Environment
Agency

Perfluorooctane sulfonate (PFOS) and related substances: sources, pathways and environmental data

October 2019

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Published by:

Environment Agency
Horizon House, Deanery Road,
Bristol BS1 5AH

www.gov.uk/environment-agency

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Executive summary

Perfluorooctane sulfonate (PFOS) belongs to a large, diverse group of man-made substances known collectively as perfluoroalkyl and polyfluoroalkyl substances (PFASs). Substances in this group are known for their water, grease and stain repellent properties. Over the past 50 years, perfluoroalkylated substances such as PFOS and PFOS related substances have been used in a diverse range of domestic consumer products, as well as in industrial processes and in aqueous film forming foams (AFFFs) used in fire-fighting.

PFOS is extremely persistent, toxic and bioaccumulates through the food chain. Most uses of PFOS have now been phased out, banned or restricted under a number of UK, EU and international regulations. PFOS was listed as a persistent organic pollutant (POP) in Annex B (restriction) of the UNEP Stockholm Convention on POPs in 2009.

In the Priority Substances Directive (2013/39/EU), PFOS is classed as a Water Framework Directive priority hazardous substance and as a ubiquitous persistent, bioaccumulative and toxic substance.

Despite the restrictions on use, older consumer products such as carpets, textiles and upholstery that have been treated with PFOS or PFOS-related substances will continue to act as a source of PFOS. Emissions can occur during the use, washing and disposal of such items, entering the environment via waste water treatment works or waste management facilities. Evidence in the scientific literature suggests the limited removal of PFOS is likely to occur via adsorption to sludge. Academic studies suggest that PFOS may also be formed during waste water treatment as a result the transformation of other PFOS related substances.

Additional, potentially significant sources of PFOS to the environment include landfill sites, industrial discharges and local historical contamination – especially around sites such as military bases and airports where there may have been significant use of AFFFs during fire-fighting training. PFOS can be present in soil from such historical sources or from the spreading of sewage sludge to land. Because PFOS is very water soluble and consequently very mobile, it can enter surface waters from contaminated soil as well as leach to groundwater.

PFOS is a widespread environmental contaminant. Our monitoring programme in surface waters has reported the presence of PFOS in all fish sampled from fresh, estuarine and coastal waters. Measured concentrations in fish ranged from below the environmental quality standard (EQS) to up to 4 times greater than the biota EQS.

The biota EQS for PFOS was set to protect both wildlife and people and is based on human health endpoints as these are the most sensitive. There are currently no regulatory limits for this substance in food, including fish, although this situation will be reviewed on the basis of new European Food Safety Authority opinions.

Monitoring of biota presents a number of challenges that are not encountered when we sample water including animal welfare concerns and practical considerations driven by the availability of suitable animals, accessibility and ecological impact of sampling. Consequently the extent of our biota surveillance programme is much smaller than our water monitoring network.

PFOS is frequently detected in surface waters across England. Concentrations of PFOS in water vary, but are typically reported at levels above a freshwater annual average (AA) EQS, a value that has been calculated from the biota EQS.

Analysis of our water and biota data from the same freshwater locations over several years suggests that using the water EQS to assess exceedance of the biota EQS may over predict the likely failure of the biota standard.

Analysis of measured concentrations of PFOS in freshwater and fish in the same locations suggest a correlation. We have used this to estimate the level in water above which we can infer failure of the biota EQS with reasonable confidence.

This provides the possibility of using water data to inform a national model of PFOS risk, drawing on relatively plentiful water sampling locations to supplement the limited coverage offered by biota sampling alone.

PFOS is one of the most frequently detected compounds in our groundwater monitoring programme, with 30% of sites sampled having positive detections (Lapworth et al, 2018).

Our evidence presents a clear picture of significant and widespread environmental contamination by PFOS. Limited data are available on trends in environmental concentrations over time. Some data in biota and water samples show a decline in environmental levels over time although many studies report no trend, whilst a few report increasing trends. The variability in reported temporal trends may reflect geographic variations as well as differing exposure routes within the food web.

To ensure appropriate and effective actions are implemented we need to better understand the sources of PFOS, the pathways and their relative significance, including the significance of high PFOS concentrations in groundwater and the impact on surface water quality. Further sewerage catchment, river catchment and sludge based investigations through the Water Industry Chemical Investigations Programme (CIP), and additional exploration of our existing evidence, are planned to help address this.

We are reviewing interventions that could be taken to mitigate further impacts. These include providing assurance that current legal supply and use of PFOS, such as the specialist permitted uses of PFOS, do not present a risk to the environment. We are reviewing a range of regulatory tools, across different regulatory regimes. These include lawful and unlawful stockpiles of PFOS, historic contamination, how we permit different activities and ensuring waste containing PFOS are managed correctly. This includes development of an Environment Agency strategy for sludge, which will look at the use of sludge on agricultural land.

Contents

1. Introduction

Perfluorooctane sulfonate (PFOS) belongs to a large, diverse group of man-made substances known collectively as perfluoroalkyl and polyfluoroalkyl substances (PFASs). Substances in this group are known for their water, grease and stain repellent properties.

Over the past 50 years, perfluoroalkylated substances such as PFOS and PFOS related substances have been used in a diverse range of domestic consumer products.

The term ‘PFOS related substances’ is commonly used to refer to any or all of the substances which contain the PFOS moiety that may break down in the environment to give PFOS (Environment Agency, 2004).

PFOS and PFOS related substances have been used historically to provide soil, oil and water resistance to textiles, clothes, home furnishings and upholstery, carpets and leather, paper and packaging, and coatings and coating additives (Environment Agency, 2004; KemI and the Swedish EPA, 2004). It was once the main ingredient in the popular product Scotchguard™ used to treat textiles and home furnishings. PFOS was voluntarily phased out by its main global producer, 3M, in 2001.

PFOS was also widely used as a component of aqueous film-forming foams (AFFFs) used in fire-fighting and in industrial processes such as chromium plating. Most uses of PFOS have now been phased out, banned or restricted in favour of alternatives under a number of UK, EU and International regulations (Section 5).

Releases to the environment arise mainly from the use, washing and disposal of consumer products previously treated with PFOS related substances (Environment Agency, 2004; Earnshaw et al., 2014). Waste water treatment works (WwTWs) are a significant source of PFOS to the environment (Earnshaw et al, 2014; Lindim et al, 2015; Whiting et al, 2012). Its use in fire training and major incidents has also resulted in historical contamination of soil, groundwater and surface water (Weiß et al., 2012; West, 2015; Ahrens et al., 2015; Filipovic, 2015).

PFOS is frequently detected in the water environment, even in relatively pristine areas such as the Arctic (Loos et al., 2008; Buck et. al, 2011; Munoz et al., 2015). PFOS and related substances are very stable and do not break down easily, remaining in the environment for many years. They can accumulate in wildlife and humans, and are potentially harmful.

Exposure to PFOS can cause significant health problems in birds, mammals and humans – ranging from changes in organ and/or body weights, cancer, and developmental abnormalities to death (Public Health England, 2009; COT, 2006).

PFOS is also toxic to aquatic organisms including fish, invertebrates and algae (KemI and the Swedish EPA, 2004; Environment Agency, 2004; EC, 2011; European Commission (impact assessment), 2011).

The extreme persistence, potential to bioaccumulate and toxicity of PFOS meet the criteria for classification as a Persistent Organic Pollutant (POP). As such PFOS was listed on Annex B (restriction) of the UNEP Stockholm POPs Convention in 2009.

PFOS is a priority hazardous substances under the Water Framework Directive (WFD). It was included as a priority substance in the revised Priority Substances Directive (2013/39/EU), with the objective of achieving good chemical status in surface waters by 2027. In line with the reporting requirements of the Priority Substances Directive, monitoring programmes and a draft programme of measures for PFOS were reported for the first time to the Commission in December 2018.

Environmental quality standards (EQSs) for PFOS are listed in both water and biota. The annual average (AA) EQS for inland surface waters is 6.5×10^{-4}µg/l and the AA EQS for other surface waters is 1.3×10^{-4}µg/l. The biota EQS is 9.1µg/kg wet weight.

In water at environmentally relevant pH values, PFOS is not present as perfluorooctane sulfonic acid or as one of its salts, but instead as the fully dissociated anion, perfluorooctane sulfonate ($C_8F_{17}SO_3^{2-}$). The anion is very water soluble and consequently is very mobile and may leach to groundwater.

PFOS may be formed as a degradation or transformation product of related substances (known as PFOS-substances) and polymers (PFOS-polymers) (Environment Agency, 2004). The number of substances involved, and the lack of information about the degree to which they act as sources of PFOS in the environment, has led to previous risk evaluation work (OECD, 2002; Environment Agency, 2004) grouping substances into three types (PFOS, PFOS substances and PFOS polymers) to simplify their evaluation for risk assessment purposes. Restrictions on PFOS, as described in Section 5 apply to both PFOS and PFOS related substances. A comprehensive list of PFOS related substances was published by the OECD in 2007 (OECD, 2007)

An overview of the substances, their groupings and historic uses as defined in the OECD hazard assessment (OECD, 2007; OECD, 2002) is given in Appendix 1 to illustrate the scale and nature of the issue.

This document describes the major sources of PFOS and pathways to the environment in Section 3, and environmental concentrations in Section 4.

PFOS is only one of a large and diverse group. A broader overview of two of the major classes of fluorinated chemicals, poly- and perfluoroalkyl substances (PFAS), likely to be used in the UK, including UK sources and environmental monitoring data, can be found in a separate report (Environment Agency, unpublished). A useful overview of the terminology and classification of PFASs is provided by Ahrens and Bundschuh (2014).

Several reviews have been published in recent years on the environmental fate, toxicity and environmental occurrence of PFAS because of the interest in this large and diverse group of substances as emerging contaminants (Lassen et at., 2013).

The environmental fate and effects of PFOS, PFAS and other related substances have been the subject of numerous comprehensive reviews in recent years. This document provides an overview of the available evidence. More detail can be found in the following publications: OECD, 2002; Environment Agency 2004; Kannan 2011; European Commission, 2011; Lassen et al., 2013; Ahrens & Bundschuh, 2014).

2. Use Pattern

PFOS based compounds were first produced by 3M in 1949. Between 1966 and 1990 production of PFOS increased. Production peaked between 1990 and 2000.

PFOS and PFOS related substances have been used historically to provide soil, oil and water resistance to textiles, clothes, home furnishings and upholstery, carpets and leather, paper and packaging, and coatings and coating additives (Environment Agency, 2004; KemI and the Swedish EPA, 2004). It was once the main ingredient in the popular product Scotchguard (3M). PFOS was voluntarily phased out by its main global producer, 3M in 2001.

PFOS and related substances have also had several uses including floor and car polish; paints and coatings; and dyes and inks which are now restricted (UNEP, 2010).

Although PFOS is now restricted in these applications, fluorotelomer-based polymers and shorter chain (C4) chain fluorinated polymers are still used as a 'best available technique' (BAT) to deliver the desired performance in textiles, leather and paper. PFOS may be present in these fluoropolymers in trace amounts as a by-product from the manufacturing process (UNIDO et al., 2012). Section 5 describes the restrictions and upper limits of PFOS that are permitted as impurities in these applications.

PFOS has also been used in aqueous film forming foams (AFFFs) used in fire-fighting to extinguish flammable liquids and as a wetting agent in controlled electroplating systems, although these uses are now banned.

Until recently, PFOS could be used in the EU for hydraulic fluids for aviation; photographic coatings applied to films, papers or printing plates; photoresists or anti-reflective coatings for photolithography processes. However, in the 2019 recast of the EU POPs, Commission Regulation (EU) 2019/1021, all previously exempted uses were removed with the exception of using PFOS as a mist suppressant for non-decorative hard chromium (VI) plating in closed loop systems.

Stockpiles of approximately 56.8kgs of neat PFOS for use as mist suppressants were notified to the Environment Agency in 2018, as required by Commission Regulation (EU) No 850/2004.

Restrictions on the use of PFOS and PFOS related substances are described fully in Section 5.

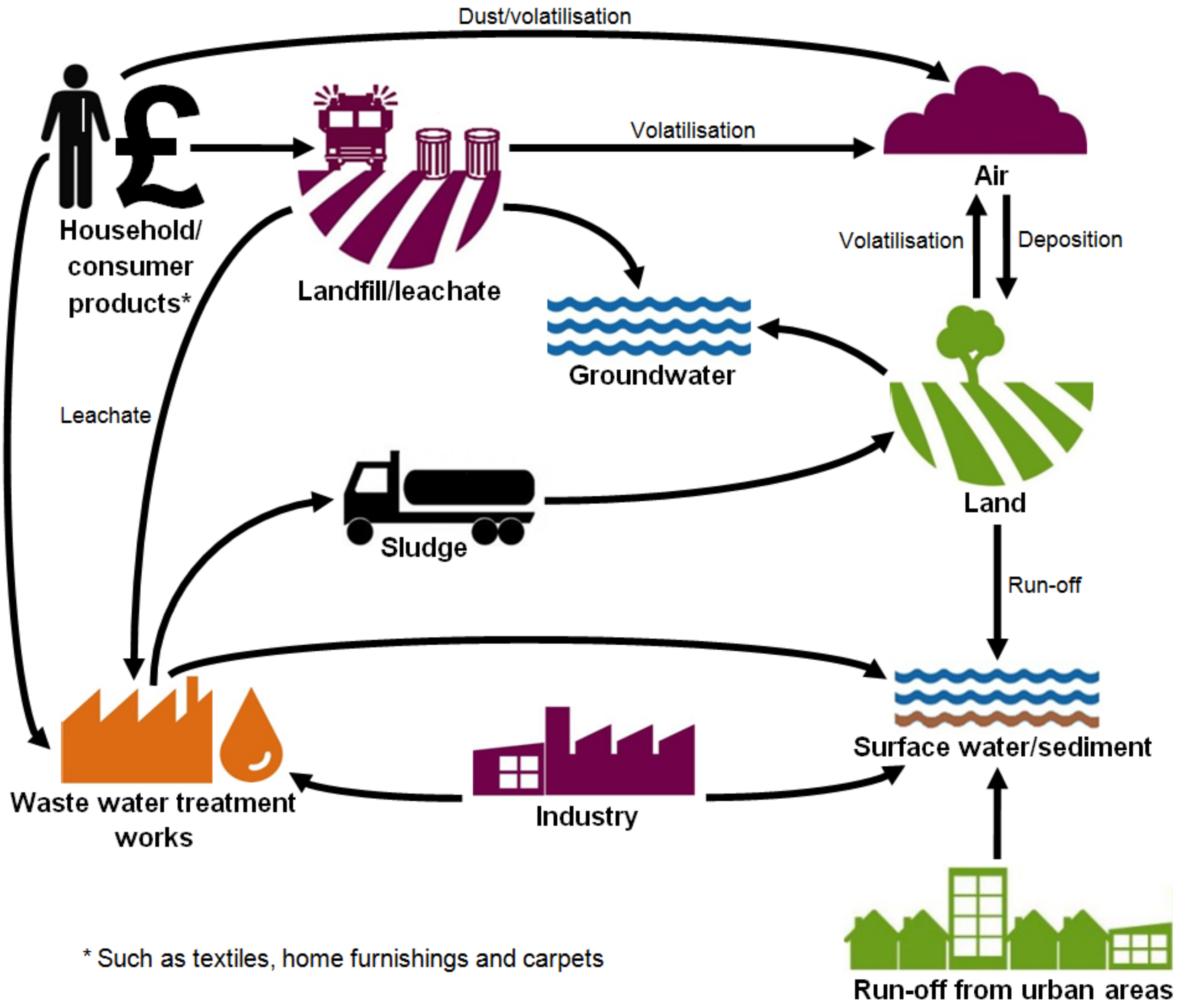
Previous checks have not found significant non-compliance with restrictions on use of PFOS in England (Environment Agency, 2010, 2011, 2012). We are currently working with the metal industry sector to determine if PFOS is being used in plating processes, to ensure compliance with the relevant restrictions and POP stockpile notifications.

3. Sources and pathways

Although most uses of PFOS and PFOS related substances are now banned or heavily restricted, older consumer products such as carpets, textiles and upholstery that have been manufactured and treated with PFOS related compounds will continue to act as a source of PFOS to the environment. Legacy emissions can occur during use, washing and disposal or recycling of such items (Schultz et al., 2006; Earnshaw et al., 2014; Lindim et al., 2015). The manufacturer 3M estimated that losses from consumer products can represent 85% of total indirect emissions (as cited by Paul et al, 2009).

The main environmental release pathways of PFOS are shown in Figure 1.

Figure 1. Sources and pathways of PFOS and its precursors into the environment



* Such as textiles, home furnishings and carpets

3.1. Emissions to water

Annual emissions of PFOS to water and land for the UK, estimated as part of the POPs inventory reporting requirements are around 300 to 800kg PFOS to water and 5kg PFOS to land (AEA, 2012). This is the most recent emissions data reported by the POPs inventory for PFOS at the time of publication of this report.

These values are broadly in agreement with estimates of the total mass of PFOS discharged annually via UK rivers determined by Earnshaw et al. (2014). These authors used modelled and monitored data collected from the rivers Aire and Calder to estimate the total mass of PFOS discharged via UK rivers to be in the range 215 to 310kg (Earnshaw et al., 2014).

The Pollution Inventory (PI), which reports releases and transfers of substances from regulated activities in England, includes only one company reporting emissions of PFOS above the reporting threshold (0.1kg) in 2017, the most recent reporting year.

The company, which is classed as being within the Refineries and Fuel sector, reported annual emissions of 1kg of PFOS to controlled waters. As PI data only provides information from regulated industrial activities, this value is not considered to be fully representative of all PFOS emissions to the environment.

PFOS is moderately soluble in water (600 mg/l), with water solubility decreasing as salinity increases. PFOS has a moderate potential to sorb to soil and a lower sorption potential in sediments (Environment Agency, 2004). The degree of sorption can vary depending on the level of salinity, pH and total organic carbon (You et al., 2010; Pan and You, 2010).

PFOS is mainly transported in the dissolved phase in rivers rather than being adsorbed to suspended solids and has the potential for long-range transport in the water-column (Ahrens et al., 2009; Ahrens et al., 2011).

Estuaries may act as sinks for PFOS because of the change in salinity and the consequent change in solubility and partitioning behaviour (Pan and You, 2010; Wang, 2015). At high salinity, the concentration of PFOS is likely to be higher in sediment but low in the water column compared with freshwaters.

Waste water treatment works (WwTWs) are a primary pathway of release for PFOS to surface waters (Sinclair and Kannan, 2006; Earnshaw et al., 2014; Alder and Voet, 2015; UKWIR, 2018a; 2019).

Monitoring carried out as part of the second phase of the Chemicals Investigation Programme (CIP2) has also demonstrated that the presence of PFOS is often found in both WwTW effluent and receiving waters, at sites across England, frequently at concentrations significantly above the water column EQS (UKWIR, 2019).

Section 4.2.1 describes data on concentrations of PFOS in and around English WwTWs as part of the Chemicals Investigation Programme (CIP) in more detail.

PFOS has been reported in samples collected upstream of WwTWs and the effluent from WwTWs (Chen et al, 2018; UKWIR, 2019), suggesting both WwTWs themselves and additional sources upstream of the monitored WwTWs are contributing to the overall load of PFOS measured downstream of WwTWs (UKWIR, 2019). Some of the CIP2 sites with elevated upstream concentrations had no obvious point sources such as other WwTWs or industrial discharges above them.

For substances such as PFOS, that are water soluble at environmentally relevant pH, and very stable and persistent, it is possible that a discharge near catchment headwaters might elevate the concentration to a value that additional discharges, from subsequent

WwTWs, simply maintain as the load of PFOS and flow increase, resulting in a relatively static concentration of PFOS throughout the catchment (UKWIR, 2018a).

Data collected through the CIP has suggested that there are potentially significant, but as yet unknown sources of PFOS upstream of some works which influence downstream water quality (UKWIR, 2018a; UKWIR 2019). This is likely to vary according to the degree of urbanisation and nature of industry in catchment.

Catchments investigations undertaken as part of the CIP suggested that emissions from some industrial sites and landfills can lead to significantly elevated PFOS levels locally. Further investigation to understand sources and pathways of PFOS is required (UKWIR, 2018b).

In contrast, comparison of modelled and monitored PFOS data from the rivers Aire and Calder showed that spatial concentration trends were reasonably well predicted using population density (Earnshaw et al., 2014). They concluded for the areas studied, that the majority of PFOS emissions arose from WwTWs receiving municipal waste waters, and that PFOS emissions could be mostly attributed to local population rather than major industrial, firefighting or landfill emissions (Earnshaw et al., 2014).

The evidence we have from both the CIP and wider scientific literature suggests that the PFOS load in effluent from WwTWs across England varies according to the nature of the inputs received by WwTWs. However, concentration appears to be significantly related to the degree of urbanisation (Earnshaw et al., 2014; UKWIR, 2019). In addition to emissions from domestic sources of PFOS, landfill leachate and industrial discharges, may contribute to the PFOS load emitted from WwTWs.

Further investigation into the sources of PFOS to surface waters in the UK is planned through the next phase of the CIP and further exploration of our own monitoring data.

A large variability in measured concentrations, removal efficiencies and per capita emissions of PFOS from WwTWs has been reported in published studies in the scientific literature. Variability in concentration was noted even for WwTWs with analogous technology and similar population equivalents. (Arvaniti and Stasinakis, 2015).

There is some evidence that PFOS can be formed in WwTWs through the transformation of precursor compounds. Higher concentrations of PFOS have been reported in the effluents from some WwTWs compared to incoming waste water (Posner and Jarnberg, 2004; Schultz et al., 2006; Becker et al., 2008; Arvanii and Stasinakis, 2015). This usually occurs during secondary treatment by activated sludge, where PFOS levels can significantly increase (Earnshaw et al., 2014; Schultz et al., 2006; Sinclair and Kannan, 2006). For example, Becker et al. (2008) reports factors of 3 fold increases in mass flow of PFOS during wastewater processing. There is little information available on factors such as concentrations of pre-cursor compounds or conditions for transformation during waste water treatment and currently no UK-specific data.

3.2. Emissions to land

Removal of PFOS related substances in WwTWs occurs primarily through adsorption to sludge, rather than microbial degradation (Vecitis et al., 2009).

Reported removal rates through partitioning to sludge vary between 15 and 50% depending on the nature of treatment at the works (Beker et al., 2008; Lindim et al., 2015; Alder and Voet, 2015). Application of sewage sludge to land, is therefore a potential exposure route for PFOS to agricultural soil and subsequent contamination of groundwater through infiltration or surface water via surface run-off following rainfall (KemI and the Swedish EPA, 2004; Environment Agency 2004).

Land spreading of sewage sludge is regulated by the Sludge (Use in Agriculture) (Amendment) Regulations 1990 (SI 1990/880) which set limits for the amounts of certain trace metals. There are no statutory limits currently for PFOS and related substances.

A literature review of the levels of PFOS in sludge (Environment Agency 2017), notes typical levels of PFOS in municipal biowastes, including green and food composts, are probably low (typically less than 10µg PFOS kg^{-1} dry weight) but that levels of PFOS in digestates, biosolids and composted biosolids were much higher and variable. Only limited UK data were available; concentrations of 60.9µg PFOS kg^{-1} dry weight and 200µ PFOS kg^{-1} (dry weight) in biosolids were reported from two UK sources (Rigby et al (2017) cited in Environment Agency, 2017).As part of the third phase of the Chemicals Investigation Programme (CIP3), sludge from a large number of WwTWs will be sampled and levels of PFOS and other PFAS determined. This work will report in September 2021.

PFOS is very mobile and can enter groundwater through surface water seepage and leaching from contaminated soil (Braunig et al., 2019; Liu et al., 2017).

The historic use of AFFF fire-fighting products containing PFOS have left behind a legacy of soil contamination and associated groundwater, surface water and drinking water contamination near to fire training areas, airports and sites of major incidents (Defra, 2008; Weiß et al., 2012; Ahrens et al., 2015; Filipovic, 2015; Braunig et al, 2019).

Braunig et al (2019) found leachable concentrations of PFOS up to 550µg/l at airports where AFFF fire-fighting foam had been used. Groundwater contamination by PFOS has been a long-standing issue at Buncefield following a major incident at the Buncefield Oil Storage Depot in Hemel Hempstead where approximately 0.5 tonnes of PFOS foam was used in 2005 (Defra, 2012).

3.3. Atmospheric emissions

Varying concentrations have been found in indoor air and dust samples from homes, offices, classrooms and cars, potentially leading to human exposure and outdoor contamination (Goosey and Harrad, 2011, 2012; Bjorklund et al., 2009).

PFOS can be deposited from the atmosphere in dust and enter surface runoff (Sasaki et al., 2003). High levels were found on particulate matter in runoff, collected from both industrial and commercial areas, suspected to have originated from products entering the waste stream (Xiao et al., 2012).

3.4. Emissions from waste

A report by 3M, (cited by Kim et al., 2015) estimates that approximately 53% of the initial concentration of fluoro-chemicals in treated carpets remain in the carpet prior to disposal. Disposal to landfill of old consumer items such as treated carpets will therefore contribute to elevated concentrations of PFOS in landfill leachate.

Landfill leachate may be a source of PFOS and related substances to the environment either directly, via leakage from the site, or indirectly via leachate transported for treatment at WwTWs.

Releases of PFOS following disposal of products and waste containing PFOS substances to landfill are not well quantified for UK landfills. Therefore the significance of this pathway is less well understood and is an area for further research. It is possible that at a local scale, landfill leachate containing PFOS levels in the microgramme per litre (µg/l) range could still contribute a relatively significant load to the local environment.

A number of studies are underway to investigate the amount of POPs, including PFOS, in waste streams and in landfill leachate itself. Information from these studies will become available over the next five years and help better understand the pathways and impacts of POPs in the wider environment. Further details of this work are periodically made available through the website of the Stockholm Convention as part of the UK POPs National Implementation Plan.

Concentrations of PFOS in leachate will vary from site to site, with factors such as pH, temperature and ionic strength influencing concentrations in leachate (Kim et al., 2015).

A critical review of scientific publications carried out by Hamid et al., (2018) summarises available evidence on the occurrence of PFAS, including PFOS and their sources in landfills. The presence of PFOS in landfill leachates has been widely reported in the scientific literature in studies from North America, several North European countries, Australia and China (Hamid et al, 2018). The authors noted the presence of elevated concentrations of PFAS in ambient air at landfill sites, highlighting that landfills may act as emission sources of atmospheric PFOS and other PFAS. The significance of emissions via this route will be influenced by the specific site and risk mitigation measures in place. The strong sorption of PFOS to landfill solids, efficient trapping of PFOS in landfill gas collection, and partitioning of PFOS to landfill leachate may all reduce ambient concentrations in air (Ahrens et al., 2011).

Landfill leachate may be disposed of via WwTWs. Future work carried out under the CIP will include water companies investigating influences on chemical loads in WwTWs, including landfill leachate and other trade waste.

4. Monitoring data

4.1. Biota monitoring

As part of a programme of work to enable us to assess risks from persistent, bioaccumulative and toxic (PBT) substances in England we have gathered data on PFOS residues in freshwater and saline biota from around England. Sampling for PFOS as part of this programme began in 2016.

The Priority Substances Directive (2013/39/EU) specifies a biota standard of 9.1µg/kg wet weight for PFOS.

Comparison of measured concentrations in fish with the biota EQS is used to assess long-term risks to wildlife and people because it measures chemical concentrations found in organisms living in water. However, monitoring of biota presents a number of challenges that are not encountered when we sample water. These include animal welfare concerns, potential for ecological impact and problems accessing sites with sufficient animals for analysis. This constrains the extent of the biota surveillance programme compared with our water column monitoring programme.

The biota EQS for PFOS is set to protect both wildlife and people and is based on human health endpoints as these are the most sensitive. There are currently no regulatory limits for this substance in food, including fish, although this situation will be reviewed on the basis of new European Food Safety Authority opinions.

4.1.1. Freshwater fish data

Between 2016 and 2018 we sampled 57 freshwater sites for fish (roach 'Rutilus rutilus', brown trout ‘Salmo trutta’ and chubb 'Squalius cephalus').

Sampling locations and mean measured PFOS concentrations in freshwater and saline fish, as assessed against the biota EQS, are summarised in Table 1 and shown in Figure 2. The average measured concentration is based on three years of data where available. We have compared our data with the biota EQS to estimate the level of risk. PFOS was found in measureable concentrations in fish at all locations sampled.

Table 1. Summary of assessment of the mean measured whole fish concentration of PFOS reported as wet weight, normalised.

Sample type	Number of sites PFOS concentration is below EQS biota	Number of sites PFOS concentration is above EQS biota	Concentration range (µg/kg)
Freshwater, fish	34 (60%)	23 (40%)	0.9 - 37.6
Saline waters, fish	13 (81%)	3 (19%)	1 – 21.6

Concentrations of PFOS reported in Table 1 are those measured in whole fish. Values are reported as wet weight for comparison with the EQS but have been normalised to a standard dry weight. Normalisation of measured concentrations is a useful approach, allowing for comparison of concentrations in samples from different locations. It is described in detail in the Technical Guidance Document on biota monitoring (EC, 2014). Data for fish from saline waters are discussed in Section 4.2.2

In freshwater fish, mean measured concentrations of PFOS range from 0.9µg/kg to 37.6µg/kg.

Concentrations of PFOS in fish are below the EQS at 34 freshwater sites (60%) and above the EQS at 23 sites (40%). At a small number of freshwater sites (15% of those sampled), fish had measured PFOS residues 3 to 4 times higher than the EQS. However, at most sites the margin between measured concentration and the biota EQS was small.

The fish sampled are typically smaller than those likely to be consumed by humans, but we report concentrations in those fish at “face value”. The European Commission (EC) suggest transforming this data to estimate the concentrations that would occur in larger fish representing a higher trophic level (EC, 2014). This transformation of the data allows a harmonised view across the EU about levels observed in the different types and sizes of fish but is subject to uncertainty because of uncertainties and variations in possible trophic magnification factors. By reporting concentrations at ‘face value’ and not adjusting concentrations to larger higher trophic level fish it is possible that concentrations of chemicals that bio magnify in fish at a higher trophic status may be under estimated.

Estuarine and coastal data

Results are presented in Figure 2 and summarised in Table 1.

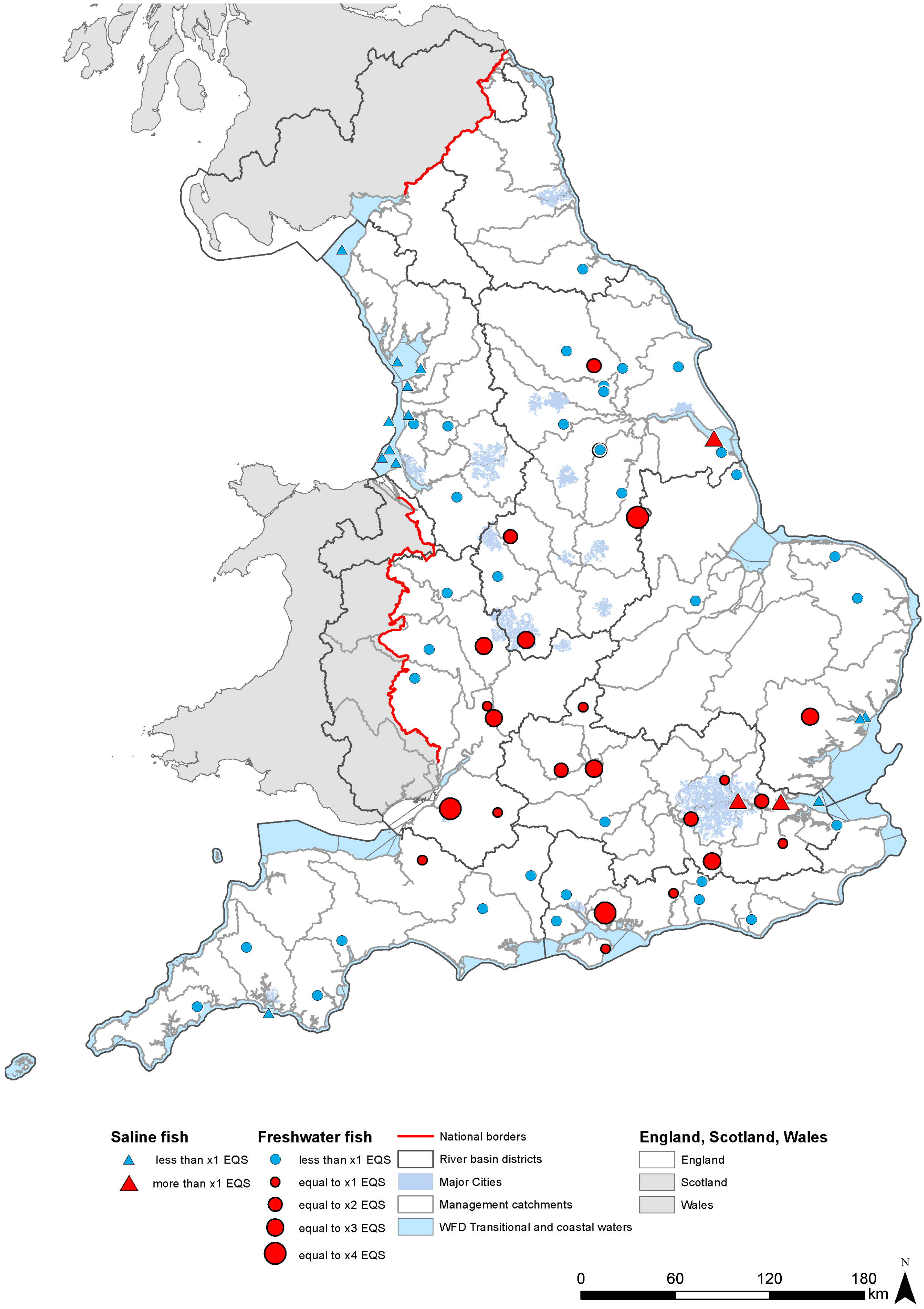
Although the biota EQS applies to fish, Member States have the flexibility to apply an EQS for an alternative matrix or biota taxon, for example the blue mussel 'Mytilus edulis'. On this basis, and building on the OSPAR monitoring programme established since 1999, PFOS analysis in mussels 'Mytilus edulis' was included as part of our saline waters sampling programme at 15 sites from 2016. However, PFOS was not detected in any mussel samples collected. There is evidence to suggest that mussels are not a suitable substrate for analysis of PFOS as they have an internal detoxification process that limits bioaccumulation of PFOS (Fernández-Sanjuan et al, 2010).

A whole fish sampling programme was instigated in 2018, collecting fish - dab ('Limanda limanda') and flounder ('Platichthys flesus') from 16 sites in saline waters around England in 2018.

All fish sampled from estuaries and coastal waters had detectable levels of PFOS.

Mean concentrations of PFOS in fish ranged from 1µg/kg to 21.6µg/kg. Fish from three of the sites sampled had concentrations of PFOS greater than the EQS threshold of 9.1µg/kg - two in the Thames estuary and one site at Grimsby in the Humber estuary.

Figure 2. Mean measured whole fish concentrations of PFOS (wet weight, normalised) in freshwater and saline fish assessed against biota EQS.



4.2. Water column monitoring

4.2.1. Inland surface waters

Since 2016, we have sampled approximately 470 freshwater sites in England for PFOS as part of our surveillance monitoring programme.

Using an average site concentration, we have compared our data against the relevant water column annual average (AA) EQS for PFOS as an initial assessment of risk. For inland surface waters the Priority Substances Directive (2013/39/EU) specifies a water column based AA EQS of 6.5×10^{-4}µg/l. Sampling locations, and measured average concentrations, of PFOS compared against the AA EQS in water are mapped in Figure 3 and summarised below.

The data illustrate a wide range in concentrations of PFOS across England and, in some cases, high exceedances of the EQS.

Measured concentrations range from 0.000053µg/l. below the EQS, up to 0.084µg/l, over 100 times higher than the EQS threshold. At one site the concentration measured was 0.75µg/l – more than three orders of magnitude higher than the EQS.

At approximately 8% of freshwater sites, measured concentrations of PFOS were below the AA EQS.

Concentrations of PFOS and other PFAS in both groundwaters and surface waters were measured as part of a monitoring study in 2006 to investigate the occurrence of PFOS and related compounds in the environment (Environment Agency, 2007). It is not possible to directly compare our recent water column monitoring with these older data because of differences in sampling locations and analytical methods. However, it is notable that despite improved analytical methods the number of sites with concentrations significantly higher than the EQS is lower in our recent monitoring, suggesting environmental levels of PFOS might be declining.

In the 2006 monitoring study, concentrations greater than 0.1µg/l (more than 100 times greater than the EQS) were measured at 14 out of 172 (8%) of surface water sites (Environment Agency, 2007). In contrast only 2 out of 473 sites sampled between 2016 and 2018 had concentrations more than 100 times higher than the EQS, equating to less than 1% of sites.

The Priority Substances Directive also sets out a maximum allowable concentration (MAC) for PFOS of 36µg/l for inland surface waters and 7.2µg/l for other surface waters. The MAC is a threshold intended to protect the aquatic environment from short-term toxic effects. The MAC EQS should be applied where the biota EQS are applied or where emissions or environmental concentrations indicate potential short-term risk.

All measured concentrations in freshwaters, estuaries and coastal waters are below the MAC EQS.

4.2.2. UKWIR Chemical Investigation programme (CIP2)

Monitoring carried out under the CIP2 programme commenced in 2015. The programme is a collaboration between water companies in England and Wales, the Environment Agency and Natural Resources Wales (NRW). Because of the size of the work programme, it is divided into four 'tranches' - the third of which (2017 to 2019) is the most recent to be completed. A further phase of monitoring, tranche 4, will be reported as it is completed over the period 2018 to 2020. Once the programme is complete in 2020, effluent from over 600 WwTWs will have been sampled for a wide range of chemicals including PFOS, together with associated upstream and downstream river samples.

The CIP2 has focused on sites with low dilution in the receiving waters and so at greatest risk of causing noncompliance with EQSs downstream. WwTWs sampled have ranged in size from 250-1.6 million population equivalents (PE), although most are between 5,000-50,000 PE.

In each tranche approximately 150 works have been sampled 20 times over 12 months. Upstream and downstream environmental samples have also been taken 36 times over 2 years, providing a detailed picture of chemical loads and discharges at these sites.

A summary of measured PFOS concentrations in the WwTW effluents, sites sampled upstream of the WwTWs, and the downstream sites collected between 2017 and 2019 in tranche 3 are presented in Table 2.

The mean concentration in effluent across all WwTWs sampled is 0.01µg/l, with a standard deviation of 0.024µg/l, indicating a wide variability in values measured in effluent between different WwTWs.

The mean PFOS concentration measured at sites upstream of the CIP2 tranche 3 WwTWs was 0.0043µg/l and downstream of the discharge a mean value of 0.0059µg/l was reported.

Mean concentrations of PFOS are within the same range found through our own monitoring (Section 4.2.1). Collectively the data show that there is a widespread and variable level of contamination of surface waters by PFOS, frequently at levels exceeding the AA water column EQS.

Table 3. Summary of PFOS concentrations in WwTWs effluent, upstream samples and downstream of discharges measured as part of CIP2 tranche 3 (UKWIR, 2019).

Sample	units	mean	Standard deviation (between WwTWs)	median	25 %ile	75 %ile	95 %ile
Effluent	µg/l	0.010	0.024	0.0039	0.0024	0.0074	0.034
Upstream	µg/l	0.0043	0.0068	0.0021	0.0008	0.0056	n/a
downstream	µg/l	0.0059	0.0091	0.0029	0.0013	0.0064	n/a

A large variability in concentration between individual WwTWs is observed with a high number of samples with PFOS concentrations above the water column EQS

At approximately 90% of the 450 WwTWs sampled to date under CIP2, the concentration of PFOS downstream of the WwTWs discharge is above the water column EQS (UKWIR, 2019). This level of exceedance is considerably greater than that reported for many of the other substances monitored as part of the CIP2.

The concentration of PFOS was close to, or above, the EQS in samples collected upstream of many WwTWs (UKWIR, 2017; 2019) as well as downstream, indicating that local WwTW discharges are often not the only source. In such situations, whilst the WwTW discharge is not the sole cause of the downstream EQS exceedance, the additional discharge from the WwTW may increase the level by which the EQS is exceeded.

The influence of upstream concentrations of PFOS to the overall load measured downstream of some WwTWs in CIP2 highlights the need to consider upstream and wider catchment issues. This includes the extent of urbanisation and the nature of any legacy or local industrial emissions. Additionally, it may in part, explain the wide variability in measured loads of PFOS observed across English surface waters.

4.2.3. Estuaries and coastal waters

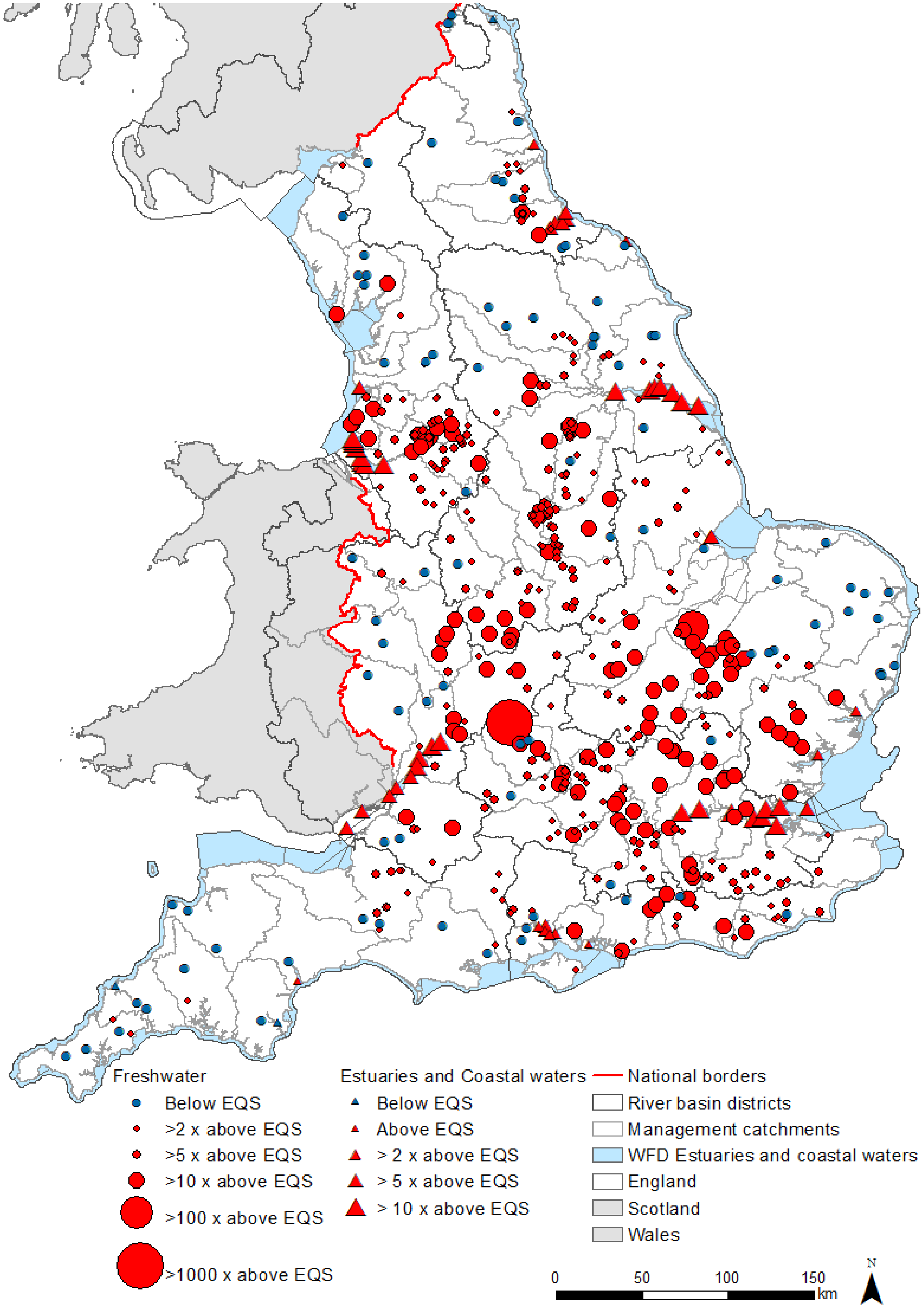
Between 2016 and 2018 we have measured PFOS concentrations in water at 55 estuarine and coastal sites. The water AA EQS is lower in saline waters (0.00013µg/l) compared with freshwaters.

A comparison of measured concentrations against the EQS is mapped in Figure 3 and described below. Mean measured concentrations range from 0.00004µg/l to 0.011µg/l.

The concentration of PFOS was less than the EQS at only 3% of sites. A small number of sites had concentrations between 1 to 2 times greater than the EQS but over 50% of sites had concentrations more than 10 times the EQS.

The highest concentrations measured were more than 50 times the EQS. Samples from the upper Humber and Thames estuaries had the highest concentrations. A concentration gradient was observed along the estuaries. Concentrations of PFOS were highest in the upper estuaries where salinity was lower and decreased towards the mouth of the estuaries.

Figure 3. Sampling locations and mean measured PFOS concentrations from Environment Agency monitoring compared with the water AA EQS in England, 2016 to 2018



4.2.4. Derivation of an alternative water threshold for PFOS

For substances with a biota standard, it is theoretically possible to derive an equivalent water threshold that corresponds to the EQS in biota. The approach is described in detail in the EC Technical Guidance for Deriving Environmental Quality Standards (EC, 2011)

The annual average (AA) water EQS specified in the 2013 Priority Substances Directive (2013/39/EU) for PFOS has been determined in this way and is sometimes termed the back-calculated water threshold. It is set, in theory, to provide an equivalent level of protection as the biota EQS.

Comparison of our water column and fish residue data, collected in the same river reaches, against the relevant EQS suggests that the water AA EQS for PFOS may over predict the likely failure of the biota standard observed in fish living in the same stretch of river. (Environment Agency, 2017 unpublished).

Back-calculated water thresholds are based on toxicological data but are subject to some uncertainty. This is because they rely on bioaccumulation factors which are not always available or consistent.

Evidence gathered from analysing water and biota samples from the same freshwater locations over several years suggests a correlation between measured concentrations of PFOS in water and fish.

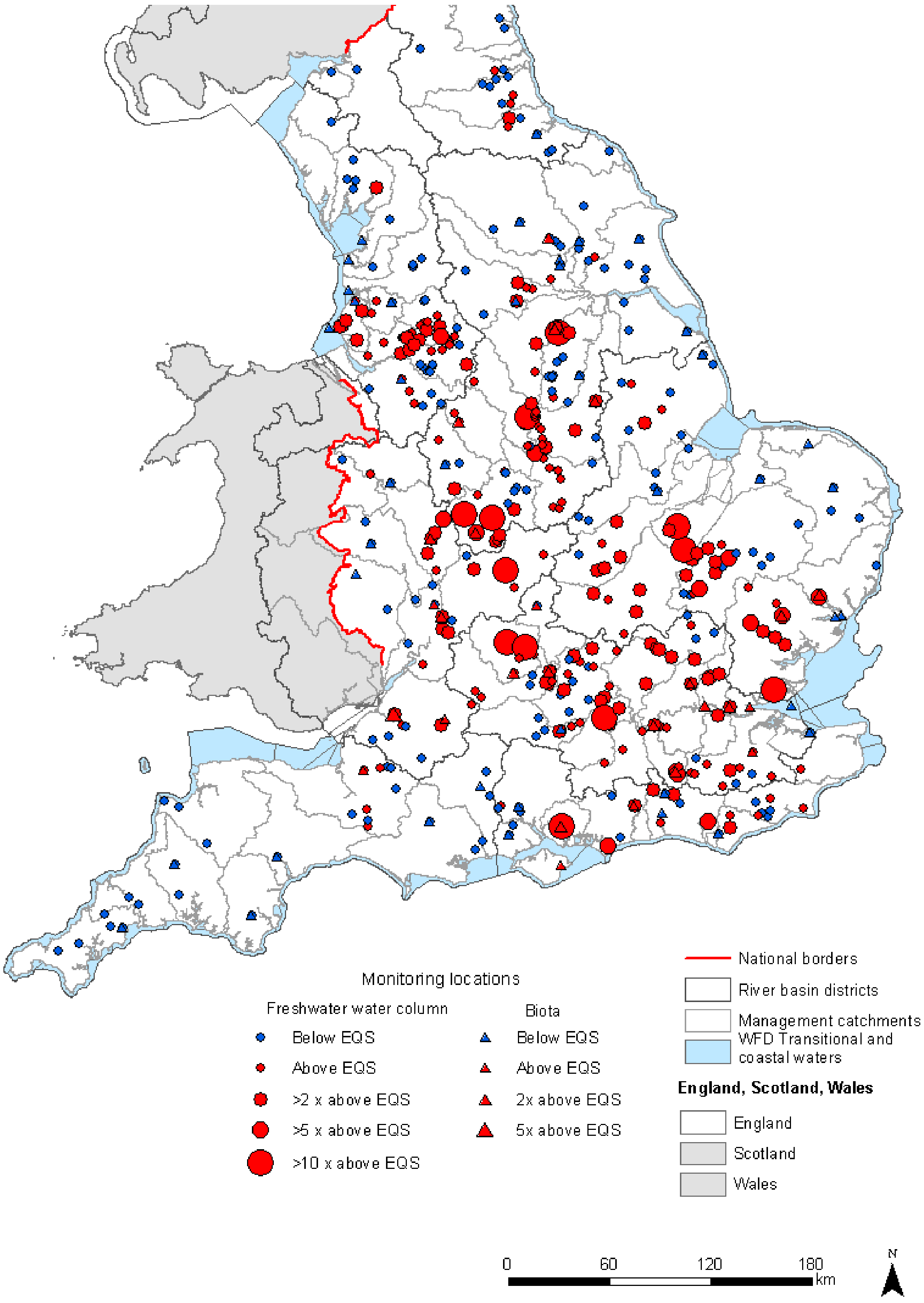
Using the observed relationship between PFOS in freshwater and biota, and Spearman’s rank correlation, we have estimated a water column concentration above which we can be reasonably confident the biota EQS is likely to be failed. The resulting empirically-derived threshold in water is 0.003µg/l, compared to the value of 0.00065µg/l given in the EQS dossier (EC, 2011).

The derivation of an empirical water threshold opens up the possibility of using our water column data to model a national assessment of risk, drawing on more widespread and extensive water sampling locations to supplement the limited coverage offered by biota sampling alone. This approach explicitly uses compliance with the biota EQS to inform the derivation of a water threshold but avoids reliance on bioaccumulation factors.

Figure 4 shows our biota monitoring data assessed against the biota EQS, and water column data assessed against our alterative threshold. Much greater spatial coverage is possible when we are able to supplement our limited biota monitoring network (Figure 2) with water column data.

As we collect additional monitoring data we will continue to explore the potential for this approach. It is important to note that the alternative threshold described above is based on monitoring data collected between 2016 and 2018. As we incorporate more water data it is likely that this alternative water threshold value could change slightly in the future.

Figure 4. Water column data assessed against the 'alternative' water threshold of 0.003µg/l combined with biota data assessed against the EQS.



4.3. Groundwater

The focus of this narrative is on contributing effects to, and assessment of, the condition of surface waters in relation to PFOS. However, the contamination of groundwaters is considered under the Groundwater Directive (2006/118/EC as amended by 2014/80/EU) to see if this contamination contributes to more than 50% of any surface water failures under the WFD.

Levels of PFOS in groundwater have been measured as part of our on-going monitoring programme investigating levels of organic contaminants in groundwater.

We have used a semi-quantitative screening approach targeted to contaminants of interest. The screening approach encompasses a broad and diverse range of contaminants in order to identify those contaminants of emerging concern in groundwater.

The data have been analysed and summarised and can be accessed in full in the report 'Micro-organic contaminants in groundwater in England' published by the British Geological Survey (BGS) (Lapworth et al., 2018)

PFOS was one of the most frequently detected contaminants measured in groundwater at the sites sampled between 2016 and 2017, with 30% of analyses showing a positive detection (limit of detection 0.01µg/l).

Detections were mainly in the London area and the authors suggest that this contamination may be a consequence of the use of PFOS containing foams to control the fire during a major incident at Buncefield in 2005. Other high localised detections are noted in Hampshire and Birmingham.

The mean PFOS concentration in groundwater is 0.003µg/l and standard deviation 0.03µg/l. The maximum concentration reported is 0.4µg/l.

Further understanding of the sources and pathways, as well as the significance of high concentrations of PFOS in groundwater on surface water quality is needed. We will be assessing this further as we develop water body classifications for the draft river basin plans.

4.4. Trends

Quantitative information on emissions, discharges and losses of PFOS and on loads transported by rivers and atmosphere to the sea are scarce (OSPAR, 2010). Releases to the environment are likely to have decreased since 2001 because of the sharp drop in production and consumption as restrictions came into force. However, even with existing restrictions, releases of PFOS to the environment will continue for some time during use and disposal of items containing PFOS.

The pattern of PFOS contamination in wildlife varies greatly among species and geographical locations. PFOS tends to be the dominant perfluoroalkylated compounds but other PFAS compounds are also reported. (Huber et al., 2012; Kratzer et al., 2011; Ahrens et al., 2009).

The Centre for Environment Fisheries and Aquaculture Science (CEFAS) measured levels of various PFAS in harbour porpoises stranded or by-caught in the UK during 2012-2014 (Barber et al., 2016). Livers from 51 animals were analysed. PFOS was found in all samples. Comparison of the data from 2012 to 2014 with an earlier study also carried out by CEFAS (Law et al., 2008) shows that the mean concentration of PFOS in UK harbour porpoises had decreased by approximately one third since 2001. The mean PFOS concentration reported in UK harbour porpoises in 2012 to 14 was 178ng/g wet weight compared with 600ng/g wet weight in 2001. A similar study of harbour porpoises in

Northern Europe between 1991 and 2008 showed comparable decreasing concentrations of PFOS on a wider scale (Huber et al., 2012).

Many other studies (Ahrens et al., 2009; Ullah et al., 2014; Routti et al. 2016) have reported similar trends in environmental levels of PFOS over time, with increasing concentrations up to the early 2000s, and a subsequent levelling off or decreasing concentration, although trends reported may not always be statistically significant.

The OSPAR quality status report (2010) notes that the pattern of wildlife contamination by perfluoroalkylated substances (PFAS), including PFOS, varies greatly among species and geographical locations in the OSPAR area.

Overall a decreasing trend in PFOS levels in mammals is observed from the south to north of the OSPAR area. Data from seabird eggs from northern Norway suggest that increasing PFOS concentrations levelled off between 1993 and 2003 and have since decreased. However, Swedish time series for PFOS in guillemot eggs between 1968 and 2003 suggest a continuous increase in concentration at an average of 7 – 11% per year. As more recent data are not available, we do not know if this trend has levelled off since restrictions on PFOS and PFOS related substances were implemented.

The most recent OSPAR Co-ordinated Environmental Monitoring Programme (CEMP) assessments on data collected in 2018, show a small number of sites (8) across OSPAR region I (Arctic Sea) and Region II (Greater North Sea) where trend in PFOS concentrations in fish was assessed over 3 or more years. At all sites assessed, a decreasing trend in PFOS concentrations was reported (OSPAR, 2019). No data for UK waters were available as part of this assessment.

A systematic review covering 186 articles and 26 grey literature reports of the effect of restrictions on PFAS, including PFOS, on global concentrations was published by Land et al (2018). Overall the review of evidence suggested that for PFOS in environmental samples there are no clear patterns of declining trends yet. Insignificant and decreasing trends were equally predominant in studies reporting times series concentrations of PFOS in fish, mussels and loggerhead sea turtles.

Statistically significant declines in surface waters in Tokyo Bay, Korea and east coast of China were reported. In contrast, statistically significant increasing trends over time were reported in sediment for studies in China, North America and Japan. No specific conclusions for UK waters or organisms were reported. In a number of cases, insignificant or no trend is noted as consequence of low power to detect a trend. This highlights the need to ensure appropriate and robust study design when collecting data to assess long term temporal trends.

The Predatory Bird Monitoring Scheme (PBMS) conducted a study between 1977 and 2014 (Walker, 2015) to assess the concentrations of perfluorinated compounds (PFCs), such as PFOS, in the eggs of a top predator, the northern gannet ('Morus bassanus') from colonies off the UK coast. PFOS residues in gannet eggs appear to have peaked in the mid-1990s.

Concentrations of PFOS and other PFAS are being measured in Eurasian otters (‘Lutra lutra’) as part of ongoing work by the Cardiff Otter Project . This work is yet to publish any results but provides the opportunity to examine temporal differences in PFOS concentrations across the UK in a top predator. In addition, comparison of concentrations of PFOS in otters with measured concentrations in fish collected in the same location, enable further investigation of transfer of PFOS through the food web.

5. Restrictions

Under Commission Regulation (EU) 2019/1021 the use of PFOS and PFOS related substances are prohibited. There is only one time-limited exemption remaining; the use of PFOS as a mist suppressant for non-decorative hard chromium (VI) plating in closed loop systems.

Since 2006 the use of PFOS and PFOS related substances has been restricted under the Marketing & Use Directive (Directive 2006/122/EC). These prohibitions applied to:

- substances or preparations with a PFOS concentration of greater than 0.001%, by weight
- semi-finished products or articles (or parts of these items) with a PFOS concentration equal to or greater than 0.1% by weight
- Textiles or other coated materials, with the amount of PFOS equal to or greater than 1μg/m^2 of the coated material.

These concentrations represented a level at which PFOS was considered to have a technical benefit – lower concentrations were reasoned as 'unintentional trace contamination'.

A number of specialist uses were exempted from the restrictions until recently. These include use of PFOS in photoresistors or anti-reflective coatings for photolithography processes; photographic coatings applied to films, papers, or printing plates; mist suppressants for non-decorative hard chromium (VI) plating in closed loop systems; and hydraulic fluids for aviation.

In addition, there was a time-limited exemption for use of PFOS as a wetting agent in controlled electroplating systems. This expired 26 August 2015.

Fire-fighting foams that were placed on the market before 27 December 2006 could also be used until 27 June 2011.

At the 9th Conference of the Parties of the Basel, Rotterdam & Stockholm conventions, Geneva, Switzerland, 29th April – 10th May 2019, updates to the acceptable uses and exemptions permitted for PFOS were agreed. The only remaining permitted use in the EU (as a mist suppressant for non-decorative hard chromium (VI) plating in closed loop systems) will now have a time limited exemption for 5 years. Parties to the convention have until December 2020 to update their national laws to comply with this decision.

Articles already in use in the EU before 25 August 2010 containing PFOS as a constituent of such articles are allowed.

The recast legislation requires holders of a stock pile greater than 50kg consisting of or containing PFOS for exempt uses to notify the Environment Agency. This applies to manufacturers, importers, suppliers and users. There are general exemptions which allow the selling of POPs such as PFOS to laboratories for research and development purposes (Commission Regulation (EU) No 2019/1021; Article 4).

In the UK, competent authorities, enforcing authorities, powers and penalties relating to POPs are set out in the Persistent Organic Pollutants Regulations 2007 No.3106.

Waste containing PFOS at a concentration above 50mg/kg (50ppm), as listed in Annex IV Commission Regulation (EU) No 850/2004, must be considered as POPs waste. As such they must be disposed of, or recovered, in such a way to destroy or irreversibly transform the POP content of the waste. The only known condition whereby PFOS is degraded is through high temperature incineration.

Any waste with a PFOS concentration less than 50mg/kg, should be disposed of in line with the relevant waste legislation.

Compliance with restrictions is thought to be good (Environment Agency, 2010, 2011, 2012), although a recent German study found products such as carpet, leather and outdoor materials, exceeding the limit in the EU regulations (Kotthoff et al., 2015).

At the 9th Conference of the Parties of the Basel, Rotterdam & Stockholm Conventions, held in 2019, the acceptable uses and exemptions permitted for PFOS were updated. It was agreed to move the hard metal plating use from a category of “acceptable use” with no time limit to a time-limited (5 year) exemption. Only two other uses, as an insecticide and as firefighting foams, were retained but these are already banned in the EU.

6. Discussion

The extreme chemical stability, and oil, grease and water repellent properties, of PFOS and PFOS related substances have enabled them to be used in a wide variety of applications where chemical resistance and durability are desirable. However, this very stability and also the unusual mobility of the substance have given us a contamination legacy which is unusually difficult to deal with.

Despite restrictions on use, older consumer products that have been manufactured and treated with PFOS will continue to act as a source of emissions for some time yet. Significant quantities of consumer goods containing PFOS and PFOS related substances may still be circulation and yet to enter the waste stream. Legacy product contamination should be further examined to determine if cost effective measures may exist to partition and destroy waste PFOS to prevent its loss to the environment.

Until recently a number of specialist uses of PFOS have been allowed. This is still the case for a limited time period), for the use of PFOS for chromium (VI) plating in closed loop systems.

Whilst WwTWs are a significant source of PFOS to the environment, other sources may also be significant in a catchment including landfill sites, industrial discharges and local historical contamination, especially around sites such as military bases and airports.

Our environmental data presents a clear picture of the significant and widespread environmental contamination by PFOS, often at levels of concern.

To ensure appropriate and effective actions are implemented we need to better understand the sources of PFOS and their relative significance, which may vary at the local scale. Further sewerage catchment, river catchment and sludge based investigations through the Water Industry CIP may help to address this.

A number of studies are underway concerning the amount of POPs, including PFOS, in waste streams and in landfill leachate itself. Information from these studies will become available over the next 5 years and help better understand the pathways and impacts of POPs in the wider environment.

Further details of this work are periodically made available through the website of the Stockholm Convention as part of the UK POPs National Implementation Plan.

We will continue to develop a picture of national risk through our biota and water column monitoring.

Limited data are available on trends in environmental concentrations over time. Some data in biota and waters samples show a decline in environmental levels over time, although many studies report no trend and a few report increasing trends. The variability in reported temporal trends may reflect geographic variations as well as differing exposure routes within the food web.

Whilst we continue to build a clearer picture about the level of environmental contamination caused by PFOS, and where this contamination is, there are actions we can undertake to try to mitigate further impacts. These should include continued enforcement of the restrictions on the supply and use of PFOS. This is particularly important as PFOS can still be legally supplied for certain exempt uses; providing a presence in the market place that needs careful management.

We are reviewing interventions that could be taken to mitigate further impacts. These include providing assurance that current legal supply and use of PFOS, such as specialist permitted uses of PFOS, do not present a risk to the environment. We are reviewing a range of regulatory tools, across different regulatory regimes. These include lawful and unlawful stockpiles of PFOS, historic contamination, how we permit different activities and ensuring waste containing PFOS are managed correctly.

Other per- and polyfluoroalkyl substances (PFAS) may break down to PFOS in the environment or be transformed during wastewater treatment. This presents a significant challenge as there are potentially hundreds to thousands of these substances currently in use. We have initiated a study to get a better understanding of sources and pathways of these chemicals to the environment.

It seems likely that we will have to live with a degree of PFOS contamination in our environment for the foreseeable future, but this should not prevent us from taking positive action where this is appropriate to mitigate the effects of this persistent problem.

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8. List of abbreviations

AA

Annual Average

AFFF

Aqueous film-forming foams

BAT

Best available technology

CEFAS

Centre for Environment, Fisheries and Aquaculture Science

CIP

Chemical Investigations Programme

CIP2

Chemical Investigations Programme, phase 2

CIP3

Chemical Investigations Programme, phase 3

EQS

Environmental Quality Standard

MAC

Maximum Allowable Concentration

OECD

Organisation for Economic Co-operation and Development

OSPAR

The OSPAR convention is the Convention for the Protection of the Marine Environment of the North-East Atlantic. See https://www.ospar.org/convention. It is the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North-East Atlantic.

PBT

Persistent, bioaccumulative, toxic. PFAS

Polyfluoroalkyl substances

PFOS

Perfluorooctane sulfonate

PI

Pollution Inventory

POP

Persistent organic pollutant

uPBT

Ubiquitous PBT

UKWIR

UK Water Industry Research https://ukwir.org/

WFD
The Water Framework Directive

WwTW
Waste water treatment works

9. Glossary

Adsorb

A sorption process in which one substance becomes attached to another via adhesion to the surface.

Bioaccumulate

The accumulation of a substance, such as a toxic chemical, in various tissues of a living organism.

Bioavailability

The extent to which a substance can be absorbed by a living organism

Biota

The animal and plant life of a particular region, habitat, or geological period

Moiety

A distinct part of a large molecule

OSPAR

The mechanism by which 15 governments and the EU cooperate to protect the marine environment of the North-East Atlantic.

PBT

Persistent, bioaccumulative and toxic. These substances are a class of compounds that have high resistance to degradation from abiotic and biotic factors, high mobility in the environment and high toxicity.

PFOS related substances

Any or all of the substances which contain the PFOS moiety that may break down in the environment to give PFOS

Pollution Inventory

The inventory collates data from large regulated industrial sites on emissions of specified substances to air and controlled waters and sewers, as well as quantities of waste transferred off site. The thresholds for reporting are generally lower than those under the UK PRTR.

Sorption

A physical or chemical process in which one substance takes up or holds another

Stockholm Convention

The Stockholm Convention is a global treaty to protect human health and the environment from persistent organic pollutants (POPs) and came into force in May 2004.

UK PRTR

The register collates data from industrial and business facilities on emissions to air, water and soil, as well as data on quantities of waste transferred off site. Data from the PI that meet the required reporting thresholds form a subset of the UK PRTR, as well as data from Local Authorities.

uPBT

Ubiquitous PBT. PBTs that are widespread and found everywhere

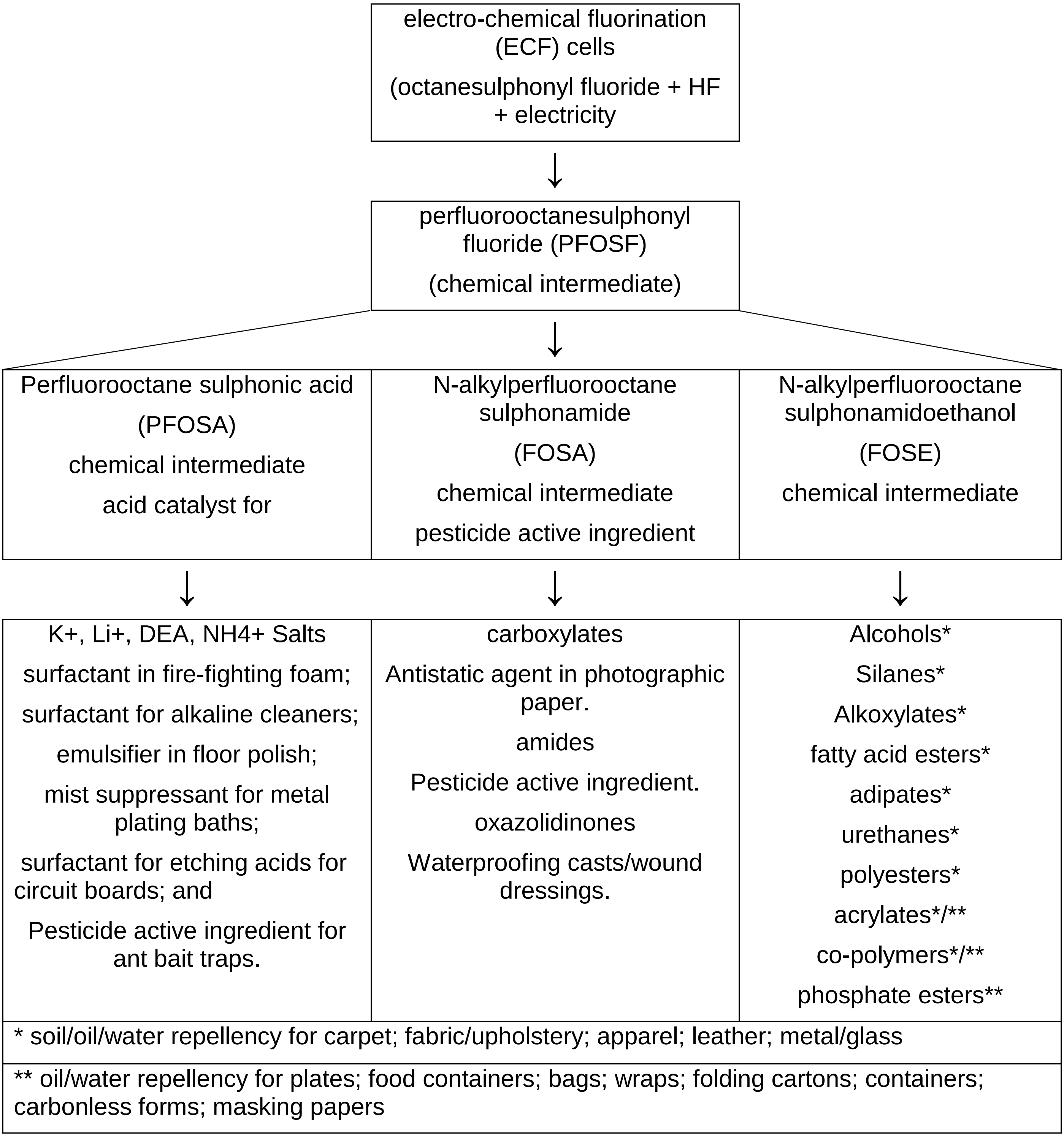
Wet weight

Whole weight, fresh weight and wet weight refer to the sample as it is received whole or wet, regardless of whether it is a whole organism or parts of the organism.

10. Appendix

10.1. Major Product Categories and Applications for perfluorooctyl sulphonates

Perfluorooctyl Sulfonates: Major Product Categories (OECD, 2002)



electro-chemical fluorination (ECF) cells

(octanesulphonyl fluoride + HF + electricity

↓

perfluorooctanesulphonyl fluoride (PFOSF)

(chemical intermediate)

↓

Perfluorooctane sulphonic acid (PFOSA) chemical intermediate acid catalyst for	N-alkylperfluorooctane sulphonamide (FOSA) chemical intermediate pesticide active ingredient	N-alkylperfluorooctane sulphonamidoethanol (FOSE) chemical intermediate
↓	↓	↓
K+, Li+, DEA, NH4+ Salts surfactant in fire-fighting foam; surfactant for alkaline cleaners; emulsifier in floor polish; mist suppressant for metal plating baths; surfactant for etching acids for circuit boards; and Pesticide active ingredient for ant bait traps.	carboxylates Antistatic agent in photographic paper. amides Pesticide active ingredient. oxazolidinones Waterproofing casts/wound dressings.	Alcohols* Silanes* Alkoxylates* fatty acid esters* adipates* urethanes* polyesters* acrylates*/** co-polymers*/** phosphate esters**

* soil/oil/water repellency for carpet; fabric/upholstery; apparel; leather; metal/glass

** oil/water repellency for plates; food containers; bags; wraps; folding cartons; containers; carbonless forms; masking papers

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