Environment Agency

Developing thresholds for managing PFAS in the water environment

Chief Scientist's Group report

January 2026

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Dr Robert Bradburne
Chief Scientist

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Executive summary

Per- and polyfluoroalkyl substances (PFAS) are a large and chemically diverse group of synthetic fluorinated organic chemicals widely used in industrial applications and consumer items. They are extremely persistent in the environment, with some known to bioaccumulate and be harmful to health. Additionally, some have high environmental mobility. This, in combination with their persistence, means they can travel far from their original source. Environmental monitoring data indicates many PFAS are present in our rivers, estuaries and groundwater.

Environmental Quality Standards (EQSs) are an important tool in water quality legislation in England. They represent the concentration (threshold) of a substance in water above which an adverse effect on aquatic life, and in some cases human health, may occur. There is only one EQS for PFAS - a statutory standard for perfluorooctane sulphonate (PFOS) listed under The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

In the absence of EQSs for other PFAS, thresholds are needed by the Environment Agency for assessing and managing the environmental risks from PFAS in rivers, lakes, estuaries and coastal waters.

Deriving thresholds for PFAS is challenging for several reasons: (i) there are many PFAS, and they are chemically diverse and (ii) sufficient reliable and relevant (eco)toxicity data are only available for a few PFAS.

A pragmatic approach was adopted, using readily available, reliable data and following existing guidance for EQS derivation (EC, 2018). The method for EQS derivation was modified to focus on the endpoint considered likely to be the most sensitive for these substances - the protection of human health via the consumption of fish. Thereore altough the threshold values derived in this project are not EQSs, they have been derived using the same principles.

A biota-based threshold value of 77 ng/kg was derived for the sum of four PFAS (PFOS, perfluorooctanoic acid (PFOA), perfluorohexane sulfonic acid (PFHxS) and perfluorononanoic acid (PFNA)), using the tolerable weekly intake (TWI) derived by the European Food Safety Authority (EFSA) (EFSA, 2020). The threshold relates to the combined concentration of these four PFAS in fish.

Most environmental monitoring in the aquatic environment comprises water samples, therefore substances with a biota-based EQS typically have an equivalent water concentration value. This facilitates comparison of the biota threshold with concentrations detected in water or discharges to water.

The equivalent water concentrations derived are 0.015 ng/L for PFOS, 0.4 ng/L for PFOA, 0.2 ng/L for PFHxS and 0.3 ng/L for PFNA. The lower value derived for PFOS relative to the other three substances reflects the greater bioaccumulation of this substance.

EQS are normally derived for individual substances. However, the effects data used to derive these thresholds relates to the combined exposure to four PFAS. Consequently, the equivalent water concentration values should not be used as individual threshold limits, unless only one of the 4 substances is present.

We have considered how the combined effects of the four PFAS could be considered using equivalant water concentrations for the individual PFAS. Due to the large range of values, it’s not appropriate to use the lowest concentration as a proxy for all four substances. Instead, the Hazard Index (HI) approach can be used to assess the effects of combined exposure to these four PFAS. This is consistent with the development of soil screening values in the UK for these four PFAS, where the HI approach was also used (CL:AIRE, 2024).

The HI is used when two or more of the four PFAS of interest are present in an environmental sample or discharge. However, because it does not provide a single concentration for the four PFAS in water, it is a different approach to that currently used for EQSs or predicted no-effect concentration (PNECs).

PFOS is included in this report as it is one of the four PFAS covered by the health-based guidance value used to derive the thresholds. The threshold for PFOS derived in this project is lower than the EQS for PFOS as more recent toxicology and bioaccumulation data have been used. The thresholds derived in this report are not EQSs but have been derived using the same principles. The values derived here for PFOS do not replace the existing statutory EQS for PFOS.

This report reflects the data and information available at the time. It should be reviewed if additional significant information becomes available.

This is a research report and is not government policy or official guidance.

1. Introduction

Per- and polyfluoroalkyl substances (PFAS) are a large and chemically diverse group of synthetic fluorinated organic chemicals widely used in industrial applications and consumer items. The properties of PFAS include heat resistance and oil and water repellency, resulting in their use in a wide variety of products including aqueous fire-fighting foams, hydraulic fluids and coatings on packaging and textiles.

PFAS are extremely persistent in the environment, with some known to bioaccumulate and be harmful to health. Additionally, some have high environmental mobility which, in combination with their extreme persistence, means they can travel far from their original source. The presence of PFAS in the environment is of concern because of their impact on health and possible long-term exposure due to their persistence. Research is ongoing globally to better understand the potential impact on the environment and human health from this large and complex group of substances and inform risk management and mediation actions.

Regulatory thresholds for chemicals, such as environmental quality standards (EQSs), are a key tool in water quality legislation in England. An EQS represents the concentration of a chemical in the water environment above which an adverse effect on aquatic life, and in some cases human health, may occur. They are used to assess the potential impact of chemicals detected in the environment and to manage risks from their release.

Several protection endpoints are considered when deriving an EQS, including toxicity to aquatic life, secondary poisoning and effects on human health. Aquatic toxicity is assessed for all substances, but other endpoints such as secondary poisoning are only considered if the substance has certain hazardous properties defined in the EQS guidance (EC, 2018). Impact via consumption of fish is assessed, for example, if a substance has the potential to bioaccumulate or cause serious damage to human health through prolonged exposure. When multiple protection endpoints are considered the most sensitive determines the EQS for that substance. EQSs are generally expressed as concentrations in water. However, for secondary poisoning and impacts on health via consumption of fish the EQS is expressed as a concentration in biota (fish or shellfish).

In England there is a statutory EQS for one PFAS - perfluorooctane sulphonate (PFOS). This EQS was published in the EU EQS Directive (2013/39/EU) and transposed into English legislation via The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015. The biota-based EQS of 9100 ng/kg relates to the protection of human health via the consumption of fish. In addition, there is an EQS for the water column, of 0.65 ng/L in freshwater, which is equivalent to the biota EQS.

Monitoring data shows many PFAS are present in our rivers, estuaries and coastal waters. Without an EQS for most PFAS in England, effects-based thresholds are required to assist Environment Agency staff in assessing and managing the risk from their presence in the aquatic environment and discharges to the water environment. For example, thresholds are used to contextualise monitoring data supplied by site operators at high-risk sites under Regulation 61 of the Environmental Regulations and to inform risk assessment of concentrations in discharges from regulated sites.

This project was commissioned to address the Environment Agency's immediate need for additional thresholds for PFAS for the water environment by determining scientifically robust effects thresholds for several PFAS. A pragmatic approach was taken, with the substances considered being driven by availability of relevant, readily available data and operational need, with emphasis on those PFAS that are frequently detected in English rivers, lakes, estuaries and coastal waters.

2. Method

Deriving thresholds for PFAS is challenging for several reasons: (i) there are many PFAS, and they are chemically diverse and (ii) sufficient reliable and relevant (eco)toxicity data are only available for a few substances. Several different approaches have been used by regulators globally to derive thresholds for PFAS (EA, 2025). These include approaches for individual substances, groups of specific PFAS and total PFAS. Some approaches have used effects data while others are based on analytical or technology capability.

The method for deriving EQSs (EC, 2018) was used in this project to determine effects-based thresholds for additional PFAS. This provided consistency in the overall approach with existing EQSs. However, for pragmatic reasons, minor modifications were made to the approach to meet the operational timescales. For example, only the protection endpoint of human health via the consumption of fish was considered. This was identified as the most sensitive protection endpoint when deriving the EQS for PFOS. Based on available data it is considered likely to also be the most sensitive protection endpoint for the PFAS considered in this report.

2.1 Deriving a biota threshold for the protection of human health

An oral health-based guidance value (HBGV) such as a Tolerable Daily Intake (TDI), Acceptable Daily Intake (ADI) derived by an authoritative national or international body such as the World Health Organisation (WHO) is used, where available, to derive a threshold for the protection of human health via the consumption of fish. The latter is referred to as a $QS_{biota,hh}$ in the EQS guidance and is used for ease of reference in this report when referring to thresholds derived for this endpoint (EC, 2018).

In 2020 the European Food Safety Authority (EFSA) assessed risks to human health from the consumption of PFAS in food and derived a Tolerable Weekly Intake (TWI) (EFSA, 2020). This TWI relates to the sum of four PFAS (perfluorooctane sulphonate (PFOS) (perfluorooctanoic acid (PFOA), perfluorohexane sulfonic acid (PFHxS) and perfluorononanoic acid (PFNA)) considered to contribute most to the levels of PFAS found in human serum.

This TWI was selected for the derivation of the thresholds in this report as it is a recent, relevant oral HBGV derived by an authoritative international body. In addition, it relates to PFAS of interest to the Environment Agency for example PFOA (EA, 2021). This TWI has been used to determine regulatory thresholds for PFAS by several European countries including Denmark, Sweden, Germany and Belgium (EA, 2025). It was also used in the derivation of soil screening values in England and Wales (CL:AIRE, 2024). The EU EQS proposal for a group of 25 PFAS also uses the EFSA (2020) TWI as it’s basis (EU, 2025).

A previous HBGV (EFSA, 2008) was used to derive the EQS for PFOS, although this has now been superseded by the EFSA TWI (2020) noted above.

The TWI (EFSA, 2020) of 4.4 ng/kg body weight (bw) per week is expressed as a weekly intake value. A daily tolerable intake value is required to derive a $QS_{biota,hh}$ (EC,2018). The TWI was therefore divided by seven to get an equivalent daily intake value of 0.628 ng/kg weight (bw) per day.

Alongside a relevant HBGV, information on (i) the quantity of fish consumed each day and (ii) the proportion of the diet from fishery products are used to derive a $QS_{biota,hh}$ (EC, 2018). As for previous EQS derivation the default values included in the EQS guidance (EC, 2018) were used.

The default value for daily fish consumption is 0.114kg per day per person, which equates to 0.00163kg fish per kg bw per day, using an average body weight per person of 70kg. The default value for the proportion of the diet from fishery products is 0.2. This is noted to be a conservative value based on the 20% default allocation factor used by the WHO (2011).

Using the above information and the following equation (EC, 2018) a **$QS_{biota,hh}$ of 77 ng/kg** was derived. This relates to the **sum of the four PFAS (PFOS, PFOA, PFNA and PFHxS**) covered by the EFSA TWI (2020).

$$QS_{biota,hh} = \frac{\text{(proportion of diet from fishery products) (Toxicity threshold } (TL_{hh}))}{\text{(daily fish consumption)}}$$

$$QS_{biota,hh} = \frac{(0.2) \times (0.628 \text{ ng/kg bw/day})}{0.00163 \text{ kg/kg bw/day}} = 77 \text{ ng/kg}$$

2.2 Deriving equivalent water concentrations

Most regulatory monitoring in the aquatic environment involves collecting water samples rather than biota such as fish. Therefore, having a water-based threshold, in addition to a biota (fish) threshold, is useful to assess the concentrations detected in water samples or discharges to the water environment. It also minimises the need to sample fish.

An equivalent water concentration for the $QS_{biota,hh}$ of 77 ng/kg was derived using the method outlined in the EQS guidance (EC, 2018) and is summarised below.

2.2.1 Outline of Approach

Information on the bioaccumulation potential of the substance of interest is required to determine an equivalent water concentration. Bioaccumulation factors (BAFs), bioconcentration factors (BCFs) or biomagnification factors (BMFs)/trophic magnification factors (TMF) can be used (EC, 2018). However, the relevant field derived BAFs are preferred where available (EC, 2018).

BAFs consider the uptake of a chemical by an organism via water, food and sediments, unlike BCFs which only consider uptake via water. BAFs can be determined for the whole organism or a specific tissue such as muscle or liver. Variability in the BAFs reported for a substance can be due to several factors including differences between species and the concentration to which they are exposed, as well as the test conditions. The guidance (EC,

2018) specifies that relevant and reliable BAFs for fish in trophic level 4 are preferred when deriving equivalent water concentrations, as the $QS_{biota,hh}$ applies at the trophic level of predatory fish (EC, 2018).

The following equation (EC, 2018) is used to derive a water concentration equivalent to the $QS_{biota,hh}$:

$$QS_{water,biota} = QS_{biota,hh}/BAF$$

If multiple relevant BAF values are available for a substance the geometric mean of the values should be used (EC, 2018). The equivalent water concentration derived is applicable to both freshwater and saltwater environments (EC, 2018).

2.2.2 Locating BAFs for PFOS, PFNA, PFOA and PFHxS

The $QS_{biota,hh}$ of 77 ng/kg derived in Section 2.1 is for the sum of four PFAS (PFOS, PFOA, PFNA and PFHxS). A literature search was undertaken to locate BAFs for each of these PFAS.

The grey literature was searched using Google and the search term ‘BAFs and PFAS’, to locate relevant reports by authoritative bodies. Reports by the European Chemicals Agency (ECHA) and scientific institutions such as the National Institute for Public Health and the Environment (RIVM) in the Netherlands were among those located.

Scopus was used to search the peer reviewed scientific literature. The search term (PFAS OR PFNA OR PFOA OR PFOS OR PFHxS) AND (bioaccumulation OR BAF or BCF) AND (Fish*) identified 471 papers. Screening by title and abstract excluded papers which did not report BAFs for fish for these four PFAS. This resulted in 99 papers for further consideration. Papers published before 2020 were then excluded as two recent and comprehensive compilations of BAFs for PFAS, covering this period, were found during the literature search (Burkhard (2021); ITRC (2023)). Only four of the remaining 59 papers reported BAF values of relevance to this project; for relevant PFAS, relevant tissues (whole fish and muscle/fillet) and for fish of an appropriate trophic level. The values reported were within the range of those noted in the Burkhard (2021) and ITRC (2023) compilations.

Both Burkhard (2021) and ITRC (2023) included BAFs for the four PFAS of interest (PFOS, PFNA, PFOA and PFHxS) and are useful resources for this project. Burkhard (2021) collated BAFs for PFAS from several sources in 2018, including the peer reviewed scientific literature and ToxNet (a collation of toxicology databases), with subsequent searches in 2019 and the first half of 2020. The ITRC (2023) compiled BAF values from numerous published studies up to September 2021. The BAFs compiled in both sources were compared. There was significant overlap in the studies contained in both compliations. Where additional BAFs were noted in the ITRC (2023) they were in a comparable range to those noted in Burkhard (2021).

2.2.3 Selection of BAF values

The study by Burkhard (2021) was used as the source of BAFs for this project. It represents a recent collation of BAFs for PFAS, including the four of interest in this report. It also includes an assessment of data quality and details on the trophic level of the fish studied. Each study considered by Burkhard (2021) was assigned as high, medium and low-quality using criteria (See Appendix 1 for further detail) which align with the EQS guidance (EC, 2018). The EQS guidance (EC, 2018) advises use of BAFs for fish at higher trophic levels and preferably from field studies. BAFs for both whole fish and muscle/fillet are relevant to the protection endpoint of human health via consumption of fish. The following criteria were used to select BAFs for the four PFAS (PFOA, PFOS, PFNA and PFHxS) from Burkhard (2021), to derive equivalent water concentrations.

- BAFs measured in fish at trophic level 3.6 or above
- BAFs determined from field studies
- BAFs determined in either whole fish or muscle/fillet
- BAFs identified as of high or medium quality (Burkhard,2021) (see Appendix 1 for details of the reliability criteria used to assign high/medium/low quality)

BAFs meeting all the above criteria were identified and are summarised in Table 1. Where multiple relevant BAF values were located for a substance the geomean, average and median were calculated.

Table 1. Summary of relevant and reliable BAFs for fish of trophic level 3.6 and above for PFOS, PFOA, PFNA and PFHxS (based on log BAFs sourced from Burkhard, 2021)

PFAS	Number of studies	Number of species	Estimated trophic level range	Number of BAFs	Range of BAFs	Average	Geometric mean	Median
PFOS (whole fish)	7	7	3.62 – 4.4	29	100 – 85114	6310	5012	7943
PFOS (muscle/fillet)	8	12	3.6 – 4.5	20	251 – 5754	1349	1259	1349
PFOA (whole fish)	5	5	3.66 – 4.5	16	10 – 3981	229	174	234
PFOA (muscle/fillet)	4	8	3.6 – 4.5	9	7.94 – 190	17.8	15.8	12.6

PFAS	Number of studies	Number of species	Estimated trophic level range	Number of BAFs	Range of BAFs	Average	Geometric mean	Median
PFNA (whole fish)	5	5	3.6 – 4.16	12	1.15 – 8128	1259	229	3981
PFNA (muscle/fillet)	6	7	3.6 – 4.5	7	13.8 – 427	112	93	110
PFHxS (whole fish)	5	5	3.62 – 4.4	13	25 – 2512	525	417	871
PFHxS (muscle/fillet)	6	10	3.6 – 4.5	12	3.98 – 209	22.4	15	8

2.2.4 Derivation of equivalent water concentrations

The selected BAFs (see Table 1) were used to determine the equivalent water concentrations for each of the four PFAS using the following equation (EC, 2018):

$$QS_{water,biota} = QS_{biota,hh}/BAF$$

Calculations using BAFs for whole fish and for muscle/fillet were performed and the concentrations derived are summarised in Table 2 (See Appendix 2 for further detail). As multiple relevant BAFs were available for each of the 4 PFAS, the geometric mean for each was used in the calculation as recommended in the EQS guidance (EC, 2018).

Table 2 Summary of equivalent water concentrations for the four PFAS using the geometric mean BAF for whole body and muscle/fillet

PFAS	Whole body	Muscle/fillet
PFOA	0.4 ng/L	5 ng/L
PFHxS	0.2 ng/L	5 ng/L
PFNA	0.3 ng/l	0.8 ng/L
PFOS	0.015 ng/L	0.06 ng/L

3. Discussion

This project has derived thresholds for additional PFAS, as there is currently only an EQS for PFOS. These are required to help inform decisions by the Environment Agency when assessing water quality monitoring data and risks associated with PFAS in discharges. Our aim was therefore to derive scientifically robust values for selected PFAS, using readily available data, for use as water quality thresholds in the absence of EQS for most PFAS.

The methodology for deriving EQSs (EC, 2018) was used as the basis for derivation of the thresholds. A pragmatic approach was taken which focussed on using readily available reliable hazard data and considered only the protection of human health via consumption of fish. This endpoint was the most sensitive when deriving the EQS for PFOS. Based on the available aquatic toxicity data for these substances, we consider this is also likely to be the case for these PFAS. Ecotoxicology data indicates effects at higher concentrations than those for human health via consumption of fish. The findings of this project are discussed in more detail below.

3.1 Biota value for human health via consumption of fish

The $QS_{biota,hh}$ of 77 ng/kg derived here is expressed as the sum of four PFAS; PFOS, PFOA, PFNA and PFHxS, as per the HBGV on which it is based. Whilst this does not fully reflect the wider environmental burden of PFAS, it does provide an important and useful step forward by enabling additional PFAS to be considered in regulatory and operational decisions. The $QS_{biota,hh}$ value derived has a transparent scientific basis.

The discussion below highlights some important aspects of the approach taken.

The TWI of 4.4ng/kg bw per week (EFSA, 2020) was used. This value was considered a pragmatic and justifiable choice for a HBGV because (i) it is a regulatory value derived by an authoritative body, so meets the criteria described in the EQS guidance (EC, 2018) and (ii) it considers PFAS that are a priority to the Environment Agency for threshold development based on frequency of detection and known toxicological impacts.

EFSA is an authoritative body which provides independent scientific advice on risks associated with the food chain, including derivation of reference values and opinions on safe limits for chemicals in food. Additionally, there is precedent for using this value. This TWI has been used to determine regulatory thresholds for PFAS by several European countries including Denmark, Sweden, Germany and Belgium (EA, 2025). It was also used in the derivation of soil screening values in England and Wales (CL:AIRE, 2024). In addition, the EU EQS proposal for a group of 25 PFAS has used this TWI as it’s basis (EU, 2025).

Some concerns over the basis of the EFSA TWI (2020) have been raised previously, including by the UK Committee on Toxicity (CoT) in a statement published in 2022 (CoT, 2022). The CoT questioned the biological significance of the response (immunological) on which the TWI is based. They were however unable to propose an alternative value (CoT, 2022). CoT are currently reviewing available toxicological data to determine either an HBGV for PFAS, or several HBGVs, according to data available (CoT, 2023). The outcome of the CoT review will inform future PFAS threshold derivation, but the timeline for completion is unknown. In the absence of an alternative recommended value, and while awaiting the outcome of the CoT review, we consider it is appropriate to use the EFSA TWI (2020) for the derivation of a biota threshold.

In following the approach outlined in the EQS guidance (EC, 2018) default values for the daily quantity of fish consumed by individuals and the proportion of the diet from fishery products were used to determine the $QS_{biota,hh}$. These values reflect a European diet, with typically higher fish consumption than the UK. The threshold values derived here could therefore be refined in future if a UK specific value for fish consumption for use in EQS/threshold derivation is agreed instead of the EU default value.

3.2 Equivalent water threshold

Derivation of a water threshold equivalent to the $QS_{biota,hh}$ is useful for several reasons described previously. A water threshold is also more useful for activities such as assessing concentrations present in discharges to water and interpretation of river, lake and estuarine monitoring data.

Several of the current EQSs published in the EU EQS Directive (2013/39/EU) and transposed into English legislation via The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 are based on equivalent water concentrations, including the Annual Average EQS for PFOS in water. Derivation of equivalent water concentrations can be technically challenging. This is discussed further below.

3.2.1 Selection of bioaccumulation data

The choice of bioaccumulation data used to derive equivalent water concentrations is a source of uncertainty in the thresholds derived, due to the variability in data.

The quality and reliability of bioaccumulation data used in this project was considered when selecting suitable data. Only BAFs determined to be high or medium quality (Burkard, 2021) were used. In addition, only field derived BAFs were used and only for fish from the appropriate trophic level as per the EQS guidance (EC, 2018). Field derived BAFs are preferred to BCFs as they assess the uptake of a chemical by an organism via water, food and sediments unlike a BCF which only considers uptake via water.

Although the above considerations were applied, the BAF values collated for each of the four PFAS varied considerably (see Table 1). Variability in field derived BAFs can result from differences in the species, size, age and tissue of the organisms studied. In addition, exposure concentration may influence the BAF determined in a study (EU, 2022; RIVM, 2017). Burkhard (2021) observed that some studies report a potential inverse relationship between exposure concentration and bioconcentration data (BCF), with BCFs decreasing as exposure concentration increases. The relationship between concentration dependence and bioaccumulation data for PFAS, including how findings from laboratory studies may apply to field studies and the mechanisms involved, is not yet fully understood. Due to the uncertainty around the concentration dependency of BAF values for PFAS, this was not considered when deriving equivalent water concentrations in this report.

Multiple BAFs were available that met the specified selection criteria for each of the four PFAS and there was no reliance on a single value. The geomean of the selected values was used as per the EQS guidance (EC, 2018).

BAFs for fish may be derived for the whole body or specific organs such as the liver. The EQS guidance (EC, 2018) does not specify whether whole body or organ specific BAFs should be used to derive equivalent water concentrations for the $QS_{biota,hh}$. Similarly, guidance for deriving water quality criteria in the US (US EPA, 2000) does not specify the type of BAF to use in these situations. Recent work to determine a threshold for PFOA noted it was not appropriate to consider BAFs for tissues that are not commonly consumed such as gall bladder (US EPA, 2024) but did not specify which should be used.

Whole body BAFs provide an indication of overall accumulation by an organism. They have typically been used when deriving EQS values for priority and priority hazardous substances under the Water Framework Directive. For example, a BCF for whole fish was used when deriving the biota EQS for PFOS in preference to the value for edible tissues available from the same study. Although a BCF, rather than a BAF was used in this instance due to the availability of data, it reflects the decision to use a value for whole fish rather than a specific tissue. There is however also a case for using BAFs based on muscle/fillet since they are representative of the portion of the fish usually consumed. The Minnesota Pollution Control Agency (MCPA) (2024), for example, used the BAF for fillet/muscle when deriving criteria for PFAS for the protection of human health.

Both whole body and muscle/fillet BAFs were collated for the four PFAS considered in this report and used to determine equivalent water concentrations. Comparison of the values derived show that use of whole body BAFs resulted in lower thresholds than those using muscle/fillet BAFs, particularly for PFOA, PFHxS and PFNA (see Table 2). For PFOS the two values were similar.

In the absence of specific guidance on choice of BAFs, and with examples in the literature of the use of both whole organism and muscle/fillet values, we have taken a conservative approach and used the whole body BAF values, as they resulted in lower equivalent water concentrations for all four PFAS considered. This aligns with the approach that has generally been used for the derivation of EQS by the EU to date. The decision around the type of BAF to use is not specific to PFAS and is relevant to the derivation of equivalent water concentrations for other substances.

3.2.2 Grouping approach: sum of four PFAS

The $QS_{biota,hh}$ is expressed as the sum of four PFAS, (PFOS, PFOA, PFHxS and PFNA) as per the TWI on which it is based (EFSA, 2020). This is different to most EQSs which are based on individual substances. Expression as the sum of the four PFAS brings additional challenges when deriving an equivalent water concentration. In the absence of guidance on the approach to use in these situations we have explored options for considering combined effects of a group of substances.

The effects data on which the EFSA TWI (2020) is based relates to combined exposure to the four PFAS. Whilst suitable BAFs are available for the individual PFAS (see Table 1) we do not have specific BAFs relating to combined exposure of organisms to the four PFAS. The water equivalent threshold concentrations derived in this project are therefore based on the accumulation of individual substances. These values are only applicable as equivalent water concentrations to the biota-based threshold ($QS_{biota,hh}$) where just one of the four PFAS is present. If more than one is present, the combined effect should be taken into consideration.

We have considered how the assessment of combined effects could be taken into account. Due to the large range of equivalent water concentration values, it's not appropriate to use the lowest value as a proxy for all four substances. The lowest value (0.015ng/L for PFOS) is much lower than the concentrations derived for the other three substances. If used to reflect the sum of the four PFAS it would therefore be very precautionary, particularly if PFOS was not present alongside the other three in either an environmental sample or a discharge to the water environment.

A critical review of approaches used to derive thresholds for PFAS by other regulators globally is being undertaken by the Environment Agency and includes assessment of approaches for groups of chemicals. One such approach is the Hazard Index (HI) which enables the combined effects of several substances to be considered. It involves the derivation of Hazard Quotients (HQs) for each substance of interest. These are calculated by deviding the concentration detected with an appropriate threshold. The HQs calculated are then summed to derive the Hazard Index. The approach assumes simple additive effects from the combined exposure of the chemicals of interest. If the value of the HI calculated from the sum of the HQs is >1 the concentrations of the four PFAS present are considered to result in an exceedance of the biota threshold derived.

The Hazard Index approach is used here assuming simple additive effects and equal potency, but differences in exposure due to variation in bioaccumulation. Thresholds used to derive HQs are often individual HBGVs for the different substances, to reflect their different potencies. Here, the equivalent water concentrations are derived using the same HBGV, which is based on the combined effects of the four PFAS, but account for variation in exposure due to differences in bioaccumulation.

The Hazard Index is calculated for the four PFAS as noted below. Only those of the four PFAS detected in a sample or the effluent being assessed, it is not considered when determining the Hazard Index.

$$\text{Hazard Index (HI)} = HQ_{PFOA} + HQ_{PFOS} + HQ_{PFHxS} + HQ_{PFNA}$$

There is precedent for using this approach in assessing the combined effect of several PFAS. The Hazard Index approach was recently used, for example, when developing soil screening values in the UK for the same four PFAS (CL:AIRE, 2024). Screening values were derived for each of the individual PFAS using the EFSA TWI (EFSA, 2020) and the Hazard Index approach was used to consider the combined effect of the four substances.

We consider the application of the Hazard Index approach suitable for the assessment of risk of the four PFAS in water samples. This would enable assessment of environmental data, by determining if combination of the water concentrations for the four PFAS meant the biota-based threshold ($QS_{biota,hh}$) was exceeded. However, because it does not provide a single concentration for the four PFAS in water, it is a different approach to that currently used for EQSs or predicted no-effect concentration (PNECs).

3.3 Existing statutory EQS for PFOS

There is a statutory EQS for PFOS. It comprises a biota EQS of 9100 ng/kg derived for the protection of human health via the consumption of fish and a freshwater EQS of 0.65 ng/L, which is the water concentration equivalent to the biota EQS. This value was derived using a previous HBGV – a tolerable daily intake of 150 ng/kg bw/day for PFOS derived by EFSA (EFSA, 2008). This has been superseded by the EFSA TWI (EFSA, 2020) of 4.4 ng/kg bw/week (0.628ng/kg bw/day) used in this project.

The current EFSA TWI value is lower than the value published in 2008. It reflects more recent toxicity data for PFOS and the other PFAS considered. Using the more recent HBGV results in a $QS_{biota,hh}$ value lower than the current EQS for PFOS. The equivalent water concentration calculated for PFOS in this report is consequently lower due to use of the more recent HBGV. Additionally, the bioaccumulation data used reflects additional BAF data now available for PFOS.

PFOS is one of the four PFAS covered by the EFSA TWI (EFSA, 2020) and has been considered as part of this project. However, at the time of writing this report (2025), the thresholds derived here for PFOS do not replace the statutory EQS for PFOS.

This report is based on information that was readily available at the time of writing. Assessment of the hazardous properties of PFAS remains an active area of research and we anticipate that new knowledge and insights on both individual substances and groups of PFAS will become available in the future. The thresholds derived in this report should be reviewed as and when significant new information, such as the conclusions of the UK CoT review on appropriate health-based guidelines, become available (COT, 2023).

4. Conclusions

This project was commissioned to derive scientifically robust effects-based thresholds in water for PFAS. A pragmatic approach was adopted, using readily available, reliable data and following existing guidance for EQS derivation, modified to focus on the most relevant endpoint for these substances - the protection of human health via the consumption of fish. The PFAS considered were chosen based on availability of suitable toxicology data, as well as operational need.

The outcomes of this work are:

- A biota-based threshold was derived for the protection of human health via the consumption of fish ($QS_{biota,hh}$).
- The threshold value is **77 ng/kg** as a **concentration measured in fish** for the sum of four PFAS (**PFOS, PFOA, PFHxS** and **PFNA**).
- The threshold was derived using a suitable health-based guidance value, a tolerable weekly intake (TWI) for the sum of 4 PFAS (EFSA, 2020) and the approach outlined in the EQS guidance (EC, 2018).
- The EFSA TWI (i) is a regulatory HBGV derived by an authoritative body, so meets the criteria described in the EQS guidance (EC, 2018) and (ii) it considers PFOA, a priority for threshold development based on frequency of detection and known toxicological impacts.
- The fact the biota-based threshold ($QS_{biota,hh}$) is expressed as the sum of the four PFAS, introduces complexity when deriving an equivalent water concentration using the methodology in the EQS guidance (EC, 2018) since EQS and PNECs are normally derived for individual substances.
- **Equivalent water concentrations of 0.015 ng/L for PFOS, 0.4 ng/L for PFOA, 0.2 ng/L for PFHxS and 0.3 ng/L for PFNA** were determined from the biota threshold, using selected BAFs for the four PFAS. These values are applicable in situations where only one of the four PFAS is present, but don't account for the combined effects where more than one is detected.
- The lower value for PFOS of 0.015 ng/L reflects the higher BAF values for this substance compared to the other three PFAS. This value is much lower than the current statutory EQS for PFOS and reflects the use of more recent effects and bioaccumulation data.
- Acknowledging the complexity of applying a threshold derived for the sum of 4 PFAS, we propose use of the Hazard Index approach to assess whether concentrations of the four PFAS measured in a sample/discharge would result in exceedance of the $QS_{biota,hh}$ and thus pose a potential combined risk.
- The HI is used to assess environmental risk when two or more of the four PFAS of interest are present in an environmental sample or discharge. However, because it does not provide a single concentration for the four PFAS in water, it is a different approach to that currently used for EQSs or predicted no-effect concentration (PNECs).
- PFOS is included in this report as it is one of the four PFAS covered by the health-based guidance value used to derive the thresholds. The concentrations derived

here are lower than the EQS for PFOS as they use more recent toxicology and bioaccumulation data. The thresholds derived in this report are not EQSs but have been derived using the same principles. The values derived here for PFOS do not replace the existing statutory EQS for PFOS.

- This report and the thresholds derived reflect the data and information available at the time of writing (2025). PFAS are an active area of research. The outcomes of this report should be reviewed as further data and greater understanding of this group of substances develops. The outcome of the CoT review on health-based guidelines will be useful.
- This project has highlighted aspects of threshold development for further consideration in future EQS derivation in general, for example, the use of BAFs for whole fish or for muscle/fillet.
- This is a research report and is not government policy or official guidance.

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List of abbreviations

ADI	Acceptable Daily Intake
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMF	Biomagnification Factor
CoT	Committee of Toxicology
ECHA	European Chemicals Agency
EFSA	European Food Safety Authority
EQS	Environmental Quality Standard
HBGV	Health Based Guideline Value
PFAS	Per- and polyfluoroalkyl substances
PFHxS	Perfluorohexane sulfonate
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctane Sulfonic Acid
PFNA	Perfluorononanoic Acid
$QS_{biota,hh}$	Threshold in biota re: human health via consumption of fish
$QS_{water,biota}$	Equivalent water concentration for the $QS_{biota,hh}$
RIVM	National Institute for Public Health and the Environment (Netherlands)
TDI	Tolerable Daily Intake
TMF	Trophic Magnification Factor
TWI	Tolerable Weekly Intake

Glossary

BAF	BAFs consider the uptake of a chemical by an organism via water, food and sediments, unlike BCFs which only consider uptake via water. BAFs can be determined for the whole organism or a specific tissue such as muscle or liver.
EFSA	The European Food Safety Authority (EFSA) is an agency of the European Union. It provides independent scientific advice on risks associated with the food chain, which includes derivation of reference values and opinions on safe limits for chemicals in food.
EQS	An EQS represents the concentration of a chemical in the water environment above which an adverse effect on aquatic life, and in some cases human health, may occur. EQSs are used to assess the potential impact of chemicals detected in the environment and to manage risks from their release.
Equivalent water concentration	This term refers in this report a concentration of a substance in water that is equivalent to the concentration in biota set in a biota based threshold value. As most environmental monitoring in the aquatic environment comprises water samples, substances with a biota-based EQS typically have an equivalent water concentration value. A water-based threshold is also more useful for assessing risks of substances in discharges to water. It also minimises the need to sample fish.
Hazard Index	Hazard Index (HI) which enables the combined effects of several substances to be considered. Hazard Quotients (HQs) are derived for each substance of interest, which are then summed to derive the Hazard Index. The approach assumes simple additive effects from the combined exposure of the chemicals of interest. The HQs are derived by dividing the concentration detected with a relevant threshold. If the value of the HI calculated from the sum of the HQs is >1 the threshold is effectively exceeded, which indicates a potential risk.
HBGV	A health based guidance value (HBGV) describe the maximum exposure via the oral route not expected to result in an appreciable health risk. They are determined based on available toxicity data, uncertainties in these data and the likely duration of exposure. They are widely used in exposure assessments of chemicals in food and feed.

PFAS	Per- and polyfluoroalkyl substances (PFAS) are a large and chemically diverse group of synthetic fluorinated organic chemicals widely used in industrial applications and consumer items.
Threshold	In this report the term threshold is used to represent the concentration of a chemical in the water environment above which there is the potential for adverse effects on human health via the consumption of fish. It is used rather than the term EQS as the latter relates specifically to thresholds that have been derived and incorporated under legislation relating to the Water Framework Directive

Appendix 1 - Criteria used in Burkhard (2021) to BAF values located as high/medium/low

Unlike for BCFs and ecotoxicity tests there are no standard guidelines for studies to determine BAFs. Burkhard (2021) used 5 criteria to evaluate the quality of the BAFs collated. These were:-

- number of water samples
- number of organism samples
- temporal co-ordination of water and organism samples
- spatial co-ordination of water and organism samples
- evaluation of the general experimental design

These criteria are comparable with the EU EQS guidance (EC, 2018) which notes that reliable field studies for determining BAFs requires all biota and water samples to originate from the same area and from the same period in time. The influence of spatial and temporal factors on the BAF value is also highlighted in papers such as that by Flinders et al (2025) which reported that spatial proximity between water and fish tissue sampling locations was the primary driver of BAF variability.

Burkhard (2021) assigned a score for each study for each of the five criteria. The overall score was used to assign the study as high, medium or low. The author considered these bandings to be somewhat equivalent to the bandings of Reliable, Reliable with Restrictions and Not Reliable used in the Klimisch system to assess the quality of ecotoxicity studies.

The criteria and the associated scores used by Burkhard (2021) are summarised in Table 1 below. Studies assigned an overall score of 4 or 5 were noted as high quality, 5 or 6 medium quality and those with a score of 7 to 10 low quality.

Table 1. Evaluation criteria used by Burkhard (2021) to assess the quality of the BAF studies located

Criteria	Score		
Score assigned where:-	1	2	3
Number of water samples	>3	2-3	1
Number of organism samples	>3	2-3	1
Temporal co-ordination	Concurrent collection	Within 1yr time window	Collection period >1year
Spatial co-ordination	Colocated collection	Reasonably close (within 1-2km)	Significantly different locations
General experimental design*	Default quality value = 0		Mixed species tissue samples

*The general experimental design criterion was assigned a default value of 0 except for studies in which the tissues analysed were composites of mixed species or were simply reported as a general taxonomic group eg Bivalvia. For these two cases then assigned value of 3.

Burkhard (2021) noted the characteristics of studies with low quality rankings included:-

- BAFs based on single water sample or single biota sample
- BAFs derived from regional monitoring studies in which global averages for residues in water and fish were used
- BAFs derived from studies in which the alignment of sampling locations was clearly defined in the report
- BAFs derived from studies in which tissue samples were composed of mixed species

Appendix 2 - Derivation of the equivalent water concentrations

PFOA

Using the geometric mean of 174 for relevant BAFs for whole fish, the equivalent water concentration is 0.0004µg/L. Using the geometric mean of 15.8 for relevant BAFs for muscle/fillet the equivalent water concentration is 0.005µg/L.

PFHxS

Using the geometric mean of 417 for relevant BAFs for whole fish the equivalent water concentration is 0.0002µg/L. For muscle/fillet the equivalent water concentration using the geometric mean of BAFs of 15 is 0.005µg/L.

PFNA

Using the geometric mean of 229 for relevant BAFs for whole fish the equivalent water concentration is 0.0003µg/L. For muscle/fillet the equivalent water concentration is 0.0008µg/L using the geometric mean of BAFs of 93.

PFOS

Using the geometric mean of 5012 for relevant BAFs for whole fish the equivalent water concentration is 0.000015µg/L. For muscle/fillet the equivalent water concentration was 0.00006µg/L using the geometric mean of 1259 for available BAFs.

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