ECG Early Careers Environmental Brief (ECGECEB No 3)

Adverse effects and control legislation of poly- and perfluoroalkyl substances

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Poly- and perfluoroalkyl substances (PFASs) are a group of anthropogenic chemicals used globally as emulsifiers or surface protectors in many industrial and consumer applications. They are used, for example, in food packaging and cooking products, carpets, clothes, mattresses, and fire extinguishers (*1*). These substances are also widely known as perfluorinated chemicals (PFCs) but should not be confused with perfluorocarbons, which are potent greenhouse gases. PFASs consist of a partly (poly) or fully (per) fluorinated carbon chain that is connected to functional groups containing, for example, oxygen, sulfur and/or nitrogen atoms. Their potential to be bioaccumulative, toxic **(Table 1)**, and highly persistent has been increasingly recognised (*1*).

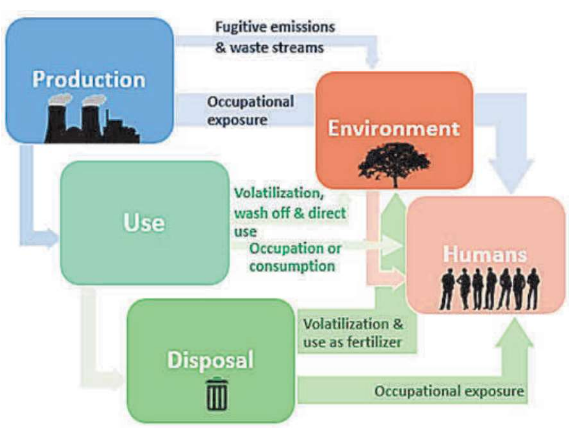

Figure 1. *Routes by which PFASs may be potentially released to the environment and exposure to humans, Adapted from: (2), with added data from (3).*

PFASs are a group of over 3000 compounds, typically subdividided into long and short chain compound groups, depending on the length of the carbon chains in their structure. The environmental and human health response varies, but long chain PFASs (containing 6 or more carbon atoms) are more potent. In recent years, efforts have been made to limit exposure of humans and the environment to perfluoroalkyl acids (PFAAs), such as PFOA and PFOS **(Table 1)** (*2*).

Class	Sub-class	Com-pound	Guidance level
Perfluoro-alkyl acids (PFAAs)	Perfluoro-carboxylic acid (PFCA)	Perfluoro-octanoic acid (PFOA)	0.3 µg/L
	Perfluoro-alkane-sulfonic acid (PFSA)	Perfluoro-octane-sulfonate (PFOS)	0.3 µg/L
PFAA pre-cursors	Perfluoroalkane sulfonyl fluoride (PASF) based substances		Variable
	Fluorotelometer-based substances		Variable
Others	Fluoropolymers		Variable
	Perfluoropolyethers (PFPE)		Variable

Table 1. *Simplified classification of PFASs, and guidance levels above which pose risk to human health. Adapted from: (1) and (2).*

Effect on the Natural Environment

PFASs can enter the environment in solid, gas, or liquid form during manufacturing, use, or disposal **(Figure 1)**. Pathways include fugitive emissions or wastewater streams during production, volatilisation during use, and use of sewage sludge as fertiliser during disposal. Through these pathways, natural ecosystems such as waterways, soils, and biota become polluted with PFASs. Although land is exposed to the largest amount (>200 tonnes globally on average per year), PFASs can be transported thousands of miles through water currents and through the atmosphere as aerosols (*2*). Oceans are the largest reservoir, where PFASs are mainly present as polyfluoroalkyl acids (PFAAs). Deep water and surface currents aid in global transportation. Studies have shown their presence as far as the arctic (*3*). PFASs are stable in the environment and are resistant to biodegradation, and physical degradation through exposure to air, water or sunlight. Long chain PFASs are often accumulated by organisms faster than the rate of expulsion, and thus are bioaccumulative. Biomagnification also occurs when concentrations are passed up the food-chain through consumption (*1*).

Effect on Human Health

Humans are exposed to PFASs through interaction with the environment, such as contaminated air, water, soils, and dust, as well as through use of PFAS-containing products. Occupational exposure occurs during the production and disposal stages. The main pathways are through consumption of food grown in contaminated soils and of contaminated drinking water. PFASs are found in the blood of the general population in small concentrations owing to their wide distribution, most commonly in the form of PFOA and PFOS (*2*). They have a long residence time and may remain in the blood stream for over 1000 days (*3*). High levels of PFASs have negative effects on reproduction and foetal development, resulting e.g. in reduced birth weight (*3*). They have also been shown to cause developmental, endocrine, neurobehavioral, and metabolic toxicity in animal experiments. Chronic toxicology testing has been carried out for PFAO and PFOS; both substances caused tumours in rats, suggesting carcinogenic properties (*1*).

Control Legislation

Between 2004 and 2009, the Organisation for Economic Co-operation and Development (OECD) carried out three studies to identify and quantify sources of PFAS. Organisations in participating countries were required to report all PFASs manufactured or imported into their jurisdiction (*4*).

Following this, the European Union set out regulations developed in association with advocacy groups, industry, and researchers. The use, production, import and export of PFOS and its derivatives have been prohibited/restricted under the EU Commission Regulation No 757/2010 of 24 August 2010. It is likely they will soon be recognised as a priority hazardous substance in Directive COM (2011) 876, amending the Directive on Environmental Quality Standards (Directive 2008/105/EC) and the Water Framework Directive (2000/60/EC). PFOA and certain perfluoro-carboxylic acids (PFCA) are listed as substances of very high concern (SVHC) under the EU Chemicals Regulation REACH, which obligates industries to register products containing these PFASs. The long-term goal is to completely substitute these harmful substances (*4*).

Further Research & Remediation

Current legislation focuses on phasing out long chain PFASs by prohibiting the sale of PFOA and related compounds as standalone substances, and limiting concentrations in various manufactured products between 2020 and 2032. The phase out process is slow to lessen economic challenges (*5*). However, as the substances may travel across country borders via fugitive emissions and water currents, commitment is required on a global level to reduce human and environmental exposure. In conjunction, *in situ* remediation technologies for contaminated land require further development; currently used pump-and-treat techniques are expensive and energy-intensive (*2*). Dilution and burial techniques should also be considered to remedy already contaminated environments and reduce the residence time in soils and waterways.

Substances that are structurally similar to the potent long chain PFASs are being used as alternatives in industry, but these remain unassessed and unregulated (*2*). This is a cost-effective solution but does not address the issue of PFAS accumulation. Further research needs to evaluate their potential risks related to human and environmental exposure.

References

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