Emerging chemical risks in Europe — ‘PFAS’

It is currently not possible to perform in-depth environmental and health risk assessments of all chemical substances in use in Europe because of the great variety of chemicals and their diverse uses. New and legacy chemicals continue to be released into Europe’s environment, adding to the total chemical burden on Europe’s citizens and ecosystems. Early identification of emerging risks is one of the activities of the European Environment Agency (EEA). This briefing summarises the known and potential risks to human health and the environment in Europe posed by a group of very persistent chemicals, the per- and polyfluorinated alkyl substances (PFAS).

Key Messages

- Comprising more than 4 700 chemicals, per and polyfluorinated alkyl substances (PFAS) are a group of widely used, man-made chemicals that accumulate over time in humans and in the environment.
- National monitoring activities have detected PFAS in the environment across Europe. The production and use of PFAS in products has resulted in the contamination of drinking water supplies in several European countries. In some highly polluted areas, concentrations of perfluorooctanoic acid (PFOA) and perfluorosulfonic acid (PFOS) in drinking water were above the limit value for individual PFAS proposed in the 2018 recast of the EU Drinking Water Directive (EC, 2017).
- Human biomonitoring has detected a range of PFAS in the blood of European citizens. Though the levels for the most prevalent, studied and regulated PFAS, PFOA and PFOS are decreasing, levels of more ‘novel’ PFAS are increasing. In some areas, concentrations of PFOA and PFOS in the most exposed citizens were above proposed benchmark levels for adverse effects in humans.
- Due to the large number of PFAS chemicals, a substance-by-substance risk assessment and management approach is not adequate to efficiently prevent risk to the environment and human health from a single PFAS or mixtures of them.
- Taking precautionary risk management actions for groups of chemicals and promoting the use of chemicals that are ‘safe-and-circular-by-design’ could help to limit future pollution.

What are PFAS and what are they used for?

PFAS are a group of more than 4 700 man-made chemicals (OECD, 2018), the two most well-known of which are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) (Box 1). PFAS are used in a wide variety of consumer products and industrial applications because of their unique chemical and physical properties, including oil and water repellence, temperature and chemical resistance, and surfactant properties. PFAS have been used in firefighting foams, non-stick metal coatings for frying pans, paper food packaging, creams and cosmetics, textiles for furniture and outdoor clothing, paints and photography, chrome plating, pesticides and pharmaceuticals. Very limited information is available regarding which specific PFAS are used in which applications and at what levels in Europe.

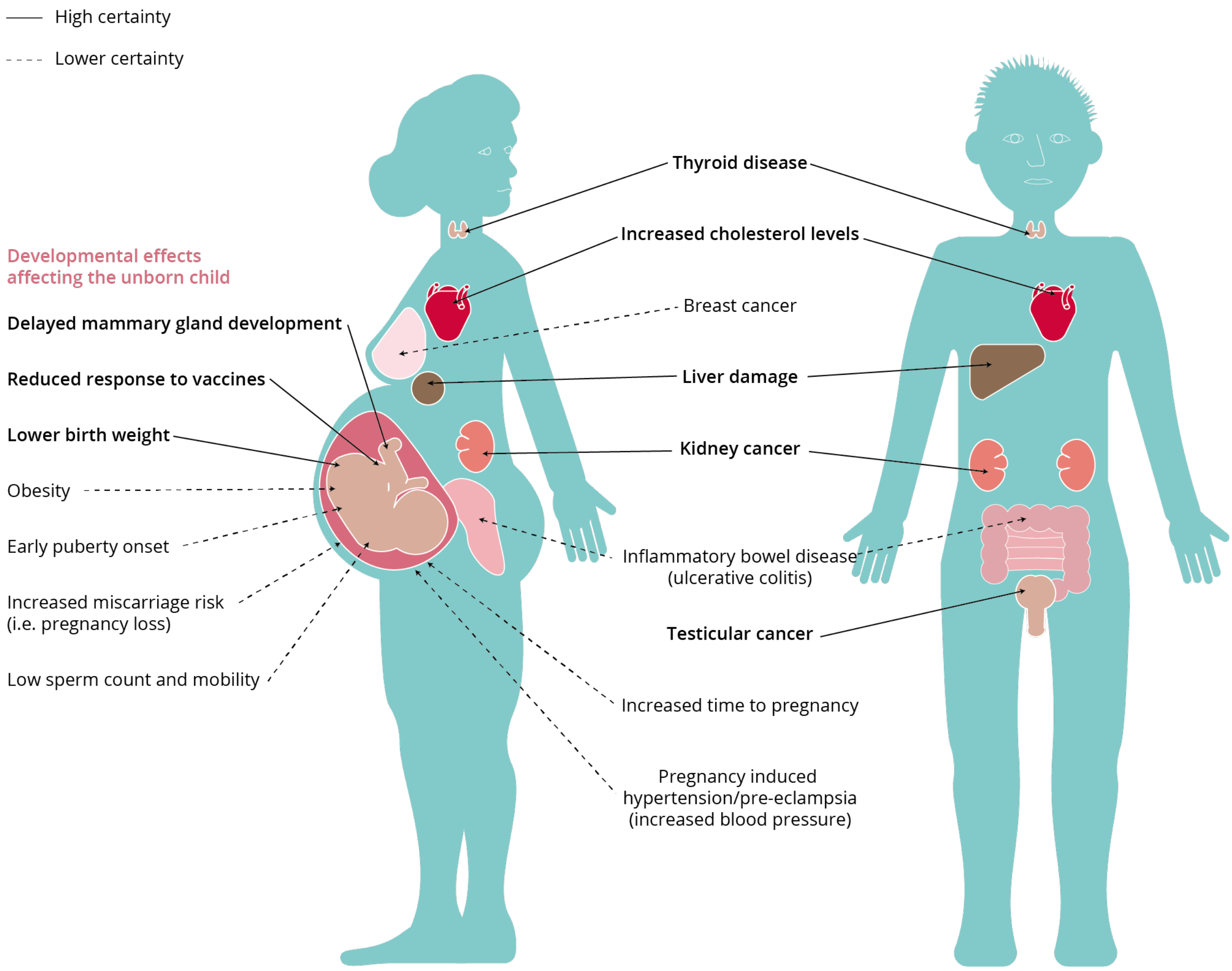
Box 1

PFAS are a group of organic chemicals that contain a stable (unreactive) fluoro-carbon segment. Polyfluorinated PFAS contain both fluoro-carbon and hydro-carbon segments where the non-fluorinated part can degrade and ultimately form perfluorinated PFAS acids, such as PFOA and PFOS. While the long-chain PFAS accumulate in humans, animals and sediment/soil, the short-chain PFAS accumulate in the environment (German EPA, 2017, 2018) due to their persistency and high mobility in air and water. The OECD provides further information on groups of PFAS.

Why are PFAS a concern?

PFAS either are, or degrade to, persistent chemicals that accumulate in humans, animals and the environment. This adds to the total burden of chemicals to which people are exposed (Evans et al., 2016) and increases the risk of health impacts. Of the relatively few well-studied PFAS, most are considered moderately to highly toxic, particularly for children's development. Figure 1 summarises current knowledge of the health impacts of PFAS.

Figure 1. Effects of PFAS on human health



Sources: US National Toxicology Program, (2016); C8 Health Project Reports, (2012); WHO IARC, (2017); Barry et al., (2013); Fenton et al., (2009); and White et al., (2011).

People most at risk of adverse health impacts are those exposed to high levels of PFAS, and vulnerable population groups such as children and the elderly. Fewer studies have investigated effects on biota (Land et al., 2018). Throughout life, people and animals accumulate PFAS in their bodies. In 2018, the European Food Safety Authority (EFSA) re-evaluated the multiple lines of evidence of PFOA and PFOS toxicities, which resulted in significantly lower provisional ‘safe’ limits, known as the ‘tolerable weekly intake’ (TWI) (EFSA, 2018). The assessment concluded that a considerable proportion of the European population is expected to exceed the TWI due to intake of PFAS from food and drinking water.

Costs to society arising from PFAS exposure are high, with the annual health-related costs estimated to be EUR 52-84 billion across Europe in a recent study (Nordic Council of Ministers, 2019). The study notes that these costs are likely underestimated, as only a limited range of health effects (high cholesterol, decreased immune system and cancer) linked to exposure to a few specific PFAS were included in the estimates. In addition, PFAS pollution also affects ecosystems and generates costs through the need for remediation of polluted soil and water. Such costs are currently difficult to assess since information on the number and scale of sites contaminated with PFAS in Europe and on how PFAS impact ecosystems is lacking.

What are the main sources of environmental PFAS pollution?

- Production and use of PFAShave been the main sources of PFAS contamination over time (Wang et al., 2014a, 2014b; Hu et al., 2016) for instance from fluoropolymer production installations and from the use of PFAS-containing firefighting foams (Figure 1). Other sources include PFAS produced and applied to textiles and paper and painting/printing facilities (Danish EPA, 2014). Less is known about potential releases of PFAS from other uses such as oil extraction and mining (Kissa, 2001), and the production of medical devices, pharmaceuticals and pesticides (Krafft and Riess, 2015).
- PFAS in consumer products, such as textiles, furniture, polishing and cleaning agents and creams, may contaminate dust and air, while food contact materials can contaminate food (Nordic Council of Ministers, 2019; Danish EPA, 2018). Drugs and medical devices may be other sources.
- Emissions to the environment occur via industrial waste water releases, as well as emissions to air from industrial production sites followed by deposition onto soil and water bodies. Industrial and urban waste water treatment plants are also a significant source of PFAS, via air, water and sludge (Hamid, et al., 2016; Eriksson et al., 2017).
- Reuse of contaminated sewage sludge as fertilisers has led to PFAS pollution of soil (Ghisi et al., 2019) and water in Austria, Germany, Switzerland and the US (Nordic Council of Ministers, 2019). The recycling of PFAS containing materials such as food contact materials and the formation of volatile fluorinated gases during waste incineration (Danish EPA, 2019) are other possible sources of PFAS pollution.

Where are PFAS found in Europe’s environment?

PFAS are ubiquitous in the aquatic environment and organisms (Valsecchi et al., 2013) across Europe, and have been detected in air, soil, plants and biota (Houde et al., 2006). Areas around industrial production, manufacturing and application sites have been found to be particularly contaminated by PFAS. This has led to contaminated drinking water around factories in Belgium, Italy and the Netherlands, and around airports and military bases in Germany, Sweden and the United Kingdom (IPEN, 2018; Hu et al., 2016). The total number of sites potentially emitting PFAS is estimated to be in the order of 100 000 in Europe (Nordic Council of Ministers, 2019).

Generally, regulated PFAS have been substituted with other short-chain and polymeric PFAS.

Regrettably, several of these ‘novel’ PFAS and their short chain degradation products are also persistent. In particular, short-chain PFAS accumulate in the environment and have been found to contaminate surface, ground- and drinking water (Eschauzier et al., 2012; Sun et al., 2016; Gebbink et al., 2017), and accumulate in plants (Ghisi et al., 2019), which may lead to increases in human dietary exposure.

Novel PFAS are increasingly detected (Xiao, 2017) in European surface waters. PFAS water pollution has been identified in countries across Europe, including Austria, Denmark, France, Germany, the Netherlands and Sweden, as well as outside the EU. Several PFAS are sufficiently volatile to be considered long-range transboundary air pollutants, implying that emissions outside Europe are transported into Europe where they may accumulate in cold areas such as the Arctic (EEA, 2017). The well-known and regularly monitored PFAS (mainly perfluorinated acids) account only for a fraction of the chemical burden from PFAS present in human blood, the environment and wildlife (Koch et al., 2019).

While both well-known and novel PFAS have been detected in drinking water in non-EU countries (Xiao, 2017; Kaboré et al., 2018; Dauchy, 2019), at present there is little monitoring data available in the EU for drinking water. A case study by the World Health Organization (WHO) documents the story of PFAS contamination of the drinking water of 21 municipalities in the Veneto region of Italy. Industrial activity in the area had polluted both surface waters and ground water, as well as the drinking water of approximately 127 000 citizens (WHO, 2017). Monitoring conducted by the authorities of the Veneto Region found PFOS in 63-100 % of the locations sampled and PFOA in 100 % of the sites.

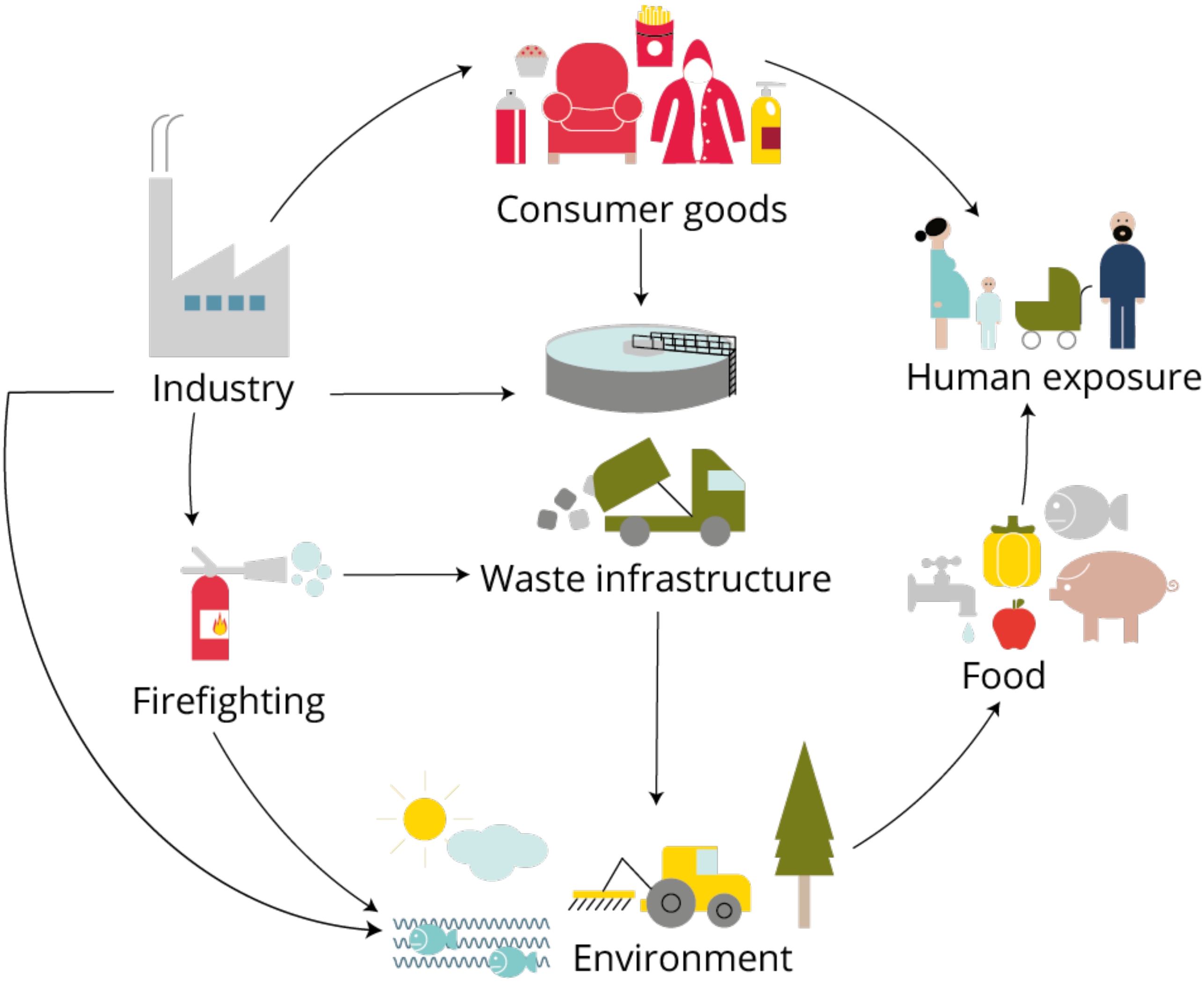
For comparison, the European Commission proposed a limit value of 0.1 µg/L for each individual PFAS in the 2018 recast of the EU Drinking Water Directive. This draft limit value was exceeded by a factor of 130 for PFOS and 66 for PFOA in samples taken in the Veneto Region.

PFOS and their derivatives are included as a priority hazardous substance under the EU Water Framework Directive (EU, 2013), with a much lower Environmental Quality Standard (AA-EQS) limit value of 0.65 ng/L (0.00065 µg/L) in inland surface waters and 0.13 ng/L in seawater. Member States are due to report on compliance with the PFOS EQS by 2021. Samples taken in 2013 in Northern Europe exceeded this EQS in 27 % of river sites and 94 % of Baltic Sea and Kattegat seawater (Nguyen et al., 2017).

What are the main routes of human exposure to PFAS?

The main exposure pathways for human and environmental exposures are shown in Figure 2. For the general population, PFAS sources include drinking water, food, consumer products and dust (EFSA, 2018). In food, fish species at the top of the food chain and shellfish are significant sources of PFAS exposure. Livestock raised on contaminated land can accumulate PFAS in their meat, milk and eggs (Ingelido et al., 2018; Numata et al., 2014). Direct exposure may also come via skin creams and cosmetics (Danish EPA, 2018; Schultes et al., 2018) or via air from sprays and dust from PFAS-coated textiles. There is little knowledge on uptake via skin and the lungs, which can be severely affected by PFAS (Nørgaard et al., 2010; Sørli et al., 2020). Consumer exposure may also occur via other routes such as via floor, wood, stone, and car polishing and cleaning products. Groups that may be exposed to high concentrations of PFAS include workers and people eating or drinking water and foods contaminated via PFAS treated food contact materials (Susmann et al., 2019). Though PFAS are used in drugs and medical equipment, there is little information on exposure via these routes.

Figure 2: Typical PFAS exposure pathways



PFAS are transferred in the womb from mother to child and unless exposure decreases with age, the PFAS body burden increases due to bioaccumulation (Koponen et al., 2018). Evidence of internal PFAS exposure in humans is available from several national human biomonitoring studies conducted inside and outside Europe. Men generally have higher PFAS body burdens and serum levels (Ingelido et al., 2018) because they excrete fewer PFAS. For the most regulated PFAS, such as PFOA and PFOS, consistent declines have been observed over the past 10-20 years in Europe (e.g. in Belgium, Denmark, Finland, Germany, Spain and Sweden). This decrease in levels in humans is likely to result from reduced exposure as a result of regulatory and non-regulatory action on consumer products, such as food contact materials (Susmann et al., 2019) and textiles (Greenpeace, 2017).

Despite the decreases in long-chain PFAS levels in human blood, concentrations of PFOA and PFOS measured in human blood still exceed the EFSA benchmark dose levels (known as $BMDL_5$). This is particularly true for children and highly exposed sections of the European population (Buekers et al., 2018). The $BMDL_5$ reflect the concentration in blood at which critical effects occur (cholesterol effects for adults and immune-toxicity for children) and are the basis for the provisional TWIs for PFOA and PFOS (EFSA, 2018).

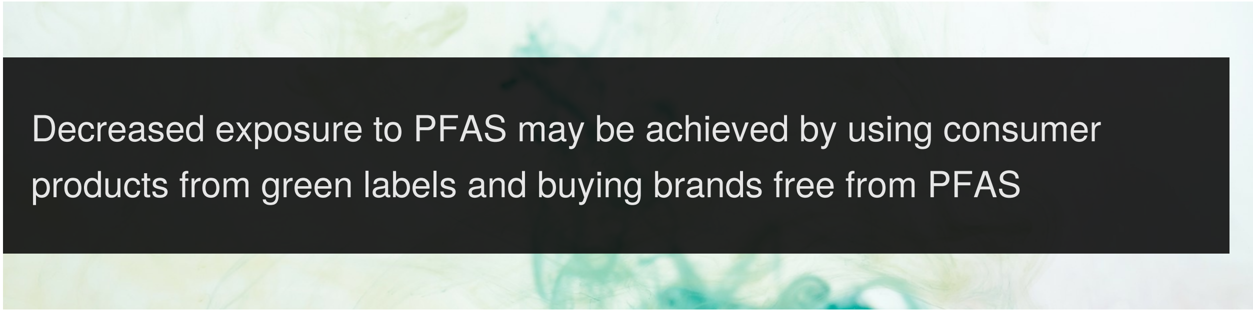
The above mentioned human biomonitoring study in the Veneto Region investigated human exposure to PFOA and PFOS in the period 2015-2016 among 257 Italian residents of contaminated areas and 250 residents of background areas (Ingelido et al., 2018). The PFOA blood concentrations of residents of contaminated areas were 9-64 times higher than those of the background population. For PFOS, the levels were 1.4-1.6 times higher. Levels of PFOA in the highly exposed population were 0.2 to 26 times greater than the EFSA $BDML_5$, while for PFOS, the figure was 0.3-1.3 times. EU research projects, such as Human Biomonitoring for Europe (HBM4EU) (Box 2), are currently working to produce a representative picture of PFAS exposure for the European population, as well as investigating links between exposure and health effects.

Box 2

The Human Biomonitoring for Europe (HBM4EU) initiative is a 5-year EU Horizon 2020 research programme designed to translate human biomonitoring science into policy-relevant knowledge. A main task within the project is to generate representative chemical exposure data for the European population through harmonised human biomonitoring. PFAS is one of the 18 HBM4EU priority substance groups investigated by HBM4EU to better understand exposure and effects on health.

How can consumers avoid PFAS?

It is difficult for citizens to totally avoid exposure to PFAS. Using PFAS-free personal care products and cooking materials and avoiding direct contact with PFAS-containing products helps to reduce exposure. Decreased exposure to PFAS may be achieved by using consumer products from green labels and buying brands free from PFAS. General and specific guidance to consumers and business on how to find PFAS-free alternatives is provided by consumer organisations and some national institutions (see Danish EPA, German EPA and Swedish KEMI).



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What is being done in the EU and globally?

Measures to reduce PFAS pollution are in place, mainly addressing well-known PFAS substances and their precursors. PFOS and PFOA are listed under Annex A of the Stockholm Convention on persistent organic pollutants (POPs), implying that parties to the Convention should 'eliminate the production and use' of the chemicals.

At EU level, PFOS is restricted under the EU POPs Regulation (EU, 2019). PFOA and its precursors are currently restricted under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation (EU, 2006), including their presence in products made or imported into the EU. This will soon be replaced by a new restriction under the POPs Regulation, which will have more limited derogations, following a decision taken at the Stockholm Convention.

A number of other PFAS are on the REACH list of Substances of Very High Concern (SVHCs). In June 2019, GenX (a short-chain PFAS substitute for PFOA in fluoropolymer production) was the first chemical added to the SVHC list on the basis of its persistent, mobile and toxic properties posing a threat to drinking water and the environment. Several PFAS are on the Community Rolling Action Plan for evaluation over the coming years. As mentioned above, PFOA and PFOS are priority hazardous substances under the Water Framework Directive (EC, 2017; EU, 2000).

Across Europe, several countries have been active in monitoring PFAS in environmental media as well as in humans and products. Some countries have set national limit values for water and soil (Denmark, Germany, the Netherlands and Sweden), for textiles (Norway) and for food contact materials (Denmark). Several EU Member States have set drinking water limits for specific PFAS and for groups of PFAS (Dauchy, 2019). In June 2019, Denmark announced a ban on PFAS-treated food contact materials, to enter into force in 2020.

Looking ahead

With more than 4 700 known PFAS, undertaking substance-by-substance risk assessments and comprehensive environmental monitoring to understand exposure would be an extremely lengthy and resource-intensive process. As a result, complementary and precautionary approaches to managing PFAS are being explored.

This includes the regulation of PFAS as a class, or as subgroups, based on toxicity or chemical similarities. The proposal to establish a new 'group limit' value for PFAS of 0.5 µg/L, in addition to limits for 16 individual PFAS of 0.1 µg/L in drinking water under the recast of the EU Drinking Water Directive is currently under consideration at EU level. Such measures can be supported by cost-effective and targeted monitoring of PFAS in the environment to provide early warning signals of pollution.

In June 2019, the European Council of Ministers (EC, 2019) highlighted the widespread occurrence of PFAS in the environment, products and people, and called for an action plan to eliminate all non-essential uses of PFAS (Cousins et al., 2019).

The move towards zero pollution requires that product life cycles are made safer from the start (Warner and Ludwig, 2016), based on the concept of safe-and-circular-by-design (van der Waals et al., 2019). This approach offers opportunities to protect the health of Europe's citizens and environment at the same time as driving innovation for safer chemicals.

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