Forever chemicals under the microscope: How Europe's fishmeal industry is confronting PFAS

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For decades, marine ingredients have anchored modern aquaculture — long recognized as the "golden standards" in fish nutrition. But in recent years, however, a new challenge has emerged across food and feed systems, and even in wildlife: the emergence of "forever chemicals" (PFAS). Their persistence has understandably raised concerns from manufacturers, regulators, and consumers.

In response, the marine ingredients industry has taken a science-driven approach. Industry partners have built an extensive database, profiling PFAS occurrence in marine ingredients across Europe, covering species origin, oceanographic regions, and raw material streams. This aligns with a growing knowledge base from scientific studies and monitoring programs showing that farmed fish exhibit PFAS levels below detection limits or well below EU thresholds. Together, these findings highlight an important message for the European blue value chain: with robust monitoring and responsible sourcing, the role of marine ingredients is not compromised. From the industry's perspective, it is critical that PFAS pollution is also addressed and regulated at its source, rather than managed through downstream restrictions.

What are PFAS and where can they be found?

Per- and polyfluoroalkyl substances (PFAS) are a large group of more than 4,000 synthetic chemicals that have been widely used across a remarkable diversity of industrial and consumer applications since the 1950s: from non-stick cookware, waterproof textiles, to food packaging and fire-fighting foams. Their appeal lies in their chemical stability: the carbon-fluorine bond is among the strongest in organic chemistry, giving PFAS the potent ability to repel both water and oil, along with a thermal stability that has made them highly desirable across a wide range of indoor and outdoor applications.

However, the stability that makes PFAS so useful is also their Achilles heel. These compounds degrade extremely slowly in the environment, which has earned them the nickname "forever chemicals." Entirely man-made and produced in substantial quantities, PFAS are now globally distributed contaminants. Once released, their persistence and mobility allow them to migrate easily in soils and aquatic environments where they can be taken up by plants, invertebrates, and animals. Over time, these compounds move through food webs, leading to low but measurable concentrations in a wide range of foods, from crops and dairy products to meat, eggs, and seafood. Their presence across such a wide range of products underscores that PFAS contamination is not confined to any single sector but represents a systemic challenge for both environmental management and food safety. For products of aquatic and marine origins, trace amounts of PFAS have been detected in a variety of products — including shellfish, wild and farmed fish, as well as the marine ingredients such as fishmeal and fish oil derived from them. Their presence underscores the need for ongoing vigilance, robust monitoring, and upstream action to reduce environmental sources.

Evolving regulation of PFAS in food and feed

Regulatory frameworks for PFAS are developing rapidly across Europe as authorities attempt to keep pace with the growing body of scientific evidence and rising public concern. In 2020 (EFSA Journal, 18(9), 6223), the European Food Safety Authority (EFSA) published a landmark re-evaluation of PFAS exposure risks, setting a tolerable weekly intake (TWI) of 4.4 nanograms per kilogram of body weight. This was designed to protect against adverse effects observed in humans and applies to the sum of four well-studied PFAS compounds — PFOS, PFOA, PFNA, and PFHxS. It reflects total dietary exposure from all food sources rather than from any single ingredient.

In response, the European Commission has established maximum levels (MLs) for these four PFAS in various foods of animal origin, including fish, meat, eggs, and offal, in Regulation (EU) 2023/915. These limits, which range depending on the product, were introduced to create a common reference point for risk management across Member States.

Interestingly, the acceptable limits for fish products differ markedly between species. For instance, the maximum level for the sum of the four PFAS compounds is 2 µg/kg for commonly consumed species such as trout or salmon, 8 µg/kg for most marine species, including herring and sprat, and up to 45 µg/kg for species such as eel (Table 1). At first glance, this might suggest that certain fish are viewed as "more toxic" than others under EU law. In practice, however, these differences reflect dietary exposure modelling used by EFSA to translate the TWI of 4.4 ng/kg body weight into realistic consumption-based limits. This highlights the complexity of PFAS risk management in the EU: limits are derived not just from contamination levels but from a holistic assessment of exposure, bioaccumulation, and consumption behavior, aligning regulation with both toxicological evidence and dietary context.

There are still no harmonized EU limits for PFAS in feed materials, including marine ingredients such as fishmeal and fish oil. Member States have been encouraged to implement national surveillance programs to establish baseline data on PFAS concentrations in feeds and raw materials, using aligned methodology. This work is intended to build a more coherent picture of environmental exposure in feed chains and will ultimately inform future policy development. An EFSA recommendation on possible maximum levels for PFAS in feed is anticipated later in the future, once sufficient monitoring data and risk assessments have been consolidated.

Without intervention, 4.4 million tonnes of PFAS could enter the environment over the next 30 years

Beyond the feed sphere, PFAS are now a central focus of the EU Chemicals Strategy for Sustainability, which aims to tackle pollution at its source rather than downstream. The European Chemicals Agency (ECHA)

Table 1. Maximum levels (µg/kg wet weight) for the sum of four PFAS compounds (PFOS, PFOA, PFNA, PFHxS) in foods of animal origin as established under Commission Regulation (EU) 2022/2388, now consolidated into Regulation (EU) 2023/915. Values represent the sum of the four PFAS unless otherwise indicated. These limits form the current EU reference for managing PFAS exposure in food products, with no equivalent limits yet established for feed materials.

Foodstuffs	PFOS	PFOA	PFNA	PFHxS	Sum of PFAS4
1. Eggs	1.0	0.30	0.70	0.30	1.7
2. Fishery products and bivalve mollusks					
2.1 Fish meat					
2.1.1 Muscle meat of fish, except those listed under 2.1.2 and 2.1.3, and not intended for infants/young children *mainly for fish such as salmon and trout*	2.0	0.20	0.50	0.20	2.0
2.1.2 Muscle meat of the following fish (for food not for infants/ young children): *mainly marine fishes such as herring and cod and sprats*	7.0	1.0	2.5	0.20	8.0
2.1.3 Muscle meat of the same species listed above, when intended for infants and young children *mainly fish species such as eels, char and roach*	35	8.0	8.0	1.5	45
2.2 Crustaceans and bivalve mollusks (muscle meat, appendages, and abdomen; for crabs/crab-like crustaceans, muscle from appendages)	3.0	0.70	1.0	1.5	5.0
3. Meat and edible offal					
3.1 Meat of bovine animals, pig and poultry	1.0	0.30	0.20	0.20	1.3
3.2 Meat of sheep	1.0	0.20	0.20	0.20	1.0
3.3 Offal of bovine animals, sheep, pig and poultry	3.0	0.50	0.30	0.30	3.5
3.4 Meat of game animals (except bear)	5.0	1.5	0.50	0.50	6.0
3.5 Offal of game animals (except bear)	50	50	25	45	90

is currently reviewing a joint restriction proposal from Denmark, Germany, the Netherlands, Norway, and Sweden under the REACH Regulation, seeking to limit the manufacture, marketing, and use of PFAS across nearly all sectors. Without intervention, authorities estimate that around 4.4 million tonnes of PFAS could enter the environment over the next 30 years. A scientific evaluation of the proposal is expected by the end of 2026, after which the European Commission may consider one of the most far-reaching chemical restrictions ever implemented in the EU. If adopted, the measure would mark a major shift in how persistent pollutants are managed – addressing emissions at their origin rather than controlling residues downstream.

How has the marine ingredients sector responded?

At present, PFAS monitoring in marine ingredients remains largely industry led. EFFOP–Marine Nutrients Europe, representing the European fishmeal and fish oil producers, has been working to establish a coordinated, data-driven monitoring framework that captures the natural variability associated with species, fishing areas, seasons, and production conditions. In 2023, responding to EFSA's Call for Continuous Collection of Chemical Contaminant Occurrence Data in Food and Feed, EFFOP submitted a dataset covering 175 distinct fishmeal batches — the most extensive PFAS dataset of its kind to date. The objective was to build a robust evidence base to inform EFSA's ongoing risk assessments and support the development of proportionate, risk-based management strategies for future regulation in feed materials.

While it is still too early to gauge the full implications for the industry, establishing feed limits with low PFAS thresholds — without a balanced risk-benefit assessment — would restrict the use of some raw material streams. Evidence from other sectors does show that PFAS compounds can exhibit high binding affinity in specific animal matrices, such as organic egg-laying hens (Granby *et al*., 2024), and in these cases, a tailored limit would be necessary to avoid compromising the EU's current limits for food products and our TWI. By contrast, toxicokinetic relationships in fish and other aquatic organisms remain poorly understood. The degree to which PFAS are absorbed, distributed, metabolized, and excreted varies between species and depends strongly on the compound's chain length and functional group. As a result, there is no robust quantitative framework for predicting PFAS bioaccumulation in fish under commercial aquaculture conditions, although emerging monitoring and modelling data are beginning to offer useful insights.

Monitoring data confirms absence of PFAS in Norwegian salmon

The Monitoring Programme for Fish Feed, coordinated annually by the Institute of Marine Research (IMR) on behalf of the Norwegian Food Safety Authority, plays a central role in assessing undesirable substances in aquafeeds and raw materials used in Norwegian aquaculture. The program routinely analyses feeds and ingredients for contaminants, such as metals, organic pollutants, and PFAS, ensuring compliance with national and EU standards while tracking long-term trends. The most recent report (Lundebye *et al.*, 2024) provides one of the most comprehensive snapshots of contaminant prevalence in the aquafeed sector. Most feeds contained PFAS below detection limits, with 8% of samples registering measurable concentrations of 0.6-3.2 µg/kg. Complementary surveillance programs extend this monitoring to farmed fish, where PFAS residues are also measured directly. In 2024, the IMR analyzed 1015 samples from farms across Norway for unauthorized substances and environmental contaminants (Carey & Bernhard, 2025). Most PFAS compounds were below their respective limits of quantification, and no samples exceeded EU maximum levels. Comparable results have been reported elsewhere in Europe. A recent Dutch study (Zafeiraki *et al.*, 2019) of wild and farmed aquatic species found that farmed fish, such as trout, catfish, turbot, salmon, tilapia, and pangasius, consistently showed the lowest PFAS concentrations among all

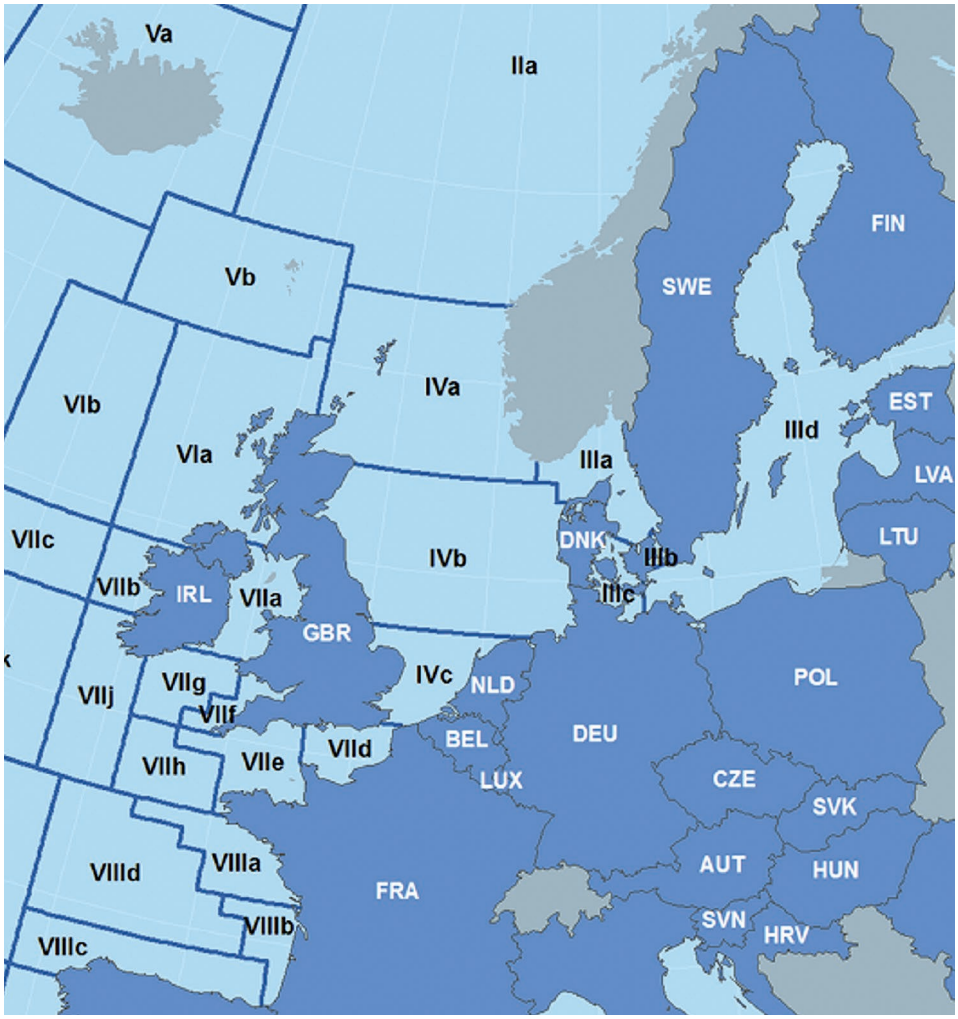

Figure 1. Geographical scope of EFFOP's PFAS sampling program across FAO Major Fishing Areas. Utilizing the FAO ocean area classification system, EFFOP's monitoring covers a broad range of fishing zones across northern European waters. The sampling framework is designed to capture variability in PFAS concentrations across species, oceanic origin, and season, providing representative coverage of the raw materials used in European fishmeal and fish oil production.

samples analyzed, with average levels ranging from 0.06 to 1.5 µg/kg — markedly below those measured in wild-caught fish and shrimp.

Taken together, the available evidence indicates that PFAS levels in aquaculture products are generally low, and that uptake from feed appears limited under current production conditions. However, PFAS behavior varies considerably among animal species. These differences highlight the need for future regulatory limits to be species-specific, reflecting distinct toxicokinetic pathways and accumulation potentials across aquatic organisms. A one-size-fits-all approach will risk imposing disproportionate restrictions on certain sectors without improving food safety outcomes. Continued research, harmonized monitoring, and data sharing between regulators and industry will therefore be essential to ensure that future PFAS management in feed and food systems remains scientifically justified, proportionate, and effective.

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