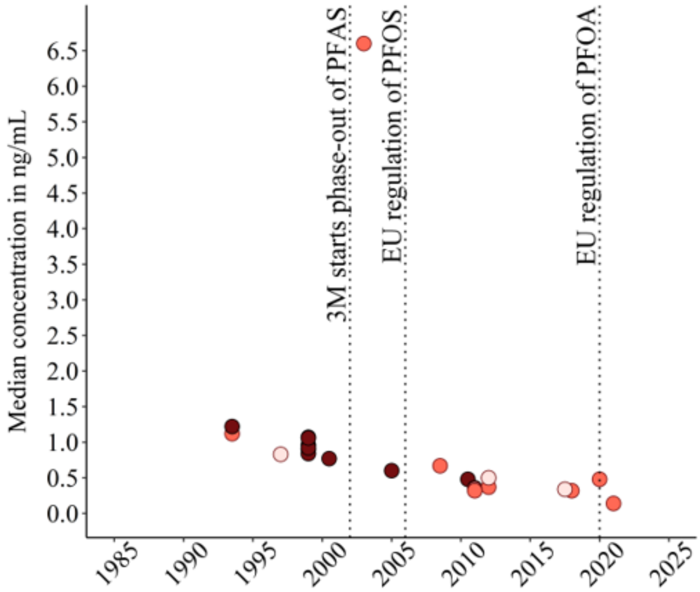

Figure 5-2. Median concentration (ng/ml) of PFHxS measured in Danish population in period of 1988-2021 (Hull et al., 2023).

The presence of PFHxS in humans confirms that the Danish population is exposed to this substance. In general, the dietary intake is considered to be one of the main contributors to the overall human exposure. However, only few studies confirm the presence of PFHxS in food and drinking water in Denmark.

Furthermore, workers could be exposed to PFHxS contained in waste and stockpiles such as firefighting foams. Regarding firefighting foams, it can be assumed that PFAS and PFHxS is still present in firefighting foams on the market despite the decline in the use of PFAS in AFFF in recent years.

6. Dechlorane Plus

Dechlorane Plus (DP, CAS No. 13560-89-9) is a man-made substance mainly used as a polychlorinated flame retardant. The technical DP mixture consists of two stereoisomers, syn-DP (CAS No. 135821-03-3) and anti-DP (CAS No. 135821-74-8). Concentration of syn-DP is in the range of 25-35% and of anti-DP 65-75% (UNEP, 2022a).

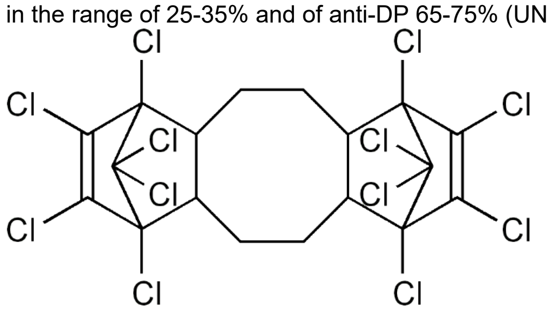

Figure 6-1. The chemical structure of Dechlorane Plus (CAS no.: 13560-89-9).

6.1 Production in Denmark

Dechlorane Plus is not manufactured in Denmark or the EU, but only imported as a substance, in mixtures or in articles (ECHA, 2021a). According to the publicly available information, only two manufacturers in the world synthesize DP, US Occidental Chemical Corporation (OxyChem), with a current annual production of 450–4,500 tons, and Anpon Electrochemical CO. Ltd. (Jiangsu Province, China) with a volume production of 300–1,000 tons/year (Ghelli et al., 2021; Hansen et al., 2020).

6.2 Current use and supply in Denmark

In the EU, according to the REACH registration data, DP is manufactured and/or imported to the European Economic Area in the range of 10 – 100 tons per year (ECHA, 2021a). Known uses in the EU include sectors such as automotive and aviation sectors and other uses such as computers, electronics and imported articles (ECHA, 2021a). Under REACH, DP is registered for industrial use in polymer preparations and compounds, semiconductors, adhesives, and sealants (UNEP, 2022b).

As of December 2023, Dechlorane Plus is not yet listed in the EU-POP-Regulation and as such is not yet legally banned in the EU. However, a draft delegated Regulation for listing Dechlorane Plus in the POP-Regulation has been published. The restriction foresees the following time limited exemptions (time periods not specified yet):

6. aerospace and defence applications;
7. medical imaging applications;
8. radiotherapy devices and installations;
9. replacement parts for the following articles, where dechlorane plus was initially used in the manufacture of those articles:
    - 9.1. land based motor vehicles;
    - 9.2. marine, gardening and forestry machinery applications;
    - 9.3. aerospace and defence applications;
    - 9.4. medical imaging applications;
    - 9.5. radiotherapy devices and installations;

Even after listing, DP can be present in the listed exemptions.

6.3 Historical use and supply in Denmark

DP has been commercially in use since the 1960s (UNEP, 2022b). It was originally developed as a replacement for the flame retardant and insecticide dechlorane (Mirex). Its main use is as an alternative for the brominated flame retardant decaBDE and Mirex (UNEP, 2022b).

6.4 Presence in waste, stockpiles, and contaminated areas

Stockpiles of Dechlorane Plus and contaminated areas in Denmark could not be identified. Since there is no production of DP in Denmark, it can be estimated that occurrence of Dechlorane Plus is probably in products currently in use, including imported plastic products.

Other than Denmark, DP has been detected in the sludge from Norwegian sewage treatment plant with the average concentration of 14.2 ng/g dry weight (sum of syn-DP and anti-DP, n=2) (The Norwegian Environmental Agency, 2019).

6.5 Presence in food and drinking water

Studies indicating presence of DP in food present on the Danish market could not be identified.

A review study from Ghelli et al., (2021) provides concentrations of DP isomers in various food samples from different European countries. An overview of compiled concentrations is given in the table below (TABLE 6-1).

TABLE 6-1. Concentrations (pg/g ww) of Dechlorane Plus in fish, seafood, dairy products, egg, and meat in Europe (Ghelli et al., 2021).

Type of food	Number of samples	∑DP	Country
Catfish	102	8.05-11.64*	FR
Fish and seafood	42	**223.21x10³***	Europe
Freshwater fish	4	ND	GR
	10	1.28x10³*	SI, HR, BA
	13	ND	RS
	48	1.14x10³*	ES
	44	23	DE
Salmon	8	6.13*	BE
	25	244.6*	LV
Fish and fish products	11	ND	BE
	61	ND	BE
	8	14.46-14.46	LV
European eel	45	30 (770*)	DE
	58	260	LV
Milk	16	17.61*	BE
	1	ND	BE
Milk and dairy products	38	9	BE
	8	16.41-16.41	LV
Egg	8	26.27	BE
	2	ND	BE
	8	30.33-30.33	LV
Egg and egg products	4	159	BE
Meat and poultry	16	10.02*	BE
	1	ND	BE
	3	10	BE
Meat	8	8.52-8.52	LV
Animal fat	18	19.10*	BE
Vegetable oil	2	19.11*	BE

Type of food	Number of samples	∑DP	Country
Vegetable oil	4	7.57-14.40	LV
Vegetable fat	1	ND	BE
Animal and vegetable fat	9	ND	BE
Bread and cereals	4	14.32-14.40	LV

* concentration given in pg/g lw

Country abbreviations: BA – Bosnia and Herzegovina, BE – Belgium, DE – Germany, ES – Spain, FR – France, GR – Greece, HR – Croatia, LV – Latvia, RS – Serbia, SI – Slovenia.

The highest concentration of ∑DP of 223 x 103 pg/g lw (sum of syn-DP and anti-DP, corresponding to 223 ng/g lw) was reported in fish and seafood available on the European market. Ghelli et al., (2021) reports that recalculated average value (in case when only raw samples are considered) is strongly influenced by the presence of highly contaminated samples of mussels collected from Denmark. However, original data on the concentration of DP in the Danish mussel samples could not be identified and additional information about source or reason of contamination is not available. Despite difficult comparison of concentrations in food samples influenced by variety of data, Ghelli et al., (2021) concludes widespread DP contamination in various types of food demonstrates DP is globally distributed across Europe.

6.6 Release of the substance and presence in the environment

Releases of DP to the environment are linked to the life cycle stages of articles since there is no unintentional production of DP and its isomers. Therefore, activities such as use of articles, waste handling, recycling, landfill leachate and run-off of wastewater treatment can lead to the release of DP into the environment (UNEP, 2022b).

Its use as a flame retardant in electrical and electronic equipment indicates e-waste recycling facilities could be a source of release of DP into the environment (ECHA, 2021a; UNEP, 2022b).

The waste consultancy Danish Waste Solutions investigated the leaching of problematic substances during storage of waste from electrical and electronic equipment (WEEE) without weatherproof covering (DK EPA, 2023g). The leachate from three leaching tests comprising mixed-WEEE (small household and IT devices), LCD/CRT screen and refrigerators was tested for, amongst others, DP. Leachates were produced by simulating rain (irrigation of test containers) once a week for 6 weeks. DP was sought to be analysed in the leachates by targeted screening of LC-MS chromatograms along with brominated flame retardants. A detection limit was not stated (due to the analytical method applied). DP was not identified in any of the leachate samples, indicating that uncovered storage of WEEE may not be a significant source to DP release in the environment.

In biota, anti-DP was detected in herring gull eggs collected from Denmark in concentrations up to 0.17 ng/g ww, while syn-DP was below LOD in all samples. Both isomers were also measured in other egg samples, i.e., egg samples of Black guillemot, Common guillemot, fulmar and Ural owl from different Nordic countries, however, all concentrations were below the LOD. In the samples of freshwater fish (i.e., perch) collected from Denmark, both syn-DP and anti-SP were below the LOD. This was also the case for cod and samples of pine needles. In the blubber of grey seal samples collected from two different locations in Denmark, syn-DP was detected in concentration of 0.96 ng/g ww while anti-DP was detected in concentration of 1.79 ng/g ww. All samples were collected in 2019 (Nordic Council of Ministers, 2022).

De Wit et al., (2020) investigated the occurrence of syn-DP anti-DP in Baltic Sea biota sampled from 9 different locations, including the one from Denmark. Most of the samples were collected in 2015 and 2016, except for harbour seal (2012-2016), grey seal (2006-2010), porpoise (2006-2012) and one pooled herring sample (2014). Species collected for chemical analysis consisted of blue mussel, eelpout, common eider, Atlantic herring, common guillemot, white-tailed eagle, grey seal, harbour seal, and harbour porpoise. Obtained concentrations are given in table below (TABLE 6-2).

DP is not comprised by the Danish environmental monitoring programme NOVANA.

TABLE 6-2. Concentrations of syn-DP and anti-DP (ng/g lw) measured in different species and tissues collected from Baltic Sea.

Species	Tissue	n	Location, year	syn-DP	anti-DP
Blue mussel	Soft body	100	Darßer Ort, 2015, DE	<0.18	<0.21
Eelpout	Muscle	47	Darßer Ort, 2015, DE	<0.14	<0.16
Herring	Muscle	38	Byxelkrok, 2016, SE	0.048	0.10
Herring	Muscle	40	Byxelkrok, 2014, SE	0.021	0.039
Grey seal	Blubber	5	Baltic Proper, 2009-2010	12	52
Grey seal	Blubber	4	Baltic Proper, 2006-2009	0.077	0.16
Harbour seal	Blubber	5	Baltic Proper, 2014-2015	<0.022	0.058
Harbour seal	Blubber	4	Baltic Proper, 2012-2016	0.077	0.13
Harbour porpoise	Blubber	2	SW Baltic Proper, 2008	<0.017	0.028
Harbour porpoise	Blubber	4	SW Baltic Proper, 2006-2012	0.068	0.12
Common eider	Egg	5	Christiansø, 2015, DK	0.077	0.17
Common eider	Egg	5	Christiansø, 2015, DK	0.13	0.26
Common eider	Liver	5	Christiansø, 2015, DK	14	38
Common eider	Liver	5	Christiansø, 2015, DK	18	65
Common guillemot	Egg	4	St. Karlsö, 2016, SE	0.10	0.26
Common guillemot	Egg	5	St. Karlsö, 2016, SE	0.15	0.54
White-tailed eagle	Egg	5	Östersjön, 2015	3.2	7.3
White-tailed eagle	Egg	4	Östersjön, 2015	4.2	8.3

< means that the measured concentration is below the LOD

Other than Denmark, in a monitoring programme conducted in 2019, DP was detected in storm water, in sediment, in fish and invertebrates of the Inner Oslofjord food web, and in herring gull (blood and eggs) (TABLE 6-3).

TABLE 6-3. Average concentrations of syn-DP and anti-DP in sediment (ng/g dw), species of the Inner Oslofjord food web (ng/g ww), herring gull (blood and egg) (ng/g ww), storm water (ng/l). Components that were not detected in any replicate samples of species are noted as n.d. Where given, detection frequency (DF) is provided together with the concentration (in parentheses) (The Norwegian Environmental Agency, 2020).

Sample (matrix)	Matrix	Number of samples	Syn-DP (DF)	Anti-DP (DF)
Sediment	Whole sediment	1	0.44	1.01
Herring gull (blood)	Blood	15 individuals	0.065 (8/13) 7.33* (8/13)	0.140 (10/15) 15.02 (8/13)
Herring gull (egg)	Egg	15 eggs	0.299 (8/13) 3.56* (10/15)	0.795 (10/15) 9.60* (10/15)
Inputs storm water	Water (dissolved)	2	0.79	1.53
	Particulate fraction	2	5.45	38.31
Food web of the Inner Oslofjord				
Polychaetes	Pooled samples, whole individuals	3 pooled samples	0.050	0.094
Zooplankton (krill)	Pooled samples, whole individuals	3 pooled samples	0.015	0.028
Prawns	Pooled samples, soft tissue tails	3 pooled samples	n.d.	0.021
Blue mussel	Pooled samples, soft body	3 pooled samples	n.d.	0.094
Herring	Muscle	3 pooled samples	0.085	0.151
Cod	Muscle, liver, bile	15 individuals	0.059 (2/15)	0.075 (2/15)

* concentration in ng/g lw (lipid weight)

Concentration of DP in sediment in the inner Oslofjord appeared in the same concentration range as in sediments of the North American Great Lakes. In eggs of herring gull DP was found in high variability, with higher concentration in eggs on a wet to weight basis, than in blood. Contrary, on a lipid weight basis, the concentrations were higher in blood. In blood, the anti-DP was found in higher concentrations than the syn-DP, while the opposite appeared for eggs. The mean concentration of Dechlorane Plus (sum of the syn- and anti-isomers) in the eggs appeared approximately twice as high as the previous year, and thus ranged from similar to a factor of approximately 3 times lower than those in eggs of herring gull from the Laurentian Great Lakes and a factor of ~5 lower than eggs of herring gull from Niagara River, closer to a Dechlorane Plus manufacturing plant.

Furthermore, DP isomers were detected in the storm water (n=4, 2 samples of dissolved/filtered fraction and 2 samples of particulate fraction) collected in Norway in 2019. Detection rate is not given. Concentrations of several ng/l were detected mostly in the particulate fraction of storm water. Average concentration of syn-DP was 5.45 ng/l in particles and 0.79 ng/l in water fraction while an average concentration of anti-DP was 38.31 ng/l in particulate fraction and 1.53 ng/l in dissolved fraction of storm water (The Norwegian Environmental Agency, 2020).

6.7 Assessment of environmental and human exposure

6.7.1 Environmental exposure

The high adsorption potential of DP and environmental monitoring data (e.g., The Norwegian Environmental Agency, 2020) indicate that DP is present in sediment and soil rather than the water phase (ECHA, 2021a). This was also confirmed by a study conducted in Norway on the presence of DP in storm water where concentrations of DP were measured both in dissolved and particulate fraction. Higher concentrations of both syn-DP and anti-DP were observed in the particulate fraction (The Norwegian Environmental Agency, 2020).

Additionally, at the wastewater treatment plants, due to high adsorption potential, it is more likely that DP will rather be present in the sewage sludge than in the water phase. For example, as part of the environmental monitoring in Norway, syn-DP and anti-DP were only detected in sludge in average concentration of 2,480 and 11,745 ng/g dw, respectively (The Norwegian Environmental Agency, 2019).

As a man-made substance, DP occurs in the environment only as a consequence of human activities. Numerous studies conducted in Denmark and other European countries indicate DP is widely distributed in the environment. The Annex XV report for DP (ECHA, 2021a) documents high concentration of DP can be found close to the e-waste recycling facilities, pointing at such facilities as release sources to the environment. A Danish study on leachates from WEEE storage provides an indication that DP does not leach from storage of WEEE. However, the study also has some limitations (simulating storage as the only WEEE-related activity, limited experimental period, LOD not available). A follow up on studies or data investigating the presence of DP in the close vicinity of e-waste recycling facilities in Denmark would elucidate whether this is relevant for the environmental exposure in Denmark as well.

6.7.2 Human exposure

Human exposure to DP, including syn-DP and anti-DP, can occur through worker exposure, consumer exposure and indirect exposure to DP present in the environment (ECHA, 2021a). More specifically, this includes exposure through indoor dust, food, indoor and ambient air, drinking water, soil, and sediment (UNEP, 2022b; DK EPA, 2023b). The unborn child can be exposed to DP via the umbilical cord and exposure via breast milk also occurs (ECHA, 2021a).

Under the Regulation for maximum residues of pesticides in or on food and feed (Regulation (EC) No 396/2005), thresholds for dicofol have been in place since 2008.

Human biomonitoring data from Denmark are not available, but data exist for several other EU-countries and one neighbouring country. Syn-DP and anti-DP were measured in children serum and plasma samples collected from Norway, Slovenia, Greece, and France. All samples were collected between 2014 and 2020 (Gilles et al., 2021). The results are shown in TABLE 6-4. In blood samples from France, detection frequency was below 40% and only one sample from Greece had detectable concentrations of syn-DP while no anti-DP was not detected. Detection frequencies for syn- and anti-DP in samples from Norway were 100% and 99%, respectively (Van Der Schyff et al., 2023). Regional differences in serum levels of DP are visible when compared across France, Norway, and Slovenia (SI>NO>FR), however, clear cause on the regional differences has not been identified (Melymuk & Bajard, 2022).

TABLE 6-4. Detection frequencies and concentrations of ∑DP (ng/g lipid) in children's blood sampled between 2014 and 2020 from European countries.

Country	Detection frequency	Median	95th percentile
France	34%	-	1.29
Greece	2%	-	-
Slovenia	-	16	24.8
Norway	100%	3.17	33.1

A study from Martinez et al., (2021) gives an overview of studies that measured DP and their dechlorinated forms in human samples from Norway (i.e., blood, milk, hair, nail). According to this source, Čechová et al. (2017), measured syn-DP and anti-DP in milk samples (n=305) collected during 2003-2006 at average concentrations of 0.355 (7% detection frequency) and 0.055 ng/g lipid (26% detection frequency), respectively. Cequier et al., (2015), cited in Martinez et al. (2021) detected syn-DP and anti-DP in serum samples (n=48) collected in 2012 in concentrations (median value) of 0.45 ng/g lipid (78% detection frequency) and 0.85 ng/g lipid (89% detection frequency), respectively. Furthermore, Tay et al. (2019), cited in Martinez et al. (2021) measured concentration in the samples of serum (n=61) collected in 2013 and reported an average concentration of 2.1 ng/g lipid and 5.3 ng/g lipid for syn-DP and anti-DP, respectively. Detection frequency was 3% for both isomers.

Fromme et al. (2015) analysed 42 plasma samples for DP from randomly selected blood donors in Germany. The median and maximum concentration for the ∑DP (93% detection rate of syn-DP and 79% detection rate of anti-DP) was 2 and 51 ng/g lw, respectively. Based on 180 samples of archived blood plasma from Germany collected between 1995 and 2017, no clear time trends in exposure were observed by Fromme et al. (2020) as cited in RAC/SEAC (2022).

DP has been detected in indoor and domestic dust samples collected from several countries other than Denmark (UNEP, 2022b).

In Europe, concentrations of DP have been reported in blood serum from adults from several countries such as France, Germany, Sweden, and Norway. The Annex XV report states median level of anti-DP in serum in the range from below the LOD in Sweden and Norway and up to 1.23 ng/g serum lipids in Germany (ECHA, 2021a).

Dechlorane Plus is included in the NoFlame project, which in a cooperation of four Danish universities reviewed i) emission of flame retardants from building materials, ii) skin absorption and iii) presence of the substances in house dust and breast milk (Vogel et al., 2017). Initially, the NoFlame project focussed on brominated flame retardants, but DP was also included at a later stage as well as review of blood monitoring data. In a literature review based on some of the Norwegian and German studies mentioned above, Vogel et al. (2017) report that levels of DP in blood in Europe (0.5-2 ng/g lipid) are similar to levels of the legacy flame retardant BDE-47 in Europe, but that exposure for children is usually higher than for adults. Occupationally exposed adults, e.g., workers in recycling of electronic waste, may experience significantly elevated exposures (Vogel et al., 2017). Corresponding conclusions regarding the presence of DP in breast milk were not available in this review.

Possible route of human exposure to DP in Denmark could be through the consumption of fish, however, in the samples of edible fish such as perch and cod collected in Denmark, both syn-DP and anti-DP were below LOD (Nordic Council of Ministers, 2022). Additionally, the exposure of humans can occur during the indoor and outdoor consumer product use, and in the waste management of plastics and electronics. Studies conducted in Denmark and other

European countries indicate humans are exposed to this substance and more studies should be conducted to better understand the exposure routes and impact this substance might have.

7. UV-328

UV-328 belongs to the group of the substituted benzotriazole UV-absorbers. It can absorb the entire spectrum of UV light without being destroyed. It has the CAS number 25973-55-1 and the chemical name 2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol.

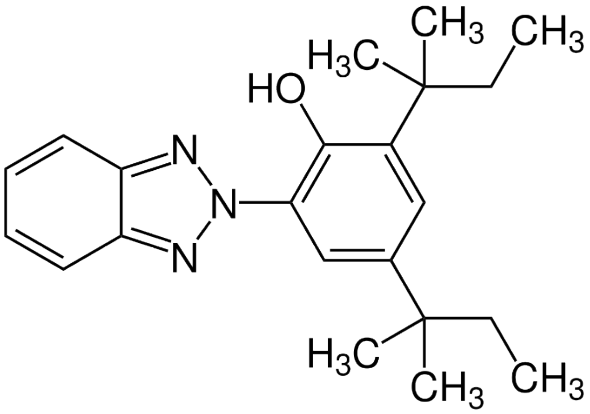

Figure 7-1: Structural formula of UV-328

7.1 Production in Denmark

There is no registration of UV-328 by Danish companies under REACH (ECHA, 2021b).

7.2 Current use and supply in Denmark

UV-328 was included in the authorisation list under REACH (Annex XIV) on 06.02.2020 with a latest application date of 27.05.2022, meaning that before this date companies will have to apply in order to continue to produce/import/use the substance in Europe (ECHA, 2020a). However, no application for authorisation has been received, indicating that the substance is no longer produced or used in Europe and Denmark.

7.3 Historical use and supply in Denmark

UV-328 is used as a broad band UV absorber, as it absorbs the entire spectrum of UV radiation without being destroyed. Thus, it is used in applications which are typically used outdoors. In Europe, ~50% of UV-328 was used in car coatings and special industrial wood coatings. Another 40% was used for the protection of plastics and rubbers, which includes e.g. PVC, polycarbonates, polyacrylates and polyester. Typical concentrations in plastics range between 0.2-3 w% depending on plastic and application (Annex XV report, Germany, 2014). Products containing UV-328 can have entered Denmark through import from countries outside the EU or from the European market.

Typical products apart from automobiles include for example outdoor furniture, plastic shrink films, fabric/textile/leather products, furniture/furnishings, inert pesticides, construction materials, fillers, surface treatment, adhesives and various kinds of paints, varnishes and lacquers (ECHA, 2020b).

A survey of unwanted substances in building materials identified uses of UV-328 in Denmark in paint and lacquers, ABS-, epoxy-, and fibre-resins, in PVC, and in binders in 2012 (DK EPA, 2016).

UV-328 has been listed in the list of over 400 functional additives or pigments used in plastics, which was established as the 'Plastic additives initiative'[16] in a joint project by ECHA and 21 industry sector organisations. The objective of the initiative was to characterise the uses of high volumes plastic additives (>100 t/y) and assess the extent to which the additives may be released from plastic articles from 2016 to 2018. Details on historic/current use or release are not publicly available from this initiative.

7.4 Presence in waste, stockpiles, and contaminated areas

There is currently no established technology for the identification and separation of UV-328 containing waste, leading to uncertainties during the waste phase. However, it can be assumed that the majority of UV-328 will enter the waste phase with the products it is used in. The largest share of UV-328 is expected to be found in the paints/coatings of end-of-life vehicles. The paint typically stays on the metal frame of the vehicle, which is typically recycled by melting. It can be assumed that UV-328 is destroyed during this process, however scientific evidence confirming this is lacking. Significant UV-328 emissions during the proper disposal of end-of-life vehicles are not expected (UNEP, 2023).

As a phenolic benzotriazole, UV-328 will partly be decomposed by mechanical recycling. Residues may be present in recycled materials. If UV-328 is used in thermosetting plastics such as polyurethane and epoxies, it will decompose by feedstock recycling (DK EPA, 2014). UV-328 decomposes at temperatures below 200 °C, therefore it can be assumed that it is completely destroyed in appropriate waste incineration facilities (UNEP, 2022b).

As UV-328 is used in a wide range of plastics, it can be found in many different plastic waste streams such as household, construction and industrial waste. However, no widely established identification method for UV-328 in waste is available. After entering the waste phase, it is difficult to separate the UV-328 containing fraction as UV-328 does not contain easily detectable atoms such as halogens, sulphur or phosphorus. As such, if it is known that a product contains UV-328, it should be separated when entering the waste phase, as a technology for the separation after being mixed with other waste is currently not established, unless the waste fraction is to be treated thermally; in this case, destruction of UV-328 can be anticipated.

Stockpiles of UV-328 and contaminated areas in Denmark could not be identified. The biggest occurrence of UV-328 is probably in products currently in use with the highest share likely in vehicles.

7.5 Presence in food and drinking water

UV-328 was found in edible fish species such as cod sampled in Denmark with a concentration of up 0.41 ng/g (100% detection frequency) (Nordic council of Ministers, 2022) and with a detection frequency of 20% and a maximum concentration of 19.5 ng/g ww in samples from the Oslofjord (Thomas & Schalbach, 2014).

Groundwater monitoring data for UV-328 are not available.

7.6 Release of the substance and presence in the environment

UV-328 is not chemically bound to materials, and the substance may therefore be released from products and enter the environment, indicating the importance of the use and waste phase (UNEP, 2022b).

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[16] Plastic additives initiative https://echa.europa.eu/de/mapping-exercise-plastic-additives-initiative

The presence of UV-328 could be confirmed in effluent (detection in 100% of the samples) and sludge (detection in 50% of the samples) from waste water treatment in Sweden and in landfill leachate (Brorström-Lundén et al., 2011). In Norway, UV-328 was found at notable concentrations in sewage treatment plant samples, especially in sludge (Ruus et al., 2019, 2020, cited in UNEP, 2023). This indicates that the substance leaches out from products and can ultimately be emitted into the environment. In the liquid phase, UV-328 quickly binds to solids and suspended particles and mainly ends up in sludge, however, a small fraction remains in the water phase. Data on the presence of UV-328 in Danish sewage sludge have not been identified and it is therefore not known whether application of sludge on agricultural land presents a release pathway of UV-328 into the environment in Denmark.

7.7 Assessment of environmental and human exposure

7.7.1 Environmental exposure

UV-328 has been detected in various biota samples from Denmark. The substance was detected in concentrations up to 0.19 ng/g (44% detection frequency) in herring gull eggs, 0.41 ng/g in cod (100% detection frequency) and 0.8 ng/g (50% detection frequency) in grey seal. In two samples, UV-328 could not be detected (Nordic Council of Ministers, 2022).

The same publication also provides results from various bird and fish species in other Nordic countries (Norway, Sweden, Iceland). UV-328 was detected in 43% of bird egg samples (14 samples total) with an average concentration of 0.38 ng/g ww (max 1.83 ng/g ww). The highest concentration was found from a sample form the inner Oslofjord. In freshwater fish, UV-328 was detected in 5% of the samples (19 samples total) with a concentration of 0.12 ng/g ww. In marine mammals it was detected in 50% of samples (2 samples total) with a concentration of 0.8 ng/g ww (max 2.79 ng/g ww). In terrestrial mammals (moose, red deer and reindeer) UV-328 (or any other analysed UV-filter) could not be detected (n=9) (Nordic Council of Ministers, 2022).

In the Oslofjord, UV-328 was not detected in shrimp or crab samples (45 samples), however, it was detected in cod liver with a detection frequency of 20% and a maximum concentration of 19.5 ng/g ww (Thomas & Schalbach, 2014). While UV-328 was detected in cod liver, there was no indication on the biomagnification in the organisms that were collected (DK EPA, 2015). Furthermore, in sediment from the fjord, UV-328 was detected in all five samples with a maximum concentration of 25 ng/g dw. In sediment samples from lake Mjøsa (Norway), it could not be detected (n=5). In fish from the same lake (n=45), sludge (n=10), effluent (n=15) from various waste water treatment plants and in landfill leachate and particulate (n=9) from Norway, UV-328 could also not be detected (Thomas & Schalbach, 2014).

In Sweden, UV-328 could not be detected in air samples from background, urban and industrial sampling points (n=8). In soil, the substance was detected once in urban soil (n=4) with a concentration of 0.74 µg/g dw. In surface water from rural and urban sites, the substance was detected in all samples with concentrations ranging from 1.7 to 10 ng/l (n=6). Similarly, the substance was detected in four background and urban sediments in concentrations up to 1.2 µg/g dw (n=6) as well as in the effluent (n=5) and sludge (n=8) from Swedish wastewater treatment plants in concentrations up to 15 ng/l and 37 µg/g dw. In landfill leachate UV-328 was detected in all four samples with the highest concentration being 91 ng/l and in storm water concentrations of up to 1.3 ng/l were measured (75% detection frequency, n=4). In fish, UV-328 could not be detected (n=4) (Brorström-Lundén et al., 2011).

The listed concentrations in the environment are lower (usually 2-4 orders of magnitude, for sediment 1-2 orders of magnitude) than the predicted no-effect concentrations (PNEC) for water, STP, sediment, soil and secondary poisoning reported in the risk profile for UV-328 (UNEP, 2022b). There is therefore no immediate concern that the concentrations in the environment cause an unacceptable environmental risk. However, there are no data available for Danish surface water and sediment and it is thus not known whether this conclusion also applies for the environment in Denmark.

7.7.2 Human exposure

In Spain, UV-328 was detected in 2 out of 12 human adipose tissue samples with a concentration of up to ~6 ng/g lw (Yanagimoto et al., 2011), confirming that humans are exposed to the substance. Specific sources regarding the human exposure to UV-328 could not be identified.
However, a possible exposure route may be fish, as the presence of the substance was confirmed in Danish and Norwegian cod (see chapter 7.5).

Humans may be exposed to UV-328 through ingestion of contaminated dust. Kim et al., (2012) documented exposure to UV-328 via house dust in a residential area in the Philippines. The estimated daily intakes were below guideline values, however, the authors point out that toddlers are at higher risk due to higher dust exposure. Danish or European exposure data via house dust are not available and it is thus not know whether the presence of the substance in plastic consumer products contributes to the exposure.

8. Strategy and action plan elements

8.1 Measures to reduce or eliminate the release by substance

As party to the Convention, Denmark is required to ban, and/or take the necessary legal and administrative measure steps to ban the production, use, import and export of the newly added POPs.

8.1.1 Dicofol

There are several regulations in place that prohibit the use of dicofol in the European Union.

From 2020, the POP Regulation (Commission Delegated Regulation (EU) 2020/1204) prohibits manufacturing and use of dicofol in another substance, mixture, or article.

Before addition of dicofol to the POP Regulation, dicofol was regulated by Commission Regulation (EC) No 2076/2002, which does not approve use of dicofol as a plant protection product in the EU with the last existing authorization being expired in 2010.

Under the Regulation for maximum residues of pesticides in or on food and feed (Regulation (EC) No 396/2005), thresholds for dicofol have been in place since 2008.

The EU Directive on the quality of water intended for human consumption defines the maximum concentration allowed in drinking water as 0.1 µg/l for a single pesticide or metabolite, and 0.5 µg/l for the total sum of pesticides. This Directive was implemented in Danish law via the Danish statutory order on drinking water (Drikkevandsbekendtgørelsen), including a list of pesticides for mandatory surveillance (dicofol is not comprised by the list).

In the Danish Statutory Order no. 796 of 13/06/2023, the EU-derived EQS for dicofol for inland water (lakes and stream) of $1{,}3 \times 10^{-3}$ µg/l and other surface water (marine) $3{,}2 \times 10^{-5}$ µg/l are listed.
Due to being identified as a priority hazardous substance, the Water Framework Directive (Directive 2000/60/EC) makes it obligatory to cease all discharges to the environment which go beyond the EQS target thresholds.

Dicofol may be imported with contaminated foodstuff, however, based on the results from Danish Pesticide Residues in Food monitoring, measured concentrations were well below the allowed maximum residue levels (MRLs) as defined by Regulation (EC) No 396/2005 on MRLs in food and feed. Therefore, it can be concluded there is no appreciable risk of adverse health effects following dietary exposure to dicofol.

There are only few data indicating the environmental presence of dicofol in Denmark, e.g., dicofol was measured in sediment samples, however, all concentrations were below the detection limit. Dicofol is practically insoluble in water and adheres strongly to organic matter (log K_{ow} 3.5-6.06) and partitions therefore primarily to soil and sediment in the environment. However, EQS for sediment (and biota) are not defined.

Studies investigating presence of dicofol in human samples in Denmark were not identified, neither were studies on waste, stockpiles, and contaminated areas, meaning there is some uncertainty about the presence of dicofol in the Danish environment.

Overall, given the significant time that has passed since the legal use of dicofol and the limited total use during the 36 year period where the substance has been sold in Denmark, it is not likely that significant environmental and human exposure to difocol occurs in Denmark. Therefore, no additional initiatives are proposed.

8.1.2 Methoxychlor

Regulations that prohibit the production, use and import are in place in Denmark. The substance is listed as Annex A (prohibition of production and use) without specific exemptions under the Stockholm Convention, and it is expected that this is directly translated into the EU POP Regulation.

Methoxychlor is regulated by Commission Regulation (EC) No 2076/2002, which does not approve use of the substance as a plant protection product in the EU.

Environmental quality criteria for the water, soil and sediment compartments are not established. Under the Regulation for maximum residues of pesticides in or on food and feed (Regulation (EC) No 396/2005), thresholds for methoxychlor have been in place since 2006.

The EU Directive on the quality of water intended for human consumption defines the maximum concentration allowed in drinking water as 0.1 µg/l for a single pesticide or metabolite, and 0.5 µg/l for the total sum of pesticides, as implemented by the Danish statutory order on drinking water. Methoxychlor has not been detected in groundwater in Denmark, also, it is not comprised of the list of pesticides for mandatory surveillance.

Methoxychlor may be imported with contaminated foodstuff, but maximum residue limits for food stuff are in place, and human exposure related to presence of the substance via contaminated food appears insignificant, based on limited number of detections in European food monitoring and no detections in the Danish Pesticide Residues in Food monitoring during the past two decades.

However, only few environmental monitoring data are available for Denmark, therefore there is uncertainty about the environmental presence of the substance. Additional environmental data, hereunder especially sediment data of water bodies receiving surface-runoff from orchards and horticulture, would contribute to an accurate assessment of the substance's presence in the environment. Data from other EU Member States with similar climatic conditions could also support an assessment.

Methoxychlor has been detected in human breast milk and placenta, however, limited knowledge about sources of human exposure as well as time trends are available.

Overall, stockpiles, contaminated areas and/or environmental and human exposure are unlikely to be significant in Denmark, due to limited historical uses of pesticide products containing the substance in Denmark. However, data availability for specific Danish data are limited and additional data from Denmark or other Member States may support the assessment of the Danish situation. Therefore, it may be relevant to check for additional data at a later stage. As measures prohibiting the use of the substance and thus limiting environmental and human exposure already are in place, a decreasing exposure trend can be expected. Therefore, no further initiatives are proposed with regard to methoxychlor.

8.1.3 PFOA, its salts and PFOA related compounds

Regulations that prohibit the production, use and import are in place in Denmark through the POP Regulation (Regulation 2019/1021).

Quality criteria for PFOA in groundwater, sludge, and soil are established. Quality criteria for surface water and quality standards for PFOA in drinking water are established. The quality criteria for surface water are established as a sum of 24 PFAS compounds which include both PFOA and PFHxS.

PFOA, its salts and PFOA related compounds are, like other stable PFAS, ubiquitously present in the environment. Knowledge about potential release sources, such as stockpiles or release from waste treatment, is vital to prevent increasing environmental exposures. Estimates on the amount of PFOA in stockpiles in Denmark are not available. Human exposure in the Danish population is generally decreasing, however, the main exposure pathways are not clear. Also, it is noted that this conclusion applies to PFOA, which human and environmental exposure is well-investigated compared to other PFAS, and not to PFAS is general. For PFOA, it can be anticipated that increased national and international attention and regulation will contribute to a further decrease of human exposure.

In fall 2023, a PFAS taskforce was established by the DK EPA. The members are experts on various aspects of PFAS related topics, such as presence in soil and groundwater, regulation, contaminant transport and healthcare etc. By 2024, the taskforce will present an overview of the knowledge gaps related to PFAS in Denmark. During 2024, the taskforce will formulate and prioritise PFAS related initiatives in order to close knowledge gaps. Any initiatives on PFOA (and PFHxS), its salts and related compounds should be coordinated with the initiatives proposed by the task force (DK EPA, 2023f). A PFAS action plan with focus on protection and monitoring of the exposure of people and the environment is expected. The knowledge gaps identified in this NIP related to PFOA will likely be handled in that context. Therefore, the work of the PFAS taskforce will be followed closely with focus on initiatives closing the knowledge gaps identified for PFOA. These initiatives are listed in TABLE 8-1.

TABLE 8-1. Initiatives in relation to PFOA, its salts and PFOA related compounds.

No.	Initiative	Description	Responsible	Timeframe
1	Follow the work of the PFAS taskforce	Follow and assess the work of PFAS taskforce with focus on: • The presence of PFOA precursors in the environment, especially regarding a potential increase in PFOA concentration in various media. • Knowledge generation regarding presence and removal of PFOA in leachate from landfills.	MIM	2024-2029
2	Follow-up on waste incineration	Knowledge generation regarding waste incineration	MIM	2024-2029
3	Follow-up on stockpiles	Remind stakeholders of their information and management obligations, if they are holders of a stockpile.	MIM	2024-2026

8.1.4 PFHxS, its salts and PFHxS related compounds

Similar to PFOA, PFHxS, its salts and related substances belong to the group of PFAS. The substances were never produced in Denmark. Historically, PFHxS has been used in numerous applications in Denmark. These include for example cardboard and paper, chemical industry, dry cleaners, textile and leather and wood and furniture.
Under the POP Regulation, there are no use exemptions for PFHxS, its salts and related substances.

PFHxS is ubiquitously present in the Danish environment with measured concentrations in both water, soil and air compartments.

The presence of PFHxS in humans confirms that the Danish population is exposed to this substance, however, the human biomonitoring data show that the trend is declining. Some of the measures and initiatives as described for PFOA, its salts and PFOA related compounds, do also apply for PFHxS, its salts and related substances (TABLE 8-2).

TABLE 8-2. Initiatives in relation to PFHxS, its salts and PFHxS related compounds.

No.	Initiative	Description	Responsible	Timeframe
1	Follow-up on waste incineration	Knowledge generation regarding waste incineration	MIM	2024-2029
2	Follow-up on stockpiles	Remind stakeholders of their information and management obligations, if they are holders of a stockpile.	MIM	2024-2026

8.1.5 Dechlorane Plus

There is a limited information available on the presence of DP in waste, stockpile, and contaminated areas in Denmark. Investigation on the leaching of problematic substances during storage of WEEE without weatherproof covering indicated uncovered storage of WEEE may not be a significant source of DP release in the environment. Furthermore, since there is no production of DP in Denmark, it can be estimated that the biggest stockpile of DP is probably in products currently in use which subsequently could end up in waste incineration plants. At this point, there are limited data available on the fate of DP in incineration plants and more studies are needed to better understand the incineration efficiency of waste containing DP.

Human exposure to DP can occur through dietary intake, however, there is a limited number of studies indicating presence of DP in food present on Danish market. Several other studies confirmed DP is present in various types of food in European countries other than Denmark, indicating widespread DP contamination and distribution across Europe.

There is limited information on the presence of DP in the environment. In general, high adsorption potential of DP and environmental monitoring data indicate DP is present rather in sediment and soil than water.

In biota, ∑DP concentrations were ranging below LOD (e.g., samples of freshwater fish, cod) to 83 ng/g lw in common eider collected from Baltic Sea. Furthermore, time trend analysis (1986-2014) of several organic pollutants in peregrine falcon eggs from South Greenland indicated concentrations for DP seemed to increase in contrast to other “novel” flame retardants which could be due to increased use of DP as a decaBDE substitute.

Possible route of human exposure to DP in Denmark could be through the consumption of fish, however, in the samples of edible fish such as perch and cod collected in Denmark, both syn-DP and anti-DP were below LOD. Additionally, the exposure of humans can occur during the indoor and outdoor consumer product use, and in the waste management of plastics and electronics.

Human biomonitoring data from Denmark are not available. Studies conducted in other European countries indicate there are regional differences when it comes to presence of DP in humans. The significance of the different possible exposure routes for the general population is not known and time trend data of environmental and human exposure are limited. A few data indicate that exposure of children may be higher compared to adults, which may relate to exposure via the indoor environment.

As described in TABLE 8-3, initiatives to follow-up on data availability regarding environmental exposure as well as assessing the need of defining environmental quality criteria will be conducted by MIM.

TABLE 8-3. Initiatives in relation to Dechlorane Plus.

No.	Initiative	Description	Responsible	Timeframe
1	Follow-up on data availability	Screening of DP in the environment as a part of NOVANA.	MIM	2024-2029
2	Assess the need of environmental quality criteria for the water environment	Assess whether an EQS for biota (and possibly sediment) to assess environmental exposure data is needed – pending the outcome of the NOVANA screening.	MIM/ DK EPA	2024-2029

8.1.6 UV-328

UV-328 was included in the authorisation list under REACH (Annex XIV) on 06.02.2020 with a sunset date of 27.05.2022, meaning that before this date companies will have to apply in order to continue to produce/import/use the substance in Europe (ECHA, 2020a). However, no request for authorisation has been received, indicating that the substance is no longer used in Europe and Denmark.

The European Automotive Manufacturers' Association (ACEA) is currently in the process of phasing out UV-328. By 2026, the substance will be phased out from their new products (UNEP, 2022b).

UV-328 has a wide range of applications. ~50% was used in car coatings and special industrial wood coatings. Another 40% are used for the protection of plastics and rubbers, which includes e.g. PVC, polycarbonates, polyacrylates and polyester.

Reuse and recycling of UV-328 containing wastes and stockpiles is not allowed under the Convention. However, there is limited knowledge whether products/components entering the waste contain UV-328, as no suitable detection technology is available on the market. This also makes the separation from UV-328 containing waste difficult. Wastes containing UV-328 should be thermally treated in order to ensure destruction of the substances and prevent recycling of the substance.

The biggest occurrence of UV-328 is probably in products currently on the market with the highest share likely in vehicles, however data are lacking.

Additionally, few data on the presence of UV-328 in the Danish and Nordic environment are available. Some biota data are available, at concentrations below levels of concern. Monitoring data in water and sediment are lacking.

Few data on human exposure to UV-328 in Denmark or the EU are currently available. A Spanish study indicates that humans are exposed to the substances. International studies on the exposure via house dust are available but would need to be confirmed in Europe. As such, it is thus not known whether the (former) use of the substance in plastic consumer products contributes to exposure to humans.

Initiatives for UV-328 are listed in TABLE 8-4.

TABLE 8-4. Initiatives in relation to UV-328.

No.	Initiative	Description	Responsible	Timeframe
1	Follow-up on data availability	Screening of UV-328 in the environment as a part of NOVANA.	MIM	2024-2029

8.2 Summary and timetable

A summary of the initiatives and the timetable for the implementation is provided in TABLE 8-5.

TABLE 8-5. Summary of initiatives of the newly added POP

Substance	No.	Initiative	Description	Responsible	Timeframe
Dicofol	-	-	(Additional measures not required)	-	-
Methoxychlor	-	-	(Additional measures not required)	-	-
PFOA, its salts and PFOA related compounds	1	Follow the work of the PFAS taskforce	Follow and assess the work of PFAS taskforce with focus on: • The presence of PFOA precursors in the environment, especially regarding a potential increase in PFOA concentration in various media. • Knowledge generation regarding presence and removal of PFOA in leachate from landfills.	MIM	2024-2029
	2	Follow-up on waste incineration	Knowledge generation regarding waste incineration	MIM	2024-2029
	3	Follow-up on stockpiles	Remind stakeholders of their information and management obligations, if they are holders of a stockpile.	MIM	2024-2026
PFHxS, its salts and PFHxS related compounds	1	Follow-up on waste incineration	Knowledge generation regarding waste incineration	MIM	2024-2029
	2	Follow-up on stockpiles	Remind stakeholders of their information and management obligations, if they are holders of a stockpile.	MIM	2024-2026
Dechlorane Plus	1	Follow-up on data availability	Screening of DP in the environment as a part of NOVANA.	MIM	2024-2029
	2	Assess the need of environmental quality criteria for the water environment	Assess whether an EQS for biota (and possibly sediment) to assess environmental exposure data is needed – pending the outcome of the NOVANA screening.	MIM/ DK EPA	2024-2029
UV-328	1	Follow-up on data availability	Screening of UV-328 in the environment as a part of NOVANA.	MIM	2024-2029

9. Follow-up on initiatives identified in the previous NIP and updated information about selected previously added POPs

The objective of the chapter is to provide updated information for selected POPs that have been added to the Stockholm Convention before 2018. These POPs have been reviewed in the earlier Danish NIPs. However, for some of these POPs, new data are available, requiring an update of the Danish situation for those substances.

9.1 Follow-up on initiatives identified in the previous NIP

In the earlier update of the NIP (MIM, 2018), the Danish situation was described for the POPs substances added to the Convention between 2013 and 2017; namely hexachlorobutadiene (HCBD), decabromodiphenyl ether (decaBDE), short-chained chlorinated paraffins (SCCPs), pentachlorophenol (PCP) and its salts and esters, polychlorinated naphthalenes (PCNs) and hexabromocyclododecane (HBCDD or HBCD).
Furthermore, the previous NIP identified a few initiatives ensuring the implementation of the requirements of the Stockholm Convention in Denmark. For additional information about the previously added POPs as well as the main challenges with the substances, please refer to the last NIP update (MIM, 2018).

TABLE 9-1 summarises the 2018 initiatives, as well as the current status of the initiatives for each substance.

TABLE 9-1. Substances and initiatives as identified in previous NIP update (MIM 2018) as well as current status.

Substance/ Area	No.	Initiative/description	Time frame	Responsible[1]	Status 2023
DecaBDE and other PBDEs	1	**Control and awareness raising** Undertake control of products on the Danish market. Assess how materials with PBDEs can be separated from the waste stream prior to recovery and other waste treatment. Prepare advice for recycling companies	Continually	MIM	Brominated flame retardants (isomers BDE-47, BDE-99, BDE-100) were included in a market and literature survey of emission of particles and volatile substances from gaming equipment on the Danish market in 2022. No elevated levels of PBDEs were found (DK EPA, 2023i). In 2023, an enforcement project on flame retardants in electrically heated textiles was initiated, covering, among other substances, PBDEs. The project will be finalised in 2024. In 2020, PBDE´s (and other hazardous substances) were included in chapter 11 in the Danish Statutory Order on Waste. According to chapter 11 a building must be screened for hazardous substances prior to demolition. Waste from the demolition containing or contaminated with hazardous substances must be separated from the rest. A desk study on destruction of POPs (including PBDE) in MSW incinerator was published in 2019 (DK EPA, 2019). The study was not able to finally conclude on the destruction efficiency. The work to assess the destruction efficiencies therefore continues.
SCCPs	1	**Evaluate need for further information** Evaluate the need for further information on SCCP-waste to contractors, property owners, municipalities, and other stakeholders involved in activities related to building renovation and demolition.	2019-2020	MIM	MIM has since 2019 worked with initiatives to increase better sorting of building waste in order to increase recycling and at the same time prevent POP and other hazardous materials from re-entering in new products. An example is the regulation that is presently developed regarding better screening of (larger) buildings before demolition. This is expected to be followed up by information for relevant stakeholders. This initiative also targets SCCP.

Substance/ Area	No.	Initiative/description	Time frame	Responsible[1]	Status 2023
		If the evaluation demonstrates the need for further information, the MFVM will prepare it accordingly.			
HBCDD	1	**Assess the need for selective collection and disposal of EPS and XPS with HBCD** Assess whether selective sorting with the aim of destruction of EPS and XPS with HBCDD should be required on the basis of an evaluation of the efficiency of incineration of HBCDD in MSW incinerators.	2019-2020	MIM	A desk study on destruction of POPs (including HBCD) in MSW incinerators was published in 2019 (DK EPA, 2019). The study was not able to finally conclude on the destruction efficiency. The work to assess the destruction efficiencies therefore continues.
	2	**Evaluate need for further information** Evaluate the need for further information for contractors, property owners, municipalities, and other stakeholders involved in activities related to building renovation and demolition on identification and handling of HBCDD-waste. If the evaluation demonstrates the need for further information, the MFVM will prepare the required guidelines.	2019-2020	MIM	MIM has since 2019 worked with initiatives to increase better sorting of building waste in order to increase recycling and at the same time prevent POP and other hazardous materials from re-entering in new products. An example is the regulation that is presently developed regarding better screening of (larger) buildings before demolition. This is expected to be followed up by information for relevant stakeholders. This initiative will also target a substance as HBCDD.
PCB	1	**PCB in transformers and capacitors**	2019-2020	MIM	The investigation has been finalized. It indicates that large PCB-transformers (with concentrations > 500 ppm) have been disposed of in Denmark. The investigation also

Substance/ Area	No.	Initiative/description	Time frame	Responsible[1]	Status 2023
		Finalise current study on PCB in transformers and capacitors and evaluate if further initiatives are needed			indicates that of smaller number of large PCB-capacitors may still be present in Denmark. Low concentrations of PCB (< 50 ppm) are still found in large transformers and capacitors that are being disposed of in Denmark. The source of the low concentrations of PCB in large transformers and capacitors are believed to be: residues of PCB's that have not been completely removed when transformers have been decontaminated, PCB-contamination on the production site and/or use of regenerated PCB-containing oil. Small PCB-capacitors in fluorescent lamps are still in use in Denmark. The results do not warrant further initiatives.
	2	**Follow the results of the risk assessment of low-chlorinated PCBs** Follow the results of the ongoing HESPERUS project, which assesses the risk of low-chlorinated PCB in the indoor environment. Assess to what extent further actions would be needed based on the results of the project.	2019-2022	The Danish Health Authority	HESPERUS (Health Effects of PCBs in Residences and Schools) denotes a project studying the long-term health effects of the lower-chlorinated, semi-volatile PCBs in the indoor environment in two separate cohorts of individuals who have either attended schools or lived in apartment buildings (Bräuner et al., 2016). The Danish Health Authority and the Danish Patient Safety Authority collaborate on health effects of exposure to PCBs with the register-based 'Health Effects of PCBs in Indoor Air' (HESPAIR) cohort, comprising ca. 52,000 Danish residents of two residential areas with apartments built with and without PCB-containing materials. The authorities have followed and assessed the results of the HESPAIR studies, in total five peer-reviewed publications. An association between indoor exposure to low-chlorinated PCBs and a marginally increased risk of type 2 diabetes without an exposure-response relationship was described. Additionally, limited support for an increased risk of cardiovascular disease, no increased risk for development of

Substance/ Area	No.	Initiative/description	Time frame	Responsible[1]	Status 2023
					most specific cancer types except meningiomas and liver cancer, and no consistent increased risk of effects on male reproductive parameters was associated to indoor exposure to low-chlorinated PCBs. In contrast, an increased risk of cryptorchidism among boys after maternal airborne exposure has been described. According to the Danish Health Authority, the human observational study results need further corroboration in other studies to draw consolidated conclusions and potential subsequent regulatory actions. Furthermore, experimental investigations on the hazardous properties of the low-chlorinated, non-dioxin-like PCBs are also necessary. Updated information for the school cohort under HESPERUS was not identified.
	3	**Waste incineration** Further assessment of the destruction of PCB in MSW incinerators. Revisit the assessment of destruction efficiency for PCB along with results of the ongoing assessment of efficiencies for other POPs. Assess, on this basis, the need for further initiatives	2019-2020	MIM	A desk study on destruction of POPs (including PCB) in MSW incinerator was published in 2019 (DK EPA, 2019). The study was not able to finally conclude on the destruction efficiency. The work to assess the destruction efficiencies therefore continues.
PFOS	1	**Withdrawal of notification** Withdraw notification of PFOS in mist suppressants for non-decorative hard chrome plating.	2018-2019	MIM	Denmark has informed about the phase out of PFOS for non-decorative chrome plating and the switch to alternatives for this application in the national reports under the Stockholm Convention and POPs Regulation.

Substance/ Area	No.	Initiative/description	Time frame	Responsible[1]	Status 2023
		Inform the Secretariat of the SC and the European Commission on Denmark's experience with the substitution of PFOS for this application			
	2	**Waste incineration** Evaluate the need for further initiatives based on the results of a desk study on destruction of PFOS and other POPs in MSW incinerators operating at a temperature of 850˚C	2019-2020	MIM	A desk study on destruction of PFAS (including PFOS) in MSW incinerator was conducted in 2023 (DK EPA 2023b). This knowledge is used in the ongoing work regarding action on PFAS in waste.
Dioxins and other unintentionally formed POPs	1	Inform users to use clean and dry wood and not to burn waste in wood stoves in future campaigns	2019-2020	MIM	Campaigns have been carried out by the Danish EPA
	2	Undertake screening surveys for emissions of HCBD and PCNs	Continually	MIM	The work on emission inventories is continuously developed.. No new information is available for HCBD and PCNs in emissions and it has to be further evaluated to what extent it is possible to include these substances in a screening survey.
	3	Follow the progress of the HALOSEP project and, on the basis of the results, assess whether further activities should be initiated and whether changes should be made to the legislation on disposal of flue-gas cleaning products. MIM will assess whether further activities should be initiated and whether changes to the legislation regarding the disposal of	2020-continually	MIM	The HALOSEP process has been in full scale application since January 2021 at the municipal waste incineration plant Vestforbrænding in Copenhagen. Currently, the flue gas cleaning residue at Vestforbrænding is classified as non-hazardous waste. However, it is currently exported for landfilling in Sweden, as none of the Danish waste recipients are approved to receive this comparatively

Substance/ Area	No.	Initiative/description	Time frame	Responsible[1]	Status 2023
		flue gas cleaning products should be made.			new waste fraction and guidelines regarding possible use of the waste, e.g. for building purposes, are lacking. The Danish EPA is planning a dialogue with Vestforbrænding primo 2024 to learn more about their results.

[1] In the 2018 NIP, reference is made to the Ministry of Food and Environment (Danish abbreviation: MFVM).

[2] The publications can be found here: Kofoed et al., (2021): Maternal exposure to airborne polychlorinated biphenyls (PCBs) and risk of adverse birth outcomes; Tøttenborg et al., (2022): Prenatal exposure to airborne polychlorinated biphenyl congeners and male reproductive health; Deen et al., (2022): Cancer Risk following Residential Exposure to Airborne Polychlorinated Biphenyls: A Danish Register-Based Cohort Study. Environ Health Perspect; Deen et al., (2023): Risk of cardiovascular diseases following residential exposure to airborne polychlorinated biphenyls: A register-based cohort study; Deen et al., (2023a): Exposure to airborne polychlorinated biphenyls and type 2 diabetes in a Danish cohort.

9.2 Updated information about selected previously added POPs

9.2.1 PFOS, its salts and PFOS-F

In 2020, high concentrations of PFOS were detected in the municipal wastewater treatment plant in Korsør. The source of the contamination was identified as a fire training facility near Korsør (Korsør brandskole). Following this the site was investigated in 2021 and extensive PFOS contamination was found, both in soil and groundwater, drains and surface water. Cows were grazing at wetlands that were repeatedly flooded with PFOS contaminated surface water, leading to high concentration of PFOS in veal meat (180 ng/g), exceeding the TWI values from EFSA. As high concentrations of PFOS were found in the blood in the population who had consumed the meat, this was the start of the "Korsør case" (Slagelse Municipality, 2023).

In Danish marine waters, fish were collected from nine sampling stations under the NOVANA programme in 2021 (Hansen & Høgslund, 2023). Liver samples were analysed for PFOS, since PFAS compounds tend to accumulate in the liver of fish, and hence, analysing liver samples gives the highest probability of detection. The detection rate was 100% of the nine samples. The median PFOS concentration in 2021 was 0.54 µg/kg wet weight (ww). The highest concentrations were measured at two sampling stations in Øresund with 1.1 µg/kg ww (Kalvebod) and 0.9 µg/kg ww (Nivå Bugt). Generally, there were no exceedances of the quality criterion for fish as food products, 9.1 µg/kg ww, which is specified for muscle tissue. The concentration in fish muscle tissue has been shown to be a factor 5-10 lower than the concentration in fish liver tissue. Hence, the observations were in compliance with the quality criterion, even without converting to the lower concentration in muscle tissue. Comparing to previous NOVANA sampling campaigns, a significant decreasing trend was seen in PFOS concentrations in fish lever. An example is shown in Figure 9-1.

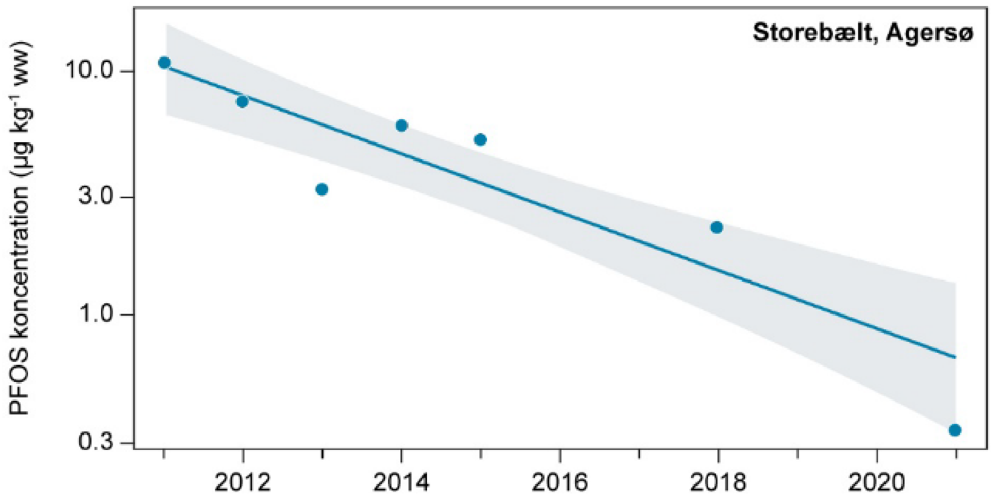

Figure 9-1 PFOS concentration in fish liver from sampling station Agersø in Storebælt (Hansen & Høgslund, 2023).

The DVFA surveying of PFAS in food includes yearly measurements of PFOS in wild fish. During 2020 – 2022, each year 18 – 21 samples of 10 – 11 fish species were analysed for eight PFAS substances, hereunder PFOS. PFOS was detected in 5 – 13 out of 18 – 21 samples at concentrations of 0.4 – 2.2 µg/kg. PFOS was only detected in bottom-dwelling fish and measured concentrations were below EU limit values for PFOS (DVFA, 2021, 2023a, 2023b).

Based on review and synthesis of numerous human exposure studies, Hull et al., (2023) recently published a review study with temporal trends of PFAS concentrations in the Danish population (Figure 4-3). Overall, an increase of PFOS exposure in the period from 1988 until late 1990s followed by a decrease from 2000 to 2021, was concluded for the population in Denmark and other European countries. For more details on the study, see section 4.7.2 and Figure 4-3.

With respect to current use and supply in Denmark, data for PFOS and PFOS-related substances from Statistics Denmark[17] were retrieved for PFOS and PFOS-related substances.

TABLE 9-2 shows the net import of PFOS and PFOS-related substances as such or in products as extracted from Statistics Denmark (statistics UVH3).

The main reported PFOS-related substances in 2022 were n-methylperfluorooctane sulphonamide (CAS No. 31506-32-8), tetraethylammonium perfluorooctane sulphonate (CAS No. 56773-42-3) and diethanolammonium perfluorooctane sulphonate (CAS No. 70225-14-8). In the REACH registration database on ECHA's website, tetraethylammonium perfluorooctane sulphonate substances are registered with "ceased manufacture" and no volumes. In the PFAS restriction proposal, the registered tonnage band for the substance is indicated at 0-10 t/y (ECHA, 2023). The other two substances are preregistered under REACH but not registered.

TABLE 9-2. Net import of PFOS and PFOS-related substances as substances or in products. Quantities rounded to one decimal. Substances with recent registered net import (2021, 2022) in bold.

CN 8 code		Net import, t/y				
		2018	2019	2020	2021	2022
2904 3100	Perfluorooctane sulphonic acid	0.0	0.0	0.0	0.0	0.0
2904 3200	Ammonium perfluorooctane sulphonate	0.0	0.0	0.0	0.0	0.0
2904 3300	Lithium perfluorooctane sulphonate	0.0	0.0	0.0	0.0	0.0
2904 3400	Potassium perfluorooctane sulphonate	0.0	0.0	0.0	0.0	0.0
2904 3500	Other salts of perfluorooctane sulphonic acid	0.0	0.0	0.0	0.0	0.0
2904 3600	**Perfluorooctane sulphonyl fluoride**	**0.0**	**0.0**	**0.0**	**45.5**	**0.0**
2922 1600	**Diethanolammonium perfluorooctane sulphonate**	**0.2**	**0.2**	**0.4**	**0.5**	**0.1**
2923 3000	**Tetraethylammonium perfluorooctane sulphonate**	**11.6**	**2.0**	**1.6**	**1.6**	**2.5**
2923 4000	Didecyldimethylammonium perfluorooctane sulphonate	0.0	0.0	0.0	0.0	0.0
2935 1000	**N-Methylperfluorooctane sulphonamide**	**11.1**	**22.5**	**11.8**	**0.0**	**26.4**
2935 2000	N-Ethylperfluorooctane sulphonamide	0.0	0.0	0.0	0.0	0.0
2935 3000	N-Ethyl-N-(2-hydroxyethyl) perfluorooctane sulphonamide	0.0	0.0	0.0	0.0	0.0
2935 4000	N-(2-Hydroxyethyl)-N-methylperfluorooctane sulphonamide	0.0	0.0	0.0	0.0	0.0
2935 5000	Other perfluorooctane sulphonamides	1.4	1.4	0.0	0.0	0.0
3824 8700	**Containing perfluorooctane sulphonic acid, its salts, perfluorooctane sulphonamides, or perfluorooctane sulphonyl fluoride**	**0.0**	**10.0**	**0.0**	**0.0**	**0.8**

[17] Statistics Denmark https://www.dst.dk/en/

The registered import of four specific PFOS-related substances is surprising considering that the use of the substances has been restricted in the EU for several years. As shown in the TABLE 9-3 below, two of the substances are not registered (but preregistered) under REACH whereas the other two are registered. However, the registered substances factsheets under" total tonnage band" indicate that manufacture has ceased. Data from the SPIN database[18] with data from the Product Registries in the Nordic Countries (Denmark, Finland, Norway, Sweden) indicate that three of the substances have formerly been used in the countries but the quantities are confidential. In the SPIN database, the consumption of tetraethylammonium perfluorooctane sulphonate (CAS No. 56773-42-3) in Denmark in 2021 is indicated as "confidential".

TABLE 9-3. Supporting information for the four specific substances indicated as imported.

	CAS No	SPIN (use data for DK, FI, NO and SE)	REACH registering
Perfluorooctane sulphonyl fluoride	307-35-7	No data	Registered - indicated as "Cease manufacture" and no volume
Diethanolammonium perfluorooctane sulphonate	70225-14-8	Conf. data until 2012	Not registered
Tetraethylammonium perfluorooctane sulphonate	56773-42-3	Conf. data until 2021	Registered - indicated as "Cease manufacture" and no volume
N-Methylperfluorooctane sulphonamide	31506-32-8	Conf. data until 2003 (only SE)	Not registered

A likely explanation for the registered import of tetraethylammonium perfluorooctane sulphonate could be that the importer historically has used this commodity code and still uses it in the absence of other specific codes for the used PFAS.

The 45.5 t/y reported for perfluorooctane sulphonyl fluoride (PFOS-F) in 2021 could be an accidential mix-up of commodity codes as no import of N-methylperfluorooctane sulphonamide is registered for the same year.

For N-methylperfluorooctane sulphonamide and diethanolammonium perfluorooctane sulphonate, no likely explanation for the registered quantities has been identified.

For N-methylperfluorooctane sulphonamide, import has during the period 2018-2022 been registered from France, Poland, Sweden, and Czeck Republic (from up to three countries some years) meaning that the registered import is not due to a single erroneous reporting. According to Nicolajsen and Tsitonaki (2016), no data are reported to the Danish Product Registry for this substance.

The MIM will follow up on this information and take action as appropriate.

The European Commission has published an initiative to draft an act to revise the entry of PFOS in the POP Regulation to align it with the with the entry of PFOA with respect to substance identity and unintentional trace contamination (UTC) levels when present in substances, mixtures and articles[19]. This would lower the UTC value from 10 mg/kg to 0.025 mg/kg for PFOS and its salts and the UTC value for PFOS-related compounds to 1 mg/kg when present in substances, mixtures and articles. The current specific exemption for use in

[18] SPIN - Substances in Preparations in Nordic Countries, http://spin2000.net/

[19] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13666-Persistent-organic-pollutants-PFOS-limits-and-exemptions_en

non-decorative hard chromium plating and the reference to the use of specific standard analytical tests would both be deleted.

9.2.2 PCP

Pentachlorophenol and its salts and esters were previously used in Denmark as a wood preservative. They have never been produced in Denmark but imported and used in the country.
The previous NIP (MIM, 2018) concluded there are no significant issues with regard to the presence of PCP in the waste streams with no further actions needed in order to comply with the requirements of the Stockholm Convention and the POP Regulation.

In the meantime, some new relevant data became available regarding the presence of PCP in the food on Danish market and the overall environmental and human health exposure. However, it should be noted that new data on PCP are very limited and thus does not change the overall conclusion given in the NIP from 2018 where the substance was originally introduced.

Findings on the presence of PCP in food on the European market do not raise any concerns since there were only few detections or no detections at all. More specifically, in the European Union report from 2017 on pesticide residues in food published by EFSA, PCP was not quantified in any of the 6984 samples taken for analysis from six different European countries (EFSA, 2019). A year later, PCP was quantified in only 1 out of the 7471 samples (quantification rate of 0.01%) taken for analysis from 7 different European countries (EFSA, 2020).

PCP was detected in the study from Lübeck et al., (2023) which measured PCP in freshwater sediment samples (n=17) from Copenhagen, Denmark. In the sediment samples (0-30 cm) collected in 2017 from the lake Utterslev Mose and the adjacent fortress channel, PCP was measured in a concentration range of <LOQ-7.64 ng/g ww and 2.46-44.13 ng/g ww, respectively. PCP was detected in 16 out of 17 collected samples. As concluded by the study, this is probably due to the continuous influx of the surrounding sewer overflow and other man-made pollutants for several decades. In another lake sediment within the Capital Region, Bagsværd Sø, a concentration of 20 ng/g dw was measured in 2022. Measured concentrations in other sediment samples taken between 1995-2022 of lakes, streams and marine areas (n=69) as well as in the water compartment (n=987) were generally below the quantification limit.[20] However, it is noted that the quantification limits for sediments are rather high (10-50 µg/kg dw). Due to the limited information available for Denmark, there is uncertainty regarding the significance of the PCP being present in sediments.

There have also been few changes in the regulation. More specifically, with the Regulation (EU) 2021/277, the European Commission amended the Annex I of EU POP Regulation where PCP is now listed with Unintentional Trace Contaminant (UTC) limit value. To allow the recycling of wood chips and facility enforcement, a UTC limit of 5 mg/kg (0.0005 % by weight) is set. The update entered into force in 2021. Furthermore, with Regulation (EU) 2022/2400, the European Commission amended the EU POP Regulation and added new Annex IV and V waste limit values for PCP. Previously, PCP did not have an Annex IV and V limit value. Thus, new limit values of 100 mg/kg in Annex IV and of 1,000 mg/kg in Annex V were set for PCP.

9.2.3 PBDE

The previous NIP from 2018 reflected on the measures introduced for decaBDE, technical pentaBDE, and technical octaBDE.

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[20] Available at https://miljoedata.miljoeportal.dk/, chemistry search parameter "Pentachlorphenol" (accessed November 28, 2023).

As part of the OSPAR assessment, PBDE concentrations were measured in sediment and biota from several monitoring sites, including Denmark, Norway, and Germany. Observations for PBDE in biota were recorded across stations from 1999 to 2020, while observations for PBDE in sediment spanned the period from 2006 to 2020. Obtained results were compared with the OSPAR Background Assessment Concentrations (BAC) and the Federal Environmental Quality Guidelines (FEQG). Comparison showed that concentrations of PBDE in the OSPAR assessment area are either stable or decreasing. Although the concentrations remain above the BAC, they are generally below the Federal Environmental Quality Guidelines (FEQG). As a result, PBDE concentrations are not expected to have harmful effects on marine organisms (Viñas et al., 2022).

With Regulation (EU) 2022/2400 the European Commission amended the EU POP Regulation and added new Annex IV waste limit values for the sum of the listed PBDE. The previous limit value of 1,000 mg/kg for the sum of tetra-, penta-, hexa- and heptaBDE (note: decaBDE was not yet included in this limit value) was replaced with 500 mg/kg until 29.12.2025 (including decaBDE). Between 30.12.2025 and 29.12.2027 a value of 350 mg/kg or the unintentional trace contamination value stated in Annex I, whichever is higher is valid. Starting 30.12.2027 a value of 200 mg/kg or the unintentional trace contamination value stated in Annex I, whichever is higher, is valid.

There has also been an additional change in the regulation. More specifically, with the Regulation (EU) 2022/2400 the European Commission amended the EU POP Regulation Annex V. Previously, a limit value of 10,000 mg/kg for the sum of tetraBDE, pentaBDE, hexaBDE and heptaBDE was set. The entry in Annex V now also includes decaBDE, in line with the entry in Annex IV.

9.2.4 Dioxins

Dioxins have never been produced intentionally but are unintentionally formed by a number of industrial chemical processes and combustion processes. Total emissions of dioxins (PCDD/PCDF) have decreased by 56 % since 1990, mainly due to a decrease in the energy industries caused by improved abatement at coal fired power plants and waste incineration plants (Figure 9-2, Nielsen et al., 2023). Most of the reduction took place from 1990 to 1999, largely as a consequence of the introduction of an EU-level emission limit value for dioxins (MIM, 2018). Emissions from non-industrial combustion (mainly wood combustion in residential plants) have increased as newer technologies have higher emission factors compared to older technologies. However, in later years the reduced wood consumption has led to falling emissions.

The main sources of dioxin emissions are the burning of biomass in wood-burning stoves and other small combustion plants, as well as fires. Non-industrial combustion (stoves and other small combustion plants) accounts for about 65% of total emissions (Figure 9-3, Nielsen et al., 2023).

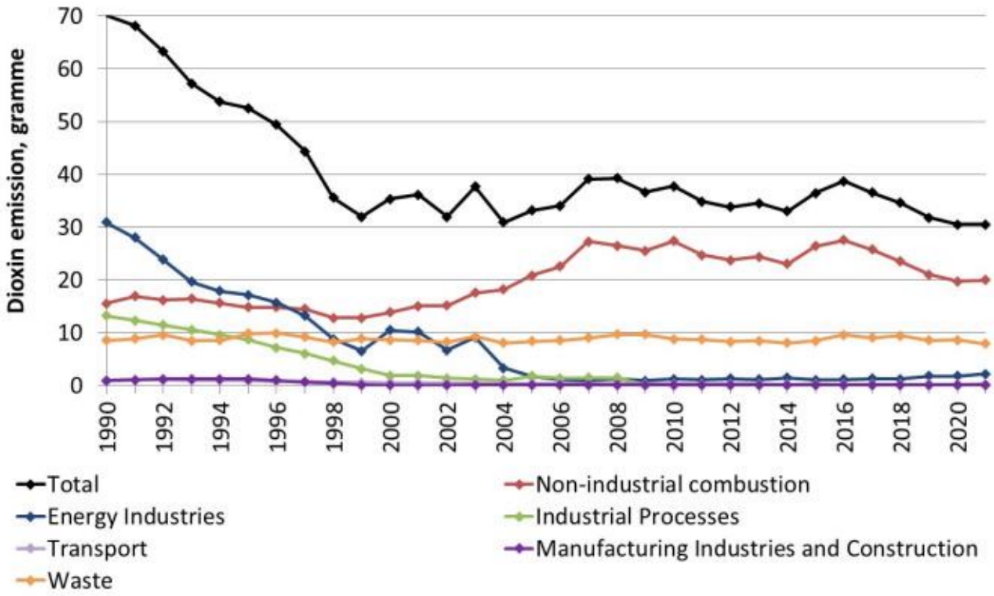

Figure 9-2 Emissions of dioxins and furans, time series for 1990 to 2021 (from Nielsen et al., 2023)

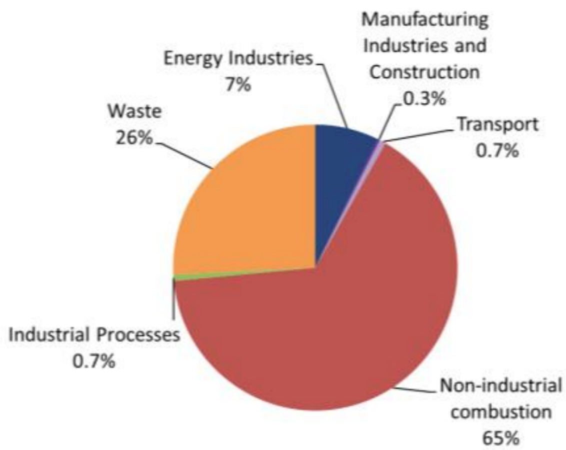

Figure 9-3 Emissions of dioxins and furans. Distribution according to the main sectors (2021) (from Nielsen et al., 2023)

With Regulation (EU) 2022/2400 the European Commission amended the EU POP Regulation and added new Annex IV waste limit values for dioxins. The previous limit value of 15 µg/kg was replaced with 5 µg/kg. Additionally, Article 21a was establishing transition periods for certain wastes such as fly ashes from biomass for heat and power production which had a limit value of 10 µg/kg until 31.12.2023, after which the 5 µg/kg (5,000 ng/kg) is the legal limit. Similarly, a limit value of 15 µg/kg is valid for ashes and soot from private households until 31.12.2024, after which the limit value of 5 µg/kg is valid. The Regulation also amended the Annex V limit value of 5 mg/kg which now also includes dioxin-like PCB (dl-PCB).

In order to reduce pollution from wood-burning stoves, new rules were introduced in Denmark with the statutory order on replacement or decommissioning of certain small combustion units

(BEK no. 1449 of 17/06/2021)[21]. This means that from 2021, homeowners are obliged to scrap or replace old wood-burning stoves produced before 2003 with a new stove, creating less pollution when they buy a new house. This statutory order was followed by the statutory order no. 640 of 24/05/2023[22] with an option for the municipalities to ban old wood stoves in areas with district heating. It is up to the municipalities to decide if they want to join this statutory order on old wood stoves. The statutory order entered into force in July 2023.

The statutory orders have an effect on the emission of dioxin, as a certain proportion of wood-burning stoves will be completely closed down, and firewood consumption will therefore fall. In the statutory order covering new owners of private homes about 50 % completely shut down their wood-burning stove instead of replacing. It should also be noted that according to a firewood consumption survey, firewood consumption has fallen by over 30% from 2015 to 2019 (Danish Energy Agency, 2020).

In a recent study by the Danish EPA (DK EPA, 2023h), the concentration of dioxins and furans in ash and soot from the combustion of biomass for heat and energy was studied in order to reconsider use and handling of the combustions waste (bottom ash, fly ash/soot). The study includes both small units such as wood-burning stoves (approx. 5 kW) and larger biomass boilers (1-40 MW). The authors describe that ash and soot from wood-burning stoves is usually handled as residual waste, while bottom and fly ash from larger biomass boilers are often used as fertilizer on agricultural land.
The results show that the amount of dioxins in bottom ash were much lower than for the associated soot/fly ash, irrespective whether the combustion products stem from wood-burning stoves, straw-fired plants or wood-fired plants. In most cases in this study, the toxicity equivalent TEQ is <1 ng/kg (total range 0–24 ng/kg) for bottom ash.
In the fly ash/soot, the TEQ are in the ranges:
124–1,290 ng/kg for wood stoves,
14–437 ng/kg for wood-fired boilers (79–142 ng/kg for wood-pellet-fired ones), and
2–417 ng/kg for straw-fired boilers.

The measured concentrations are all below the Annex IV waste limit values for dioxins in the POP Regulation. The study concludes that many factors impact the concentration of dioxins in the combustion waste, e.g. biomass type, different brands of stoves, boilers/combustion plants and different operating patterns (DK EPA, 2023h).

Another effort to reduce environmental dioxin emission is presented by the HALOSEP project, which originated from the Swedish recycling group Stena Metall AB and has been developed since 2010. With the improvement of flue gas cleaning during primarily the 1990's, emissions of dioxins to air have been reduced significantly, so that waste incineration today only accounts for a minor fraction of dioxin emissions to air. In contrast, the content of dioxins in the flue gas cleaning residues and fly ash have increased. The purpose of the HALOSEP project is to offer a local management method for fly ash from waste incineration, instead of exporting flue gas residues for landfilling/depositing in underground mines. Basically, the fly ash is lead through a process with several treatment steps, which in the end separate water, salt and a metal fraction. Hazardous substances are stabilised in a residual treatment product. The ultimate aim of the process is that the residual treatment product can be reused as building

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[21] In Danish: "Bekendtgørelse om udskiftning eller nedlæggelse af visse fyringsanlæg til fast brændsel under 1 MW ved ejerskifte af fast ejendom" https://www.retsinformation.dk/eli/lta/2021/1449https://www.retsinformation.dk/eli/lta/2021/1449

[22] In Danish: "Bekendtgørelse om kommunale forskrifter om udskiftning eller nedlæggelse af ældre brændeovne og pejseindsatse i områder med kollektiv varmeforsyning" https://www.retsinformation.dk/eli/lta/2023/640

material in e.g. as building material in road construction. The process has been in full-scale application at the MSW incineration plant Vestforbrænding in Copenhagen since 2021. Vestforbrænding reports that about 30-40% of dioxins in the fly ash are removed during the process, as the concentrations in fly ash and residual treatment product are about the same, but the amount of the residual treatment product only constitutes only about 60% of the amount of fly ash. The residual product is currently exported for landfilling in Sweden, as none of the Danish waste recipients are approved to receive this comparatively new waste fraction. The residual treatment product at Vestforbrænding is currently classified as non-hazardous waste, however, it is also noted that several substances are close to waste limit values (Vestforbrænding, 2023). Guidelines regarding possible uses of this waste fraction are currently missing.

Several companies in Denmark work with pyrolysis as a waste-to-energy recovery method, this includes waste such as plastics, wastewater sludge and different biomasses e.g. straw and digestat. Waste and biomass of diverse origin is via the pyrolysis process transformed into an oil, which again can be used as fuel or raw material in plastics production. Pyrolysis usually occurs at temperature around 500-600°C, whereas the dioxin formation temperature window is 400-700 °C. The formation of dioxins during pyrolysis of plastic waste or other waste is therefore a matter of concern, and comprehensive data are currently not available on this subject.

9.2.5 DDT

DDT is one out of the 12 initial POPs recognized under the Convention and described in the first Danish NIP (MIM, 2006), as well as in the update from 2018 (MIM, 2018). DDT is one out of two POPs listed on Annex B (Restriction) of the Convention, as DDT continues to be applied against mosquitoes in several countries to control malaria.

The first NIP (MIM, 2006) concluded that as a result of the low or non-existent occurrences of DDT in foodstuffs, waste products, the environment and the groundwater, no further initiatives would be necessary.

Currently, a soil quality criterion for DDT is defined at 0.5 mg/kg soil. The soil quality criterion is a value that must ensure that the free and very sensitive use of the land is sound in terms of health. The Environmental Protection Agency informs that there is currently no evidence available that causes the soil quality criterion for DDT to be raised. A cut-off criterion (being higher than the soil quality criterion), indicating the level of a substances above which soil must be remediated before it may be used for housing or other sensitive uses, is currently not defined for DDT.

DDT was detected sporadically in foods in the Danish Pesticide Residues in Food monitoring programme. Based on the detection during 2010-2017, hazard quotients for both children and adults were below 0.08, thus not indicating any risk (DTU Food, 2019).
DDT was sporadically detected in lamb or bovine meat during 2018 and 2019, but in concentrations below MRL (DTU Food, 2019a: 2021). During the food surveys of the later years, DDT was not detected. The results indicate that human exposure via food uptake continues to decrease. This is in line with earlier findings, describing that the daily intake has fallen significantly for DDT the past 20 years and that the content of POPs pesticides found does not give grounds for health concerns (MIM, 2006).

9.2.6 Lindane

Lindane is a chemical substance previously used as an insecticide with a number of approved applications in Denmark. Sale and use of lindane in Denmark was banned by Act no. 438 in

1994[23]. The NIP from 2012 (MIM, 2006) in which the substance was originally presented, concluded no further initiatives are needed since the substance is present in the environment at either very low or no concentrations at all.

In a recent study of Voutchkova et al., (2021), conducted with the aim to estimate pesticides in public drinking water at the household taps in Denmark, lindane was not detected in any of the samples (n=35) collected in 2019 from 23 different waterworks.

In an assessment from 2009, an investigation on which priority hazardous substances (PHS) pose a risk of exceeding the environmental quality standards (EQSs) for surface waters due to losses from contaminated sites and soils was performed. For lindane, two former production sites, Nordisk Alkali Biokemi (NAB) and Kemisk Værk Køge, were identified as the major potential sources of contamination. Investigations on point sources of lindane showed that lindane is found only in groundwater on forestry sites while in the case of machine stations and horticulture sites it was found only in the soil on 11 and 14% of the sites, respectively. When considering a total number of investigated sites (n=6), lindane was found in the groundwater in 17% of the sites (1 site). Ultimately, the risk of groundwater pollution with lindane on agricultural sites was estimated at 0.8%. It was also estimated that the size of a spill on production sites might be more than 100 m^2 with several of them on each site. Spill areas are estimated at around or smaller than 100 m^2 on agricultural sites. When it comes to exceeding the EQS, it was estimated 45% of all sites (i.e., 270 sites) have a risk of exceeding the EQS (MIM, 2009).

In a more recent publication from Vijgen et al., (2022) a systematic inventory on HCH or lindane is presented which might be of more significance, as it gives information on the location of suspected contaminated sites. This inventory, which was part of the international collaboration, revealed that there are in total 299 sites in Europe where HCH was handled (Figure 9-4). 8 sites were identified in Denmark (TABLE 9-4 and Figure 9-5).

TABLE 9-4. Overview of HCH suspected sites in Denmark (Vijgen et al., 2022).

Site	Number of sites	Names of processing sites
Production site	1	- Søborg, DK-SO-01
Processing site	5	- Esbjerg Kemikaliefabrik (DK-EB-01) - Kemisk Værk Køge (DK-SC-01) - Midol A/S (DK-IS-01) - Nordisk Alkali Biokemi (DK-NA-01) - Du Pont - former Grindstedværket A / S (DK-GR-01)
Waste deposit site	2	- Banegravsdepotet i Grindsted (DK-GR-01-01) - Grindsted Losseplads (DK-GR-01-02)

[23] Danish: LOV nr 438 af 01/06/1994, Lov om ændring af lov om kemiske stoffer og produkter (Forbud mod bekæmpelsesmidler, der indeholder visse aktivstoffer)

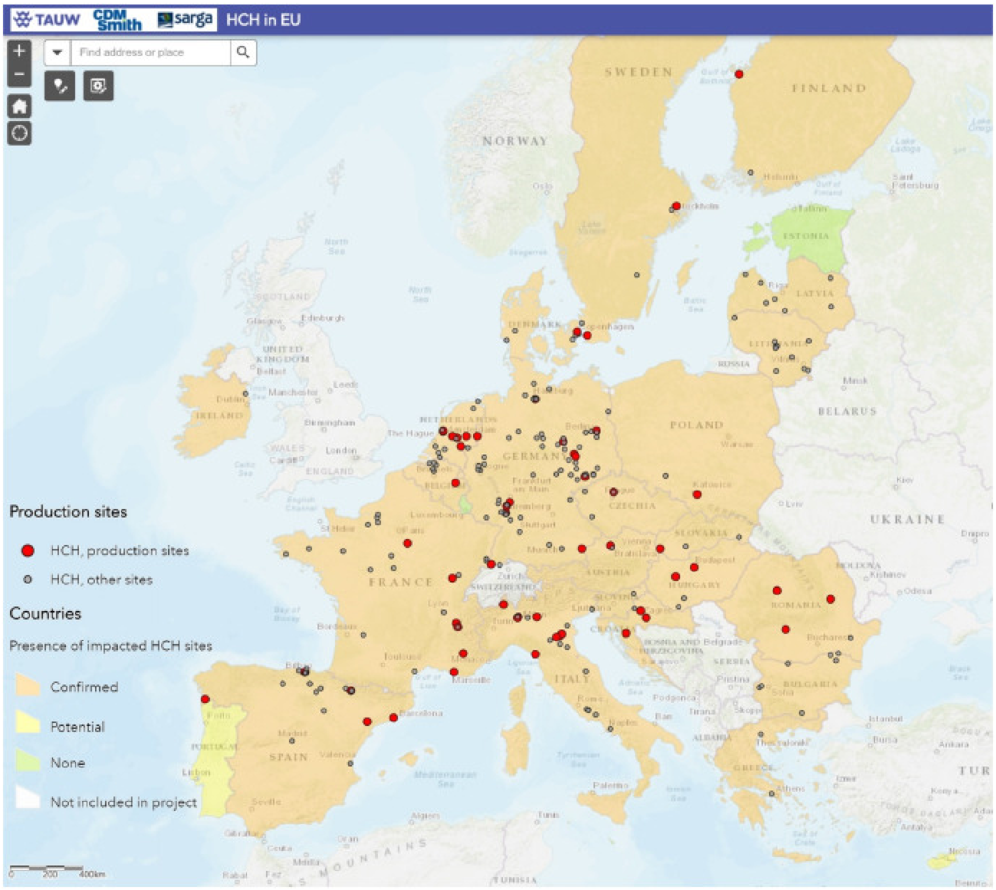

Figure 9-4. EU overview map with 299 identified sites where HCHs were handled (Vijgen et al., 2022).

Figure 9-5. Map of Denmark with the sites that are potentially impacted by HCH and lindane (European Commission, 2021b)

According to the European Commission, (2021b), the former Grindstedværket A/S factory in Grindsted (currently DuPont - DK-GR-01) is suspected of contaminating at least two waste dumps with HCH due to discharge of untreated waste waters or solid wastes. These locations are included in the Danish regions' general action on soil contamination. There are no specific actions for lindane, but the substance is included in the general risk assessment of sites. In relation to the contaminated sites at Grindsted, no further action is taken. At the sites where HCH has been detected, it is not considered to pose a risk (Danish Regions, 2023).

In the NIP from 2012, where the substance was originally presented, it was concluded that no further initiatives are needed for lindane in Denmark. This was due to low or non-existent presence of this substance in food, waste, the environment, and groundwater. New data have become available since (as outlined above), however, these data do not provide reason for concern. Therefore, further initiatives on lindane are not needed.

9.2.7 PCB

Polychlorinated biphenyls (PCBs) were widely used as flame retardants, plasticizers, and dielectric fluid. Due to numerous hazardous properties, they were regulated in Denmark and in the EU long before the Stockholm Convention came into force.

In general, a concern regarding the presence of PCBs in building materials was stressed in both previous NIPs. A more recent study from Hammel et al., (2023), confirmed, again, PCBs are present in housing estates (Brøndby Strand Parkerne) erected between 1969 and 1974. While the aim of the study was to identify dominant pathways of PCB exposure for residents of contaminated apartment buildings in Denmark, it also showed PCB is still present in materials assembled almost 50 years ago. All samples such as air, house dust, and surface wipes, as well as personal samples such as hand wipes and serum, were collected in 2017 and analysed for 15 PCB congeners (i.e., 7 indicator PCBs and further PCB-8, -11, -18, -31, -44, -66, -74, -99 and -105). Concentrations measured in corresponding environment or personal samples were used for the calculation of estimated daily intakes (EDIs) which were normalized to participants' body masses. Ultimately, these were used for the estimation of body burden which indicated that highest body burden comes from air and is followed by dermal and dietary uptake (Figure 9-6).

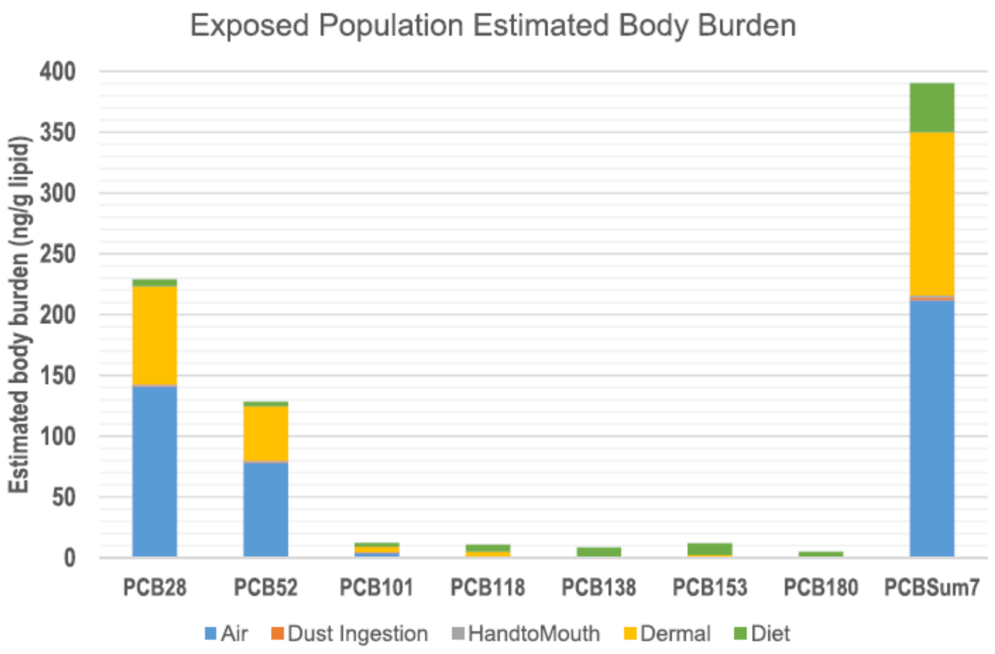

Figure 9-6. Median pathway-specific body burdens for each of seven PCB congeners and sum of seven indicator PCBs for the exposed population (Hammel et al., 2023).

Findings from the above presented study confirm, indeed, the persistence of PCBs in building materials and significant exposure to humans. However, with this issue already being addressed in previous NIPs and numerous initiatives already implemented, no further initiatives are needed.

Furthermore, Tøttenborg et al., (2022) investigated exposure of men to lower chlorinated PCBs (LC-PCBs) from indoor air of private homes built with PCB-containing materials. The study population included men whose mothers had lived in a contaminated apartment in Denmark (n=73) and men whose mothers had lived in an uncontaminated apartment in Denmark (n=111). Sampling took place from 2017 and 2019. Two residential areas included in the study were Farum Midtpunkt and Brøndby Strand Parkerne. PCB-28 concentrations in uncontaminated apartments were in the range of <LOD-19.8 ng/m^3 (Farum Midtpunkt) and 0.18-10 ng/m^3 (Brøndby Strand Parkerne). In contaminated apartments, PCB-28 concentration was in the range of 14.9-296 ng/m^3 (Farum Midtpunkt) and 2.6-487.2 ng/m^3 (Brøndby Strand Parkerne). For residents from Farum Midtpunkt, plasma samples revealed that the median combined concentration of congeners containing four or fewer chlorine atoms was 52 times higher in individuals exposed to the contamination compared to those who were not exposed. The concentrations were 3.51 µg/l (with a range from the 5th to 95th percentile of 0.55 to 13.28 µg/l) for the exposed group and 0.07 µg/l (with a range from the 5th to 95th percentile of 0.04 to 0.39 µg/l) for the unexposed group. Similarly, in Brøndby Strand Parkerne, a comparable contrast was observed, with a median concentration of 2.26 µg/l (with a range from the 5th to 95th percentile of 0.69 to 9.51 µg/l) for exposed individuals in contrast to 0.07 µg/l (with a range from the 5th to 95th percentile of 0.002 to 0.41 µg/l) for those who were not exposed. These studies affirm that residing in a building contaminated with PCBs significantly contributes to the accumulation of LC-PCBs in the body.

In the previous NIP from 2018 it was addressed that there is a lack of knowledge regarding the long-term health effects following airborne PCB exposure. For the same reason, Kofoed et al., (2021) conducted a study to determine whether exposure to airborne PCB during pregnancy leads to adverse birth outcomes. The authors noted an increased risk of cryptorchidism in boys due to maternal exposure to airborne LC-PCBs, ultimately concluding that LC-PCBs exposure may also lead to developmental toxicity. However, given the limitations in the exposure measurement method, inability to conduct dose-response analyses, and the scarcity of comparable literature, the authors concluded larger cohort studies are required for a thorough examination of the safety of residing and working in the PCB-contaminated environments during and before pregnancy.

According to the information provided on the OSPAR Assessment Portal (OAP), PCBs were measured in sediment, fish and shellfish from several monitoring sites, including Artic Waters, Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast. Samples were collected in period of 1985 to 2020 at frequencies ranging from annually to every five years. Obtained results were compared with BAC and Environmental Assessment Criteria (EACs). As concluded by the assessment, PCBs continue to be detected in marine sediments and in the biota (fish and shellfish) within the OSPAR Maritime Area. In some areas, the concentrations are assessed to be at levels that could have detrimental effects on marine life. While concentrations are decreasing in many sub-regions, there is one sub-region (in biota from the Southern North Sea) that shows an increasing trend. With the exception of the most toxic form (PCB-CB118), concentrations of all PCB congeners in sediment and biota are below the threshold at which they might pose an unacceptable risk to the environment. However, mean concentrations of PCB-CB118 in sediment are at or above this threshold in two of the six areas assessed, and in biota, this is the case for seven out of thirteen areas assessed. Despite PCBs being banned over 30 years ago, PCBs persist in sediment for extended periods and have the potential for biomagnification. They continue to enter the environment through secondary sources such as leachate from waste disposal sites thus indicating further research is needed to better define and quantify these inputs (Webster & Fryer, 2022).

9.2.8 SCCP

Regulation (EU) 2022/2400 the European Commission amended the EU POP Regulation and added new Annex IV waste limit values for the SCCP. The previous limit value of 10,000 mg/kg was replaced by 1,500 mg/kg. This limit value is subject to review by the European Commission, who shall adopt a legislative proposal to lower this value no later than 30.12.2027.

9.2.9 HBCDD

Regulation (EU) 2022/2400 the European Commission amended the EU POP Regulation and added new Annex IV waste limit values for HCBDD. The previous limit value of 1,000 mg/kg was replaced by 500 mg/kg. This limit value is subject to review by the European Commission, who shall adopt a legislative proposal to lower this value not higher than 200 mg/kg no later than 30.12.2027.

Abbreviations

AFFF	Aqueous film-forming foams
APFO	Ammonium perfluorooctanoate
CLRTAP	UNECE Convention on Long-range Transboundary Air Pollution
CLP	Classification, labelling and packaging
CMR	Carcinogenic, mutagenic or toxic for reproduction
DCE	Danish Center for Environment and Energy
DecaBDE	Decabromodiphenyl ether
Dioxins	Term for polychlorinated dibenzo-p-dioxins (PCDD) and poly-chlorinated dibenzofurans (PCDF)
DVFA	Danish Veterinary and Food Administration
dw	Dry weight
EC	European Community
ECHA	European Chemicals Agency
EEE	Electrical and electronic equipment
EFSA	European Food Safety Authority
E-PRTR	European Pollutant Release and Transfer Register
EPA	Environmental Protection Agency
EQS	Environmental quality standards
EU	European Union
FCM	Food contact material
GRUMO	Groundwater monitoring programme
HCH	Hexachlorocyclohexane, three forms: α, b and γ
LOD	Limit of detection
LOQ	Limit of quantification
LRTAP	Long-Range Transboundary Air Pollution
lw	Lipid weight
MSW	Municipal solid waste
NGO	Non-governmental organization
NIP	National Implementation Plan [for the Stockholm Convention]
NOVANA	The national programme for monitoring the aquatic environment and nature
octaBDE	Octabromodiphenyl ether
OECD	Organisation for Economic Cooperation and Development
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PBT	Persistent, bioaccumulative and toxic
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzofurans
PCP	Pentachlorophenol
pentaBDE	Pentabromodiphenyl ether
PFAS	Per- and polyfluoroalkyl substances
PFAS4	PFOS, PFOA, PFHxS and PFNA
PFAS12	Sum of 12 PFAS: PFBS (perfluorobutane sulfonic acid), PFHxS (perfluorohexane sulfonic acid), PFOS (perfluorooctane sulfonic acid), PFOSA (perfluorooctane sulfonamide), 6:2 FTS (6:2 fluorotelomer sulfonic acid), PFBA (perfluorobutanoic acid), PFPeA (perfluoropentanoic acid), PFHxA (perfluorohexanoic acid), PFHpA (perfluoroheptanoic acid), PFOA

	(perfluorooctanoic acid), PFNA (perfluorononanoic acid) and PFDA (perfluorodecanoic acid)
PFAS22	Sum of 22 PFASPFBA (perfluorobutanoic acid), PFPeA (perfluoropentanoic acid), PFHxA (perfluorohexanoic acid), PFHpA (perfluoroheptanoic acid), PFOA (perfluorooctanoic acid), PFNA (perfluorononanoic acid), PFDA (perfluorodecanoic acid), PFUnDA (perfluorundecanoic acid), PFDoDA (perfluorododecanoic acid), PFTrDA (perfluorotridecanoic acid), PFBS (perfluorobutane sulphonic acid), PFPeS (perfluoropentane sulphonic acid), PFHxS (perfluorohexane sulphonic acid), PFHpS (perfluoroheptane sulfonic acid), PFOS (perfluorooctane sulfonic acid), PFNS (perfluorononane sulfonic acid), PFDS (perfluorodecane sulfonic acid), PFUnDS (perfluorundecane sulfonic acid), PFDoDS (perfluorododecane sulfonic acid), PFTrDS (perfluorotridecane sulfonic acid), PFOSA (perfluorooctane sulfonamide), 6:2 FTS (6:2 fluorotelomer sulphonic acid)
PFHxS	Perfluorohexane sulfonic acid/sulfonate
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid/sulfonate
PFOSF	Perfluorooctanesulfonyl fluoride
PEC	Predicted Environmental Concentration
PNEC	Predicted No-Effect Concentration
POP	Persistent organic pollutant
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation (EC) No 1907/2006)
RoHS	Restriction of Hazardous Substances (...in electrical and electronic products Directive 2002/95/EC
TDI	Tolerable Daily Intake
TEF	Toxicity equivalency factor (for dioxins and dioxin-like PCBs)
TEQ	Dioxin toxicity equivalents (for dioxins and dioxin-like PCBs)
UNECE	United Nations Economic Commission for Europe
UTC	Unintentional Trace Contaminant
vPvB	Very persistent and very bioaccumulative
WEEE	Waste from electrical and electronic equipment
WWTP	Waste water treatment plant

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