英国内における「米軍航空基地立地自治体による PFAS 環境調査の内容及び結果」に関する調査結果について

１　貴県からの質問内容

米軍航空基地周辺において、基地が立地する自治体では PFAS に関しどのような環境調査を行ってきたか。また、その結果はどうだったか。

２　英国内の米軍航空基地

英国内には米軍航空基地が以下のとおり 6 拠点存在する（全てイングランドにある）。

⑴ RAF Fairford Air Force Base
RAF Fairford Air Force Base in Fairford, United Kingdom | MilitaryBases.com

⑵ RAF Croughton Air Force Base
RAF Croughton Air Force Base in Northamptonshire, United Kingdom | MilitaryBases.com

⑶ RAF Alconbury
RAF Alconbury in Alconbury, United Kingdom | MilitaryBases.com

⑷ RAF Mildenhall Air Force
RAF Mildenhall Air Force in Mildenhall, United Kingdom | MilitaryBases.com

⑸RAF Lakenheath Air Force
RAF Lakenheath Air Force in Lakenheath, United Kingdom | MilitaryBases.com

⑹ RAF Menwith Hill Air Force
RAF Menwith Hill Air Force Harrogate, United Kingdom | MilitaryBases.com

英国内米軍航空基地全体図
US Military Bases in the United Kingdom | MilitaryBases.com

３　調査方法

当該調査を行うにあたり、以下の組織に情報公開法に基づく請求またはメールでの問い合わせを行った。なお、インターネットによる調査も並行して行ったものの、回答となるような情報を見つけることは出来なかった。参考までに、PFAS について言及された記事やサイトについて「５　その他」に記載する。

⑴ Drinking Water Inspectorate（飲料水検査局）
英国内のイングランドとウェールズを対象に、飲料水の品質と安全性を監視する役割を担っている組織。
公式サイト：Drinking Water Inspectorate (dwi.gov.uk)

⑵ Environment Agency（環境庁）
英国内の環境保護および水資源の管理を行う政府系組織。
公式サイト：Environment Agency - GOV.UK (www.gov.uk)

⑶ Defence Infrastructure Organisation（防衛インフラストラクチャーオーガニゼーション）
公式サイト：Defence Infrastructure Organisation - GOV.UK (www.gov.uk)

国防施設や基地の管理・保守を行う政府機関。Ministry of Defence（国防省）の一部。

⑷米軍航空基地がある英国内 5 つの地方自治体
・RAF Fairford Air Force Base - Cotswold District Council
・RAF Croughton Air Force Base - West Northamptonshire Council
・RAF Mildenhall Hill Air Force および RAF Lakenheath Air Force
- West Suffolk Council
・RAF Menwith Hill Air Force - North Yorkshire Council
・RAF Alconbury - Huntingdonshire District Council

⑸Greater London Authority（大ロンドン庁）

グレーターロンドン（ロンドン市＜City of London＞と 32 のロンドン自治区からなる 1 つの行政区画）内の行政事務を担う。グレーターロンドン内に米軍航空基地はないが、参考までに調査内容に関連する情報がないか問い合わせた。

公式サイト：Home page (london.gov.uk)

4　調査結果

各組織からの回答は以下のとおり。一部の組織で一般的な PFAS に関する水質調査を行ってはいるものの、国家安全保障上の理由により PFAS による影響と米軍航空基地を直接結び付けるような調査は行われていない。

⑴ Drinking Water Inspectorate（飲料水検査局）

＜当事務所からの質問＞
①イングランドの米軍航空基地周辺の給水エリアにおける PFAS の検査やより一般的な水質検査についてご教示願いたい。
②イングランドの米軍航空基地で存在が確認された PFAS について、今までイングランドで問題になったことはあったか。

＜質問に対する回答＞
①下記回答訳全文を参照。
②水道事業者が米軍航空基地等で行った PFAS に関するリスク調査は、通常の流域リスク評価の一部として実施されたものである。Drinking Water Inspectorate（以下、DWI とする。）では、国家安全保障上の理由から、米軍航空基地を含むセキュリティ性の高い資産および場所と PFAS 等にかかるデータを関連付けることはない。

＜回答訳全文＞

DWI は、イングランドおよびウェールズを対象に 2009 年以来、水道事業者に対して PFAS のうち主要な化学物質である PFOS と PFAS に関するガイダンスを示してきた（別添 1：イングランド版、別添 2：ウェールズ版を参照）。ガイダンスは最新の知見を反映するために最近更新された（別添 3：ガイダンスノート：飲料水の水質に関する長期計画　を参照）ことにより、他の PFAS に該当する化学物質も考慮されるようになった。現在行われている毒性学に関するデータは決定的なものではなく、世界的に更なる研究が行われているところであり、予防的なアプローチが適切である。

イングランドでは、The Water Supply (Water Quality) Regulations 2016 (as amended)（水供給（水質）規制＜改定後＞）により、飲料水として「健康」に摂取することができるとみなされるためには、人の健康に潜在的な危険をもたらすレベルの物質を含んではいけないと定められている。

イングランドとウェールズの公共飲料水の水質は DWI によって行われており、DWI は飲料水の検査に使用する 20 種類の PFAS の完全定量分析法の研究を開始し、2022 年にはこの分析法が利用可能となった。試験所ではさらなる研究と分析法の開発が続けられており、2021 年 10 月に DWI が注目すべきとして特定した 47 種類の PFAS をより広範に分析できるようになった。

DWI のガイダンスでは、水道事業者はリスク評価において、DWI が特定した物質を考慮し、必要であれば、適切な供給源においてこれらの物質のモニタリングを開始することを検討するよう求めている。

水道事業者は、供給される水の品質に対するリスクを特定する責任があり、飲料水の供給が飲料水として「健康」に摂取することができない原因となる可能性があると考えられる元素、生物、物質について、飲料水のサンプルを採取することが義務付けられている。これには、PFOS と PFOA 以外の PFAS 物質の検出も含まれる。また、供給される水の品質や十分な供給に影響を及ぼす、または及ぼす可能性のある事象が発生した場合は、DWI に通知することが義務付けられている。

2021 年 10 月、DWI は水道事業者宛に対し、飲料水として使用される取水源の原水における PFAS のサンプリング、試験、モニタリングに関する追加要件を通知した。このモニタリングから収集された情報は、水道事業者のリスク評価に使用され、リスクを防止し、飲料水として「健康」に摂取できる品質を維持するために必要と思われる改善措置の基礎となり、将来の飲料水政策と規制のアプローチをサポートする。

PFAS に関する最新情報に関する概要は、2024 年 1 月に発行されたばかりの最新の年次報告書「Drinking Water 2022」（別添 4：イングランド版、別添 5：ウェールズ版）に記載されている。

DWI が保有する PFAS に関する情報は水道事業者から収集されたもので、各事業者に直接請求することで入手可能である。過去に行われた消火用フォームの使用により、PFAS 化合物のリスクが存在する可能性があると知られている空港や飛行場のリスク評価は、The Water Supply (Water Quality) Regulations 2016 (as amended)（水供給（水質）規制＜改定後＞）規則 27 に基づき指示されたもので、各水道事業者が実施する通常の流域リスク評価の一部である。

私たちがデータを照合する際には、国家安全保障上の理由から、セキュリティ性の高い場所や資産とは通常関連づけられず、これは米軍航空基地についても同様である。

⑵ Environment Agency（環境庁）

＜当事務所からの質問＞
DWI に対する質問と同内容。

＜質問に対する回答＞
①Environment Agency では、PFAS に関する包括的な水質モニタリングを行っているものの、米軍航空基地を含む軍事基地では PFAS の検査は行っていない。しかしな

がら、英国内 8 つの空港付近における地表水の PFAS のモニタリングは行っており、報告書を作成している（別添 6 を参照)。
②上記のとおり軍事基地内での PFAS の検査は行っておらず、特段回答なし。

＜その他参考情報＞
・PFAS に分類される化学物質のうち、PFOS と PFOA については、完全に定量的なモニタリング情報があり、OPENWIMS データで見ることができる。これは主に表流水（陸に存在する水資源のうち、湖沼の水のようにその存在が完全に表地面にあるもの。類義語に地表水があるが、表地水は水たまりなど停滞した水を含むのに対し、表流水は含まない。）に関するデータであるが、地下水のデータもある。
OPENWIMS データリンク：Open WIMS data
・40 種類以上の PFAS のスキャンモニタリングデータも保有している。これは、PFHxS、PFBS、PFPeS を除く、全ての PFAS 濃度にかかる定量的推定値である。
PFHxS、PFBS、PFPeS の有無のみを報告しているのは、現時点で検出されるこれらの物質の濃度にかかる推定値が信頼できないためである。
スキャンモニタリングデータリンク：Water quality monitoring data GC-MS and LC-MS semi-quantitative screen - data.gov.uk

⑶Defence Infrastructure Organisation（防衛インフラストラクチャーオーガニゼーション）

＜当事務所からの質問＞
①英国の米軍航空基地周辺の給水区域において、どのような PFAS 検査が実施されたか。
②イングランドの米軍航空基地で存在が確認された PFAS について、今までイングランドで問題になったことはあったか。

＜質問に対する回答＞
①質問に関する情報は保有していない。なお、次の情報が参考になると思われる。公共用水の取水においては、Drinking Water Inspectorate Regulations（飲料水検査局規制）に従い、水道事業者によって検査される。公共用水以外の取水においては、地方自治体または取水事業者のいずれかによって検査される。
② Ministry of Defence（国防省）は現在、フッ素系消火フォームを段階的に廃止している。PFAS を含む消火用フォームの使用に関しては国際的に懸念があるところであり、英国の規制については現在策定中である。

⑷米軍航空基地がある英国内 5 つの地方自治体（カッコ内は該当する地方自治体内にある米軍航空基地名）
・Cotswold District Council（RAF Fairford Air Force Base）
・West Northamptonshire Council（RAF Croughton Air Force Base）
・West Suffolk Council（RAF Mildenhall Hill Air Force および RAF Lakenheath Air Force）

・North Yorkshire Council（RAF Menwith Hill Air Force）
・Huntingdonshire District Council（RAF Alconbury）

＜当事務所からの質問内容＞
①貴地方自治体（カウンシル）は、環境衛生または公害防止の観点において、貴自治体内にある米軍航空基地周辺での PFAS に関する問題について対応したことがあるか。
②上記について対応したことがある場合、どのような分析方法が用いられたのか。
③貴地方自治体（カウンシル）は、環境衛生または公害防止以外の理由で貴自治体内の米軍航空基地周辺において PFAS にかかるモニタリングを行ったことがあるか。

＜各地方自治体からの回答＞
・Cotswold District Council（RAF Fairford Air Force Base）
①当自治体の記録には、PFAS が関与する問題に対して環境衛生または公害防止の観点で対応した記録はない。
②該当なし。
③当自治体内の米軍航空基地周辺にてサンプリングが必要となる開発は最近行われていない。Part 2A of the Environmental Protection Act 1990（環境保護法 1990 年のパート 2A）に基づく調査も実施していない※。RAF Fairford Air Force Base 内にボーリング孔があることは知っているが、当自治体ではリスク評価やサンプリングは行っていない。米軍航空基地は情報制限区域であるため地方自治体はリスク評価やサンプリングは行っておらず、地方自治体は得たデータを直接 DWI に送っているだけである。

※Part 2A of the Environmental Protection Act 1990 は、地方自治体が汚染された土地を特定するために各自治体の土地を検査することを義務づけている。該当する条文は、別添 7 の法令ガイダンス資料 p.6 を参照すること。

・West Northamptonshire Council（RAF Croughton Air Force Base）
①～③いずれも該当なし。

・West Suffolk Council（RAF Mildenhall Hill Air Force および RAF Lakenheath Air Force）
①当自治体の記録には、PFAS が関与する問題に対して環境衛生または公害防止の観点で対応した記録はない。
②該当なし。
③当自治体では米軍航空基地周辺の PFAS を監視していないが、Anglian Water という水道事業者が基地近くの Isleham（RAF Mildenhall Hill Air Force 近く）で PFAS に関する調査を行っているようである。

・North Yorkshire Council（RAF Menwith Hill Air Force）

①～③当自治体では、米軍航空基地周辺で PFAS に関するいかなる問題にも対応しておらず、いかなるモニタリングも実施していない。

・Huntingdonshire District Council（RAF Alconbury）
①～③いずれも該当なし。

⑸ London Greater Authority（大ロンドン庁）

＜当事務所からの質問＞
　英国内の米軍航空基地周辺では PFAS が問題になっていたが、このことについて何か取り組みを行っているか。

＜質問に対する回答＞
　LGA としては、'polluter pays' principle（汚染者負担原則）いわゆる汚染者が汚染につながる活動を削減できるようなインセンティブを与える方法を取っている。具体的には、汚染物を対処するための費用を負担させるという立場を LGA は取っているが、特段 PFAS に特化して取り組んできたわけではなかった。LGA では、PFAS をはじめとした PoPs（残留性有機汚染物質）を含む特定の製品の廃棄に対して、多くの取り組みを行っている。新しい要件として、健康や環境に有害な化学物質（通常は難燃剤）を含むカーテン・椅子・ソファなど布が使われる家具を焼却処分するように LGA では義務付けている。

5　その他
　インターネット調査による PFAS について言及された記事やサイトは以下のとおり。
⑴ Written questions and answers - Written questions, answers and statements - UK Parliament
　2023 年 12 月 8 日時点、英国議会にて行われた Environment, Food and Rural Affairs（環境・食糧・農村地域省）に対する質問。飲料水中の PFAS レベルに関するガイダンスを更新することによる潜在的メリットについて評価を行ったのかという質問に対し、Environment, Food and Rural Affairs は次のように答えている。DWI による PFAS のガイダンスで定められた値は 100ng/ℓ であり、この数値は飲料水が安全に飲めることを保証するために適切であると the UK Health Security Agency（英国健康安全保障局）と合意されたものである。飲料水供給における PFAS がこの数値を超えているという裏付けはなく、DWI および水道事業者、政府全体で PFAS の発生源、潜在的なリスクを評価するための作業が継続して行われているところである。

⑵ Toxic PFAS chemicals in tap water near Heathrow and Gatwick | openDemocracy
　ヒースロー空港およびガトウィック空港から 10 マイル以内の住民に対し、1 リットルあたり 15ng の PFAS を含む飲料水が供給されていることが判明。これは、消防士の訓練中に使用される消火用フォームが原因ではないかといわれているが、基準値の 100ng/ℓ を大きく下回っており、特段措置は取られていない。また、イングランドとウェールズにおいては、現在既に知られている 47 種類の PFAS にのみ個別に適用さ

れ、それぞれの種類の PFAS が 100ng/ℓ を超えない限りは基準値越えとみなされない。

⑶RSC challenges UK Government to reduce PFAS levels in British water as research highlights serious health risks posed by ‘forever chemicals’
　2023 年 10 月、Royal Society of Chemistry（英国王立化学会）は、イングランドとウェールズの水路それぞれ 35%、37%が中・高リスクの PFAS 濃度であると分析し、英国政府に対して、現在の規定値である 100ng/ℓ から 10 分の 1 の 10ng/ℓ に引き下げることを求めている。

⑷UK drinking water standards called out over ‘forever chemicals’ risk · Manchester Metropolitan University (mmu.ac.uk)
　内容は⑶の記事とほぼ同内容。Royal Society of Chemistry の PFAS の研究に Manchester Metropolitan University が協力していたため、大学の HP でも記載されている。

⑸Experts call for tighter limits on 'forever chemicals' in water - BBC News
　上記⑶⑷の研究について、BBC でも取り上げられている。

⑹UK ministers under pressure to tighten laws on ‘forever chemicals’ in drinking water | PFAS | The Guardian
　上記⑶⑷の研究について、Guardian（英国の大手新聞社）でも取り上げられている。

別添1：イングランド向けガイダンス

dwi

Public Health England

Drinking Water Safety

Guidance to Health and Water Professionals

Drinking Water Safety

Guidance to Health and Water Professionals

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Foreword

10 September 2020

In 2007 there was a major water supply incident involving the loss of water supplies to 160,000 properties in Cheltenham, Gloucester, Tewkesbury and a large part of rural Gloucestershire due to the waterworks being flooded by the River Severn. Subsequent to this, and other incidents, national level discussions between the Drinking Water Inspectorate (DWI) and the Public Health bodies in 2009 led to the first agreement to prepare and publish joint guidance to health and water professionals in support of drinking water quality risk assessments and the issuing of consumer protection advice.

In developing this guidance it was recognised the need to set out for health professionals the structure and legal framework of the water industry in England and Wales, and to describe the arrangements in place for securing the quality and safety of drinking water on a day-to-day basis. This position has been reinforced since 2009 with two further significant incidents where DWI and Public Health England (PHE) were instrumental in decisions that were made at the time and in the subsequent investigations. The first of these incidents was at Alderney water treatment works, (Bournemouth Water) where an increase in cryptosporidiosis in the community in 2013 was identified by PHE and investigated by the DWI who proved this to be linked to the water supply. The second was in 2015 where the detection of *Cryptosporidium* in water leaving Franklaw works, operated by United Utilities, resulted in a boil water notice to more than 700,000 consumers. Learning from these events and other legislative and organisational changes have led to this updated publication.

It is against this background that consultants in health protection, and other health professionals, may be called upon to give public health advice to the water industry and local government on consumer protection in relation to a water supply incident. This information will provide health professionals with useful context to the annual Chief Inspectors DWI publication, *Drinking Water*, setting out the annual results of drinking water tests and documenting the learning from water quality incidents.
In their day-to-day role, water quality scientists in the water industry work closely with health professionals in PHE, Public Health Wales (PHW) and local authorities. We consider the maintenance of sound working relationships to be very important in the identification as well as the delivery of effective and timely responses to water quality

incidents and emergencies. This guidance, together with Water Supply Risk Assessments (based on WHO Water Safety Plan Methodology), should form the basis of regular dialogue at local level to develop collective knowledge, understanding and trust.

In the preparation of this guidance it has been uppermost in our mind that the safety of drinking water in England and Wales is something the public is able to take for granted, because the day-to-day water supply arrangements in place are comprehensive and demonstrably based on sound science with a fully transparent system of independent scrutiny and appropriate sanctions in place. This guidance should be incorporated into existing training regimes and included in water supply and public health operating and emergency management procedures.

Marcus Rink
Chief Inspector of Drinking Water
Drinking Water Inspectorate

David Rhodes
Director Environmental Public Health
Public Health England.

1. Introduction

This document has been developed jointly by the Drinking Water Inspectorate (DWI) and Public Health England (PHE). It is intended to inform all health professionals, which includes, Consultants in Health Protection (CHPs) and the Environmental Health Officers and Practitioners (EHOs and EHP) within Local Authorities about the structure and legal framework of the water industry in England. It also explains when and how these professionals are likely to be called upon to give health protection advice about drinking water quality to the water industry, local authorities, consumers and DWI.

For cross border issues please note that this document has two versions published individually for England and Wales. In the event of a cross border incident it is recommended that both documents are used for guidance.

2. The Legal Framework

2.1. Drinking Water Inspectorate

The DWI is the drinking water quality regulator for England and Wales. It was formed in 1990 on the privatisation of the water industry. It is part of the Department for Environment, Food and Rural Affairs (Defra), but its Chief Inspector is appointed by the Secretary of State for Environment, Food and Rural Affairs (in England) and separately by Welsh Ministers in Wales. The overarching objective of DWI is to maintain public confidence in the safety and quality of public water supplies through the exercise of its powers of reporting, audit, inspection, enforcement and prosecution. The DWI also has a role in providing both governments with advice on water supply and quality matters.

The regulatory framework for water supplies in England and Wales is set out in the Water Industry Act 1991 (WIA). The 1991 WIA was amended by the Water Act 2003 and the Water Act 2014. The Act defines the powers and duties under which DWI operates and also the duties of water companies and licensees. Under the 1991 Act the authorities responsible for regulating the quality of public supplies are the Secretary of State for Environment, Food and Rural Affairs (in England) and Welsh Ministers. DWI's website http://www.dwi.gov.uk holds the relevant legislation.

Confirmation of the details of the statutory duties of water companies and the powers of the Chief Inspector are detailed below.

2.2. Public Water Suppliers

Public water supplies in England and Wales are provided by a number of water suppliers.

Water companies operating the public water networks hold appointments as water suppliers, and those operating the public wastewater networks hold appointments as sewerage service suppliers, for the purposes of the WIA 1991. They supply water and wastewater services direct to household customers (and in some cases to non-household customers) who are connected to their networks. There are currently:

- 11 regional water and sewerage suppliers
- 6 regional water only companies,
- 9 small water and sewerage suppliers

A full list is available at https://www.ofwat.gov.uk/regulated-companies/ofwat-industry-overview/licences/

Since 1 April 2017, holders of new water supply and/or sewerage licences (WSSL) can provide supplies of water and sewerage services to eligible non-household premises. Some licensees may be limited to providing water supplies or sewerage services to their own sites and those of persons associated with them (known as self-supply). Water supply licensees in England can currently have:

- A retail authorisation: this allows the licensee to supply water to non-household premises using the public water networks operated by water suppliers whose areas are wholly or mainly in England.

- A wholesale authorisation: this currently allows the licensee to introduce water into the public water networks of water suppliers whose areas are wholly or mainly in England in order to supply the licensee's own customers if their non-household premises consume at least 5 megalitres of water a year.

There are currently over 40 retail authorisations across England and Wales whereby the licensee provides retail services such as; billing, meter reading, customer enquiries, customer side water efficiency measures. A full list is available at:
https://www.ofwat.gov.uk/regulated-companies/ofwat-industry-overview/licences/

Licensees are under the control of Ofwat, the economic regulator for the water and sewerage industry in England and Wales. Ofwat's main duties are to:

- Further the consumer objective to protect the interests of consumers, wherever appropriate by promoting effective competition

- Secure that water companies (meaning water and sewerage suppliers) properly carry out their statutory functions

- Secure that water companies can (in particular through securing reasonable returns on their capital) finance the proper carrying out of their statutory functions

- Secure that water supply licensees and sewerage licensees properly carry out their licensed activities and statutory functions

- Further the resilience objective to secure the long-term resilience of water companies' water supply and wastewater systems; and to secure that they take steps to enable them, in the long term, to meet the need for water supplies and wastewater services.

The quality and quantity of water resources (groundwater, rivers, streams, lakes, and raw water reservoirs) is regulated by the Environment Agency (EA), a non-departmental public body of the Department of Environment, Food and Rural Affairs. All water regulators (DWI, Ofwat, and EA) have separate duties, but they co-operate over matters of common interest through Memoranda of Understanding. More information can be found at: http://www.environment-agency.gov.uk/ and http://www.ofwat.gov.uk/.

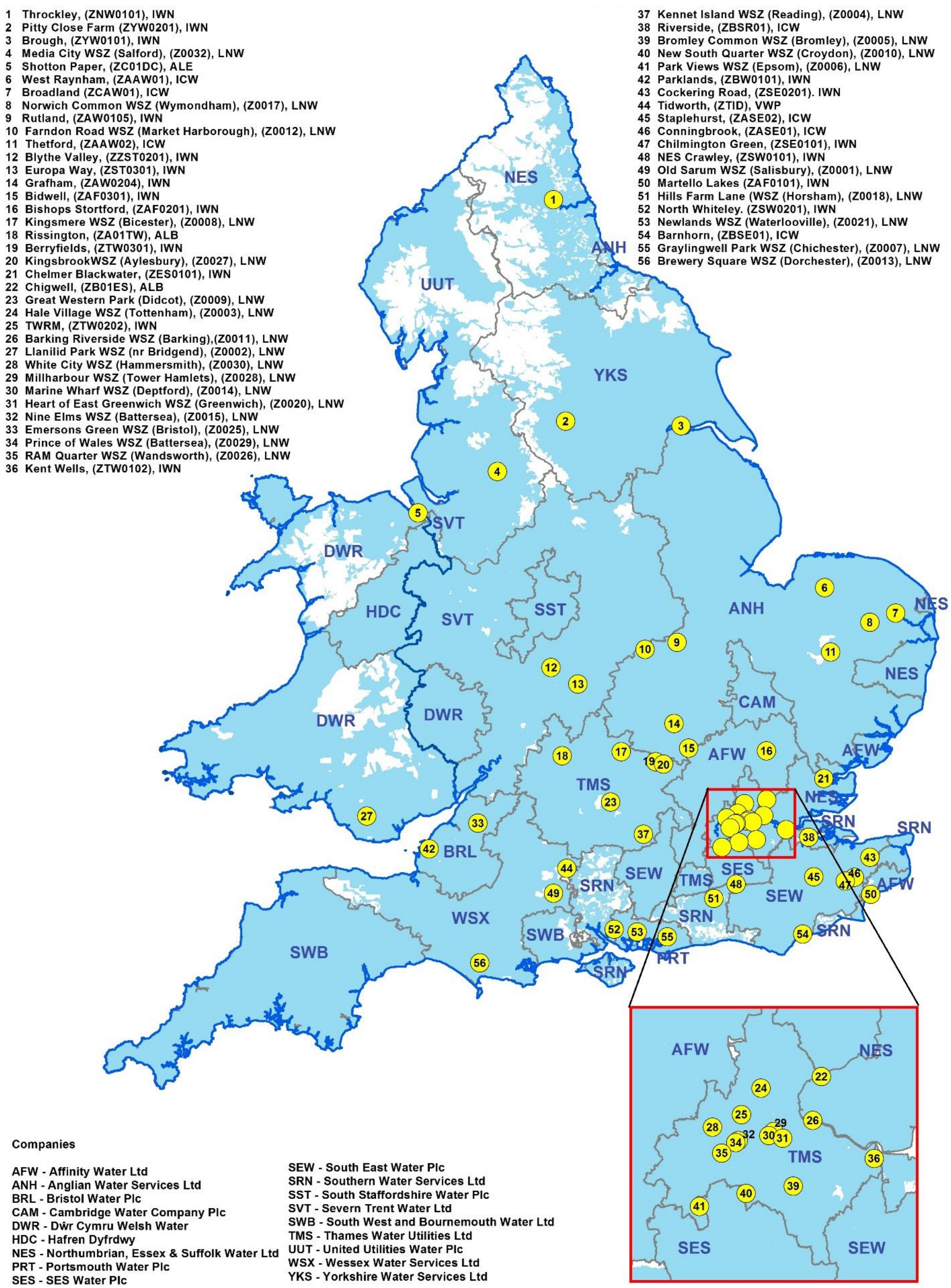


Figure 1: Water suppliers in England and Wales

Under WIA section 68 1991, the water supplier is under a statutory duty to supply wholesome water for domestic use or commercial food production purposes. This duty is enforceable by the Secretary of State, ultimately by Court order. For a water supplier, wholesomeness is defined in Regulation 4 of the Water Supply (Water Quality) Regulations 2016 (as amended) in England. These regulations, including the definition of wholesomeness, implement the European Drinking Water Directive for public water supplies. Under these regulations, the water supplier has a wide range of monitoring and other obligations which are also enforceable by the Secretary of State, ultimately by Court Order. Loss or damage caused by a failure of a water supplier to supply wholesome water for domestic purposes could result in a civil claim for damages by consumers. Supply by a water supplier of water unfit for human consumption is also a criminal offence under section 70 WIA. Additional offences cover design and operation of treatment works and requirements to disinfect water.

The Secretary of State's functions in relation to drinking water quality and sufficiency are performed by the Chief Inspector of Drinking Water and Inspectors appointed by Secretary of State under section 86 WIA. This includes being able to obtain relevant information on drinking water quality. It is a criminal offence under section 207 WIA for a water supplier knowingly or recklessly to supply false information under, or for the purposes of, the WIA. The Chief Inspector and statutory Inspectors have additional functions specific to their appointments which include the Chief Inspector being able to institute and carry out prosecution proceedings in the name of the Chief Inspector. In addition to this, penalty fines can be given by the DWI, on behalf of the Secretary of State, to water companies that do not comply with their duties in respect of drinking water quality under the WIA or the regulations.

The Water Industry (Suppliers Information) Direction 2019 requires water companies to notify the Inspectorate of any event which by its nature has affected or is likely to affect the quality or sufficiency of the water supplied by it. The Direction also requires companies to provide additional information at specified time periods in a format determined by the Inspectorate. The Inspectorate has issued guidance to water companies as to the reporting requirement of the Direction on its website at http://www.dwi.gov.uk and this is updated periodically.

2.3. Private Water Supplies

The WIA 1991 defines water supplies that are not provided by statutorily appointed water companies as private water supplies (PWS). PWS are highly variable in their circumstances, lay out and size. There are approximately 37,700 private water supplies in England, 68% of which serve a single household[1].

The risk of health effects from failures of water quality standards in single domestic PWS is not necessarily restricted to the immediate household or residents living at that address. A recent study in Cornwall found that 31% of single domestic PWS were not

[1] Drinking Water 2019 – Private Water Supplies in England http://dwi.gov.uk/about/annual-report/2019/PWS-2019-England.pdf

correctly identified and shared their supplies with other properties[2]. When enquiries are made regarding single domestic private supplies action should be taken to investigate if there are other properties also supplied from the source.

Most private water supplies are located in rural and remote areas. However, there are many more people, other than those served by a private supply that will have some contact with water from private water supplies as these can be used in the manufacture of certain foods and beverages, and serve various public buildings such as hospitals, village halls, hotels or, more often, campsites and leisure parks.

The quality of PWS is regulated by local authorities, who are responsible for enforcement of the Private Water Supplies Regulations 2016 (as amended). The drinking water standards which apply to private supplies are the same as those for public supplies as they are similarly derived from the Drinking Water Directive, but for the smallest public supplies much more emphasis is placed on risk assessment and risk mitigation rather than very occasional monitoring.

PWS are categorised in the relevant Private Water Supply regulations as described in the table below and this allows for proportionate and risk based monitoring.

Details of the sampling and monitoring requirements for England and Wales differ slightly and both have been included for comparison.

Table 1: Private Water Supplies are categorised in the relevant Private Water Supply regulations (2016), this allows for proportionate and risk based monitoring. Note the differences between the English and Welsh regulations.

	England	Wales
Regulation 8 supplies	Where water is supplied by a water undertaker or water supply licensee, and is then further distributed by a person other than a water undertaker or water supply licensee, the local authority must carry out monitoring on the basis of the risk assessment.	Where water is supplied by a water undertaker or a water supply licensee and is then further distributed by a person other than a water undertaker or a water supply licensee, the local authority must carry out any monitoring which the risk assessment shows to be necessary
Regulation 9 supplies	A supply covered by Regulation 9 is a private water supply (other than a supply specified in regulation 8) that : - supplies an average daily volume of water of $10m^3$ or more, or	A supply covered by Regulation 9 is a private water supply (other than a supply specified in regulation 8) that : - supplies an average daily volume of water of $10m^3$ or more; or

[2] Crabbe, H.; Close, R.; Rimmell, A.; Leonardi, G.; Watts, M.J.; Ander, E.L.; Hamilton, E.M.; Middleton, D.R.S.; Smedley, P.L.; Gregory, M.; et al. Estimating the population exposed to arsenic from groundwater-sourced private drinking water supplies in Cornwall, UK. In Best Practice Guide on the Control of Arsenic in Drinking Water; Bhattacharya, P., Polya, D.A., Jovanovic, D., Eds.; IWA Publishing: London, UK, 2017; Chapter A3; pp. 161–170. ISBN 139-7-81-84339385-6.

	- supplies water as part of a commercial or public activity. Where this applies, the local authority must monitor for parameters directed by the regulations and carry out any additional monitoring that the risk assessment shows to be necessary.	- supplies water as part of a commercial or public activity. Where this applies, the local authority must monitor for parameters directed by the regulations and carry out any additional monitoring that the risk assessment shows to be necessary.
Regulation 10 supplies	Where a private water supply is not covered by regulation 8 or 9 or is not a supply to a single dwelling which is not used for commercial or public activity, the local authority must monitor for 5 specified parameters and any other parameter designated in the regulations where the supply is identified as being at risk of not meeting concentrations or values specified. Anything else identified in the risk assessment as a potential danger to human health must additionally be sampled. This sampling must be done at least every 5 years and more frequently if the risk assessment shows this to be necessary.	This regulation applies to a private water supply to a single dwelling which is not used as part of a commercial or public activity (in which case regulation 9 applies) or as part of a domestic tenancy (in which case regulation 11 applies). Where this regulation applies, the local authority - may monitor the supply in accordance with the requirements in regulation 11(1); and - must do so if requested to do so by the owner or occupier of that dwelling.
Regulation 11 supplies		Where a private water supply is not covered by regulation 8 or 9 or is not a supply to a single dwelling which is not used for commercial or public activity, the local authority must monitor for 5 specified parameters and any other parameter designated in the regulations where the supply is identified as being at risk of not meeting concentrations or values specified. Anything else identified in the risk assessment as a potential danger to human health must additionally be sampled. This must be done at least every 5 years and more frequently if the risk assessment shows this to be necessary.
Single domestic dwellings	In the case of a private water supply to a single dwelling not provided as part of a commercial or public activity, a local authority may monitor the supply in accordance with the requirements for Regulation 10 supplies, and must do so if requested to do so by the owner or occupier of that dwelling.	

The role of DWI in respect of private supplies is to provide expert technical advice to local authorities, ensuring consistency of interpretation of drinking water legislation. The DWI are also responsible for collecting information from local authorities about PWS and reporting this annually alongside information about public water supplies. The regulations and DWI guidance is available on the DWI website[3]. For the majority of enquiries to PHE the most common involvement with drinking water is likely to be giving health protection advice to a local authority in respect of the quality of drinking water from a private water supply.

2.4. Public Health England

Public Health England is an executive agency of the Department of Health & Social Care (DHSC) created by the White Paper 'Healthy Lives, Healthy People: Our strategy for public health in England' released in November 2010. It took on the transfer of powers of the Health Protection Agency repealed by the Health & Social Care Act 2012.

Public Health England exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. We do this through world-class science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. We are an executive agency of the Department of Health, and are a distinct delivery organisation with operational autonomy to advise and support national and local government, local authorities, NHS, industry and the public in a evidence-based professional, scientific manner.

PHE is accountable to the Secretary of State for Health and Social Care and the Parliamentary under Secretary of State for Prevention, Public Health and Primary Care for delivering or supporting delivery of these responsibilities which are set out in an annual remit letter which is available on the PHE website at: https://www.gov.uk/government/publications/phe-priorities-in-health-and-social-care-2019-to-2020

PHE has several core responsibilities as outlined on the PHE website (https://www.gov.uk/government/organisations/public-health-england);

- making the public healthier and reducing differences between the health of different groups by promoting healthier lifestyles, advising government and supporting action by local government, the NHS and the public
- protecting the nation from public health hazards
- preparing for and responding to public health emergencies
- improving the health of the whole population by sharing our information and expertise, and identifying and preparing for future public health challenges
- supporting local authorities and the National Health Service to plan and provide health and social care services such as immunisation and screening programmes, and to develop the public health system and its specialist workforce

[3] www.dwi.gov.uk

- researching, collecting and analysing data to improve our understanding of public health challenges, and come up with answers to public health problems

PHE has an important role in reviewing and publishing the evidence and supporting scientific expert committees, to allow faster progress on improving the public's health.

PHE Centres are the front door for most of PHE's local services across health improvement, healthcare public health and health protection. Depending on their size and geography, Centres may have one or more local health protection teams who can assist with specific health protection enquiries. Each centre director is a partner in the local public health system. PHE have 8 local centres, plus an integrated region and centre for London, and 4 regional groups (north of England, south of England, Midlands and east of England, and London). https://www.gov.uk/government/collections/contacts-public-health-england-regions-local-centres-and-emergency.

Similar arrangements exist for Scotland and Northern Ireland. In Northern Ireland, the health protection function is delivered by the regional Health Protection Service of the Public Health Agency and in Scotland by Health Protection.

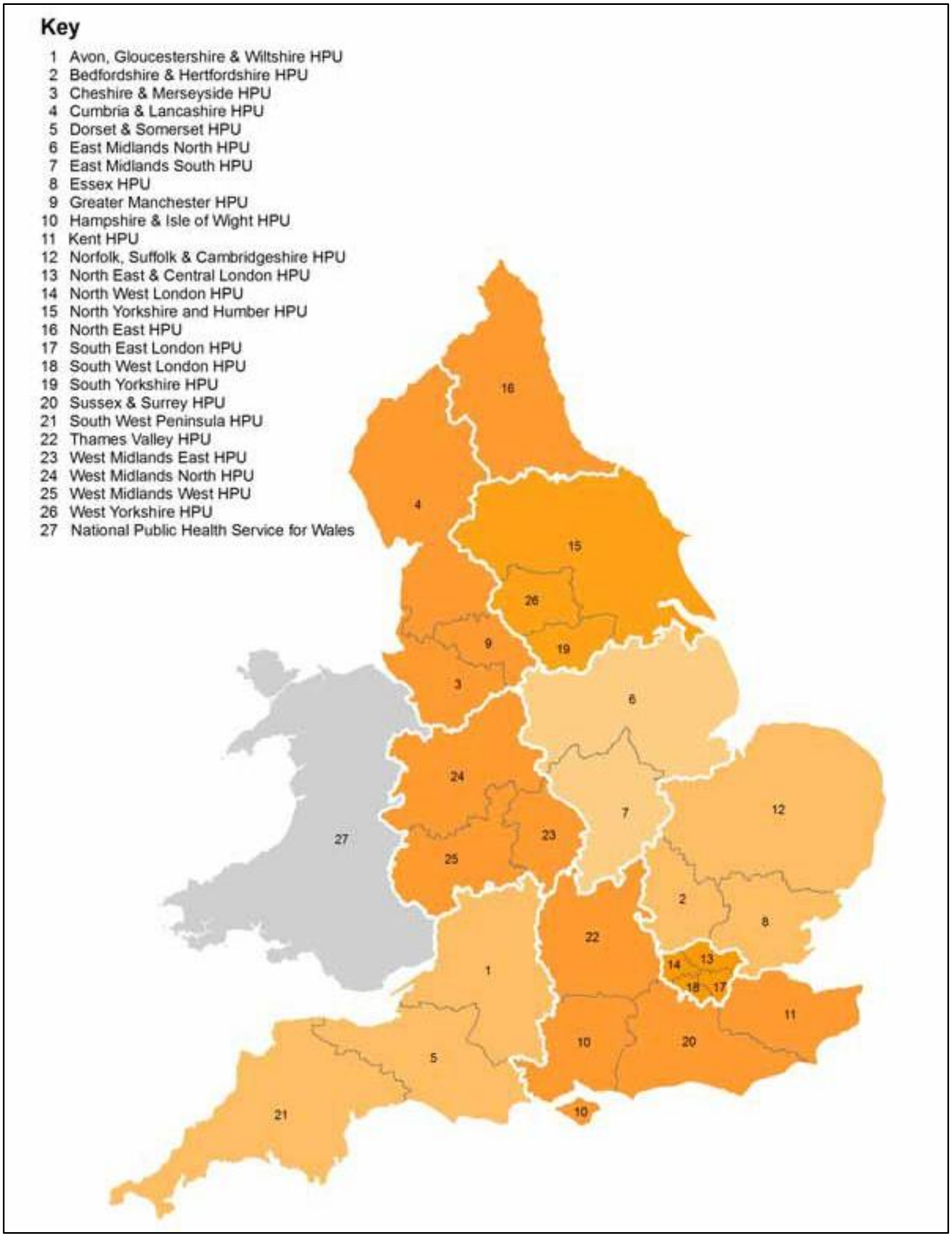


Figure 2: Boundaries for PHE Health Protection Teams

2.5. Local Authorities

2.5.1. The Water Industry Act 1991

For public water supplies this means that local authorities must have effective working arrangements in place with all water companies and licensees who supply water in their area. In particular, local authorities have a duty under section 77 of the Act to keep themselves informed about the wholesomeness and sufficiency of public water supplies in their area, and the Secretary of State has the power to direct local authorities on how to exercise their powers and duties, if deemed necessary. Local authorities also have powers to enforce water companies to provide alternative supplies when piped water supplies are unavailable.

Section 80 of the Water Industry Act 1991[4] places responsibility on local authorities for checking the safety and sufficiency of all water supplies in their area and subsequent sections powers to serve notice on relevant persons to rectify issues causing water quality problems. There is an appeal process for relevant persons for notices served under Section 80 of The Act, whereby the DWI Chief Inspector can be requested to review the notice and can either confirm the notice (with or without modifications), or not confirm the notice. This notice relates to issues of wholesomeness.

2.5.2. Regulations

Regulation 18 of the Private Water Supply Regulations allows for notices to be served by a local authority where water is a potential risk to human health, and in this case, the local authority must serve a notice. Any appeal by relevant persons in this situation must take the matter to a Magistrates' Court.

3. Wholesome Drinking Water

By law (the 1991 WIA), drinking water must be wholesome at the time of supply. Wholesomeness is defined by reference to drinking water quality standards and other requirements set out in the Water Supply (Water Quality) Regulations 2016 (as amended). Similarly for the Private Supply Regulations, regulation 4 also covers wholesomeness. These regulations are available on the DWI website (www.dwi.gov.uk). Many of the standards come from the 1998 European Drinking Water Directive which came into force fully on 25 December 2003 and subsequent amendments. The Directive focuses on those parameters of importance to human health, but it also includes others that relate to the control of water treatment processes and the aesthetic quality of drinking water. The Directive allows Member States to set additional or tighter national standards to secure the good quality of drinking water already achieved and to prevent it from deteriorating in the future. The Drinking Water Directive is currently under review. All requirements of the existing EU Drinking Water Directive are transposed into the Drinking Water Regulations for England and Wales and will be enforced by the DWI.

[4] https://www.legislation.gov.uk/ukpga/1991/56/contents

More information on the Directive standards is given in Annex 1 together with information about other substances that may be found in water and waterborne pathogens.

Where a breach of a drinking water quality standard has occurred that might have a potential impact on public health, water companies and local authorities are required to inform Public Health England and to agree, and undertake, the appropriate investigations and mitigation measures to control or prevent potential risk to health.

3.1. Drinking Water Testing

Water companies and local authorities have a duty to collect samples and test these for each of the substances and organisms (known as parameters) in the respective regulations. Over 3.5 million tests are carried out each year at consumers' taps, service reservoirs and treatment works supplied by water companies and over 180,000 tests on samples from private supplies are commissioned by local authorities across England and Wales. Companies must make the results of this testing available to their customers on request. Local authorities are required to provide sample results to the Inspectorate. The Inspectorate's role is to independently verify that this testing is being carried out to a high standard of quality control, for example laboratories are all accredited through the United Kingdom Accreditation Service (UKAS) to the standard recognised for drinking water (Drinking Water Testing Specification, DWTS). In respect of testing drinking water, the work of drinking water Inspectors is aimed at providing public reassurance that the robustness and integrity of analytical results is beyond question. DWI does not routinely test drinking water, although it has the power to commission independent tests if there is a compelling public interest and adequate justification.

Water companies are required to provide DWI with full details of their annual monitoring programme in advance and the results of these tests are subsequently transferred electronically to DWI on a monthly basis. DWI publishes a summary of the results of a water company's monitoring annually on its website.

Local authorities must also have in place robust arrangements for taking and analysing samples from private water supplies, as well as carrying out risk assessments by competent persons. They are able to charge the owners/uses of private water supplies for monitoring their supply. As local authorities do not have their own laboratories they will use an external accredited laboratory often a private company or water company and, to a lesser degree, may send samples to a public analyst or a specialist Public Health Food, Water and Environment laboratory.

Local authorities recover their costs for their regulatory activities, including risk assessments, investigations and monitoring. There is no legal requirement on local authorities to sample public water supplies, but samples may be collected when acting to resolve a water quality problem within a public building or in respect of social housing for example.

Organisers of temporary event such as the Glastonbury festival an agricultural show or carnival are required to ensure that the water they supply is safe to drink. It is their responsibility to make sure that fittings and fixtures meet regulatory requirements and ensure that the safety and security of the drinking water is maintained throughout the course of the event. For events supplied from the public supply, the Water Company is responsible for making sure the water at the point of connection is safe and wholesome and they also have the power to carry out inspections of the pipework within the site. If the organisers intend to use a private water supply, the local authority is responsible for carrying out a risk assessment and monitoring of the supply at the event. In all cases, the local authority will expect organisers to comply with British Standard BS8551:2015 Provision and management of temporary water supplies and distribution networks (not including provisions for statutory emergencies). The short term provision of water for a temporary event using tankers, bowsers, mobile or static tanks should not be regarded automatically as a regulation 8 situation. For all Regulation 8 supplies, the water company is still responsible for monitoring and enforcing the Water Supply (Water Fittings) Regulations 1999.

In the event of an infectious disease outbreak (e.g. SARS-CoV-2 (CoViD-19)) the requirements of the regulations continue to apply, including those relating to sampling and compliance, monitoring, reporting and any other operations intended to secure the abstraction, treatment, storage and delivery of wholesome water. Additionally, the requirements of the Information Direction relating to non-compliance with the Regulations continues to apply. In such an outbreak, customer facing staff, especially samplers who visit domestic premises, may experience an increased level of difficulty as fears, rational, or otherwise, may impede the normal daily work. A dynamic risk assessment should be made in such circumstances and it is expected that a sampler would make a reasonable number of attempts to obtain a sample. Reasoning for not taking a sample should always be documented. Any change in government advice relating to an infectious disease outbreak may be region specific and could include restricted areas which may make it difficult or impossible to enter domestic premises or areas. In such circumstances a Regulation 7 notice may be issued to water companies giving a variation on sampling. In all circumstances water companies must prioritise the operation of treatment works and continue to monitor critical control points such as point of disinfection and service reservoirs. Online telemetry should always remain in operation.

Laboratories should make contingency plans for continuing analytical services in circumstances where movement and staff availability are limited or restricted. Where there are impacts on analytical capability the Inspectorate will be notified. In all circumstances, microbiological analysis including *Cryptosporidium spp.* will be prioritised.

4. The Safety of Drinking Water

The regulations make specific provisions for drinking water safety and require water companies and local authorities in respect to private supplies to implement a risk management (water safety plan) approach to water production and distribution as recommended by the World Health Organisation (2011 WHO Guidelines for Drinking Water Quality). The latest WHO guidance on water safety planning is available at; http://www.who.int/water_sanitation_health/water-quality/safety-planning/wsp-publications/en/.

Publications include:

- Water safety plan manual
- Climate – resilient water safety plans
- Principles and practices of drinking water chlorination
- Potable reuse
- Water safety planning for urban water utilities
- Protecting surface water for health
- A practical guide to auditing water safety plans
- Water safety plan – A field guide
- Water safety in distribution systems
- Water safety in buildings
- Water safety plans – managing drinking water quality for public health

4.1. Water Company Responsibility In Relation To Water Safety

Water companies are required to have adequate water treatment in place, informed by a regulatory, raw water monitoring programme. They must disinfect all water before supplying it and, where necessary, subject the water to sufficient preliminary treatment to prepare it for disinfection (regulation 26). As a minimum this must ensure that the turbidity of water is <1 NTU (Nephelometric Turbidity Units) prior to disinfection. The method of disinfection is not set out in law, but DWI require water companies to define and document their disinfection policy and implement it through written procedures for each treatment works.

For every treatment works and associated water supply system, water companies have to carry out and keep up-to-date a risk assessment to establish whether there is a significant risk of supplying water that would constitute '*a potential danger to human health or is likely to be unwholesome*'. Reports on these risk assessments are submitted to DWI and are subject to audit and enforcement action where necessary. *Potential danger to human health* is a term which derives from the Drinking Water Directive. In practice, in the UK, this term is understood better as a potential risk to public health generally. It is not a consideration of the medical needs of a particular individual. Likewise, the risk assessment is concerned with the human population. There is no requirement to assess the risk to pets, livestock or fish.

As well as covering microbiological, chemical and radiological hazards, regulatory risk assessments also cover other physical and organisational hazards which may result in a failure of the water supply (no water) or consumers rejecting the water for aesthetic reasons i.e. not wholesome. Where an unacceptable risk is identified, water companies must put in place an urgent programme for mitigation and control, including, where necessary, short, medium and long-term improvement measures. DWI requires water companies to communicate effectively about their risk assessments with key stakeholders and this means that PHE and local authorities should be briefed on, and consulted about, specific risk assessments for water supplies in their areas. Through these consultations, Public Health Professionals have the opportunity to become familiar with the local water supply arrangements, to ask questions and satisfy themselves that it fully takes account of the public health needs of the local community. If they are not satisfied in this respect they should raise their concerns with the water company in question and the DWI. DWI has the power to issue notices directing a water company to take certain actions in respect of its risk assessments.

Other water safety requirements of the regulations include the fact that water companies must treat water to make it less aggressive towards lead and copper plumbing where this has been shown to be a problem with a specific water supply. There are also regulatory controls (regulation 31) over the chemicals and materials of construction that water companies are permitted to use. DWI operates a national approvals system for chemicals and materials of construction, and the published list of approved products is available on the DWI website. The Centre for Radiation, Chemical and Environmental Hazards (CRCE) of PHE provides toxicological advice to DWI in respect of decisions about the approval of materials.

Water suppliers that fail to adequately treat and/or disinfect their water supplies, or fail to take action in respect of their risk assessments, or who use unapproved chemicals or materials, may have committed a criminal offence. DWI Inspectors carry out independent technical audits of company records and sites to ensure that operational and management procedures are robust. If deficiencies are identified, DWI has the power to take enforcement action to require improvements to be made.

It is not uncommon for a drinking water quality problem to be due to the condition of building water systems rather than the distribution system owned and operated by the water company. Water companies have powers under the Water Supply (Water Fittings) Regulations 1999 to inspect premises to ensure the public water mains are protected by backflow devices or other means from any possibility of contamination from water used in industrial processes, wastewater or any private supply. Water companies have a programme of regular inspections of high risk building water systems in place and will carry out inspections in response to unexplained consumer complaints. They also have a programme to check any new connections to their distribution networks. It is not uncommon to find interconnections between private and public supplies that are not sufficiently protected by backflow prevention. Water companies should be aware of high risk locations in their area (farms, industrial units) and ensure that an appropriate inspection regime is in place. Local authorities should be vigilant and identify any risk of interconnections with mains water identified when carrying out risk assessments should be escalated and mitigating protection put in place.

Water companies adhere to stringent hygiene procedures to ensure that none of their employees or contractors is allowed to work in restricted water supply areas if they are suffering from an infectious disease that may be waterborne. Water Hygiene training courses are delivered through Energy and Utility Skills and a Water Hygiene (EUSR) Card is issued. The course emphasises awareness of individuals' responsibilities towards the potable water supply and verifies that the employee has demonstrated an appropriate level of knowledge and awareness with regards to hygiene and water quality issues.

5. Events and Incidents

5.1. Public Water Supplies

Section 70 of the WIA 1991 makes it a criminal offence for a water company to supply water that is unfit for human consumption. However, the WIA provides a defence for the water company if it can show that it had no reasonable grounds for suspecting that unfit water would be consumed, or it had taken all reasonable steps and exercised all due diligence to ensure that water was fit for human consumption on leaving its pipes. There is a regulatory duty on water companies to notify DWI of any event which has the potential to give rise to a significant risk to public health or otherwise cause consumers concern directly (appearance of water) or indirectly (adverse media comment). It is also regulatory duty for such events to be notified to local authorities, Public Health England and the Consumer Council for Water. Others, including consumers, journalists and whistle-blowers, can also make the DWI aware of any actual or potential event.

Inspectors will assess the significance of all notified events on a risk-based approach. Where necessary, they will investigate and take enforcement action which may include initiating proceedings or issuing a caution or notice. In addition to the offence of supplying water unfit for human consumption in the Act, it is also a criminal offence for a company to fail to comply with Regulation 26 (adequate treatment and disinfection of water) or Regulation 31 (use of only approved chemicals and materials).

When conducting their investigation, Inspectors will gather evidence in the form of technical and management information from the company and through interviews of relevant persons, including members of the public, contractors, consultants and advisors, potentially including local authority and PHE staff. Inspectors are trained in, and follow, Police and Criminal Evidence Act (PACE) procedures. DWI publishes its findings and recommendations in the form of an Event Assessment Letter (EAL) and copies of these are provided to PHE, the affected local authorities and the Consumer Council for Water.

A water quality event is defined as any biological, chemical or radiological occurrence which by its nature is required to be notified under the Water Supply (Water Quality) Regulations 2016 or the Private Water Supplies Regulations 2016. When an event has the potential to have a significant impact on public health, it can be escalated to an incident and an Incident Management Team (IMT) formed. Examples of "significant" would include outbreaks of water-related illness or a sizeable population exposed to a chemicals of health significance where the contaminant is at levels above the prescribed concentration or value[5]. Box 1 includes examples of the criteria that may be used to trigger an IMT.

Box 1: Criteria for establishing an Incident Management Team (IMT)

- An **exceedence** of drinking water standards (e.g. a prescribed concentration or value (PCV)) and guidelines as set out in the Water Supply (Water Quality) Regulations 2016 or the Private Water Supplies Regulations 2016 that is unacceptable in terms of public health (termed a non-compliance event).
- Reports of an **unusual deterioration or changes** in water quality that may have an implication on public health. For example, analytical data suggesting increase metal or pesticide concentrations, changes in colour or turbidity that may indicate a change in the water treatment process.
- Reports of **failure or poor performance** of water treatment and disinfection activity (for example a near miss).
- Reports of **potential external contamination of** a water supply or water catchment area that could result in a future non-compliance event or near miss (for example diesel spillage threatening water supply).
- Reports of **site security issues** associated with water supply or treatment process.
- Any evidence of **unusual and unexplained clustering of cases** in the community related to a water supply.
- Any significant **perceived risk** to the health of consumers.
- Significant **consumer perception or concern** about the quality of the water supplied or changes in water quality.
- One or more core partners have already declared the event a public health incident.
- Any combination of the above

If the incident becomes an outbreak, an outbreak should be declared, the IMT dissolved and an Outbreak Control Team (OCT) formed. Both the need to establish an IMT and its membership will vary from case to case and will be determined by the Director of Public Health (DPH) in consultation with the Consultant in Health Protection

[5] Some chemicals have PCVs that are not health based and it is unlikely an IMT would be called for contaminants where the PCV is based on taste and odour.

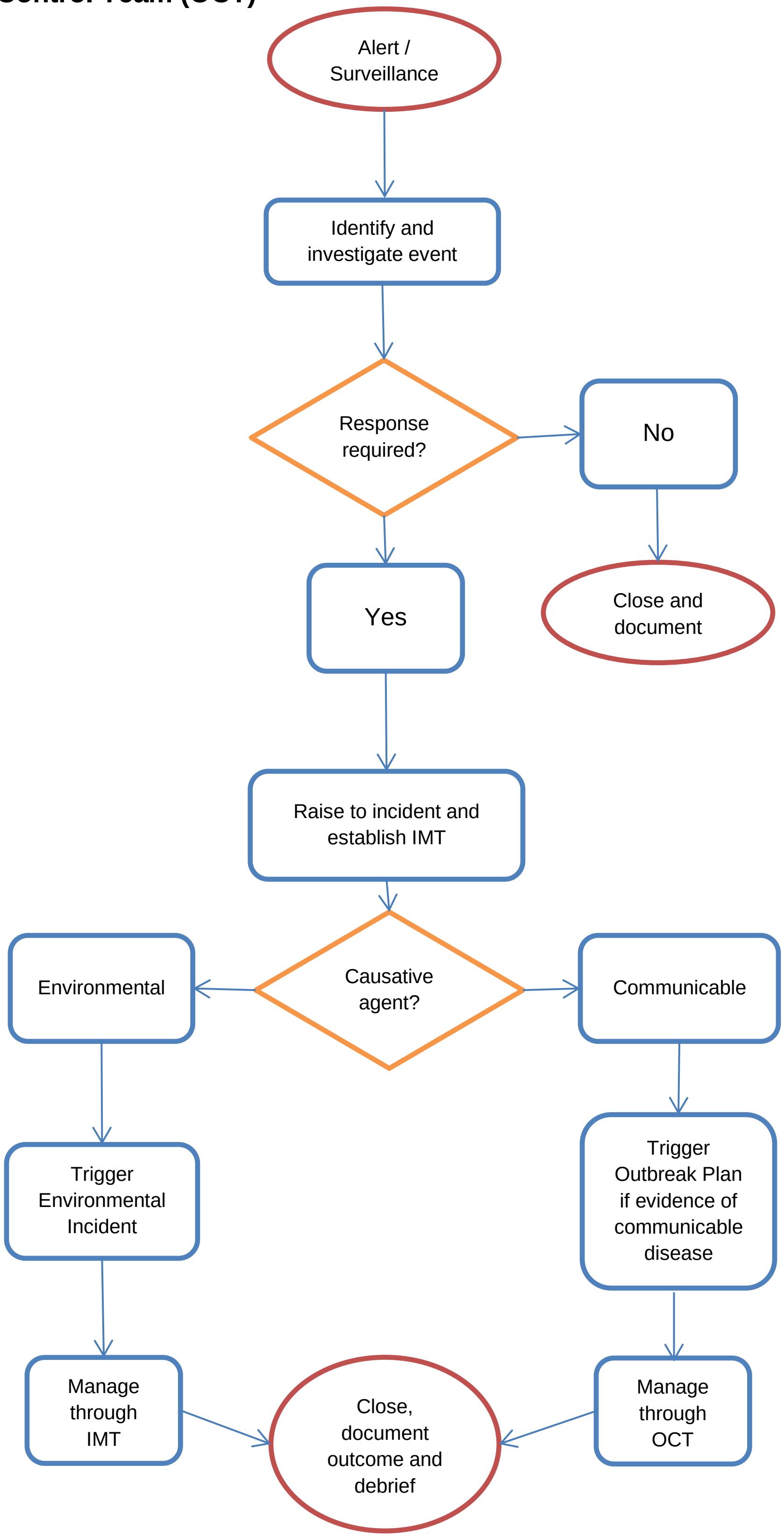
(CHP) / CCDC in Public Health England, the role of the OCT or science advisory group is provided in PHE guidance.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/781573/INIDC_guidance_v1.0.pdf

An outbreak is usually declared jointly by Consultant in Communicable Disease Control/ Consultant in Health Protection (CCDC/CHP) in conjunction with the Local Authority and the Health Board (including the Clinical Lead for Microbiology and the Director of Public Health). More details on the role of the OCT can be found in the PHE Communicable Disease Outbreak Management Operational Guidance document.

Guidance for investigating non-infectious disease clusters from potential environmental causes can be found at
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/781573/INIDC_guidance_v1.0.pdf

Figure 3 presents a flowchart summarising the IMT/ OCT decision.

Figure 3: Flowchart summarising the activation process for an Incident Management Team (IMT) or Outbreak Control Team (OCT)



The primary objective of the IMT or OCT is to protect public health by identifying the source of the contamination and implementing the necessary control measures to minimise or reduce exposure and prevent further spread, recurrence or exposure. Core members of the IMT/OCT include PHE, Local Authorities and Water Companies. Co-opted members can also include the EA, Food Standards Agency and the DWI. The IMT/OCT will usually be chaired by a DPH within the relevant authority and the Chair will be agreed at the first meeting. However, any member of the IMT can chair by the agreement of the members of the IMT.

The core actions of an IMT/OCT include:

- Undertake a risk assessment to identify the contaminant(s), the source and extent of contamination.

- Identify gaps and information needed to update the risk assessment.

- Evaluate and characterise the risk to public health and likely illness in the community, including defining the population at risk and identifying any high risk / susceptible individuals such as immuno-compromised groups, home dialysis patients, health-care settings.

- Declare an 'Outbreak' if there is evidence of communicable disease following the contamination incident.

- Agree and initiate immediate and long-term control measures to reduce exposure. Immediate control measures may have been taken by the water company before the IMT is formed and these should be reviewed by the IMT. Box 2 summarises some of these control measures.

- Communicate to the public and medical professionals including publication of media statements.

- Consider undertaking an epidemiological study to describe symptoms/cases.

- Monitor control measures by continued surveillance for disease/symptoms.

- Lift Warning Notices subject to agreed criteria being met.

- Evaluate the management of the incident and make appropriate recommendations for the future.

- Declare the incident over.

- Produce report on the outcome including recommendations and epidemiological report (if required).

Box 2: Examples of control measures in response to water quality event

<u>Immediate:</u>

- Stop water abstraction
- Flushing of supply system or individual supply pipes
- Issue warning advice/ notices:
    - Boil before Use for drinking and food preparation (BWA)
    - Do not use for Drinking or Cooking (DND)
    - Do not use for Drinking, Cooking or Washing (DNU)
- Providing alternative supplies, such as:
    - Bottled water (also see http://www.legislation.gov.uk/wsi/2015/1867/contents/made)
    - Bowsers and tankers
    - Diverting sources or Re-zoning (introduction of water from a different supply)

<u>Long-term / permanent:</u>

- Additional water treatment processes (process control)
    - Activated carbon
    - Water filters
    - Increased disinfection
    - Phosphate dosing
- Replacement of water pipes e.g. lead pipes
- Permanent provision of different supply (e.g. moving from private water supply to mains)

<u>Public Health controls:</u>

- Isolate or exclusion of cases and contacts
- Screening and monitoring of contacts
- Immunisation or prophylaxis
- Specific advice and interventions to highly susceptible groups e.g. protection measures for:
    - for immunosuppressed groups
    - recommend home dialysis patients receive treatment in hospital
    - lead exposure and children
    - bottled water and infants

The water company may also set up their own operational Incident Management Team (WCo-IMT) tasked with issuing any short-term health protection warning to consumers and carrying out the necessary work to restore the water supply to normal. This will link closely to the IMT/OCT and one or more members of the WCo-IMT will sit on the IMT/OCT and provide operational updates and report back to the Water Company any requests for information and advice.

While the vast majority of events will be managed through an OCT/IMT, there will be rare occasions where an event may necessitate the activation of civil contingency arrangements. This is likely to where the nature or scale of the event meets the definition of a major incident in the Civil Contingencies Act. A major incident is defined as “an event or situation, with a range of serious consequences, which requires special arrangements to be implemented by one or more emergency responder agencies.”

Scenarios where this may be necessary include a suspected chemical, biological, radiological, nuclear and explosive (CBRNe) event, a widespread communicable disease outbreak or chemical incident that creates the risk that essential services will be overwhelmed or an event that require the implementation of civil restrictions on health protection grounds. In such scenarios, a Category 1 responder such as the emergency services or Public Health can initiate formal command control structures to manage the incident. These may involve escalation to the relevant Local Resilience Forum and the establishment of a Tactical Coordinating Group (TCG or Silver Command) and/or Strategic Coordinating Group (SCG or Gold Command). The SCG sets the strategy within which lower levels of command will operate.

Typically, the police will chair the SCG but it can be any Category 1 responder. If required, the SCG can access scientific and technical support through the Scientific and Technical Advisory Cell (STAC) which is usually chaired by PHE. The membership of STAC will depend on the nature of the incident and the specific response requirements that arise locally. For most incidents scientific advice is best provided through existing channels and agencies who routinely attend the SCG. A STAC should only be activated when there is a collective expectation that it can add value to the incident response.

At national level, if the scale of the event warrants it, the Civil Contingencies Secretariat may institute national response plans including regular meetings of the Civil Contingencies Committee (CCC) and the establishment of a Scientific Advisory Group for Emergencies (SAGE). For water emergencies, DWI would normally be invited to be a member of SAGE. Good communication between the STAC and the SAGE will be essential.

One of the requirements of the investigation is to evaluate the event and prepare a written report on the health impacts and disseminate any lessons learnt. This may include results of any epidemiological studies. The timing of the evaluation can be flexible; OCT/IMT may find it helpful to have time to reflect on the event prior to carrying out the evaluation. At this stage, any urgent recommendations will need to be flagged up prior to the full report. It is very important that this report confines itself to the health study and does not include details about the water supply or its management, because these matters will be investigated and reported upon by DWI and details may form the basis of criminal proceedings. It should be noted that the DWI report on an event usually takes the form of an assessment letter (EAL) which will be sent to all the parties involved in the event and will describe the DWI's findings, actions and conclusions. If the event investigation leads to the initiation of proceedings in court, the EAL will be issued only when the case had been concluded. It is recommended that the Chair of the IMT establishes direct contact with DWI when the IMT is first formed, to establish effective communications. It was a recommendation of the Third Report of the Expert Group on *Cryptosporidium* in Water Supplies (the Bouchier Report) published in 1998, that any report by an IMT be submitted to the Chief Inspector so that DWI can issue guidance to the water industry in respect of any key learning points.

5.2. Private Water Supplies

Regulation 18 of the Private Water Supply Regulations 2016 (as amended) in England requires that if any private supply of water intended for human consumption constitutes a potential danger to human health, a local authority acting under these Regulations must serve a Notice on any relevant person. The Water Industry Act 1991 defines relevant persons in Section 80. A Notice may be served on one, several or all of the relevant persons, depending on the cause of the potential danger to health and the appropriate mitigation required. In addition, the local authority should take into account any local agreements, covenants or deeds which specify responsibilities for specific aspects of the supply or its management. Further guidance on this is available on DWI's website.

Regulation 6 requires a local authority to undertake a risk assessment at least every five years for each private water supply within their area with the exception of a supply to a single dwelling where the supply is not provided as part of a commercial of public activity. Local authorities must carry out a risk assessment of such single dwellings if requested by the owner or occupier of the dwelling. The purpose of the risk assessment is to establish whether there is a significant risk of supplying water that could constitute a potential danger to human health. Local authorities must also use the risk assessment process to establish whether there is a risk of non-compliance with any of the standards or indicator parameter values outlined in the Regulations. The risk assessment should also be used as part of the information to enable local authorities to consider whether it can exclude parameters from any monitoring requirements. A link to the relevant tool can be found from this link: http://www.dwi.gov.uk/private-water-supply/local-auth/risk-assessment.html

If information is not provided by a relevant person, the local authority can use its powers under Section 85(1) of the Water Industry Act 1991 to serve a Notice on any person requiring that person to provide information about premises on a supply.

6. Protecting the Public during an Event or Incident

6.1. Public Water Supplies

Due to the nature and complexity of operational activities involved in the supply of drinking water, water companies will take a number of actions to protect public health, such as the provision of advice to consumers, some examples of which are described below. On many occasions the company should, and will, notify PHE and local authority staff as part of this process. The purpose of this notification is to provide PHE and the local authority the opportunity to provide medical/public health advice to the company that is pertinent to the local community affected. However, the responsibility for issuing warning notices to consumers and providing alternative water supplies (rezoning, tankers, bowsers and bottles) rests, at all times, with the water company. An example of the notification template generated by DWI and circulated upon notification of an event affecting the quality or sufficiency of drinking water is provided in Annex 2.

As a matter of routine day-to-day water supply operations, temporary precautionary advice is issued by water companies to householders via social media platforms and water company website area bulletin updates. Additional precautionary advice may be given in the form of letters, leaflets or warning notices to specific consumer premises. The public is familiar with, and is therefore responsive to, such advice coming from their water supply company. Water bills sent to customers provide a number to ring to report a problem with the water supply. Water company websites and social media channels, provide water quality advice and can be an effective route of contact for the public to their water supplier. Local authorities for private water supplies will also issue precautionary advice where necessary. Listed below are the typical situations where precautionary advice is issued, together with details of how this is done, who is involved and why.

Planned work on the water supply: advance notices are delivered to each building in the affected streets in addition to emails and text messages sent to registered consumers. The notice will give details of the work, particularly the timing of any shut down of the supply. For example, it may advise that water may be discoloured when the supply is restored and what to do if this does not clear on flushing the mains tap.

Unplanned disruption to the water supply: typically caused by a burst main. Company website and social medial channels will be updated with area bulletins and customers ringing their water company will be given advice, often through a recorded message set up for particular post codes. The water company will notify the local authority and PHE of any disruption which is likely to be protracted (i.e. difficult to repair) or attract adverse media comment (i.e. traffic congestion) or affect a large number of homes and businesses. Companies have direct arrangements for providing alternate supplies by tanker, bowser and bottles to priority customers such as hospitals and schools.

Adverse routine test result- single household: samples are taken at random from consumers' taps every day of the year from network water supply zones. Adverse results are notified straightaway by the laboratory to the water company. The company will assess the risk to the consumer and arrange to collect further samples. The water company may choose to give precautionary advice to the householder until the cause of any problem has been identified. This advice is given verbally in the first instance, it may be to flush the tap before drawing water, or to boil the water before use, or not to drink or use the water. In the latter, more serious cases, the water company will usually provide an alternative bottled water supply for drinking. The water company will notify and consult the local authority and PHE of the adverse result and the action being taken.

Consumer water quality complaint – single household: companies have risk assessment procedures in place to ensure that a water quality scientist is notified of any call from a customer attributing illness to the water supply, or reporting an objectionable taste, odour or discolouration. If the problem is not clearly linked to a known operational problem, advice will be given over the phone and arrangements will then be made to collect samples and /or inspect the plumbing at the property. The water company will notify the local authority and PHE of any adverse results. Customers reporting illness will be advised to visit their local doctor/ registered general practitioner. If it is clear that the person has been diagnosed with a water-related illness (e.g. cryptosporidiosis) or notifiable disease (Health Protection Regulation, 2010) the regional PHE team will be notified straightaway.

Adverse sample result or issue identified as affecting several properties or streets: during the investigation of an adverse result or consumer complaint at a single household (see above), it may become evident to a water company that there is a risk of contamination of the wider water supply, typically as a result of an illegal cross connection or inadequate back flow arrangements or spillage of chemicals. In these situations the company will issue precautionary boil water or do not drink notices to several premises or streets as a precaution. Examples of these notices are given in Annex 3. The water company will provide alternate supplies in the same way as it does for an unplanned disruption (see above). When the situation is resolved, water companies will deliver a second notice to say that the water supply has been restored to normal. The water company website, social medial channels and direct consumer text messages and emails will also be used. The water company will notify and consult the local authority and PHE of the situation and the action being taken.

Adverse sample result or some other type of problem affecting a water treatment works or a service reservoir/water tower: the water company will establish an Incident Management Team for any event involving an actual or potential risk to the water supply from a strategic water asset. All relevant local authorities and PHE will be notified and consulted by the water company and advised of the immediate actions being taken. The company will make arrangements at this time for a meeting (or conference call) with regional PHE groups and local authorities to discuss the risk assessment and the need for the public to be issued with precautionary advice and alternative water supply arrangements.

In a large scale event, the hazards posed by issuing a wide-scale warning notice need to be balanced carefully against the nature of the water supply event. Experience has shown that it is often preferable to implement enhanced health surveillance of the affected community instead of issuing a warning notice. Each situation has to be judged on its merits, taking into account local knowledge and whether or not water supplies can be returned to normal quickly or an alternate piped supply provided (by rezoning). If a decision is taken to issue boil water or do not drink advice, the basis for lifting the advice must be agreed at the same time. Experience has shown that significant problems can arise if the criteria for lifting the notice have not been decided when advice is first issued, although the criteria may need to be refined if new information becomes available.

The responsibility for issuing warning notices and providing alternative water supplies (rezoning, tankers, bowsers and bottles) rests at all times with the water company.

Local authorities have a responsibility for decisions about the continued operation of premises manufacturing or serving food and drink, and for public buildings such as schools and leisure centres. The regional PHE group and local authority is responsible for initiating contingency arrangements for hospitals and other health services. All responding agencies should ensure that only a common agreed form of public advice in the form of, for example, Frequently Asked Questions (FAQ) is provided to their staff in call centres or placed on websites. FAQs should be regularly reviewed such that they are in line with PHE, and DWI current guidance. There is also public health advice available on many other websites such as the PHE webpages and some reference laboratories. These links are included in Annex 1. Annex 4 also provides advice on precautions to be taken by the immunosuppressed individual in relation to boil water notices

6.2. Private Water Supplies

Where water from a private water supply in unwholesome, Section 80 of the Water Industry Act 1991 provides powers for local authorities to serve notice on all relevant persons on a private water supply, specifying the actions needed to correct the issue. Notices should have clear timescales and example template for local authorities are provided on DWI's website. Where the relevant persons do not take the actions required, the local authority may arrange for the work to be done and recharge the appropriate relevant persons.

In many cases the actions to be taken by the relevant person in relation to an issue on a private water supply will be very similar to those given above for public water supplies albeit on a smaller scale. However the relevant persons or the consumers may like to obtain advice from the local authority, PHE, their local water company or the Inspectorate in the case where they do not have the skills to solve the issues identified themselves. In protecting consumers on private water supplies, local authorities have the powers to issue notices restricting the use of water (Boil Water notice, Do Not Drink notice, Do Not Use notice). These notices should be served on all relevant persons on the supply. **When serving such a notice it is not acceptable to have no end point for the restriction. Local authorities need to specify a time limit, what needs to be done to rectify the problem and have included criteria for lifting the restriction.**

A case study on the inappropriate use of a private supply by a food business is given in the Chief Inspector's report on Private supplies in 2015[6]. In this example the food business had a private borehole and a connection to the mains water supply however following a water fittings inspection by the water company the food business was unable to make use of the mains supply as contraventions were found and therefore drew down on the borehole such that the quality deteriorated. Had there been better collaboration between the parties involved, the substantive economic, reputational and regulatory costs may have been avoided.

[6] Drinking Water 2015 – Private Water Supplies in Wales – Case study 6 pp 31-35. http://www.dwi.gov.uk/about/annual-report/2015/pws-wales.pdf

Another case example from 2015[7] involved an outbreak of *Escherichia coli* O157 (*E. coli* 0157) which occurred due to cattle accessing a spring source used as a private water supply to holiday lets. The underlying route causes were a change of use of the land from grazing sheep to grazing cattle, that cattle were able to reach the borehole headworks and defecate on it and that the original UV treatment system was undersized for subsequent increases in volumes of water needed to supply additional holiday homes put onto the supply. The outbreak highlighted the challenge of managing and investigating a situation where cases and contacts were spread widely. Overall 21 cases were identified ranging from a 2 year old to a 79 year old. What greatly aided the response to this outbreak was the promptness at which colleagues from other Health Protection Teams informed the PHE Cumbria and Lancashire team of their cases which could be potentially linked to the holiday let, and on the 13 August 2015 a "prohibition of use" notice was served on the water supply.

A number of learning points were identified from this case:

- The Internal Communications Summary highlighted the potential outbreak to other regional PHE teams and to NHS Scotland. This greatly speeded up the ability to link cases and confirm the outbreak.
- There is a need to respond promptly if a health professional thinks they have a linked case.
- An OCT allows for all responsible parties to manage the source and outbreak effectively.
- Health and water professionals need to be aware that the standard test for *E.coli* as a faecal indicator in PWS samples does not detect *E. coli* O157 per se, but is instead designed to identify faecal contamination; a positive sample should highlight the need for more detailed sampling that can speciate the bacterium.

Resources to aid the public health advice of the water quality of are outlined in Annex 1.

The chemical quality of private supplies can be driven by the quality of groundwater, from where the private supply is sourced. Many factors influence quality of groundwater, such as past industrial activity, soil contamination, seasonality, drought and precipitation rates. In some regions of England and Wales, private supplies are directly influenced by local geology or soil quality. From the 2011-2013 Cornwall study of single domestic PWS by PHE, it was found that up to 35% of supplies had exceedances of one or more prescribed concentration or value (PCV) of a range of chemicals and that 20% of households had one or more exceedance of health-based values for drinking water[8].

[7] Drinking Water 2015 – Private Water Supplies in England – Case study 7 pp 39-46. http://www.dwi.gov.uk/about/annual-report/2015/pws-wales.pdf

[8] Crabbe, H. Fletcher, T, Close, R. Watts, M.J., Ander, E.L., Smedley, P.L, Verlander, N.Q., Gregory, M., Middleton, D. R. S., Polya, D, Studden. M, and Leonardi, G.S. (2017) Hazard Ranking Method for Populations Exposed to Arsenic in Private Water Supplies: Relation to Bedrock Geology. Int. J. Environ. Res. Public Health 2017, 14, 1490;

The risk of arsenic contamination was associated with the type of local bedrock geology. Bedrock geology influences soil quality and both have been shown to influence groundwater quality. The British Geological Survey normal background soil contamination maps[9] show where there are high levels of arsenic, cadmium, copper, nickel and lead in soil. These maps can be used to give some idea of the areas where soil quality and bedrock may influence chemical quality of local ground water sources. This gives an indication for the risk of chemical contamination of single domestic private supplies and the need for risk assessments, water testing and monitoring.

Local authorities are best placed to advise on the intervention and treatment options of addressing microbiological and chemical quality of private supplies however they may need support from PHE and the local water company to understand the consequences of the identified risk. Information that might assist local authorities faced with a water quality problem is provided on the DWI's website in the *Manual on Treatment for Small Water Supply Systems*[10]

Safety of private supplies does not rely solely on testing. Risk assessment from source to tap combined with verification by testing should constitute the minimum activities. The risk assessment will then identify and need to sample beyond the levels laid down in regulations and there is freedom for local authorities to expand sampling in response to risk assessments.

7. Precautionary Advice and Key Event Learning Points

Two aspects of issuing warning advice to the public have proved problematic on more than one occasion in the past: the nature/type of the warning given and the provision of alternate supplies. The advice which follows draws not only on problematic events, but also those that were well managed.

7.1. Types of Precautionary Advice

When deciding on the advice to be given there is a choice to be made between one of three types of warning message:

- Boil before Use for drinking and food preparation (BWA – Boil Water Advice).
- Do not use for Drinking or Cooking (DND- Do Not Drink).
- Do not use for Drinking, Cooking or Washing (DNU- Do Not Use).

doi:10.3390/ijerph14121490http://dx.doi.org/10.3390/ijerph14121490

9 http://mapapps2.bgs.ac.uk/bccs/home.html

10 http://www.dwi.gov.uk/private-water-supply/installations/updated-manual-on-treatment-for-small-supplies.pdf

Whereas a BWA notice causes inconvenience in the home and can be disruptive to certain businesses (food and drink retailers and manufacturers) and public buildings (health care premises), the water industry has substantive experience of the practical aspects which are manageable and the public is familiar with the concept. Consumers should be advised that they should only use ice made from boiled water and should discard any ice previously made.

By contrast, a DND notice poses a more significant challenge to a water supplier due to the need to make 100 per cent provision of alternative water supplies for drinking and cooking. These logistical problems are magnified and further compounded in the case of a DNU notice because of the hygiene issues implicit in restricting the public's access to piped water for bathing, washing and toilet flushing. In some cases it may still be possible to use the water for flushing the toilet but the water supplier involved should make this clear to their consumers. Furthermore, the public is unfamiliar with water restrictions of this nature and on a large scale, and a far wider range of businesses will be affected. It is recommended that DNU notices are reserved for use only in those circumstances where there is unequivocal evidence of persistent contamination of the water supply with a substance (or radioactivity) at a level where short-term exposure is known to give rise to adverse health effects in the otherwise healthy population, and measures to restore the water supply to normal are likely to be protracted (weeks, rather than hours or days). Generally, the type of circumstances when a DNU notice might be considered are those where there is a major chemical pollution event which cannot be contained by the water supplier through stopping abstraction at the treatment works and/or the contamination has entered the treated water distribution system and the extent of the contaminated water cannot quickly be identified and contained/removed.

Another relevant scenario would be where the contaminant cannot be detected by a change in appearance, taste or smell of water (meaning consumers would not be alerted to the problem and thus unlikely to take avoiding action without being warned).

In most water quality events, therefore, the decision about which warning notice to issue is a choice between a BWA and a DND. Where there has been a loss of supplies due to a failure of an asset, the water supplier will be able to access records of water fittings inspections and identify whether there are any premises in the affected area classified as high risk in terms of potential to cause water contamination due to back flow or back siphonage. All high risk premises are routinely inspected and checked to ensure adequate back flow protection is in place. Furthermore, a back flow event is limited in scale impacting only on adjacent premises and streets in the immediate vicinity of the back flow site. Accordingly, a BWA notice (not a DWD notice) is the most appropriate one to use in 'loss of supply' events. As with DNU notices, the use of a DND notice should be reserved for those situations to safeguard against exposure to chemicals at a level where short-term exposure is assessed as being likely to give rise to adverse health effects.

The above guidance relates to the general public and in any event it is always important to separately consider the need to issue specific and different advice for vulnerable or sensitive users (e.g. pregnant women, babies and immunosuppressed individuals). This should always be done through pre-arranged communication routes and professional networks, e.g. by local authorities for food manufacturers/retailers, through GPs or other established medical networks. Water suppliers have standing arrangements in place for notifying dialysis patients and for alternative supply arrangements for hospitals. PHE and local authorities will want to have standing arrangements in place for communicating with other vulnerable groups and other types of health and social care premises. For example, in the event of an infectious disease outbreak (e.g. SARS-CoV-2 (CoViD-19)) local authorities and GPs hold lists for vulnerable consumers who would be shielding and unable to attend bottled water stations. In such circumstances all vulnerable persons should be encouraged to separately register with the water company as requiring bottled water delivery and additional service where required. Current advice for the immunosuppressed in relation to *Cryptosporidium* is contained in Annex 4.

In support of reaching a decision about the most appropriate warning message, the water industry has access to a number of dedicated resources; the UKWIR (UK Water Industry Research) Toxicological Datasheets and Microbiology Datasheets[11] and the Call off Contract. The UKWIR Toxicological Datasheets and Microbiology Datasheets are jointly funded by the water industry and DWI and provide information to assist water suppliers to respond in a rapid and effective manner to a water contamination incident. It should be noted that only UKWIR members have access to these datasheets. In an event, the water company will be able to provide content from the UKWIR database to the PHE group or local authority where necessary. The UKWIR datasheets are updated every 5 years to ensure that they contain the most relevant information. The datasheets provide the user with; occurrence and likely sources of the contaminant, information on legislation and standards associated with the parameter, human health and mammalian toxicity data, health based and operational Suggested No Adverse Response Levels (SNARL) values for use in short term exposure situations, taste and odour data including thresholds and descriptors, information and advice concerning substance removal by water and wastewater treatment processes and information on analytical methods and detection limits. The derivation of SNARL values provides the suggested concentration of a contaminant in water that is considered to represent no significant risk to human health over a short period. SNARLS values are generally given for 24 hours or 7 days exposure only and include levels for adults, child and infant intakes. SNARLS are calculated using toxicological data or other derived values (such as the WHO Tolerable Daily Intakes) and include the reasoning behind any uncertainty factors applied. The assumptions used to derive SNARLs are a 60 kg adult drinking 2 L (of water)/ day, a 10 kg child drinking 1 L/ day and a 5 kg bottle-fed infant drinking 0.75 L/day. It is important to note that SNARL values do not constitute standards and are suggested values only to provide guidance to public health professionals.

The Call off Contract is an arrangement put in place and managed by DWI, whereby in an emergency or a security event a water company can access timely, sophisticated analysis for chemicals, toxins and organisms outside the range of routine capability of

[11] Data Sheets by UKWIR require a log on password that can be provided by UKWIR https://ukwir.org/eng/online-tools

water testing laboratories. Specialists in PHE, PHW and wider government are involved with DWI in the ongoing development of the facilities and resources inherent in the Call off Contract.

The water industry has arrangements in place to enable the rapid analysis of a range of contaminants that may result from the deliberate contamination of water supplies however the contractual arrangements of the Call off Contract are overseen by DWI and analysis can only be initiated by a DWI Inspector at the request of a named contact within a water company. The Inspectorate funds research into rapid analytical methods to support this contract.

7.2. Dissemination of Precautionary Advice

Consumers expect to receive and obtain information about their water supply from their water supplier or the relevant person in respect of a private supply. Every household and business or public premise receives details of how to contact their water supplier with their water bill. However, people who live in private rented or social housing may pay their water bill through the landlord, leaseholder or general rates and may not receive a bill directly. It is important, therefore, for local authorities to have plans in place to assist the water company by making social housing managers, landlords and leaseholders aware of any warning advice and generally take steps to facilitate its dissemination to residents and to publicise the water company telephone and website contact details.

The water company or local authority in the case of a private supply, is best placed to identify the area affected by any water supply event. This will be done using a variety of tools, e.g. GIS systems, customer and postcode databases. Some companies now publish the affected area on their websites during an event. As a general principle, at the outset of any event, the water company will err on the side of caution and overestimate the size of the affected area. This is because water supply arrangements can be complex, for example, there can be more than one pipe and supply serving a single street. Also, the water company is often able to quickly rezone an area of supply providing alternative safe supplies by means of pipes. Most water companies will place a description of the affected area by postcode on their website and all water companies will set up a recorded telephone message service which recognises the postcode of the caller and advertises the event information to callers. PHE and local authorities should make sure that warning communications issued by them for vulnerable or sensitive groups of water users direct people to appropriate information about the affected area. It is very important to understand that this information is likely to change during the course of an event. In an event affecting public supplies, it is not recommended that CHPs or local authorities prepare their own or separate notices or descriptions of affected areas. Public facing health services and organisations such as NHS 111 should also be advised to direct people to the water company as the single definitive source of information.

Whereas the water company will deal with issuing advice to the general public and will also handle calls from consumers seeking clarification of the affected area or additional information, it is the role of PHE to make contact information available to the water company to facilitate the referral of anyone who is reporting illness symptoms. This will be a non-public CHP number or email for water company use only or other professionals. It is also the role of the CHP to assist the water company in modifying its standard pre- prepared Frequently Asked Questions (FAQ) and Answers to take account of unique or specific features of the event. The jointly agreed FAQ will be provided to water company call centre staff and can be issued to other organisations that may be called by the public, e.g. local authorities, NHS 111. Every effort should be made to ensure that a common script is used by all organisations in their call centres and on their websites. The CHP should also be contacted in relation to consumer advice for Private Water Supplies

8. Provision of Alternate Supplies

When there is an extended loss of water supplies or a DND/DNU notice is issued, water companies will provide alternate supplies by several methods depending on the nature and scale of the event:

- Bottled water.
- Static tanks, collapsible boxes with liners or mobile tanks (known as bowsers) and tankers.
- Rezoning (introduction of water from a different source into the piped network).

When bottled water is supplied by a water company in place of a piped supply they must comply with the Water Supply (Water Quality) Regulations 2016 (as amended). Some commercially available bottled waters may not be suitable for making up feeds for infants due to their mineral (salt) content and all bottled water, like tap water, must be boiled and then cooled prior to use for infant feeds. Water companies have standing arrangements in place for the provision of alternate supplies by means of bottles or containers and compliance with the relevant regulations will be covered by documented procedures and within the contractual arrangements with third parties.

The water industry has mutual aid arrangements in place for the mobilisation of tankers and static tanks. Static and mobile tanks and tankers will be clearly marked with a permanent notice at the draw off point to warn users that the water must be boiled before use. While such water supplies will be from a safe source and water companies have strict hygiene arrangements in place for the tanks and tankers themselves, there is no control over the hygienic status of the containers used by the public for collecting water from the draw off point or for storing it within the home. The standing boil water advice therefore safeguards against these hygiene risks.

When static and mobile tanks are deployed they will be refilled by the water company using tankers on a regular basis and their locations publicised. The tanks are designed to be as vandal-proof as possible, however it is not unknown for the public to attempt to damage or remove these tanks. Local authorities have a role to play in the selection of sites and promotion of monitoring of the security of static tanks by, for example, local community groups, neighbourhood watch schemes etc.

The Security and Emergencies Direction issued by the Department for Environment, Food, and Rural Affairs (Defra) indicates that water company plans should aim to commence the distribution of water by alternative means as soon as possible after the failure has occurred. The amount to be provided should be at least ten litres of water per person per day to all those affected within the first 24 hours of an undertaker becoming aware of an event and this supply should be maintained until the piped supply is restored.

While water suppliers must plan for a minimum of ten litres per person per day in accordance with the notification, there may be emergencies where logistical problems prevent this being achieved in the first 24 hours. It is also recognised that for a major event, the ten litre requirement may not be achievable until the numbers affected are reduced to a level within the Local Response Plan.

If the event is more protracted and piped water is not available for drinking, cooking or washing, the target amount of water to be supplied will be increased. Defra has issued guidance on this additional planning target in 2017. In these protracted circumstances, additional advice will need to be provided to the public regarding sanitation. PHE will lead in the provision of this advice to the public.

In the case of private supplies, the Drinking Water Inspectorate has issued guidance on managing insufficiency of private water supplies[12] which recommends the following;

- Local authorities identify, along with water companies, local options for the provision of alternative water supplies in emergency situations;
- That relevant persons on a supply have a robust documented contingency plan for temporary disruptions (planned maintenance etc.);

The guidance goes on to provide options for provision of and emergency supply.

9. Public Information about Drinking Water Quality

Up until the 2007 Amendment Regulations there was a regulatory requirement on water suppliers to supply all local authorities within their area with an annual report on drinking water quality in a specified format. This is no longer the case, because DWI publishes annual summaries of water company results with a commentary about the significance of the information for the benefit of consumers, businesses, local authorities, health professionals and other regulators. The latest drinking water quality test results for each

[12] http://www.dwi.gov.uk/stakeholders/guidance-and-codes-of-practice/pws-alt-supplies.pdf

water company are summarised on the DWI website[13]. Water companies are still required by the regulations to provide information on drinking water quality on request to any person. This has to be free of charge for information on the zone in which the person resides, but a charge can be made for information on wider areas of supply.

Water companies and CHPs should maintain good liaison and there should be at least an annual meeting of the water companies, local authorities and CHPs to exchange information. CHPs are also welcome to contact DWI at any time for any information on drinking water quality.

Other sources of water quality information include the company's own websites, Ofwat pages and the Discover Water site[14], which compares water company performance on all matters including water quality.

9.1. Consumer Complaints

If a consumer believes there is something wrong with the drinking water in their home or workplace they should contact their water company or, in the case of a private supply, their local authority environmental health department. Water companies can arrange for tests to be done or check that plumbing arrangements are correct and comply with the Water Supply (Water Fittings) Regulations 1999. Companies will advise consumers of the action to be taken or, if required, will take enforcement action to secure improvements in plumbing. If the consumer considers that the water company did not deal with their drinking water quality concerns appropriately they can ask DWI to look into the matter on their behalf.

If the complaint is about another aspect of the water service, such as water charges or pressure, consumers should take the matter up with the regional branch of the Consumer Council for Water[15].

If the water quality concern is about the quality of a water course or water body, the query should be directed to the Environment Agency. The Environment Agency deals with the protection of the environment and regulates water abstraction and discharges to the water environment.

10. Other UK Drinking Water Regulators

There are equivalent organisations to the Drinking Water Inspectorate in Scotland (the Drinking Water Quality Regulator) and Northern Ireland (the Drinking Water Inspectorate for Northern Ireland). Each has their own regulations and legal responsibilities, but these are almost identical to those applying in England and Wales. The main difference is that

[13] http://www.dwi.gov.uk/about/annual-report/index.htm

[14] www.discoverwater.co.uk

[15] The Consumer Council for Water (CCWater) represents water and sewerage consumers in England and Wales. Their website at http://www.ccwater.org.uk holds more information on their role

there are only single, state owned water suppliers in Scotland and Northern Ireland.

11. Control of New and Emerging Issues: Approach and Rationale

In addition to meeting the numerical standards specified in the regulations, to be considered 'wholesome', drinking water must not contain any micro-organism or substance at a concentration which would (on its own or in combination with another micro-organism or substance) constitute a potential danger to human health.

Where micro-organisms or substances not specified in the regulations are identified, their potential danger to human health is assessed on a case-by-case basis. This will involve water companies discussing their findings with CHPs and local health authorities to determine the significance for the local community, in particular are there are specific groups of individuals who may be more susceptible to the potential effects? Where the presence of certain substances may be potentially more widespread, or where an emerging issue is considered more significant, DWI may issue national guidance to the water industry. This guidance is based on national advice from PHE Centre for Radiation, Chemical and Environmental Hazards (CRCE). It is circulated to all water suppliers, and published on DWI's website (see http://www.dwi.gov.uk).

12. Drinking Water Quality and Health Research Programme

On behalf of the Government, (Defra) DWI manages the national Drinking Water Quality and Health (DWQH) Research Programme. The research supports Defra and Welsh Government policy on the quality and regulation of water supplies and enables the UK to contribute to the international evidence base for drinking water quality regulations and standards.

Electronic copies of the final reports of all Drinking Water Quality and Health (DWQH) research projects are available on DWI's website[16].

Executive summaries are also posted on the Foundation for Water Research (FWR) website[17] which also provides links to other research programmes.

DWI and PHE/ PHW have arrangements between them such that PHE/ PHW act as national advisors on the health aspects of drinking water. Continual dialogue exists between PHE/ PHW and DWI staff responsible for scientific evidence on current and emerging issues. Additionally, the DWQH research programme manager co-ordinates formal horizon scanning meetings to identify emerging issues for inclusion in the programme. These discussions involve representatives from across government, other UK drinking water regulators and organisations, such as UKWIR, PHE, PHW, EA, NRW, independent experts, and others.

[16] www.dwi.gov.uk
[17] www.fwr.org

13. References to Regulation

Water Industry Act 1991
https://www.legislation.gov.uk/ukpga/1991/56/contents

Water Act
2014: https://www.legislation.gov.uk/ukpga/2014/21/pdfs/ukpga_20140021_en.pdf
2003: http://dwi.gov.uk/stakeholders/legislation/wa2003.pdf

Water Supply (Water Quality) Regulations 2016 (as amended) in England
https://www.legislation.gov.uk/uksi/2016/614/contents/made

Water Supply (Water Quality) Regulations 2018 in Wales
https://www.legislation.gov.uk/wsi/2018/647/contents/made

The Private Water Supplies Regulations 2016 (as amended)
https://www.legislation.gov.uk/uksi/2016/618/contents/made

The Private Water Supplies Regulations 2017 (Wales)
https://www.legislation.gov.uk/wsi/2017/1041/contents/made

The Water Supply (Water Fittings) Regulations 1999
http://dwi.gov.uk/stakeholders/legislation/ws(fittings)regs1999.pdf

Annex 1: Drinking Water Hazards

The drinking water quality standards are set out in statute in the Water Supply (Water Quality) Regulations 2016 (as amended) which apply in England and the Water Supply (Water Quality) Regulations 2018 which apply in Wales. The same, or very similar, standards are set out in equivalent regulations in Northern Ireland and Scotland. Most of the standards are those set out in the European Drinking Water Directive and are derived mainly from the recommendations of the World Health Organisation (WHO). There are also some national standards. Each regulated substance or organism is known as a parameter. As well as setting standards for each parameter, the regulations state how often each one should be tested for and where the samples for testing should be taken. About one-third of samples are taken from consumers' taps and the rest are taken from treatment works or treated water storage reservoirs. The parameters and standards are described below. Anyone wishing to find out more about how each standard is derived can do so by accessing the published WHO expert opinion[18]. When the regulations are revised there is full public consultation by Defra.

Microbiological Standards

To protect public health there are microbiological standards which must be met at each treatment works and treated water service reservoir or water tower. Microbiological tests are also undertaken on consumer tap samples. The significance of individual test results for each microbiological parameter at each location varies and a single positive result does not necessarily mean that water is unsafe to drink. Other information is required to assess water safety. Each of the standards is listed below:

***Escherichia coli* and Enterococci** are bacteria present in the gut of warm-blooded animals. They should not be present in drinking water and, if found, immediate action is required to identify and remove any source of faecal contamination that is found. The standard is 0 per 100ml.

Clostridium perfringens is a spore-forming bacterium that is present in the gut of warm-blooded animals. The spores can survive disinfection. The presence of spores in drinking water in the absence of *E.coli* and Enterococci indicates historic or remote faecal contamination that requires investigation. The standard is 0 per 100ml.

Coliform bacteria are widely distributed in the environment often as a result of human or animal activity, but some grow on plant matter. Their presence in a water supply indicates a need to investigate the integrity of the water supply system. The standard is 0 per 100ml.

Colony Counts are general techniques for detecting a wide range of bacteria, the types and numbers being dependent on the conditions of the test. These counts, if done

[18] http://www.who.int/water_sanitation_health/water-quality/guidelines/drinking-water-guidelines-revision/en/

regularly, can help to inform water management, but they have no direct health significance. The standard is ‘no abnormal change’.

Health Based Chemical Standards

Health-based standards for chemical parameters are set using a precautionary approach and on the basis of a lifetime’s consumption of water and taking into account other exposure through routes other than drinking water (e.g. food). Just because a standard has been set for a substance does not mean that it is present in drinking water. The vast majority of the regulated chemicals are never found in drinking water in England and Wales at levels approaching or exceeding the standards. Others may occur only in very specific or local circumstances which are described below. A common situation is leaching from fixtures and fittings or pipework within a specific building water system. The chemical parameters for which prescribed concentrations or values are specified in the Water Supply (Water Quality) Regulations 2016 (as amended) are:

Acrylamide monomer is not normally found in drinking water. It is produced in the manufacture of polyacrylamides occasionally used in water treatment. Its presence in drinking water is limited by control of the product specification. The standard is 0.1 µg/l.

Antimony is rarely found in drinking water. Trace amounts can be derived from brass tap fittings and solders. The standard is 5 µg Sb/l.

Arsenic occurs naturally in only a few sources of groundwater. Specific water treatment is required to remove it. The standard is 10 µg As/l.

Benzene is present in petrol. It is not found in drinking water, but it can migrate through underground plastic water pipes if petrol is spilt in the vicinity. Some bottled waters and soft drinks which include sodium benzoate as an ingredient have been reported as containing benzene. The standard is 1 µg/l.

Benzo (a) pyrene is one of several compounds known as polycyclic aromatic hydrocarbons (PAHs). Their source in drinking water is as a result of deterioration of coal tar which was used to line water pipes up until the early 1970s. Due to extensive water mains refurbishment and renewal it is now rare to detect this substance in drinking water. The standard is 0.01 µg/l.

Boron in surface water sources comes from industrial discharges or from detergents in treated sewage effluents. It can be present in partially desalinated seawater when this is used to supplement drinking water supplies. Concentrations found in drinking waters are generally very low. The standard is 1 mg B/l.

Bromate can be formed during disinfection of drinking water as a result of a reaction between naturally occurring bromide and strong oxidants (usually ozone). It may be generated in the manufacture of sodium hypochlorite disinfectant.
Exceptionally, groundwater beneath an industrial site can become contaminated with

bromate. The standard is 10 µg BrO_3/l.

Cadmium is rarely detected in drinking water and trace amounts are usually due to dissolution of impurities from plumbing fittings. The standard is 5 µg Cd/l.

Chromium in drinking water comes from the coatings on some taps and plumbing fittings. The standard is 50 µg Cr/l.

Copper in drinking water comes mostly from copper pipes and fittings in households. In general, water sources are not aggressive towards copper, but problems very occasionally occur on new housing estates or in new installations. These 'blue water' events can be avoided by good plumbing practices. The standard is 2 mg Cu/l.

Cyanide is not normally present in drinking water, but could be present in surface water as a result of a specific industrial contamination incident. The standard is 50 µg CN/l.

1,2-Dicholoroethane is a solvent that may be found in groundwater in the vicinity of industrial sites. Where necessary it can be removed by special water treatment. The standard is 3 µg/l.

Epichlorhydrin can be found in trace amounts in polyamine water treatment chemicals. Its presence in drinking water is limited by control of the product specification. The standard is 0.1 µg/l.

Fluoride occurs naturally in many water sources, especially groundwater. It cannot be removed by conventional water treatment, so high levels must be reduced by blending with another low fluoride water source. In addition, some water companies in England are required by the local health authority to fluoridate water supplies as a protection against tooth decay. No fluoridation takes place in Wales. The standard is 1.5 mg F/l.

Lead very occasionally occurs naturally in raw waters, but the usual reason for its presence in drinking water is lead plumbing in older properties. It can also arise from the illegal use of lead solder in water supply installations. If the water supply has a tendency to dissolve lead then water companies treat the water to reduce consumer exposure. The permanent remedy is for householders to remove lead pipes and fittings. The standard is currently 10 µg Pb/l.

Mercury is not normally found in sources of drinking water in the UK. The standard is 1 µg Hg/l.

Nickel occurs naturally in some groundwater and, where necessary, special treatment can be installed to remove it. Another source of nickel in drinking water is the coatings on modern taps and other plumbing fittings. The standard is 20 µg Ni/l.

Nitrate occurs naturally in all source waters although higher concentrations tend to occur where fertilisers are used on the land. Nitrate can be removed by ion exchange water treatment or through blending with other low nitrate sources. The standard is 50 mg NO_3/l.

Nitrite is sometimes produced as a by-product when chloramine (a mixture of chlorine and ammonia) is used as the essential residual disinfectant in a public water supply. Chloramine is the residual disinfectant of choice in large distributions systems because it is more stable and long-lasting. Careful operation of the disinfection process ensures that levels of nitrite are below the standards of 0.1 mg NO_2/l in water leaving water treatment works and 0.5 mg NO_2/l at consumers' taps.

Pesticides – organochlorine compounds (aldrin, dieldrin, heptachlor, heptachlor epoxide) are no longer used in the UK because they are persistent in the environment. They are very unlikely to be found in drinking water. The standard for each compound is 0.03 µg/l.

Pesticides – other than organochlorine compounds are a diverse and large group of organic compounds used as weed-killers, insecticides and fungicides. Many water sources contain traces of one or more pesticides as a result of both agricultural uses mainly on crops and non-agricultural uses, mainly for weed control on highways and in gardens. Where needed, water companies have installed water treatment (activated carbon and ozone) so that pesticides are not found in drinking water. The standard is 0.1 µg/l for each individual substance and 0.5 µg/l for the total of all pesticides. Water companies must test for those pesticides used widely in their area of supply. Pesticide monitoring thus varies according to the probability and anticipated nature of contamination.

Polycyclic aromatic hydrocarbons is a group name for several substances present in petroleum-based products such as coal tar. The standard is 0.1 µg/l for the sum of all the substances (see Benzo(a)pyrene listed above for more information).
Selenium is an essential element and a necessary dietary component. Amounts in drinking water are usually well below the standard of 10 µg Se/l.

Tetrachloroethane and Trichloroethene are solvents that may occur in groundwater in the vicinity of industrial sites. Where necessary they are removed by specialist treatment. The standard is 10 µg/l for the sum of both substances.

Trihalomethanes are formed during disinfection of water by a reaction between chlorine and naturally occurring organic substances. Their production is minimised by good operational practice. The standard is 100 µg/l.

Vinyl chloride may be present in plastic pipes as a residual of the manufacturing process of polyvinyl chloride (PVC) water pipes. Its presence in drinking water is controlled by product specification. The standard is 0.5 µg/l.

National Chemical and Physical Standards

The European Drinking Water Directive (DWD) recognises that Member States can set additional standards and the UK has decided to retain national mandatory standards for several parameters set in the original 1980 DWD that have become additional monitoring parameters in the 1998 DWD. Most of the standards are set on the basis that higher levels may make the water unacceptable to consumers on the grounds of taste, odour or appearance.

Aluminium occurs naturally in some source waters. It is removed from drinking water by conventional water treatment (coagulation and filtration). Aluminium sulphate and polyaluminium chloride may be used as water treatment chemicals at some water treatment works. The standard is 200 µg Al/l.

Colour occurs naturally in upland water sources and is caused by natural organics which are characteristic of these catchments. It is removed by conventional water treatment. The standard is 20 mg/l on the Pt/Co scale.

Iron is present naturally in many water sources. It is removed by water treatment. Some iron compounds are used as water treatment chemicals. However, the most common source of iron in drinking water is corrosion of iron water mains. The standard is 200 µg Fe/l.

Odour and Taste can arise as a consequence of natural substances in surface waters, particularly between late spring through to early autumn. Water treatment with activated carbon or ozone will remove these natural substances. The standard is described as acceptable to consumers and no abnormal change in odour or taste.

Sodium is a component of common salt (sodium chloride). It is present in seawater and brackish groundwater. Some water treatment chemicals contain sodium. Concentrations in drinking water are extremely low, but some water softeners can add significant amounts where they are installed in homes or factories. The standard is 200 mg Na/l.

Tetrachloromethane is a solvent that may occur in groundwater in the vicinity of industrial sites. Where necessary it is removed by specialist water treatment.
The standard is 3 µg/l.

Turbidity is a measure of the cloudiness of water. It can arise from disturbance of sediment within water mains. The standard at consumers' taps is 4 NTU (see also turbidity at treatment works below).

On occasion, the measurement of turbidity is carried out by a method other than that specified in the drinking water regulations and the results reported as a quantity of suspended solids. This cannot be easily converted to NTU. Organisations responsible for testing water under the relevant drinking water regulations are required to use the designated methods and report in the units specified in the regulations.

Additional Monitoring Parameters

In addition to the drinking water standards, water companies are required to test for additional indicator parameters to assist them with good water supply management and the control of drinking water quality. Some of these parameters have a European guide value set for the purpose of triggering an investigation of the water supply.

Ammonium salts are naturally present in trace amounts in most waters. Their presence might indicate contamination of sanitary significance and they interfere with the operation of the disinfection process. The guide value is 0.5 mg NH_4/l

Chloride is a component of common salt. It may occur in water naturally, but it may also be present due to local use of de-icing salt, leachate impaction or saline intrusion. The guide value is 250 mg Cl/l.

Conductivity is a non-specific measure of the amount of natural dissolved inorganic substances in source waters. The guide value is 2,500 µS/cm.

Hydrogen Ion (pH) gives an indication of the degree of acidity of the water. A pH of 7 is neutral; values below 7 are acidic and values above 7 are alkaline. A low pH water may result in pipe corrosion. This is corrected by adding an alkali during water treatment. The guide value is a range between 6.5 and 9.5.

Indicative Dose is a measure of the effective dose of radiation the body will receive from consumption of the water. It is calculated only when screening values for gross alpha or gross beta (radiation) are exceeded. The guide value is 0.10 mSv/year. For more information on monitoring for radioactive substances see; http://dwi.defra.gov.uk/private-water-supply/regs-guidance/Guidance/info-notes/england/reg-11.pdf

Radon is a radioactive gas that occurs naturally in the environment. The guide value is 100 Bq/l.

Sulphate occurs naturally in all waters and cannot be removed by treatment. The guide value is 250 mg SO_4/l.

Total Organic Carbon represents the total amount of organic matter present in water. The guide value is ‘no abnormal change’.

Tritium is a radioactive isotope of hydrogen. Tritium is present in the environment is mainly of man-made origin, but some tritium is formed naturally as a result of cosmic ray interactions in the upper atmosphere, but these levels are very low. Discharges to the environment are strictly controlled and there is a national programme of monitoring surface waters. The guide value for drinking water sources is 100 Bq/l.

Turbidity measurement is an important non-specific water quality control parameter at water treatment works because it can be monitored continuously on line and alarms set to alert operators to deterioration in raw water quality or the need to optimise water treatment. The standard at treatment works is 1 NTU.

Other Pathogenic Organisms

There are a wide range of pathogenic organisms capable of causing adverse human health effects if they are introduced into drinking water supplies. Contaminated water can be the source of large outbreaks of disease, however, for the majority of waterborne pathogens there are other equally important sources of infection, such as person to person contact and food. The human health effects caused by waterborne transmission vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, typhoid fever, cholera, cryptosporidiosis and giardiasis. Most waterborne pathogens are introduced into drinking water supplies in human or animal faeces, they do not grow in water and infection is initiated in the gastrointestinal tract. However, some are environmental organisms that grow in water and soil, and can cause opportunistic infections through other routes of transmission, such as inhalation leading to respiratory infections (legionellosis) or infections at sites as diverse as skin and brain (*Naegleria fowleri*).

For an exhaustive global list of fact sheets on pathogenic organisms potentially associated with water-related infections see Chapter 11 of the WHO Guidelines for Drinking Water Quality[19] Set out below is a summary of the subset of pathogenic organisms of direct relevance to waterborne transmission in the context of UK private and public water supplies.

Bacterial Pathogens

Aeromonas species occur widely in water, soil and food, and are capable of growth in water distribution systems. They are capable of infecting open wounds and septicaemia can occur in immuno-compromised persons. The presence of aeromonads in drinking water is generally considered a nuisance rather than a health hazard. The organisms are detected by colony counts and controlled by good water supply distribution management and hygiene practices.

Campylobacter species are one of the most important causes of acute gastroenteritis worldwide. *Campylobacter jejuni* is the most frequently isolated species from patients with acute diarrhoeal disease. As few as 1,000 organisms can cause infection and most infections occur in infants and young children. Wild and domestic animals, especially poultry, wild birds and cattle, are important sources, other sources include domestic pets and contaminated food and drinking water, including meat and unpasteurised milk. Control of drinking water transmission relies on the protection of raw water sources from

[19] http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/

animal and human waste, adequate disinfection and protection of stored water from animal and bird faeces.

Escherichia coli **pathogenic strains:** Most *E. coli* strains are present in large numbers in the normal gut flora of humans and animals. A few strains can cause serious disease (bacteraemisa, urinary tract infections, meningitis) in other parts of the body and some cause acute diarrhoea. These enteropathogenic *E. coli* are identified on the basis of virulence factors and the most well known in the context of waterborne transmission are the enterohaemorrhagice *E. coli* (EHEC), particularly serotypes O157:H7 and O111. As few as 100 organisms can cause infection and up to seven per cent of cases develop a potentially fatal haemolytic uraemic syndrome (HUS) characterized by acute renal failure due to production of two enterotoxins simultaneously. Control of drinking water transmission of pathogenic *E. coli* is the same as that for other *E. coli,* namely raw water protection from faecal waste, adequate disinfection and protection of stored water.

Legionella Although all *Legionella* species are potentially pathogenic for humans, *Legionalla pneumophila* is the major species responsible for legionellosis which occurs in two clinical forms; legionnaire's disease, a pneumonia, and Pontiac fever, a milder respiratory infection. *Legionella spp* are common in surface waters and moist soils, and they grow in warm conditions in the range of 25 – 50 degrees centigrade. Transmission is via inhalation. Control focuses on building water system design and maintenance through minimising the production of water aerosols and limiting growth conditions by keeping cold water cold and hot water hot. Most large waterborne outbreaks have been linked to cooling towers which are poorly maintained, whereas sporadic infections are more commonly linked to hot water systems in large buildings.

Mycobacteria The non-tuberculous or atypical strains are natural inhabitants of water environments. They can give rise to a range of diseases involving the skeleton, lymph nodes, skin and soft tissue as well as respiratory, gastrointestinal and genitourinary tracts. They are a major cause of disseminated infections in immunosuppressed patients and a common cause of death in HIV positive persons. Only two species have been reported in tap water, *M. kansasii* and *M. avium* complex. Water-related infections due to the latter have been attributed to unfiltered water supplies and *M. kansasii* has been found in domestic showers and hospital water systems in the Netherlands and UK respectively.

The organisms are more resistant to disinfection with chlorine than other bacteria, such as coliforms, therefore control relies on treatment by filtration and effective management of distribution systems to minimise growth conditions and maintenance of a persistent level of residual chlorine.

Pseudomonads are common environmental organisms with similar characteristics to Aeromonads (see above). *Pseudomonas aerugionsa* is capable of growing on specific construction materials used in building plumbing systems, swimming pools and spas. Exposure to high numbers in water in the latter settings can cause folliculitis (rashes) and ear infections, and the organism can infect wounds and give rise to septaceamia and meningitis in the immunosuppressed patient. Control is through the use of suitable approved materials in the design of pools, spas, plumbing systems and water mains.

Incidences of high numbers of the organism in packaged waters has been associated with complaints of taste and odour, and this has resulted in a monitoring standard of <1 per 250ml being set for bottled waters. Bottled water guidence can be found at https://www.food.gov.uk/business-guidance/water-guidance-for-wales-and-northern-ireland. There is no equivalent standard for public water supplies due to the fact they are not normally in packaged form.

Salmonella spp species cause either gastroenteritis, septicaemia, enteric/typhoid fever and can remain in a carrier state in previously infected persons. Typically diarrhoea is accompanied by fever and abdominal pain which is self-limiting, but infection with *S. typhi* and *S. paratyphi* (typhoid strains) is more serious and can be fatal. Waterborne typhoid fever outbreaks have devastating public health implications. The typhoid strains are restricted to humans, but others such as *S. typhimurium* and *S. enteritidis* occur in a wide range of livestock, including poultry. Contamination has been detected in many foods and milk, and these pathogens gain access to water sources from sewage discharges, livestock and wild animals. Control measures involve protection of raw water from animal and human waste, adequate disinfection and protection of stored water from animal and bird faeces.

Shigella spp cause serious intestinal diseases mostly in young children, including bacillary dystentery. Only 10 – 100 organisms are required to cause infection resulting in severe watery diarrhoea, abdominal pain and fever. A milder self-limiting disease is caused by the *S. sonnei* strain. The organisms are restricted to humans and higher primates with most cases of shigellosis occurring in the institutional setting due to poor sanitation.

Prevention of waterborne outbreaks is important due to the severity of the illness caused and control is by protection of raw and treated water from human waste combined with adequate disinfection.

Toxic Cyanobacteria are photosynthetic bacteria that share some properties in common with algae, hence they are commonly known as blue green algae. However, there are many which are not blue green and can range in colour from yellow to brown and red. Cyanobacteria are common in the environment occurring in soil, sea water and freshwater. Sunlight and warm weather stimulate growth especially in stagnant waters or low flow conditions and in the presence of high nutrient levels (eutrophic waters). Some will form floating surface blooms or scums, others stay mixed in the water column or are bottom dwelling (benthic). Their public health significance derives from the ability of some species to form toxins. At least 13 toxin producing species have been identified and each toxin has specific properties with distinct concerns, including liver damage, neurotoxicity and tumour production. Acute symptoms after exposure include gastric disorders, fever and irritations of the skin, ears, eyes, nose and throat. Cyanobacteria do not multiply in the body and hence they are not infectious. Control relates to source water abstraction management and the minimisation of algal blooms together with prevention of direct recreational contact with algal blooms and by excluding light from stored water tanks.

Vibrio spp Non-toxigenic strains are widely distributed in water environments, but toxigenic strains occur in water less often because they are generally limited to humans, although they have been found inside aquatic organisms like crustaceans and algae. The prevalence of *V. cholerae* declines notably in colder waters (below 20 degrees centigrade).Illness symptoms are due to the production of the cholera enterotoxin. The majority of those infected do not develop illness, however those who do will experience characteristic 'rice water stools' and suffer severe dehydration and loss of electrolytes which is fatal without treatment. High numbers of organisms are required to cause infection, therefore person to person contact is not the main cause of spread and serious outbreaks are due to poor sanitation and ingestion of faecally contaminated food and water. Control is by protection of raw water from human waste, adequate disinfection and protection of stored water.

Viral Pathogens

Viruses associated with waterborne transmission are predominantly those that infect the gastrointestinal tract and are excreted in human faeces (enteric viruses). As a group, viruses can cause a wide variety of infections and symptoms involving different routes of transmission, sites of infection and routes of excretion. It is worthy of note that viruses responsible for respiratory infection can be discharged in faeces and contaminated water may therefore be a route of transmission through aerosols and droplets. It is also thought that polyomaviruses excreted in urine and linked to long-term health effects have the potential for waterborne transmission. An important issue for control of waterborne transmission is the fact that viruses generally survive better in water, particularly in cold climates, than bacterial indicator organisms. Consequently, satisfactory indicator test results do not preclude the presence of viruses. Another important factor to be considered is the greater resistance of viruses to disinfection compared to bacteria.

Adenoviruses Infections have been linked to consumption of contaminated food and drinking water, although person to person spread through shared utensils and contaminated surfaces in the institutional setting is the more common source of outbreaks of gastroenteritis. Eye infections have been linked to the sharing of towels and goggles when swimming. These viruses consist of double stranded DNA and generally do not grow in cell culture, therefore detection relies on polymerase chain reaction (PCR) techniques. Control is made problematic because human adenoviruses are exceptionally resistant to disinfection, especially UV light irradiation. Protection of raw and treated water is therefore very important to control risks from drinking water supplies.

Astroviruses are single stranded RNA viruses detected in environmental samples by PCR techniques. They cause self-limiting gastroenteritis in young children and infected individuals excrete large numbers of the virus in faeces, hence the viruses will be present in sewage. Person to person spread in day care, home settings and institutions is common. Contaminated food and water may be an important route of transmission. Control measures are the same as for Adenoviruses although UV maybe more effective.

Caliciviruses are single stranded RNA viruses which include the genera Norovirus (Norwalk like viruses). The human caliciviruses are a major cause of acute viral gastroenteritis in all age groups. Symptoms include nausea, vomiting and abdominal cramps. Less than half of those infected present with diarrhoea and some have a fever. Known as winter vomiting disease the symptoms are relatively mild and self-limiting, however the high attack rate denotes a low infectious dose. Since the virus is excreted in faeces it will occur in domestic waste water as well as contaminated food and drinking water. Numerous water-related outbreaks have been documented in relation to recreational water, ice, water on cruise ships, other drinking waters and shellfish harvested in polluted estuarine waters. Control measures relate to the protection of raw and treated water from faecal contamination and adequate disinfection.

Enteroviruses are a wide group of viruses which include poliovirus, coxsackievirus, echovirus. They are the smallest viruses and consist of a single stranded RNA genome. Many can be detected in environmental samples by cell culture. Enteroviruses are all excreted in the faeces of infected individuals and are therefore the most numerous viruses in sewage and sewage polluted waters, however the predominant route of transmission is by person to person contact and inhalation. Control measures relate to the protection of raw and treated water from faecal contamination and adequate disinfection.

Hepatitis A is highly infectious and the infecting dose is low. Like other enteric viruses, Hepatitis A virus enters the gastrointestinal tract by ingestion where it infects epithelial cells and then enters the bloodstream to reach the liver where it can cause severe damage in around ten per cent of adult cases. There is a long incubation phase of around 30 days followed by a characteristic onset of symptoms, such as fever, malaise, nausea, anorexia and eventually jaundice. The evidence for waterborne transmission of Hepatitis A is well documented and stronger than it is for all other viruses. Food borne outbreaks are also relatively common. Travel of people from areas with good sanitation to those with poor sanitation is associated with a high risk of infection, as is drug abuse. Control measures relate to the protection of raw and treated water from faecal contamination and adequate disinfection.

Hepatitis E is similar in its effects to Hepatitis A, however, the incubation period for infection is longer and there is a high mortality rate in pregnant women. Currently cases and outbreaks are rare in the UK. Control measures are the same as Hepatitis A above.

Rotavirus are double stranded RNA viruses some of which infect humans while others are specific to animals. They are not grown readily in cell culture, but can be detected in environmental samples by PCR techniques. Human rotaviruses are the most important single cause of infant death in the world. The virus infects cells in the villi of the small intestine and disrupts sodium and glucose transport. Person to person transmission and inhalation are the important routes of spread, however, both water and food borne outbreaks are documented. Rotavirus may be more resistant to conventional disinfection techniques than other viruses. Control measures are the protection of source and treated water from contamination by human faecal wastes, and careful attention to adequate treatment and disinfection of drinking water prior to supply to consumers.

Protozoan Pathogens

Protozoa are common causes of human and animal infection which present real challenges for control because most produce cysts or oocysts that are extremely resistant to disinfection and survive for long periods in water and the environment.

Ancanthamoeba is a free living amoebae common in water and soil. Under unfavourable conditions it develops a dormant cyst capable of withstanding extremes of temperature (-26 to 56 degrees C). Cases of acanthameobic keratitis, a painful infection of the cornea, have been associated with the use of tap water in preparing solutions for washing contact lenses. It is a rare disease but may lead to impaired vision, blindness and loss of the eye. Since the cleaning of contact lenses is not considered to be a normal domestic use of tap water, control is through the purchase and use of proprietary, sterile, lens cleaning solutions.

Cryptosporidium This parasite has a complex life cycle which causes a self-limiting, but prolonged unpleasant, diarrhoeal illness in humans and animals. It forms oocysts which are shed in faeces in very high numbers. The main route of infection is by person to person spread and by direct contact with farm animals and sometimes pets. However, outbreaks due to faecally contaminated drinking water are widely documented. Ingestion of ten oocysts or fewer can lead to infection. The oocysts are very resistant to chlorine, therefore control is achieved by source water (catchment) protection, filtration and disinfection with UV irradiation. For information on *Cryptosporidium* in drinking water is available on DWI's website[20]

Health teams are advised that they liaise with the local water company to review Cryptosporidium monitoring data if a change in the number or distribution of cases of cryptosporidiosis notified by diagnostic laboratories is observed.

Any trigger level for notification by the water companies to health teams and thresholds for action will need to vary depending on many factors, not limited to but including: the treatment in place at the water treatment works and its performance, the historical results for the works, and the population served. Features of the parasites present (such as their potential infectivity for humans) are also part of the equation but that information may not be available or only obtained later. Review on a case-by-case basis therefore forms a pragmatic approach. It is therefore important to keep ongoing communication with the water companies.

[20] http://www.dwi.gov.uk/research/bouchier/index.htm

Giardia is a protozoan which colonises the gastrointestinal tract of humans, and some animals, forming a thick walled cyst which is shed intermittently in faeces. It causes diarrhoea and malabsorption in the small intestine. Illness is generally self-limiting, but can be chronic, lasting over one year, in otherwise healthy people. As few as ten cysts are required for infection. The cysts survive for months in water. Person to person contact is the commonest route of transmission between children. Although more resistant to disinfection with chlorine than bacterial pathogens, unlike *Cryptosporidium*, chlorination can be used as a control measure together with filtration and source water protection.

Naegleria fowleri is a free living amoeboflagellate distributed widely in the environment which forms resistant cysts under unfavourable conditions. It causes primary amoebic meningocephalitis in healthy people by entering the brain through penetration of the olfactory mucosa. The disease is acute and patients often die within ten days before diagonosis. Cases are rare, but occur every year. Naegleria are thermotolerant and found in warmer waters such as hot springs and swimming pools or spas. Infection is contracted by exposure of the nasal passages to contaminated water and thus predominantly associated with recreational water uses. Control is by means of reducing water temperature (below 25 degrees C) and the maintenance of a stable and effective residual chlorine level of at least 0.5 mg/l.

Other Chemicals

Perfluorooctane sulphonate (PFOS) and perfuoroocanoic acid (PFOA) may be present in the environment and water sources as a consequence of their historic use as firefighting foams. DWI has issued guidance based on PHE advice on trigger levels for monitoring and notification in respect of both these substances (http://dwi.gov.uk/stakeholders/information-letters/2009/10_2009annex.pdf).

N-nitrosodimethylamine (NDMA) is a by-product of industrial processes that use nitrate and/or nitrite and amines. It can also be formed during sewage treatment and during water treatment as a disinfection by-product. It is generally accepted as being a genotoxic carcinogen. DWI has issued guidance based on PHE advice on trigger levels for monitoring and notification in respect of this substance (DWI Information Letter 07/2012).

Chromium VI is a toxic form of the chromium element and DWI has provided some advice on this chemical. (DWI Information Letter 02/2017: http://dwi.gov.uk/stakeholders/information-letters/2017/02-2017.pdf)

Other Resources

Other resources for public health advice of microbiological contaminants include:

- PHE webpages – https://www.gov.uk/topic/health-protection

- PHW webpages - https://phw.nhs.wales/
- Cryptosporidium Reference Unit - https://www.gov.uk/guidance/cryptosporidium-reference-unit-cru

Some additional resources for public health advice on chemical and radiological contaminants include:

- PHE's Chemical Hazards Compendium https://www.gov.uk/government/collections/chemical-hazards-compendium
- Section 8.7 of the WHO publication, Guidelines for Drinking Water Quality (4th Edn.), which identifies local actions in response to chemical water quality problems and emergencies. In particular sections 8.7.3 and 8.7.4 in relation to talking to the right people and public advice. http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/
- In England, refer to local HPT and PHE CRCE duty desk for advice: email crce-ehe@phe.gov.uk
- In Wales, refer to local Health Board and CRCE Wales for advice.

Annex 2: Content of Notifications about Drinking Water Quality Events

Set out below is the template used by DWI Inspectors when contacted by a water company making the initial notification of a water quality event. The text in italics indicates the nature of the information that DWI expects the company to provide as a minimum at the outset of an event. This is the type of information that a CCDC can expect to be provided with by a water company when they first contact a CCDC with a view to obtaining health advice. Typical additional questions that a CCDC may want to ask the water company to enable a health risk assessment to be made are listed below.

DWI Water Quality Event Notification Template

Company	*Water supplier making the notification and responsible for the affected water supply, if more than one water company is affected by a water quality event then each one will notify their particular circumstances*
Name of event	*Water company description of the event which will be used throughout the management and subsequent investigation of the event, usually takes the form of nature/location descriptor, e.g. burst trunk main in Essex Road, Islington*
Person making the notification	*Name of water company person making the notification and responsible for ongoing updates*
Date and time of notification	*Time/Date when DWI Inspector received notification*
Date/Time/Location of event	*Time when company first became aware of an event and the location of the assets first affected, e.g. works, reservoir, street*
Nature of event	*Water company description of what has happened, typically a description of the impact, e.g. discoloured water and low pressure complaints from consumers; report received from Environment Agency of dead fish one mile upstream of abstraction intake at N works; sample result from X location with a result of Y etc.*
Population and Area affected	*Estimate of population resident in the water quality zones potentially affected by the event, together with names of the water quality zones.*

Likely cause(s)	*Water company initial assessment of the cause of the event, e.g. third party damage to a water main; illegal discharge from a factory into the River X etc.*
Action taken to inform/protect consumers and details of risk	*Details of:* *advice issued to consumers, e.g BWA notice* *alternative supplies provided* *any customer call centre/website tape recorded message*

Action being taken to rectify the situation	*Details of the action already taken and planned to restore the water supply to normal*
LAs/HAs informed?	*Name of person notified in the relevant local authorities and the Health Protection Unit of PHE/PHW and the nature of any advice provided and/or any conference calls/meetings arranged*
Level of publicity	*Details of any media awareness*

Additional information that may be required to support a health risk assessment by PHE.

1. Description of affected water supply from source to tap, in particular, details of source water (surface, ground), water treatment in use and/or proposed either temporarily/permanently, treated water storage (service reservoirs, towers, tanks, tankers, bowsers, bottles), distribution mains (details of planned or unplanned work and nature of materials if work on mains involved), nature of building (public, private, social care, office, factory etc.) including any high risk premises in respect of back flow prevention inspection.
2. Nature of any actual or suspected contaminants (chemical, biological, radiological) and concentration of any contaminant/organism, including details of samples already taken and samples planned to be taken.
3. Historic water quality testing data (should also refer to drinking water, annual report by DWI if the event relates to a known or ongoing problem).
4. UKWIR (for example Toxicological Datasheets or Microsheet Data) or WHO information about the contaminants/organisms.
5. Technical information about any loss of, or proposed changes to, water treatment, including disinfection at works, also details of addition of chlorine to the network or service reservoirs (DWI is the source of advice on approved treatment chemicals, treatment performance and operational best practice).
6. For incidents at a works or a service reservoir, an estimate of the time required for the contaminants/organisms to pass through the water supply system under normal operating conditions and, where relevant, any remedial measure, such as removing assets from supply, rezoning or high velocity flushing, which may affect these time estimates (the water industry and the Environment Agency have time of travel models for river pollution incident.

Annex 3: Examples of Precautionary Notices for Consumers

The following pages provide suggested templates that could be used by authorities with powers to issue restriction notices. While companies generally have their own notices, there has been a demand for templates that could be used by other authorities (local authorities). Examples provided below include ‘Boil water’ notice, ‘Do not drink’ notice, ‘Do not use’ notice and also an ‘All clear’ notice used to inform consumers of the return of normal supplies. These are available as Microsoft Word templates on the DWI website. It is important that they are branded by the authority using them in the normal manner for their communication with customers as this will allow consumers to understand who is issuing the instructions and will be able to identify with the normal branding.

Boil Water Notice

Text box to identify the name of the issuing authority and any relevant 'branding'

This is an instruction to

BOIL YOUR TAP WATER

UNTIL FURTHER NOTICE

USE **BOILED** AND COOLED TAP WATER FOR

- Drinking/cleaning teeth
- Cooking
- Making Ice
- Making up babies' feed
- For pets

YOU CAN USE **UNBOILED** WATER FOR

- Bathing
- Washing clothes
- Washing dishes
- Flushing the toilet

You will be advised by [insert name of organisation that will rescind the BWN] when your supply is back to normal.
For any questions about this instruction please contact [insert name of organisation providing advice]

Do Not Drink Notice

Text box to identify the name of the issuing authority and any relevant 'branding'

This is an instruction

DO NOT DRINK YOUR TAP WATER UNTIL FURTHER NOTICE

DO NOT USE TAP WATER FOR

- Drinking or cleaning teeth
- Cooking or preparing food or babies' feed
- Making Ice
- For pets' water

TAP WATER CAN BE USED FOR

- Washing and bathing
- Washing clothes
- Washing dishes
- Flushing the toilet

You will be advised by [insert name of organisation that will rescind the BWN] when your supply is back to normal.
For any questions about this instruction please contact [insert name of organisation providing advice]

Do Not Use Notice

Text box to identify the name of the issuing authority and any relevant 'branding'

This is an instruction

DO NOT USE YOUR TAP WATER UNTIL FURTHER NOTICE

DO NOT USE TAP WATER FOR

- Drinking or cleaning teeth
- Cooking or preparing food or babies' feed
- Making Ice
- For pets' water
- Washing and bathing
- Washing clothes or dishes

TAP WATER CAN BE USED FOR

- Flushing the toilet [amend depending on nature of issue]

You will be advised by [insert name of organisation that will rescind the BWN] when your supply is back to normal.
For any questions about this instruction please contact [insert name and contact details of organisation providing advice]

All Clear Notice

Text box to identify the name of the issuing authority and any relevant 'branding'

This is an instruction

YOU MAY NOW USE YOUR TAP WATER

- Your tap water supply is now back to normal
- Please run your taps to make sure that fresh water is drawn through the system before using it.

For any questions about this instruction please contact [insert name and contact details of organisation providing advice]

Annex 4: Advice on Precautions to be taken by the Immunosuppressed Individual in Relation to Boil Water Notices

CMO's Update - a communication to all doctors from the Chief Medical Officer

The Bouchier Report *Cryptosporidium* in Water Supplies: Third Report of the Group of Experts (1998)[21] included advice for the immunosuppressed. This was publicised in the February 1999 edition of Chief Medical Officer's (CMO) Update 2. A working group of specialists chaired by Professor Ian Bouchier then defined further which groups of immunosuppressed patients are at particular risk of cryptosporidiosis infection and should boil their drinking water in the August 1999 edition of the CMO's update[22]. The level of T-cell function and the duration of any immune suppression were considered to be crucial factors in susceptibility to Cryptosporidium. The group concluded that the advice should be that anyone whose T-cell function is compromised (this includes people with HIV infection who are immunosuppressed, children with severe combined immunodeficiency (SCID) and those with specific T-cell deficiencies, such as CD40 ligand deficiency, also known as Hyper IgM Syndrome), should be advised to boil and cool their drinking water from whatever source. This includes tap or bottled water, and ice cubes should also be produced from boiled and cooled water.

It is especially important to boil water from a private water supply serving a property (or properties), even with UV treatment, as this will not have any residual disinfection, and also where there is a potable supply where outlets do not come direct from the rising main, e.g. where a storage tank is used. This advice would also extend to avoiding the use of un-boiled water for cleaning teeth. See http://www.dwi.gov.uk/stakeholders/guidance-and-codes-of-practice/Boiling-water01-15.pdf

Any particularly vulnerable sub-group should be risk assessed and advised by their managing clinical consultant to take additional precautions as appropriate

UK guidance on the safety of various types of bottled water is to be found on the NHS choices web site for use by infants. The salt and sulphate content of bottled water may not be sufficiently low for infant formula. https://www.nhs.uk/common-health-questions/childrens-health/can-i-use-bottled-water-to-make-up-baby-formula-infant-formula/

[21] *Cryptosporidium* in Water Supplies – Third Report of the Group of Experts to: Department of the Environment, Transport and the Regions & Department of Health. Chairman Professor Ian Bouchier November 1998. HMSO

[22] http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4013568.pdf

guardians of drinking water quality

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Tel: 0300 068 6400 | http://www.dwi.gov.uk

別添2：ウェールズ向けガイダンス

GIG CYMRU NHS WALES

Iechyd Cyhoeddus Cymru
Public Health Wales

Water Health Partnership for Wales

Drinking Water Safety
Guidance to Health and Water Professionals

Drinking Water Safety

Guidance to Health and Water Professionals

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Foreword

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In 2007 there was a major water supply incident involving the loss of water supplies to 160,000 properties in Cheltenham, Gloucester, Tewkesbury and a large part of rural Gloucestershire due to the waterworks being inundated with flood water. Subsequent to this, and other incidents, national level discussions between DWI and the Health Protection Agency (HPA) (forerunner of the PHE) in 2009 led to the first agreement to prepare and publish joint guidance to health and water professionals in support of drinking water quality risk assessments and the issuing of consumer protection advice.

In developing this guidance it was recognised the need to set out for health professionals the structure and legal framework of the water industry in England and Wales, and to describe the arrangements in place for securing the quality and safety of drinking water on a day-to-day basis. This position has been reinforced since 2009 with two further significant incidents where DWI and Public Health England (PHE) were instrumental in decisions that were made at the time and in the subsequent investigations. The first of these incidents was at Alderney water treatment works run by Bournemouth Water where an increase in cryptosporidiosis in the community in 2013 was identified by PHE and investigated by DWI who proved this to be linked to the water supply. The second was in 2015 where the detection of *Cryptosporidium* in water leaving Franklaw works, operated by United Utilities, resulted in a boil water notice to more than 700,000 consumers. Learning from these events and other legislative and organisational changes have led to this updated publication.

It is against this background that consultants in health protection, and other health professionals, may be called upon to give public health advice to the water industry and local government on consumer protection in relation to a water supply incident. We also felt that this information would provide health professionals with useful context to the publication, *Drinking Water*, setting out the annual results of drinking water tests and documenting the learning from water quality incidents.

In their day-to-day role, water quality scientists in the water industry work closely with health professionals in PHE, PHW and local authorities. We consider the maintenance of sound working relationships to be very important in the identification as well as the delivery of effective and timely responses to water quality incidents and emergencies. This guidance, together with Water Supply Risk Assessments (based on WHO Water Safety Plan Methodology), should form the basis of regular dialogue at local level to develop collective knowledge, understanding and trust.

In the preparation of this guidance it has been uppermost in our mind that the safety of drinking water in England and Wales is something the public is able to take for granted, because the day-to-day water supply arrangements in place are comprehensive and demonstrably based on sound science with a fully transparent system of independent scrutiny and appropriate sanctions in place. Accordingly, this guidance contains nothing new and we do not believe that its adoption will require any special action to be taken by the water industry or health professionals over and above its incorporation into existing training regimes, and its inclusion in water supply and public health operating and emergency management procedures.

Marcus Rink
Chief Inspector of Drinking Water
Drinking Water Inspectorate

Andrew Jones
Representative of Public Health Wales Executive
Public Health Wales

1. Introduction

This document has been developed jointly by the Drinking Water Inspectorate (DWI) and Public Health Wales (PHW). It is intended to inform public health specialists and consultants such as Consultants in Communicable Disease Control (CCDCs) and Consultants in Health Protection (CHPs), and Environmental Health Officers and Practitioners (EHOs and EHP) within Local Authorities about the structure and legal framework of the water industry in Wales. It also explains when and how these professionals are likely to be called upon to give health protection advice about drinking water quality to the water industry, local authorities, consumers and DWI.

For cross border issues please note that this document has two versions published individually for England and Wales. In the event of a cross border incident it is recommended that both documents are used for guidance.

2. The Legal Framework

2.1. Drinking Water Inspectorate

The Drinking Water Inspectorate (DWI) is the drinking water quality regulator for England and Wales. It was formed in 1990 on the privatisation of the water industry. It is part of the Department for Environment, Food and Rural Affairs (Defra), but its Chief Inspector is appointed by the Secretary of State for Environment, Food and Rural Affairs (in England) and separately by Welsh Ministers in Wales. The overarching objective of DWI is to maintain public confidence in the safety and quality of public water supplies through the exercise of its powers of reporting, audit, inspection, enforcement and prosecution. The DWI also has a role in providing both governments with advice on water supply and quality matters.

The regulatory framework for water supplies in England and Wales is set out in the Water Industry Act 1991 (the 1991 Act). The 1991 Act was amended by the Water Act 2003 and the Water Act 2014. The Act defines the powers and duties under which DWI operates and also the duties of water companies and licensees. Under the 1991 Act the authorities responsible for regulating the quality of public supplies are the Secretary of State for Environment, Food and Rural Affairs (in England) and Welsh Ministers. DWI's website http://www.dwi.gov.uk holds the relevant legislation.

Confirmation of the details of the statutory duties of water companies and the powers of the Chief Inspector are detailed below.

2.2. Public Water Supplies

Public water supplies in England and Wales are provided by a number of water suppliers.

Water companies operating the public water networks hold appointments as water suppliers, and those operating the public wastewater networks hold appointments as sewerage service suppliers, for the purposes of the Water Industry Act 1991. They also supply water and wastewater services direct to household customers (and in some cases to non-household customers) who are connected to their networks. There are currently:

- 11 regional water and sewerage suppliers
- 6 regional water only companies,
- 9 small water and sewerage suppliers

A full list is available at https://www.ofwat.gov.uk/regulated-companies/ofwat-industry-overview/licences/

Since 1 April 2017, holders of new water supply and/or sewerage licences (WSSL) can provide supplies of water and sewerage services to eligible non-household premises. Some licensees may be limited to providing water supplies or sewerage services to their own sites and those of persons associated with them (known as self-supply). In Wales, water supply licences can currently have:

- A restricted retail authorisation: this allows the licensee to supply water to large non-household premises (consuming at least 50 megalitres of water a year) using the public water networks operated by water suppliers whose areas are wholly or mainly in Wales.

- A supplementary authorisation: this allows the licensee to introduce water into the public water networks of water suppliers whose areas are wholly or mainly in Wales in order to supply the licensee's own customers if their non-household premises consume at least 50 megalitres of water a year.

There are currently over 40 retail authorisations across Wales and England whereby the licensee provides retail services such as; billing, meter reading, customer enquiries, customer side water efficiency measures. A full list is available at: https://www.ofwat.gov.uk/regulated-companies/ofwat-industry-overview/licences/

Licences are under the control of Ofwat, the economic regulator for the water and sewerage industry in England and Wales. Ofwat's main duties are to:

- Further the consumer objective to protect the interests of consumers, wherever appropriate by promoting effective competition

- Secure that water companies (meaning water and sewerage suppliers) properly carry out their statutory functions
- Secure that water companies can (in particular through securing reasonable returns on their capital) finance the proper carrying out of their statutory functions

- Secure that water supply licensees and sewerage licensees properly carry out their licensed activities and statutory functions
- Further the resilience objective to secure the long-term resilience of water companies' water supply and wastewater systems; and to secure that they take steps to enable them, in the long term, to meet the need for water supplies and wastewater services

The management and protection of water resources (groundwater, rivers, streams, lakes, and raw water reservoirs) is responsibility of Natural Resources Wales, a Welsh Government Sponsored Body. All water regulators (DWI, Ofwat, and NRW) have separate duties, but they co-operate over matters of common interest through Memoranda of Understanding. More information can be found at: http://www.ofwat.gov.uk/ and https://naturalresources.wales/

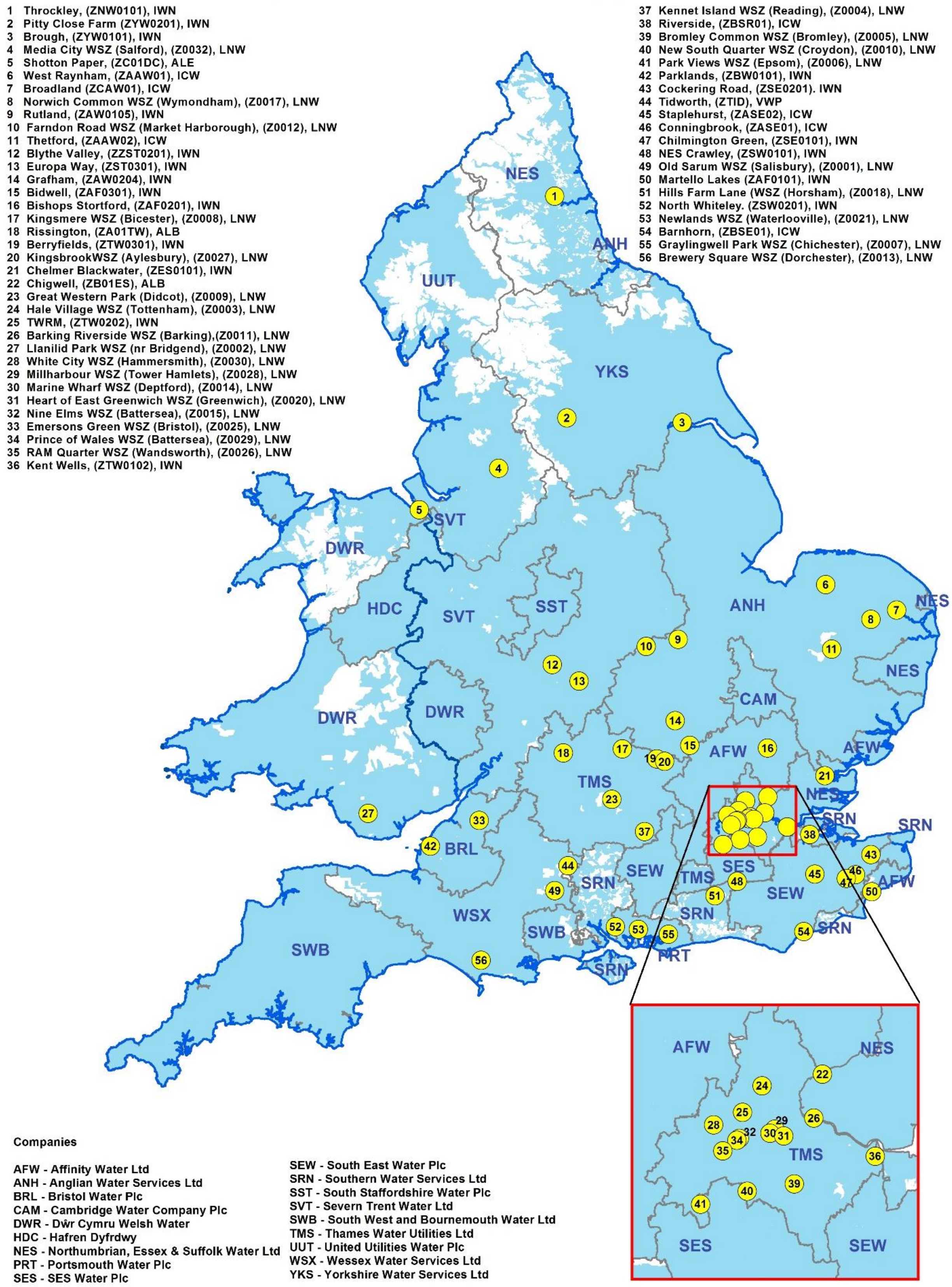


Figure 1: Water Suppliers in England and Wales

Under WIA section 68 1991, the water supplier is under a statutory duty to supply wholesome water for domestic use or commercial food production purposes. This duty is enforceable by the Secretary of State, ultimately by Court order. For a water supplier, wholesomeness is defined in Water Supply (Water Quality) Regulations 2018 in Wales. These regulations, including the definition of wholesomeness, implement the EC Drinking Water Directive for public water supplies. Under these regulations, the water supplier has a wide range of monitoring and other obligations which are also enforceable by the Welsh Ministers, ultimately by Court Order. Loss or damage caused by a failure of a water supplier to supply wholesome water for domestic purposes could result in a civil claim for damages by consumers. Supply by a water supplier of water unfit for human consumption is also a criminal offence under section 70 WIA. Additional offences cover design and operation of treatment works and requirements to disinfect water.

The Welsh Ministers' functions in relation to drinking water quality and sufficiency are performed by the Chief Inspector of Drinking Water and expert inspectors appointed by Secretary of State under section 86 WIA. This includes being able to obtain relevant information on drinking water quality. It is a criminal offence under section 207 WIA for a water supplier knowingly or recklessly to supply false information under, or for the purposes of, the WIA. The Chief Inspector and statutory inspectors have additional functions specific to their appointments which include the Chief Inspector being able to institute and carry out prosecution proceedings in the name of the Chief Inspector. In addition to this, penalty fines can be given by the DWI, on behalf of the Secretary of State, to water companies that do not comply with their duties in respect of drinking water quality under the WIA or the regulations.

The Water Industry (Suppliers Information) Direction 2019 requires water companies to notify the Inspectorate of any event which by its nature has affected or is likely to affect the quality or sufficiency of the water supplied by it. The Direction also requires companies to provide additional information at specified time periods in a format determined by the Inspectorate. The Inspectorate has issued guidance to water companies as to the reporting requirement of the Direction on its website at http://www.dwi.gov.uk and this is updated periodically.

2.3. Private Water Supplies

The Water Industry 1991 Act defines water supplies that are not provided by statutorily appointed water companies as private water supplies. Private water supplies are highly variable in their circumstances, lay out and size. There are approximately 13,880 private water supplies registered in Wales, 84% of which serve a single household[1]. This figure is likely to be an underestimate of the actual number of private water supplies since connections to a single property may not always be registered. It is thought that nearly 80,000 people in Wales are on (or have access to) a private water supply.

[1] Drinking Water 2019 – Private Water Supplies in Wales http://dwi.gov.uk/about/annual-report/2019/PWS-2019-Wales.pdf

The risk of health effects from failures of water quality standards in single domestic PWS is not necessarily restricted to the immediate household or residents living at that address. A recent study in Cornwall found that 31% of single domestic PWS were not

correctly identified and shared their supplies with other properties[2]. When enquiries are made regarding single domestic private supplies action should be taken to investigate if there are other properties also supplied from the source.

Most private water supplies are located in rural and remote areas. However, there are many more people, other than those served by a private supply that will have some contact with water from private water supplies as these can be used in the manufacture of certain foods and beverages, and serve various public buildings such as hospitals, village halls, hotels or, more often, campsites and leisure parks.

The quality of private water supplies is regulated by local authorities, who are responsible for enforcement of the Private Water Supplies (Wales) Regulations 2017. The drinking water standards which apply to private supplies are the same as those for public supplies as they are similarly derived from the Drinking Water Directive, but for the smallest public supplies much more emphasis is placed on risk assessment and risk mitigation rather than very occasional monitoring.

Private water supplies are categorised in the relevant Private Water Supply regulations as described in the table below and this allows for proportionate and risk based monitoring.

Details of the sampling and monitoring requirements for England and Wales differ slightly and both have been included for comparison.

Table 1: Private Water Supplies are categorised in the relevant Private Water Supply regulations (2017), this allows for proportionate and risk based monitoring. Note the differences between English and Welsh regulations.

	England	**Wales**
Regulation 8 supplies	Where water is supplied by a water undertaker or water supply licensee, and is then further distributed by a person other than a water undertaker or water supply licensee, the local authority must carry out monitoring on the basis of the risk assessment.	Where water is supplied by a water undertaker or a water supply licensee and is then further distributed by a person other than a water undertaker or a water supply licensee, the local authority must carry out any monitoring which the risk assessment shows to be necessary

[2] Crabbe, H.; Close, R.; Rimmell, A.; Leonardi, G.; Watts, M.J.; Ander, E.L.; Hamilton, E.M.; Middleton, D.R.S.; Smedley, P.L.; Gregory, M.; et al. Estimating the population exposed to arsenic from groundwater-sourced private drinking water supplies in Cornwall, UK. In Best Practice Guide on the Control of Arsenic in Drinking Water; Bhattacharya, P., Polya, D.A., Jovanovic, D., Eds.; IWA Publishing: London, UK, 2017; Chapter A3; pp. 161–170. ISBN 139-7-81-84339385-6.

Regulation 9 supplies	A supply covered by Regulation 9 is a private water supply (other than a supply specified in regulation 8) that : - supplies an average daily volume of water of $10m^3$ or more, or - supplies water as part of a commercial or public activity. Where this applies, the local authority must monitor for parameters directed by the regulations and carry out any additional monitoring that the risk assessment shows to be necessary.	A supply covered by Regulation 9 is a private water supply (other than a supply specified in regulation 8) that : - supplies an average daily volume of water of $10m^3$ or more; or - supplies water as part of a commercial or public activity. Where this applies, the local authority must monitor for parameters directed by the regulations and carry out any additional monitoring that the risk assessment shows to be necessary.
Regulation 10 supplies	Where a private water supply is not covered by regulation 8 or 9 or is not a supply to a single dwelling which is not used for commercial or public activity, the local authority must monitor for 5 specified parameters and any other parameter designated in the regulations where the supply is identified as being at risk of not meeting concentrations or values specified and anything else identified in the risk assessment as a potential danger to human health. This must be done at least every 5 years and more frequently if the risk assessment shows this to be necessary.	This regulation applies to a private water supply to a single dwelling which is not used as part of a commercial or public activity (in which case regulation 9 applies) or as part of a domestic tenancy (in which case regulation 11 applies). Where this regulation applies, the local authority - may monitor the supply in accordance with the requirements in regulation 11(1); and - must do so if requested to do so by the owner or occupier of that dwelling.
Regulation 11 supplies		Where a private water supply is not covered by regulation 8 or 9 or is not a supply to a single dwelling which is not used for commercial or public activity, the local authority must monitor for 5 specified parameters and any other parameter designated in the regulations where the supply is identified as being at risk of not meeting concentrations or values specified and anything else identified in the risk assessment as a potential danger to human health. This must be done at least every 5 years and more frequently if the risk assessment shows this to be necessary.
Single domestic dwellings	In the case of a private water supply to a single dwelling not provided as part of a commercial or public activity, a local authority may monitor the supply in accordance with the requirements for	

	Regulation 10 supplies, and must do so if requested to do so by the owner or occupier of that dwelling.	

The role of DWI in respect of private supplies is to provide expert technical advice to local authorities, ensuring consistency of interpretation of drinking water legislation. The DWI are also responsible for collecting information from local authorities about private water supplies and reporting this annually alongside information about public water supplies. The regulations and DWI guidance is available on the DWI website[3]. For the majority of enquiries to PHW the most common involvement with drinking water is likely to be giving health protection advice to a local authority in respect of the quality of drinking water from a private water supply.

2.4. Public Health Wales

Public Health Wales was established as an NHS Trust on 1 October 2009 and is accountable to Cabinet Secretary for Health, Well-being and Sport in the Welsh Government. It has four statutory functions:

- To provide and manage a range of public health, health protection, healthcare improvement, health advisory, child protection and microbiological laboratory services and services relating to the surveillance, prevention and control of communicable diseases;

- To develop and maintain arrangements for making information about matters related to the protection and improvement of health in Wales available to the public; to undertake and commission research into such matters and to contribute to the provision and development of training in such matters;

- To undertake the systematic collection, analysis and dissemination of information about the health of the people of Wales including cancer incidence, mortality and survival; and prevalence of congenital anomalies; and

- To provide, manage, monitor, evaluate and conduct research into screening of health conditions and screening of health related matters.

The Health Protection Division provides advice and support on communicable disease and environmental public health issues to Local Health Boards, GPs and primary care, NHS Trusts, Local Authorities and the Welsh Government. The Division provides an all Wales Acute Response Service (AWARE) which deals with any cases on infectious disease or environmental incidents. The Division also has four health protection teams strategically located around Wales (North Wales, South Wales, South East Wales and Mid and West Wales) and a Wales wide Environmental Public Health Service dealing with non-communicable environmental hazards.

[3] www.dwi.gov.uk

All healthcare services in Wales are delivered through seven Health Boards within specified geographical areas. Each health board employs a Clinical Lead for Microbiology and a Director of Public Health who are supported by Public Health Wales. The seven Health Boards are listed below and shown in Figure 2;

- Aneurin Bevan University Health Board (covering Blaenau Gwent, Caerphilly, Monmouthshire, Newport, Torfaen and South Powys)
- Betsi Cadwaladr University Health Board (covering the areas of Anglesey, Conwy, Denbighshire, Flintshire, Gwynedd and Wrexham)
- Cardiff & Vale University Health Board (covering Cardiff and the Vale of Glamorgan)
- Cwm Taf Morgannwg University Health Board (covering Rhondda Cynon Taf)
- Hywel Dda University Health Board (covering Carmarthenshire, Ceredigion and Pembrokeshire)
- Powys Teaching Health Board (covering Powys)
- Swansea Bay University Health Board (formerly Abertawe Bro Morgannwg University Health Board) (covering Swansea, Neath and Port Talbot)

Similar arrangements exist for Scotland and Northern Ireland. In Northern Ireland, the health protection function is delivered by the regional Health Protection Service of the Public Health Agency and in Scotland by Health Protection.

Figure 2: Boundaries for PHW Health Boards

2.5. Local Authorities

2.5.1. The Water Industry Act 1991

For public water supplies this means that local authorities must have effective working arrangements in place with all water companies and licensees who supply water in their area. In particular, local authorities have a duty under section 77 of the Act to keep themselves informed about the wholesomeness and sufficiency of public water supplies in their area, and the Welsh Ministers have the power to direct local authorities on how to exercise their powers and duties, if deemed necessary. Local authorities also have powers to enforce water companies to provide alternative supplies when piped water supplies are unavailable.

Section 80 of the Water Industry Act 1991[4] places responsibility on local authorities for checking the safety and sufficiency of all water supplies in their area and subsequent

[4] https://www.legislation.gov.uk/ukpga/1991/56/contents

sections powers to serve notice on relevant persons to rectify issues causing water quality problems. There is an appeal process for relevant persons for notices served under Section 80 of The Act, whereby the Chief Inspector can be requested to review the notice and can either confirm the notice (with or without modifications), or not confirm the notice. This notice relates to issues of wholesomeness.

2.5.2. Regulations

Regulation 20 of the Private Water Supply Regulations allows for notices to be served by a local authority where water is a potential risk to human health, and in this case, the local authority must serve a notice. Any appeal by relevant persons in this situation must take the matter to a Magistrates' Court.

2.5.3. The Water Health Partnership for Wales

Established in 2006, the Water Health Partnership for Wales brings together public health professionals to work on issues related to water and health. Their scope includes private and public drinking water supplies. The main aims are to keep up to date on emerging issues and to work together to protect public health. Membership is free and is open by invitation, to anyone working in water and health-related roles. Members include Public Health Wales, Welsh Government, DWI, local authorities, the Consumer Council for Water (Wales), Water Companies, Natural Resources Wales, the Food Standards Agency and the Water Regulatory Advisory Service. It is overseen by a Steering Group which sets strategic direction and agrees a work plan and has a number of Task and Finish (Working) Groups which carry out research and development work for the Partnership. Current work areas include lead in drinking water, private water supplies, bathing and recreational waters and public buildings. More information on the Partnership can be found at http://www.waterhealthpartnership.wales

3. Wholesome Drinking Water

By law (the 1991 Act), drinking water must be wholesome at the time of supply. Wholesomeness is defined by reference to drinking water quality standards and other requirements set out in the Water Supply (Water Quality) Regulations 2018. Similarly for the Private Supply Regulations Regulation 4 also covers wholesomeness. These regulations are available on the DWI website (www.dwi.gov.uk). Many of the standards come from the 1998 European Drinking Water Directive which came into force fully on 25 December 2003 and subsequent amendments. The Directive focuses on those parameters of importance to human health, but it also includes others that relate to the control of water treatment processes and the aesthetic quality of drinking water. The Directive allows Member States to set additional or tighter national standards to secure the good quality of drinking water already achieved and to prevent it from deteriorating in the future. The Drinking Water Directive is currently under review. All requirements of the existing EU Drinking Water Directive are transposed into the Drinking Water Regulations for England and Wales and will be enforced by the DWI. More information on the Directive standards is given in Annex 1 together with information about other substances that may be found in water and waterborne pathogens.

Where a breach of a drinking water quality standard has occurred that might have a potential impact on public health, water companies and local authorities are required to inform Public Health Wales and to agree, and undertake, the appropriate investigations and mitigation measures to control or prevent potential risk to health.

3.1. Drinking Water Testing

Water companies and local authorities have a duty to collect samples and test these for each of the substances and organisms (known as parameters) in the respective regulations. Over 3.5 million tests are carried out each year at consumers' taps, service reservoirs and treatment works supplied by water companies and over 180,000 tests on samples from private supplies are commissioned by local authorities across Wales and England. Companies must make the results of this testing available to their customers on request. Local authorities are required to provide sample results to the Inspectorate. The Inspectorate's role is to independently verify that this testing is being carried out to a high standard of quality control, for example laboratories are all accredited through the United Kingdom Accreditation Service (UKAS) to the standard recognised for drinking water (Drinking Water Testing Specification, DWTS). In respect of testing drinking water, the work of drinking water Inspectors is aimed at providing public reassurance that the robustness and integrity of analytical results is beyond question. DWI does not routinely test drinking water, although it has the power to commission independent tests if there is a compelling public interest and adequate justification.

Water companies are required to provide DWI with full details of their annual monitoring programme in advance and the results of these tests are subsequently transferred electronically to DWI on a monthly basis. DWI publishes a summary of the results of a water company's monitoring annually on its website.

Local authorities must also have in place robust arrangements for taking and analysing samples from private water supplies, as well as carrying out risk assessments by competent persons. They are able to charge the owners/uses of private water supplies for monitoring their supply. As local authorities do not have their own laboratories they will use an external accredited laboratory often a private company or water company and, to a lesser degree, may send samples to a public analyst or a specialist Public Health Food, Water and Environment laboratory.

Local authorities recover their costs for their regulatory activities, including risk assessments, investigations and monitoring. There is no legal requirement on local authorities to sample public water supplies, but samples may be collected when acting to resolve a water quality problem within a public building or in respect of social housing for example.

Organisers of temporary event such as an Eisteddfod, agricultural show or carnival are required to ensure that the water they supply is safe to drink. It is their responsibility to make sure that fittings and fixtures meet regulatory requirements and ensure that the safety and security of the drinking water is maintained throughout the course of the event. For events supplied from the public supply, the Water Company is responsible for making sure the water at the point of connection is safe and wholesome and they also have the power to carry out inspections of the pipework within the site. If the organisers intend to use a private water supply, the local authority is responsible for carrying out a risk assessment and monitoring of the supply at the event. In all cases, the local authority will expect organisers to comply with British Standard BS8551:2015 Provision and management of temporary water supplies and distribution networks (not including provisions for statutory emergencies). The Water Health Partnership has produced guidelines for the provision of temporary drinking water (http://www.waterhealthpartnership.wales/opendoc/349865)

In the event of an infectious disease outbreak (e.g. SARS-CoV-2 (CoViD-19)) the requirements of the regulations continue to apply, including those relating to sampling and compliance, monitoring, reporting and any other operations intended to secure the abstraction, treatment, storage and delivery of wholesome water. Additionally, the requirements of the Information Direction relating to non-compliance with the Regulations continues to apply. In such an outbreak, customer facing staff, especially samplers who visit domestic premises, may experience an increased level of difficulty as fears, rational, or otherwise, may impede the normal daily work. A dynamic risk assessment should be made in such circumstances and it is expected that a sampler would make a reasonable number of attempts to obtain a sample. Reasoning for not taking a sample should always be documented. Any change in government advice relating to an infectious disease outbreak may be region specific and could include restricted areas which may make it difficult or impossible to enter domestic premises or areas. In such circumstances a Regulation 7 notice may be issued to water companies giving a variation on sampling. In all circumstances water companies must prioritise the operation of treatment works and continue to monitor critical control points such as point of disinfection and service reservoirs. Online telemetry should always remain in operation.

Laboratories should make contingency plans for continuing analytical services in circumstances where movement and staff availability are limited or restricted. Where there are impacts on analytical capability the Inspectorate will be notified. In all circumstances, microbiological analysis including *Cryptosporidium spp.* will be prioritised.

4. The Safety of Drinking Water

The regulations make specific provisions for drinking water safety and require water companies and local authorities in respect to private supplies to implement a risk management (water safety plan) approach to water production and distribution as recommended by the World Health Organisation (2011 WHO Guidelines for Drinking Water Quality). The latest WHO guidance is available at: http://www.who.int/water_sanitation_health/water-quality/safety-planning/wsp-publications/en/.

Publications include:

- Water safety plan manual
- Climate – resilient water safety plans
- Principles and practices of drinking water chlorination
- Potable reuse
- Water safety planning for urban water utilities
- Protecting surface water for health
- A practical guide to auditing water safety plans
- Water safety plan – A field guide
- Water safety in distribution systems
- Water safety in buildings
- Water safety plans – managing drinking water quality for public health

4.1. Water Company Responsibility in Relation to Water Safety

Water companies are required to have adequate water treatment in place, informed by a regulatory, raw water monitoring programme. They must disinfect all water before supplying it and, where necessary, subject the water to sufficient preliminary treatment to prepare it for disinfection (regulation 26). As a minimum this must ensure that the turbidity of water is <1 NTU (Nephelometric Turbidity Units). The method of disinfection is not set out in law, but DWI require water companies to define and document their disinfection policy and implement it through written procedures for each treatment works.

For every treatment works and associated water supply system, water companies have to carry out and keep up-to-date a risk assessment to establish whether there is a significant risk of supplying water that would constitute '*a potential danger to human health or is likely to be unwholesome*'. Reports on these risk assessments are submitted to DWI and are subject to audit and enforcement action where necessary. *Potential danger to human health* is a term which derives from the Drinking Water Directive. In practice, in the UK, this term is understood better as a potential risk to public health generally. It is not a consideration of the medical needs of a particular individual. Likewise, the risk assessment is concerned with the human population. There is no requirement to assess the risk to pets, livestock or fish.

As well as covering microbiological, chemical and radiological hazards, regulatory risk assessments also cover other physical and organisational hazards which may result in a failure of the water supply (no water) or consumers rejecting the water for aesthetic reasons i.e. not wholesome. Where an unacceptable risk is identified, water companies must put in place an urgent programme for mitigation and control, including, where necessary, short, medium and long-term improvement measures. DWI requires water companies to communicate effectively about their risk assessments with key stakeholders and this means that Public Health Wales, Health Boards and local authorities should be briefed on, and consulted about, each specific risk assessment for water supplies in their areas. Through these consultations, Public Health Professionals have the opportunity to become familiar with the local water supply arrangements, to ask questions and satisfy themselves that it fully takes account of the public health needs of the local community. If they are not satisfied in this respect they should raise their concerns with the water company in question and the DWI. DWI has the power to issue notices directing a water company to take certain actions in respect of its risk assessments.

Other water safety requirements of the regulations include the fact that water companies must treat water to make it less aggressive towards lead and copper plumbing where this has been shown to be a problem with a specific water supply. There are also regulatory controls (regulation 31) over the chemicals and materials of construction that water companies are permitted to use. DWI operates a national approvals system for chemicals and materials of construction, and the published list of approved products is available on the DWI website. The Centre for Radiation, Chemical and Environmental Hazards (CRCE) of PHE provides toxicological advice to DWI in respect of decisions about the approval of materials.

Water suppliers that fail to adequately treat and/or disinfect their water supplies, or fail to take action in respect of their risk assessments, or who use unapproved chemicals or materials, may have committed a criminal offence. DWI Inspectors carry out independent technical audits of company records and sites to ensure that operational and management procedures are robust. If deficiencies are identified, DWI has the power to take enforcement action to require improvements to be made.

It is not uncommon for a drinking water quality problem to be due to the condition of building water systems rather than the distribution system owned and operated by the water company. Water companies have powers (the Water Fittings Regulations 1999) to inspect premises to ensure the public water mains are protected by backflow devices or other means from any possibility of contamination from water used in industrial processes, wastewater or any private supply. Water companies have a programme of regular inspections of high risk building water systems in place and will carry out inspections in response to unexplained consumer complaints. They also have a programme to check any new connections to their distribution networks. It is not uncommon to find interconnections between private and public supplies that are not sufficiently protected by backflow prevention. Water companies should be aware of high risk locations in their area (farms, industrial units) and ensure that an appropriate inspection regime is in place. Local authorities should be vigilant and identify any risk of interconnections with mains water identified when carrying out risk assessments should be escalated and mitigating protection put in place.

Water companies adhere to stringent hygiene procedures to ensure that none of their employees or contractors is allowed to work in restricted water supply areas if they are suffering from an infectious disease that may be waterborne. Water Hygiene training courses are delivered through Energy and Utility Skills and a Water Hygiene (EUSR) Card is issued. The course emphasises awareness of individuals' responsibilities towards the potable water supply and verifies that the employee has demonstrated an appropriate level of knowledge and awareness with regards to hygiene and water quality issues.

5. Events and Incidents

5.1. Public Water Supplies

Section 70 of the 1991 Act makes it a criminal offence for a water company to supply water that is unfit for human consumption. However, the Act provides a defence for the water company if it can show that it had no reasonable grounds for suspecting that unfit water would be consumed, or it had taken all reasonable steps and exercised all due diligence to ensure that water was fit for human consumption on leaving its pipes. There is a regulatory duty on water companies to notify DWI of any event which has the potential to give rise to a significant risk to public health or otherwise cause consumers concern directly (appearance of water) or indirectly (adverse media comment). It is also regulatory duty for such events to be notified to local authorities, Public Health Wales Health Boards and the Consumer Council for Water. Others, including consumers, journalists and whistle-blowers, can also make DWI aware of any actual or potential event.

Inspectors will assess the significance of all notified events on a risk-based approach. Where necessary, they will investigate and take enforcement action which may include initiating proceedings or issuing a caution or notice. In addition to the offence of supplying water unfit for human consumption in the Act, it is also a criminal offence for a company to fail to comply with Regulation 26 (adequate treatment and disinfection of water) or Regulation 31 (use of only approved chemicals and materials).

When conducting their investigation, Inspectors will gather evidence in the form of technical and management information from the company and through interviews of relevant persons, including members of the public, contractors, consultants and advisors, potentially including local authority and PHW staff. Inspectors are trained in, and follow, Police and Criminal Evidence Act (PACE) procedures. DWI publishes its findings and recommendations in the form of an Event Assessment Letter (EAL) and copies of these are provided to the local authority, Public Health Wales and the Consumer Council for Water in the affected area.

A water quality event is defined as any biological, chemical or radiological occurrence which by its nature is required to be notified under the Water Supply (Water Quality) Regulations 206 or the Private Water Supplies (Wales) (Amendment) Regulations 2017. When an event has the potential to have a significant impact on public health, it can be escalated to an incident and an Incident Management Team (IMT) formed. Examples of “significant” would include outbreaks of water-related illness or a sizeable population exposed to a chemicals of health significance where the contaminant at levels above the prescribed concentration or value[5]. Box 1 includes examples of the criteria that may be used to trigger an IMT.

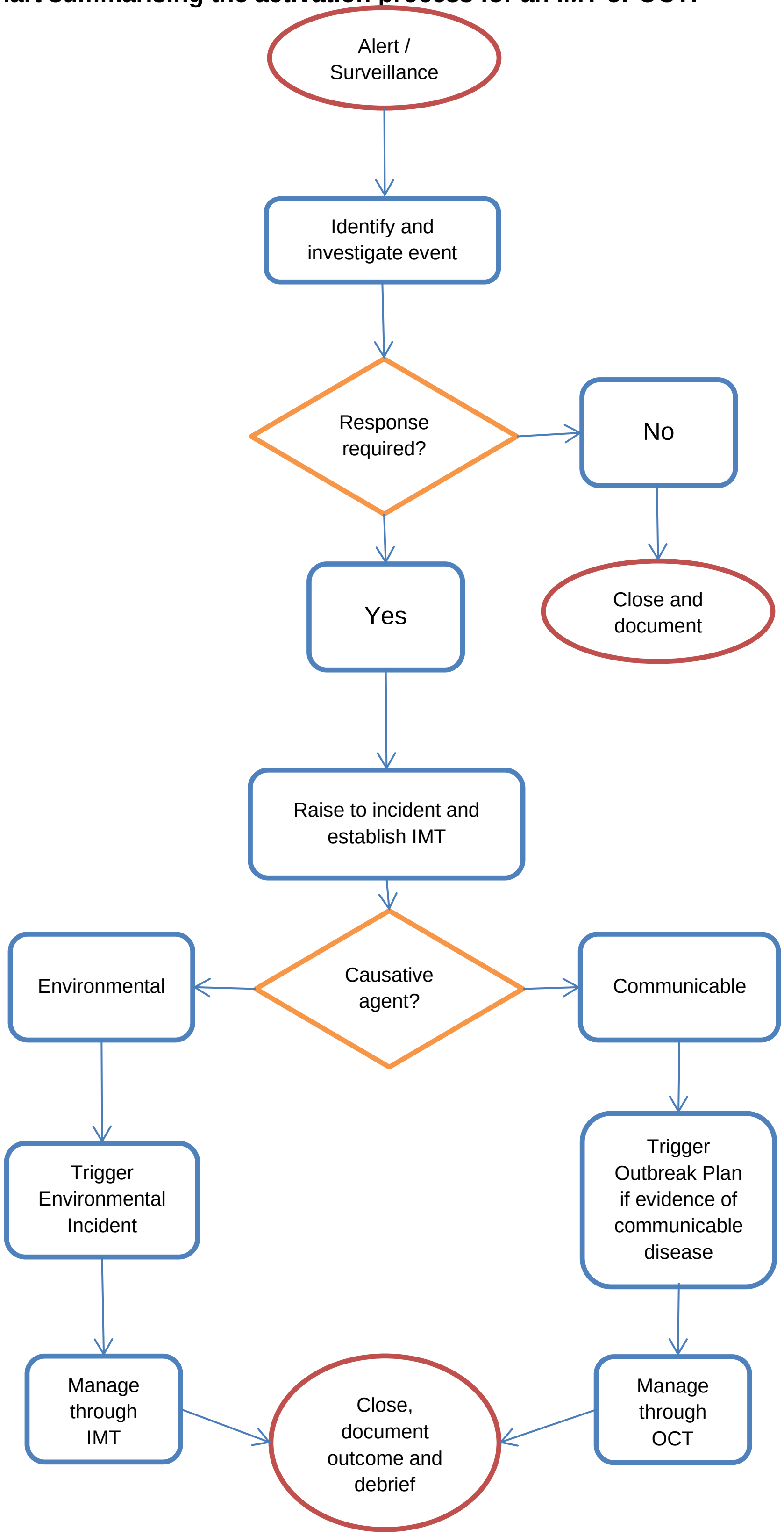
[5] Some chemicals have PCVs that are not health based and it is unlikely an IMT would be called for contaminants where the PCV is based on taste and odour.

Box 1: Criteria for establishing an Incident Management Team (IMT)

- An **exceedence** of drinking water standards (e.g. a prescribed concentration or value (PCV)) and guidelines as set out in the Water Supply (Water Quality) Regulations 2016 (as amended) or the Private Water Supplies Regulations 2016 that is unacceptable in terms of public health (termed a non-compliance event).
- Reports of an **unusual deterioration or changes** in water quality that may have an implication on public health. For example, analytical data suggesting increase metal or pesticide concentrations, changes in colour or turbidity that may indicate a change in the water treatment process.
- Reports of **failure or poor performance** of water treatment and disinfection activity (for example a near miss).
- Reports of **potential external contamination of** a water supply or water catchment area that could result in a future non-compliance event or near miss (for example diesel spillage threatening water supply).
- Reports of **site security issues** associated with water supply or treatment process.
- Any evidence of **unusual and unexplained clustering of cases** in the community related to a water supply.
- Any significant **perceived risk** to the health of consumers.
- Significant **consumer perception or concern** about the quality of the water supplied or changes in water quality.
- One or more core partners have already declared the event a public health incident.
- Any combination of the above

If the incident becomes an outbreak, an outbreak should be declared, the IMT dissolved and an OCT formed. An outbreak is usually declared jointly by Consultant in Communicable Disease Control/Consultant in Health Protection (CCDC/CHP) in conjunction with the Local Authority and the Health Board (including the Clinical Lead for Microbiology and the Director of Public Health). More details on the role of the OCT can be found in the Wales Outbreak Plan (The Communicable Disease Outbreak Plan for Wales). Figure 3 presents a flowchart summarising the IMT/ OCT decision.

Figure 3: Flowchart summarising the activation process for an IMT or OCT.



The primary objective of the IMT or OCT is to protect public health by identifying the source of the contamination and implementing the necessary control measures to minimise or reduce exposure and prevent further spread, recurrence or exposure. Core members of the IMT/OCT include Public Health Wales, Local Authorities, Local Health Board and Water Companies. Co-opted members can also include Natural Resources Wales, Food Standards Agency and the DWI. The IMT/OCT will usually be chaired by a health or the local authority representative and the Chair will be agreed at the first meeting. However, any member of the IMT can chair by the agreement of the members of the IMT.

The core actions of an IMT/OCT include:

- Undertake a risk assessment to identify the contaminant(s), the source and extent of contamination.

- Identify gaps and information needed to update the risk assessment.

- Evaluate and characterise the risk to public health and likely illness in the community, including defining the population at risk and identifying any high risk / susceptible individuals such as immuno-compromised groups, home dialysis patients, health-care settings.

- Declare an ‘Outbreak’ if there is evidence of communicable disease following the contamination incident.

- Agree and initiate immediate and long-term control measures to reduce exposure. Immediate control measures may have been taken by the water company before the IMT is formed and these should be reviewed by the IMT. Box 2 summarises some of these control measures.

- Communicate to the public and medical professionals including publication of media statements.

- Consider undertaking an epidemiological study to describe symptoms/cases:

- Monitor control measures by continued surveillance for disease/symptoms.

- Lift Warning Notices subject to agreed criteria being met.

- Evaluate the management of the incident and make appropriate recommendations for the future.

- Declare the incident over.

- Produce report on the outcome including recommendations and epidemiological report (if required).

Box 2: Examples of control measures in response to water quality event

Immediate:

- Stop water abstraction
- Flushing of supply system or individual supply pipes
- Issue warning advice/ notices:
  - Boil before Use for drinking and food preparation (BWA)
  - Do not use for Drinking or Cooking (DND)
  - Do not use for Drinking, Cooking or Washing (DNU)
- Providing alternative supplies, such as:
  - Bottled water (also see http://www.legislation.gov.uk/wsi/2015/1867/contents/made)
  - Bowsers and tankers
  - Diverting sources or Re-zoning (introduction of water from a different supply)

Long-term / permanent:

- Additional water treatment processes (process control)
  - Activated carbon
  - Water filters
  - Increased disinfection
  - Phosphate dosing
- Replacement of water pipes e.g. lead pipes
- Permanent provision of different supply (e.g. moving from private water supply to mains)

Public Health controls:

- Isolate or exclusion of cases and contacts
- Screening and monitoring of contacts
- Immunisation or prophylaxis
- Specific advice and interventions to highly susceptible groups e.g. protection measures for:
  - for immunosuppressed groups
  - recommend home dialysis patients receive treatment in hospital
  - lead exposure and children
  - bottled water and infants

The water company may also set up their own operational Incident Management Team (WCo-IMT) tasked with issuing any short-term health protection warning to consumers and carrying out the necessary work to restore the water supply to normal. This will link closely to the IMT/OCT and one or more members of the WCo-IMT will sit on the IMT/OCT and provide operational updates and report back to the Water Company any requests for information and advice.

While the vast majority of events will be managed through an OCT/IMT, there will be rare occasions where an event may necessitate the activation of civil contingency arrangements. This is likely to where the nature or scale of the event meets the definition of a major incident in the Civil Contingencies Act. A major incident is defined as “an event or situation, with a range of serious consequences, which requires special arrangements to be implemented by one or more emergency responder agencies.”

Scenarios where this may be necessary include a suspected CBRNe event, a widespread communicable disease outbreak or chemical incident that creates the risk that essential services will be overwhelmed or an event that require the implementation of civil restrictions on health protection grounds. In such scenarios, a Category 1 responder such as the emergency services or Public Health can initiate formal command control structures to manage the incident. These may involve escalation to the relevant Local Resilience Forum and the establishment of a Tactical Coordinating Group (TCG or Silver Command) and/or Strategic Coordinating Group (SCG or Gold Command). The SCG sets the strategy within which lower levels of command will operate.

Typically, the police will chair the SCG but it can be any Category 1 responder. If required, the SCG can access scientific and technical support through the Scientific and Technical Advisory Cell (STAC) which is usually chaired by Public Health Wales. The membership of STAC will depend on the nature of the incident and the specific response requirements that arise locally. For most incidents scientific advice is best provided through existing channels and agencies who routinely attend the SCG. A STAC should only be activated when there is a collective expectation that it can add value to the incident response.

At national level, if the scale of the event warrants it, the Civil Contingencies Secretariat may institute national response plans including regular meetings of the Civil Contingencies Committee (CCC) and the establishment of a Scientific Advisory Group for Emergencies (SAGE). For water emergencies, DWI would normally be invited to be a member of SAGE. Good communication between the STAC and the SAGE will be essential.

One of the requirements of the investigation is to evaluate the event and prepare a written report on the health impacts and disseminate any lessons learnt. This may include results of any epidemiological studies. The timing of the evaluation can be flexible; OCT/IMT may find it helpful to have time to reflect on the event prior to carrying out the evaluation. At this stage, any urgent recommendations will need to be flagged up prior to the full report. It is very important that this report confines itself to the health study and does not include details about the water supply or its management, because these matters will be investigated and reported upon by DWI and details may form the basis of criminal proceedings. It should be noted that the DWI report on an event usually takes the form of an Event Assessment Letter which will be sent to all the parties involved in the event and will describe its findings, actions and conclusions. If the event investigation leads to the initiation of proceedings in court, the Event Assessment Letter will be issued only when the case had been concluded. It is recommended that the Chair of the IMT establishes direct contact with DWI when the IMT is first formed, to establish effective routes of ongoing communications throughout the work of the IMT. It was a recommendation of the Third Report of the Expert Group on *Cryptosporidium* in Water Supplies (the Bouchier Report) published in 1998, that any report by an IMT be submitted to the Chief Inspector so that DWI can issue guidance to the water industry in respect of any key learning points.

5.2. Private Water Supplies

Regulation 20 of the Private Water Supply Regulations 2017 in Wales requires that if any private supply of water intended for human consumption constitutes a potential danger to human health, a local authority acting under these Regulations must serve a Notice on any relevant person. The Water Industry Act 1991 defines relevant persons in Section 80. A Notice may be served on one, several or all of the relevant persons, depending on the cause of the potential danger to health and the appropriate mitigation required. In addition, the local authority should take into account any local agreements, covenants or deeds which specify responsibilities for specific aspects of the supply or its management. Further guidance on this is available on DWI's website.

Regulation 6 requires a local authority to undertake a risk assessment at least every five years for each private water supply within their area with the exception of a supply to a single dwelling where the supply is not provided as part of a commercial of public activity. Local authorities must carry out a risk assessment of such single dwellings if requested by the owner or occupier of the dwelling. The purpose of the risk assessment is to establish whether there is a significant risk of supplying water that could constitute a potential danger to human health. Local authorities must also use the risk assessment process to establish whether there is a risk of non-compliance with any of the standards or indicator parameter values outlined in the Regulations. The risk assessment should also be used as part of the information to enable local authorities to consider whether it can exclude parameters from any monitoring requirements. A link to the relevant tool can be found from this link: http://www.dwi.gov.uk/private-water-supply/local-auth/risk-assessment.html

If information is not provided by a relevant person, the local authority can use its powers under Section 85(1) of the Water Industry Act 1991 to serve a Notice on any person requiring that person to provide information about premises on a supply.

6. Protecting the Public during an Event or Incident

6.1. Public Water Supplies

Due to the nature and complexity of operational activities involved in the supply of drinking water, water companies will take a number of actions to protect public health, such as the provision of advice to consumers, some examples of which are described below. On many occasions the company should, and will, notify health protection staff within Public Health Wales and local authority staff (EHOs) as part of this process. The purpose of this notification is to provide medical/public health advice to the company that is pertinent to the local community affected. However, the responsibility for issuing warning notices to consumers and providing alternative water supplies (rezoning, tankers, bowsers and bottles) rests, at all times, with the water company. An example of the notification template generated by DWI and circulated upon notification of an event affecting the quality or sufficiency of drinking water is provided in Annex 2.

As a matter of routine day-to-day water supply operations, temporary precautionary advice is issued by water companies to householders via social media platforms and water company website area bulletin updates. Additional precautionary advice may be given in the form of letters, leaflets or warning notices to specific consumer premises. The public is familiar with, and is therefore responsive to, such advice coming from their water supply company. Water bills sent to customers provide a number to ring to report a problem with the water supply. Most water companies have a website and social media channels to ensure the public have access to timely information and updates.Water company websites and social media channels, provide water quality advice and can be an effective route of contact for the public to their water supplier. Local authorities for private water supplies will also issue precautionary advice where necessary. Listed below are the typical situations where precautionary advice is issued, together with details of how this is done, who is involved and why.

Planned work on the water supply: advance notices are delivered to each building in the affected streets in addition to emails and text messages sent to registered consumers. The notice will give details of the work, particularly the timing of any shut down of the supply. For example, it may advise that water may be discoloured when the supply is restored and what to do if this does not clear on flushing the mains tap.

Unplanned disruption to the water supply: typically caused by a burst main. Company website and social medial channels will be updated with area bulletins and customers ringing their water company will be given advice, often through a recorded message set up for particular post codes. The water company will notify Public Health Wales (CCDC/CHP) and the local authority of any disruption which is likely to be protracted (i.e. difficult to repair) or attract adverse media comment (i.e. traffic congestion) or affect a large number of homes and businesses. Companies have direct arrangements for providing alternate supplies by tanker, bowser and bottles to priority customers such as hospitals and schools.

Adverse routine test result – single household: samples are taken at random from consumers' taps every day of the year. Adverse results are notified straightaway by the laboratory to the water company, the company will assess the risk to the consumer and arrange to collect further samples and will give advice to the householder about precautions to be taken until the cause of any problem has been identified. This advice is given verbally in the first instance, it may be to flush the tap before drawing water, or to boil the water before use, or not to drink or use the water. In the latter case the water company will usually provide an alternate supply of water for drinking in the form of bottles. The water company will notify the local authority and CCDC/CHP of the adverse result and the action being taken.

Consumer water quality complaint – single household: companies have risk assessment procedures in place to ensure that a water quality scientist is notified of any call from a customer attributing illness to the water supply, or reporting an objectionable taste or discolouration. If the problem is not clearly linked to a known operational problem, advice will be given over the phone and arrangements will then be made to either inspect the plumbing or collect samples or both. The water company will notify the local authority and CCDC/CHP of any adverse results. Customers reporting illness will be advised to see their GP. If it is clear that the person has been diagnosed with a water-related illness (e.g. cryptosporidiosis) the PHW health board will be notified straightaway.

Adverse sample result or some other type of problem affecting several properties or streets: during the investigation of an adverse result or consumer complaint at a single household (see above), it may become evident to a water company that there is a risk of contamination of the wider water supply, typically as a result of an illegal cross connection or inadequate back flow arrangements or spillage of chemicals. In these situations the company will issue precautionary boil water or do not drink notices to several premises or streets as a precaution. Examples of these notices are given in Annex 3. The water company will provide alternate supplies in the same way as it does for an unplanned disruption (see above). When the situation is resolved, water companies will deliver a second notice to say that the water supply has been restored to normal. The water company website, social medial channels and direct consumer text messages and emails will also be used. .The water company will notify the local authority and CCDC/CHP of the situation and the action being taken.

Adverse sample result or some other type of problem affecting a water treatment works or a service reservoir/water tower: the water company will establish an Incident Management Team for any event involving an actual or potential risk to the water supply from a strategic water asset. All relevant local authorities and CCDC/CHPs will be notified by the water company and advised of the immediate actions being put in hand. The company will make arrangements at this time for a meeting (or conference call) with CCDC/CHPs to discuss the risk assessment and the need for the public to be issued with precautionary advice and alternative water supply arrangements.

In a large scale event, the hazards posed by issuing a wide-scale warning notice need to be balanced carefully against the nature of the water supply event. Experience has shown that it is often preferable to implement enhanced health surveillance of the affected community instead of issuing a warning notice. Each situation has to be judged on its merits, taking into account local knowledge and whether or not water supplies can be returned to normal quickly or an alternate piped supply provided (by rezoning). If a decision is taken to issue boil water or do not drink advice, the basis for lifting the advice must be agreed at the same time. Experience has shown that significant problems can arise if the criteria for lifting the notice have not been decided when advice is first issued, although the criteria may need to be refined if new information becomes available.

The responsibility for issuing warning notices and providing alternative water supplies (rezoning, tankers, bowsers and bottles) rests at all times with the water company.

Local authorities have a responsibility for decisions about the continued operation of premises manufacturing or serving food and drink, and for public buildings such as schools and leisure centres. The CHP is responsible for initiating contingency arrangements for hospitals and other health services. All responding agencies should ensure that only a common agreed form of public advice in the form of, for example, Frequently Asked Questions (FAQ) is provided to their staff in call centres or placed on websites. FAQs should be regularly reviewed such that they are in line with PHW and DWI current guidance. There is also public health advice available on many other websites such as the PHW webpages and some reference laboratories. These links are included in Annex 1. Annex 4 also provides advice on precautions to be taken by the immunosuppressed individual in relation to boil water notices

6.2. Private Water Supplies

Where water from a private water supply in unwholesome, Section 80 of the Water Industry Act 1991 provides powers for local authorities to serve notice on all relevant persons on a private water supply, specifying the actions needed to correct the issue. Notices should have clear timescales and example template for local authorities are provided on DWI's website. Where the relevant persons do not take the actions required, the local authority may arrange for the work to be done and recharge the appropriate relevant persons.

In many cases the actions to be taken by the relevant person in relation to an issue on a private water supply will be very similar to those given above for public water supplies albeit on a smaller scale. However the relevant persons or the consumers may like to obtain advice from the local authority, PHW, their local water company or the Inspectorate in the case where they do not have the skills to solve the issues identified themselves. In protecting consumers on private water supplies, local authorities have the powers to issue notices restricting the use of water (Boil Water notice, Do Not Drink notice, Do Not Use notice). These notices should be served on all relevant persons on the supply. **When serving such a notice it is not acceptable to have no end point for the restriction. Local authorities need to specify a time limit, what needs to be done to rectify the problem and have include criteria for lifting the restriction.**

A case study on the inappropriate use of a private supply by a food business is given in the Chief Inspector's report on Private supplies in 2015[6]. In this example the food business had a private borehole and a connection to the mains water supply however following a water fittings inspection by the water company the food business was unable to make use of the mains supply as contraventions were found and therefore drew down on the borehole such that the quality deteriorated. Had there been better collaboration between the parties involved, the substantive economic, reputational and regulatory costs may have been avoided.

[6] Drinking Water 2015 – Private Water Supplies in Wales – Case study 6 pp 31-35. http://www.dwi.gov.uk/about/annual-report/2015/pws-wales.pdf

Another case example from 2015[7] involved an outbreak of *Escherichia coli* O157 (*E. coli* 0157) which occurred due to cattle accessing a spring source used as a private water supply to holiday lets. The underlying route causes were a change of use of the land from grazing sheep to grazing cattle, that cattle were able to reach the borehole headworks and defecate on it and that the original UV treatment system was undersized for subsequent increases in volumes of water needed to supply additional holiday homes put onto the supply. The outbreak highlighted the challenge of managing and investigating a situation where cases and contacts were spread widely. Overall 21 cases were identified ranging from a 2 year old to a 79 year old. What greatly aided the response to this outbreak was the promptness at which colleagues from other Health Protection Teams informed the PHE Cumbria and Lancashire team of their cases which could be potentially linked to the holiday let, and on the 13 August 2015 a "prohibition of use" notice was served on the water supply.

A number of learning points were identified from this case:

- The Internal Communications Summary highlighted the potential outbreak to other regional PHE teams and to NHS Scotland. This greatly speeded up the ability to link cases and confirm the outbreak.
- There is a need to respond promptly if a health professional thinks they have a linked case.
- An OCT allows for all responsible parties to manage the source and outbreak effectively.
- Health and water professionals need to be aware that the standard test for *E.coli* as a faecal indicator in PWS samples does not detect *E. coli* O157 per se, but is instead designed to identify faecal contamination; a positive sample should highlight the need for more detailed sampling that can speciate the bacterium.

Resources to aid the public health advice of the water quality of are outlined in Annex 1.

The chemical quality of private supplies can be driven by the quality of groundwater, from where the private supply is sourced. Many factors influence quality of groundwater, such as past industrial activity, soil contamination, seasonality, drought and precipitation rates. In some regions of England and Wales, private supplies are directly influenced by local geology or soil quality. From the 2011-2013 Cornwall study of single domestic PWS by PHE, it was found that up to 35% of supplies had exceedances of one or more prescribed concentration or value (PCV) of a range of chemicals and that 20% of households had one or more exceedance of health-based values for drinking water[8].

[7] Drinking Water 2015 – Private Water Supplies in England – Case study 7 pp 39-46. http://www.dwi.gov.uk/about/annual-report/2015/pws-wales.pdf

[8] Crabbe, H. Fletcher, T, Close, R. Watts, M.J., Ander, E.L., Smedley, P.L, Verlander, N.Q., Gregory, M., Middleton, D. R. S., Polya, D, Studden. M, and Leonardi, G.S. (2017) Hazard Ranking Method for Populations Exposed to Arsenic in Private Water Supplies: Relation to Bedrock Geology. Int. J. Environ. Res. Public Health 2017, 14, 1490; doi:10.3390/ijerph14121490http://dx.doi.org/10.3390/ijerph14121490

The risk of arsenic contamination was associated with the type of local bedrock geology. Bedrock geology influences soil quality and both have been shown to influence groundwater quality. The British Geological Survey normal background soil contamination maps[9] show where there are high levels of arsenic, cadmium, copper, nickel and lead in soil. These maps can be used to give some idea of the areas where soil quality and bedrock may influence chemical quality of local ground water sources. This gives an indication for the risk of chemical contamination of single domestic private supplies and the need for water testing and monitoring.

Local authorities are best placed to advise on the intervention and treatment options of addressing microbiological and chemical quality of private supplies however they may need support from PHW Health Boards to understand the consequences of the identified risk. Information that might assist local authorities faced with a water quality problem is provided on the DWI's website in the *Manual on Treatment for Small Water Supply Systems*[10]

Safety of private supplies does not rely solely on testing. Risk assessment from source to tap combined with verification by testing should constitute the minimum activities. The risk assessment will then identify and need to sample beyond the levels laid down in regulations and there is freedom for local authorities to expand sampling in response to risk assessments.

7. Precautionary Advice and Key Event Learning Points

Two aspects of issuing warning advice to the public have proved problematic on more than one occasion in the past: the nature/type of the warning given and the provision of alternate supplies. The advice which follows draws not only on problematic events, but also those that were well managed.

7.1. Types of Precautionary Advice

When deciding on the advice to be given there is a choice to be made between one of three types of warning message:

- Boil before Use for drinking and food preparation (BWA – Boil Water Advice).
- Do not use for Drinking or Cooking (DND- Do Not Drink).
- Do not use for Drinking, Cooking or Washing (DNU- Do Not Use).

Whereas a BWA notice causes inconvenience in the home and can be disruptive to

9 http://mapapps2.bgs.ac.uk/bccs/home.html
10 http://www.dwi.gov.uk/private-water-supply/installations/updated-manual-on-treatment-for-small-supplies.pdf

certain businesses (food and drink retailers and manufacturers) and public buildings (health care premises), the water industry has substantive experience of the practical aspects which are manageable and the public is familiar with the concept. Consumers should be advised that they should only use ice made from boiled water and should discard any ice previously made.

By contrast, a DND notice poses a more significant challenge to a water supplier due to the need to make 100 per cent provision of alternative water supplies for drinking and cooking. These logistical problems are magnified and further compounded in the case of a DNU notice because of the hygiene issues implicit in restricting the public's access to piped water for showering and bathing. In some cases it may still be possible to use the water for flushing the toilet but the water supplier involved should make this clear to their consumers. Furthermore, the public is unfamiliar with water restrictions of this nature and on a large scale, and a far wider range of businesses will be affected. It is recommended that DNU notices are reserved for use only in those circumstances where there is unequivocal evidence of persistent contamination of the water supply with a substance (or radioactivity) at a level where short-term exposure is known to give rise to adverse health effects in the otherwise healthy population, and measures to restore the water supply to normal are likely to be protracted (weeks, rather than hours or days). Generally, the type of circumstances when a DNU notice might be considered are those where there is a major chemical pollution event which cannot be contained by the water supplier through stopping abstraction at the treatment works and/or the contamination has entered the treated water distribution system and the extent of the contaminated water cannot quickly be identified and contained/removed.

Another relevant scenario would be where the contaminant cannot be detected by a change in appearance, taste or smell of water (meaning consumers would not be alerted to the problem and thus unlikely to take avoiding action without being warned). In most water quality events, therefore, the decision about which warning notice to issue is a choice between a BWA and a DND. Where there has been a loss of supplies due to a failure of an asset, the water supplier will be able to access records of water fittings inspections and identify whether there are any premises in the affected area classified as high risk in terms of potential to cause water contamination due to back flow or back siphonage. All high risk premises are routinely inspected and checked to ensure adequate back flow protection is in place. Furthermore, a back flow event is limited in scale impacting only on adjacent premises and streets in the immediate vicinity of the back flow site. Accordingly, a BWA notice (not a DWD notice) is the most appropriate one to use in 'loss of supply' events. As with DNU notices, the use of a DND notice should be reserved for those situations to safeguard against exposure to chemicals at a level where short-term exposure is assessed as being likely to give rise to adverse health effects.

The above guidance relates to the general public and in any event it is always important to separately consider the need to issue specific and different advice for vulnerable or sensitive users (e.g. pregnant women, babies and immunosuppressed individuals). This should always be done through pre-arranged communication routes and professional networks, e.g. by local authorities for food manufacturers/retailers, by CCDC/CHPs through GPs or other established medical networks. Water suppliers have standing arrangements in place for notifying dialysis patients and for alternative supply arrangements for hospitals. CCDC/CHPs and local authorities will want to have standing arrangements in place for communicating with other vulnerable groups and other types of health and social care premises. For example, in the event of an infectious disease outbreak (e.g. SARS-CoV-2 (CoViD-19)) local authorities and GPs hold lists for vulnerable consumers who would be shielding and unable to attend bottled water stations. In such circumstances all vulnerable persons should be encouraged to separately register with the water company as requiring bottled water delivery and additional service where required. Current advice for the immunosuppressed in relation to *Cryptosporidium* is contained in Annex 4.

In support of reaching a decision about the most appropriate warning message, the water industry has access to a number of dedicated resources; the UKWIR (UK Water Industry Research) Toxicological Datasheets and Microbiology Datasheets[11] and the Call off Contract. The UKWIR Toxicological Datasheets and Microbiology Datasheets are jointly funded by the water industry and DWI and provide information to assist water suppliers to respond in a rapid and effective manner to a water contamination incident. It should be noted that only UKWIR members have access to these datasheets. In an event, the water company will be able to provide content from the UKWIR database to PHW. The UKWIR datasheets are updated every 5 years to ensure that they contain the most relevant information. The datasheets provide the user with; occurrence and likely sources of the contaminant, information on legislation and standards associated with the parameter, human health and mammalian toxicity data, health based and operational Suggested No Adverse Response Levels (SNARL) values for use in short term exposure situations, taste and odour data including thresholds and descriptors, information and advice concerning substance removal by water and wastewater treatment processes and information on analytical methods and detection limits. The derivation of SNARL values provides the suggested concentration of a contaminant in water that is considered to represent no significant risk to human health over a short period. SNARLS values are generally given for 24 hours or 7 days exposure only and include levels for adults, child and infant intakes. SNARLS are calculated using toxicological data or other derived values (such as the WHO Tolerable Daily Intakes) and include the reasoning behind any uncertainty factors applied. The assumptions used to derive SNARLs are a 60 kg adult drinking 2 L (of water)/ day, a 10 kg child drinking 1 L/ day and a 5 kg bottle-fed infant drinking 0.75 L/day. It is important to note that SNARL values do not constitute standards and are suggested values only to provide guidance to public health professionals.

The Call off Contract is an arrangement put in place and managed by DWI, whereby in an emergency or a security event a water company can access timely, sophisticated analysis for chemicals, toxins and organisms outside the range of routine capability of water testing laboratories. Specialists in PHE, PHW and wider government are

[11] Data Sheets by UKWIR require a log on password that can be provided by UKWIR https://ukwir.org/eng/online-tools

involved with DWI in the ongoing development of the facilities and resources inherent in the Call off Contract.

The water industry has arrangements in place to enable the rapid analysis of a range of contaminants that may result from the deliberate contamination of water supplies however the contractual arrangements of the Call off Contract are overseen by DWI and analysis can only be initiated by a DWI Inspector at the request of a named contact within a water company. The Inspectorate funds research into rapid analytical methods to support this contract.

7.2. Dissemination of Precautionary Advice

Consumers expect to receive and obtain information about their water supply from their water supplier or the relevant person in respect of a private supply. Every household and business or public premise receives details of how to contact their water supplier with their water bill. However, people who live in private rented or social housing may pay their water bill through the landlord, leaseholder or general rates and may not receive a bill directly. It is important, therefore, for local authorities to have plans in place to assist the water company by making social housing managers, landlords and leaseholders aware of any warning advice and generally take steps to facilitate its dissemination to residents and to publicise the water company telephone and website contact details.

The water company or local authority in the case of a private supply, is best placed to identify the area affected by any water supply event. This will be done using a variety of tools, e.g. GIS systems, customer and postcode databases. Some companies now publish the affected area on their websites during an event. As a general principle, at the outset of any event, the water company will err on the side of caution and overestimate the size of the affected area. This is because water supply arrangements can be complex, for example, there can be more than one pipe and supply serving a single street. Also, the water company is often able to quickly rezone an area of supply providing alternative safe supplies by means of pipes. Most water companies will place a description of the affected area by postcode on their website and all water companies will set up a recorded telephone message service which recognises the postcode of the caller and advertises the event information to callers. CCDC/CHPs and local authorities should make sure that warning communications issued by them for vulnerable or sensitive groups of water users direct people to appropriate information about the affected area. It is very important to understand that this information is likely to change during the course of an event. In an event affecting public supplies, it is not recommended that CCDC/CHPs or local authorities prepare their own or separate notices or descriptions of affected areas. Public facing health services and organisations such as NHS 111 Wales (https://111.wales.nhs.uk/) should also be advised to direct people to the water company as the single definitive source of information.

Whereas the water company will deal with issuing advice to the general public and will also handle calls from consumers seeking clarification of the affected area or additional information, it is the role of the PHW to make contact information available to the water company to facilitate the referral of anyone who is reporting illness symptoms. This will be a non-public PHW number or email for water company use only or other professionals. It is also the role of PHW to assist the water company in modifying its standard pre- prepared Frequently Asked Questions (FAQ) and Answers to take account of unique or specific features of the event. The jointly agreed FAQ will be provided to water company call centre staff and can be issued to other organisations that may be called by the public, e.g. local authorities, NHS 111 Wales. Every effort should be made to ensure that a common script is used by all organisations in their call centres and on their websites. The PHW should also be contacted in relation to consumer advice for Private Water Supplies

8. Provision of Alternate Supplies

When there is an extended loss of water supplies or a DND/DNU notice is issued, water companies will provide alternate supplies by several methods depending on the nature and scale of the event:

- Bottled water.
- Static tanks, collapsible boxes with liners or mobile tanks (known as bowsers) and tankers.
- Rezoning (introduction of water from a different source into the piped network).

When bottled water is supplied by a water company in place of a piped supply they must comply with the Water Supply (Water Quality) Regulations 2018. Some commercially available bottled waters may not be suitable for making up feeds for infants due to their mineral (salt) content and all bottled water, like tap water, must be boiled and then cooled prior to use for infant feeds. Water companies have standing arrangements in place for the provision of alternate supplies by means of bottles or containers and compliance with the relevant regulations will be covered by documented procedures and within the contractual arrangements with third parties. The water industry has mutual aid arrangements in place for the mobilisation of tankers and static tanks. Static and mobile tanks and tankers will be clearly marked with a permanent notice at the draw off point to warn users that the water must be boiled before use. While such water supplies will be from a safe source and water companies have strict hygiene arrangements in place for the tanks and tankers themselves, there is no control over the hygienic status of the containers used by the public for collecting water from the draw off point or for storing it within the home. The standing boil water advice therefore safeguards against these hygiene risks.

When static and mobile tanks are deployed they will be refilled by the water company using tankers on a regular basis and their locations publicised. The tanks are designed

to be as vandal-proof as possible, however it is not unknown for the public to attempt to damage or remove these tanks. Local authorities have a role to play in the selection of sites and promotion of monitoring of the security of static tanks by, for example, local community groups, neighbourhood watch schemes etc.
The Security and Emergencies Direction issued by the Department for Environment, Food, and Rural Affairs (Defra) indicates that water company plans should aim to commence the distribution of water by alternative means as soon as possible after the failure has occurred. The amount to be provided should be at least ten litres of water per person per day to all those affected within the first 24 hours of an undertaker becoming aware of an event and this supply should be maintained until the piped supply is restored.

While water suppliers must plan for a minimum of ten litres per person per day in accordance with the notification, there may be emergencies where logistical problems prevent this being achieved in the first 24 hours. It is also recognised that for a major event, the ten litre requirement may not be achievable until the numbers affected are reduced to a level within the Local Response Plan.

If the event is more protracted and piped water is not available for drinking, cooking or washing, the target amount of water to be supplied will be increased. Defra has issued guidance on this additional planning target in 2017. In these protracted circumstances, additional advice will need to be provided to the public regarding sanitation. PHW will lead in the provision of this advice to the public.

In the case of private supplies, the Drinking Water Inspectorate has issued guidance on managing insufficiency of private water supplies[12] which recommends the following;

- Local authorities identify, along with water companies, local options for the provision of alternative water supplies in emergency situations;
- That relevant persons on a supply have a robust documented contingency plan for temporary disruptions (planned maintenance etc.);

The guidance goes on to provide options for provision of and emergency supply.

9. Public Information about Drinking Water Quality

Up until the 2007 Amendment Regulations there was a regulatory requirement on water suppliers to supply all local authorities within their area with an annual report on drinking water quality in a specified format. This is no longer the case, because DWI publishes annual summaries of water company results with a commentary about the significance of the information for the benefit of consumers, businesses, local authorities, health professionals and other regulators. The latest drinking water quality

[12] http://www.dwi.gov.uk/stakeholders/guidance-and-codes-of-practice/pws-alt-supplies.pdf

test results for each water company are summarised on the DWI website[13]. Water companies are still required by the regulations to provide information on drinking water quality on request to any person. This has to be free of charge for information on the zone in which the person resides, but a charge can be made for information on wider areas of supply.

Water companies and CCDC/CHPs should maintain good liaison and there should be at least an annual meeting of the water companies, local authorities and CCDC/CHPs to exchange information, but CCDC/CHPs are also welcome to contact DWI at any time for any information on drinking water quality.

Other sources of water quality information includes the company's own websites, Ofwat pages and the Discover Water site[14], which compares water companies performance on all matters including water quality.

9.1. Consumer Complaints

If a consumer believes there is something wrong with the drinking water in their home or workplace they should contact their water company or, in the case of a private supply, their local authority environmental health department. Water companies can arrange for tests to be done or check that plumbing arrangements are correct and comply with the Water Supply (Water Fittings) Regulations 1999. Companies will advise consumers of the action to be taken or, if required, will take enforcement action to secure improvements in plumbing. If the consumer considers that the water company did not deal with their drinking water quality concerns appropriately they can ask DWI to look into the matter on their behalf.

If the complaint is about another aspect of the water service, such as water charges or pressure, consumers should take the matter up with the regional branch of the Consumer Council for Water[15].

If the water quality concern is about the quality of a water course or water body, the query should be directed to Natural Resources Wales. Natural Resources Wales deals with the protection of the environment and regulates water abstraction and discharges to the water environment.

10. Other UK Drinking Water Regulators

There are equivalent organisations to the Drinking Water Inspectorate in Scotland (the Drinking Water Quality Regulator) and Northern Ireland (the Drinking Water Inspectorate for Northern Ireland). Each has their own regulations and legal

[13] http://www.dwi.gov.uk/about/annual-report/index.htm

[14] www.discoverwater.co.uk

[15] The Consumer Council for Water (CCWater) represents water and sewerage consumers in England and Wales. Their website at http://www.ccwater.org.uk holds more information on their role

responsibilities, but these are almost identical to those applying in England and Wales. The main difference is that there are only single, state owned water suppliers in Scotland and Northern Ireland.

11. Control of New and Emerging Issues: Approach and Rationale

In addition to meeting the numerical standards specified in the regulations, to be considered ‘wholesome’, drinking water must not contain any micro-organism or substance at a concentration which would (on its own or in combination with another micro-organism or substance) constitute a potential danger to human health.

Where micro-organisms or substances not specified in the regulations are identified, their potential danger to human health is assessed on a case-by-case basis. This will involve water companies discussing their findings with CCDC/CHPs and EHOs to determine the significance for the local community, in particular are there are specific groups of individuals who may be more susceptible to the potential effects? Where the presence of certain substances may be potentially more widespread (, or where an emerging issue is considered more significant, DWI may issue national guidance to the water industry. This guidance is based on national advice from PHE Centre for Radiation, Chemical and Environmental Hazards CRCE. It is circulated to all water suppliers, and published on DWI’s website (see http://www.dwi.gov.uk).

12. Drinking Water Quality and Health Research Programme

On behalf of the Government, (Defra) DWI manages the national Drinking Water Quality and Health (DWQH) Research Programme. The research supports Defra and Welsh Government policy on the quality and regulation of water supplies and enables the UK to contribute to the international evidence base for drinking water quality regulations and standards.

Electronic copies of the final reports of all Drinking Water Quality and Health (DWQH) research projects are available on DWI’s website[16].

Executive summaries are also posted on the Foundation for Water Research (FWR) website[17] which also provides links to other research programmes.

DWI and PHW/ PHE have arrangements between them such that PHW/ PHE act as national advisors on the health aspects of drinking water. Continual dialogue exists between PHW/ PHE and DWI staff responsible for scientific evidence on current and emerging issues. Additionally, the DWQH research programme manager co-ordinates formal horizon scanning meetings to identify emerging issues for inclusion in the

[16] www.dwi.gov.uk
[17] www.fwr.org

programme. These discussions involve representatives from across government, other UK drinking water regulators and organisations, such as UKWIR, PHE, PHW, NRW, EA, independent experts, and others.

13. References to Regulation

Water Industry Act 1991
https://www.legislation.gov.uk/ukpga/1991/56/contents

Water Act
2014: https://www.legislation.gov.uk/ukpga/2014/21/pdfs/ukpga_20140021_en.pdf
2003: http://dwi.gov.uk/stakeholders/legislation/wa2003.pdf

Water Supply (Water Quality) Regulations 2016 (as amended) in England
https://www.legislation.gov.uk/uksi/2016/614/contents/made

Water Supply (Water Quality) Regulations 2018 in Wales
https://www.legislation.gov.uk/wsi/2018/647/contents/made

The Private Water Supplies Regulations 2016 (as amended)
https://www.legislation.gov.uk/uksi/2016/618/contents/made

The Private Water Supplies Regulations 2017 (Wales)
https://www.legislation.gov.uk/wsi/2017/1041/contents/made

The Water Supply (Water Fittings) Regulations 1999
http://dwi.gov.uk/stakeholders/legislation/ws(fittings)regs1999.pdf

Annex 1: Drinking Water Hazards

The drinking water quality standards are set out in statute in the Water Supply (Water Quality) Regulations 2016 (as amended) which apply in England and the Water Supply (Water Quality) Regulations 2018 which apply in Wales. The same, or very similar, standards are set out in equivalent regulations in Northern Ireland and Scotland. Most of the standards are those set out in the European Drinking Water Directive and are derived mainly from the recommendations of the World Health Organisation (WHO). There are also some national standards. Each regulated substance or organism is known as a parameter. As well as setting standards for each parameter, the regulations state how often each one should be tested for and where the samples for testing should be taken. About one-third of samples are taken from consumers' taps and the rest are taken from treatment works or treated water storage reservoirs. The parameters and standards are described below. Anyone wishing to find out more about how each standard is derived can do so by accessing the published WHO expert opinion[18]. When the regulations are revised there is full public consultation by Defra.

Microbiological Standards

To protect public health there are microbiological standards which must be met at each treatment works and treated water service reservoir or water tower. Microbiological tests are also undertaken on consumer tap samples. The significance of individual test results for each microbiological parameter at each location varies and a single positive result does not necessarily mean that water is unsafe to drink. Other information is required to assess water safety. Each of the standards is listed below:

Escherichia coli **and Enterococci** are bacteria present in the gut of warm-blooded animals. They should not be present in drinking water and, if found, immediate action is required to identify and remove any source of faecal contamination that is found.
The standard is 0 per 100ml.

Clostridium perfringens is a spore-forming bacterium that is present in the gut of warm-blooded animals. The spores can survive disinfection. The presence of spores in drinking water in the absence of *E.coli* and Enterococci indicates historic or remote faecal contamination that requires investigation. The standard is 0 per 100ml.

Coliform bacteria are widely distributed in the environment often as a result of human or animal activity, but some grow on plant matter. Their presence in a water supply indicates a need to investigate the integrity of the water supply system. The standard is 0 per 100ml.

Colony Counts are general techniques for detecting a wide range of bacteria, the types and numbers being dependent on the conditions of the test. These counts, if

[18] http://www.who.int/water_sanitation_health/water-quality/guidelines/drinking-water-guidelines-revision/en/

done regularly, can help to inform water management, but they have no direct health significance. The standard is ‘no abnormal change’.

Health Based Chemical Standards

Health-based standards for chemical parameters are set using a precautionary approach and on the basis of a lifetime’s consumption of water and taking into account other exposure through routes other than drinking water (e.g. food). Just because a standard has been set for a substance does not mean that it is present in drinking water. The vast majority of the regulated chemicals are never found in drinking water in England and Wales at levels approaching or exceeding the standards. Others may occur only in very specific or local circumstances which are described below. A common situation is leaching from fixtures and fittings or pipework within a specific building water system.

The chemical parameters for which prescribed concentrations or values are specified in the Water Supply (Water Quality) Regulations 2018 in Wales are:

Acrylamide monomer is not normally found in drinking water. It is produced in the manufacture of polyacrylamides occasionally used in water treatment. Its presence in drinking water is limited by control of the product specification. The standard is 0.1 µg/l.

Antimony is rarely found in drinking water. Trace amounts can be derived from brass tap fittings and solders. The standard is 5 µg Sb/l.

Arsenic occurs naturally in only a few sources of groundwater. Specific water treatment is required to remove it. The standard is 10 µg As/l.

Benzene is present in petrol. It is not found in drinking water, but it can migrate through underground plastic water pipes if petrol is spilt in the vicinity. Some bottled waters and soft drinks which include sodium benzoate as an ingredient have been reported as containing benzene. The standard is 1 µg/l.

Benzo (a) pyrene is one of several compounds known as polycyclic aromatic hydrocarbons (PAHs). Their source in drinking water is as a result of deterioration of coal tar which was used to line water pipes up until the early 1970s. Due to extensive water mains refurbishment and renewal it is now rare to detect this substance in drinking water. The standard is 0.01 µg/l.

Boron in surface water sources comes from industrial discharges or from detergents in treated sewage effluents. It can be present in partially desalinated seawater when this is used to supplement drinking water supplies. Concentrations found in drinking waters are generally very low. The standard is 1 mg B/l.

Bromate can be formed during disinfection of drinking water as a result of a reaction between naturally occurring bromide and strong oxidants (usually ozone). It may be generated in the manufacture of sodium hypochlorite disinfectant. Exceptionally, groundwater beneath an industrial site can become contaminated with bromate. The standard is 10 µg BrO_3/l.

Cadmium is rarely detected in drinking water and trace amounts are usually due to dissolution of impurities from plumbing fittings. The standard is 5 µg Cd/l.

Chromium in drinking water comes from the coatings on some taps and plumbing fittings. The standard is 50 µg Cr/l.

Copper in drinking water comes mostly from copper pipes and fittings in households. In general, water sources are not aggressive towards copper, but problems very occasionally occur on new housing estates or in new installations. These 'blue water' events can be avoided by good plumbing practices. The standard is 2 mg Cu/l.

Cyanide is not normally present in drinking water, but could be present in surface water as a result of a specific industrial contamination incident. The standard is 50 µg CN/l.

1,2-Dicholoroethane is a solvent that may be found in groundwater in the vicinity of industrial sites. Where necessary it can be removed by special water treatment. The standard is 3 µg/l.

Epichlorhydrin can be found in trace amounts in polyamine water treatment chemicals. Its presence in drinking water is limited by control of the product specification. The standard is 0.1 µg/l.

Fluoride occurs naturally in many water sources, especially groundwater. It cannot be removed by conventional water treatment, so high levels must be reduced by blending with another low fluoride water source. In addition, some water companies in England are required by the local health authority to fluoridate water supplies as a protection against tooth decay. No fluoridation takes place in Wales.The standard is 1.5 mg F/l.

Lead very occasionally occurs naturally in raw waters, but the usual reason for its presence in drinking water is lead plumbing in older properties. It can also arise from the illegal use of lead solder in water supply installations. If the water supply has a tendency to dissolve lead then water companies treat the water to reduce consumer exposure. The permanent remedy is for householders to remove lead pipes and fittings. The standard is currently 10 µg Pb/l.

Mercury is not normally found in sources of drinking water in the UK. The standard is 1 µg Hg/l.

Nickel occurs naturally in some groundwater and, where necessary, special treatment can be installed to remove it. Another source of nickel in drinking water is the coatings on modern taps and other plumbing fittings. The standard is 20 µg Ni/l.

Nitrate occurs naturally in all source waters although higher concentrations tend to occur where fertilisers are used on the land. Nitrate can be removed by ion exchange water treatment or through blending with other low nitrate sources. The standard is 50 mg NO_3/l.

Nitrite is sometimes produced as a by-product when chloramine (a mixture of chlorine and ammonia) is used as the essential residual disinfectant in a public water supply.
Chloramine is the residual disinfectant of choice in large distributions systems because it is more stable and long-lasting. Careful operation of the disinfection process ensures that levels of nitrite are below the standards of 0.1 mg NO_2/l in water leaving water treatment works and 0.5 mg NO_2/l at consumers' taps.

Pesticides – organochlorine compounds (aldrin, dieldrin, heptachlor, heptachlor epoxide) are no longer used in the UK because they are persistent in the environment. They are very unlikely to be found in drinking water. The standard for each compound is 0.03 µg/l.

Pesticides – other than organochlorine compounds are a diverse and large group of organic compounds used as weed-killers, insecticides and fungicides. Many water sources contain traces of one or more pesticides as a result of both agricultural uses mainly on crops and non-agricultural uses, mainly for weed control on highways and in gardens. Where needed, water companies have installed water treatment (activated carbon and ozone) so that pesticides are not found in drinking water. The standard is 0.1 µg/l for each individual substance and 0.5 µg/l for the total of all pesticides. Water companies must test for those pesticides used widely in their area of supply. Pesticide monitoring thus varies according to the probability and anticipated nature of contamination.

Polycyclic aromatic hydrocarbons is a group name for several substances present in petroleum-based products such as coal tar. The standard is 0.1 µg/l for the sum of all the substances (see Benzo(a)pyrene listed above for more information).

Selenium is an essential element and a necessary dietary component. Amounts in drinking water are usually well below the standard of 10 µg Se/l.

Tetrachloroethane and Trichloroethene are solvents that may occur in groundwater in the vicinity of industrial sites. Where necessary they are removed by specialist treatment. The standard is 10 µg/l for the sum of both substances.

Trihalomethanes are formed during disinfection of water by a reaction between chlorine and naturally occurring organic substances. Their production is minimised by good operational practice. The standard is 100 µg/l.

Vinyl chloride may be present in plastic pipes as a residual of the manufacturing process of polyvinyl chloride (PVC) water pipes. Its presence in drinking water is controlled by product specification. The standard is 0.5 µg/l.

National Chemical and Physical Standards

The European Drinking Water Directive (DWD) recognises that Member States can set additional standards and the UK has decided to retain national mandatory standards for several parameters set in the original 1980 DWD that have become additional monitoring parameters in the 1998 DWD. Most of the standards are set on the basis that higher levels may make the water unacceptable to consumers on the grounds of taste, odour or appearance.

Aluminium occurs naturally in some source waters. It is removed from drinking water by conventional water treatment (coagulation and filtration). Aluminium sulphate and polyaluminium chloride may be used as water treatment chemicals at some water treatment works. The standard is 200 µg Al/l.

Colour occurs naturally in upland water sources and is caused by natural organics which are characteristic of these catchments. It is removed by conventional water treatment. The standard is 20 mg/l on the Pt/Co scale.

Iron is present naturally in many water sources. It is removed by water treatment. Some iron compounds are used as water treatment chemicals. However, the most common source of iron in drinking water is corrosion of iron water mains. The standard is 200 µg Fe/l.

Odour and Taste can arise as a consequence of natural substances in surface waters, particularly between late spring through to early autumn. Water treatment with activated carbon or ozone will remove these natural substances. The standard is described as acceptable to consumers and no abnormal change in odour or taste.

Sodium is a component of common salt (sodium chloride). It is present in seawater and brackish groundwater. Some water treatment chemicals contain sodium. Concentrations in drinking water are extremely low, but some water softeners can add significant amounts where they are installed in homes or factories. The standard is 200 mg Na/l.

Tetrachloromethane is a solvent that may occur in groundwater in the vicinity of industrial sites. Where necessary it is removed by specialist water treatment. The standard is 3 µg/l.

Turbidity is a measure of the cloudiness of water. It can arise from disturbance of sediment within water mains. The standard at consumers' taps is 4 NTU (see also turbidity at treatment works below).

On occasion, the measurement of turbidity is carried out by a method other than that specified in the drinking water regulations and the results reported as a quantity of suspended solids. This cannot be easily converted to NTU. Organisations responsible for testing water under the relevant drinking water regulations are required to use the designated methods and report in the units specified in the regulations

Additional Monitoring Parameters

In addition to the drinking water standards, water companies are required to test for additional indicator parameters to assist them with good water supply management and the control of drinking water quality. Some of these parameters have a European guide value set for the purpose of triggering an investigation of the water supply.

Ammonium salts are naturally present in trace amounts in most waters. Their presence might indicate contamination of sanitary significance and they interfere with the operation of the disinfection process. The guide value is 0.5 mg NH_4/l.

Chloride is a component of common salt. It may occur in water naturally, but it may also be present due to local use of de-icing salt, leachate impaction or saline intrusion. The guide value is 250 mg Cl/l.

Conductivity is a non-specific measure of the amount of natural dissolved inorganic substances in source waters. The guide value is 2,500 µS/cm.

Hydrogen Ion (pH) gives an indication of the degree of acidity of the water. A pH of 7 is neutral; values below 7 are acidic and values above 7 are alkaline. A low pH water may result in pipe corrosion. This is corrected by adding an alkali during water treatment. The guide value is a range between 6.5 and 9.5.

Indicative Dose is a measure of the effective dose of radiation the body will receive from consumption of the water. It is calculated only when screening values for gross alpha or gross beta (radiation) are exceeded. The guide value is 0.10 mSv/year.
For more information on monitoring for radioactive substances see;
http://dwi.defra.gov.uk/private-water-supply/regs-guidance/Guidance/info-notes/england/reg-11.pdf

Radon is a radioactive gas that occurs naturally in the environment. The guide value is 100 Bq/l.

Sulphate occurs naturally in all waters and cannot be removed by treatment. The guide value is 250 mg SO_4/l.

Total Organic Carbon represents the total amount of organic matter present in water. The guide value is ‘no abnormal change’.

Tritium is a radioactive isotope of hydrogen. Tritium is present in the environment is mainly of man-made origin, but some tritium is formed naturally as a result of cosmic ray interactions in the upper atmosphere, but these levels are very low. Discharges to the environment are strictly controlled and there is a national programme of monitoring surface waters. The guide value for drinking water sources is 100 Bq/l.

Turbidity measurement is an important non-specific water quality control parameter at water treatment works because it can be monitored continuously on line and alarms set to alert operators to deterioration in raw water quality or the need to optimise water treatment. The standard at treatment works is 1 NTU.

Other Pathogenic Organisms

There are a wide range of pathogenic organisms capable of causing adverse human health effects if they are introduced into drinking water supplies. Contaminated water can be the source of large outbreaks of disease, however, for the majority of waterborne pathogens there are other equally important sources of infection, such as person to person contact and food. The human health effects caused by waterborne transmission vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, typhoid fever, cholera, cryptosporidiosis and giardiasis. Most waterborne pathogens are introduced into drinking water supplies in human or animal faeces, they do not grow in water and infection is initiated in the gastrointestinal tract. However, some are environmental organisms that grow in water and soil, and can cause opportunistic infections through other routes of transmission, such as inhalation leading to respiratory infections (legionellosis) or infections at sites as diverse as skin and brain (*Naegleria fowleri*).

For an exhaustive global list of fact sheets on pathogenic organisms potentially associated with water-related infections see Chapter 11 of the WHO Guidelines for Drinking Water Quality[19] Set out below is a summary of the subset of pathogenic organisms of direct relevance to waterborne transmission in the context of UK private and public water supplies.

Bacterial Pathogens

Aeromonas species occur widely in water, soil and food, and are capable of growth in water distribution systems. They are capable of infecting open wounds and septicaemia can occur in immuno-compromised persons. The presence of aeromonads in drinking water is generally considered a nuisance rather than a health hazard. The organisms are detected by colony counts and controlled by good water supply distribution management and hygiene practices.

Campylobacter species are one of the most important causes of acute gastroenteritis worldwide. *Campylobacter jejuni* is the most frequently isolated species from patients with acute diarrhoeal disease. As few as 1,000 organisms can cause infection and most infections occur in infants and young children. Wild and domestic animals, especially poultry, wild birds and cattle, are important sources, other sources include domestic pets and contaminated food and drinking water, including meat and unpasteurised milk. Control of drinking water transmission relies on the protection of raw water sources from animal and human waste, adequate disinfection and protection of stored water from animal and bird faeces.

***Escherichia coli* pathogenic strains** Most *E. coli* strains are present in large numbers in the normal gut flora of humans and animals. A few strains can cause serious disease (bacteraemisa, urinary tract infections, meningitis) in other parts of the body and some cause acute diarrhoea.

These enteropathogenic *E. coli* are identified on the basis of virulence factors and

[19] http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/

the most well known in the context of waterborne transmission are the enterohaemorrhagice *E. coli* (EHEC), particularly serotypes O157:H7 and O111. As few as 100 organisms can cause infection and up to seven per cent of cases develop a potentially fatal haemolytic uraemic syndrome (HUS) characterized by acute renal failure due to production of two enterotoxins simultaneously. Control of drinking water transmission of pathogenic *E. coli* is the same as that for other *E. coli,* namely raw water protection from faecal waste, adequate disinfection and protection of stored water.

Legionella species are potentially pathogenic for humans, *Legionalla pneumophila* is the major species responsible for legionellosis which occurs in two clinical forms; legionnaire's disease, a pneumonia, and Pontiac fever, a milder respiratory infection. *Legionella spp* are common in surface waters and moist soils, and they grow in warm conditions in the range of 25 – 50 degrees centigrade. Transmission is via inhalation. Control focuses on building water system design and maintenance through minimising the production of water aerosols and limiting growth conditions by keeping cold water cold and hot water hot. Most large waterborne outbreaks have been linked to cooling towers which are poorly maintained, whereas sporadic infections are more commonly linked to hot water systems in large buildings.

Mycobacteria The non-tuberculous or atypical strains are natural inhabitants of water environments. They can give rise to a range of diseases involving the skeleton, lymph nodes, skin and soft tissue as well as respiratory, gastrointestinal and genitourinary tracts. They are a major cause of disseminated infections in immunosuppressed patients and a common cause of death in HIV positive persons. Only two species have been reported in tap water, *M. kansasii* and *M. avium* complex. Water-related infections due to the latter have been attributed to unfiltered water supplies and *M. kansasii* has been found in domestic showers and hospital water systems in the Netherlands and UK respectively.

The organisms are more resistant to disinfection with chlorine than other bacteria, such as coliforms, therefore control relies on treatment by filtration and effective management of distribution systems to minimise growth conditions and maintenance of a persistent level of residual chlorine.

Pseudomonads are common environmental organisms with similar characteristics to Aeromonads (see above). *Pseudomonas aerugionsa* is capable of growing on specific construction materials used in building plumbing systems, swimming pools and spas. Exposure to high numbers in water in the latter settings can cause folliculitis (rashes) and ear infections, and the organism can infect wounds and give rise to septaceamia and meningitis in the immunosuppressed patient. Control is through the use of suitable approved materials in the design of pools, spas, plumbing systems and water mains.
Incidences of high numbers of the organism in packaged waters has been associated with complaints of taste and odour, and this has resulted in a monitoring standard of <1 per 250ml being set for bottled waters. Bottled water guidence can be found at https://www.food.gov.uk/business-guidance/water-guidance-for-wales-and-northern-ireland. There is no equivalent standard for public water supplies due to the fact they are not normally in packaged form.

Salmonella spp species cause either gastroenteritis, septicaemia, enteric/typhoid fever and a carrier state in previously infected persons. Typically diarrhoea is accompanied by fever and abdominal pain which is self-limiting, but infection with *S. typhi* and *S. paratyphi* (typhoid strains) is more serious and can be fatal. Waterborne typhoid fever outbreaks have devastating public health implications. The typhoid strains are restricted to humans, but others such as *S. typhimurium* and *S. enteritidis* occur in a wide range of livestock, including poultry. Contamination has been detected in many foods and milk, and these pathogens gain access to water sources from sewage discharges, livestock and wild animals. Control measures involve protection of raw water from animal and human waste, adequate disinfection and protection of stored water from animal and bird faeces.

Shigella spp cause serious intestinal diseases mostly in young children, including bacillary dystentery. Only 10 – 100 organisms are required to cause infection resulting in severe watery diarrhoea, abdominal pain and fever. A milder self-limiting disease is caused by the *S. sonnei* strain. The organisms are restricted to humans and higher primates with most cases of shigellosis occurring in the institutional setting due to poor sanitation.

Prevention of waterborne outbreaks is important due to the severity of the illness caused and control is by protection of raw and treated water from human waste combined with adequate disinfection.

Toxic Cyanobacteria are photosynthetic bacteria that share some properties in common with algae, hence they are commonly known as blue green algae. However, there are many which are not blue green and can range in colour from yellow to brown and red. Cyanobacteria are common in the environment occurring in soil, sea water and freshwater. Sunlight and warm weather stimulate growth especially in stagnant waters or low flow conditions and in the presence of high nutrient levels (eutrophic waters). Some will form floating surface blooms or scums, others stay mixed in the water column or are bottom dwelling (benthic). Their public health significance derives from the ability of some species to form toxins. At least 13 toxin producing species have been identified and each toxin has specific properties with distinct concerns, including liver damage, neurotoxicity and tumour production. Acute symptoms after exposure include gastric disorders, fever and irritations of the skin, ears, eyes, nose and throat. Cyanobacteria do not multiply in the body and hence they are not infectious. Control relates to source water abstraction management and the minimisation of algal blooms together with prevention of direct recreational contact with algal blooms and by excluding light from stored water tanks.

Vibrio spp Non-toxigenic strains are widely distributed in water environments, but toxigenic strains occur in water less often because they are generally limited to humans, although they have been found inside aquatic organisms like crustaceans and algae. The prevalence of *V. cholerae* declines notably in colder waters (below 20 degrees centigrade).Illness symptoms are due to the production of the cholera enterotoxin. The majority of those infected do not develop illness, however those who do will experience characteristic ‘rice water stools’ and suffer severe dehydration and loss of electrolytes which is fatal without treatment. High numbers of organisms are required to cause infection, therefore person to person contact is not the main cause of spread and serious outbreaks are due to poor sanitation and ingestion of faecally contaminated food and water. Control is by protection of raw water from human waste, adequate disinfection and protection of stored water.

Viral Pathogens

Viruses associated with waterborne transmission are predominantly those that infect the gastrointestinal tract and are excreted in human faeces (enteric viruses). As a group, viruses can cause a wide variety of infections and symptoms involving different routes of transmission, sites of infection and routes of excretion. It is worthy of note that viruses responsible for respiratory infection can be discharged in faeces and contaminated water may therefore be a route of transmission through aerosols and droplets. It is also thought that polyomaviruses excreted in urine and linked to long-term health effects have the potential for waterborne transmission. An important issue for control of waterborne transmission is the fact that viruses generally survive better in water, particularly in cold climates, than bacterial indicator organisms. Consequently, satisfactory indicator test results do not preclude the presence of viruses. Another important factor to be considered is the greater resistance of viruses to disinfection compared to bacteria.

Adenoviruses Infections have been linked to consumption of contaminated food and drinking water, although person to person spread through shared utensils and contaminated surfaces in the institutional setting is the more common source of outbreaks of gastroenteritis. Eye infections have been linked to the sharing of towels and goggles when swimming. These viruses consist of double stranded DNA and generally do not grow in cell culture, therefore detection relies on polymerase chain reaction (PCR) techniques. Control is made problematic because human adenoviruses are exceptionally resistant to disinfection, especially UV light irradiation. Protection of raw and treated water is therefore very important to control risks from drinking water supplies.

Astroviruses are single stranded RNA viruses detected in environmental samples by PCR techniques. They cause self-limiting gastroenteritis in young children and infected individuals excrete large numbers of the virus in faeces, hence the viruses will be present in sewage. Person to person spread in day care, home settings and institutions is common. Contaminated food and water may be an important route of transmission. Control measures are the same as for Adenoviruses although UV maybe more effective.

Caliciviruses are single stranded RNA viruses which include the genera Norovirus (Norwalk like viruses). The human caliciviruses are a major cause of acute viral gastroenteritis in all age groups. Symptoms include nausea, vomiting and abdominal cramps. Less than half of those infected present with diarrhoea and some have a fever. Known as winter vomiting disease the symptoms are relatively mild and self-limiting, however the high attack rate denotes a low infectious dose. Since the virus is excreted in faeces it will occur in domestic waste water as well as contaminated food and drinking water. Numerous water-related outbreaks have been documented in relation to recreational water, ice, water on cruise ships, other drinking waters and shellfish harvested in polluted estuarine waters. Control measures relate to the protection of raw and treated water from faecal contamination and adequate disinfection.

Enteroviruses are a wide group of viruses which include poliovirus, coxsackievirus, echovirus. They are the smallest viruses and consist of a single stranded RNA genome. Many can be detected in environmental samples by cell culture. Enteroviruses are all excreted in the faeces of infected individuals and are therefore the most numerous viruses in sewage and sewage polluted waters, however the predominant route of transmission is by person to person contact and inhalation. Control measures relate to the protection of raw and treated water from faecal contamination and adequate disinfection.

Hepatitis A is highly infectious and the infecting dose is low. Like other enteric viruses, Hepatitis A virus enters the gastrointestinal tract by ingestion where it infects epithelial cells and then enters the bloodstream to reach the liver where it can cause severe damage in around ten per cent of adult cases. There is a long incubation phase of around 30 days followed by a characteristic onset of symptoms, such as fever, malaise, nausea, anorexia and eventually jaundice. The evidence for waterborne transmission of Hepatitis A is well documented and stronger than it is for all other viruses. Food borne outbreaks are also relatively common. Travel of people from areas with good sanitation to those with poor sanitation is associated with a high risk of infection, as is drug abuse. Control measures relate to the protection of raw and treated water from faecal contamination and adequate disinfection.

Hepatitis E is similar in its effects to Hepatitis A, however, the incubation period for infection is longer and there is a high mortality rate in pregnant women. Currently cases and outbreaks are rare in the UK. Control measures are the same as Hepatitis A above.

Rotavirus are double stranded RNA viruses some of which infect humans while others are specific to animals. They are not grown readily in cell culture, but can be detected in environmental samples by PCR techniques. Human rotaviruses are the most important single cause of infant death in the world. The virus infects cells in the villi of the small intestine and disrupts sodium and glucose transport. Person to person transmission and inhalation are the important routes of spread, however, both water and food borne outbreaks are documented. Rotavirus may be more resistant to conventional disinfection techniques than other viruses. Control measures are the protection of source and treated water from contamination by human faecal wastes, and careful attention to adequate treatment and disinfection of drinking water prior to supply to consumers.

Protozoan Pathogens

Protozoa are common causes of human and animal infection which present real challenges for control because most produce cysts or oocysts that are extremely resistant to disinfection and survive for long periods in water and the environment.

Ancanthamoeba is a free living amoebae common in water and soil. Under unfavourable conditions it develops a dormant cyst capable of withstanding extremes of temperature (-26 to 56 degrees C). Cases of acanthameobic keratitis, a painful infection of the cornea, have been associated with the use of tap water in preparing solutions for washing contact lenses.

It is a rare disease but may lead to impaired vision, blindness and loss of the eye. Since the cleaning of contact lenses is not considered to be a normal domestic use of tap water, control is through the purchase and use of proprietary, sterile, lens cleaning solutions.

Cryptosporidium This parasite has a complex life cycle which causes a self-limiting, but prolonged unpleasant, diarrhoeal illness in humans and animals. It forms oocysts which are shed in faeces in very high numbers. The main route of infection is by person to person spread and by direct contact with farm animals and sometimes pets. However, outbreaks due to faecally contaminated drinking water are widely documented. Ingestion of ten oocysts or fewer can lead to infection. The oocysts are very resistant to chlorine, therefore control is achieved by source water (catchment) protection, filtration and disinfection with UV irradiation. For information on *Cryptosporidium* in drinking water is available on DWI's website[20]

Health teams are advised that they liaise with the local water company to review Cryptosporidium monitoring data if a change in the number or distribution of cases of cryptosporidiosis notified by diagnostic laboratories is observed.

Any trigger level for notification by the water companies to health teams and thresholds for action will need to vary depending on many factors, not limited to but including: the treatment in place at the water treatment works and its performance, the historical results for the works, and the population served. Features of the parasites present (such as their potential infectivity for humans) are also part of the equation but that information may not be available or only obtained later. Review on a case-by-case basis therefore forms a pragmatic approach. It is therefore important to keep ongoing communication with the water companies.

Giardia is a protozoan which colonises the gastrointestinal tract of humans, and some animals, forming a thick walled cyst which is shed intermittently in faeces. It causes diarrhoea and malabsorption in the small intestine. Illness is generally self-limiting, but can be chronic, lasting over one year, in otherwise healthy people. As few as ten cysts are required for infection. The cysts survive for months in water. Person to person contact is the commonest route of transmission between children. Although more resistant to disinfection with chlorine than bacterial pathogens, unlike *Cryptosporidium*, chlorination can be used as a control measure together with filtration and source water protection.

Naegleria fowleri is a free living amoeboflagellate distributed widely in the environment which forms resistant cysts under unfavourable conditions. It causes primary amoebic meningocephalitis in healthy people by entering the brain through penetration of the olfactory mucosa. The disease is acute and patients often die within ten days before diagonosis. Cases are rare, but occur every year. Naegleria are thermotolerant and found in warmer waters such as hot springs and swimming pools or spas. Infection is contracted by exposure of the nasal passages to contaminated water and thus predominantly associated with recreational water uses. Control is by means of reducing water temperature (below 25 degrees C) and the maintenance of a stable and effective residual chlorine level of at least 0.5 mg/l.

[20] http://www.dwi.gov.uk/research/bouchier/index.htm

Other Chemicals

Perfluorooctane sulphonate (PFOS) and perfuoroocanoic acid (PFOA) may be present in the environment and water sources as a consequence of their historic use as firefighting foams. DWI has issued guidance based on PHE advice on trigger levels for monitoring and notification in respect of both these substances (http://dwi.gov.uk/stakeholders/information-letters/2009/10_2009annex.pdf).

N-nitrosodimethylamine (NDMA) is a by-product of industrial processes that use nitrate and/or nitrite and amines. It can also be formed during sewage treatment and during water treatment as a disinfection by-product. It is generally accepted as being a genotoxic carcinogen. DWI has issued guidance based on PHE advice on trigger levels for monitoring and notification in respect of this substance (DWI Information Letter 07/2012).

Chromium VI is a toxic form of the chromium element and DWI has provided some advice on this chemical. (DWI Information Letter 02/2017: http://dwi.gov.uk/stakeholders/information-letters/2017/02-2017.pdf)

Other Resources

Other resources for public health advice of microbiological contaminants include:

- PHW Webpages - https://phw.nhs.wales/
- PHE webpages – https://www.gov.uk/topic/health-protection
- Cryptosporidium Reference Unit - https://www.gov.uk/guidance/cryptosporidium-reference-unit-cru

Some additional resources for public health advice on chemical and radiological contaminants include:

- PHE’s Chemical Hazards Compendium https://www.gov.uk/government/collections/chemical-hazards-compendium
- Section 8.7 of the WHO publication, Guidelines for Drinking Water Quality (4th Edn.), which identifies local actions in response to chemical water quality problems and emergencies. In particular sections 8.7.3 and 8.7.4 in relation to talking to the right people and public advice. http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/
- In England, refer to local HPT and PHE CRCE duty desk for advice: email crce-ehe@phe.gov.uk
- In Wales, refer to local Health Board and CRCE Wales for advice.

Annex 2: Content of Notifications about Drinking Water Quality Events

Set out below is the template used by DWI Inspectors when contacted by a water company making the initial notification of a water quality event. The text in italics indicates the nature of the information that DWI expects the company to provide as a minimum at the outset of an event. This is the type of information that a CCDC can expect to be provided with by a water company when they first contact a CCDC with a view to obtaining health advice. Typical additional questions that a CCDC may want to ask the water company to enable a health risk assessment to be made are listed below.

DWI Water Quality Event Notification Template

Company	*Water supplier making the notification and responsible for the affected water supply, if more than one water company is affected by a water quality event then each one will notify their particular circumstances*
Name of event	*Water company description of the event which will be used throughout the management and subsequent investigation of the event, usually takes the form of nature/location descriptor, e.g. burst trunk main in Essex Road, Islington*
Person making the notification	*Name of water company person making the notification and responsible for ongoing updates*
Date and time of notification	*Time/Date when DWI inspector received notification*
Date/Time/Location of event	*Time when company first became aware of an event and the location of the assets first affected, e.g. works, reservoir, street*
Nature of event	*Water company description of what has happened, typically a description of the impact, e.g. discoloured water and low pressure complaints from consumers; report received from Environment Agency of dead fish one mile upstream of abstraction intake at N works; sample result from X location with a result of Y etc.*
Population and Area affected	*Estimate of population resident in the water quality zones potentially affected by the event, together with names of the water quality zones.*
Likely cause(s)	*Water company initial assessment of the cause of the event, e.g. third party damage to a water main; illegal discharge from a factory into the River X etc*

Action taken to inform/protect consumers and details of risk assessment	*Details of:* *advice issued to consumers, e.g BWA notice* *alternative supplies provided* *any customer call centre/website tape recorded message*

Action being taken to rectify the situation	*Details of the action already taken and planned to restore the water supply to normal*
LAs/HAs informed?	*Name of person notified in the relevant local authorities and the Health Protection Unit of PHE/PHW and the nature of any advice provided and/or any conference calls/meetings arranged*
Level of publicity	*Details of any media awareness*

Additional information that may be required to support a health risk assessment by PHW.

1. Description of affected water supply from source to tap, in particular, details of source water (surface, ground), water treatment in use and/or proposed either temporarily/permanently, treated water storage (service reservoirs, towers, tanks, tankers, bowsers, bottles), distribution mains (details of planned or unplanned work and nature of materials if work on mains involved), nature of building (public, private, social care, office, factory etc.) including any high risk premises in respect of back flow prevention inspection.
2. Nature of any actual or suspected contaminants (chemical, biological, radiological) and concentration of any contaminant/organism, including details of samples already taken and samples planned to be taken.
3. Historic water quality testing data (should also refer to drinking water, annual report by DWI if the event relates to a known or ongoing problem).
4. UKWIR (for example Toxicological Datasheets or Microsheet Data) or WHO information about the contaminants/organisms.
5. Technical information about any loss of, or proposed changes to, water treatment, including disinfection at works, also details of addition of chlorine to the network or service reservoirs (DWI is the source of advice on approved treatment chemicals, treatment performance and operational best practice).
6. For incidents at a works or a service reservoir, an estimate of the time required for the contaminants/organisms to pass through the water supply system under normal operating conditions and, where relevant, any remedial measure, such as removing assets from supply, rezoning or high velocity flushing, which may affect these time estimates (the water industry and Natural Resources Wales have time of travel models for river pollution incidents.

Annex 3: Examples of Precautionary Notices for Consumers

The following pages provide suggested templates that could be used by authorities with powers to issue restriction notices. While companies generally have their own notices, there has been a demand for templates that could be used by other authorities (local authorities). Examples provided below include ‘Boil water’ notice, ‘Do not drink’ notice, ‘Do not use’ notice and also an ‘All clear’ notice used to inform consumers of the return of normal supplies. These are available as Microsoft Word templates on the DWI website. It is important that they are branded by the authority using them in the normal manner for their communication with customers as this will allow consumers to understand who is issuing the instructions and will be able to identify with the normal branding.

Boil Water Notice

Text box to identify the name of the issuing authority and any relevant 'branding'

This is an instruction to

BOIL YOUR TAP WATER

UNTIL FURTHER NOTICE

USE **BOILED** AND COOLED TAP WATER FOR

- Drinking/cleaning teeth
- Cooking
- Making Ice
- Making up babies' feed
- For pets

YOU CAN USE **UNBOILED** WATER FOR

- Bathing
- Washing clothes
- Washing dishes
- Flushing the toilet

You will be advised by [insert name of organisation that will rescind the BWN] when your supply is back to normal.
For any questions about this instruction please contact [insert name of organisation providing advice]

Do Not Drink Notice

Text box to identify the name of the issuing authority and any relevant ‘branding’

This is an instruction

DO NOT DRINK YOUR TAP WATER UNTIL FURTHER NOTICE

DO NOT USE TAP WATER FOR

- Drinking or cleaning teeth
- Cooking or preparing food or babies’ feed
- Making Ice
- For pets’ water

TAP WATER CAN BE USED FOR

- Washing and bathing
- Washing clothes
- Washing dishes
- Flushing the toilet

You will be advised by [insert name of organisation that will rescind the BWN] when your supply is back to normal.
For any questions about this instruction please contact [insert name of organisation providing advice]

Do Not Use Notice

Text box to identify the name of the issuing authority and any relevant 'branding'

This is an instruction

DO NOT USE YOUR TAP WATER UNTIL FURTHER NOTICE

DO NOT USE TAP WATER FOR

- Drinking or cleaning teeth
- Cooking or preparing food or babies' feed
- Making Ice
- For pets' water
- Washing and bathing
- Washing clothes or dishes

TAP WATER CAN BE USED FOR

- Flushing the toilet [amend depending on nature of issue]

You will be advised by [insert name of organisation that will rescind the BWN] when your supply is back to normal.
For any questions about this instruction please contact [insert name and contact details of organisation providing advice]

All Clear Notice

Text box to identify the name of the issuing authority and any relevant 'branding'

This is an instruction

YOU MAY NOW USE YOUR TAP WATER

- Your tap water supply is now back to normal
- Please run your taps to make sure that fresh water is drawn through the system before using it.

For any questions about this instruction please contact [insert name and contact details of organisation providing advice]

Annex 4: Advice on Precautions to be taken by the Immunosuppressed Individual in Relation to Boil Water Notices

CMO's Update[22] - a communication to all doctors from the Chief Medical Officer

The Bouchier Report *Cryptosporidium* in Water Supplies: Third Report of the Group of Experts (1998)[21] included advice for the immunosuppressed. This was publicised in the February 1999 edition of Chief Medical Officer's (CMO) Update[22]. A working group of specialists chaired by Professor Ian Bouchier then defined further which groups of immunosuppressed patients are at particular risk of cryptosporidiosis infection and should boil their drinking water in the August 1999 edition of the CMOS's update[22]. The level of T-cell function and the duration of any immune suppression were considered to be crucial factors in susceptibility to Cryptosporidium. The group concluded that the advice should be that anyone whose T-cell function is compromised (this includes people with HIV infection who are immunosuppressed, children with severe combined immunodeficiency (SCID) and those with specific T-cell deficiencies, such as CD40 ligand deficiency, also known as Hyper IgM Syndrome), should be advised to boil and cool their drinking water from whatever source. This includes tap or bottled water, and ice cubes should also be produced from boiled and cooled water.

It is especially important to boil water from a private water supply serving a property (or properties), even with UV treatment, as this will not have any residual disinfection, and also where there is a potable supply where outlets do not come direct from the rising main, e.g where a storage tank is used. This advice would also extend to avoiding the use of un-boiled water for cleaning teeth. See http://www.dwi.gov.uk/stakeholders/guidance-and-codes-of-practice/Boiling-water01-15.pdf

Any particularly vulnerable sub-group should be risk assessed and advised by their managing clinical consultant to take additional precautions as appropriate

UK guidance on the safety of various types of bottled water is to be found on the NHS choices web site for use by infants. The salt and sulphate content of bottled water may not be sufficiently low for infant formula. https://www.nhs.uk/common-health-questions/childrens-health/can-i-use-bottled-water-to-make-up-baby-formula-infant-formula/

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[21] *Cryptosporidium* in Water Supplies – Third Report of the Group of Experts to: Department of the Environment, Transport and the Regions & Department of Health. Chairman Professor Ian Bouchier November 1998. HMSO

[22] http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4013568.pdf

guardians of drinking water quality

Drinking Water Inspectorate | Nobel House | London | SW1J 3JR

Tel: 0300 068 6400 | http://www.dwi.gov.uk

Drinking Water Inspectorate
Guidance to water companies

Guidance Note: Long term planning for the quality of drinking water supplies

Guidance Note on Long Term Planning for the quality of drinking water supplies

1. Purpose

1.1. The purpose of this guidance note, henceforth 'the Guidance' is to provide water companies and other stakeholders with direction on long term planning for the quality of drinking water supplies.

1.2. The Guidance provides clarity on the expectations of the Drinking Water Inspectorate 'the Inspectorate' as companies prepare their business planning scope and proposals for the next periodic review PR24.

1.3. The Guidance also provides advice on how the Inspectorate might assist companies in the periodic review process for setting of prices, led by Ofwat, including details of arrangements for information submissions to the Inspectorate; the Inspectorate's assessment processes; and a timeline for supporting current expectations of PR24 requirements.

1.4. The Guidance takes account of the Strategic Policy Statement (SPS) (https://www.gov.uk/government/publications/strategic-policy-statement-to-ofwat-incorporating-social-and-environmental-guidance/february-2022-the-governments-strategic-priorities-for-ofwat) to Ofwat from the Defra Secretary of State on strategic priorities and the current draft Welsh Government Strategic Priorities and Objectives Statement to Ofwat from the Welsh Government with a focus on strategic objectives for Wales. The Guidance also has due regard to key policy documents from both the UK government and the Welsh Government where appropriate.

1.5. This Guidance note is not intended to be a comprehensive review of water supply practice. There are no new policy initiatives set out herein, and no new legal obligations. The focus is on delivery of existing obligations, including recent and imminent legislative changes, addressing current and emerging matters whilst using current good practice within a long-term planning context.

1.6. We will update this document as necessary to take account of developments in legislation, policy and industry good practice and future periodic reviews. The Inspectorate welcomes comments on the document, including suggestions for areas or matters not currently included.

1.7. The regulatory framework that sets the context for the Guidance is summarised in our Guidance on the Regulations: Introduction to the Public Water Supply Regulations in England and Wales (https://www.dwi.gov.uk/water-companies/guidance-and-codes-of-practice/guidance-on-implementing-the-water-supply-water-quality-regulations).

2. Content summary

3. Principles of approach

3.1 The Inspectorate expects all water companies to take a source to tap approach to manage their water supplies to protect the health of their consumers and maintain consumer confidence in the supply and services provided. Central to achieving these objectives is the mandatory use of Water Safety Plans (WSPs) and the inherent approach to assessing and managing risks. The Inspectorate recognises that the water safety planning approach is both national and international best practice for water supply management.

3.2 The delivery of this approach should be efficient and sustainable and contribute to a lasting legacy of long-term benefit for both the company and its consumers. To have legitimacy, and to gain the support of the Inspectorate, a company's WSP approach needs to be transparent about the identified challenges and risks, risk management and both the short and long-term investment requirements, for current consumers and future generations.

3.3 For all aspects of planning, whether for event management, drought management, water resource management, maintenance management or operations management, it is a fundamental requirement that drinking water quality is always central to, and accounted for, in all cost benefit assessments of options considered. It is expected that companies will always plan to meet their statutory obligations for drinking water quality.

3.4 The sustainability and resilience of the quality of supplies are important for consumers and their confidence; hence these aspects need to be an integral part of all planning and delivery functions of a company. It is expected that companies will plan for existing and future needs from a stewardship perspective across generations of consumers. To do so, companies will need to foster and develop their supply chain to enable and retain the knowledge and skills that are the bedrock for building efficient, innovative solutions and services.

3.5 In respect of routine operational resilience, it is expected that every company will proactively plan for the resistance to and recovery from potential adverse events that might otherwise impact on consumers, with a view to maintaining levels of drinking water quality protection, confidence, acceptability and services. There are threats to the sector from a range of notable sources such as:

- Extreme weather incidents disrupting supplies (planning, preparation, resilience, and compliance with SEMD requirements)
- Longer term impacts of climate change (temperature changes, risk to water availability, efficacy of some treatment processes etc.)
- Unauthorised IT intrusion and manipulation (impact of data, control systems for example) hence the need for suitable provisions under NIS.

3.6 Given the relative stability of the legislative framework for drinking water quality, and the consistency of approach over time, the Inspectorate expects that companies' operations and maintenance arrangements should consistently, proactively and sustainably meet all statutory obligations, while addressing any localised changes to risk profiles using established risk assessment reporting processes. We believe that this is at the heart of the relationship between a water company and its consumers. It is underpinned by the embedded company culture and staff behaviours that support a level of quality and service that consumers expect, and it underpins how problems are effectively addressed when they arise. By its activities over time, a company demonstrates its trustworthiness, to gain the trust and confidence of its consumers.

3.7 References in this Guidance to the **Act** and the **Regulations** are to the Water Industry Act 1991 (and updates/amendments), and the Water Supply (Water Quality) Regulations 2016 for England and the Water Supply (Water Quality) Regulations 2018 for Wales. Links to these and other relevant key legislation can be found on the Inspectorate's website (https://www.dwi.gov.uk/water-companies/legislation). In addition, references to NIS and SEMD refer to the Network and Information Systems (NIS) regulations (2018) (https://www.dwi.gov.uk/the-network-and-information-systems-nis-regulations-2018) and the Security and Emergency Measures (Water and Sewerage Undertakers and Water Supply Licensees) (SEMD) Direction 2022 (https://www.dwi.gov.uk/semd).

4. Climate change and climate resilience

4.1 Climate change adaptation

4.1.1 Climate change represents a major threat to the global environment and test our ability to effectively cope with the changes it brings. All parts of society and industry will in some way have to adapt to maintain broader sustainability in the future. Climate change specific adaptation planning and implementation will be key to the future of water treatment and supply services. The inspectorate recognises that companies have been working to deliver appropriate planning for climate change and encourages further risk based and prioritised activity to continue.

4.1.2 The UK Meteorological Office's latest UK climate change projections (UKCP18) indicate that in England and Wales we will see warmer, wetter winters combined with hotter and drier summers, though summer rainfall events when they occur will be of higher intensity. These 'new' seasonal variations will be challenging for companies, and they will need to use adaptive scenario planning in order to sustain resilient services.

4.2 Playing our part – Drive to net zero

4.2.1 The Inspectorate recognises that the effects of climate change present current and ongoing risks to delivering safe and wholesome drinking water. We also know there is a regulatory role to play in facilitating the sector, where appropriate, to respond to both the risks (extreme weather events, water scarcity etc.) and opportunities (innovations to reduce demand, leakage reduction, more energy and chemical efficient treatment processes, low emission vehicles, green employment etc.) that climate change presents.

4.2.2 Water UK has published a net zero route map (https://www.water.org.uk/routemap2030/wp-content/uploads/2020/11/Water-UK-Net-Zero-2030-Routemap.pdf), outlining steps to achieving a target of net zero emissions for the water and wastewater operations by 2030. The UK government has a broader societal based goal of achieving net zero emissions from all activities by 2050. Both are stretching targets and the Inspectorate is supportive of both these key initiatives. The priority for effective supply of high-quality drinking water will remain paramount, however where feasible we expect companies to use innovative approaches with net zero as one of the key secondary objectives.

4.3 Energy use and sources

4.3.1 Treating and transporting drinking water supplies is a very energy intensive activity. Companies should plan to provide consistent and robust sources of energy for key water treatment applications. In doing so we expect companies to make sustainable energy choices that minimise the production of greenhouse gases and in doing so contribute to climate change mitigation targets.

4.3.2 The reliability of power supplies is paramount for water treatment works and the processes therein, hence it may not be feasible and/or desirable to rely on certain types of site based renewable energy sources, which may by their nature have variations in available output. Where renewables do feature in the overall basket of energy options, we expect companies to include some form of backup and redundancy with alternative supplies available. Companies should also consider arrangements to procure greener electricity supplies from major generators.

4.3.3 The reliability of power supplies has been an issue for some companies in recent years, and it is important that designs consider the redundancy of power supplies in general. Power supply resilience is vital for the continuity of almost all water treatment and supply services, and it is expected that companies will work towards improving sites where significant outage risks still exist.

4.4 Extreme weather

4.4.1 Climate change is a driver for extreme weather conditions, including low and high temperature events, high intensity and/or prolonged rainfall events increasing the likelihood of flooding.

4.4.2 In the period between December 2017 and February 2018 England and Wales and many parts of the wider UK experienced a series of cold weather events that not only brought considerable snowfall but uncharacteristically low temperatures. These conditions impaired logistics for deliveries, staff availability, general operations and impacted some treatment processes. A key notable impact on consumers were significant loss of service events, mainly due to bursts, following the rapid freeze-thaw cycle.

4.4.3 Recent high temperature events in 2020 placed significant pressure on the supply availability of some companies. It was notable that the high temperatures were combined with the unusual situation of a population predominantly staying home due to COVID-19 restrictions and further increasing demand for water during an already hot period.

4.4.4 Extreme rainfall events can lead to flooding, based both on the intensity of direct rainfall and/or via surface water runoff exceeding the capacity of receiving watercourses. In certain circumstances the rainfall and/or flooding can create ground instability with incidents of landslides. Some extreme rainfall events can have significant adverse impacts on raw water quality such as increased turbidity, reduced quality from overland flow entering source water bodies and the potential for increased discharges from storm overflows.

4.4.5 Companies should continue to improve their forecasting capability for how such adverse events may impact their ability to deliver supplies, maintaining the integrity of their water supply networks and preparing suitable contingency plans to mitigate.

4.4.6 It is accepted that such extreme weather events will become more frequent and could be more severe in terms of intensity and length as our climate changes. Companies will need to plan and prepare effective responses to such events that recognise the various ways in which their business delivery may be impacted, and how this can be managed in terms of service continuity and resilience.

4.5 Resilience

4.5.1 Ongoing climate change poses a threat to the sectors medium and long-term resilience that could detrimentally impact water supply, water quality and infrastructure asset performance.

4.5.2 Having considered extreme weather in the previous section it readily leads to considering the requirements for improving asset and service resilience. In June 2021 the Climate Change Committee published the [Adaptation Committee's Independent Assessment of UK Climate Risk](https://www.theccc.org.uk/publication/independent-assessment-of-uk-climate-risk) (https://www.theccc.org.uk/publication/independent-assessment-of-uk-climate-risk). The report highlighted the following (quoted directly from the summary):

- Water infrastructure, such as reservoirs, dams, pipelines, water treatment plants and sewage treatment plants, are all at risk from the impacts of climate change, especially increases in the frequency and intensity of surface water and coastal flooding.
- Water infrastructure assets represent a key element of the UK infrastructure system and could affect, or be affected by, failures of other assets due to extreme weather, such as energy systems, transport and information and communications technology (ICT).
- There are also risks to buried infrastructure, such as water pipelines, with damage potentially becoming more frequent in future due to flooding and subsidence.
- More frequent flooding could also impact on water treatment facilities leading to potential reductions in water quality, in turn impacting upon health.
- Future projections of more frequent and intense dry periods lead to concerns around the availability of public water supplies in future, especially in England and parts of Wales. Private water supplies are also at risk.

- Aquifers near the coast could be at greater risk from saltwater intrusion due to sea level rise, though the risk is thought to be low in places where aquifers are important water sources.

The above points are a snapshot overview of the risks the sector faces to deliver effective services and maintaining an operative asset base.

4.5.2 The Inspectorate advises companies to pay specific attention to address the risks noted above in all aspects of their business planning towards maintaining safe and wholesome drinking water supplies.

4.5.3 Resilience can be delivered in a variety of ways, including for example allowing higher resistance asset designs, greater redundancy of assets, designs for quicker recovery post adverse events and interim measures for supply when primary assets are unavailable.

4.5.4 The Inspectorate has issued IL 01/2022 Guidance of Alternative Supply Operations 2022 (https://cdn.dwi.gov.uk/wp-content/uploads/2022/03/21150250/Information-Letter-01_2022-Alternative-Water-Supplies.pdf) providing guidance on the requirements expected when providing alternative supply arrangements. In association with the various methods, it is vital that companies have a realistic understanding of the types of risk each part of their asset base may represent, and how these combine into an overall risk to service for consumers. A company's management appetite for carrying such risks should be matched or exceeded by the deployable risk mitigation options.

4.6 Efficacy of treatment processes

4.6.1 Current water treatment systems operate in a design window commonly based on the quality of abstracted raw water. Climate change driven changes in raw water quality, outside of the expected design criteria for effective treatment works performance is a risk.

4.6.2 Raw surface water sources such as rivers and reservoirs in particular, may be subject to:

- lower mean and minimum flows that will increase the concentration of some components in the raw water that will reduce overall quality;
- increased environmental water temperatures that in turn cause increasing eutrophication and excess algal growth reducing raw water quality;

- additionally, the quality of raw water sources may also be compromised by increased sediment or nutrient inputs due to increased run-off extreme rainfall events.

4.6.3 In terms of final water quality in supply companies will need to be focused on how increased average, peak temperature and range of temperature fluctuations (day to night, seasonal) may impact water quality. For example, higher temperatures will increase the rate of degradation of chlorine and the overall longevity of the effects dosing in the network. Near or at surface networks, fittings and storage infrastructure will be the most vulnerable to increasing temperature effects. Companies should particularly consider such issues when supporting water supplies for temporary events.

4.6.4 Companies should, as part of their catchment management work, take steps to address the issues of deterioration in raw water quality with due regard to the impacts of increasing temperature and run-off.

4.6.5 Companies should review their treatment approaches and systems, including technologies and chemicals as to how well these may function under various stress scenarios induced by absolute temperature changes and/or fluctuations. Where appropriate companies should plan to implement improvements and additions to existing processes to address any such issues in advance of them occurring and impacting the ability to supply wholesome drinking water.

5. Broad considerations in planning for the long term

5.1 Recent drinking water quality performance

5.1.1 The top issues resulting in notified events were identified in the Inspectorate's Triennial Report 2017-2019 for England (https://www.gov.uk/government/publications/drinking-water-quality-in-england-2017-to-2019) and the Triennial Report 2017-2019 for Wales (https://cdn.dwi.gov.uk/wp-content/uploads/2021/12/22163642/Drinking-water-quality-in-Wales-2017-to-2019-accessible.pdf, both published in December 2021. The Inspectorate published two triennial reports, one for England and the other for Wales.

5.1.2 The headlines indicated that from the many thousands of samples taken by water companies during 2017 to 2019 approximately 99.95% met the regulatory standards. The majority of controlled substances met the regulatory standards all of the time (100% compliance). Every sample that failed to meet the standards was investigated and, where necessary, specific actions were required of water companies to protect consumers and prevent recurrence. In England lead and nickel had the poorest performance, with lead (99.38%) and nickel (99.74%), followed by coliforms (99.78%), odour (99.78%), iron (99.82%), and taste (99.90%). In Wales the areas of lowest performance were similar but in a different order as follows; iron (99.52%), followed by odour (99.68%), taste (99.81%), nickel, (99.81%), lead (99.81%), coliforms (99.86%) and manganese (99.88%).

5.1.3 Overall, the reports demonstrate the high quality of drinking water in England and Wales over the period. The Inspectorate expects companies to develop and progress performance outcomes via continuous improvement planning. Companies should have due regard to the priority of failures occurring in their own services and addressing the necessary mitigating options with a risk-based approach, to ensure longer term compliance with the regulations.

5.2 Risk assessment

5.2.1 It is mandatory for water companies to carry out risk assessments of all of their water supply systems, from source to tap, adopting a drinking water safety plan approach. Companies should give due consideration to the range of risks that may impact both the quality and sufficiency of water at all sources as part of the risk assessment process, with recognition of common hazards and those that may be emerging in the medium to long term. Companies should ensure appropriate attention is given to identifying risks arising from sources of any potential substances that may give rise to unwholesome water or a concern to human health in relation to raw water abstractions.

These risk assessments should account for the full range of recipient properties receiving water supplies including private dwellings, commercial properties, and public buildings. In doing so the risk assessment approach should consider not only the predominant usage in these properties, but also reflect the populations using the water facilities therein.

Where surface abstractions are in the vicinity, and downstream of effluent discharges, particular attention should be given to the following: the geographic relationship of the discharge and abstraction points; the variability of overall effluent quality; the timing and the duration of discharges; seasonality and the temporal conditions in the receiving water body, for example.

The risk assessment reports subsequently submitted to the Inspectorate should identify the hazard (or partially mitigated hazard) and any associated parameters, evidence that the cause of the hazard has been identified and confirmed and the range of options for mitigation considered including, where appropriate, catchment management measures. There must also be a clear statement of how the benefits delivered by the actions will be measured (to include the scope, frequency and location of monitoring).

5.2.2 Companies are required to keep under review, their risk assessments for all their water supplies, and to report updates to the Inspectorate in a timely manner. In doing so, they should have regard to any learning from drinking water quality events and/or near misses that are circulated by the Inspectorate or companies from time to time. Companies should review and learn from water quality event summaries and guidance published on the Inspectorate website. Water safety planning, drinking water quality and delivering sufficiency requirements are all linked in terms of delivering appropriate services to consumers.

5.2.3 If a regulatory risk assessment identifies clear actual or potentially significant risks, the company must manage and mitigate the risks from the hazard in a timely, effective and efficient manner to the benefit of consumers. The Inspectorate may consider putting in place legal instruments to ensure that desired outcomes are achieved.

6. Long term planning from source to tap

6.1 Catchment management

6.1.1 Our environment and water in the catchment is the first point of consideration when delivering a water quality first approach. It is the first opportunity to consider the hazards, and changes which may impact the quality of drinking water and how these may be mitigated. Drought, flood and source availability as well as anthropogenic activities (such as mining, agricultural, industrial or pleasure activities) will all change the risk, and these must be understood and assessed to keep water safe.

6.1.2 Catchment management schemes have been widely used by water companies to address both point source and diffuse pollution. There are many benefits to catchment management approaches that address pollution at source: such as improvements to the wider water environment; reduce the need for, or burden on, water treatment facilities; and provide sustainable, long-term, cost-effective solutions. They should remain the first consideration of all source to tap risk assessments to reduce risks prior to treatment and ultimately mitigate all significant risks to public health, wholesomeness and acceptability of water supplies.

6.1.3 The Inspectorate has actively promoted catchment management approaches for many years as a first line of defence, including incorporating their use in legal instruments arising from compliance failures, or identified risks.

6.1.4 The likelihood of success of catchment management measures varies depending on the nature of the parameter, the size and nature of the catchment, the origin of the pollution and other factors. Therefore, individual proposals will be assessed on their merits.

6.1.5 The accumulation of catchment management improvements gained from a multiplicity of proactive integrated solutions (such as stakeholder engagement at both national and local levels; pollution control; raw water management; abstraction control; and raw and/or treated water blending) may negate or delay the need for new and/or upgraded treatment processes. In addition, catchment management offers protection of the quality of water supplies.

6.1.6 It is important that submissions for continuing existing and/or starting new catchment management-based approaches are supported by proposals for monitoring and assessment of their progressive effectiveness and success criteria. To support this, we expect companies to consider investments in catchment based monitoring and real time information systems. These may also be deployed to improve and support timely identification of threats and to increase overall knowledge about catchments to improve risk management.

6.1.7 For such solutions to be effective and sustainable, they require the commitment of significant resources and multiple interactions over a prolonged period by companies, and often require the co-ordination of outputs to be delivered by various third parties. Although control of the hazard at source is always the primary objective, where catchment management solutions are specified, we recognise that the full delivery of outcomes via catchment management measures may be uncertain or may prolong the period before benefits accrue to consumers. To ensure that a legal instrument is fit for purpose, the Inspectorate will need to understand these constraints, and the other actions that the company may need to take, or to make provision for, to supplement its catchment management activities. These may include the relative contribution of catchment management activities to outcome delivery, the potential impact on priorities, the timescale for completion and the arrangements for programme recovery, if needed.

6.1.8 The Inspectorate will continue to pursue this approach to catchment management and will encourage companies to routinely incorporate catchment management solutions as a fundamental part of their source to tap management of their water supplies. This approach is consistent with wider environmental considerations and aligns with the UK government 25-year environment planning '[A Green Future: Our 25 Year Plan to Improve the Environment](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf)'(https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf) that outlines aspirations for achieving clean and plentiful water. The Inspectorate will support companies, working with the stakeholders and Regulators involved, to find and implement the most cost effective, efficient and sustainable solutions to deliver the required outcomes. The Inspectorate will continue to work with other Regulators to facilitate the scope and specification of catchment solutions where there are synergies with environmental drivers, and we expect companies to liaise with their local environmental Regulator representatives on the development of their catchment management solutions.

6.1.9 There are opportunities for companies to work with the Environment Agency and Natural Resources Wales to align the catchment-based aspects of the established Drinking Water Safety Planning (DWSP) approach with the Water Framework Directive regulations' 2017 programme of measures requirements. This includes measures with the aim of avoiding deterioration in the quality of the water, in order to reduce the level of purification treatment required in the production of drinking water. Non-statutory Safeguard Zone Action Plans for Drinking Water Protected Areas (DrWPAs) that are 'at risk' are identified by the Environment Agency. We believe that the cross-over and interaction here will be beneficial to all parties.

6.1.10 In support of catchment management opportunities, companies should have consideration of what techniques, real-time catchment-based monitoring and information systems technologies are available to deliver timely data about catchment conditions and links to raw water quality variations. The Inspectorate is supportive of implementing new technology and innovations where these demonstrate clear benefits in support of catchment management outcomes.

6.1.11 Whilst the most significant catchment management schemes, from a drinking water quality perspective, will continue to be incorporated within legal instruments, we expect companies to routinely engage in proactive catchment management activity as a matter of good practice for all their water supplies.

6.2 Raw water quality

6.2.1 Understanding the quality of water at the point of abstraction remains one of the most important foundations for delivering high quality drinking water to consumers. Companies will be familiar with the approach that requires them to understand and manage the interacting elements from source to tap. Starting from the originating catchment(s) where raw water is sourced; having a good understanding of the catchment attributes, catchment activities (agricultural, industrial and land use variable etc.); through to how water is abstracted, treated, stored and conveyed via the various company managed site and network assets; through to the internal plumbing of consumer properties (both public and private), internal fittings and then to the points of consumption.

6.2.2 Companies must be aware of risks at the point of abstraction. These should include not just the risks arising from the catchment covering geogenic and anthropogenic risks as described previously, but also any changes where the source water may have changed through raw water imports, wastewater, recycled or desalinated water which is engineered intentionally or otherwise to augment the source water. These will require a review of existing risk profiles with a water quality approach which may include re-application of a new source under regulation 15.

6.2.3 Failure or a likelihood of failure to supply wholesome water because of a deterioration or a change in raw water quality should be identified through a combination of catchment intelligence, raw water monitoring and the risk assessments carried out for each treatment works and its associated supply system. Companies will need to work with stakeholders within catchments and in particular establish and maintain strong engagement with the relevant environmental regulator for example Environment Agency, Natural Resources Wales. Deterioration in this context means a measured reduction/change in raw water quality over time, or demonstrable unmitigated volatility in quality brought about by pollution changes within the catchment, and most frequently arising from diffuse pollution, but also from changing weather patterns for example.

6.2.4 Most hazards will be known to companies and featured within existing risk assessment arrangements. However, where a deterioration in raw water quality has been identified and presents a risk to consumers (for example, the existing treatment process is not designed to deal with either the type or level of the contaminant), water companies must investigate the cause of deterioration and take action to protect consumers. This action should primarily focus on investigations in the catchment and, where feasible, specify actions to control the level of pollution entering the supply at source, although a wide range of other operational interventions, including either short-term or permanent treatment solutions, may be necessary to supplement other based catchment activities.

6.2.5 When considering catchment management/control solutions, companies should have regard to specific statutory environmental obligations, and give due consideration where their activities can play a beneficial part. However, the capacity of a company to provide for multiple drivers will depend on the level of risk to drinking water quality and whether a catchment solution could deliver in time to prevent the supply of unwholesome water. In some situations, the catchment may have been subject to other residual risks that may require a treatment solution to be installed to mitigate, and companies will be required to adopt a twin track approach that includes treatment and/or other operational control measures in addition to catchment management actions to mitigate the risks to consumers from raw water deterioration. Companies should especially apply effective adaptive planning and assessment approaches to ensure that respective treatment works are fit-for-purpose and suitable to meet the evolving risks that need to be addressed.

6.2.6 Companies also have a statutory duty to undertake monitoring of raw water at every abstraction point as part of their risk assessment of each treatment works and associated supply system. Monitoring is particularly important to improve knowledge of new and emerging risks and understanding where specific attention in risk assessments and associated responses should be implemented.

6.2.7 The Inspectorate expects companies to continue to improve their knowledge of both current and historic catchment activities that may impact the ongoing quality of raw water sources. In turn, catchment focused activities by water companies to improve raw water quality will contribute to wider environmental objectives in respect of the protection of areas from which drinking water is abstracted.

6.3 Resource management, planning and transfers

6.3.1 As an outcome of managing the predicted impacts of climate change, industrial demands and population changes, companies are planning and/or have put in place resource management plans which include transfers of raw or treated water or initiatives to reduce leakage. All plans should take a water quality first approach to ensure the water supplied is good, clean, and wholesome. It would be beneficial for companies to take a wider strategic position to achieve synergistic outcomes when considering regulatory objectives.

6.3.2 Companies must complete a risk assessment on the potential impacts on public health, wholesomeness and acceptability[1] to consumers of new or altered supply arrangements, including cross-company transfers of raw or treated water, mixing of water and new resource schemes. This must meet the requirements of the Regulations when developing options stemming from the regional plans. Where potential risks are identified, prior to making supply changes, a company must take steps to assess and mitigate those risks.

6.3.3 For raw water transfers, the development of the drinking safety plan and risk assessments should consider the risks identified within the existing 'upstream' drinking water safety plans and then identify whether further mitigation is required at the receiving location. Investigation of raw water quality risks may require further monitoring to support the existing available data sets, water quality modelling, and due regard should be given to future risks (including emerging contaminants). Acceptability considerations should be risk assessed including the change of source type which may result in a change in taste, odour or feel of the water to consumers and any impacts on the receiving distribution system such as corrosivity, for example.

6.3.4 For wholesome drinking water transfers, consideration should be given to the age of water, whether appropriate mixing is occurring within intermediary storage reservoirs or conveyance infrastructure and risks associated with disinfection by-products, especially if the supply is re-chlorinated. Consideration should also be given to acceptability risks associated with any change of source type or mixing of waters which may result in a change in taste, odour or feel of the water to consumers and any impacts on the receiving water distribution system.

6.3.5 This section is of particular importance due to a number of strategic water resource options (SROs) which are being considered as part of the joint Regulators' Alliance for Progressing Infrastructure Development (RAPID) programme. RAPID seeks to deliver a strategic step-change in water resource availability across England and Wales that will deliver more resilient access to water resources from circa 2030 onwards. Some of these schemes involve transferring water not only within their regions but also inter-regionally. Companies remain responsible for their duties to supply wholesome water irrespective of the source of water.

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[1] As defined in the Water Supply (Water Quality) Regulations 2016 in England and 2018 in Wales.

6.3.6 The Inspectorate has produced an acceptability framework, Table 6.1, to highlight some of the key acceptability considerations for companies when planning transfer schemes. Companies will need to consider the integrity of the receiving network with respect to its long-term behaviour and resistance to the chemistry associated with incoming water as well as the acceptability of the taste, odour and/or feel of 'new' water for consumers.

Table 6.1 Acceptability Framework of principles for potential consequences of introducing new sources, mixing sources, or transferring water

Relevant parameters which may be impacted by proposed action	Other factors which may impact consumers	Timescales of impacts	Possible Mitigating actions – Describe timing and frequency Required mitigating actions dependent on consumer impact and duration Describe evidence for risk and mitigation
Chlorine residual pH Lead Nickel Iron Manganese Aluminium Taste Odour Colour Turbidity Fluoride Pesticides	Consumer complaints of discolouration – brown, black, orange, white Consumer complaints – taste and odour Consumer Rejection Aggressiveness of water Changes in pressure Regulation 31 compliance Water treatment to minimise corrosion from pipes (reg 29)	Short term (days) Medium term (weeks) Longer term (months) – temporary Longer term (months) – permanent	Consumer engagement – letters Consumer engagement – social media Consumer engagement – texts Consumer engagement – press notices Consumer engagement – radio adverts Water conditioning – softening Orthophosphate dosing – lead compliance Mains flushing programmes Phased introduction or blending of new source Measures to ensure regulation 31 compliance Management of chlorine dosing Others as appropriate which may cause water to be unwholesome

For each scheme, the responsible party should consider the potential water quality impacts (whether immediately for consumers or longer-term effects) and in light of the proposed timescale for the change consider a package of mitigating actions that will be implemented together with the project plan for delivery.

6.4 Water recycling and desalination

6.4.1 Drinking water is a valuable resource and its availability and resilience is something we have come to expect. However, increasing demand and the impact of climate change means that we must continue to work on demand management and other options to ensure a sufficient supply for the future.

6.4.2 One such option that companies are considering is to further develop the capability for water recycling as a promising alternative to supplement traditional supplies. This has already been demonstrated in our ability to ‘recycle’ water through the processes we use to treat wastewater to a standard where it can be discharged into our watercourses. In future the technical potential for both this ‘indirect’ type of water recycling could be combined with more ‘direct’ recycling via water recycling plants prior to their discharges being utilised as sources for traditional water treatment works. Enhanced processes for improved water recycling have the potential to deliver additional water to consumers, however companies should be mindful of the requirement to engage with their consumers regarding expectations and acceptability of such supply methods. The Inspectorate has commissioned an innovative research project to gauge consumer perceptions around water recycling to determine the future acceptability of the various alternative approaches.

6.4.3 Another option, already in use at a site in England, is desalination. Desalination is a technically well-known and practiced approach used extensively in many parts of the world where fresh surface water or groundwater supplies are limited, as a significant approach to produce drinking water. There are technical challenges in achieving desalination consistently, such that the characteristics of the water are acceptable to consumers which may require additional treatment options or blending with other water sources.

6.4.4 Companies must remain aware of their regulatory responsibilities and duties when considering either or both options for supplementing raw or final water. Water arising from a water recycling or a desalination plant into an environmental buffer supplementing a source changes the source risk and companies must carry out a regulation 15 assessment as the source has fundamentally changed to a new source. In circumstances where a water recycling or desalination plant feed directly into a final water treatment works or is the final water source then it is the point of effective abstraction and regulation 15 would apply (for example, seawater or black/brown water). Regulation 31 applies throughout the process.

6.4.5 Companies considering water recycling and/or desalination works are encouraged to engage with the Inspectorate at earliest possible opportunity to discuss outline proposals and elements that are important for successfully delivering acceptable drinking water quality. Companies must ensure that either future water recycling or desalination solutions meet the requirements of regulation 15.

6.5 General water treatment principles

6.5.1 The Inspectorate expects water companies to use treatment processes to make water safe and clean, with the aim of proactively mitigating risks to public health, and to the wholesomeness and acceptability of supplies. The processes used should be consistent with the actual and potential hazards to be mitigated and should at a minimum meet modern standards demonstrating verifiable efficacy of treatment. For example, *Cryptosporidium* removal and/or inactivation by a multi-stage process should follow the recommendations of Badenoch (https://cdn.dwi.gov.uk/wp-content/uploads/2021/10/25144921/Badenoch_Report.pdf) and Bouchier (https://cdn.dwi.gov.uk/wp-content/uploads/2021/10/25144909/Bouchier_Report.pdf) and peer reviewed literature where removal by filtration, inactivation by UV and the return of wash-water take into account turbidity, log-removal, transmissibility/power and volume of return sufficient to mitigate any potential harm to health posed by the source. Verification may well be understood from the risk at source and the outcome at the treated water through an appropriate methodology. This is not an exhaustive list. However, it is essential to the consistent delivery of adequate treatment that treatment facilities operators are aware of any pollution challenges in the catchment which may affect the quality of raw water. This will enable them to maintain the stability and optimisation of treatment conditions. An integrated view of risk management across catchment, abstraction, storage and treatment best secures continuous adequate treatment of water and levels of service to consumers. This should include new and emerging contaminants which may be challenging to remove using current treatment processes and may require additional verification of efficacy of treatment to demonstrate a risk is mitigated.

6.5.2 It is also expected that treatment facilities will have the operational flexibility over short, medium and long-term timescales to support resilience, including suitable monitoring and fail-safe arrangements that make provision for containment and/or flow diversion, to prevent the supply of inadequately treated water to consumers. Companies should use adaptive planning techniques to ensure assets have sufficient flexibility and fitness for purpose in an evolving external environment driven by external factors such as climate change and catchment related risk developments, for example.

6.5.3 Treatment processes and controls should be reviewed in detail to check for hazards as part of a company's risk assessment process. This applies especially to the integration of new or replacement processes and equipment that should be subject to rigorous integration testing, with supplier support and operator training. There is ample evidence from event records to illustrate the unnecessary impact on consumers from relatively minor operational interruptions. Companies are reminded that it is a criminal offence to supply water that is not treated adequately, as required by the Regulations.

6.5.4 Compliance with regulation 31 requirements is a key duty of companies when planning, designing, and delivering assets. It is essential that suitable materials, products including chemicals are specified and used in construction that have no detriment to the quality of water at any stage of the treatment process and throughout the water supply system. Where any product is sourced through the supply chain, companies must satisfy themselves - through proper due diligence - that such products are compliant for their intended use before and on receipt. In addition, the storage and use of all chemicals and materials that may come into contact with water throughout the duration of their application and across the whole supply system of the company, must comply specifically with regulation 31, the associated British Standards, and conditions for use. This has been the subject of a recent Court ruling emphasising the wider intent of the regulations to safeguard water quality.

6.5.5 The integration of risk management extends to the supply side of treatment facilities. All decisions made by supply controllers or network operators on supply provision should consider implications for the quality of the supply. These considerations should include, as a minimum, the control measures necessary to mitigate any impact on the stability and optimisation of pH, colour, and phosphoric acid dosing for plumbosolvency control; on disinfection and control of disinfection by-products; on fluoridation; on the acceptability of the supply to consumers, including taste and odour, and discolouration. Companies must ensure that operator training is comprehensive and relevant to all processes in the supply chain in this regard.

6.5.6 Several water quality event investigations have identified contributing factors to operational errors that were partly linked to the inexperience and/or unfamiliarity of staff with assets. When scheduling operational manning and cover for leave/illness, companies should have due regard for the experience and capabilities of replacement staff, that are specific to the water treatment works and/or assets they are managing for example.

6.5.7 Water treatment is an evolving discipline, the Inspectorate expects companies to deliver innovations in operational technology and control systems and further develop the reliability and use of on-line monitoring systems to improve responsiveness and support use of improved digital monitors and controls. Companies should seek to further understand and quantify the security of both their physical and cyber systems such that they can mitigate risks.

6.6 Water distribution, reservoirs and asset health

6.6.1 Without any further treatment, drinking water must be maintained in a safe and secure manner as this is vital to the supply of wholesome water. This means for example that service reservoirs must be maintained in a way that ingress from environmental water is prevented. In the last 10 years there have been a number of instances where microbiological contamination has been detected such as *E. coli* particularly linked to rain and subsequently discovered ingress. Similarly, *Cryptosporidium* has been detected either through broken sub-surface piping of directly through the roof, in one case resulting in one of the most significant drinking water incidents in recent times.

6.6.2 In 2021 the Inspectorate conducted a thematic audit programme of water supply service reservoirs. The audits considered the management, monitoring, inspection, and maintenance practices and record keeping. It was found that some companies had multiple reservoir assets that had not been inspected for more than 10 years, with one company having approximately 15% of its service reservoirs in this category. Similarly, the number of reservoirs/tanks significantly over 10 years since inspection is not insignificant with one record showing an inspection had not taken place in 50 years due to the inability to physically remove the tank from supply. There were significant instances of poor record keeping where the evidence for required remedial actions was not recorded clearly or at all and in other instances, tanks which were found to be subsiding without any clear strategic action to mitigate the risk. In response to these and other findings the Inspectorate issued 10 notices (some notices referring to multiple assets) outlining corrective requirements for the issues identified in the audit reports. The Inspectorate expects to see companies delivering significant improvements in this area.

6.6.3 Distribution issues contribute to one third of notifiable drinking water quality events every year, with a quarter of these of a duration greater than 48 hours, and with an impact on, typically, some two million consumers. A notable minority of these events are caused or exacerbated by company staff. This suggests that the resilience of distribution service delivery needs to improve substantially to reduce the impact on consumers, and that current operational practice may pose a risk to wholesomeness of supplies in some circumstances.

6.6.4 The Inspectorate will continue with this policy and extend its reach to all companies where there is evidence of persistent consumer complaints about the aesthetic quality of the supply. Mitigation actions to reduce such complaints must involve operational planning for strategic and recurring cleaning/maintenance, improved treatment processes and/or permanent solutions to reduce complaints in the long term.

6.6.5 Despite significant investments in PR19 across the sector, there remain concerns about the operational performance of a number of water treatment facilities. Companies must be conversant with changing risk profiles that may have impacts at catchment, treatment and supply levels. The Inspectorate expects to see a significant improvement in the operational performance of treatment facilities, aided by consistent good practice in asset maintenance, in particular, for dosing systems, monitoring and control systems, where proactive preventative replacement strategies and/or fail-safe back-up facilities are expected as a minimum requirement. Robust processes for specification and use of controlled substances and products, together with management of the delivery and use of treatment chemicals, are also essential.

6.6.6 The distribution risk assessments required from all companies should draw on the accumulation of years of quality data; contact data; and asset specific data, including maintenance and repair history. The mitigations arising should form the basis for a proactive maintenance and operation regime. Repeat events at the same assets require an update of risk assessments, and any resulting mitigations, and may result in enforcement. Use of material and maintenance or renovation histories should enable recognition of any patterns of deterioration that cause quality issues and contribute to recognition of emerging risks. It is not acceptable to accept adverse impacts routinely and passively on the quality of supplies arising from burst mains. and in particular the associated discolouration that often arises from network flow variations caused by such supply interruptions. Recurring impacts of this type should be considered as risks to wholesomeness, and appropriate mitigation, such as flushing to control deposits or replacement of regularly failing mains put in place.

6.6.7 The Inspectorate welcomes the developments in network management, such as software aids and improved training for operators to provide 'calm systems' approaches and encourage their continuing use as operational tools. However, these do not deal with the underlying root causes of disruptions to consumer service that we expect companies to mitigate. We continue to encourage the use of real-time monitors for routine operational monitoring as investigative tools to provide improved responsiveness to interruptions. These can also deliver more efficient and effective demonstrations of actual benefit in shorter timescales following improvement works.

6.6.8 There is an ongoing need for companies to better understand, risk assess and prioritise the status of asset health risk across their asset base and distribution networks more effectively. The Inspectorate welcomed the work undertaken by Ofwat in 2020 to 2021 with companies to support further understanding about asset health/maturity in the water and sewerage sector.

6.6.9 The Inspectorate noted that changes in company sampling regimes in 2020 (primarily driven by public health COVID-19 restrictions) highlighted the presence of metals in networks, and this identifies some ongoing challenges associated with treatment works optimisation to reduce concentrations of aluminium, iron and manganese to a minimum in the final water.

6.6.10 Discolouration risks within service reservoirs should drive the need for improved risk assessment programmes for inspections and service reservoir cleaning that take account of discolouration risks, coupled with microbial and engineering risks. Companies should combine these to inform a wider operational strategy that includes network discolouration risks within operational risk assessments for networks that are at high risk of discolouration, especially for operations that may result in flow reversals or flow increases. Risk assessment requirements were noted following bursts or due to changes in demand, particularly evident when England and Wales entered COVID-19 lockdowns during 2020. The use of calm network principles is evident in some companies, as are their involvement in research projects that incorporate research results into discolouration management strategies.

6.6.11 Companies are aware of the association of discolouration events through standpipe management and training for standpipe hires, including prosecutions for illegal standpipe use and specific hydrants maintained for hire use. This must continue to be a central strategy for which there are some exemplar approaches available as good references. However, consumer contacts are often the first sight of local challenges. Therefore, detailed investigations following consumer contacts, even with low trigger levels prompting onsite investigations and action/escalation measures should be recognised as a key means to drive future improvement, particularly for those low performing companies.

6.7 Domestic and internal distribution systems

6.7.1 The domestic distribution system begins at the supply pipe to the tap. Companies view this part of the system as outside their responsibility; however, compliance is measured at the tap and can be affected by company actions such as changes in source water, leakage initiatives, metering etc, examples of how these are affected by company interventions include aggressive water on galvanised pipes resulting in discolouration, zinc and other metal leaching. Companies cutting into lead piping to fit meters without either opportunistically changing the pipe or even recording the presence of it and/or initiatives to reduce leakage without also targeting lead pipes represent missed opportunities. Companies are reminded that combined synergistic strategies should be considered and appropriately applied when delivering multiple outcomes.

6.7.2 Other point of use/consumption considerations include the incorrect use of lead solder on internal water distribution systems. When visiting consumer dwellings to investigate water quality concerns, company operatives should be vigilant when investigating elevated levels of lead to determine the likely source and advise the consumer accordingly.

6.7.3 Nickel can be an issue in both recently built and renovated properties where potentially lower quality nickel plated fittings can be a source of elevated nickel in the drinking water.

6.7.4 In addition to lead and nickel, other impacts on wholesomeness, for example from copper, can also relate to the effects of consumers' plumbing on the quality of water supplied. The Regulations require water companies to condition their supplies to mitigate such risks to water quality beyond the mains network. Guidance on potential approaches for investigations into copper and nickel failures is available on the Inspectorate's website (https://cdn.dwi.gov.uk/wp-content/uploads/2022/01/27175834/Part-7-Investigations.pdf).

6.7.5 The Inspectorate expects companies to continue to enforce the Water Supply (Water Fittings) regulations 1999 to protect wholesomeness and consumers. It is good practice for every company to have an overarching strategy that includes their lead strategy, and collaborating with other stakeholders, to identify these hazards and mitigate their risks as far as possible. This may mean removal of hazards (for example, lead communication and supply pipes; lead soldered pipe joints); provision of advice to consumers (for example, flushing; Water Fittings regulations inspections); and training of relevant stakeholders (for example, plumbers; housing associations) to ensure that water quality is maintained at the consumer's tap.

6.7.6 When a failure is caused by a private domestic system, and is indicative of a significant risk to health, companies should seek to ensure that the defect is corrected, if necessary, using their powers to prevent contamination under section 75(2) of the Act.

6.7.7 In public buildings, companies must consider whether the problem can be adequately addressed through advice to the building occupier or owner, or if action is required by them or the building owner under sections 74 and/or 75 of the Act, if necessary, using their powers of enforcement provided by the Act.

7. Specific considerations

7.1 Matters identified in risk assessments

7.1.1 Hazards identified by water companies should be submitted to the Inspectorate as part of company risk assessments. In understanding the profile of risks faced by the sector we have noted that in the last five years the top water quality hazards have been notified with respect to no supply (loss of supply), nitrate (total), metaldehyde (pesticide), *Cryptosporidium*, pesticides (total), endocrine disruptors, fire/flame retardants (due to PFAS compounds), pharmaceuticals and total coliforms.

7.1.2 A selection of these identified 'top' hazards are considered below alongside a selection of other notable points for consideration. This list is not exhaustive but identifies some key parameters which would be expected to be addressed in all risk assessments where relevant.

Nitrate – total nitrate remains a key issue arising from agricultural use and practice within source catchments. It is generally recognised in terms of occurrences and locations by companies and where it requires mitigation measures.

Cryptosporidium – There are no particular themes associated with *Cryptosporidium* hazards. Companies must be diligent and thorough in addressing this hazard and defining the root causes. Companies continue to use a variety of necessary control measures that are site, asset, and catchment specific to address this hazard.

Microbiological contamination (faecal, coliforms, clostridium) – Often root cause issues can be similar to those found with *Cryptosporidium* but also particularly with poor or inadequate asset condition and maintenance. Companies should monitor and record significant change of use activities within source catchments (industrial, agricultural, manufacturing, leisure etc.) that may increase or reduce aspects for risk to raw water quality such that corresponding risk assessments are fit for purpose.

Taste and Odour – reported across the sector for a variety of issues, including:

- Algal growth in water bodies that may have conditions that accelerate growth such as phosphate levels and residence times.
- Hydrocarbons and traces of chemicals such as 2-EDD (2-ethyl-5,5 dimethyl-1,3 dioxolane) and 2-EMD (2-ethyl-4-methyl-1,3 dioxalane) from industrial processes.

Companies must be mindful of addressing/preventing the generation and presence of such occurrences that may not be intrinsically harmful to health at very low levels but could readily lead to significant taste and odour issues for consumers.

Persistent and very persistent mobile toxins (PMTs and VPMTs) – Persistent and very persistent toxic substances/chemicals break down slowly in the environment, are toxic to organisms and can accumulate in both the environment and potentially in species such as various animals or humans. Companies should be aware of raw water abstraction sites that are in catchments associated with former and/or current industrial use where such compounds may be elevated. The Inspectorate reported research findings on Persistent, Mobile and Toxic Substances - Hazards to Drinking Water in England and Wales (https://cdn.dwi.gov.uk/wp-content/uploads/2021/09/08152716/DWI70-2-323.pdf) in January 2020. Compounds such as legacy chromium-6 arising from many different uses are a known risk reported in the Inspectorate research findings in Understanding the significance of chromium in drinking water 2015 – Ref: Defra-8930.04 (https://www.dwi.gov.uk/research/completed-research/risk-assessment-chemical/understanding-the-significance-of-chromium-in-drinking-water).

Personal care products and domestic care products – Personal care products (PCPs) and Domestic Cleaning products (DCPs) contain a wide range of chemicals, according to their intended purpose. Patterns of use between different PCPs and/or DCPs also differ and, as a consequence, the duration and levels of human exposure to the chemicals present can vary significantly. PCPs are categorised by their use and include 'leave-on' products such as cosmetics, moisturisers, body sprays and deodorants, 'rinse-off' products including shampoos, soaps, shower gels and shaving gels, and 'oral care' products such as toothpaste and mouthwashes. DCPs are classed as those used for 'laundry/dish care' including dishwasher tablets/powders, washing up liquids and laundry powders, 'surface cleaning' such as kitchen and bathroom spray cleaners, 'air care' including air fresheners and fragrances, and 'floor care' such as hard surface cleaners and carpet shampoo. Importantly, the majority of PCPs/DCPs used in the home are disposed of down the drain, thus entering the sewerage system with the potential to reach drinking water supplies via wastewater effluent discharges and/or raw sewage in storm overflows. The Inspectorate commissioned research into risks to drinking water quality associated with both PCPs and DCPs summarised in the report Personal Care Products and Domestic Cleaning Products – Toxicological Assessment of Prioritised List of Chemicals (Ref: DWI 70/2/331) (https://cdn.dwi.gov.uk/wp-content/uploads/2021/01/05120230/DWI70-2-331.pdf). This research based risk assessment concluded that for the chemicals of interest the levels potentially present in drinking water due to normal use of PCPs and DCPS are not anticipated to pose an appreciable risk to public health.

Pharmaceuticals – The main sources of trace pharmaceuticals in the water environment arise from a combination of raw sewage, disperse occurrence from veterinary use caused manure spreading and wastewater effluents. The concern arises where our environmental raw water is also a source of our drinking water supplies. In 2012 the WHO (https://apps.who.int/iris/bitstream/handle/10665/44630/9789241502085_eng.pdf;jsessionid=A5D35872110AEA0EBE3025FB11616888?sequence=1) reported that adapting the water safety plan approach to the context of pharmaceuticals means that preventing them from entering the water supply cycle during their production, consumption (ie excretion) and disposal would be a pragmatic and effective means of risk management. This approach requires a joint effort of collaboration between stakeholders to address the various parts of the life cycle of pharmaceuticals. Water companies should be ready to play a part in terms of wastewater treatment and drinking water treatment practices where there are emerging concerns to public health. The Inspectorate commissioned research into the Toxicological evaluation for pharmaceuticals in drinking water (https://cdn.dwi.gov.uk/wp-content/uploads/2020/10/27111256/DWI70-2-295.pdf) considering a selected range of pharmaceuticals published in 2014. Based on the collective evidence there is no appreciable risk to human health from the trace levels of pharmaceuticals that may be present in drinking water supplies. However, companies should be prepared with an awareness of viable treatment technologies and other mitigations, should an increase in potential risks emerge from further global studies.

7.1.3 Other key hazards such as PFAS, pesticides, lead, phosphates and radioactivity are addressed in more detail in the following sections.

7.2 PFAS compounds

7.2.1 PFAS compounds are a group of man-made perfluorinated chemicals that are commercially available in the form of salts, derivatives and various polymers. Some PFAS have been identified as being persistent, bio-accumulative in the environment and potentially toxic in terms of human health. PFAS have been used widely for a range of purposes from industrial to household products and have had or continue to have widespread use in England and Wales.

7.2.2 There has been growing scientific awareness of the attributes of PFAS and this has raised a keen interest in better understanding their potential impact on the environment and their toxicity. Currently there are no specific standards listed in the Regulations for any PFAS compounds.

7.2.3 In January 2021 the Inspectorate issued guidance for the subset of PFAS chemicals, PFOS and PFOA, that were identified as compounds of interest due to indications of their potential toxicity to human health in drinking water in England and Wales. This guidance recommended trigger values in a four-tiered approach for treated drinking water.

7.2.4 In October 2021 the Inspectorate issued an Information letter IL 05/2021 (https://cdn.dwi.gov.uk/wp-content/uploads/2021/10/04203217/Information-Letter-PFAS-Monitoring.pdf) advising that the four-tiered guidance should also be applied in parallel to raw water sources (abstracted for the purpose of drinking water) as part of risk assessments.

7.2.5 In July 2022 the Inspectorate issued Information letter IL 03/2022 (https://cdn.dwi.gov.uk/wp-content/uploads/2022/07/08101653/IL_03-2022_PFAS_Guidance-4-1.pdf) with further guidance on risk assessments, expectations, and progressive amendments to the PFAS tiered approach to risks and required actions. This Information Letter and associated guidance may be subject to updates as information becomes available and companies should familiarise themselves with the latest versions.

7.2.6 The approach recognises that in most cases specific PFAS removal/reduction measures are not yet explicitly included in the drinking water treatment cycle; whilst also acknowledging that some existing treatment practices can already reduce their concentration in treated water. The Inspectorate recognises that this is a precautionary approach but considers it appropriate given the uncertainty or absence of specific treatment technologies to reliably remove/reduce PFAS.

7.2.7 For compounds such as PFAS where no statutory standard is set, the Inspectorate seeks advice from the UK Health Security Agency (UKHSA) and, if appropriate, other independent toxicological experts to determine a level at which drinking water does not constitute a potential danger to human health, and therefore could be regarded as wholesome. In IL 03/2022 (https://cdn.dwi.gov.uk/wp-content/uploads/2022/07/08101653/IL_03-2022_PFAS_Guidance-4-1.pdf) and the upcoming Inspectorate guidance, expected in quarter three/quarter four 2022, the drinking water wholesomeness recommendation is set at 0.1 µg/L for all PFAS compounds, and this will be reviewed periodically. Companies should operationally plan not to breach this level in treated water supplies at any time. To achieve this companies should seek to have:

- An appropriate understanding about PFAS sources in catchments contributing to raw water sources
- An appropriate understanding of PFAS concentrations in all raw water sources used for drinking water abstractions
- Regular monitoring and analytical programmes for all raw water abstraction sources
- Regular monitoring and analytical programmes that are representative of consumer supply zones and/or where PFAS concentrations have an elevated trend.
- Secure and verifiable methods for managing the supply of treated water (for example, via blending and/or specific treatment processes) such that wholesomeness is ensured at all times.
- To have a plan in place to maintain wholesomeness should a review in the future require a reduction of the level of one or more PFAS based upon expert advice.

- Where GAC treatment approaches are used to reduce PFAS, particular care must be taken in understanding the risk and the efficacy of removal for each substance and when the GAC is regenerated prior to further use, its subsequent efficacy. Company protocols should allow for off-line testing, to ensure that there are no residual by-products or contaminating elements present in the regenerated cells, before returning them into the active treatment cycle.

7.3 Pesticides

7.3.1 There are approximately 20 undertakings in place that address various circumstances of non-compliance with standards for pesticides. These are predominantly still in place for metaldehyde in particular; though it is anticipated with the statutory end of use of metaldehyde in March 2022 these will successively be closed in the coming years as concentrations reduce. Other pesticides of interest, also with undertakings, include clopyralid, carbetamide and propyzamide.

7.3.2 Table 7.1 shows there are several other pesticides that are being recorded in raw water in significant numbers. However, their individual presence is more prevalent at certain sites than others, so may not necessarily be regarded as sector wide issues. However, companies must remain vigilant in assessing the sources of such pesticides that may still have significant current or legacy risk.

Table 7.1 Top 10 reported pesticides in raw water 2020-21

Rank	2020	2021
1	Metaldehyde	MCPA (Total) 4-chloro-o-tolyloxyacetic acid
2	Clopyralid (Total)	Metaldehyde
3	MCPA (Total) 4-chloro-o-tolyloxyacetic acid	2 4-D (Total)
4	MCPP(Mecoprop) (Total)	MCPP(Mecoprop) (Total)
5	Propyzamide (Total)	Triclopyr (Total)
8	Fluroxypyr	Clopyralid (Total)
7	2 4-D (Total)	Fluroxypyr
8	Bentazone (Total)	Chlortoluron (Total)
9	Triclopyr (Total)	Bentazone (Total)
10	Chlortoluron (Total)	Isoproturon (Total)

7.3.3 Some pesticides can be very difficult and expensive to remove via treatment processes and a key part of their control is via at source measures implemented across catchments, working closely with stakeholders. Companies have continued to conduct stakeholder engagement at a national level (pesticides manufacturers, suppliers, and representatives of the agriculture sector) and at local level (individual farmers, agricultural contractors, and their advisors) to mitigate the pollution of raw water sources by pesticides. We expect companies to build on the measurably good outcomes from such cooperative engagement during AMP8 and beyond.

7.3.4 The Inspectorate recognises that these programmes of work will continue to require engagement between stakeholders, and we are committed to supporting these activities. We believe this collaborative and measured approach builds consistently on current arrangements and activities; and will continue to deliver the outcomes that consumers expect at a cost that is manageable.

7.3.5 Where the voluntary catchment management initiatives do not demonstrate the improvements required, the Inspectorate will advise Ministers on the other options available to them to protect consumers, including the consideration of further targeted regulatory actions.

7.3.6 The Inspectorate recognises the challenges that pesticides contamination brings to other areas of companies' activities, in particular, abstraction management; water resource planning; and building resilience capacity. However, these constraints will continue to apply until the risks to consumers from non-compliance with pesticides standards are mitigated satisfactorily.

7.4 Lead

7.4.1 The point of compliance measurement for lead is at the consumer's tap, and action is mandatory in response to every analytical result that exceeds the standard to protect consumers.

7.4.2 The Defra Strategic Policy Statement (SPS) (https://www.gov.uk/government/publications/strategic-policy-statement-to-ofwat-incorporating-social-and-environmental-guidance/february-2022-the-governments-strategic-priorities-for-ofwat) to Ofwat for England supports action by industry to trial approaches to reducing exposure of lead to customers from drinking water, from a public health perspective. It is therefore expected that companies should investigate and develop trial projects to better understand how they can deliver further reductions on lead in drinking water effectively and efficiently.

7.4.3 The Welsh Government's Strategic Policies Statement for Wales is expected to ask Ofwat to challenge companies to deliver best value solutions (as opposed to lowest cost solutions) through their regulatory framework, encouraging investment that responds to multiple drivers (for example, investment that addresses leakage, asset health, discolouration, and lead simultaneously) or has multiple benefits and takes account of outcomes and wider environmental and social value of solutions. In Wales, companies should also seek to deliver the requirements of the Wales Water Strategy, help deliver the goals of the Well-being of Future Generations (Wales) Act 2015, and to liaise with the Water Health Partnership for Wales on the development of lead reduction policy. Companies in Wales should therefore seek synergistic strategies to reduce lead in the long term for future generations.

7.4.4 Where there is a risk of exceedances of the 10 ug/l standard, depending on circumstances, companies are required to take steps to maintain wholesomeness by treatment to reduce potential concentrations via plumbosolvency, providing public health advice and replacing their communications pipes by request when the supply pipe is also replaced. The treatment must be optimised (ie, optimum dose, with regard to water aggressivity parameters), and networks operated to maintain stability and consistency of blends in supply, for greatest effectiveness at the point of use throughout the distribution system. In the case of public buildings, a company must exercise its powers to prevent lead contamination and if necessary, achieve this by enforcement under s75 of the Water Industry Act 1991.

7.4.5 Water companies have implemented risk-based strategies to achieve compliance with the prevailing lead standard for many years. Companies are expected to continue to apply this approach to managing compliance with lead as part of their ongoing activities. Companies should keep their risk assessments under constant review and identify an appropriate integrated package of measures to mitigate any risks identified. These measures would be expected to extend beyond the regulatory minimum specified in 7.4.4 to improve societal outcomes. Examples of this would include understanding where lead is, risk profiling of zones, opportunistic replacement when for instance installing meters or tackling leakage or carrying out work in zones, identifying high risk buildings such as schools and liaising with health and local authorities.

7.4.6 In January 2021 in collaboration with WRc, the Inspectorate published the Long-term Strategies to Reduce Lead Exposure from Drinking Water (https://cdn.dwi.gov.uk/wp-content/uploads/2021/02/08150815/DWI70-2-320.pdf) research report. The report provides compelling and significant evidence of the economic implications of exposure to lead through reduced societal intellectual capacity and physiological health. This has demonstrated via cost-benefit analyses that removing lead from drinking water has a significant overall economic benefit. Therefore the long term objective is to reduce exposure to lead in drinking water as there is no safe level of human exposure to lead (WHO) (https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health).

7.4.7 The challenge to remove lead to achieve the outcome in 7.4.6 is complex not least because lead was commonly used to connect properties to the mains water network in properties before 1970. As a result, there are estimated to be around eight million properties (both private dwellings and public buildings) in the UK that still have some form of lead-based material in the drinking water system. This can only be successful through a long-term strategy over the coming decades aimed at removing lead. Strategically this should be founded on a clear understanding of how this can be achieved.

7.4.8 As part of the UK Government Green Economic Recovery initiative in 2021, two water companies were selected to undertake lead replacement programmes at scale to better understand the practical costs at scale, the technical implications of different methods and importantly the best methods for achieving good consumer engagement with subject of lead and the need to exclude historic lead supply pipes from the drinking water supply infrastructure in homes.

7.4.9 The Inspectorate expects all companies to strategically plan for the future by taking suitable approaches towards reducing lead levels in the upcoming AMP8 period and successive periods by developing and gaining experience through implementation companies should aspire to achieving positive reductions of lead in drinking water. Information which companies have gained through ongoing strategies outlined in 7.4.5 will permit effective strategies when replacing lead. For instance, replacement may be at targeted at high-risk zones where there are schools, hospitals, and other vulnerable populations in a high lead density area.

7.4.10 The Inspectorate is supportive of innovation with respect to developing technologies, initiatives and efficiencies for the benefit of future generations. Companies are encouraged to think of the wider strategies which may impact decision making either through design or consequence. For instance, in developing strategies for the removal of lead planning for reduction of phosphate dosing is a sensible outcome. This benefits the environment through reduction in waste, together with efficiencies in reducing an increasingly costly and diminishing resource. Working towards a chemical free supply synergistically reduces our carbon footprint and net zero.

7.4.11 Conversely, where companies are considering innovation, such as relining of pipes they should also balance this decision with the consequence that they must also plan for longer-term replacement. Current lining technologies, by their nature will inevitably deteriorate with age this may in turn see a return to lead level exposure and other associated new issues with the lining deterioration. Since this option is a medium-term solution which would require further intervention, this will need be coupled to an undertaking to replace the affected lead supply pipes within a formally committed period prior to deterioration in the future

7.4.12 In considering any lead strategy, companies must communicate this effectively to consumers with particular regard to vulnerable consumers and be mindful of the overall efficiency of their approaches.

7.5 Phosphates

7.5.1 Phosphates retain an interesting and unique place in both drinking water distribution and in wastewater management. We have discussed in the previous section the importance of progressively reducing consumers' exposure to lead in drinking water for public health reasons.

7.5.2 For many years companies have been able to effectively manage lead levels in drinking water to varying degrees by orthophosphate dosing in supplied water to minimise dissolution of lead from lead communication and lead supply pipes. Some companies have been rigorous in removing and replacing lead communication pipework (under their ownership) while consumers have, more often than not, retained their original lead supply pipes.

7.5.3 Orthophosphate dosing has therefore been a necessity in many areas to keep lead levels below the statutory limit of 10 ug/L where there remains customer-side lead pipework and older lead solder used in fittings. Older homes and public buildings constructed pre-1970 are more likely to have such legacy lead pipework remaining if they have not been significantly refurbished since construction.

7.5.4 There are however some current and emerging downsides with orthophosphate dosing that mean it can no longer be seen as a longer term, sustainable or optimal management solution for lead as noted below:

a) Phosphate dosing has its limitations in its actual performance. It is unlikely that it will be a suitable primary control measure to deliver future reductions in lead levels beyond the current the parametric value. The DWI\WRc research report Long-term Strategies to Reduce Lead Exposure from Drinking Water 2021 Ref DWI14372.2 (https://cdn.dwi.gov.uk/wp-content/uploads/2021/02/08150815/DWI70-2-320.pdf) has already indicated that achieving 5 µg/L consistently while lead supply pipes remain in place, is unlikely to be achievable if relying on plumbosolvency measures alone.

b) Phosphates are heavily used in fertilisers for their nutrient properties to support crop growth. However, this property becomes very problematic when the same phosphates find their way into water bodies such as streams, rivers and lakes where their presence creates eutrophication (excess nutrients) that accelerates harmful algal growth and other unwanted flora that damage the ecosystem balance. Phosphates used in water supply dosing are a small fraction of that occurring in the environment (the majority arising from agricultural run-off and effluent discharges), but the dosing component does contribute to the overall phosphate loading unless successfully removed from wastewater effluent. Phosphates in drinking water are also known to be mobilised into the environment via network leakage and can also remain as one minor component of overall loading in wastewater effluent. Defra published a Consultation on environmental targets (https://consult.defra.gov.uk/natural-environment-policy/consultation-on-environmental-targets/supporting_documents/Environment Targets Public Consultation.pdf) in May 2022, which proposed targets to reduce overall phosphorus loadings from treated wastewater by 80% by 2037 against a 2020 baseline.

c) Lastly Phosphate is a naturally occurring but non-renewable resource that is predominantly sourced from rock phosphate deposits. Phosphates are therefore generally imported for continued use in all UK sectors. The supply chain and costs associated with importing phosphates are expected to become much more difficult and costly in the future as its availability decreases. Therefore, phosphate-based compounds should not be considered as a far future control measure for lead in drinking water.

7.5.5 The situation with phosphate sources and dosing has not reached a critical point, however the indications are that it is not a solution for managing lead levels in the very long term. The Inspectorate recommends that companies undertake research to look at scenarios where they may need to reduce and rationalise phosphate dosing in response to lower long term availability and/or temporary unavailability to understand the risks and mitigate them. Associated with this, companies should also consider the future of phosphate dosing in the round, such that planning is synergised with other more maintainable initiatives for lead reduction and controls to comply with current and future drinking water limits.

7.6 Radioactivity

7.6.1 Regulations require water companies to continue to monitor for radioactivity parameters.

7.6.2 There is provision in the legislation for an exemption from monitoring for radioactivity parameters. In August 2021 the Inspectorate issued an Information Letter IL 03/2021 (https://cdn.dwi.gov.uk/wp-content/uploads/2021/08/27102506/Radioactivity-IL-03-2021.pdf) and associated guidance on the process for these exemptions is included in Annex A (https://cdn.dwi.gov.uk/wp-content/uploads/2021/08/27102503/Annex-A-Conditions-and-Requirements-for-Radioactivity-Exemption-Applications.pdf).

7.6.3 Companies are not expected to provide monitoring data for surface water supplies and groundwaters in low-risk radon hazard areas but should still confirm in their reports that a risk assessment has been carried out and that there is a low risk of radon being detected with activity levels above 100 Bq/l. Companies should demonstrate that the risk for the site has been adequately assessed and these sites will require a radioactivity notice to vary compliance monitoring frequencies. During the period the notice is in effect, we recommend that companies carry out an operational monitoring programme to demonstrate that there has been no significant change to the circumstances relating to the issue of the notice.

7.6.4 Gross alpha and gross beta remain the indicators for the measurement of indicative dose. Investigations into breaches of either gross alpha or gross beta should trigger a re-evaluation of the indicative dose calculation if there have been significant changes in the normal measured values.

7.6.5 Tritium remains the indicator parameter for man-made radioactive parameters and an exceedance in this parameter should trigger an investigation into man-made radionuclides.

7.6.6 Radon is a more recent parameter of interest and reports to date suggest that this is unlikely to be of concern in public supplies in most occurrences. Where Radon is present companies should consider the level of risk and where appropriate initiate and maintain effective mitigation.

7.7 Other enduring or emerging risks

7.7.1 We would draw companies' attention to some enduring or emerging risks for drinking water quality at a limited number of sites that may require provisions within risk assessment reports. Additionally, there are evident weather-related risks for turbidity issues and associated tastes and odours caused by Methyl-Isoborneol (MIB) and geosmin.

7.7.2 The compliance standard for nitrate remains at 50 mg/l. Any increasing trend of nitrate concentrations in groundwater should be accompanied by catchment source interventions and control measures, in the first instance, and treatment solutions should be considered as a last resort, supported by written confirmation from the relevant environmental regulator that potential catchment management solutions are exhausted.

7.7.3 Based on recent research on chromium VI, and advice that exposure should be as low as reasonably practical, the Inspectorate has provided advice on the need for action to protect consumers (https://www.dwi.gov.uk/water-companies/guidance-and-codes-of-practice/guidance-on-implementing-the-water-supply-water-quality-regulations). Companies are reminded to review their circumstances and to put in place measures to mitigate levels that occur above 3 µg/l.

7.7.4 Geosmin and MIB are naturally occurring organic compounds. They are noticeable to consumers at certain concentrations and present with an earthy/musty taste and odour; current evidence suggests they are not toxic to humans. Increased levels of these compounds in raw water at some sites can cause taste and odour issues in ongoing water supplies. Risks to the quality of water supplies presented by both geosmin and MIB are generally well understood, and company mitigation measures should be included in risk assessments.

7.7.5 Microplastics are ubiquitous in the environment according to the World Health Organization (WHO) technical report Microplastics in drinking Water (August 2019) (https://www.who.int/publications/i/item/9789241516198). Evidence confirms their presence in both marine and freshwater bodies including those used for drinking water supply abstractions. The presence of microplastics in raw water sources is mainly driven by disperse or point source discharges such as surface water run-off, effluent discharges, sewer overflows and degraded plastic waste. Their occurrence and concentration in drinking water is still a topic of research and is not particularly well understood; current indications suggest their presence is extremely low and incidental.

7.7.6 However microplastics are of some concern given their longevity in the environment, the capacity for biofilms to develop on them (albeit at very low levels) and the potential for nano-particle sized microplastics to accumulate in biological tissue. The Inspectorate would welcome further research and company investigations that consider microplastics. In the interim the Inspectorate considers some, no regrets, precautionary action is appropriate.

7.7.7 It is recommended that companies consider the removal of microplastics from both raw water sources and drinking water prior to supply. In terms of raw water reduction/removal the best approach would be effective wastewater treatment prior to effluent discharge to prevent this potential source from entering the environment. Existing water treatment approaches should be optimised, using current treatment technologies that are known to effectively remove microplastic particles.

7.7.8 Endocrine Disrupting Chemicals (EDCs) are a diverse group of chemicals that have the potential to alter the normal functioning of hormonal systems across a wide range of wildlife and in humans (especially during early development). Their presence in a variety of applications and direct pathways for release into the environment means that EDCs could reach drinking water through typical use of EDC containing products. Continuous domestic release of many of these chemicals (particularly to wastewater systems) gives rise to pseudo-persistence in the environment, and they have frequently been found within the sewerage system and rivers. EDCs have been identified as a potential cause for concern for human health by the WHO in the report State of Science Endocrine Disrupting Chemicals 2012 (https://www.who.int/publications/i/item/state-of-the-science-of-endocrine-disrupting-chemicals). Peer-reviewed and grey literature verifies the occurrence of 17-Beta-estradiol (E2), Nonyl phenol (NP) and Bisphenol A (BPA) in both surface and groundwater. Our Inspectorate research has highlighted these three EDCs as of particular interest in terms of human health and have proposed recommendations for limits in drinking water. The rate of incidence of these three EDCs in wide scale surface/groundwater monitoring programmes such as the Chemical Investigation Programme (CIP) and British Geological Survey (BGS) surveys suggests that their occurrence could be expected at low levels in drinking water sources across England and Wales. Limited information is currently available on concentrations of these substances in source/treated water or their removal using advanced drinking water treatment technologies. The Inspectorate commissioned specific research into Likelihood of three endocrine disrupting substances reaching drinking water – Ref DWI 70/2/328 (25853) (https://cdn.dwi.gov.uk/wp-content/uploads/2021/07/07110203/DWI70-2-328.pdf) that should be considered. Although no high levels of the three EDCs were noted that would be of concern, the fact that E2, NP and BPA were all found, suggests that they should all continue to be monitored on a routine basis by water companies.

7.7.9 As noted in the pharmaceuticals, personal care products and domestic care products sections emerging and enduring risks should be considered as having the potential to impact drinking water quality and companies should maintain an awareness and knowledge of the research relating to the impact such existing products and those that may come to market for use.

8. Supporting development of business plans for periodic reviews

8.1 Context

8.1.1 The Inspectorate's strategic objectives are that water suppliers provide drinking water to consumers that is safe and clean, and that the public have confidence in their water supply.

8.1.2 In addition, The UK government has set out its priorities for Ofwat's regulation of the water industry in England[2]. Ministerial guidance from the Welsh Government will be provided to Ofwat on its strategic priorities and objectives.

8.1.3 Companies should work towards improvements in cybersecurity generally and with regard to operational control systems, in particular for compliance with the Network and Information Systems (NIS) regulations 2018.

8.1.4 Companies will also be required to understand their obligations to comply with Security and Emergency Measures (Water and Sewerage Undertakers and Water Supply Licensees) Direction (SEMD). The Inspectorate, on behalf of the Secretary of State and Welsh Ministers, is responsible for the regulation of the SEMD for companies who are wholly or mainly in England and Wales.

[2] February 2022:The government's strategic priorities for Ofwat https://www.gov.uk/government/publications/strategic-policy-statement-to-ofwat-incorporating-social-and-environmental-guidance/february-2022-the-governments-strategic-priorities-for-ofwat).

8.1.5 There is specific Inspectorate guidance (https://cdn.dwi.gov.uk/wp-content/uploads/2022/05/06172210/NIS-and-SEMD-PR24-Guidance-7.pdf) on NIS and SEMD for PR24 published.

8.1.6 Companies should consider synergistic opportunities to deliver multiple benefits to achieve long term improvements that benefit drinking water quality.

8.1.7 The Inspectorate's Compliance Risk Index (CRI) has been included in Ofwat's list of mandatory performance commitments (PCs) since 2019. Our expectation, in collaboration with Ofwat, is that CRI will be retained as general PC when the draft PR24 Methodology is published in Summer 2022. The Inspectorate is in ongoing discussions with Ofwat about how CRI could be used most effectively and fairly going forward. Consumer complaints are not included in the list of PCs but companies should be aware that the Inspectorate will still be collecting consumer complaint data and may look for improved performance.

8.1.8 The Inspectorate has developed and has been implementing the Event Risk Index (ERI) for several years. The ERI is a transparent means of capturing the performance of companies when dealing with unplanned and unexpected events that could or do adversely impact drinking water quality. ERI may also be incorporated in some form of measure to gauge company performance with respect to events, though this may not necessarily be along the lines of a mandatory PC. Discussions on the use of ERI for PR24 performance monitoring are ongoing between the Inspectorate and Ofwat.

8.2 Routine arrangements

8.2.1 The requirements of primary legislation and the Regulations relating to drinking water quality are routinely discharged by water companies and overseen by the Inspectorate. However, periodic reviews provide companies with an opportunity to review their arrangements, and, in particular, enable companies to revisit and update in their revised business plans as necessary, their long-term planning requirements for the supply of drinking water.

8.2.2 The core framework for drinking water quality reviews is already in place in the form of risk assessments based on a company's water safety planning processes, which are used to inform risk assessment reports to the Inspectorate. Outputs from these processes continuously inform the risk management arrangements of the company for each of its water treatment works and supply systems, both upstream and downstream. These risk assessments identify all the relevant hazards in the catchment; in the water treatment works; in distribution systems; at the point of use; and in a company's operations and maintenance arrangements that could potentially impact on a company's ability to supply wholesome drinking water. Wholesomeness is defined in the Regulations by reference to drinking water quality standards and any other substance or organism alone or in combination with another substance that would constitute a potential danger to human health and acceptability to consumers. The minimum statutory requirement is 100% compliance with these standards.

8.2.3 The risk assessments should already consider the short, medium and long-term control mechanisms required to address each hazard and assess whether there is a need for additional control measures in the catchment at abstraction points, at the treatment works or in the associated supply system to ensure that drinking water is wholesome at the consumers' taps and that risks to human health are appropriately mitigated. These measures may need investment in existing assets or in maintaining existing control measures already in place, where these are deficient. It should be recognised that many risks may be managed already through operational and/or communications control measures, and the case for investment may relate to improving the performance, reliability, resilience, and/or sustainability of such controls.

8.2.4 Our approach provides flexibility for companies to develop solutions to deliver required outcomes and encourages innovation by companies by recognising, and making provision for, uncertainty in outcome delivery and in the duration of scheme delivery of the solutions adopted. This is especially relevant for catchment management schemes, for new technology and for innovative solutions. In agreeing to such proposals for outcome delivery, the Inspectorate will need a clear understanding of the company's provisions for all aspects of outcome delivery recovery, if needed. Where legal instruments are put in place, mitigation steps may include investigative or modelling actions to facilitate identification or confirmation of the optimum solution.

8.2.5 The change application process that is already in place will continue to be applied for revisions to agreed proposals, where applicable. This enables companies to propose alternative solutions where these have been identified and can be shown to deliver benefits over and above the original proposal, or because changed circumstances require an alternative solution. This change application process is intended for genuine unforeseen circumstances and will only be granted if deemed appropriate by the Inspectorate. In all circumstances, prompt communication with the Inspectorate is encouraged as soon as any delays are foreseen. No alternative solutions will be permitted if they are not formally accepted by the Inspectorate prior to implementation through the change application process.

8.3 Accommodating business plan reviews

8.3.1 In support of routine processes, the Inspectorate is content to consider any new or revised requirements for improvements for drinking water quality reasons that might arise from a company's review of its current risk assessments as part of its business planning process. The outcomes from risk assessments referred to above should provide the supporting information for any drinking water quality proposals to achieve identified outcomes that water companies wish to include in their business plans. Any such proposals will be scrutinised for justification of need, in accordance with our usual procedures. If proposals for control measures are supported, they will be incorporated into legal instruments that specify the solutions and timescales to be delivered, together with arrangements for monitoring progress and confirming completion and outcome delivery.

8.3.2 Although current periodic reviews span a five-year period, the Inspectorate expects that companies will need to take clear strategic long-term views on their planning needs to ensure that their risk management strategies are coherent, effective, efficient and ultimately sustainable with due regard for resilient services to consumers.

8.3.3 To provide assurance that risk assessments include a long-term view, the Inspectorate requires all water companies to prepare and submit to the Inspectorate, by the end of January 2023, a concise statement that sets out significant new future risk mitigation measures that a company considers it will need to provide for. New measures are those that are beyond routine provisions for current risk mitigation for all of a company's supplies from source to tap, insofar as they affect the quality of drinking water supplies. Items of relevance might include, but not be confined to:

- Significant costs for the sustainability of long-term catchment management provisions.
- One-off, or 'lumpy', existing asset replacement for water treatment or storage facilities.
- Additional risk mitigation at water treatment works.
- Activities on the supply network that might include maintenance/replacement of trunk mains.
- Dealing with discolouration.

- Material or condition driven activity (for example, on epoxy resin lined pipework, asbestos cement mains, and lead pipe connections); and
- Network resilience measures.

The Inspectorate recognises that this is not only an important matter but a significant task for companies to complete; however, it is emphasised that the submission is envisaged as a concise summary to enable future engagement and discussion around the details if necessary.

8.3.4 For consistency and comparison, requirements should be considered from 1 April 2025, for a duration of a minimum of 25 years or more. Duration will vary with the specific driver and companies should be mindful of the affordability and impact on customer bills when considering the implementation period. Contributions to delivery within the AMP8 period should be clearly identified. The statement should state the item for which provision is required; its location or scale; the planned timing and duration of action by the company; and an estimate of the total and annual costs involved. Appendix A is available to download from the Inspectorate's website (Price review process - Drinking Water Inspectorate (dwi.gov.uk)). The template should be completed and returned electronically to dwipricereview@defra.gov.uk by 31 January 2023.

8.3.5 Transparency about, and availability of, this information is required by the Inspectorate to inform its discussions with each company, on the adequacy of its planning for future requirements to maintain the quality of drinking water supplies to consumers. Additionally, for Welsh companies, the information will be relevant to demonstrating that both Ministerial priorities and strategic objectives and the requirements of the Wellbeing and Future Generations Act 2015 are met. For English companies, the information is relevant for demonstrating alignment with Ministerial priorities and strategic objectives on transparency in long term planning and intergenerational fairness and consistency with the objectives of the UK government's plan A Green Future: Our 25 Year Plan to Improve the Environment (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf).

8.4 Evidence to justify need

8.4.1 Water companies seeking technical support for new improvement schemes from the Inspectorate will need to demonstrate the need for each proposal. The case for justification of need must be accompanied by the evidential information which justifies the need for action, and demonstration that the risk is significant enough to act at this time, including:

a) how the company has derived the most appropriate technical and cost-effective options to mitigate each named hazard and thereby achieve compliance with the regulatory requirements.

b) summary details of the capital costs and the net additional operating costs, as part of the overall total expenditure (totex), of each of the options considered.

c) identification of the preferred option and the rationale for choosing that option and reasons for discounting all other possible options and

d) evidence that the preferred option will adequately mitigate the risk and deliver the required outcome within an appropriate timescale, and that the solution is sustainable, and improves resilience.

8.4.2 The Inspectorate will expect companies to provide detailed supporting evidence that the preferred option will mitigate the risk of the hazard occurring or, where the hazard already exists, reduce the risk to an acceptable level (ie, compliance with any relevant standard or guideline value for unlisted parameters) within a prescribed timescale. The Inspectorate will not consider submissions for individual schemes that are not accompanied by supporting evidence of the process employed by the company to assess and determine the most appropriate technical and cost-effective solutions, and specific supporting evidence of the appropriateness of the preferred option.

8.4.3 Companies' analyses should include an assessment of all relevant benefits including the benefits of provision for protection of public health, and maintenance of public confidence in drinking water supplies. These benefits should be assessed qualitatively, quantitatively and where possible, monetised, in order to demonstrate that the proposed solution is needed, has a clear driver, will deliver the required outcome within the prescribed timescale, is sustainable in the long-term and is cost-effective. We will seek confirmation from companies that proposals are consistent with their long-term strategies for delivering water supply outcomes, and that these outcomes are consistent with their consumer and stakeholder research.

8.4.4 Companies should ensure that they review their compliance returns, event assessment letters, audit letters and commentaries in the Chief Inspector's reports to ensure that issues are addressed in their business plan submissions. The Inspectorate will make use of information available to it from compliance assessments, event assessments, consumer complaints and operational audits to be assured that companies are investing in areas where there is evidence of need.

8.4.5 The information requirements to support and justify preliminary submissions for individual proposals to the Inspectorate are provided in Appendix B, which is available to download from the Inspectorate's website (https://www.dwi.gov.uk/water-companies/price-review-process/). Submissions that are not accompanied with an up-to-date regulation 28 risk assessment report and comprehensive supporting information as detailed in the Appendix B will be rejected. Submissions should be sent electronically to the Inspectorate's Price Review mailbox: dwipricereview@defra.gov.uk, according to the timescales explained in paragraph 8.7.

8.5 Decision letters and legal instruments

8.5.1 The Inspectorate will formally confirm or decline to support the proposal in a Final Decision Letter sent to a company's board level contact, copied to the day-to-day contact and the Chair of its CCG. The Letter will also indicate whether or not a legal instrument will be put in place to implement a statutory programme of work.

8.5.2 We anticipate that some proposals, in particular catchment schemes, may be submitted for regulatory support which will deliver longer-term improvements to raw water quality, but are not included by the Inspectorate in a specific drinking water quality scheme, or are not included in the environmental regulators' programmes of work. In these cases, the making of a legal instrument for drinking water quality is unlikely to be appropriate, but the proposal may be commended by the Inspectorate in the Final Decision Letter, which will also confirm that a legal instrument will not be put in place.

8.5.3 The transposition of supported proposals into formal programmes of work will reflect the regulatory position as set out in the Regulations and the relevant sections of the Act. Where there is evidence of current, or a likelihood of future, failures of a standard for a parameter linked to a hazard identified through the risk assessments, the Inspectorate will put in place notices confirming the statutory requirements.

8.5.4 All legal instruments will continue to include a demonstration of benefits stage, to provide evidence to the Inspectorate that the required outcome has been achieved following completion of the programme of work. Companies may wish to ensure that their procurement arrangements are consistent with this requirement. We will arrange meetings with companies to discuss proposals where additional actions are necessary, and also to discuss companies' proposals for maintaining and operating their water supply assets to prevent future non-compliance.

8.6 Customer and Inspectorate Engagement

8.6.1 Engagement for PR24 will be conducted via a different method than previous price reviews. The backbone of engagement with customers will be facilitated via collaborative centralised research conducted by Ofwat and CCW. Ofwat has indicated that this collaborative research will focus on three key themes:

- Research on common performance commitments.
- Outcome delivery incentive (ODI) rates research.
- Acceptability and affordability testing.

Companies will be expected to supplement the centralised research by leading their own focused customer research to gain insights through specific forums, but also by interpreting their business-as-usual contacts with customers to garner some understanding of preferences and by, for example, employing willingness-to-pay research.

8.6.2 The Inspectorate will not be directly involved with either aspect of the centralised or company led research. However, we will seek to engage at a high level with Ofwat and, where appropriate, directly with companies to discuss how drinking water quality is explicitly accounted for and to provide feedback on the emerging research outcomes. It should be noted that the Inspectorate does see a necessity to have regular engagement directly with each company on business planning for drinking water quality. This Guidance is prepared to highlight the key areas that companies should have regard, though this should not be considered a comprehensive guide for every eventuality. The Inspectorate will be available to engage with companies as necessary to provide feedback on developing drinking water proposals towards producing their business plans.

In addition to the January 2023 statement that sets out significant new future risk mitigation measures, companies should preferably follow this with submission of their draft business plans for drinking water quality investment to the Inspectorate by end of March 2023. This will allow sufficient opportunity for the Inspectorate to provide feedback ahead of the submission of Business Plans to Ofwat in Autumn 2023.

8.6.3 Companies should be able to demonstrate to the Inspectorate that their business plans include sufficient provision for operations and maintenance activities to ensure that compliance with the Act and the Regulations is maintained; that the quality of drinking water does not deteriorate; and, where it is deficient, it is improved. Companies are also expected to consider more generic risks to resilience, for example, power outages, flooding, drought, security of supply for treatment chemicals, analytical capacity, and system issues such as critical telemetry, SCADA, NIS and other IT systems.

8.6.4 The Inspectorate expects companies to have a sustainable and integrated asset management strategy for all water supply assets, that is designed to minimise the risk to consumers by proactive mitigation of the risks from drinking water quality events and non-compliance with the standards. This reflects the general duties of water companies to maintain an efficient and economical system of water supply. Risk-based asset maintenance strategies are regarded by the Inspectorate as an integral part of companies' risk assessment and risk management approaches using water safety plan methodology.

8.6.5 Asset maintenance strategies that prevent problems with drinking water quality by proactive intervention should be applied to all water treatment and distribution assets, in particular treatment works and service reservoirs. If a company does not have an adequate asset management strategy in place, then there will be a risk of future non-compliance with the statutory water quality standards and a greater likelihood of a deterioration in the aesthetic quality of drinking water as measured by consumer contacts reporting discolouration or an objectionable taste or odour.

8.6.6 Water asset management strategies must be informed by a comprehensive review of information about recent water quality incidents, breaches of standards and the number of consumer complaints because these data may be the only reliable evidence that points to systemic and persistent underperformance of existing assets.

8.7 Timeline for PR24 engagement

8.7.1 The Inspectorate's timetable for PR24 has been developed to assist companies that are required to prepare a business plan for submission to Ofwat by Autumn 2023. We would encourage companies to submit their business plan proposals for drinking water quality as early as possible, and it is advised that companies start any detailed engagement with the Inspectorate no later than September 2022 onwards.

8.7.2 We will accept submissions up to the end of March 2023, with a view to Final Decision Letters being issued by 31 August 2023. All submissions must be accompanied by up-to-date risk assessment reports. If the risk assessment report is a revised version with different risks to the version previously submitted, it would be helpful if these could be sent at least four weeks in advance of the PR24 submission, with changes clearly highlighted, to allow the Inspectorate time to review the revised risk assessment and to consider whether enforcement action may be appropriate.

8.7.3 We have set a target date of the end of February 2024 to have all necessary legal instruments in place to allow time for further planning before business plan submissions in Autumn 2024 and Ofwat's final determinations at the end of 2024.

Drinking Water 2022

Public supplies England

www.dwi.gov.uk

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Contents

Glossary

Company code with their associated company name

Code	Company Name
AFW	Affinity Water
ALE	Albion Eco Ltd
ALB	Albion Water Ltd
ANH	Anglian Water Services Ltd
BRL	Bristol Water Plc
CAM	Cambridge Water Company Plc
DWR	Dŵr Cymru Welsh Water
ESP	ESP Water Limited
HDC	Hafren Dyfrdwy
ICW	Icosa Water Ltd
IWN	Independent Water Networks
ISC	Isles of Scilly
LNW	Leep Networks Water
NES	Northumbrian, Essex and Suffolk Water
PRT	Portsmouth Water Plc
SES	SES Water
SVT	Severn Trent Water Ltd
SEW	South East Water Plc
SST	South Staffordshire Water Plc
SWB	South West and Bournemouth Water
SRN	Southern Water Services Ltd
TMS	Thames Water Utilities Ltd
UUT	United Utilities Water Plc
VWP	Veolia Water Projects
WSX	Wessex Water Services Ltd
YKS	Yorkshire Water Services Ltd

Foreword

The strategic objective of the Drinking Water Inspectorate is to protect public health and maintain public confidence in drinking water, and this is achieved by securing sufficient safe and clean drinking water, now and for future generations. This central position is shared by the public, who relate to the service aspects which affect them directly. In recent consumer preferences research, a sample of 302 people ranked the appearance and taste of their drinking water together with a constant and a safe supply as their top priorities.[1]

The UK is one of only six nations in the world with the maximum score possible in the 2022 Environmental Performance Index (**Yale**).[2] This measures diseases and deaths from exposure to unsafe sanitation and drinking water, providing countries with independent data on whether water infrastructure is sufficient to maintain public health. The absence of any disease associated with drinking water infrastructure validates the work of the Drinking Water Inspectorate and the companies it regulates in ensuring public health is protected. Whilst this is certainly good news and aligns with the high level of compliance by companies and the actions by the Inspectorate since 1991 to keep drinking water safe in line with consumer expectations, it is critical not to be complacent. To maintain this position the Inspectorate has set out four pillars upon which water company strategic plans will need to focus when considering the water supply for the future based upon current and emerging risks; these are:

- Climate Change
- Continuing and new risks
- Source to Tap Planning
- Supply Resilience

1 Research on customer preferences: A joint report by CCW and Ofwat **Understanding customers' preferences for Performance Commitments at PR24 – CCW**

2 Wolf, M. J, Emerson, J. W., Esty, D. C., de Sherbinin, A., Wendling, Z. A., et al. (2022). 2022 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy. epi.yale.edu

The impacts of climate change range from drought and prolonged periods of dryness to floods coupled with heavy rain. Extreme conditions affect resources by degrading the chemical and biological composition of the catchment and source water through pollutant concentration, increasing the risk to water treatment. These include algae, metals, turbidity, and novel pollutants, which have impacted the ability of treatment works in England to treat and supply water which is wholesome. Catchment risks must be assessed to identify the mitigations necessary in the short and long-term to ensure infrastructure is and remains fit for purpose, adaptable and is planned as a proactive strategy.

This report is accompanied by the raw water data at the points of abstraction in order to highlight the continuing and new risks posed by environmental water used for drinking. The threat of PFAS in raw water sources is evident by the work of the Inspectorate and is published in this report. Water companies must plan to mitigate these risks in their business plans, particularly since understanding of the toxicities remains uncertain. The raw water data highlights challenges such as pesticides, nitrates and other chemicals which may become transferred risks as source waters change, sources are opened or reopened, raw water transfers, recycling and other infrastructure developments. Equally important is the need to scan the horizon for risks which may not be evident now, but become important where changes in the catchment occur, including endocrine disruptors, pharmaceuticals, microplastics and post-industrial solvents. Changes in our environment, demographics, industry, customer expectations, and usage, will put pressure on aging infrastructures which are no longer able to cope or cater for these changes, some of which have been highlighted in the report, as well as difficulties enabling asset inspections, removal from supply, and replacement. The Inspectorate has an enforcement strategy linked to transformation programmes. These are utilised where there are persistent water quality risks, and focus companies on keeping water safe.

Discoloured water remains the most common reason for consumers to contact their supplier with a water quality concern in England. This is caused by resuspension of sediment within the mains, originating either from source water containing metals which pass through the water treatment works and seed the network, or from metals eroding from older iron mains. Significant investment is required to lower margins of treatment control to first remove metals more effectively, but also to replace and remediate these mains to reduce discolouration and avoid events where customers experience unwholesome water.

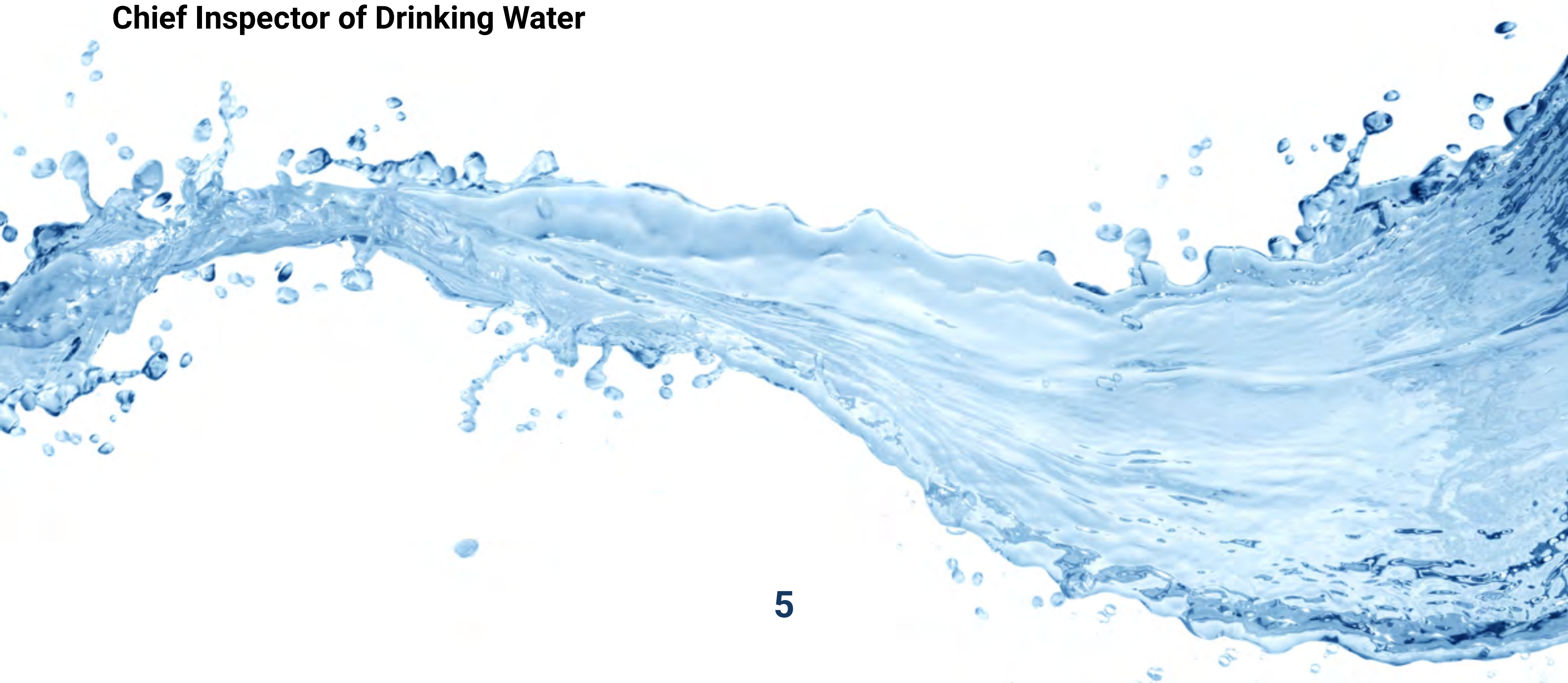
This year has identified water treatment works failures due to interrupted power supply, a significant cyber security breach, gaps in physical security, and inadequate provision of alternative supplies which has fallen short of minimum expectations. Power generators at treatment works do not in themselves provide complete resilience for supplies, since logic controllers have failed on power surges and pumped distribution systems do not have full coverage of the supply area. The impact of the December 2022 freeze/thaw event has been reported on the Inspectorate website. Whilst the response was better compared to 2018, the response has still fallen short for two companies, where there was a lack of resilience in the system coupled with insufficient headroom to recover the supply/demand balance following burst mains. The high summer demand in hot weather also caused supply interruptions. In one instance in particular, the provision of alternative supplies was well below minimum expectations. The loss of drinking water supply has severe societal impacts and investment in alternative supplies will be necessary to meet the changes of SEMD 2022 and the subsequent gaps identified in risk assessments for alternative supplies.

Finally, we must not forget the significant legacy issue of lead which remains prevalent in our homes. Scientific evidence unequivocally states that there is no safe level of lead in drinking water. Companies should be increasing their strategy, not reducing it, towards eliminating lead.

We cannot stand still, be complacent, or assume drinking water remains of such high quality that no investment above base expenditure or no action is required, because this will result in our failure to protect public health and we consequently won't be in the top six countries in the world for drinking water quality.

I began by stating that for consumers, their priority is a good clean wholesome supply. I urge companies and all involved in drinking water to adopt a balanced and strategic investment strategy for future generations.

Marcus Rink
Chief Inspector of Drinking Water



Introduction

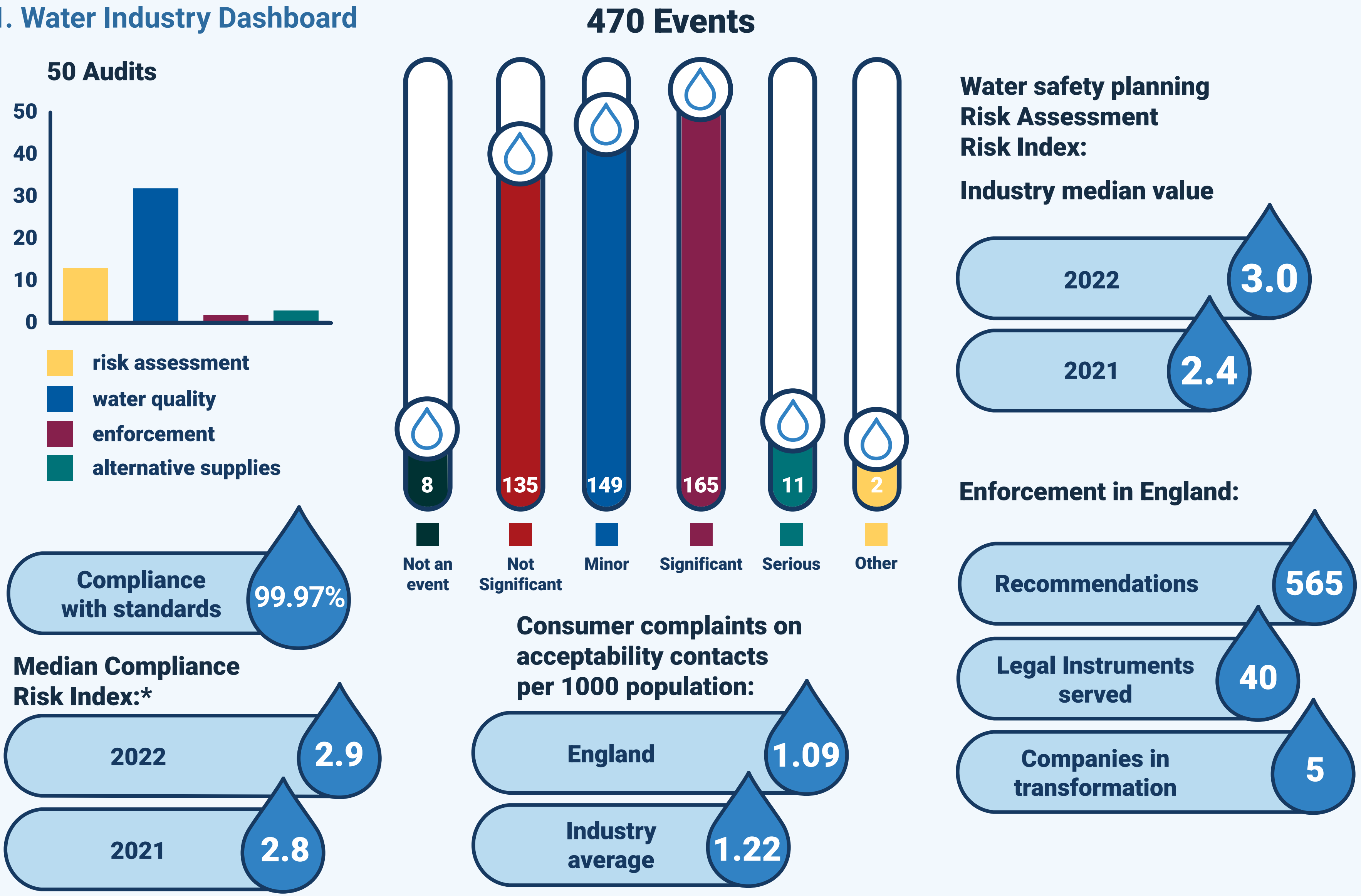
Drinking Water 2022 is the annual publication of the Chief Inspector of Drinking Water for England. It is the 33rd report of the work of the Inspectorate and presents the summary information on drinking water quality for the calendar year of 2022.

The Chief Inspector's report is published as a series of four quarterly reports which cover detailed case studies for industry learning and sharing best practice, and a final summary report for public supplies. A separate report covers the quality of private water supplies, which is available on the Drinking Water Inspectorate's website. The Inspectorate is also the regulator for the Network and Information Systems Direction and the Security and Emergency Measures Direction. Reports are made to Ministers but not published.

This report is the summary of public water supplies for England.

The industry dashboard for England 2022 is shown in summary below. The Inspectorate welcomes feedback on this report at **DWI.Enquiries@defra.gov.uk**. The inspectorate aims to respond to enquiries within 5 working days, and achieved a 96% success rate against this target in 2022.

Figure 1. Water Industry Dashboard



* excludes insets and ISC

Water supplies and testing

Set out in this report are the key facts about the quality of the public water supplies in England, which is served by 23 water companies delivering supplies to over 57 million consumers.

Table 1.

Key facts about public supply arrangements in England

Public supplies	Statistics
Population supplied	57,907,036
Water supplied (L/day)	14,123 million
Abstraction points	2,150
Treatment works	1,077
Service reservoirs	3,789
Water supply zones	1,683
Length of mains pipe (km)	321,363
Surface sources	62%
Groundwater sources	31%
Mixed sources	7%

Table 2.

Key facts about private supply arrangements in England

Private supplies	Statistics
Population supplied	956,429
Water supplied (L/day)	403,227
Number of supplies	34,904
Number of Local Authorities with private supplies	231
Surface influenced sources	43%
Groundwater sources	29%
Mains water	2%
Unknown	26%

Map 1.


Water Industry - England 2022
NES
ANH
UUT
YKS
SVT
SST
ANH
NES
SVT
NES
CAM
DWR
AFW
AFW
TMS
NES
SRN
SRN
TMS
BRL
SEW
SES
TMS
SEW
SRN
AFW
WSX
SRN
PRT
SWB
SRN
SWB
SRN
ISC
Companies
AFW - Affinity Water Ltd
ANH - Anglian Water Services Ltd
BRL - Bristol Water Plc
CAM - Cambridge Water Company Plc
DWR - Dŵr Cymru Welsh Water
ISC - Isles of Scilly
NES - Northumbrian, Essex & Suffolk Water Ltd
PRT - Portsmouth Water Plc
SES - SES Water Plc
SEW - South East Water Plc
SRN - Southern Water Services Ltd
SST - South Staffordshire Water Plc
SVT - Severn Trent Water Ltd
SWB - South West and Bournemouth Water Ltd
TMS - Thames Water Utilities Ltd
UUT - United Utilities Water Plc
WSX - Wessex Water Services Ltd
YKS - Yorkshire Water Services Ltd

The area served by each water company (Licenced undertaker) is shown in Map 1.

New appointments and variations (NAVs) are limited companies which provide a water service to customers in an area which was previously provided by the incumbent licenced supplier. NAVs supply water through new assets and compliance with the standards is consequently very good, although there were occasional issues relating to taste and nickel from chrome taps. NAVs are listed in Table 3, with the number of insets and the total population served.

Table 3.

Inset appointments

Company name	Number of insets	Total population served	Geographical spread
Albion Water (ALB)	2	2,710	London Southeast and Central Eastern England
Icosa Water (ICW)	20	4,800	Northern, Central and Eastern, London Southeast, Western England
Independent Water Networks (IWN)	72	45,098	Northern, Central and Eastern, London Southeast, Western England
Leep Networks Water (LNW)	41	67,225	Northern, Central and Eastern, London Southeast, Wales, Western England
Veolia Water Projects (VWP)	1	13,000	Western England

Sampling

The number of tests carried out by each water company is within Annex 1.

Water companies are required to take samples as specified by the Regulations to demonstrate water is wholesome. Ultimately the purpose is to maintain the confidence of the public in their water supply and protect human health.

Most companies achieved 100% or almost 100% of the target number of compliance tests. Thames Water was an outlier with only 94% of the programmed tests completed, which leaves consumers vulnerable. Verification sampling is an essential element of safe and secure drinking water.

Thames Water sampling shortfall enforcement case study

Thames Water was notified that it had and was continuing to contravene its obligation to take samples and consequently those samples which were taken were not taken at regular intervals throughout the year. Water companies must take samples at regular intervals as changes in the weather and the environment during the year alter the risk of failures. For instance, pesticides are often applied at specific times of the year, or rain is more likely during winter months. In total the company failed to take thousands of regulatory required samples (24,091 tests), for reasons that were within its control to manage. Sampling is planned the year before, so the number of staff required to take those samples and the analytical requirements are entirely foreseeable. Failure to comply with sampling and analysis requirements under the Regulations is enforceable under regulation 38 of the Water Supply (Water Quality) Regulations 2016 (as amended) and section 18(1)(a) and (6) of the Water Industry Act. As such, this contravention was not considered trivial, and the Inspectorate consulted on and made a final enforcement order in early 2023. Should the company fail to comply with the Order, further action will have to be taken.

Compliance with standards

The percentage compliance with the standards in the Water Supply (Water Quality) Regulations 2016 is shown in Table 4, and details of all the failures are set out in Annex 3 by site type and by company. The following companies reported no failures during 2022: Cambridge Water, Albion Water, Veolia Projects, Leep Networks Water and ESP Water (who started operating during 2022).

Table 4.

Percentage of samples meeting the standards

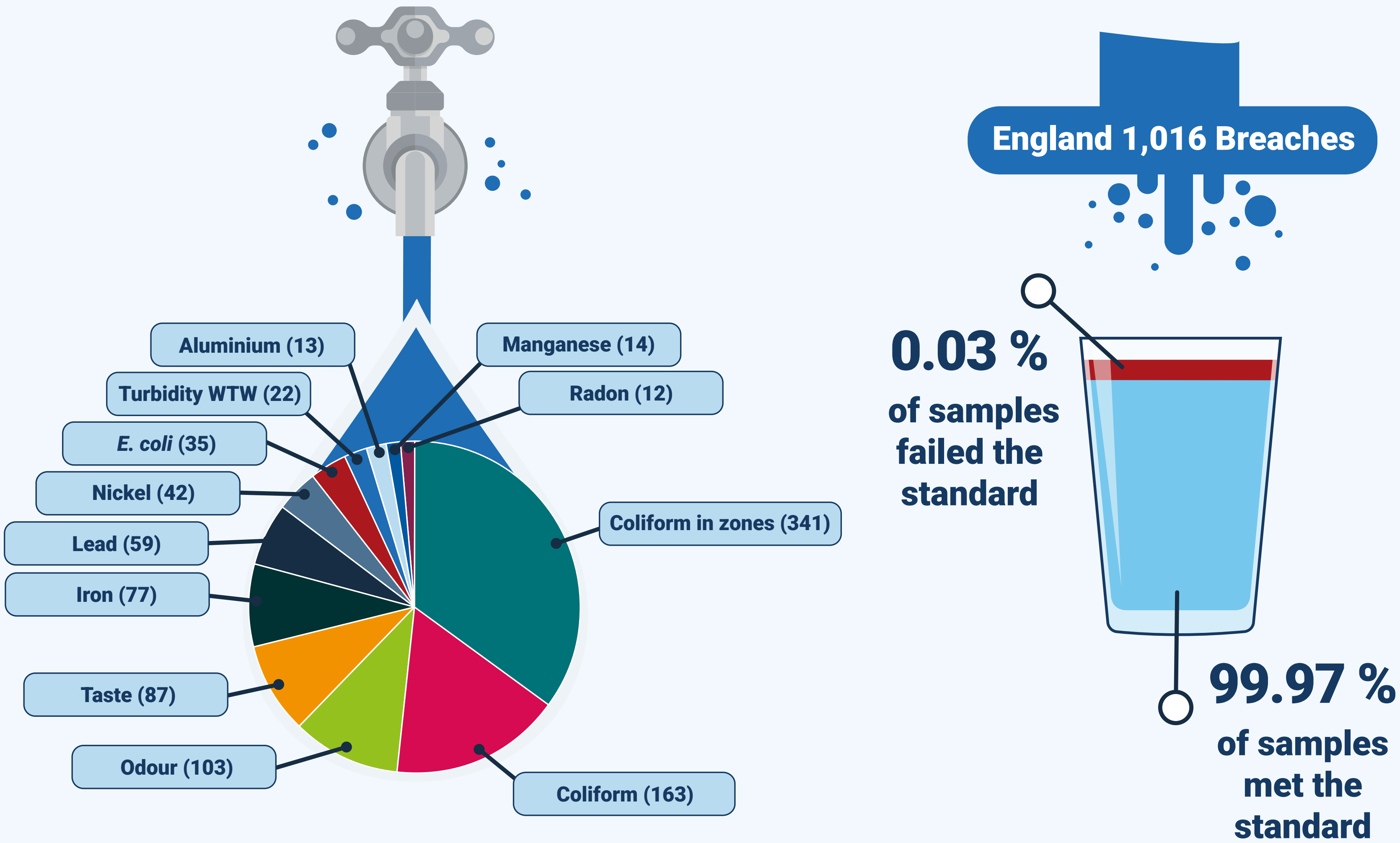
Parameter Group	% Compliance
Chemical Parameters	99.94
Indicator Parameters	99.95
Microbiological Parameters	99.99
Pesticides	100
Overall	99.97

The tap and pie chart represent the quality of drinking water received by consumers, and the numbers and parameters which failed to meet the standards in 2022.

Figure 2.

Compliance with the standards in 2022 - England

Number of Breaches

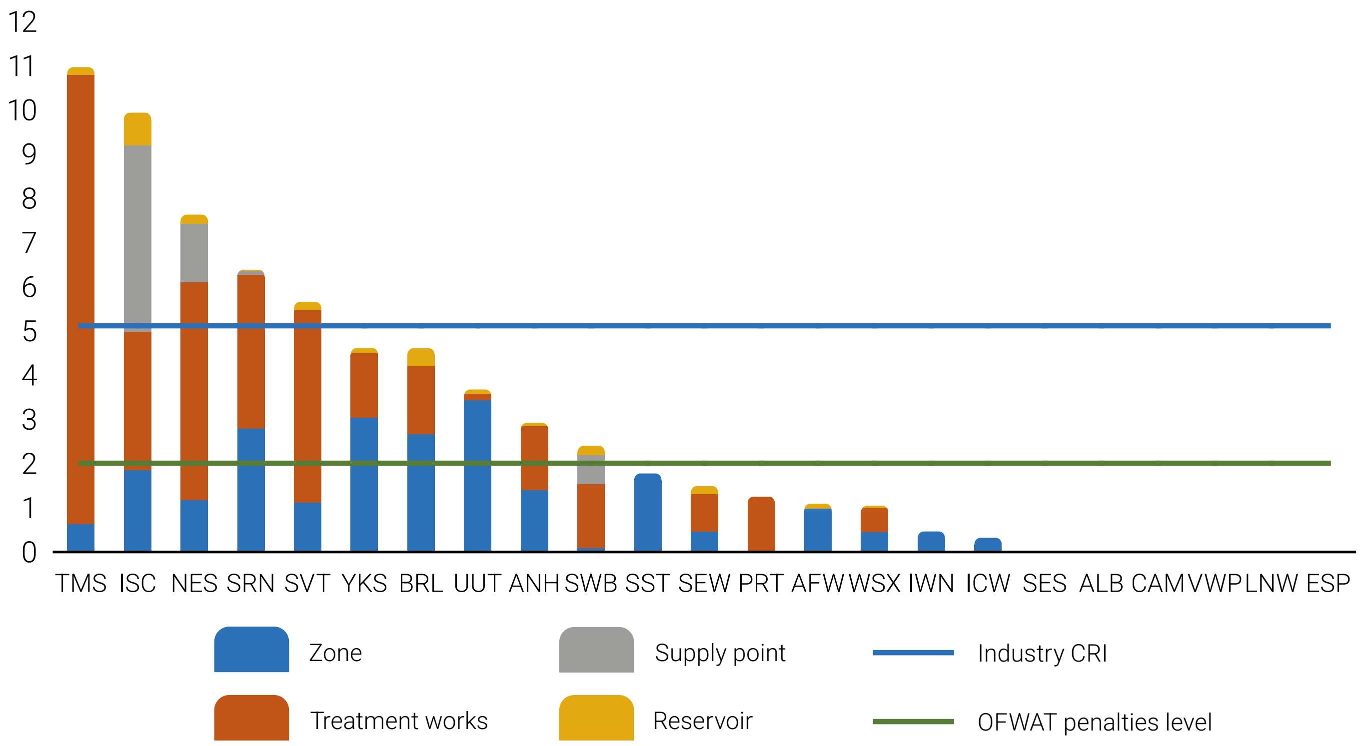


Compliance with the drinking water standards is consistently high in England, but scrutiny of company water safety plans, audits and events reveals underlying risks within the drinking water supply system. The Inspectorate has developed a series of risk indices to identify where companies are failing to address risks to supplies. The Compliance Risk Index measures risks to consumers from non-compliance with the standards, and is shared with the water industry's financial regulator, OFWAT, as a common performance measure. This integrated regulatory strategy is intended to improve water quality in the public interest.

The bar chart below shows the compliance risk index (CRI) for each company operating in England divided into site types, zones (consumer taps), water treatment works, supply points and service reservoirs.

Figure 3.

Compliance Risk Index by company England 2022



Poor asset health is the main reason for companies incurring financial penalties. CRI is weighted to key assets such as water treatment works, where the population potentially at risk from those failures is large, and with added weighting where enforcement action has already been taken.

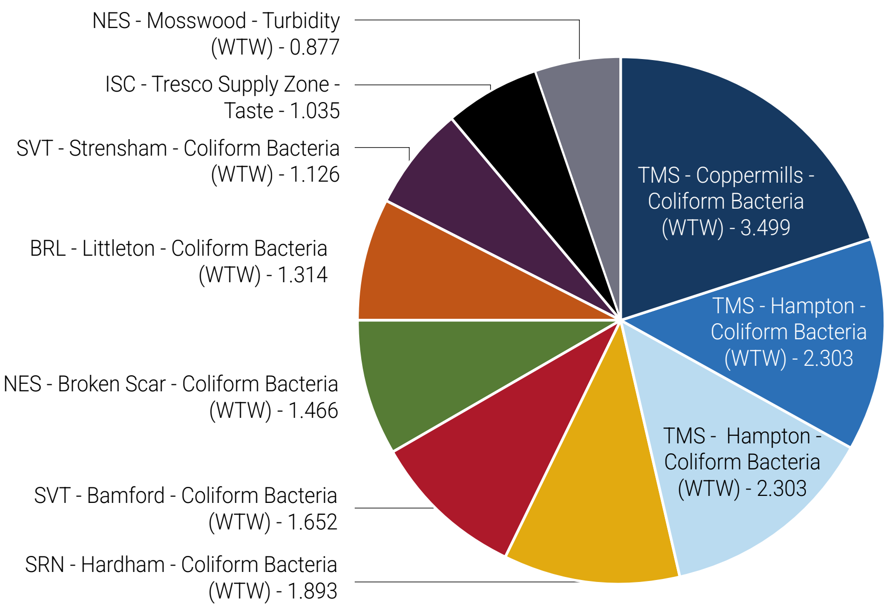
Thames Water Compliance

Thames Water reported 115 compliance breaches in 2022 which equates to 99.97% compliance demonstrating a high quality of water in supply. However, 12 of these breaches related to enforcement notices to address shortcomings at its treatment works and service reservoirs, and therefore attracted high CRI scores.

Thames Water's Coppermills slow sand water treatment works supplies a large area of northeast London, supplying around 4 million consumers, either directly or indirectly with other supplies, and is a key works. The assessment of a single coliform detection in February concluded a breach of regulation 4 (wholesomeness) had occurred. This failure resulted in the single highest individual CRI score of 2022 reflecting the critical size of the supply. Protective covers for the ammonium sulphate dosing lines into the contact tank were detached and the chamber was flooded causing a significant risk of ingress. Unmitigated risks at significant sites validate the purpose of CRI to ensure companies use proactive risk methodology to keep drinking water safe. The dosing lines have since been repaired and the tanks are to be internally inspected. This site is covered by an enforcement notice.

Figure 4.

Pie chart illustrating breaches with highest CRI scores 2022



Another key asset is Hampton treatment works which had recurrent detections of coliforms, in the autumn of 2022, the root cause being ingress into the contact tank. This site is covered by an enforcement notice and consequently the CRI for this site is the second highest during 2022. The company has been unable to conduct a thorough internal inspection and repair due to passing valves which have deteriorated over the years coupled with significant risks of supply interruptions which prevent the removal of the tank. As an interim control measure the company has installed a membrane across the roof of the tanks using plastic sheeting until further repairs can be completed. In spring 2023 the company commenced a repair and maintenance programme to allow the tanks to be isolated and internally inspected. The extent of the work the company has committed to is ambitious and welcomed to keep water quality first, however, companies are reminded that ongoing maintenance of assets should be central to proactively keeping water quality first rather than an afterthought resulting in reactive measures following repeated failures.

The Inspectorate issued new enforcement following a failure at Swinford works linked to poor filter performance. Recommendations were also made associated with 14 other breaches where the company was not fully compliant with the Regulations.

Severn Trent Water compliance

Severn Trent Water's Bamford water treatment works reported a final water sample with 3 coliforms and 19 non-coliforms per 100 mL. The works was performing within expected limits with disinfection criteria met at all times. No raw water deterioration was observed, and no issues with clarification or filtration treatment stages were found. The site investigation team confirmed that the balance tank had a leak which was being pumped away, but as the leak remained under positive pressure it was not considered a contributory factor. The tank was last inspected and flood tested in February 2020, the remotely operated vehicle (ROV) inspection in December 2022 did not identify obvious structural defects. The balance tank was isolated on 7 February 2023 and confirmed not to be cause of the leak. The contact tank's last internal inspection and clean was in September 2022. Contractors were onsite to install flow meters near the final sampling point. The door to the building remained open during the work with dust in the air considered by the company as a potential contributory factor, reminding companies of the need to risk assess the work of any contractor on a live water production site. As a precaution, the installation of dedicated final water sampling kiosk next to and separate to the building was completed.

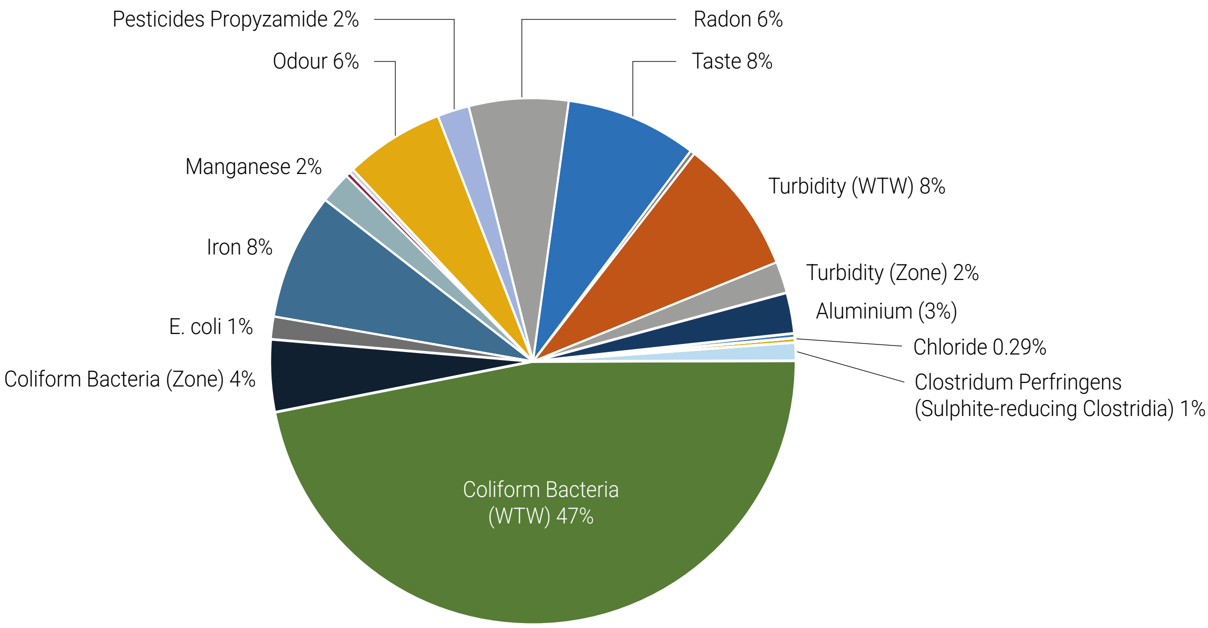
Northumbrian Water compliance

Northumbrian Water's Mosswood water treatment works had five separate compliance breaches for turbidity in 2022. The site is part of the ongoing transformation programme and HazRev (Hazard Review) work is underway to find a long-term solution to problems of sediment in deeply buried pipework and tanks.

Broken Scar water treatment works is under notice for a full inspection of the contact tanks and outlet wells, by December 2022.

Figure 5.

Proportion contributed by different parameters the CRI



Ingress and plant failure at water treatment works

Coliform failures at water treatment works was the largest contribution to CRI, which is consistent with previous years reflecting the purpose of CRI. A number of these breaches were directly attributed to the condition of treated water storage tanks at treatment works. Service reservoirs, treated water tanks, and contact tanks (and any other tanks or vessels containing treated water) that are overdue inspection and cleaning are at particular risk of compliance breaches.
All companies should have in place an effective strategic plan to inspect and clean assets and delivery of this plan should be continually reviewed to ensure tanks are inspected within risk-based frequencies.

Southern Water's Hardham water treatment works is covered by a notice. A single coliform was detected in the final treated compliance sample. Several issues were identified including potential ingress into the final High Lift Pump sump, algae present on the clarifiers, and contractor work around the sample kiosk and sample tapping. The company carried out remedial work to repair holes in the roof and gaps into the sump, and a risk assessment was undertaken for mitigating algal risks in the raw water reservoir.

95% Coliform compliance at service reservoirs

Five reservoirs failed to meet 95% compliance as required to meet the wholesomeness standard in the Regulations. These were South West and Bournemouth Water; Abbey East (Tresco); Northumbrian Water's Scotts Quarry Old; Thames Water's Hampstead North and Thames Water's Willesden.

Anglian Water's Maidford Reservoir was out of service and only sampled once in the year.

South West and Bournemouth Water considered the third failure at Abbey West service reservoir in Tresco to be the result of poor sampling technique on a rainy and windy day. The tap was flame disinfected, but there was some doubt around how effective this was, as the blow torch used failed to stay alight in the winds. Two further failures during the year coincided with coliform detections at the supplying treatment works. It is difficult for the company to maintain supplies during peak demand periods with the reservoir out of supply. The Inspectorate has issued enforcement notices to address the issues with the reservoir.

Thames Water failed to identify an ingress risk at Hampstead Reservoir following the first failure in August but identified hatch ingress following a subsequent failure three weeks later. The Inspectorate made a recommendation and the reservoir was removed from service for the rest of the year. Thames Water's Willesden service reservoir was removed from service in October following a coliform failure. The site had been out of supply between March and August for structural repairs.

Northumbrian Water's Scotts Quarry service reservoir was removed from supply for repairs twice in 2022 following failures in July and then again in November, on both occasions the company attributed the ingress to heavy rainfall. The quality of the repairs following the first detection must be brought into question by this failure, so soon after returning the tank to service.

Lead compliance and strategies for Price Review 2024

Lead is a toxic metal that can dissolve into the drinking water when it comes into contact with lead pipes. Consumers are protected to a large extent from exposure by the practice of phosphate dosing at treatment works to reduce plumbosolvency. However, compliance with the lead standard remains a concern with 1 in 200 random customer tap samples failing the lead standard.

Companies are submitting lead reduction strategies as part of their business plans for Price Review 2024 (PR24), with the majority setting a target of lead-free supplies by 2050. No company holds a complete dataset of pipe material, and the number of lead supply pipes and communication pipes are estimated.

South East Water proposes to survey all service pipes (communication and supply) within the company area, this will provide a wealth of information which can be used for future targeted work on replacements.

Companies adopt different action levels when responding to lead sample results. Some aim to respond to detections as low as 3 µg/L. Hafren Dyfrdwy have gone even lower, aiming for completely 'lead-free' supplies at schools in its area. Sutton and East Surrey Water aims to provide a lead-free supply to the point of compliance at schools, nurseries and childminders.

A number of discrete areas have been chosen for trials on phosphate disengagement, following removal of all lead pipes from a zone. These include South East Water's Coombe Water supply zone supplying 4,000 properties. These build on previous targeted disengagement trials carried out by Severn Trent Water and United Utilities. Sutton and East Surrey Water has observed that phosphate dosing has a beneficial effect on minimising nickel failures from taps and fittings in consumers' properties, and so companies need to have a strategy for nickel when considering phosphate disengagement trials.

The addition of phosphoric acid is not the only way in which a water company can reduce plumbosolvency. Companies should formulate strategies to supply stable, non-aggressive water. Few water companies include in their lead reduction strategies relevant parameters such as pH or alkalinity. Northumbrian Water has a stated aim to produce stable waters that are neither aggressive nor scale forming.

Photograph 1.

Domestic lead plumbing after removal

Technological readiness is also a factor, companies are seeking better detection systems for identifying lead pipes to reduce the time taken to find lead pipes. Several companies are also undertaking trials using relining systems, and whilst this is not a permanent solution, it may offer a pragmatic approach for reducing risk where there are shared supplies which cause challenges for ensuring agreement between all parties. Nevertheless, where pipe relining is used, this should be accompanied with the longer-term strategic solution of complete removal as not to do so would represent an ongoing cost for repeated remediation.

The scale of replacement proposed during 2025 to 2030 is substantially less than what will be required to meet the companies own 2050 targets, for example Portsmouth Water will need to be undertaking around 3,200 replacements per year to complete its estimated required 80,000 by 2050, but during the five years from 2025 the company is aiming for a total of 500 replacements. Conversely, the current rate of replacement by Thames Water will see it lead free by 2135, it has a target of 53,000 communication pipe replacements during the AMP, whereas around 48,000 are needed per year to meet the target.

Thames Water is only focusing on communication pipes and is looking to identify and employ strategies that successfully encourage property owners to replace both their external and internal lead pipework.

Dwr Cymru is developing a lead predictor model in the absence of hard data on pipe material, this also utilises data on age ranges of inhabitants and focuses on the vulnerable groups to prioritise areas for replacement. The company is estimating 180,000 lead pipes will require replacement and its AMP8 target is to replace 7,500 over five years.

Whilst the replacement of every single lead pipe will be of benefit to public health, the target which most companies have set themselves of being lead free by 2050 feels currently out of reach without a colossal effort from AMP9 onwards.

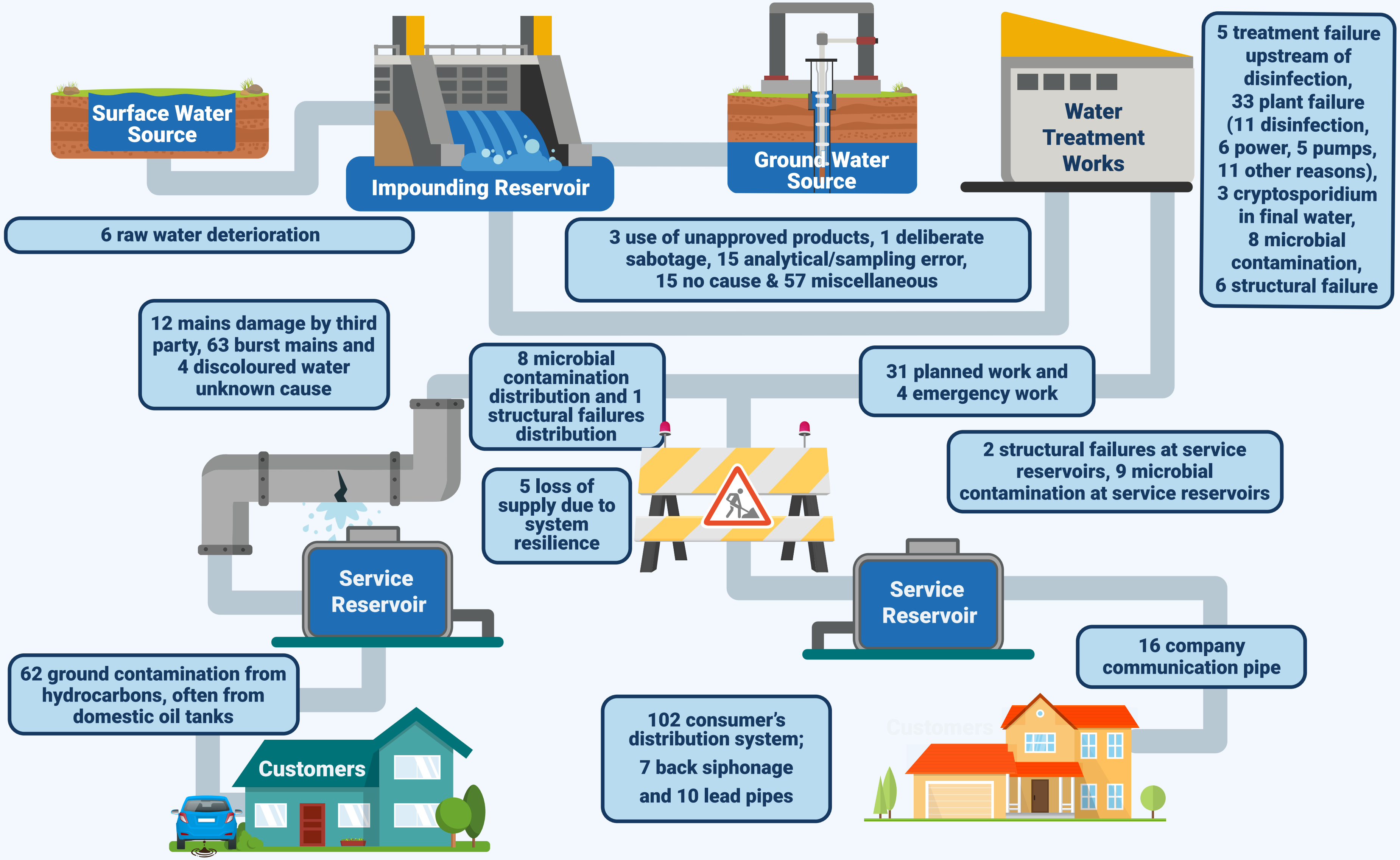
Water quality events

The Inspectorate was notified of 470 events during 2022, all of which were assessed, and enforcement action taken where necessary. The catchment diagram in Figure 6 illustrates the nature of the events and their impact on the water supply from source to tap.

Alongside the usual network issues such as burst mains and third-party damage which cause discolouration events, there were significant asset failures relating to power supply, structural integrity, treatment processes, and disinfection at water treatment works. Five water quality events occurred where the company was unable to provide a suitable supply to consumers due to a lack of resilience, and the Inspectorate has published its review and lessons learned from the 2022 December freeze/thaw event on the Inspectorate's website.

Figure 6.

Main causes of drinking water quality events 2022 in England

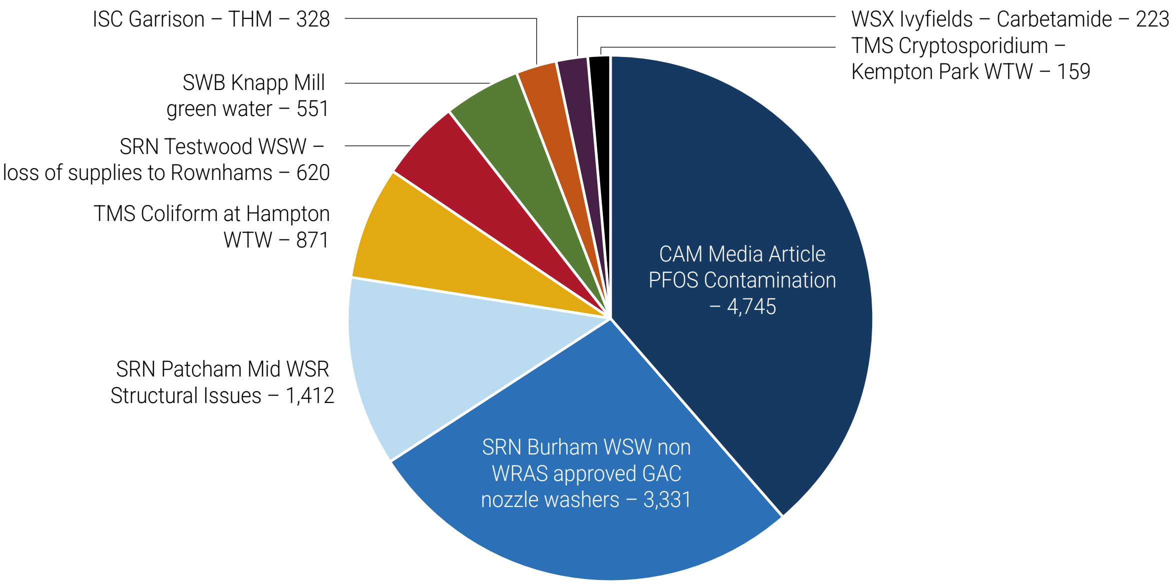


Highest scoring events

The following pie chart shows the highest scoring events in 2022. The majority occurred at water treatment works, or storage reservoirs, and therefore scored highly, in part due to the large number of consumers at risk.

Figure 7.

Pie chart showing highest scoring events in 2022 (excluding networks and information systems events)



The Cambridge Water event relating to a Guardian media article on Perfluorooctanesulfonic acid (PFOS) scored highly, representing the negative impact on consumer confidence caused by this event. Full details of the event assessment can be found on the Inspectorate's website; **Investigation into the Water Quality Event of PFOS Contamination in Duxford – Drinking Water Inspectorate (dwi.gov.uk)**

Southern Water has three high scoring events relating to the use of unapproved products in the filter nozzles at Burham water treatment works, poor asset health including structural deficits at Patcham Mid service reservoir, and lack of resilience in Rownhams supply zone. Output at Testwood and Otterbourne water treatment works was reduced following a deterioration in raw water quality and this coupled with increased leaks following December's freeze/thaw, meant that the company had to actively shut off supplies to 78,328 properties in the Rownhams supply area.

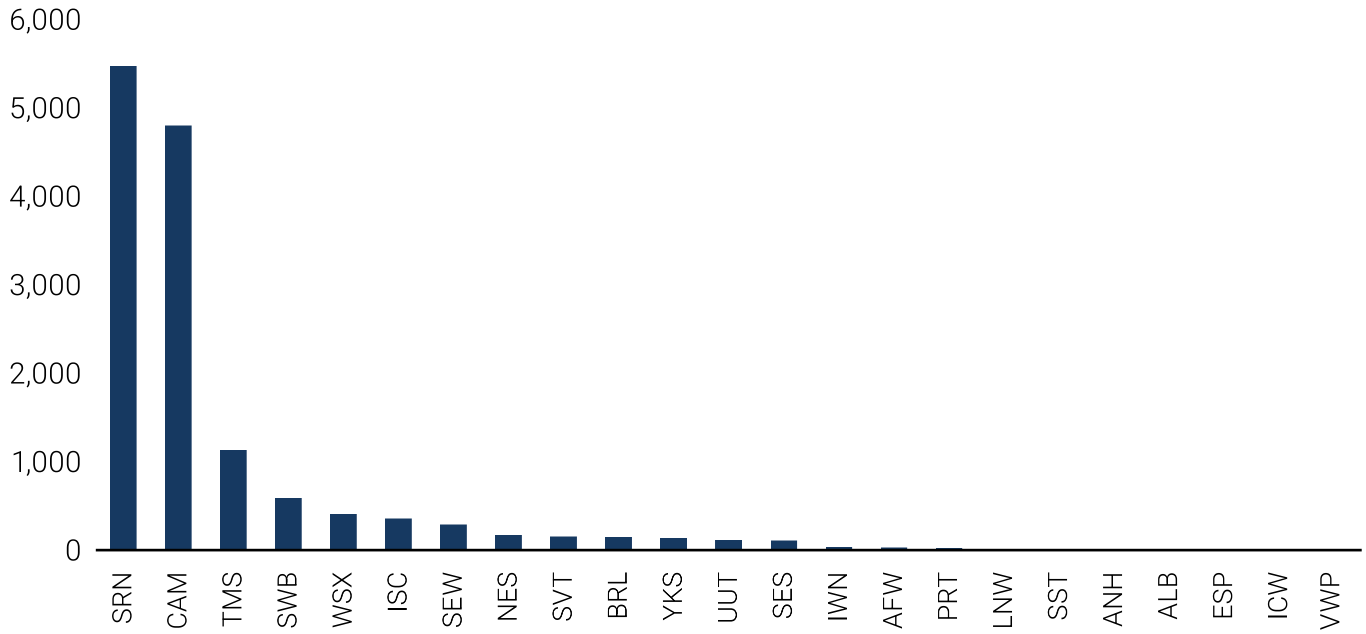
Thames Water coliform detections at Hampton water treatment works was reported as an event and scored accordingly. Following multiple coliform detections ingress was identified via the contact tank roof wall joint, however the tanks cannot be removed from supply for repairs due to failed valves and interruption to supply risks. The company is working towards a plan to repair the valves on the 'live' system to allow isolation of the contact tanks for further remediation. Due to the ongoing risks identified at the works a regulation 28(4) enforcement notice had already been issued. The company will need to demonstrate compliance with this notice and repair the tanks. In the short-term the company has installed a temporary membrane over the contact tank to mitigate the ingress risk until long term repairs can be implemented. The Inspectorate is monitoring the progress of the remedial action taken by the company.

Event Risk Index by company

Every event is assessed by the Inspectorate and given an event risk index (ERI) score to reflect the number of consumers impacted or put at risk, the duration of the event, and the seriousness of the event. The following bar chart shows the relative risk ranking of companies, derived from the sum of all the ERI scores in their supply area.

Figure 8.

Event Risk Index by company



*At time of publishing.

The 50 most serious events are published on the Inspectorate's website.

Asset health and service reservoir integrity

During 2022, there were 61 coliforms and two *E. coli* compliance failures at water treatment works. These breaches were in addition to 102 coliform and eight *E. coli* breaches from service reservoirs. Many of these breaches were not attributed to a specific cause, but ingress into contact tanks and service reservoirs is a recurrent problem.

In addition to these compliance breaches, there were 63 water quality events attributable directly to poor asset health and plant failure, including 11 failures of the disinfection system, six failures of the power supply, and eight structural failures of tanks and reservoirs.

The expectation is that companies understand their assets, through a programme of physical inspections, which may be supplemented with inspections by ROV. Physical inspections are necessary because they provide clarity and better resolution than ROVs and allow for cleaning of walls and structures within the reservoir. A maximum interval of 10 years is advised in the **Principles of Water Supply Hygiene TG9** on treated water storage, although the Inspectorate recommends more frequent inspections on a risk-based programme.

Figure 9.

Bar chart of high-risk service reservoirs by company (2022 data return)

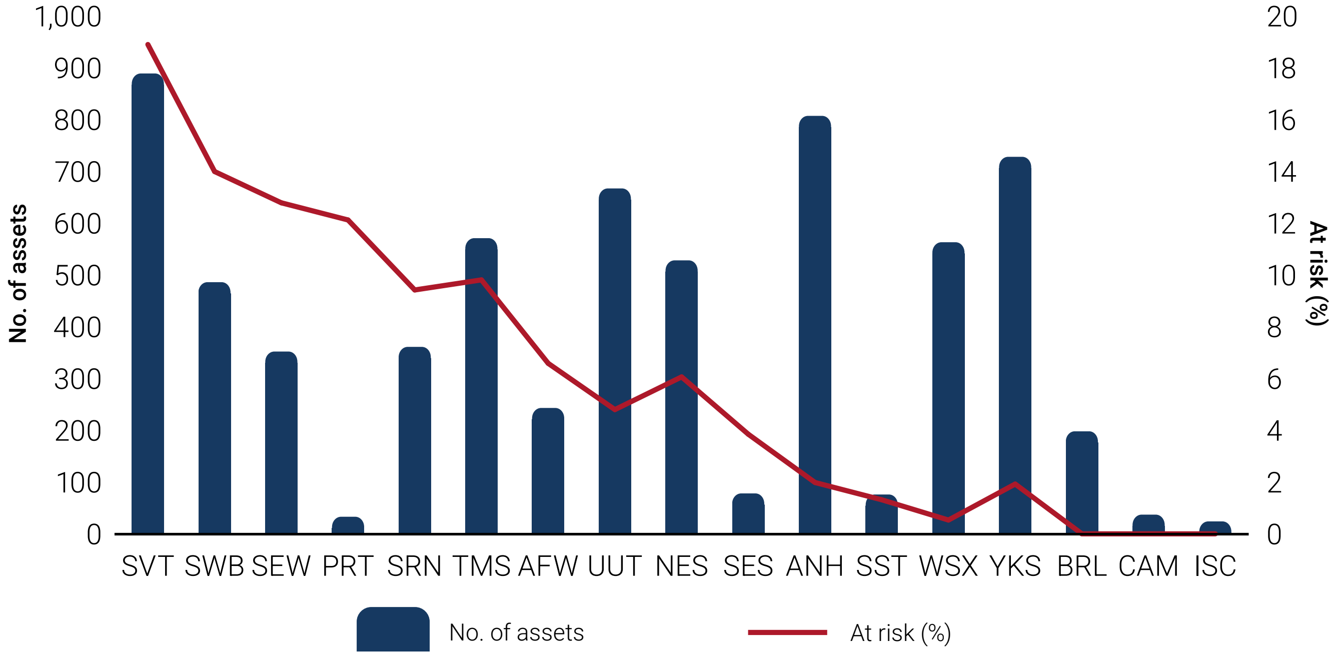


Figure 9 shows the percentage of service reservoirs at risk of failure in each company, defined as structures which have not been inspected for over 10 years.

The Inspectorate considers tanks that hold treated drinking water represent a significant potential risk to the wholesomeness of the water contained therein. That risk increases substantially if the assets are not routinely inspected and maintained.

During 2022, the Inspectorate continued work to achieve a risk-based inspection frequency for tanks, with a maximum gap between inspections of 10 years, across the industry. To that end, enforcement notices that covered multiple tanks were served under regulation 28(4) on Affinity Water, South East Water, Thames Water and Yorkshire Water. These are in addition to the existing tank notices previously served on Northumbrian Water, South West Water, Southern Water and United Utilities as part of those transformation programmes. Notices were also served on Anglian Water, Bristol Water and SES Water early in 2023.

Severn Trent Water was issued a second notice following the 2022 data return for tanks and service reservoirs where it was noted that the company was operating 38 tanks beyond a 10-year inspection frequency, with a further 63 tanks for which the last inspection date was unclear. Since then the company has progressed with the work, but envisages further challenges to meet this objective in the next few years, due to the spacing of its tank cleaning programme.

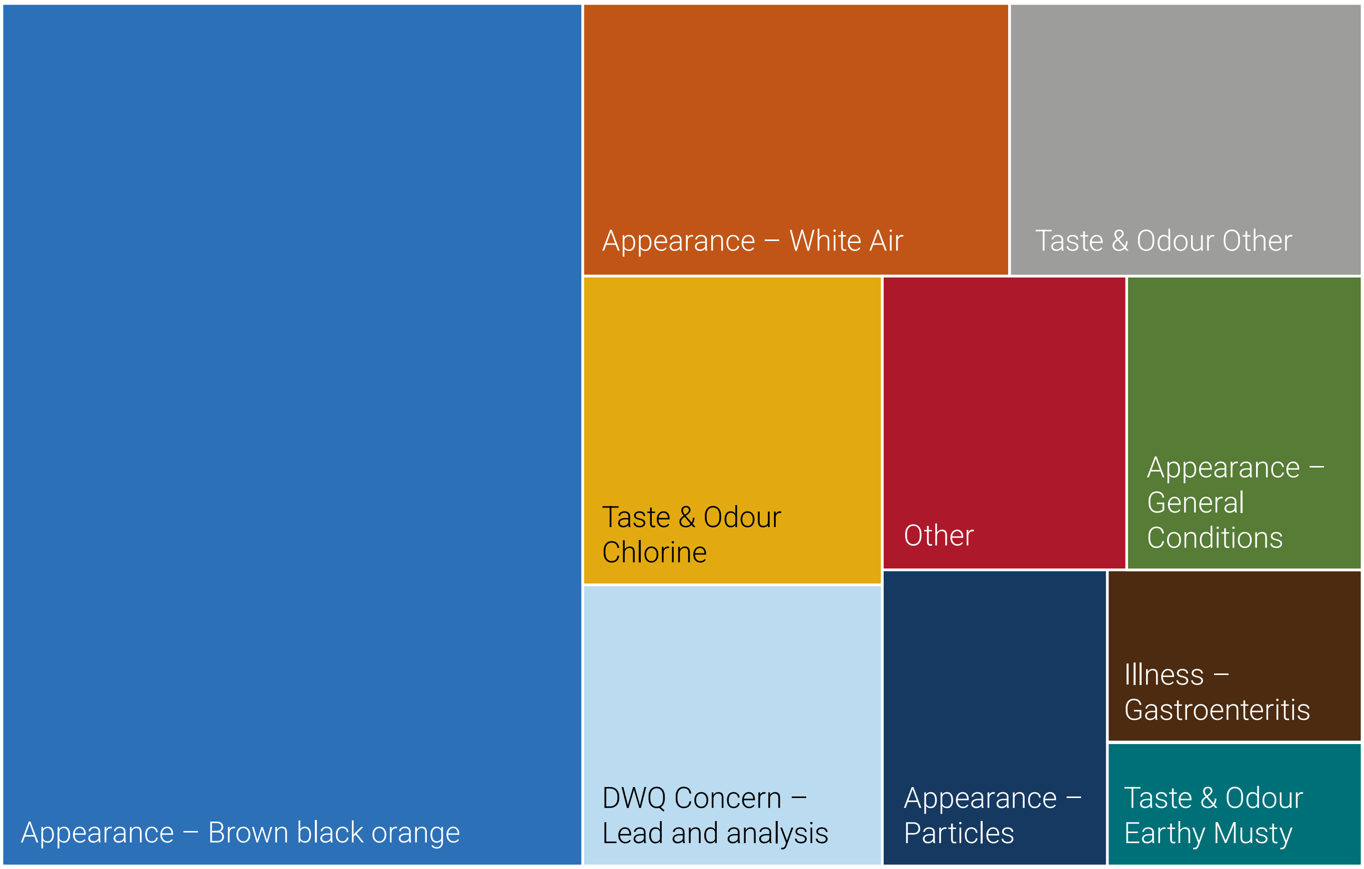
United Utilities successfully completed the delivery of its tanks notice and has achieved a full risk-based inspection programme for all of its tanks. The company is also able to isolate any of its reservoirs from supply for inspection and cleaning. This is a significant achievement, and the company is to be commended for it.

Acceptability of drinking water – consumer complaints

In 2022, there were a total of 62,928 consumer contacts in England regarding acceptability of drinking water, with a contact rate of 1.08 per 1,000 population. The most common reasons for contacting companies in relation to water quality are shown in the following treemap.

Figure 10.

Treemap demonstrating 'proportion' of consumers' complaints with regards to water quality descriptors

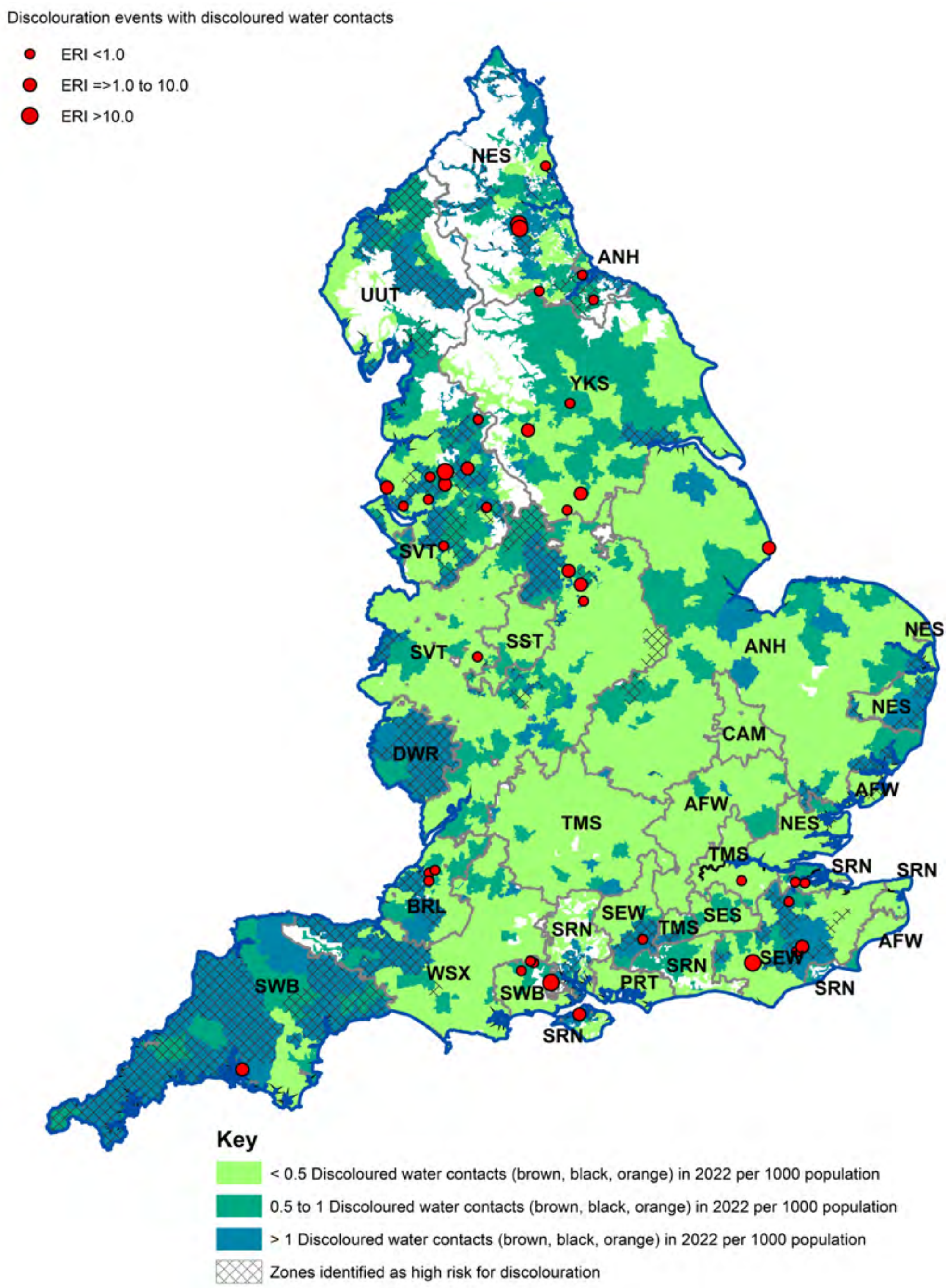


Discoloured water

The Inspectorate reviews consumer contact data for discoloured water contacts on an annual basis. Companies whose performance is poorer than the industry average are investigated, and enforcement action taken where necessary.

Map 2.

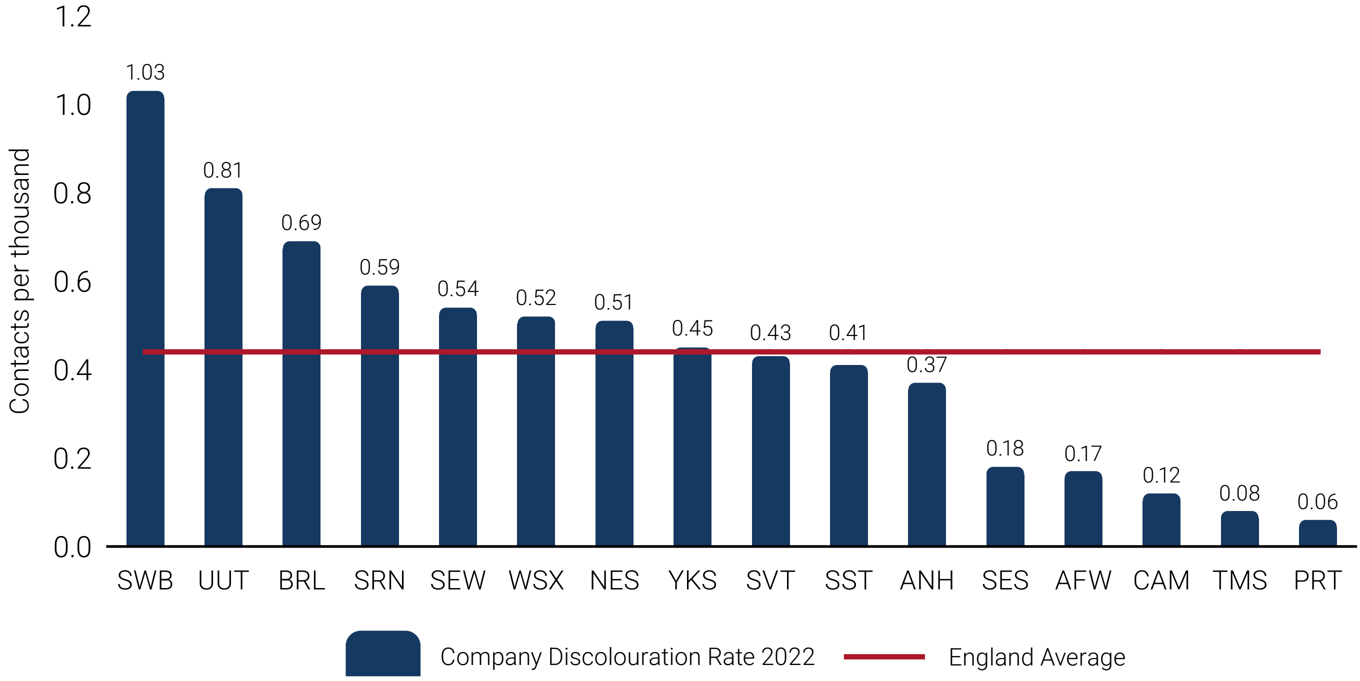
The following map shows the areas most affected by discoloured water in 2022, with events with discoloured water contacts identified by red dots



The number of consumers reporting a black/orange/brown colour to the water supply has steadily reduced since 2013, and is now approximately 0.44 per 1,000 population across England.

Figure 11.

Rate of discolouration complaints by company in 2022 (excluding ISC)



Good practice for reducing discoloured water

Discoloured water is caused by iron, aluminium and manganese sediment in the mains. Resuspension of sediment can be minimised by operating networks under calm network principles, employing standpipe management, minimising illegal hydrant use, cooperation with the fire services and other hydrant users and by the use of modelling and risk assessment to inform network operations. Consideration could be given to inlet monitoring of service reservoirs for iron, manganese and aluminium to provide additional information on metal residuals in treated water storage.

Novel, innovative and water saving approaches to network flushing are being employed to make further improvements. Drought poses a challenge to annual flushing programmes, and companies must look to innovative water saving approaches. Where possible, companies should bring forward mains flushing to avoid delay or incompletion of annual flushing programmes during the warmer months. Severn Trent was able to complete its annual flushing programme for 2022 early, to prevent non completion due to restrictions.

Other examples of good practice include contact cluster analysis to determine root causes, mains conditioning programmes, network flow optimisation, mains replacement, catchment management initiatives to improve raw water quality, and optimisation of water treatment processes to reduce residual metals in treated water; these have all been shown to have a beneficial impact. Ensuring treatment works do not seed the downstream network with iron and manganese will prevent recurrence of the problem.

Companies should be considering longer-term solutions to discoloured water, and not relying solely on network flushing programmes or filter installation on supply pipes as mitigation for individual consumer complaints.

United Utilities case study

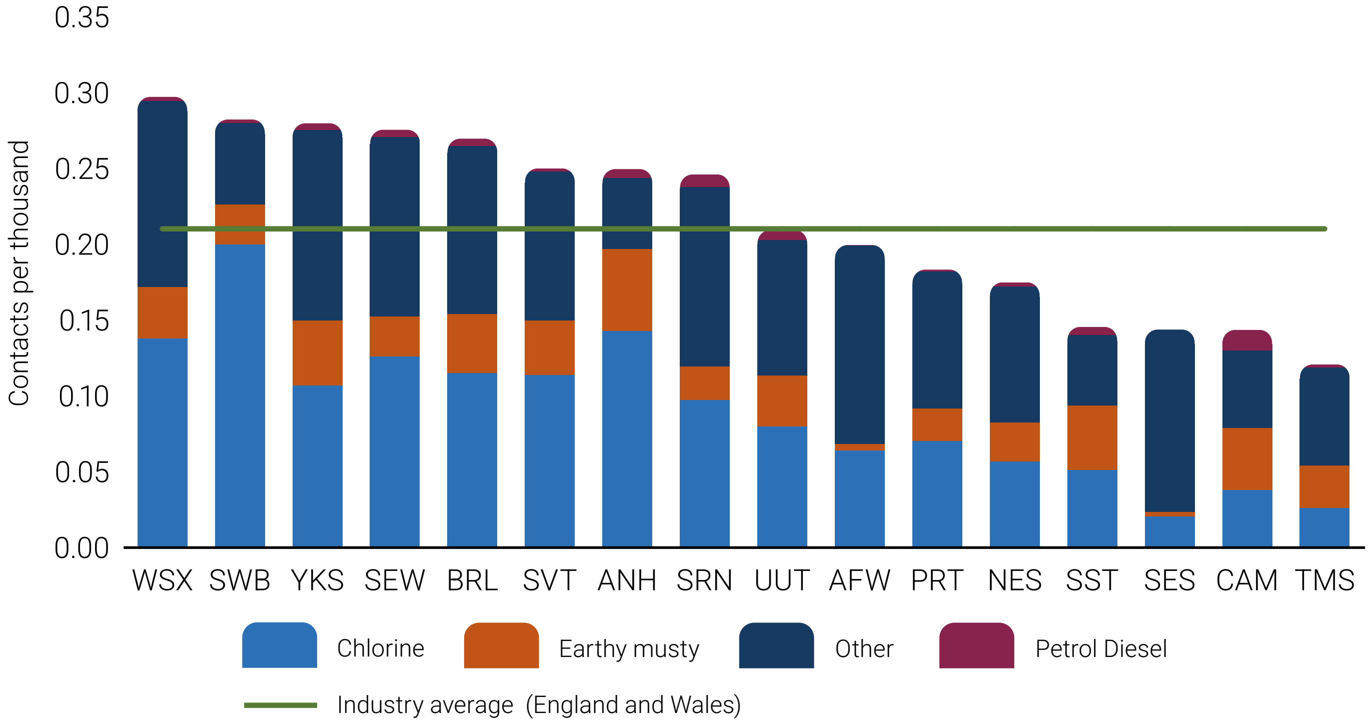
United Utilities has a company-wide discolouration enforcement notice which has been in place since 2021 and has seen a significant reduction in its company contact rate from 1.10 in 2021 to 0.81 in 2022. This has been achieved by catchment initiatives to improve raw water quality, consistently low final water metal residuals, improvements in metal monitoring at works, mains conditioning and various network flushing programmes carried out by a dedicated flushing team, replacement of cast iron distribution mains, water quality training as part of the company's Water Quality First programme, action relating to third party misuse of hydrants including the issue of warning letters and installation of hydrant caps and proactive consumer updates. The company is also working with WRc (Water Research Centre) to develop a model which will identify areas for mains rehabilitation to reduce discolouration risk.

Taste and Odour

Similar to discoloured water contacts, the contact rate for total taste and odour contacts for the industry has also gradually reduced year on year. The company contact rates are shown in Figure 12.

Figure 12.

Company taste and odour contact rates



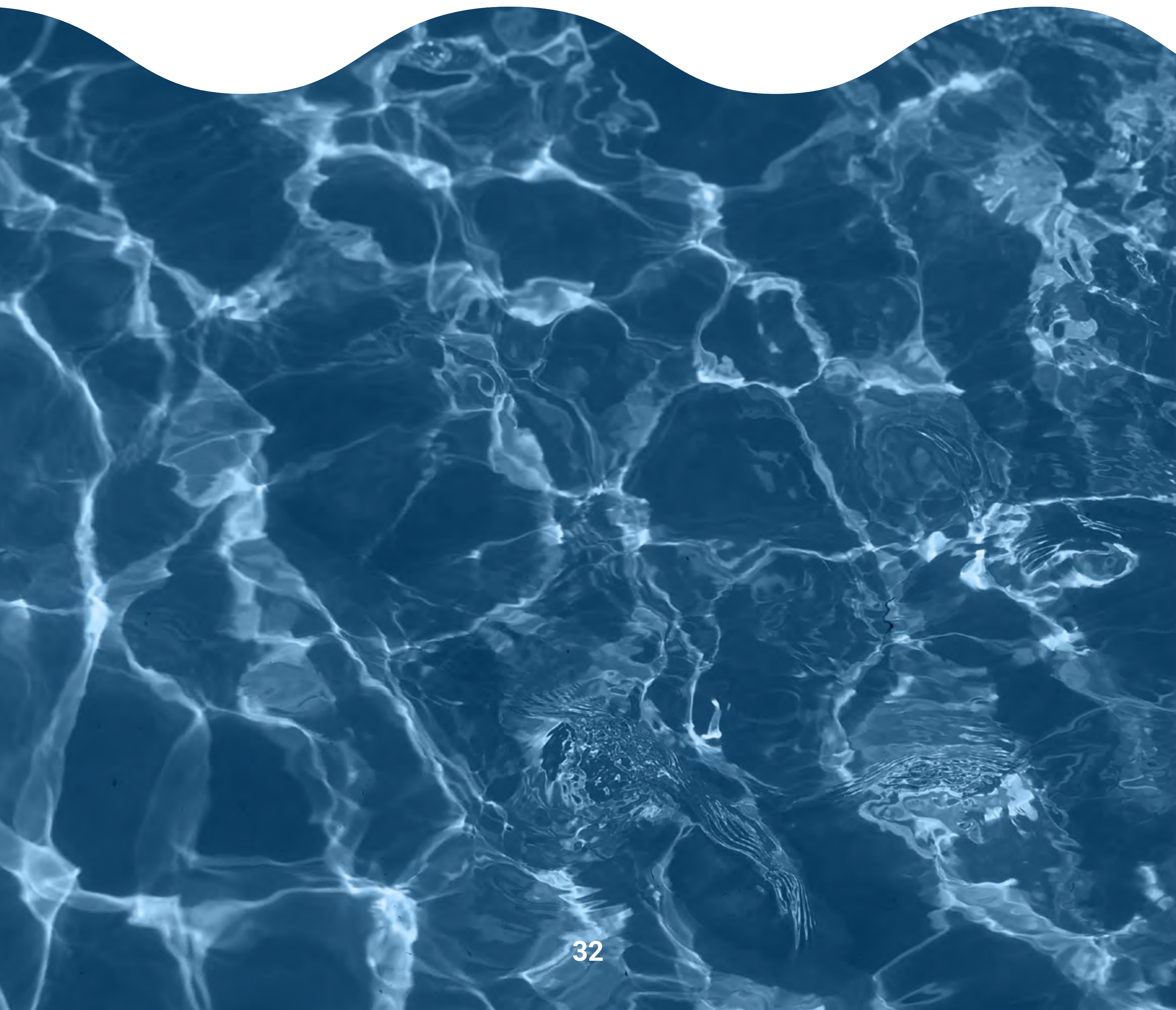
Wessex Water Newton Tony Prosecution

During a three-week period from the end of March 2021 consumers in the Amesbury area of Wiltshire complained of an unacceptable taste to their tap water which made the water undrinkable. The cause for the objectionable taste was due to the company failing to undertake the required checks on filters containing carbon media which, if completed, would have identified the presence of iodinated organic compounds leaving the treatment works.

A Granular Activated Carbon (GAC) filter was brought back into supply at the Newton Tony water treatment works supplying drinking water to approximately 17,000 consumers in the Amesbury, Wiltshire area. The GAC filter had been out of supply as the media had been removed and regenerated. Removal and regeneration of GAC media is a routine maintenance operation. On return to supply of the GAC filter, the testing and analysis of the GAC filter had been inadequate, the company did not correctly follow its own internal procedure, which required certain tests to be completed which would have identified the presence of the iodinated compounds. Following consumers complaints about the taste of their drinking water and reactive sampling and analysis by the company, iodinated compounds were detected in the supply from the GAC adsorber at the water treatment works, downstream service reservoirs and at properties in the area supplied. The company promptly removed the water treatment works and a service reservoir from supply and undertook extensive flushing and sampling of the affected area. Bottled water was supplied to consumers on request. Iodinated compounds have a low taste threshold and are therefore readily detected. Although there was no direct health risk to consumers, the taste issues caused concern, media and social media interest. The company has experience of similar events within their operating region from sites which use carbon treatment, yet the lessons learnt from these previous events did not prevent this issue from happening. Since this event the company has taken corrective measures including strengthening its own internal procedures which cover returning carbon filters to supply.

Wessex Water Services Limited pleaded guilty to an offence under section 70 of the Water Industry Act 1991 for the supply of water unfit for human consumption. The Inspectorate was critical that the company did not correctly follow its own internal testing procedures which would have identified the presence of the taste causing compounds. There were some issues reported with the communication given to consumers and provision of alternative water supplies.

At Swindon Magistrates court on 31 May 2023, Wessex Water Services Limited was fined £280,000 plus a £190 victim surcharge. Costs of £21,656.60 were agreed out of court.



Water safety planning and risk assessment

Following World Health Organisation (WHO) guidelines, the Inspectorate has adopted a water safety planning approach for drinking water quality. Companies are legally required to carry out adequate risk assessments of each supply system and submit this data to the Inspectorate (regulation 27 and 28). Hazards are identified and risks are assessed from source to tap (catchment, abstraction, treatment, storage, and distribution) and actions are put in place to maintain safe and secure supplies and prevent problems from occurring.

Raw water risk assessments

Raw water sampling data targeted at hazards

As part of the water safety plans, raw (untreated) water data is submitted annually to the Inspectorate. Sampling is targeted at hazards to understand the presence and severity of the hazard. The data are used to inform work on catchment management and the design and operation of treatment processes. The raw water summary data is provided on the Inspectorate website. The data show a continuing pressure from nitrate in raw water abstractions, and this is reflected in 34 PR24 scheme submissions to address this issue, including catchment management to reduce nitrate concentrations from agriculture, blending supplies and the introduction of additional nitrate removal processes by ion exchange treatment or other. Pesticides continue to be detected in surface water abstractions, and companies should ensure their pesticide analysis suite reflects current and legacy pesticide usage in their catchments. **Pesticide usage data** for different crops and areas is available from the Food and Environment Research Agency (FERA).

Working with the Environment Agency

Drinking water abstractions above 10 cubic metres per day are protected under the Water Environment (Water Framework Directive) (England & Wales) Regulations 2017 to ensure they are not polluted. Sources need to be protected to avoid or minimise the need for additional purification treatment which can be costly and resource intensive. Water companies and the Environment Agency identify drinking water areas that are 'at risk' of deterioration and establish safeguard zones. These are non-statutory areas where measures will be targeted to address contamination, identifying impacts, sources, actions, and measures in action plans which are periodically reviewed and updated. The raw water data provided by water companies to the Inspectorate contributes to the assessment of drinking water protected areas and safeguard zones, which are published by the Environment Agency **River Basin Management Plans**.

Perfluoroalkyl and polyfluoroalkyl substances (PFAS)

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals that have been widely used in various industries since the 1950s. They are often found in products such as non-stick cookware, waterproof clothing, carpets, food packaging, and firefighting foam.

The dangers of PFAS have become a growing concern due to their persistence in the environment, ability to accumulate in the human body, and potential health effects. In collaboration with the Environment Agency, the Inspectorate has identified 47 compounds of particular interest which companies should be monitoring (Information Letter 02/2021).

The Inspectorate uses a risk-based approach to PFAS, with escalating actions based on a tier system. In July 2022 the Inspectorate expanded its guidance to cover any PFAS, in final water. We reported on the risk assessment work by companies in CIR Quarter 2.

Table 5.

Tiered actions for controlling risks from PFAS

Tier	Results or Result Risk Assessment	Escalating actions
Tier 1	<0.01 μg/l	Risk assessment and monitoring
Tier 2	<0.1 μg/l	Risk control and consultation
Tier 3	≥0.1 μg/l	Risk reduction and notification

During 2022, the water industry in England submitted around 310,700 test results to start building a picture of PFAS risk in supply systems, although some test results were attributed to multiple points along a supply from catchment to tap. Companies were asked to prioritise raw water which may be a higher risk of the presence of PFAS. Consequently, data should be viewed as being a worse case analysis due to purposeful and repeated sampling methodology.

PFAS were detected in 11,853 or 3.8% of the test results. In the other samples no PFAS were detected, and the tests recorded an analytical result which was below the limit of detection.

Table 6 shows the 14 compounds with concentrations detected in the raw water above 0.01μg/l. Of the 47 substances which required testing, 35 were detected and a further additional PFAS compound was also found. This suggests that environmental contamination covers a wide spectrum of substances and reinforcing that this is a wider problem not easily solved by just changing the PFAS in formulations.

Table 6.

Most prevalent PFAS with the maximum concentration detected in the raw water

PFAS name	Maximum concentration in raw water μg/l
Perfluorooctane Sulfonate	1.86
PFPeA	0.253
THPFOS	0.218
Perfluorooctane Acid	0.149
PFHxS	0.09
PFBA	0.072
PFHxA	0.0596
FHxSA	0.0289
PFODA	0.027
PFBS	0.023
PFHpA	0.0123
PFPeS	0.011
FOSA	0.0107
FBSA	0.0105

A number of companies and laboratory service providers are developing in-house analytical capability, and research into treatment technologies is ongoing.

The most recent **Information Letter 02/2023** sets out expectations for companies to submit PFAS strategies for investigating risk, setting trigger levels, and taking action to mitigate PFAS risk from source to tap. Companies are required to offer section 19 undertakings to deliver their PFAS strategies over AMP8, where there is an identified current or future risk.

Tables 7 and 8 show the number of PFAS test results submitted by each company, with the number of results in each tier. Table 7 shows raw water and table 8 shows treated water, although in some cases the sample point would be the same.

Table 7.

The number of test results from raw water PFAS monitoring

Company	Total raw water tests analysed	Results below LOD	Tier 1 - <0.01 µg/l	Tier 2 - <0.1 µg/l	Tier 3 - ≥0.1 µg/l
AFW	10,652	9,999	14	566	73
ANH	121,732	116,951	4,474	285	22
BRL	2,115	1,987	113	15	0
CAM	2,822	2,807	15	0	0
ISC	799	771	21	7	0
NES	4,136	3,704	418	14	0
PRT	4,608	4,477	119	12	0
SES	366	299	66	1	0
SEW	10,976	10,610	280	86	0
SRN	12,462	11,958	406	98	0
SST	7,627	9,684	295	59	0
SVT	2,538	2,518	20	0	0
SWB	1,739	1,730	9	0	0
TMS	1,037	728	300	9	0
UUT	5,290	4,996	271	23	0
VWP	57	57	0	0	0
WSX	1,116	1,067	43	6	0
YKS	12,403	12,195	206	2	0

At Tier 2, companies are required to monitor raw and final water, and review their control measures in consultation with health authorities and the Inspectorate. The Tier 3 results at Affinity are from 5 sites which are subsequently blended, and the Tier 3 results from Anglian are from two groundwater boreholes, which are also subsequently blended.

Some companies submitted treated water monitoring data and the results are in Table 8.

Table 8.

Number of treated water samples in Tiers 1, 2 and 3 by company

Company	Total treated water tests analysed	Results below LOD	Tier 1 - <0.01 µg/l	Tier 2 - <0.1 µg/l	Tier 3 - ≥0.1 µg/l	Tier 3 in supply
AFW	4,118	3,966	9	143	0	-
ANH	120	14	106	0	0	-
BRL	752	634	83	35	0	-
CAM	1,977	1,971	6	0	0	-
ISC	470	454	14	2	0	-
NES	4,535	3,712	774	49	0	-
SES	636	499	136	1	0	-
SRN	83,868	82,067	1,688	111	2	0
SST	6,091	3,567	190	37	0	-
SVT	376	368	8	0	0	-
SWB	2,492	2,486	6	0	0	-
UUT	2,790	2,571	199	20	0	-

Southern Water reported two treated water samples within Tier 3. But these were subsequently blended in a service reservoir with a tenfold dilution, and the dilution was verified by sampling post blending.

Risk assessment national data

The Inspectorate received approximately 1.6 million (1,613,244) lines of regulation 28 data for England. The Inspectorate has seen a reduction in data lines submitted by companies this year due to changes in how some companies have assessed their hazards, with some moving to parameter only reporting, and others using new reporting systems. Most of this data for England (95.43%) indicates that risks are either being effectively mitigated or fall into categories that indicate mitigations are not currently required, with approximately 4.57% requiring further mitigation or where mitigation is being delivered.

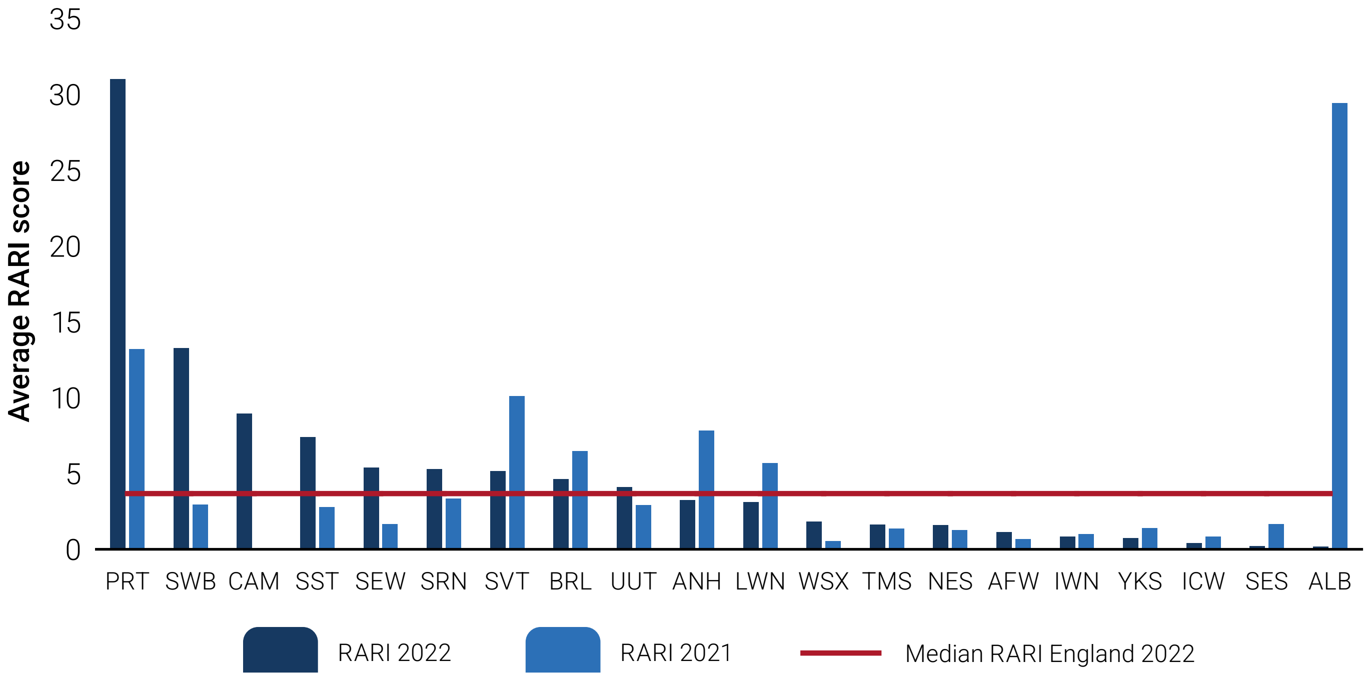
Risk Assessment Risk Index

Risks identified by water companies in their water safety plans, and reported to the Inspectorate, are classified according to whether they require action, and whether the action (mitigation) is in progress. Each risk is assigned a value according to the length of time that the risk remains partially or wholly unmitigated, and the Risk Assessment Risk Index (RARI) represents an indicator of the active risks for each company.

The Inspectorate's programme of work to collaborate with the industry to understand and resolve the differences in the way companies carry out drinking water safety plans continued throughout 2022. This has contributed to drafting of new guidance to drive consistency in water safety planning and regulation 28 reporting. This guidance should be published in late 2023, following industry review and consultation.

Figure 13.

RARI by company for England in 2021 and 2022 (excluding ISC, ALE and VWP)



There were two main outliers, Veolia Water Projects and Isles of Scilly, and these are not shown in the chart to allow for visibility of the remaining companies. Veolia remains an outlier due to the relatively small number of overall risks reported and is not shown in the graph for this reason. Isles of Scilly remains an outlier due to the number of risks requiring additional mitigations whilst work is undertaken to reduce the risks of saline intrusion, microbiological contamination, and radon.

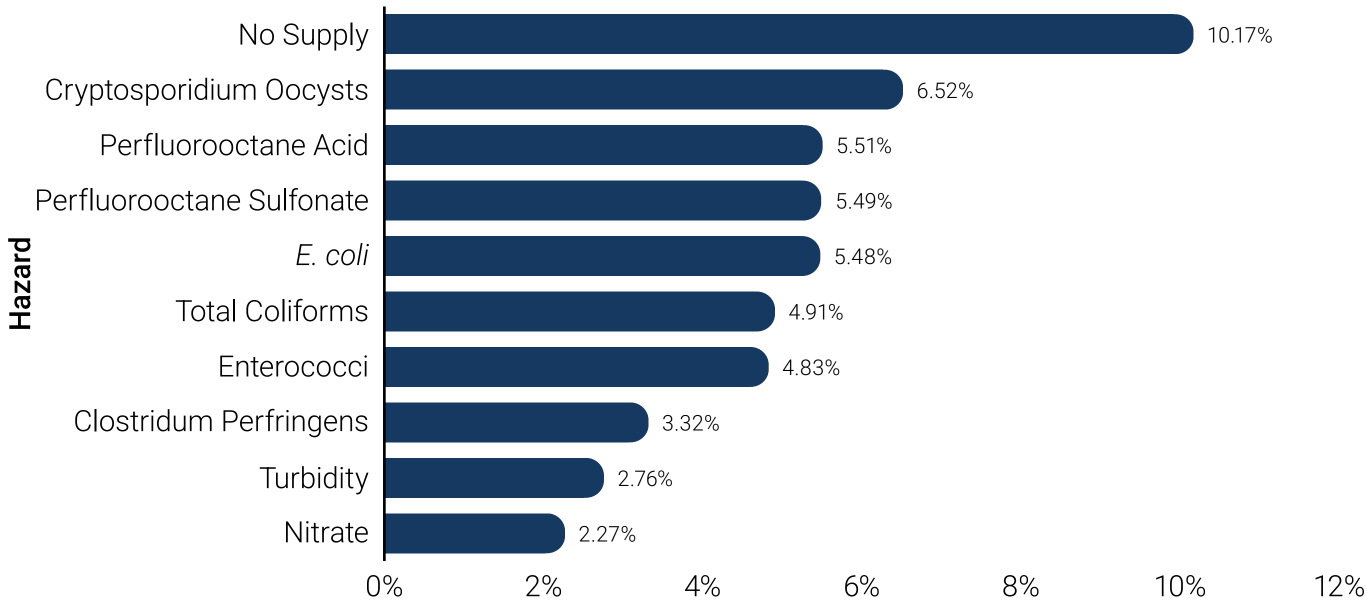
The purpose of RARI is to enable tracking of risks from an unmitigated to mitigated status. This is important to inform strategic action to proactively keep water safe. As such, it is not a measure but an information tool. As examples of best use, both Portsmouth Water and South West and Bournemouth Water have recorded the largest score increases in 2022. Portsmouth Water continues to focus on identifying risks as part of its change programme and carries its risk categories downstream, which provides an elevated risk score when compared to other companies. The company increased its risk lines reported by more than 300% with a considerable increase of categories C (additional or enhanced control measures which will reduce risk are being delivered) to E (risk under investigation), reflecting the company's efforts to identify and report new risks and investment requirement. Nitrate and *Cryptosporidium* risks carried from upstream treatment works form the highest scoring hazards.

South West and Bournemouth Water has an increased score as a result of the use of category E on most of its PFAS risk lines, especially for the PFAS group, Perfluorooctane Acid and Perfluorooctane Sulfonate individual hazards.

Cambridge Water had the lowest RARI score in 2021, therefore the company had the highest increase rate in the industry in 2022. This is, however, a good sign, as it demonstrates the company report is now reflecting current risk status, which may have proactively identified the risks posed by PFOS at Duxford.

Figure 14.

Top 10 highest scoring industry risks



Industry top hazards

The highest scoring risk across the industry during 2022 was ‘no supply’. The mitigations required, or being implemented, include mains renewals to reduce bursts and improvements in asset and network resilience.

There was significant use of ‘mutual aid’ during the summer of 2022 which saw record breaking temperatures and drought being declared across the country with areas in the South West and East officially remaining in drought well into 2023. The severity of these extreme weather events, both in terms of record temperatures and freeze / thaw events, demonstrated that there is an overall lack of preparedness for these extreme weather conditions as a result of climate change, across the industry. The industry has much to do to address this shortcoming in resilience.

The second highest scoring hazard is *Cryptosporidium*. This increased risk is likely to be a result of companies identifying and including additional risks in their drinking water safety plans (DWSP). There is ongoing work across the industry on a range of mitigations, including further catchment work to reduce the upstream risk. Turbidity remains a significant ongoing risk at water treatment works in 2022, despite improvement since 2021.

Perfluorooctane Acid (PFOA) and Perfluorooctane Sulfonate (PFOS) were the third and fourth highest risks and this represents a significant swing in risk understanding, following the requirement by the Inspectorate for companies to monitor supplies. Companies are now routinely monitoring for 47 PFAS parameters in raw and treated water. This increased risk score signals the need for companies to strategically plan mitigations and record these in their DWSPs to keep drinking water safe.

Audit programme completed by Inspectorate

The Inspectorate's audit programme and results are covered in detail in the Quarterly reports. The programme for England is in Table 9 with key findings from the water quality audits summarised.

Table 9.

Audits completed by the Inspectorate in 2022

Regulatory Driver	Audit Type	Number of audits
Risk Assessment	PFAS Risk Assessment	**10**
	Drinking Water Safety Plans	**3**
Water Quality	Asset Health	**9**
	Management of Contractors	**10**
	Event Follow Up	**6**
	Lead	**2**
	PFAS	**1**
	Legal Instrument	**1**
	Competence	**3**
Enforcement	Regulation 27	**2**
Security and Emergencies Direction	Provision of alternative supplies and service to vulnerable consumers	**3**
Total		**50**

Quarter 1 – Lead failure response and plumbosolvency control

Variation between companies in their response to lead exceedances was found as part of this series of audit, and this included the use of different trigger values and stagnation sampling. Most critically, health protection advice to consumers was also variable despite access to the same health information which states any detected level of lead has a health impact. For instance, some companies would issue do not drink advice if flushed samples remained above 10 µg/L whilst others did not. Many company investigations included identification of lead pipe material inside and outside of the home, including water fittings inspections and the use of lead solder test kits. Information from meter installations could be better utilised to feed into risk assessments and inform future lead strategies or identify hot spots, it is a missed opportunity to not gather this data, particularly since uncertainty exists around exactly how many lead connections remain in existence. It is perhaps also concerning that installation of meters into existing lead pipes does not join up the opportunity of completing two tasks in one job. Lead communication pipe replacement was found to have varying service level agreements. One company contributes £2,000 to the cost of replacing the consumer-owned supply pipe and this proactive initiative is encouraged across the industry. Some company websites were easy to navigate and provided good information on lead, whilst others were largely hidden from view. Lead information should be easy to find, with the offer of a free lead test clearly stated.

Concerns were raised around the control philosophy of phosphate dosing for plumbosolvency control. There were a small number of works where the company had run out of phosphate, despite the zonal risk assessment for lead requiring phosphate to be dosed at all times. The lack of telemetry visibility, alarms and safeguards on dosing rigs was a concern, considering that research indicates leaching can begin in as little as 24 hours after phosphate dosing stops (UKWIR 2016). Companies who are found not to be dosing phosphate as required by the regulations may be subject to enforcement action.

Quarter 2 – Asset health audits focussed on water treatment works

There were problems with asset health at most of the sites audited. Current standards mean that some older sites are no longer compliant and will require investment. For instance, outdated construction standards with rapid gravity filters (RGF) directly above a contact tank, or lack of safe access to parts of the treatment process presenting unmitigated risks of by-passing treatment if the RGF floor leaks, or the inability for companies to maintain inaccessible areas which are found to have ingress. Other issues reflected asset maintenance with evidence of poor condition of internal structures and borehole headworks where external water could access through unsealed or missing fittings. Issues with general housekeeping were observed, with poor condition of dosing pumps and unsatisfactory storage of chemicals. The condition of sample taps was noted to be of a poor standard at several of the sites visited, including leaking taps. Simple ongoing maintenance of grounds is critical since this prevents overgrowth and the risk of root damage and vermin. For instance, growth of shrubs and weeds were found near built structures, and in one case, on the roof of a treated water tank. A vermin control fence protecting a wash water recovery tank was damaged and had not been repaired, and one company was unable to locate an overflow pipe from a treated water tank.

Several of the sites audited have been subject to a HazRev process, in which every stage of the process is reviewed to identify where there are risks to drinking water quality. The Inspectorate welcomes the Hazard Review approach as a systematic way to understand the general condition and operating risks at company assets. The process can help identify where investment is needed and inform planning to ensure assets are sufficiently maintained. Companies should record these risks in their drinking water safety plans, which should feed into the company investment plans, so that investment is appropriately targeted.

Quarter 3 – Contractor supervision and communication

The Inspectorate was pleased to find some examples of good practice related to communication and supervision of contractors, although training and procedures were variable. Regulation 31 training should be completed for contractors and subcontractors to avoid offences. Several misconnections could have been avoided if basic water quality checks had been completed by the contractor when the connection was made. Many companies did not have effective supplier audit programmes to verify that contractors were operating in accordance with good practice and to protect water quality and public health. In all cases, recommendations were made for improvement.

Enforcement, transformation programmes and recommendations

Legal Instruments served in 2022

A summary of the Legal Instruments issued in 2022 is below, and thirty-seven legal instruments were closed in 2022. Current legal Instruments are published on the Inspectorate website.

Table 10.

Legal instruments issued in England, in 2022

Type of legal instrument	Number served	Companies
Regulation 27(4) notice for improvements to water safety plans	4	Affinity Water, Anglian Water, United Utilities, Veolia Water Projects
Regulation 28(4) notice relating to risks identified in water safety plans	35	Affinity Water, Anglian Water (3), Bristol Water, Portsmouth Water, SES Water, South East Water (3), Southern Water (2), South Staffordshire Water, Severn Trent Water (2), South West and Bournemouth Water (4), Thames Water (8), United Utilities, Wessex Water, Yorkshire Water (6)
Enforcement order under section 18 of the Water Industry Act 1991.	1	Southern Water

Audit strategy reviews and guidance given

Most of the legal instruments the Inspectorate serves (for example, all of the regulation 28(4) notices and section 18 enforcement orders served and the section 19 undertakings) require the company to develop and maintain an audit strategy. This is a fundamental part of delivering the legal instrument successfully and should not merely be regarded as a report to produce for the Inspectorate's benefit. The purpose of the audit strategy is to outline how the company will monitor the success of measures being delivered, as well as to monitor the effectiveness of the interim mitigation measures put into place. It should include (as a minimum) the following sections:

- Governance – for example, a defined governance structure with board level visibility and sign off, to ensure measures within a notice are delivered on time and as required under the legal instrument.
- Ownership – specific requirements outlined in the audit strategy should have named personnel/ job roles responsible for delivery of measures. This is to aid clarity and provide accountability of delivering measures.
- Monitoring – monitoring can include enhanced sampling, consumer contact tracking, online monitoring. Monitoring should be clearly defined and tracked by the company to ensure sampling is not missed or sampling rescheduled where applicable.
- Measures of success – the audit strategy should define what successful delivery of the measures and successful mitigation of the original risk(s) looks like.
- Continuous review – the audit strategy should be a dynamic document which the company uses, reviews and updates throughout the lifetime of the legal instrument.

The Inspectorate recognised there was a divergence in the standards of audit strategies between companies and so, during 2022, completed an audit of the audit strategies submitted by companies. Where audit strategies were found to be poor, the Inspectorate sought to engage with companies, to educate and guide, following which required a review and resubmission of the affected audit strategies. The Inspectorate was pleased with the response from companies in rising to this challenge and has seen substantial improvements to these essential tools since.

Any company that would like a guidance session on audit strategies, please feel free to contact the Enforcement Team so arrangements can be made.

Transformation programmes progress report

Where a company carries persistent risks with respect to water quality, the Inspectorate may implement a transformation programme. These programmes are aimed at achieving a company-wide change in the level of water quality risks being carried by a company. Part of these programmes is a series of enforcement in the form of legal instruments, targeting improvements in specific areas of a company's operation. They are bespoke for the risks observed at each of these companies. There were five transformation programmes in place at the end of 2022. These were with Northumbrian, Essex and Suffolk Water, Southern Water, South West and Bournemouth Water, Thames Water and United Utilities Water. Portsmouth Water is also within a legally defined change programme, akin to a smaller version of a transformation programme. Throughout the latter half of 2022 and continuing on into 2023, the Inspectorate is investigating, in cooperation with the company, the level of risk carried by South East Water and the potential need for transformation. A progress summary is provided below.

United Utilities Water transformation programme

United Utilities was taken out of transformation in early 2023. Since the transformation programme was instigated in 2016, the company has invested considerable effort, time and money into improving its assets. This has included improvements to site specific disinfection policies, disinfection arrangements, chemical dosing and monitoring, and taste and odour. Recently, the company achieved significant milestones with their service reservoirs notice. The Inspectorate welcome this positive action by the company in putting water quality first and all staff should be commended.

Now that the company is formally out of transformation, the focus will be on maintaining the new standard and ensuring water quality first remains at the heart of its operation.

Northumbrian, Essex and Suffolk Water transformation programme

The company has continued to deliver its transformation notices. The company has achieved significant milestones with the first tranches of HazRev reports produced. HazRevs are key to a company thoroughly understanding the risks it is carrying at its treatment works and identifying where improvements are required to mitigate those risks. The challenge for the company will now be to ensure the required improvements are captured in its business planning for AMP8 and beyond.

Southern Water transformation programme

Southern Water has made disappointing progress with some aspects of its transformation programme. The company repeatedly failed to deliver its obligations under notices at Testwood, Otterbourne, Burham, Hardham, Timsbury and Twyford treatment works. This necessitated the Inspectorate initiating further enforcement action in the form of final enforcement orders under section 18 of the Water Industry Act. The serving of six final enforcement orders on a single company by the Inspectorate is unprecedented and represents the seriousness of these failures to deliver. The company must now make a concerted effort to deliver these improvements successfully and on time, in order to mitigate the significant risks to drinking water quality.

Late in the year, the company notified the Inspectorate that it was unlikely to achieve the requirement, within a notice, of mains replacement in Hampshire and on the Isle of Wight, to reduce the risk of consumers experiencing discoloured water. The target was for 110 km to be replaced by 31 December 2025. At the time of notification, the company had replaced just 3.97 km of mains. The Inspectorate will be pursuing this further with the company, to ensure customers benefit from the improvements that are due.

Part of the original Southern Water transformation programme was a notice served under regulation 27(4), requiring all catchment risk assessments to be reviewed and revised. At the time the notice was served, the company undertook very little catchment management and there was a disconnection between catchment management and the drinking water safety plans. The company has invested in its catchment team, with a team of experts now proactively engaged in catchment risk assessments, as well as other catchment activities. Inspectors auditing the catchment risk assessment process in 2022 were pleased by the progress made by the company. It is important that the company sustain this position, as understanding catchment risks is fundamental to understanding the risks to the further supply systems.

South West and Bournemouth Water transformation programme

South West and Bournemouth Water continue to make progress with its transformation programme. South West and Bournemouth Water entered transformation in 2021 with three transformation notices served for its service reservoir inspections, hazard review of maintenance and resilience at water treatment works, and for scientific investigations.

The company is progressing well with the transformation notices. The hazard review or maintenance and resilience notice is on track to be completed by 2025 with a number of site-specific reviews (MOTs) having been completed in 2022 and reviews for the outstanding works have been planned for 2023 and 2024. An extension for the submission of the milestone for the review and reissue of site-specific disinfection policies has been granted for the scientific investigations notice, however, this will not affect the overall delivery of the notice. The tank cleaning and inspection notice is also on track with the notice being updated on a biannual basis, with tanks being removed from the notice as tank inspection, repair (if required) and cleaning is completed and tanks are added to the notice if they exceed the required inspection frequency.

As part of the original transformation programme discussions, the Inspectorate was concerned over shortcomings with the company's training records, procedures and document control. These shortcomings were considered as a theme for a potential transformation programme notice.

In 2022 the Inspectorate completed a training and management audit of South West and Bournemouth Water. The purpose of the audit was to provide the company with an opportunity to demonstrate and evidence the improvements that have been made since the initial transformation programme discussions and to help inform the Inspectorate's assessment of whether a formal notice was required.

The audit found South West and Bournemouth Water has made good progress and has clear objectives for its People and Culture programme, with the Quality First scheme forming an integral element of embedding the prioritisation of water quality throughout the company. The company is also introducing the requirement for treatment works operators to achieve a Level 3 qualification and for network operatives there is a progression scheme, which also requires Level 2 and 3 qualifications to be held.

The audit also concluded that the company appears to have a satisfactory document control procedure and system in place, however, there had been some instances where document control procedures did not appear to have been followed when the documents have been reviewed and updated. As site procedures act as control measures to the reduce the risk of failures, the Inspectorate recommended the company should ensure that the document control procedures are followed in full.

Overall, however, the assessors concluded that, due to the progress made already with the company's People and Culture Programme as part of the Quality First initiative and the current document control systems in place, a formal enforcement notice was not required. The company will be submitting regular formal updates to the Inspectorate throughout the delivery of the programme to ensure it remains on track and the objectives to put water quality at the heart of company culture is met.

Thames Water transformation programme

During 2022 the Thames Water transformation team saw considerable changes due to company restructures. The transformation programme was amalgamated into the company's public health plan. The new public health driver has brought focus to projects such as 'one version of the truth' to ensure messages are consistent across the company, and the digital twinning programme whereby the company's assets are captured in high digital detail, creating a remote tool that can be used to support planned and unplanned activities and monitor the condition of assets over time. Equally, the changes have naturally caused disruption and uncertainty to the programme for example, the role of a dedicated manager of the transformation programme was removed in 2022. The company has since seen the benefits of the dedicated role and reintroduced the role in early 2023. Notably throughout this period of turbulence has been the consistent high quality of reports for the transformation programme notices.

Continuing on from 2021, the company entered the next phase of its work to mitigate the risk from turbidity, to ensure compliance with regulation 26(1)(b) and 26(6)(b), that water leaving the company's treatment works has received sufficient preliminary treatment to prepare it for disinfection. As a result of this ongoing work, five individual sites were brought into individual notices for turbidity to allow a greater level of focus on the risk at these sites.

Thames Water's Hazrev investigations are nearing completion. All high and medium risk assets are completed, immediate risks found and dealt with, and now the company must manage the medium and lower risks identified. It was identified in 2022 that the company has insufficient risk management and tracking of jobs. The company has put in place improvements, however, the Inspectorate will continue to observe and respond to the company's mitigation of these risks during 2023, to understand whether the Hazrev notice needs to be adapted to the management of the risks now identified.

Work on the company's notice to mitigate the risk at slow sand filter sites was completed in 2022. The company has completed several actions to mitigate the risks seen from its slow sand filters. This has included critical reviews of its operation and maintenance, perimeter fencing to prevent animal access, turbidity monitoring and training. This culmination in effort has resulted in a downward projection of risk, with significantly fewer slow sand related events seen now since before the notice was served. The Hazrev's of these sites has identified some site-specific risks at these sites; the Inspectorate will continue to observe and respond to the company's mitigations of these risks, to ensure effective mitigation of risk.

The work under two of the company's management and training notices was completed towards the end of 2022/beginning of 2023, similar to the above. In 2023 the Inspectorate will be looking to see if a phase 2 of this programme is required, to address any aspects of the programme that were less successful as others (for example, the format for the 'licence to operate' training programme was not suited to network teams and requires bespoke remodelling to suit the needs of the team) or whether the systems successfully implemented under the programme are able to effectively integrate these issues into a 'business as usual' model to address.

As described previously, the Inspectorate conducted an audit of audit strategies in 2022 that identified significant weaknesses. Thames Water requested the Inspectorate's guidance on audit strategies which was given, resulting in purposeful audit strategies. As part of the company's 'first line assurance' work, it has created a mobile app that is used to audit itself against compliance with its own policies. This was used to audit the implementation of audit strategies for legal instruments, which identified useful learning (such as making it simpler for staff to evidence compliance with policies; where staff were compiling the evidence but were frustrated, they could store this in a transparent way for all to see). Considering the weaknesses found with the industry audit strategies, Thames Water's development of an app to audit its own compliance with audit strategies, would appear to be industry leading.

Portsmouth Water change programme

Core to the company's change programme is its management and training notice. In 2022 significant work was completed under this notice, which is still in the review stages. The company has taken the time to systematically plan and build the mechanism to identify all risks, and to track and address those risks that are identified. This is being made possible thanks to the additional resource committed to the programme in 2021 by the board, following a business case from the company's water quality team, bolstered by the legal instruments served. The Inspectorate looks forward to seeing how the company progress into the next phase of this notice in 2023.

South East Water

In June 2022, the Inspectorate wrote to South East Water concerning its failure to comply with the requirements of legal instruments. The letter outlined that compliance with legal instruments is not optional. The Inspectorate offered the company support to improve; however, significant improvements must be seen, or the Inspectorate would escalate enforcement.
Deficiencies included:

- Failure to meet defined deadlines for information;
- Delays to six notices (notification of some delays not received until the day before reporting deadlines);
- Poor quality milestone reports;
- Failure to take the required audit enhanced sampling, which was only discovered after the Inspectorate's enquiries; and
- Audit strategies lacking key information.

In addition to these, the Inspectorate has identified themes of risks within the company that are akin to corner stones of most transformation programmes:

- Culture of high tolerance of water quality risks
- Management and training deficiencies
- Weaknesses with policies and procedures
- Identification of risk and reporting thereof
- Failure to mitigate the risk from turbidity, to ensure compliance with regulation 26(1)(b) and 26(6)(b), that water leaving the company's treatment works has received sufficient preliminary treatment to prepare it for disinfection.

In addition, the company has seen numerous resilience related events (burst mains, power interruptions and lack of capacity to meet increased demand during extreme weather events) in 2022 that have led to water quality incidents. The company accepts that it is significantly behind the industry with implementation of a risk-based programme of tank inspections and is not planning to accelerate action to address this.

The Inspectorate is working with the company to identify the extent of the risks within each theme and the need for further enforcement action to holistically transform the company's performance.

Failure to deliver legal instruments

At the end of 2022, Anglian Water was notified of the Inspectorate's intention to take further enforcement action in the form of an enforcement order under section 18 of the Act, due to repeated failures to deliver a notice under regulation 28(4).

The Inspectorate served a notice under regulation 28(4) on the company for its Great Wratting water treatment works and Keddington water treatment works in 2020, requiring that specified measures be carried out in order to prevent the deterioration in the quality of water supplied. The notice included specific milestones that the company was required to achieve and included deadlines by which they were required to be completed. Both the milestones and dates were agreed through negotiation between the company and the Inspectorate and were understood by both parties as being realistic and achievable. The milestones were designed to mitigate the risks of metaldehyde, total pesticides, manganese and iron, taste and odour of water to zones supplied by the two treatment works.

The notice went through several version changes as work progressed in delivery. However, the final commissioning was delayed on several occasions, causing the company to submit repeated change applications to the Inspectorate.

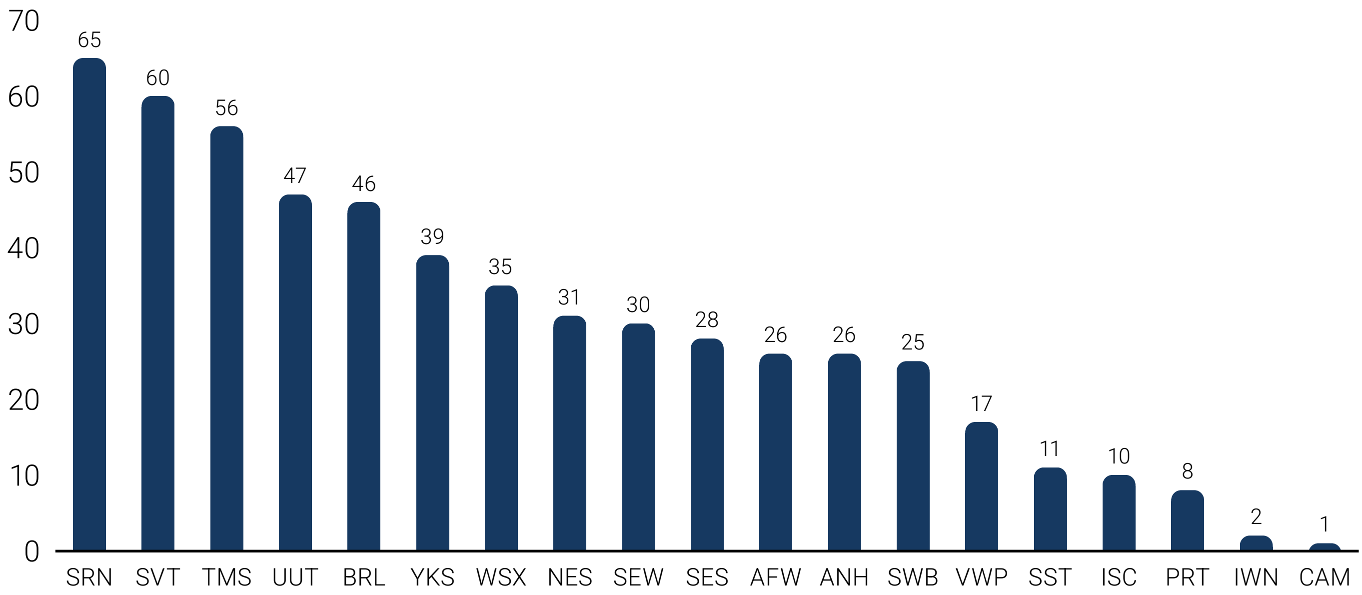
The company finally completed work on the final day of the enforcement order consultation, avoiding the need for the Inspectorate to make the order. The Inspectorate takes the delivery of legal instruments seriously. Whilst the Inspectorate accepts that a degree of flexibility is vital and operates a change process accordingly, further enforcement will be pursued where there are repeated failures to deliver as demonstrated in this case and the Southern Water cases described previously.

Recommendations

The Inspectorate made 565 recommendations to companies operating in England during 2022 relating to breaches of the Regulations, or risk of breaching the Regulations. The number of recommendations issued to each company is shown in the following bar chart.

Figure 15.

Number of recommendations by company in 2022

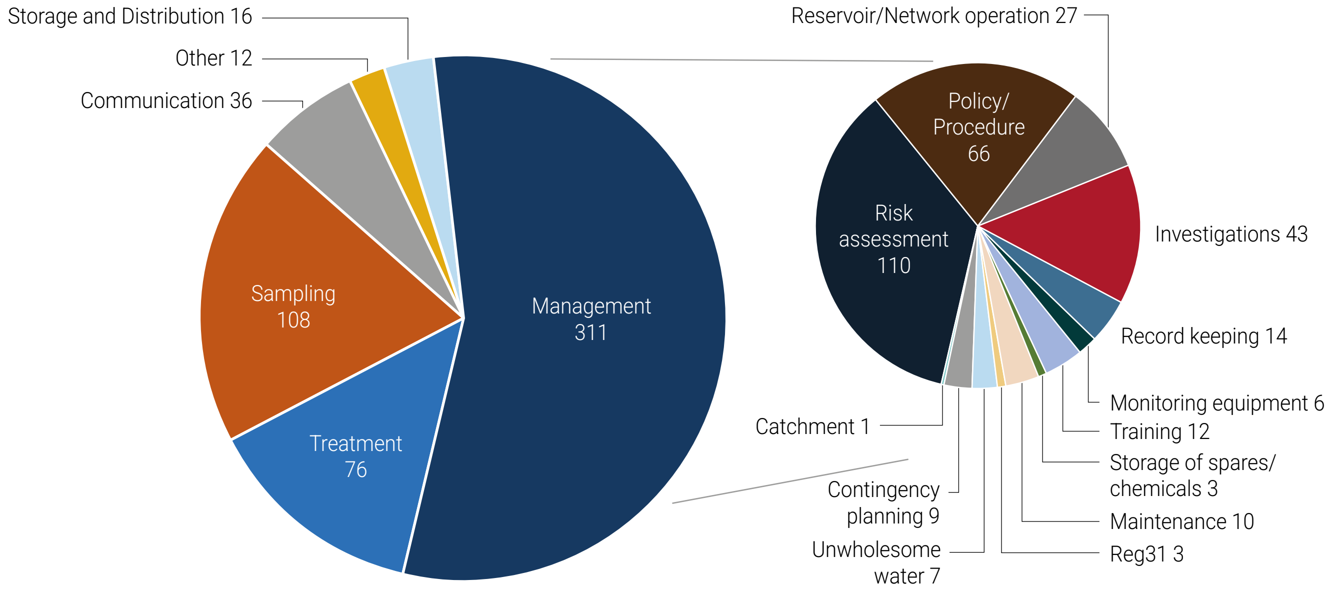


Southern Water received the highest number of recommendations, followed by Thames Water, Severn Trent Water and United Utilities. Southern Water and Thames Water are in transformation programmes with the Inspectorate, to improve performance.

The nature of the recommendations are illustrated in the following pie charts. The pie chart on the left shows the broad categories of recommendation, with most relating to deficiencies in management. The management deficiencies are further broken down in the pie chart on the right. Inadequate risk management within company DWSPs remains the largest cause of recommendations, followed by company policy and procedures, reservoir and network operations, and inadequate company investigations.

Figure 16.

Recommendations by type in 2022



Recommendations about company drinking water safety plans

A total of 110 recommendations made during 2022 in England were associated with deficiencies in company risk assessments with Bristol Water and United Utilities receiving the most recommendations for drinking water safety plans at 17 and 16 respectively.

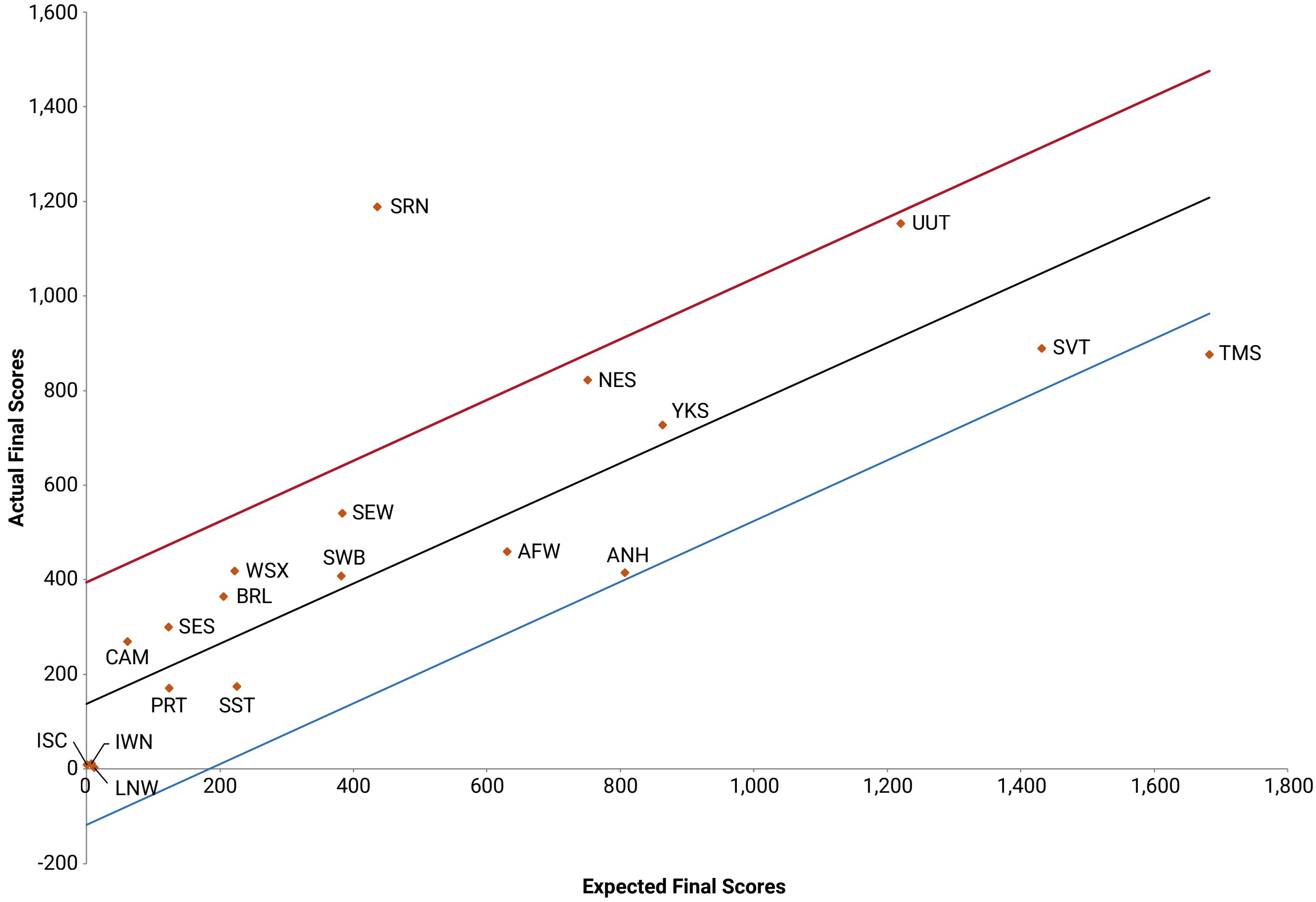
Where Lloyds Register Quality Assurance provide accreditation of a company's drinking water safety plan methodology, the audits carried out by the Inspectorates' Risk Assessment Team ensure that these methodologies are being followed and that the risks and hazards identified by the company, are classified appropriately. The audit team also ensures that companies' methodologies are in line with industry best practice and WHO guidance.

Recommendations Risk Index

The Recommendations Risk Index measures all companies' performance in recommendations against the industry. Recommendations are the first level of regulatory intervention, in line with the Better Regulation framework. For the purposes of discussion, an equal distribution of recommendations by company size (population served) is assumed. Regression analysis can be seen in Figure 17 as the central black line. A position below this line means a company is receiving fewer recommendations and/or lower scores attached to those recommendations than would be expected. A position above the black line means the opposite. Any measure has a degree of uncertainty, as such a 95% confidence interval is applied either side of the black line, represented by the red and blue lines. Southern Water is the only company showing above the tramlines which reflects the extensive amount of regulatory focus on the performance of this company.

Figure 17.

Recommendation risk index by company in 2022



Security and Emergencies Measures Direction (SEMD)

The Inspectorate regulates the security and emergency measures direction (SEMD) on behalf of the Secretary of State. After consultation with the industry, the direction was updated to a more risk-based approach.

The Inspectorate has been working with companies during a pilot year to set out expectations and drive improvement. Several companies are reviewing their reasonable worst case planning scenario, which is beneficial for the consumer. The pilot year ended in March 2023. The Inspectorate will continue to work with the industry to drive improvement, and where necessary, take enforcement action in line with the SEMD enforcement policy.

Photograph 2.

Bottled water collection point (photo courtesy of Water Direct)

Two main challenges faced by the industry in 2022 included the summer drought and the freeze / thaw experienced in December. Both events demonstrated the challenge to make available minimum quantities of alternative supplies to consumers. The Inspectorate completed four audits in the year, focusing on alternative water supplies and vulnerable consumers. Six recommendations were made to ensure companies have tested emergency plans and carry out emergency exercises. **The full report for the freeze/thaw event can be found on the Inspectorates website**.

Products in contact with drinking water (regulation 31)

During 2022, the Inspectorate continued to receive and process applications for approval of products in contact with drinking water (under regulation 31). The volume of applications processed was:

- 2022 – 145 total (32 new applications, 62 changes and 51 reapprovals)
- 2021 – 146 applications (23 new applications, 62 changes and 60 renewals)

During 2022, the team have been working with the Inspectorate's IT partners, to design and build a new regulation 31 database. The system will replace the current Word document application forms, which are emailed into the team, with online, interactive application forms that will guide applicants in providing all the necessary information for an approval to be considered. The online process will have the benefit of meeting accessibility standards thereby making them available to more people. The next phase of the project will see the approved products list transformed from a monthly, published pdf document to an interactive, searchable website which is updated in real-time. This will effectively become a live, online catalogue of approved products.

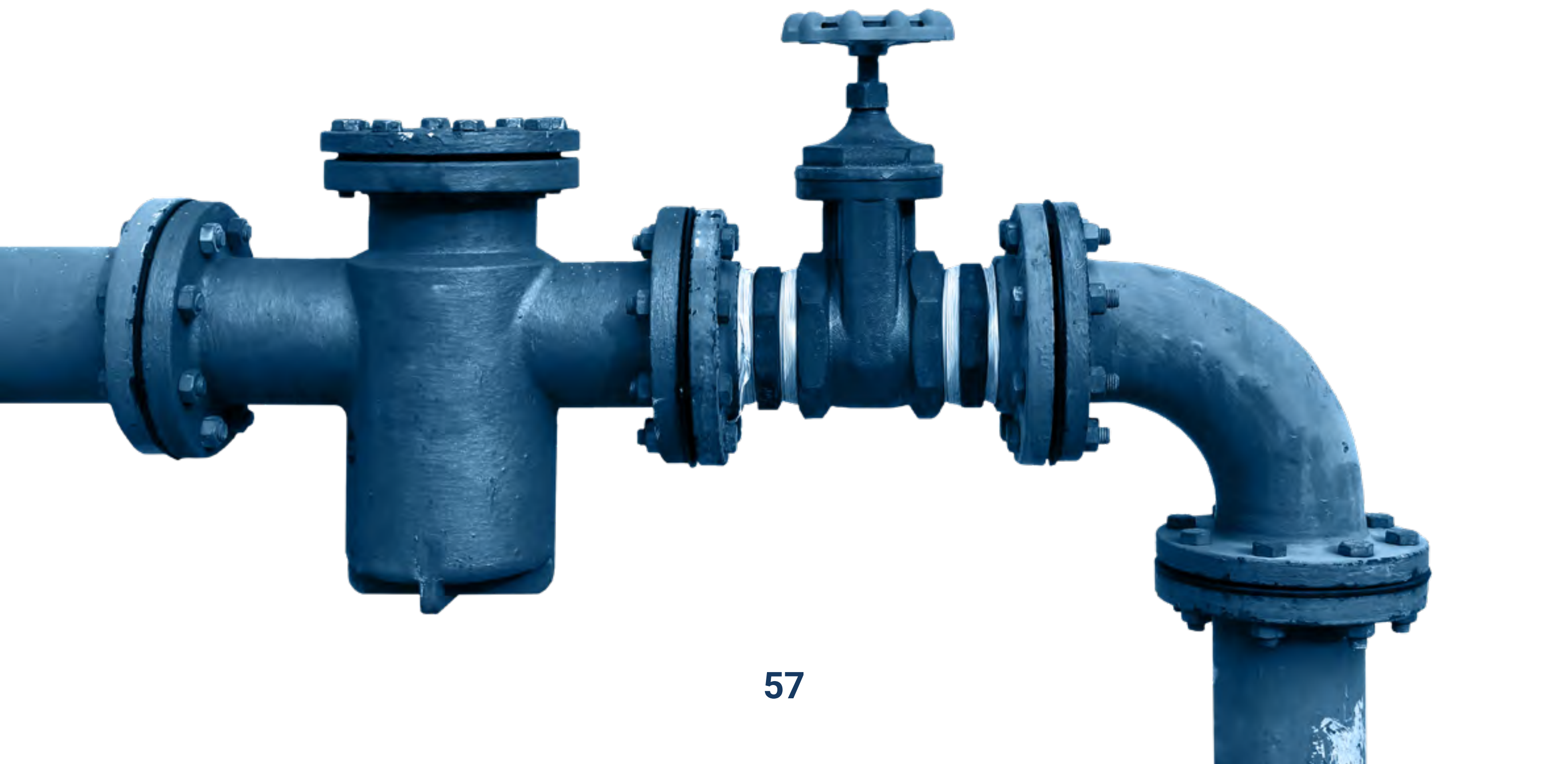
Laboratory capacity issues continue to be experienced, with the sole approved regulation 31 testing laboratory temporarily closing its doors to samples in order to relocate. However, in more positive news, both NSF and ALS have made significant progress towards becoming recognised laboratories for product approval, with the hope that testing facilities will be available again in the near future.

During the year the Inspectorate has seen drinking water quality events caused by the inappropriate use of repair materials. A key part of the regulation 31 approval process is the assessment of the manufacturer's instructions for use (IFU), which must be provided when the product is supplied as a condition of approval. The IFU is a vital source of information to the end user of the product in using it correctly and appropriately, to prevent risks to drinking water quality. Where applicable, compatible repair materials and repair techniques will be specified within the IFU. It is not appropriate to apply any other product as a repair material, even a separate, existing approved product. The interactions between the products will be unknown and untested and could have an impact on drinking water quality.

Research publications

Four research projects were completed and published in 2022. The full research reports can be accessed on the Inspectorate's website at **Research – Drinking Water Inspectorate (dwi.gov.uk)**

- Organophosphorus Flame Retardants (OPFRs) – Risk to Drinking Water in England and Wales
- Method for the Determination of Concentrations of Perfluoroalkyl Substances (PFAS) in Drinking Water
- Research on Removal of Microplastics by Drinking Water Treatment Processes
- Public Perception of Water Recycling for Drinking Water Use



Regulators' Alliance for Progressing Infrastructure Development in Water – RAPID

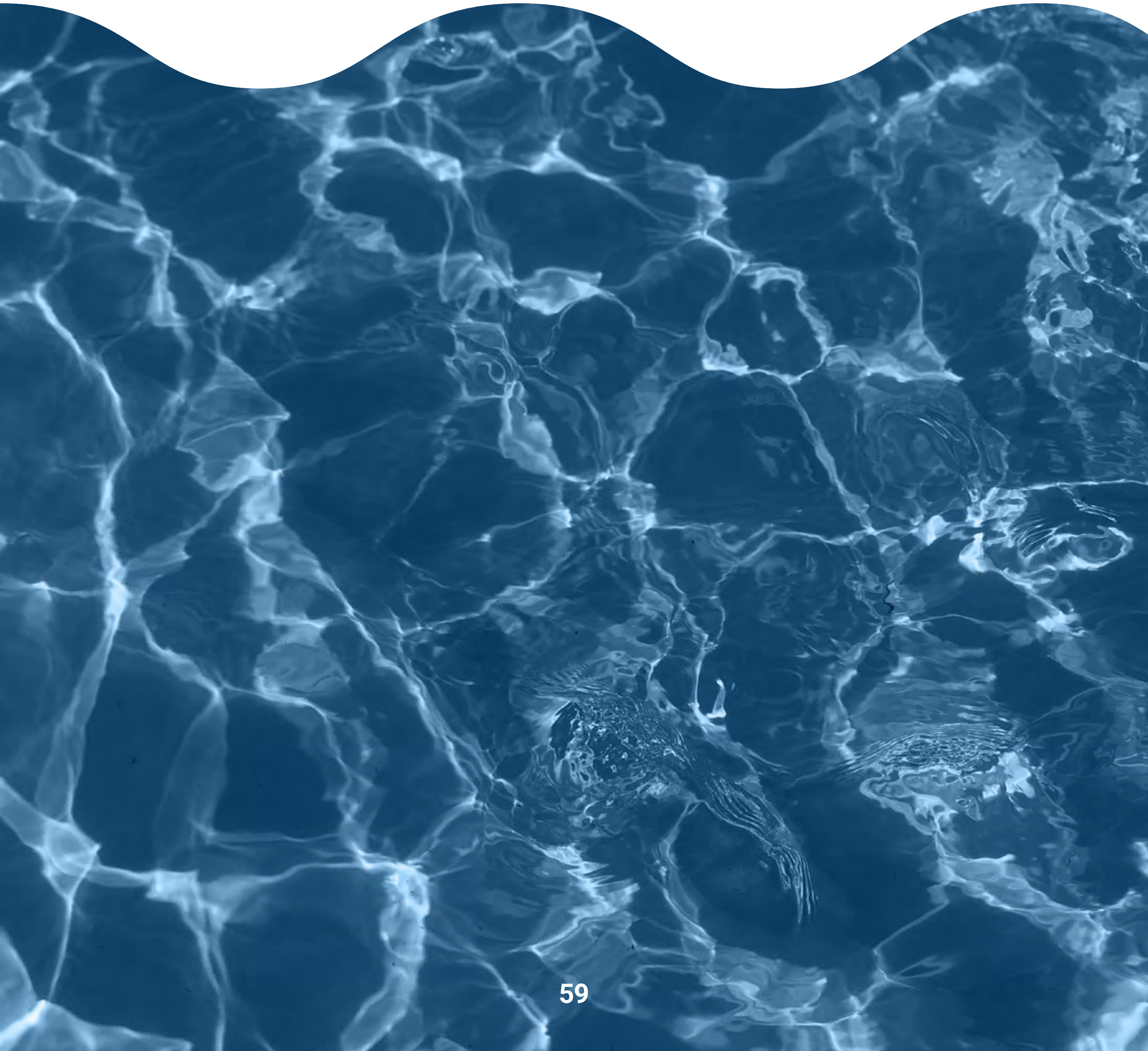
The Regulators' Alliance for Progressing Infrastructure Development in Water (RAPID) was established to coordinate development and delivery of large-scale water resources infrastructure schemes, some of which will cross company boundaries, and improve resilience of supplies. Regional planning will inform water company water resource management plans in 2024, and companies should use the planning guidance published on the Inspectorate's website to ensure risks to water quality are considered during the planning stages for all water resource schemes.

During 2022 the Inspectorate has continued to support RAPID to liaise with the Strategic Resource Options (SRO) sponsor companies, to ensure that all drinking water quality risks are being appropriately considered as the schemes are being progressed.

The Inspectorate worked with RAPID on the drinking water quality components during the publication of the draft and final decision documents for the accelerated Gate 2 and two new Gate 1 SROs, which were published in the first half of the year. In the second half of the year, the Inspectorate completed the assessment of 14 standard timeframe Gate 2 submissions which included the following drinking water quality considerations:

- Confirmation that company Water Quality teams have been engaged
- Solutions are clearly explained, and options set out
- Drinking water quality considerations for each option have been identified
- Confirmation that key DWSP risks have been identified (catchment, source water, treatment, distribution, acceptability, materials in contact with drinking water, operability)
- Forward plan for investigation of key risks and further development of DWSPs including monitoring programmes
- Confirmation as to how and when the Inspectorate will be engaged.

The assessments of the drinking water quality components feed into the cross-regulator assessment on progress of the solutions. The Inspectorate will continue to work with the SRO sponsor water companies and partner regulators throughout the gated process, to ensure the solutions are appropriately identifying drinking water quality risks and putting suitable mitigation in place, to ensure they can provide wholesome supplies.



Whistleblowers contacting the Inspectorate in 2022

On 15 December 2022 the Chief Inspector of Drinking Water and Inspectors appointed under section 86(1) of the Water Industry Act 1991 became 'prescribed persons' under the Prescribed Persons Order 2014 as amended (the Order).

Whilst the Inspectorate has historically received information from concerned employees, contractors or ex-employees of potential or known wrongdoing, by becoming a prescribed person, somebody who is making a disclosure to the Inspectorate will be afforded certain protections under the Order and the Employment Rights Act 1996. In general terms, a person passing on information concerning wrongdoing (referred to as whistleblowing) should not suffer detriment or victimisation from their employers.

The type of disclosure that would typically qualify as a protected disclosure under the Order would be if it relates to the quality and sufficiency of water supplied by the water industry and the security of network and information systems within the supply and distribution sector. This will likely be information pertaining to a breach or potential breach of the Water Supply (Water Quality) Regulations 2016 (as amended), the Network and Information Systems Regulations 2018 or the company not meeting its obligations relating to water quality or sufficiency, or potentially committing an offence under the Water Industry Act 1991.

Any persons who are wishing to report a concern or potential concern regarding suspected or known wrongdoing which the Inspectorate can investigate should do so by contacting the DWI Enquiries line (**dwi.enquiries@defra.gov.uk** or 0330 041 6501).

The Inspectorate treats all disclosures made by whistleblowers sensitively and seriously and follows up each disclosure with an appropriate investigation. The Inspectorate will protect the identity of an individual making an allegation wherever possible. However, in certain circumstances the Inspectorate may be required to reveal the identity, if required by law.

The Inspectorate will report the number of disclosures made in the reporting year (1 April – 31 March) annually in the Chief Inspector's Report and from the number of the disclosures where the Inspectorate investigated further and if further action was taken, a summary of the type of action taken (such as enforcement). The report will ensure that the anonymity of the whistleblower is protected and details of the company they work for is not reported.

Table 11.

Summary of disclosures made for the period 15 December 2022 – 31 March 2023

Number of disclosures made	Number of disclosures investigated further	Summary of action taken
0	0	N/A

Annex 1 Number of tests carried out by companies

Table 12.

Tests carried out by companies

Company	Water treatment works (number of works)	Service reservoirs (number of reservoirs)	Consumer taps (zones)	Number of tests per company	Target number of tests
Affinity Water	68,776 (92)	30,258 (157)	88,191 (89)	187,225	187,259
Albion Water	0 (0)	0 (0)	689 (2)	689	689
Anglian Water	134,102 (131)	80,454 (323)	162,816 (164)	377,372	378,237
Bristol Water	20,709 (14)	39,909 (158)	34,449 (27)	95,067	95,141
Cambridge Water	12,111 (17)	5,884 (31)	8,452 (9)	26,447	26,657
Dŵr Cymru Welsh Water (ENG)	3,519 (5)	5,522 (16)	5,751 (6)	14,792	15,111
Icosa Water Ltd	0 (0)	0 (0)	3,303 (21)	3,303	3,303
ESP Water	0	0	63 (1)	63	63
Independent Water Networks	0 (0)	0 (0)	8,921 (72)	8,921	9,043
Isles of Scilly	1,637 (9)	2,146 (9)	1,834 (5)	5,617	5,661

Company	Water treatment works (number of works)	Service reservoirs (number of reservoirs)	Consumer taps (zones)	Number of tests per company	Target number of tests
Leep Networks Water (ENG)	0 (0)	0 (0)	8,081 (41)	8,081	8,087
Northumbrian, Essex and Suffolk Water	59,653 (56)	70,279 (306)	135,891 (123)	265,823	266,057
Portsmouth Water	18,868 (16)	7,060 (29)	19,128 (15)	45,056	45,230
SES Water	12,492 (8)	7,248 (35)	19,685 (21)	39,425	39,425
Severn Trent Water	116,274 (130)	91,118 (448)	220,184 (213)	427,576	428,568
Southern Water	76,515 (84)	54,326 (215)	88,928 (76)	219,769	219,855
South Staffordshire Water	21,489 (20)	6,524 (34)	36,977 (28)	64,990	65,036
South East Water	70,643 (85)	57,279 (227)	82,394 (72)	210,316	210,391
South West and Bournemouth Water	53,223 (37)	69,760 (276)	86,713 (44)	209,696	210,676
Thames Water Utilities Ltd	92,920 (96)	77,225 (386)	231,689 (258)	401,834	425,925
United Utilities	96,093 (86)	89,060 (355)	197,439 (229)	382,592	383,405
Veolia Water Projects	796 (2)	1,248 (6)	576 (1)	2,620	2,620
Wessex Water Services Ltd	52,379 (72)	80,679 (316)	47,449 (77)	180,507	181,369
Yorkshire Water	86,992 (55)	88,420 (345)	172,979 (89)	348,391	348,548
Region overall	**999,151 (1015)**	**864,399 (3672)**	**1,662,519 (1682)**	**3,526,109**	**3,556,293**

Note: Numbers in brackets reflect the number of works, reservoirs or zones operated by that company in the region in 2021. Some companies are permitted to carry out some tests on samples taken from supply points rather than from consumers' taps.

Annex 2 Compliance with standards

Table 13.

Microbiological compliance at water treatment works

Parameter	Standard	Total number of tests	Number of tests not meeting the standard	Company
E. coli	0/100 mL	173,499	2	YKS (2)
Coliform bacteria	0/100 mL	173,500	61	ANH (8), BRL (3) ISC (4), NES (4), SVT (13), SEW (3), SWB (3), SRN (5), TMS (10), UUT (2), WSX (1), YKS (5)
Clostridium perfringens	0/100 mL	23,977	6	SRN (1), SVT (2), NES (3)
Turbidity Turbidity is a critical control parameter for water treatment and disinfection.	1 NTU	173,459	22	ANH (1), NES (5), PRT (3), SVT (2), SEW (3), SWB (1), SRN (1), TMS (5), WSX (1)

Table 14.

Microbiological compliance at service reservoirs

Parameter	Standard	Total number of tests	Number of tests not meeting the standard	Company
E. coli	0/100 mL	184,526	8	SEW (1), SVT (1), TMS (1), NES (2), UUT (1), BRL (1), YKS (1)
Coliform bacteria	0/100 mL in 95% of samples	184,501	102	ANH (7), ISC (6), SRN (1), SEW (6), SVT (12), SWB (6), TMS (7), NES (13), UUT (6), WSX (5), AFW (3), BRL (13), YKS (17) Five reservoirs failed to meet the 95% compliance rule: ANH Maidford Reservoir, ISC Abbey East (Tresco), NES Scotts Quarry Old, TMS Hampstead North, TMS Willesden

Table 15.

Microbiological compliance at consumers' taps (water supply zones)

Parameter	Standard	Total number of tests	Number of tests not meeting the standard	Company
E. coli	0/100 mL	145,904	25	ANH (4), SVT (12), TMS (2), NES (4), UUT (2), BRL (1)
Enterococci	0/100 mL	12,387	2	ANH (2)

Table 16.

Detection of E. coli and Enterococci at treatment works, service reservoirs and consumers' taps, by company

Company	*E.coli* in water leaving treatment works	*E.coli* in water leaving service reservoirs	*E.coli* at consumers' taps	Enterococci at consumers' taps
Affinity Water	0 – 13,533	0 – 7,564	0 – 9,677	0 – 677
Albion Water	0 – 0	0 – 0	0 – 24	0 – 8
Anglian Water	0 – 21,518	0 – 16,105	4 – 13,408	2 – 1,319
Bristol Water	0 – 3,426	1 – 7,981	1 – 3,169	0 – 227
Cambridge Water	0 – 2,395	0 – 1,471	0 – 1,033	0 – 71
Dŵr Cymru Welsh Water	0 – 583	0 – 1,104	0 – 493	0 – 45
Icosa Water	0 – 0	0 – 0	0 – 149	0 – 53
Independent Water Networks	0 – 0	0 – 0	0 – 499	0 – 201
Isles of Scilly	0 – 270	0 – 431	0 – 37	0 – 16
Leep Networks Water	0 – 0	0 – 0	0 – 418	0 – 143
Northumbrian, Essex and Suffolk Water	0 – 10,018	2 – 15,132	4 – 11,582	0 – 882
Portsmouth Water	0 – 3,123	0 – 1,410	0 – 1,898	0 – 115
SES Water	0 – 2,082	0 – 1,812	0 – 1,874	0 – 168
Severn Trent Water	0 – 22,841	1 – 22,417	12 – 22,042	0 – 1,609
Southern Water	0 – 12,629	0 – 10,848	0 – 6,774	0 – 550
South Staffordshire Water	0 – 4,265	0 – 1,631	0 – 3,523	0 – 267
South East Water	0 – 11,672	1 – 11,458	0 – 5,985	0 – 576
South West and Bournemouth Water	0 – 8,634	0 – 13,952	0 – 5,940	0 – 501
Thames Water Utilities Ltd	0 – 17,668	1 – 19,297	2 – 21,018	0 – 1,937
United Utilities	0 – 15,895	1 – 17,765	2 – 19,594	0– 1,792
Veolia Water Projects	0 – 156	0 – 312	0 – 36	0 – 8
Wessex Water Services Ltd	0 – 8,660	0 – 16,151	0 – 3,735	0 – 510
Yorkshire Water	2 – 14,130	1 – 17,684	0 – 12,996	0 – 712
Region overall	**2 – 173,498**	**8 – 184,525**	**25 – 145,904**	**2 – 123,87**

Note: Results are shown as the number of positive tests – the total number of tests.

Table 17.

Failures of the standards for chemical parameters

Parameter	Current standard or specified concentration[1]	Total number of tests	Number of tests not meeting the standard	Number of tests not meeting the standard per company
Aesthetic parameters				
– colour	20 mg/L Pt/Co scale	53,179	0	
– odour		53,139	103	AFW (3), ANH (16), BRL (2), DWR (1), NES (13), PRT (2), SVT (5), SEW (15), SST (7), SWB (1), SRN (6), UUT (20) WSX (1), YKS (11)
– taste	No abnormal change	53,045	88	AFW (1), ANH (7), BRL (3), DWR (1), ICW (1), IWN (3), ISC (2), NES (4), PRT (1), SVT (9), SWB (1), SRN (18), UUT (22), WSX (3), YKS (12)
1,2-dichloroethane	3 µg/L	10,082	0	
Aluminium	200 µg/L	49,001	18	AFW (3), ANH (2), BRL (1), NES (2), SVT (1), TMS (2), UUT (6), YKS (1)
Ammonium	0.5mg NH4/L	36,683	0	
Antimony	5 µg/L	12,194	0	
Arsenic	10 µg/L	12,195	1	SEW (1)
Benzene	1 µg/L	10,083	0	
Benzo(a)pyrene	0.01 µg/L	12,360	3	AFW (1), WSX (1), SWB (1)
Boron	1 µg/L	10,132	0	
Bromate	10 µg/L	10,919	0	
Cadmium	5 µgCd/L	12,235	0	
Chloride	250 mgCl/L	10,233	6	ISC (6)
Chlorine – residual (free)[2]	2 mg/L	107,935	0	

Parameter	Current standard or specified concentration[1]	Total number of tests	Number of tests not meeting the standard	Number of tests not meeting the standard per company
Chlorine – residual (total)[2]	2 mg/L	123,796	0	
Chromium	50 µgCr/L	12,389	0	
Conductivity	2500 µS/cm at 20°C	62,435	0	
Copper	2 mg/L	12,303	2	DWR (1), SVT (1)
Cyanide	50 µgCN/L	7,642	0	
Fluoride	1.5 mg/L	10,227	0	0
Iron	200 µg/L	49,437	81	AFW (2), ANH (7), BRL (2), DWR (4), NES (7), SRN (2), SVT (11), SEW (3), TMS (5), UUT (27), WSX (2), YKS (9)
Lead	10 µg/L	11,285	59	AFW (5), ANH (5), ISC (1), NES (2), PRT (1), SES (1), SRN (2), SVT (12), SEW (1), TMS (17), WSX (1), SST (2), SWB (4), YKS (5)
Manganese	50 µg/L	49,008	14	AFW (1), ANH (2), ISC (1), SRN (1), SVT (2), UUT (6), WSX (1),
Mercury	1 µgHg/L	8,517	0	
Nickel	20 µg/L	11,238	43	AFW (5), ANH (6), BRL (1), DWR (1), ISC (1), IWN (2), NES (8), SVT (2), SEW (4), TMS (5), WSX (3), SST (2), YKS (3)
Nitrate	50 mg/L	22,154	0	
Nitrite	0.5 mg/L	22,180	3	NES (2), TMS (1)
Nitrite (taken at works)	0.1 mg/L	23,400	0	
Pesticides – total	0.5 µg/L	7,297	0	

Parameter	Current standard or specified concentration[1]	Total number of tests	Number of tests not meeting the standard	Number of tests not meeting the standard per company
Pesticide – individual[3]	0.1 µg/L	171,746	3	Metazachlor NES (1) Propyzamide NES (2)
pH (Hydrogen ion)	6.5 – 9.5	53,199	3	TMS (1), UUT (1), YKS (1)
Polycyclic Aromatic Hydrocarbons (PAH)	0.1 µg/L	12,281	1	AFW (1)
Radioactivity				
Gross alpha	0.1 Bq/L	1,434	55	ANH (1), ISC (19), LNW (1), SVT (13), TMS (1), UUT (6), SST (12), VWP (2)
Gross beta	1.0 Bq/L	1,430	6	ISC (2), VWP (4)
Total indicative dose	0.1m Sv/year	2	2	VWP (2)
Tritium	100 Bq/L	316	4	VWP (4)
Selenium	0.1 µg/L	12,226	0	
Sodium	200 mg Na/L	12,398	1	AFW (1)
Sulphate	250 mg SO4/L	10,248	0	
Tetrachloroethene & Trichloroethene (sum of)	10 µg/L	11,415	1	SVT (1)
Tetrachloromethane	3 µg/L	11,495	1	ANH (1)
Trihalomethanes Total	100 µg/L	12,390	0	
Tritium	100 Bq/L	316	0	
Turbidity (at consumers' taps)	4 NTU	53,175	8	AFW (1), SRN (1), TMS (2), UUT (2), WSX (1), YKS (1)

Notes:

[1]For comparison, 1 mg/L is one part in a million, 1 µg/L is one part in a thousand million.

[2]The value of 2 mg/L at the consumer's tap is a screening value set by the Inspectorate.

[3]A further 16,677 tests were done for aldrin, dieldrin, heptachlor, heptachlor epoxide, all of which met the relevant standard of 0.03 µg/L.

[4]These are screening values to trigger action. The standard is 'Total Indicative Dose'.

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Drinking Water 2022

The Chief Inspector's report for drinking water in Wales

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Contents

Foreword

The strategic objective of the Drinking Water Inspectorate (the Inspectorate) is to protect public health and maintain public confidence in drinking water, and this is achieved by securing sufficient safe and clean drinking water, now and for future generations. This central position is shared by the public, who relate to the service aspects which affect them directly. In recent **consumer preferences research**, a sample of 302 people in England and Wales ranked the appearance and taste of their drinking water together with a constant and a safe supply as their top priorities.

The United Kingdom is one of only six nations in the world with the maximum score possible in the Sanitation and Drinking Water section of the 2022 **Environmental Performance Index**. This measures diseases and deaths from exposure to unsafe sanitation and drinking water, providing countries with independent data on whether water infrastructure is sufficient to maintain public health. The absence of any disease associated with drinking water infrastructure validates the work of the Inspectorate and the companies it regulates in ensuring public health is protected. Whilst this is certainly good news and aligns with the high level of compliance by companies in Wales of 99.97% and the actions by the Inspectorate since 1991 to keep drinking water safe and in line with consumer expectations, it is critical not to be complacent. To maintain this position, the Inspectorate has set out four pillars upon which water company strategic plans will need to focus when considering the water supply for the future based upon current and emerging risks.
These are:

- Climate change.
- Continuing and new risks.
- Source to tap planning.
- Supply resilience.

The impacts of climate change range from drought and prolonged periods of dryness to floods coupled with heavy rain. Extreme conditions affect resources by degrading the chemical and biological composition of the catchment and source water through pollutant concentration increasing the challenge to water treatment. These include algae, metals, turbidity, and novel pollutants, which have impacted the ability of treatment works in Wales to treat and supply water which is wholesome. Catchment risks must be assessed to identify mitigation necessary in the short and long-term to ensure infrastructure is and remains fit for purpose, is adaptable and is planned as a proactive strategy.

This report provides all the raw water data at the points of abstraction to highlight the continuing and new risks posed by environmental water used for drinking. The threat of PFAS in raw water sources is evident by the work of the Inspectorate and is published in this report. Water companies must strategically plan now to mitigate these risks in their business plans, particularly since understanding of the toxicities remains limited. The raw water data highlights remaining challenges such as pesticides, nitrates and other chemicals which may become transferred risks as source waters change, sources are opened or reopened, raw water is transferred, water is recycled, and infrastructure evolves. Equally important is the need to horizon scan for risks which may not be evident now but become important when changes in the catchment occur, including endocrine disruptors, pharmaceuticals, microplastics and post-industrial solvents.

Changes in our environment, demographics, industry, customer expectations and usage will put pressure on ageing infrastructure which is no longer able to cope or cater for these changes, some of which have been highlighted in the report, as well as difficulties enabling asset inspections, removal from supply for maintenance, and replacement. In Wales, 56 service reservoirs have not been inspected in the last 10 years, the oldest example dates to 1910 and in 50 percent of cases, these assets cannot be removed from service without significant enabling works to be carried out.

The Inspectorate has an enforcement strategy linked to transformation programmes to focus companies on keeping water safe. Nevertheless, discoloured water remains the most common reason for consumers to contact their supplier with a water quality concern in Wales. This is caused by resuspension of sediment within the mains, originating either from source water containing metals which pass through the water treatment works and seed the network, or from metals eroding from older iron mains. Significant investment is required to lower margins of treatment control to first remove metals more effectively but also to replace and remediate these mains to reduce discolouration and avoid events where customers experience unwholesome water.

This year has identified water treatment works failures due to power supply, a significant cyber security breach, gaps in physical security, and provision of alternative supplies which has fallen short of minimum expectations. Power generators at treatment works do not in themselves provide complete resilience for supplies since logic controllers have failed on power surges and pumped distribution systems do not have full coverage. The impact of freeze/thaw has been reported on the Inspectorate's website. Whilst an improvement compared to 2018, the response has still fallen short in the areas of two companies outside of Wales, where there was a lack of resilience in the system coupled with insufficient headroom to recover the supply/demand balance following burst mains. The high summer demand in hot weather also caused supply interruptions.

In one instance in particular, the provision of alternative supplies was well below minimum expectations. The loss of drinking water supply has severe societal impacts and investment in alternative supplies will be necessary to meet the changes of SEMD 2022 and the subsequent gaps identified in risk assessments for alternative supplies.

Finally, we must not forget the significant legacy issue of lead which remains prevalent in our homes. Scientific evidence unequivocally states that there is no safe level of lead in drinking water. Companies should be increasing their strategy, not reducing it, towards eliminating lead.

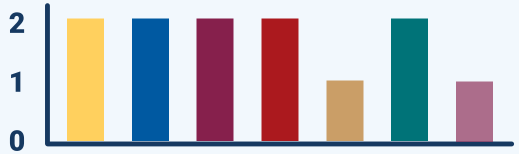
We cannot stand still, be complacent, or assume drinking water remains of such high quality that no investment above base expenditure or no action is required. This will result in our failure to protect public health and we consequently will not be in the top six countries in the world for drinking water quality.

I began by stating that for consumers their priority is a good clean wholesome supply. I urge companies and all involved in drinking water to adopt a balanced and strategic investment strategy for future generations.

Marcus Rink
Chief Inspector of Drinking Water

Water Industry Dashboard 2022

12 Audits



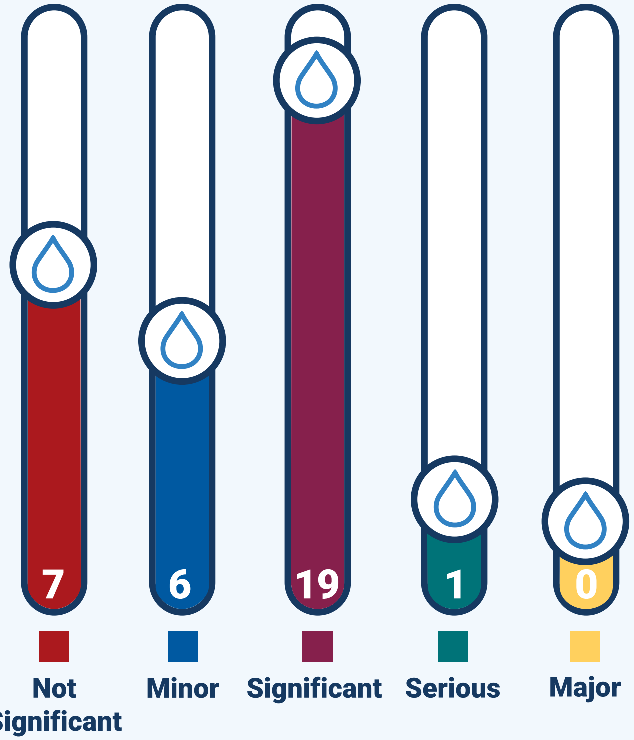
Lead		Asset health	
Contractor		Water safety plan	
Event/audit follow up		PFAS	
		SEMD	

Compliance with standards 99.97%

Compliance Risk Index:

- Dŵr Cymru Welsh Water: 5.397
- Hafren Dyfrdwy: 0.563

33 Events



Consumer complaints* on acceptability Contacts per 1000 population:

- Wales**: 2.51
- Industry average: 1.16

Water safety planning Risk Assessment Risk Index:

- Dŵr Cymru Welsh Water: 2.86
- Hafren Dyfrdwy: 124.83
- Industry median value 2022: 3.23

Enforcement in Wales:

- Recommendations: 54
- Legal Instruments served: 7
- Companies in transformation: 0

* All water quality contacts excluding enquiries
** Companies wholly or mainly in Wales

Drinking Water 2022

The Chief Inspector's report for Wales

Drinking Water 2022 is the annual publication of the Chief Inspector of Drinking Water for England and Wales. It is the 33rd report of the work of the Inspectorate and presents the summary information about drinking water quality for the calendar year of 2022. It is published as a series of four quarterly reports and a final summary report, which cover public water supplies, and a single report, which covers private water supplies. This report is the summary of public water supplies for Wales.

Water supplies and testing

Set out in this report are the key facts about the quality of the public water supplies in Wales, which is served by two water companies and two inset appointees, delivering supplies to over 3.1 million consumers. The area served by each water company is shown in Figure 1.

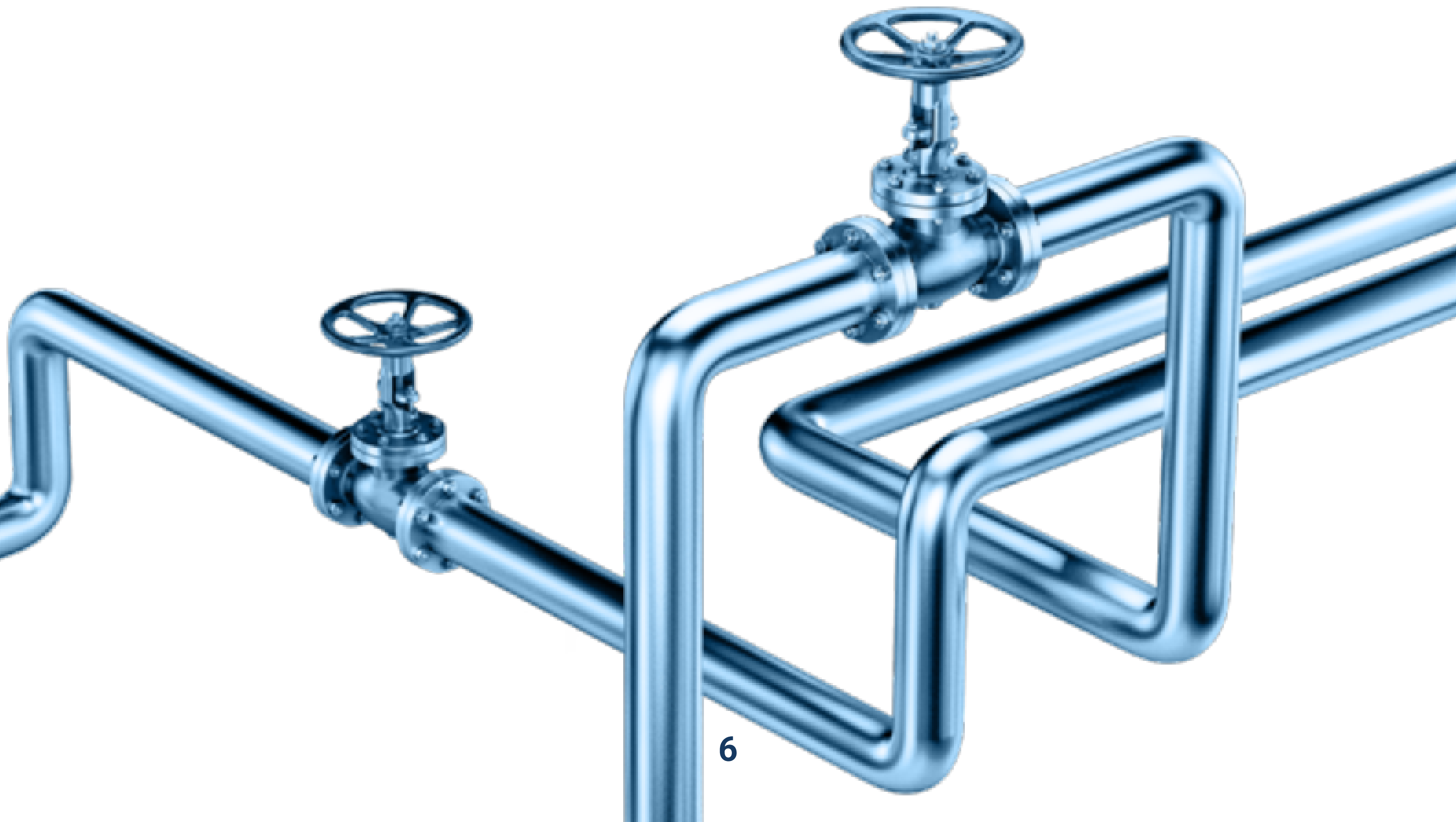


Figure 1.

Companies supplying water in Wales

Companies

ALE – Albion Eco
DWR – Dŵr Cymru Welsh Water
HDC – Hafren Dyfrdwy
LNW – Leep Water Networks

Table 1.

Key facts about public and private water supply arrangements in Wales

Public supplies		Private supplies	
Population supplied	**3,168,000**	Population supplied	**75,442**
Water supplied (L/day)	**893,845,000**	Water supplied (L/day)	**109,463**
Abstraction points	**80**	Approximate number of private water supplies*	**14,933**
Treatment works	**67**	Total number of local authorities	**22**
Service reservoirs	**398**	Number of local authorities with private supplies	**22**
Water supply zones	**96**		
Length of mains pipe (km)	**27,964**		
Water composition:		**Water composition:**	
Surface sources	**93.11%**	Surface influenced supplies	**19.61%**
Groundwater sources	**5.95%**	Groundwater sources	**39.8%**
Mixed sources	**0.94%**	Mains water	**3.69%**
		Unknown	**36.7%**

Area of supply:

Anglesey, Blaenau Gwent, Bridgend, Caerphilly, Cardiff, Cardiganshire, Carmarthenshire, Conwy, Denbighshire, Flintshire, Gwynedd, Merthyr Tydfil, Monmouthshire, Neath and Port Talbot, Newport, Pembrokeshire, Powys, Rhondda Cynon Taff, Swansea, Torfaen, Vale of Glamorgan, Wrexham County Borough.

*Boundaries for public supplies regions are based on groupings of water company zones. Boundaries for private supplies figures are based on the closest approximation of the public supply zones. Where local authorities' boundaries cross regional boundaries, the whole local authority data has been attributed to the region in which the majority of its area lies.

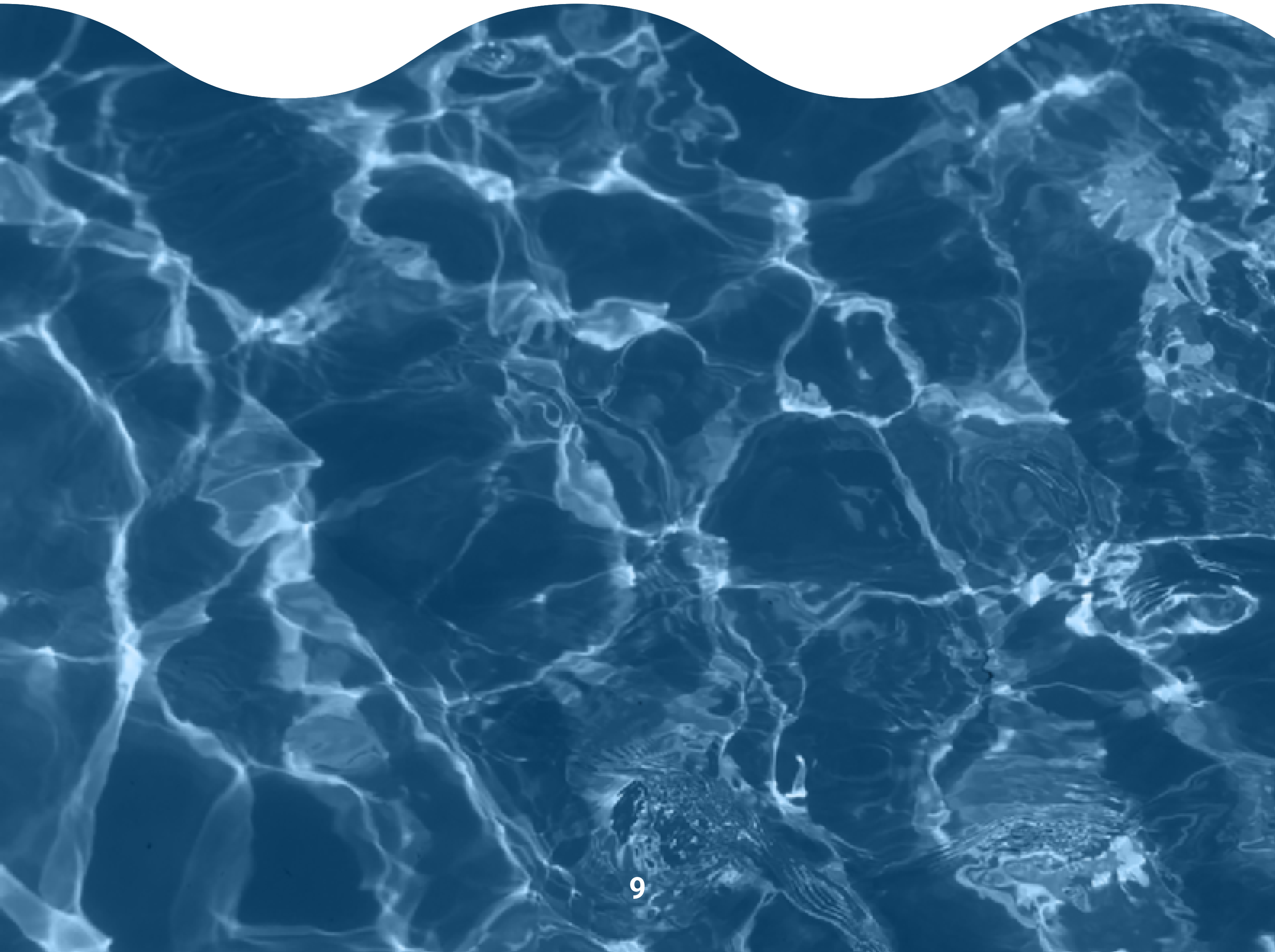
Compliance with standards

Table 2.

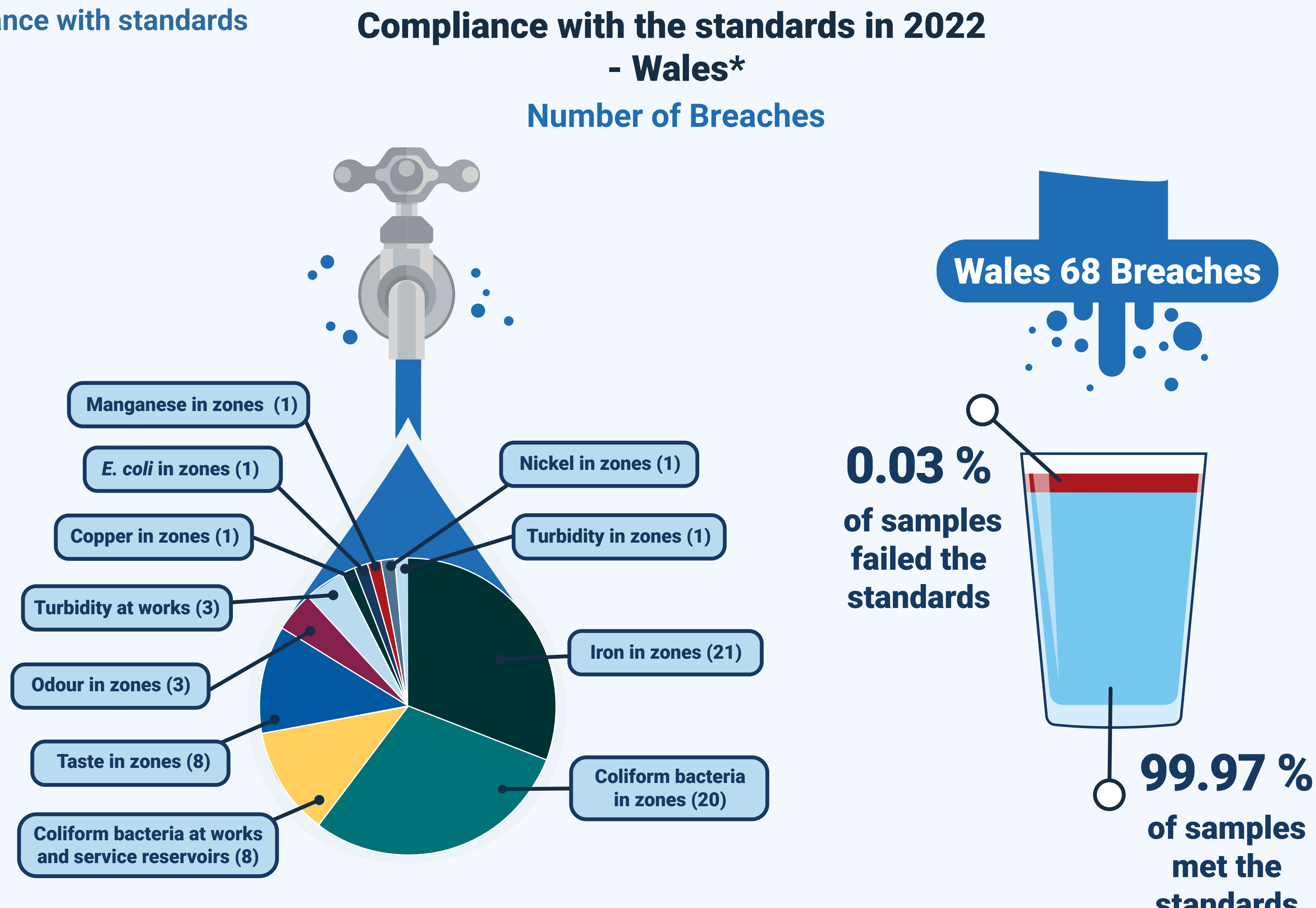
Percentage of samples meeting the standards

The percentage compliance with the standards in the Water Supply (Water Quality) Regulations 2018 (the Regulations) is shown in Table 2 below.

Parameter Group	Percentage Compliance (2dp)
Chemical Parameters	99.92%
Indicator Parameters	99.96%
Microbiological Parameters	99.99%
Pesticides	100%
Overall	99.97%



Compliance with standards



*Companies wholly or mainly in Wales

Table 3.

Number of tests carried out by companies in Wales

Company	Place of sampling: Water treatment works	Service reservoirs	Consumers’ taps (zones)	Number of tests per company	Target number of tests
Albion Eco	0 (0)	0 (0)	248 (1)	248	248
Leep Networks Water[1]	0 (0)	0 (0)	208 (1)	208	208
Dŵr Cymru Welsh Water[1]	63,396 (58)	139,486 (305)	83,807 (76)	286,689	287,008
Hafren Dyfrdwy	5,040 (6)	16,260 (83)	9,699 (18)	30,999	31,164
Wales	**68,436 (64)**	**155,746 (388)**	**93,962 (96)**	**318,184**	**318,628**

Numbers in brackets reflect the number of works, reservoirs or zones operated by that company in Wales in 2022. Some companies are permitted to carry out some tests on samples taken from supply points rather than from consumers’ taps.

[1]DWR and LNW have assets in both England and Wales, these assets have been split in each regional table.

Compliance with the drinking water standards is consistently high in Wales, but scrutiny of company water safety plans, audits and events reveals underlying risks within the drinking water supply system. The Inspectorate has developed a series of risk indices to identify where companies are failing to address risks to supplies. The Inspectorate uses the Compliance Risk Index (CRI) to measure company performance, and the impact of failures on consumers. CRI is designed primarily for the purposes of effective regulation ensuring appropriate scrutiny is directed to those areas of greatest relative risk. The chart below shows company compliance risk index performance.

Compliance in Wales has improved in 2022, following a challenging year in 2021. However, there has been no improvement over the last five years to demonstrate strategic impact on longer-term key risks. For example, the largest part of Wales’ compliance score in 2022 is made up by, and remains due to, iron breaches. These made up 2.606 (44%) of the total score, and are all in Dŵr Cymru Welsh Water zones. The largest single score in Wales was a single coliform breach at Dŵr Cymru Welsh Water’s Ponsticill treatment works in September, of 1.245. This works is subject to a notice due to the tanks exceeding the maximum 10-year inspection frequency. This accounted for 21% of total Wales score and 23% of Dŵr Cymru Welsh Water's score. Dŵr Cymru Welsh Water now has the sixth highest CRI score in the industry at 5.397 and Hafren Dyfrdwy sits in 17th place at 0.563.

In total in Wales, there were three coliform breaches at treatment works and five coliform breaches at service reservoirs in 2022, with five of these breaches covered by a legal instrument, which increased the score accordingly. Asset health is therefore the main reason for companies incurring financial penalties in Wales, because their CRI is largely driven by failures at treatment works and service reservoirs, putting large numbers of customers supplied by those assets at risk.

Figure 2.

CRI scores for companies in Wales

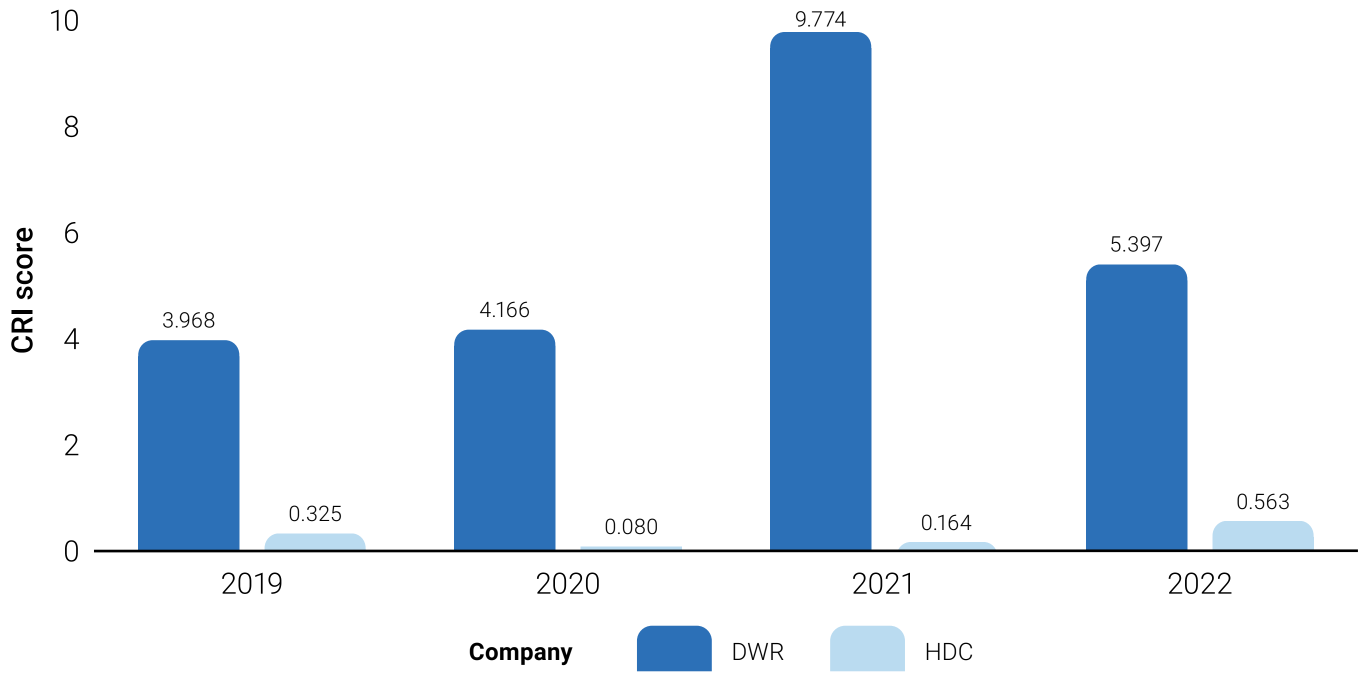
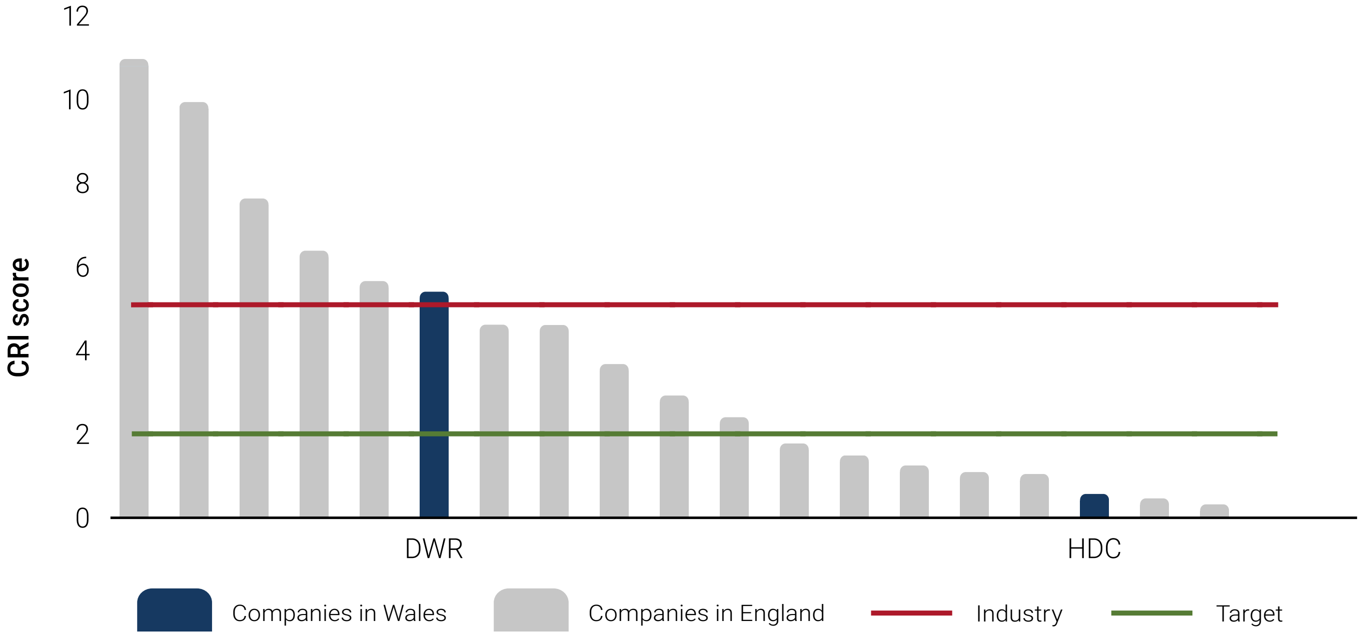


Figure 3 shows the CRI for each company operating in England and Wales.

Figure 3.

Industry Compliance Risk Index



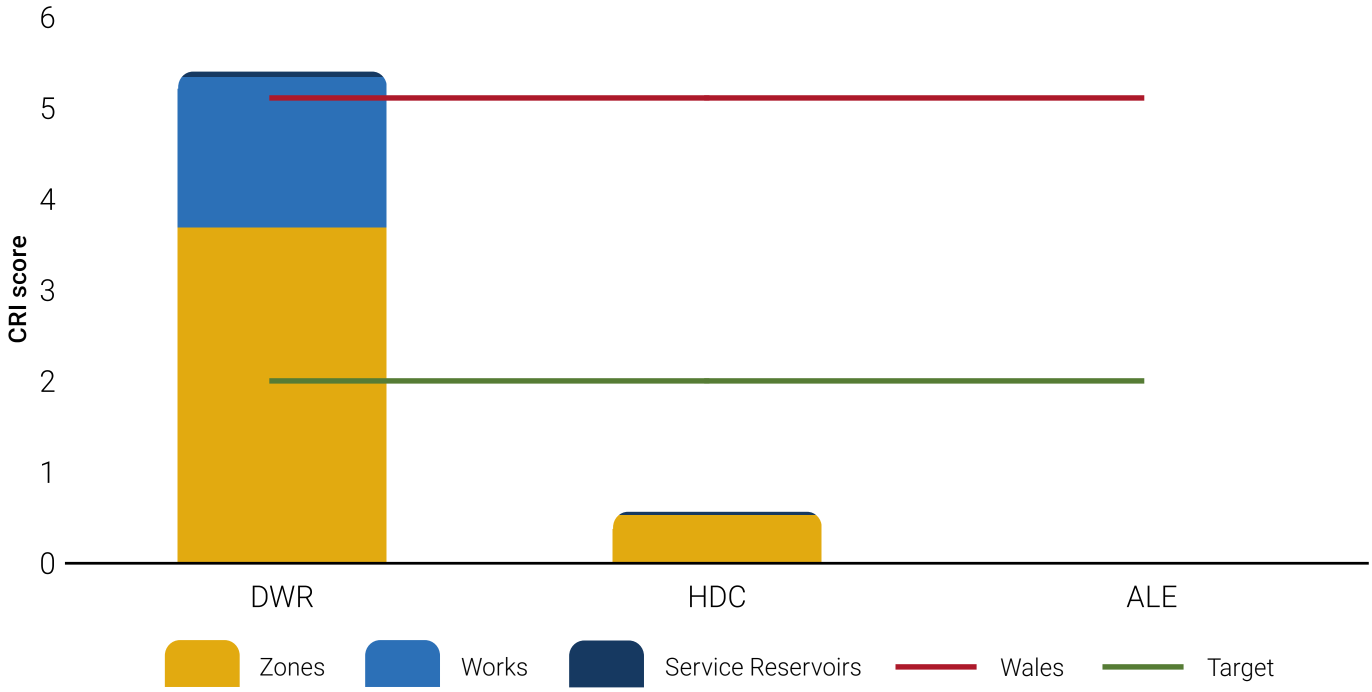
The CRI is shared with the financial regulator, Ofwat, as a common performance measure as an integrated regulatory strategy intended to promote improving water quality in the public interest. A CRI target of 2 has been set as the point at which financial penalties apply, ensuring outcomes remain achievable and equitable when used as a water quality performance objective. Companies are nevertheless required by the Regulations to achieve 100% compliance and CRI does not remove that obligation.

The median value for the industry in 2022 is 1.365 which indicates a deterioration from the 2021 value of 1.171. Dŵr Cymru Welsh Water remains in the top half of companies, although it has made some improvements in the past year.

In 2022, the CRI for companies wholly or mainly in Wales was 5.959. This is an improvement from 2021 when this figure was 9.173, however this figure is still above that in previous years. The overall CRI figure is comprised of figures representing performance at different parts of the water supply chain (treatment works, supply points, service reservoirs and zones). In Wales, the high score in 2021 was largely attributable to the Dŵr Cymru Welsh Water service reservoirs and treatment works elements of the measure, which resulted in enforcement by the Inspectorate and subsequent multiplying of these individual scores. Although there were fewer breaches at service reservoirs and treatment works in Wales in 2022, the majority of these were covered by this new legal instrument, which therefore increased the scores.

Figure 4.

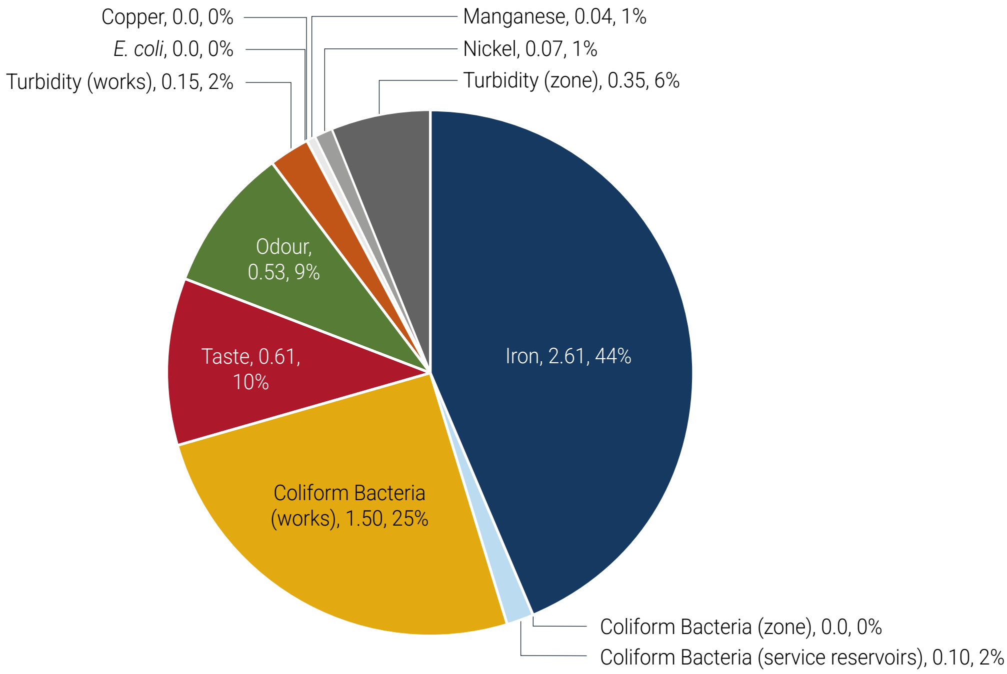
Wales Compliance Risk Index for 2022



Considering individual company performance; there was deterioration in the scores of Hafren Dyfrdwy from 0.164 in 2021 to 0.563 in 2022, however Dŵr Cymru Welsh Water improved from 9.775 to 5.397 in 2022. Dŵr Cymru Welsh Water contributed to a significant proportion of the Wales CRI figure, and also exceeded the Welsh national CRI, 9.173. CRI permits the unpacking of the key contributors to each element within the score to understand where the risks are arising, and these can be seen in Figure 4. The data includes all regulatory failures, including Indicator parameters taken at treatment works, service reservoirs and consumer taps, and is used for the CRI calculation.

Figure 5.

Wales CRI score by parameter



For companies in Wales, iron has had the most significant impact on CRI scores in 2022 and this signals the continuing need for companies in Wales to invest in short, medium and long-term strategies to mitigate and reduce these risks. This would include, flushing to remove sediment, tightening operational limits on treatment works to reduce metal throughput into the network and resizing and replacement of old deteriorating mains which both companies are committed to in their strategic plans

Following a significant increase in coliform breaches in service reservoirs and treatment works in 2021, there has been a reduction in 2022 to below numbers seen even prior to 2021. Whilst this is indeed good news, and demonstrates the hard work put in over the year to quickly remove and inspect failing reservoirs, continuing investment in enabling works to remove reservoirs from supply will be required.

Companies should be aware, particularly for discolouration notices, that CRI performance can quickly deteriorate without sufficient ongoing maintenance and discolouration risk in the network should be monitored and continuously reviewed. Further detail on the discolouration review is included later in this report.

Learning from compliance failures

Microbiological failures

In November 2022, a single coliform was detected from Dŵr Cymru Welsh Water's Cefni works in Llangefni, Gwynedd. One week after the detection, the company removed compartment A of the final water tank from service, to carry out an inspection as part of its ongoing investigations of the cause. Unfortunately, it was not possible to remove, inspect, and clean compartment B until January 2023. This is because the tank's single combined inlet outlet main prevents the isolation of compartment B without a prolonged works outage. An outage of that nature is not sustainable at this works due to downstream demand. This situation, whether at this works or any other, is impactful on a company's ability to adequately investigate regulatory breaches and protect consumers in a timely manner. It is also contrary to industry good practise on tank outages and cleaning.

The Inspectorate welcomes that Dŵr Cymru Welsh Water recognised this and has since developed new cleaning methodology. However, it notes that this cannot be implemented until an alteration on the compartment inlet/outlet arrangement has been made. This will be achieved through a capital led project, which is not due for completion until the end of this AMP (March 2025). In the meantime, the company carried out a detailed Risk Assessment/Method Statement which was produced to allow the tank to be taken out of service by shutting down the works and rezoning the supply area. This work has now been successfully completed and the works has been returned to supply. The company has since reviewed other tanks with similar constraints and has included schemes for these tanks with PR24 submissions to the Inspectorate.

Water companies should ensure that the inlet/outlet arrangements of their treated water tanks do not hinder their removal from supply in a timely manner, should this need arise at any time.

There has been an increase in turbidity breaches at treatment works in 2022, with three, all from Dŵr Cymru Welsh Water works. This compares to one in 2021, zero in 2020 and one in 2019. For the breaches reported in 2022, there were no discernible patterns for the raised turbidities detected. A breach of 2.6 NTU in March at Pilleth Knighton treatment works was attributed to an oversized sample pump. The company replaced the sample line and valves, which was found to be leaking, and also replaced the sample pump to one more suitably sized. A detection in June of 1.4 NTU at Strata Florida treatment works was attributed to the operation of a valve upstream of the final water sample tap. The company has added the valve to a list of critical assets so that future operations will be undertaken with more scrutiny.

In December, a further breach of 2.2 NTU was reported from Bontgoch treatment works and was found to be caused by a burst main downstream on the same main as the sample line was located. The Inspectorate recommended that the company included relevant sections of pipework in its risk assessments, where they form part of the treatment works asset.

Table 4. Microbiological tests

The number of tests performed and the number of tests not meeting the standard

Parameter	Current standard	Total number of tests	Number of tests not meeting the standard	Number of tests not meeting the standard per company
Water leaving water treatment works				
E. coli	0/100 mL	11,481	0	
Coliform bacteria	0/100 mL	11,481	3	DWR (3)
Clostridium perfringens	0/100 mL	609	0	
Turbidity[1]	1 NTU	11,485	3	DWR (3)
Water leaving service reservoirs				
E. coli	0/100 mL	19,275	0	
Coliform bacteria	0/100 mL in 95% of tests at each reservoir	19,275	5	HDC (2), DWR (3) All reservoirs in the region met the 95% compliance rule.
Water sampled at consumers' taps				
E. coli	0/100 mL	8,325	1	DWR (1)
Enterococci	0/100 mL	706	0	

[1] Turbidity is a critical control parameter for water treatment and disinfection.

Coliforms at works and service reservoirs

Table 5.

Detection of *E. coli* and Enterococci at treatment works, service reservoirs and consumers' taps

Company	*E. coli* in water leaving treatment works	*E. coli* in water leaving service reservoirs	*E. coli* at consumers' taps	Enterococci at consumers' taps
Albion Water	0 – 0	0 – 0	0 – 12	0 – 4
Leep Networks Water	0 – 0	0 – 0	0 – 12	0 – 4
Dŵr Cymru Welsh Water	0 – 10,481	0 – 15,210	1 – 7,689	0 – 591
Hafren Dyfrdwy	0 – 1,000	0 – 4065	0 – 612	0 – 107
Wales overall	**0 – 11,481**	**0 – 19,275**	**1 – 8,325**	**0 – 706**

Note: Results are shown as the number of positive tests – the total number of tests.

Service reservoirs and treated water tanks analysis

There has been an increased focus from the Inspectorate in recent years regarding treated water tanks, comprising of themed audits on service reservoirs, and the introduction of the annual submission of tanks data including inspection dates, starting in May 2021. For companies in Wales, this resulted in a regulation 28(4) service reservoir and tanks notice for each company, which were both served in the first half of 2022.

These notices require companies to put plans in place to enable full drain down and inspection of their service reservoirs, specifically for those which had not been fully inspected within the past 10 years, and therefore classified as 'at risk'.

Since the initial annual submission in 2021, the Inspectorate has been monitoring the performance of companies on a yearly basis. The following graphs show how companies in Wales are progressing with reducing the number of tanks which are classified as 'at risk'. The data is submitted yearly, with 2021 data up to 21 May 2021, and 2022 and 2023 data up to 30 April in those years.

Figure 6 shows an additional four tanks at risk in April 2023 compared with April 2022. The total number of tanks has changed from 711 in 2022 to 704 in 2023. When a tank's last inspection date goes beyond 10 years during the life of the notice, it is automatically added to the list of assets covered by the notice.

Figure 6.

Dŵr Cymru Welsh Water, percentage of tanks at risk against the total number of tanks

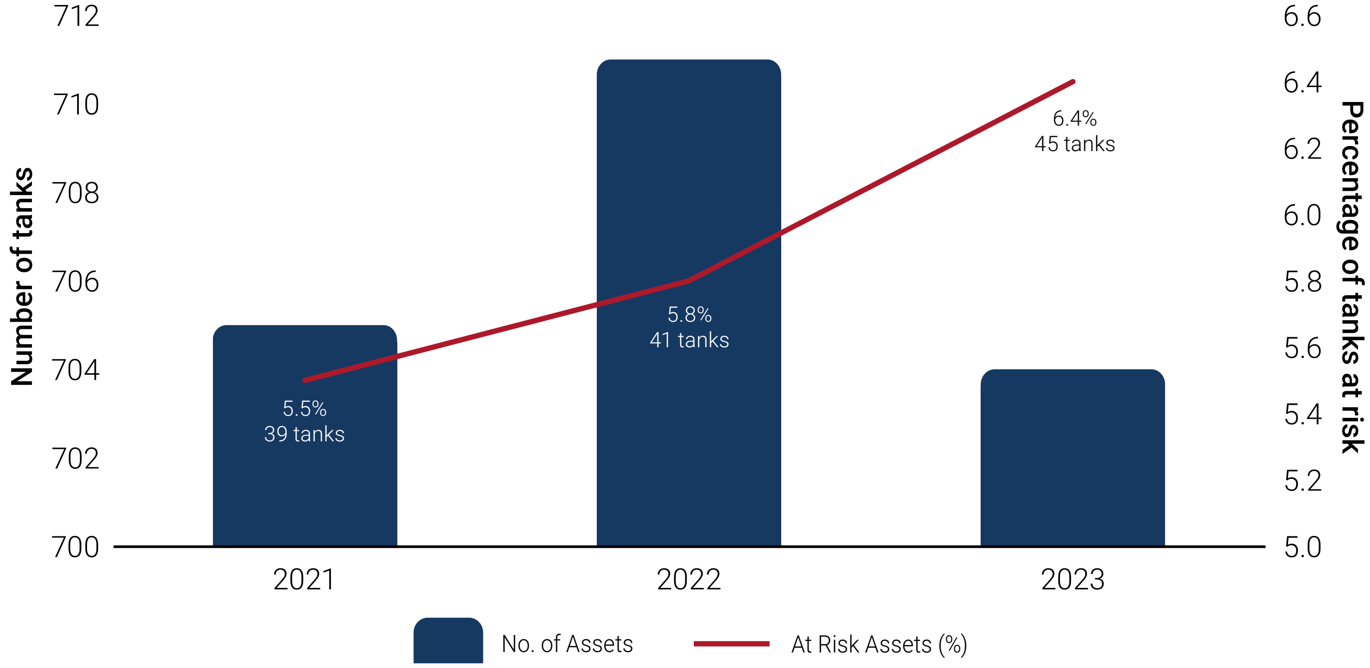
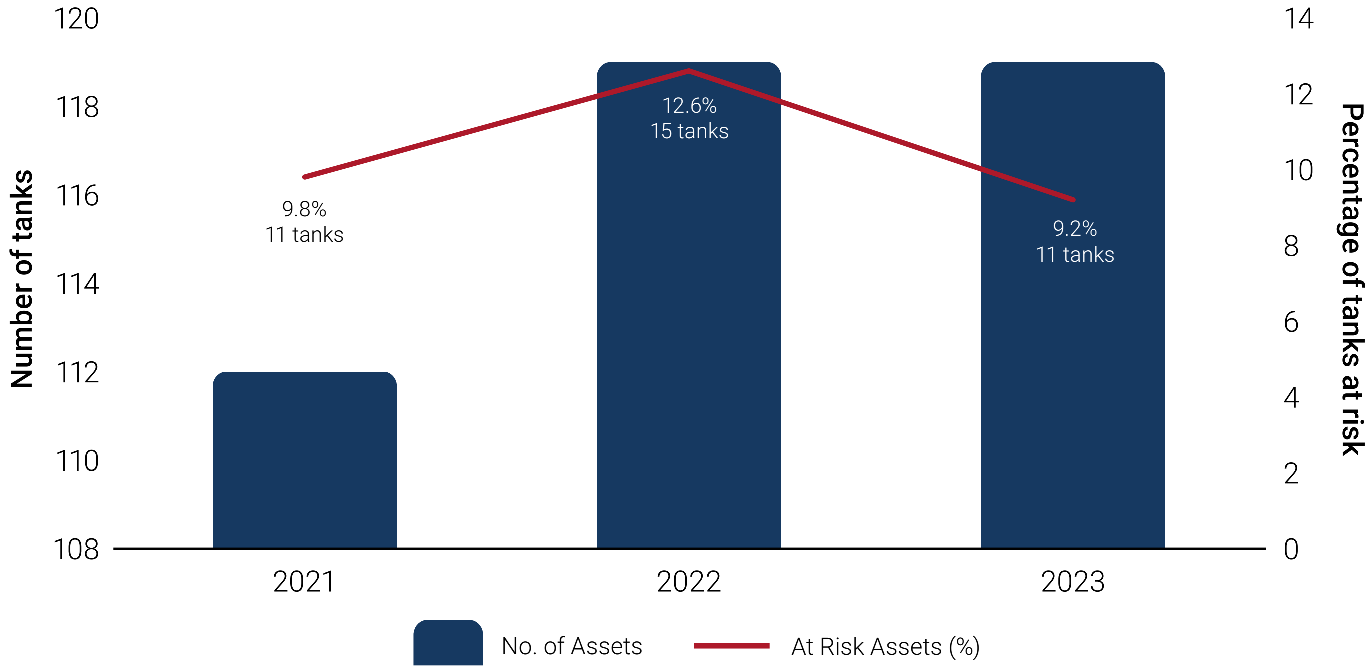


Figure 7.

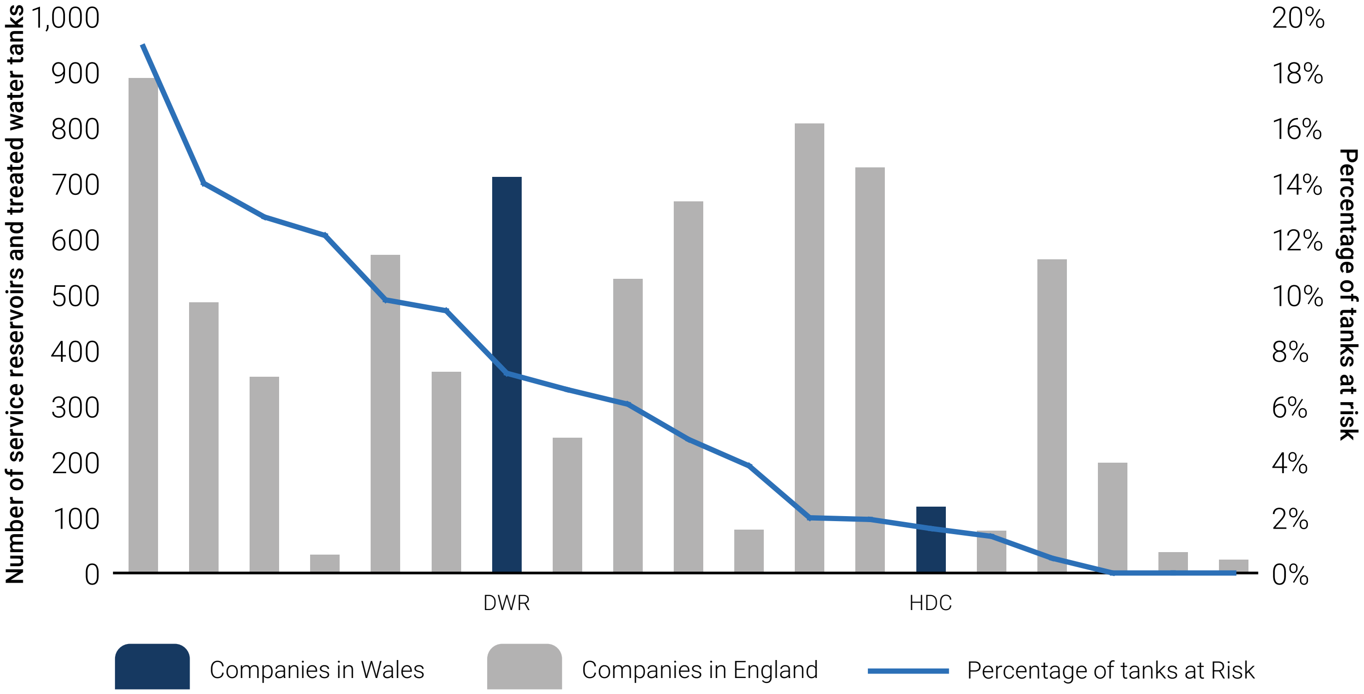
Hafren Dyfrdwy, percentage of tanks at risk against the total number of tanks



The following chart (Figure 8) shows the data submitted in April 2022, from all companies in England and Wales, with the companies with the highest percentage of 'at risk' tanks to the left-hand side of the chart.

Figure 8.

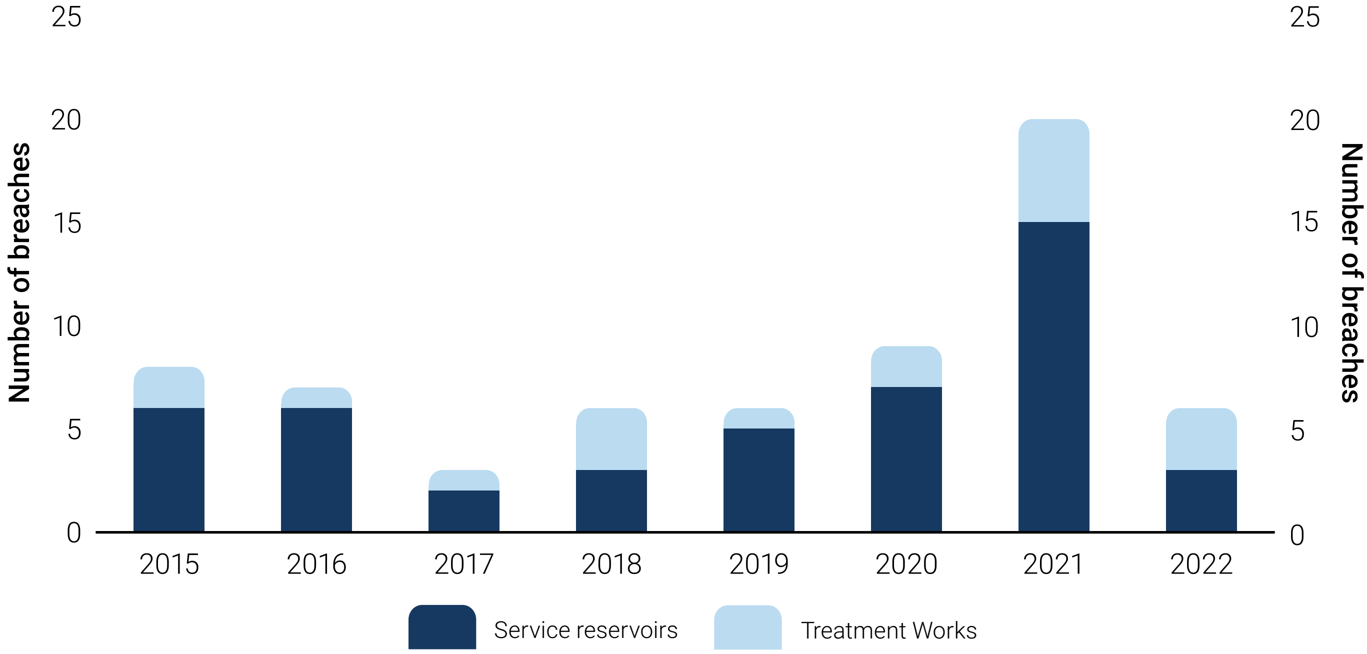
Number of service reservoirs and treated water tanks and percentage at risk in 2021/22 (does not include April 2023 submission)



The number of microbiological compliance breaches at Dŵr Cymru Welsh Water treatment works and service reservoirs has improved in 2022, with six breaches, from a high of 20 in 2021. This is shown in Figure 9. The company is progressing with the service reservoirs and tank regulation 28 notice and has reviewed and improved its policies and procedures for tank inspections, to ensure a robust risk assessment, prioritisation process and inspection takes place. This issue was previously identified by the Inspectorate as potentially contributing to the breaches reported in 2020 and 2021, with a significant number of the tanks having previously been inspected and remediated within the past 24 months prior to the breach.

Figure 9.

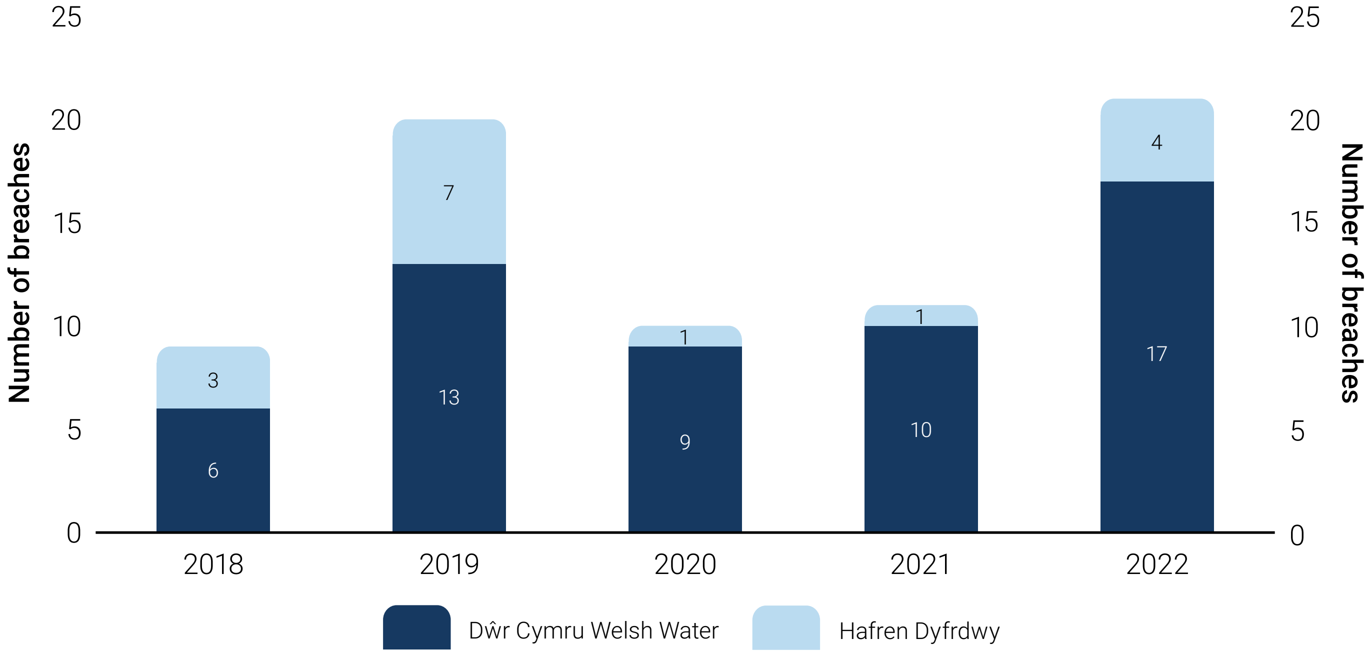
Compliance breaches at Dŵr Cymru Welsh Water service reservoirs and treatment works



In 2022, there were 20 coliform breaches and one *E. coli* breach in zones in Wales. This is an increase from previous years, with 11 in 2021, 10 and 2020, 19 in 2019 and nine in 2018. Figure 10 shows these numbers across the last five years.

Figure 10.

Number of microbiological breaches in zones



Whilst the lower figures in 2020 and 2021 can largely be explained by the pandemic, there is still a slight increase in the number of breaches in 2022 from previous years. Of the 21 breaches in 2022, 20 were attributed to the domestic distribution system, with one cause unidentified. Dŵr Cymru Welsh Water received four recommendations in relation to collecting samples from unsuitable taps and companies should be cautious when selecting taps with fittings which may render the sample unrepresentative of the mains supply. Companies should also focus on obtaining suitable evidence to prove the cause of the failure was the consumer's tap if that is the conclusion of the investigation.

A sample tap with a shower head fitting, listed as the cause of the coliform detection in a water supply zone (photo provided by Dŵr Cymru Welsh Water)

Chemical and physical parameters

Table 6 sets out the results for those chemical and physical parameters where there has been a failure to meet a prescribed standard (mandatory quality standard) and any other parameters of interest.

Table 6.

The number of tests performed and the number of tests not meeting the standard

Parameter	Current standard or specified concentration[1]	Total number of tests	Number of tests not meeting the standard	Number of tests not meeting the standard per company
Aesthetic parameters:				
– colour	20 mg/L Pt/Co scale	3,089	0	
– odour	No abnormal change	3,090	2	DWR (1), HDC (1)
– taste	No abnormal change	3,086	7	DWR (7)
1,2-dichloroethane	3 µg/L	682	0	
Aluminium	200 µg/L	3,063	0	
Ammonium	0.5 mg NH4/L	864	0	
Antimony	5 µg/L	699	0	
Arsenic	10 µg/L	699	0	
Benzene	1 µg/L	680	0	
Benzo(a)pyrene	0.01 µg/L	723	0	
Boron	1 µg/L	656	0	
Bromate	10 µg/L	700	0	
Cadmium	5 µgCd/L	699	0	
Chloride	250 mgCl/L	666	0	
Chlorine – residual (free)[2]	2 mg/L	8,329	0	
Chlorine – residual (total)[2]	2 mg/L	7,724	0	
Chromium	50 µgCr/L	699	0	
Conductivity	2500 µS/cm at 20°C	3,135	0	
Copper	2 mg/L	701	0	
Cyanide	50 µgCN/L	666	0	

Parameter	Current standard or specified concentration[1]	Total number of tests	Number of tests not meeting the standard	Number of tests not meeting the standard per company
Fluoride	1.5 mg/L	664	0	
Iron	200 µg/L	3,058	17	DWR (17)
Lead	10 µg/L	701	0	
Manganese	50 µg/L	3,060	1	DWR (1)
Mercury	1 µgHg/L	665	0	
Nickel	20 µg/L	700	0	
Nitrate	50 mg/L	700	0	
Nitrite	0.5 mg/L	700	0	
Nitrite (taken at works)	0.1 mg/L	512	0	
Pesticides – total	0.5 µg/L	863	0	
Pesticide – individual[3]	0.1 µg/L	5,763	0	
pH (Hydrogen ion)	6.5 – 9.5	3,093	0	
Polycyclic Aromatic Hydrocarbons (PAH)	0.1 µg/L	702	0	
Radioactivity				
Gross alpha	0.1 Bq/L	8	0	
Gross beta	1.0 Bq/L	4	0	
Total indicative dose	0.1 mSv/year	NA	NA	
Tritium	100 Bq/L	9	0	
Selenium	0.1 µg/L	699	0	
Sodium	200 mg Na/L	698	0	
Sulphate	250 mg SO4/L	666	0	
Tetrachloroethene & Trichloroethene	10 µg/L	678	0	
Tetrachloromethane	3 µg/L	680	0	
Trihalomethanes Total	100 µg/L	715	0	
Turbidity (at consumers' taps)	4 NTU	3,086	1	DWR (1)

Notes:

[1] For comparison, 1 mg/L is one part in a million, 1 µg/L is one part in a thousand million.

[2] The value of 2 mg/L at the consumer's tap is a screening value set by the Inspectorate.

[3] A further 2,986 tests were done for aldrin, dieldrin, heptachlor, heptachlor epoxide, all of which met the relevant standard of 0.03 µg/L.

[4] These are screening values to trigger action. The standard is 'Total Indicative Dose'.

In October 2022, a regulatory compliance sample was reported to contain 2.8 mg/L copper, from a public building in Dŵr Cymru Welsh Water's Vowchurch zone. The sample location was geographically in England. Resamples collected as part of the investigation also identified elevated lead above the regulatory limit.

Following the copper and subsequent lead breaches, the company's investigation established the cause to be long lengths of copper pipework in the property with lead soldered joints. As a solution, the company had advised the consumer to flush the pipework before use and signs were to be put up at taps in the property. The Inspectorate considers flushing to be a short-term solution and companies should work with consumers to ensure plans for a long-term solution are in place. In this case, there was also no follow up visit or call to confirm any signs had been put up, as agreed. As such, the Inspectorate was unable to conclude that further breaches of lead or copper were unlikely to recur in this property.

Regulation 21(3) of the Regulations requires the Welsh Ministers to serve a notice requiring the company to exercise its powers under section 75(2) of the Water Industry Act 1991 Act 1991 (the Act) in respect of the failure. In this case, the company did not fulfil its requirements of section 75 of the Act and therefore enforcement in the form of a regulation 21(3) notice was served to the company by the Inspectorate. Companies should be reminded of their duties with respect to breaches in public buildings and should serve a section 75 notice when appropriate, to achieve a successful outcome.

Lead

Lead is a toxic metal that can dissolve into the drinking water when it comes into contact with lead pipes. Consumers are protected to a large extent from exposure by the practice of phosphate dosing to reduce plumbosolvency. This treatment which is employed across many zones in Wales, is one of the reasons few or no consumer tap samples fail the standard for lead each year.
The number of samples required to be tested for lead by the Regulations is also quite low and will be a contributing factor. Companies are submitting lead reduction strategies as part of their business plans for Price Review 2024. They have set the target of being lead free within their water supply zones by 2050, however plans to achieve this target appear unambitious. Dŵr Cymru Welsh Water is developing a lead predictor model in the absence of hard data on pipe material, this utilises data on age ranges of inhabitants and focuses on the vulnerable groups to prioritise areas for replacement. It estimates approximately 180,000 lead pipes exist in the Dŵr Cymru Welsh Water area, however, its AMP8 target (2025 to 2030) is to replace 7,500. This current strategy will take over 120 years to achieve a lead-free supply. To achieve this with 180,000 replacements by 2050 the company would need to replace 7,500 each year. Hafren Dyfrdwy estimates approximately 26,000 lead pipes exist in its area, with a target of 2,000 replacements during AMP8. Again, this rate would need to be nearer 1,000 per year to achieve full lead pipe replacement. At the proposed rate this will take over 60 years to become a lead-free area. Whilst the replacement of every single lead pipe will be of benefit to public health, the target, which the majority of companies have set themselves, of being lead free by 2050 currently feels out of reach without a colossal effort from AMP9 onwards.

It is inevitable that chemical dosing of phosphoric acid will have to continue as the primary large-scale mitigation from the risks of lead, however in England, a number of discrete areas have been chosen for trials on phosphate disengagement where the company initiates a large project to remove all lead pipes from a specific area, enabling the chemical dosing to be switched off. These include South East Water's Coombe Water supply zone with approximately 4000 properties. These build on previous targeted disengagement trials carried out by Severn Trent Water and United Utilities. SES has observed that phosphate dosing has a beneficial effect on minimising nickel failures from taps and fittings in consumers' properties and so companies need to have a strategy for nickel when considering phosphate disengagement trials. The addition of phosphoric acid is not the only way in which a water company can reduce plumbosolvency. Companies should formulate strategies to supply stable, non-aggressive water. Few water companies include in their lead reduction strategies relevant parameters such as pH or alkalinity. Northumbrian Water has a stated aim to produce stable waters that are neither aggressive nor scale forming.

Taste and odour

Taste and odour breaches contributed 19% of the CRI score in Wales in 2022, with 11 breaches. As seen in Figure 11 this is a year-on-year increase since 2020 however, there has been an overall improvement from the pre pandemic high of 23 in 2019. The increase in number of breaches is partly explained by the publication of Information Letter 02/22 in March 2022, which required companies to report compliance samples which were not tasted, as breaches. This accounted for six additional taste breaches being reported, all from the Dŵr Cymru Welsh Water region. The company received one recommendation for these breaches in May and four recommendations for breaches in July. These related to the company's response procedures, primarily to carry out a risk assessment of the risk to public health where the company's own laboratory deems the water unfit to taste.

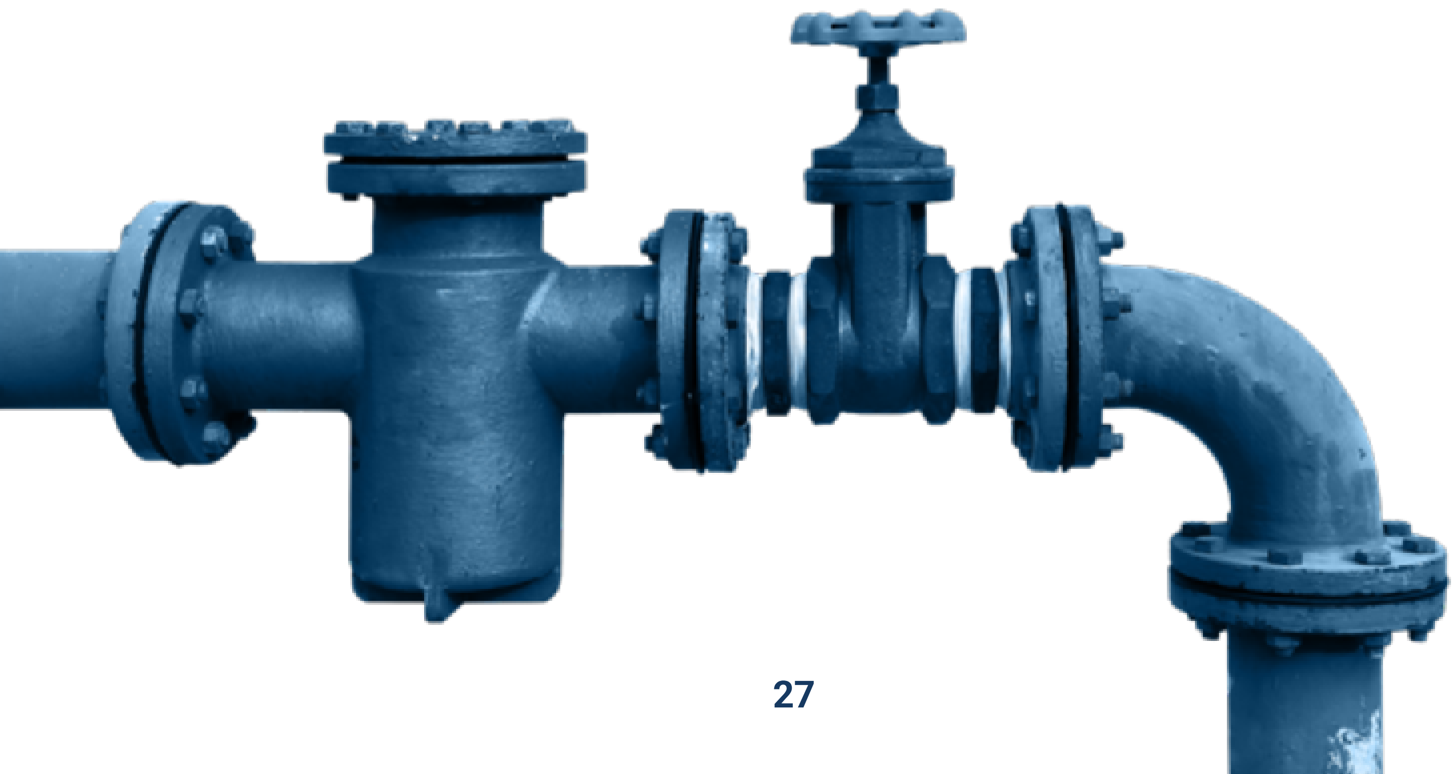
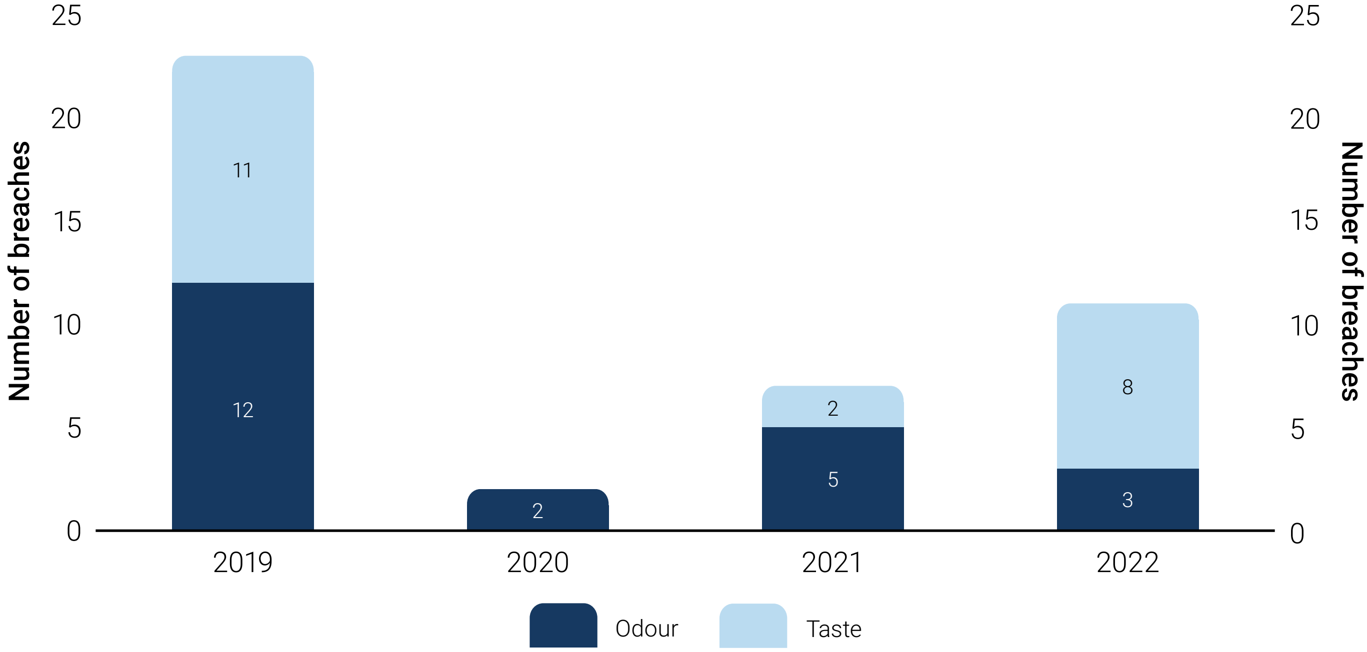


Figure 11.

Taste and odour breaches in zones (including breaches located in England)

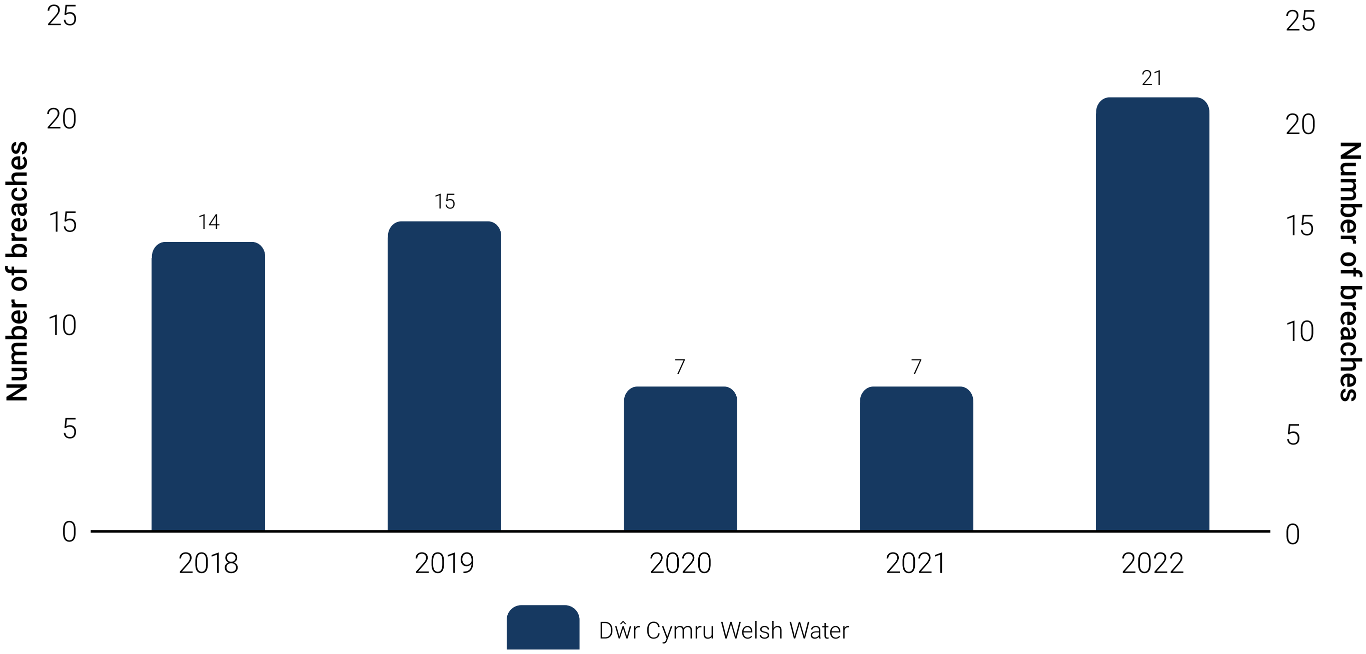


Iron

For iron, there were 21 breaches in 2022, supplying 18 zones solely in Dŵr Cymru Welsh Water's region. One of these samples also breached the standard for turbidity. A single manganese breach was also reported in Dŵr Cymru Welsh Water's Aberystwyth zone, unrelated to the iron breaches. As can be seen in Figure 12, there has been an increasing trend in iron breaches in Wales (despite lower numbers in 2020 and 2021 due to lower zonal sampling during the pandemic) and this, along with consumer contact data has led to increased focus, particularly in the Dŵr Cymru Welsh Water region. Thirteen of the breaches in 2022 for iron, manganese and turbidity (zone) attracted a score of 'enforce' or were covered by a legal instrument. Eight recommendations were given to the company on these breaches, largely regarding investigations into the root cause(s), which in many cases had not been determined and the resolving action left as turnover flushing of the main. Companies should make efforts to identify the root cause of these breaches so that actions can be taken to prevent the failure from recurring in the short, medium and long-term.

Figure 12.

Dŵr Cymru Welsh Water iron breaches

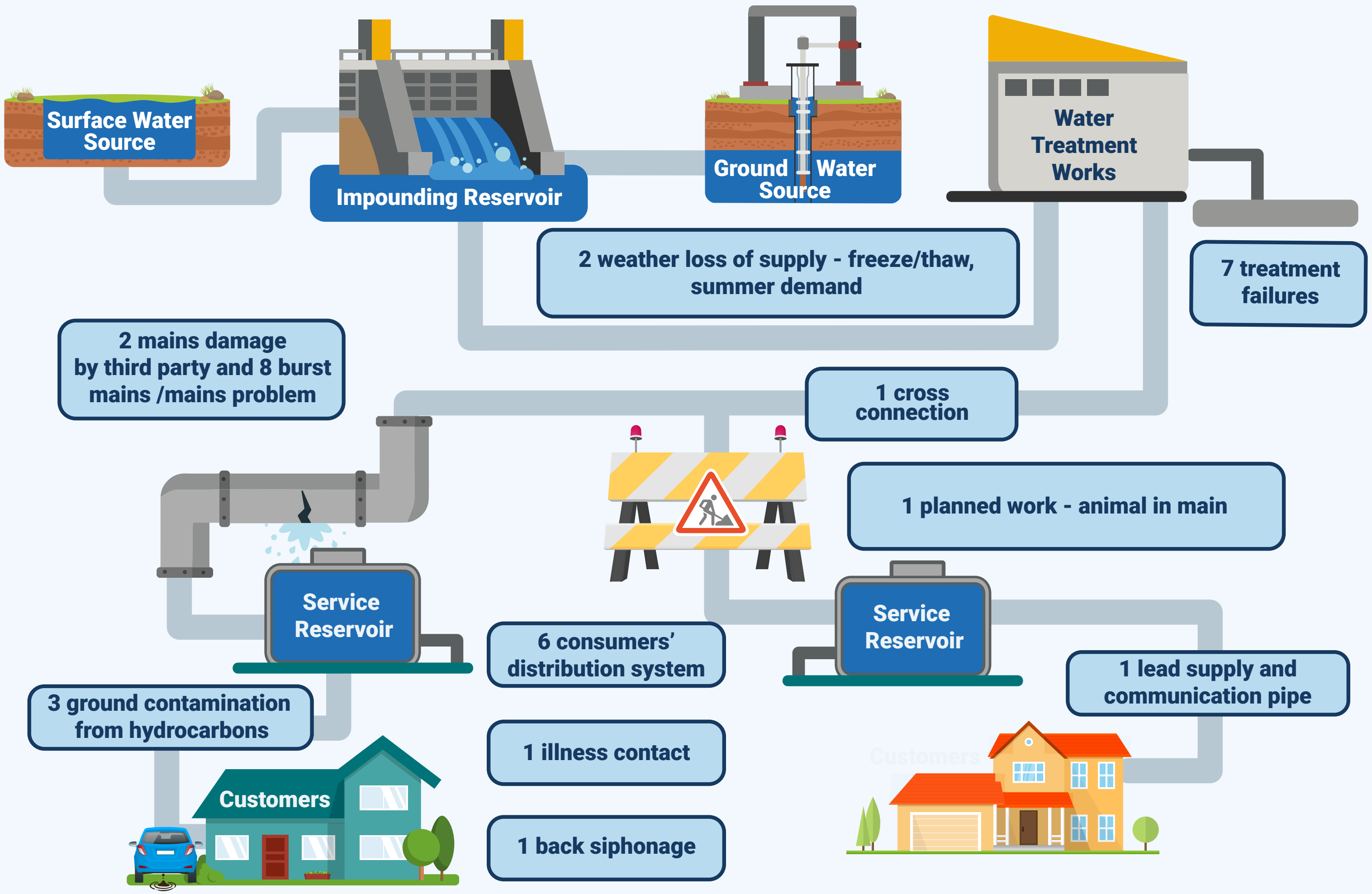


The 21 breaches ranged from 220 µg/L to 1600 µg/L. The number of breaches in 2022 compares with only seven in 2021, and seven previously in 2020. Eight of the 21 breaches were in zones for which a regulation 28 notice is in place for risks associated with discolouration and associated customer acceptability, due to the condition and operation of the network. The company concluded in each case that the cause was due to a build-up of sediment in a supplying or upstream main. The company's standard response in these instances is to carry out a reactive mains flush to remove the sediment and to add the main to an existing or new flushing programme. Following three iron failures in November 2022, the Inspectorate considered that this approach was no longer acceptable on the basis that it was not addressing the root cause of the sediment or committing to a fixed end point solution. It recommended that the company updated its regulation 18 response procedures to ensure the origin of the sediment (the root cause) was suitably investigated and identified, to inform a long-term solution. In so doing, this would prevent recurrence and mitigate any potential discolouration and consumer acceptability risk, for which the company is an industry outlier.

Water quality events

The Inspectorate was notified of 33 events during 2022 in Wales, all of which were assessed, and enforcement action was taken where necessary.

Types of events in Wales

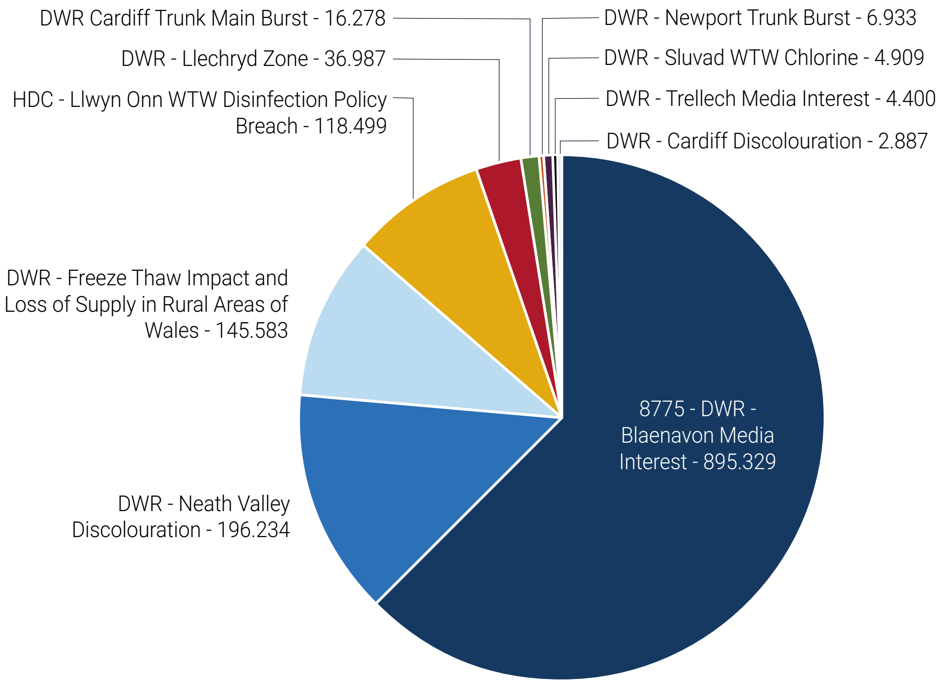


Highest Event Risk Index (ERI) scoring events

Figure 13 shows the highest scoring events in 2022. For a number of these, the assessments remain ongoing and therefore the assessment conclusions are estimated.

Figure 13.

Highest Event Risk Index

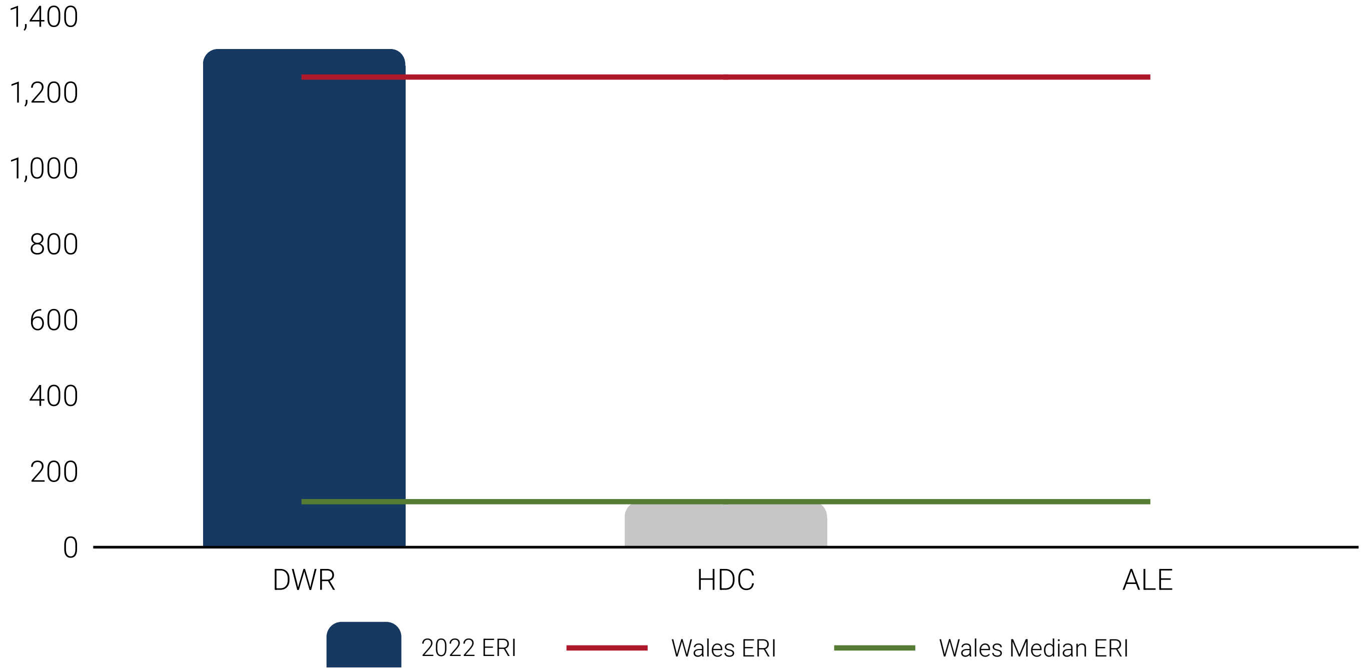


Event Risk Index by company

Most events notified to the Inspectorate in 2022 were of relatively short duration and companies took appropriate action to inform and safeguard consumers, and liaised with other stakeholders. For the benefit of the industry, the Inspectorate publishes information on events that are of wider significance, to illustrate issues that the water industry can learn from. In 2022 the ERI for Wales was 1,239.180, indicating a further deterioration in performance from 335.658 in 2021 and 4.875 in 2020. Figure 14 shows ERI for Wales in 2022.

Figure 14.

Wales ERI and median ERI



Common themes in Wales over the years have been source risks, driving adverse network outcomes, and network outcomes due to the ageing mains infrastructure. These risks manifest as taste and odour due to algal products, discolouration due to sedimentation of metals, discolouration due to bursts or loss of supplies due to bursts. This year is no exception with all but two of the top 10 events (Table 7) fitting into this category. Dŵr Cymru Welsh Water still has work to do to improve on this situation.

Table 7.

Top 10 scoring events notified in 2022

Event Name	Event Date	Cause of Event	Inspector Assessment	ERI
DWR – Blaenavon Media Interest	Oct-22	Raw water deterioration	Not completed	895.329
DWR – Neath Valley Discolouration	Jul-22	Raw water deterioration	Not completed	196.234
DWR – Freeze Thaw Impact and Loss of Supply in Rural Areas of Wales	Dec-22	Other – Loss of supply event caused by freeze thaw	Suggestions made	145.583
HDC – Llwyn Onn WTW Disinfection Policy Breach	Jul-22	Treatment failure upstream of final disinfection	Suggestions made	118.499
DWR – Llechryd Zone	Oct-22	Raw water deterioration	Not completed	36.987
DWR – Cardiff Trunk Main Burst	Nov-22	Mains problem/damage – Mains – Burst	Recommendations made	16.278
DWR – Newport Trunk Burst	Jul-22	Mains problem/damage – Mains – Burst	Recommendations made	6.933
DWR – Sluvad WTW Chlorine	Sep-22	Plant failure – Failure of loading valve on sodium bisulphate dosing system.	Recommendations made	4.909
DWR – Trellech Media Interest	Dec-22	Mains problem/damage – Mains – Burst	Recommendations made	4.400
DWR – Cardiff Discolouration	Aug-22	Mains problem/damage – Mains – Burst	No recommendations or suggestions made	2.887

The following are key events which have resulted in discolouration or bursts due to weather related impacts.

Discolouration events

There were eight events in Wales in 2022 which involved companies supplying discoloured water to consumers, all in the Dŵr Cymru Welsh Water area. Four of these were reported due to the number of discolouration contacts received and four were loss of supply events with associated discolouration when the supply returned.

Cardiff discolouration (Dŵr Cymru Welsh Water)

In August, a significant leak was found on an 18-inch cast iron trunk main supplied by Cefn Mabely service reservoir. The company carried out activities to repair the main and restore supplies, however 46 discolouration calls were received from the area affected.

Once the event was resolved, the company commissioned a report into the condition of the main, the cause of the mains failure and any future risk of a similar failure along the remaining pipe. The report concluded that the pipe had been constructed in the early 1900s, based on markings on the pipework. Despite its age, the pipe was generally found to be in good condition internally and externally, with some corrosion pitting on the external surface. These corrosion pits appeared to have coalesced, leading to the rough edge of the fracture which can be seen in the image below, and the main was likely to have been leaking for a period of time prior to the failure. It was thought the damage which had caused the corrosion was likely to have been caused by poor installation practice damaging the external coating of the pipe.

Burst section of main showing the tongue shaped failure with the fractured edge at the bottom and the sharp edge on the top (photo provided by Dŵr Cymru Welsh Water).

Further analysis on the pipe wall was carried out, with the estimated remaining asset life between 523 and 1,000 years. Whilst it may seem unlikely that this main will remain in use for the same purpose for this given timeframe, the report does however give some confidence of the condition of this trunk main and its possibility of failure. The Inspectorate welcomes in-depth condition assessment of pipe materials following failures of pipework, which may have a significant impact on consumers if there is a repeat occurrence.

Llwyn Onn breach of disinfection (Hafren Dyfrdwy)

In July 2022, Hafren Dyfrdwy reported an event at its Llwyn Onn treatment works, near Wrexham. An increase in the lime dose during the process stream led to an increased pH of above eight at the contact tank inlet. This was a breach of the company's disinfection policy and as such, was reported as an event. The company's investigation identified the root cause as a faulty controlling pH probe which had increased the lime dose to achieve the desired pH range. This probe was recalibrated, and the lime dose reduced until the pH returned to the set range. Samples collected from the works, downstream service reservoirs and in distribution were all satisfactory. Following the event, the company conducted a root cause analysis session to review the pH issues at the works. This identified several safeguards to protect water quality, which had not been effective:

- The contact tank inlet pH monitor at the site did not generate a call out for a standby operator to attend and investigate the increase in pH. This was investigated and although the alarm was correctly reporting to the SCADA system onsite, it was not correctly generating an associated call out alarm to send an operator to site. This alarm has now been amended to ensure a call out is generated.
- The alarm generated by the contact tank inlet pH monitor when the pH was raised above 8 also did not shut the site down as expected.
- The deviation alarms for the two pH probes have now been correctly configured, so an alarm will be generated if discrepancies are recorded between the probes. This will also generate a call out.

The event that occurred at Llwyn Onn in 2022 is very similar to the event which occurred at Hafren Dyfrdwy's Pendinas treatment works in 2021 (detailed in the summary report for Wales, 2021), with the cause also involving incorrect configuration of alarms. Following the repeat event at Llwyn Onn in 2022 the company carried out a systematic review of all alarms at Llwyn Onn treatment works to ensure all alarms are configured correctly and generate the desired action. However, it is nevertheless disappointing that drinking water quality was put at risk because the company had not learned from the previous event. Companies are reminded to ensure that critical alarms on their assets are configured correctly, to achieve the intended action.

Redwren discolouration investigation/ingress (Dŵr Cymru Welsh Water)

As part of investigations to reduce discolouration, contractors for Dŵr Cymru Welsh Water in February 2022 were inspecting the main by CCTV. Unexpectedly a live newt was recorded by chance inside the main. Further information regarding this event and a cross connection event in Gaufron reported at a similar time (See Quarter 1 report), was assessed as considering enforcement, primarily due to inadequate and delayed sampling in response to the risk of ingress into the network. In June 2022, an undertaking concerning regulation 18 was accepted by the company. More detail is provided in the Enforcement section.

Freeze/thaw event

Freeze/thaw is the phenomena which results in water pipes bursting as periods of cold weather are followed by a period of warmer temperatures, leading to ground movement. Water is then lost from networks due to increased bursts and leaks which depletes storage supply (for example, reservoir levels). In some cases, demand is greater than the speed water companies can refill storage systems.

Wales had one freeze/thaw event, that affected Welsh Water, mainly in the West and Mid Wales. This affected a population of up to 115,848. The company had foreseen the potential event, and had setup a proactive incident response, which reviewed resource availability, storage position and weather forecasts. As the event size started to increase the level of escalation within the business was increased. The company proactively contacted priority service customers (PSR) via SMS. Bottled Water was delivered to all PSR customers, with a total of 2,932 bottled water deliveries being made. Water was also delivered to PSR customers who were not affected by the event as a precaution.

A total of six bottled water stations were set up, along with a number of unmanned stations for consumers to collect bottled water. A number of tankers also assisted in keeping consumers in supply. When this response is compared the 10 events in England, the response compared favourably. The company was the only company to set up tanks and offer consumers "five litre grab bags" to collect water intended for toilet flushing, in addition to the bottles of water. The company also responded to requests from farms and delivered a number of tanks for livestock. The company has also proactively worked with the National Farmers Union (NFU) to improve a future response, should the need arise.

The company proactively engaged with the Inspectorate as part of the event, and this was welcomed by the Inspectorate.

The Inspectorate has published its review and lessons learned from the 2022 December freeze/thaw event on the **Inspectorate's** website.

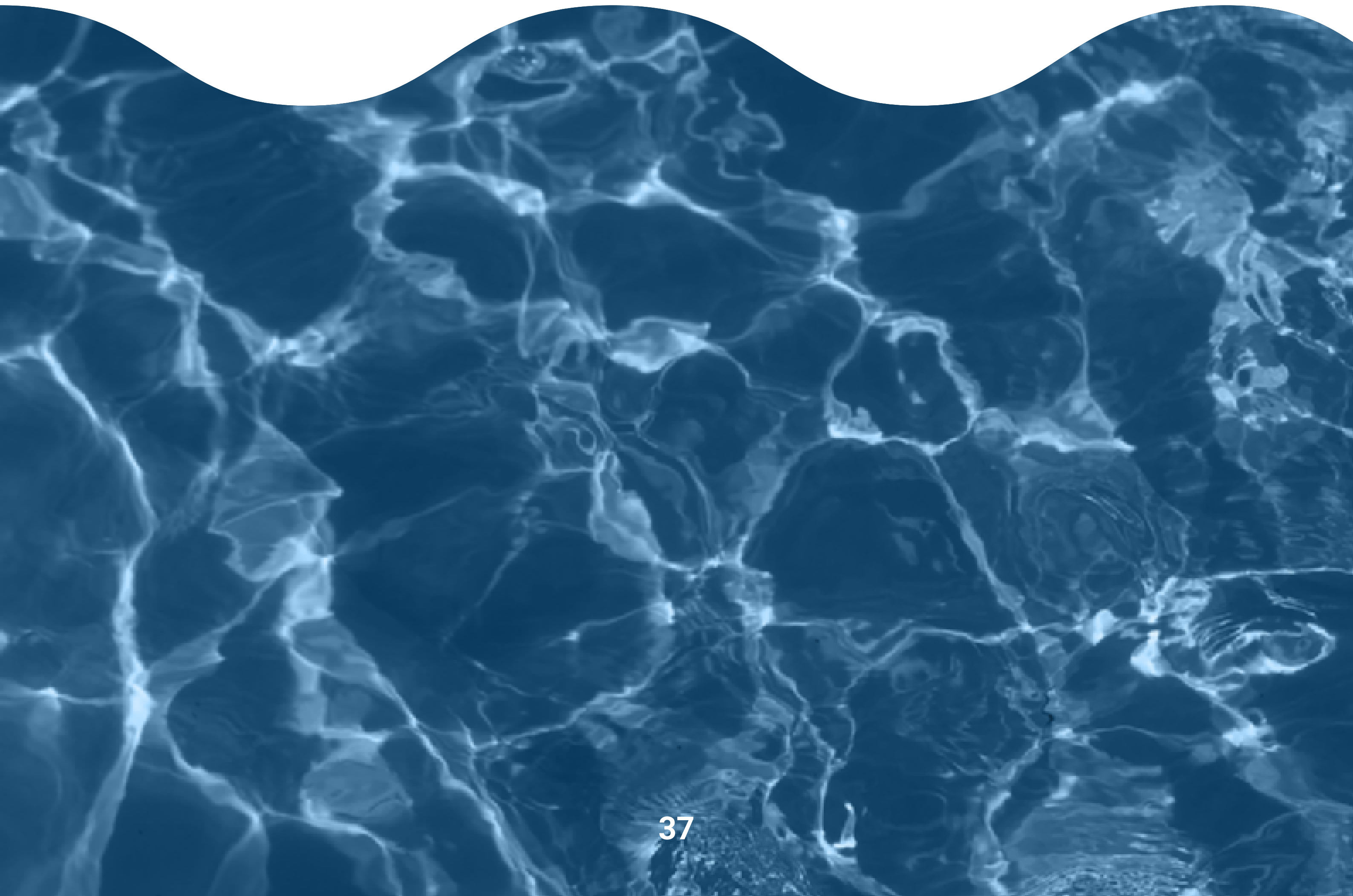
Trellech loss of supply (Dŵr Cymru Welsh Water)

In December 2022, shortly after the freeze/thaw event, a further loss of supply event affecting Trellech, near Monmouth, was reported by Dŵr Cymru Welsh Water. A burst main had been reported on 22 December which resulted in the depletion of storage at Trellech service reservoir. This caused widespread depressurisation of the network and loss of supply for 4,359 consumers in areas of rural Monmouthshire. On 25 December (Christmas Day) this was reported on the BBC Wales website and BBC news television. To resolve the incident, the company repaired the burst and tankered in supplies to restore the network. Ffynon Gaer treatment works was brought into supply to provide further support if required. The company did well to restore supplies to consumers during challenging cold weather conditions and during the holiday period. The Inspectorate issued one recommendation and several suggestions to improve the sampling procedures for tankering activities and the company has put measures in place to rectify this. During the event, the company's sampling survey identified elevated iron concentrations above the regulatory limit at seven properties in six district metering areas (DMAs). The company was able to resolve these issues in four to the DMAs, however further work was required to reduce the iron concentrations in two DMAs.

Power resilience

Sluvad low chlorine (Dŵr Cymru Welsh Water)

The impact of a power outage can have serious implications for the control and operation of a treatment works. One such occurrence happened in September 2022 where there was a power outage at Sluvad treatment works, which supplies Cwmbran, Newport, Cardiff and surrounding areas of South Wales. The works shut down as designed and, following the routine restart of the works, it was noted that the chlorine residuals in the final water entering supply were lower than normal. The company investigated and found that the sodium bisulphate, normally used to reduce the chlorine residual to the necessary concentration following disinfection, had continued to dose into the main whilst the treatment works was shutdown. As a result, low chlorine residuals were recorded in the network downstream. The company concluded that the risk of backflow into the contact tank was very low and that disinfection had not been compromised. Nevertheless, this represents a risk of microbial regrowth without a residual level of chlorine in the network and would be expected to be identified as a future risk to be mitigated. Chlorine residual checks were undertaken, the network was flushed to turnover the water with low chlorine and other investigatory samples were collected. The company's investigation determined that the loading valve at the dosing point was found to have failed and had allowed sodium bisulphate to back feed into the main. The dosing plant has now been refurbished, with all three loading valves replaced, and the company has also revised the maintenance schedules, so these are completed by specialist craft disciplines, instead of Production Technicians.



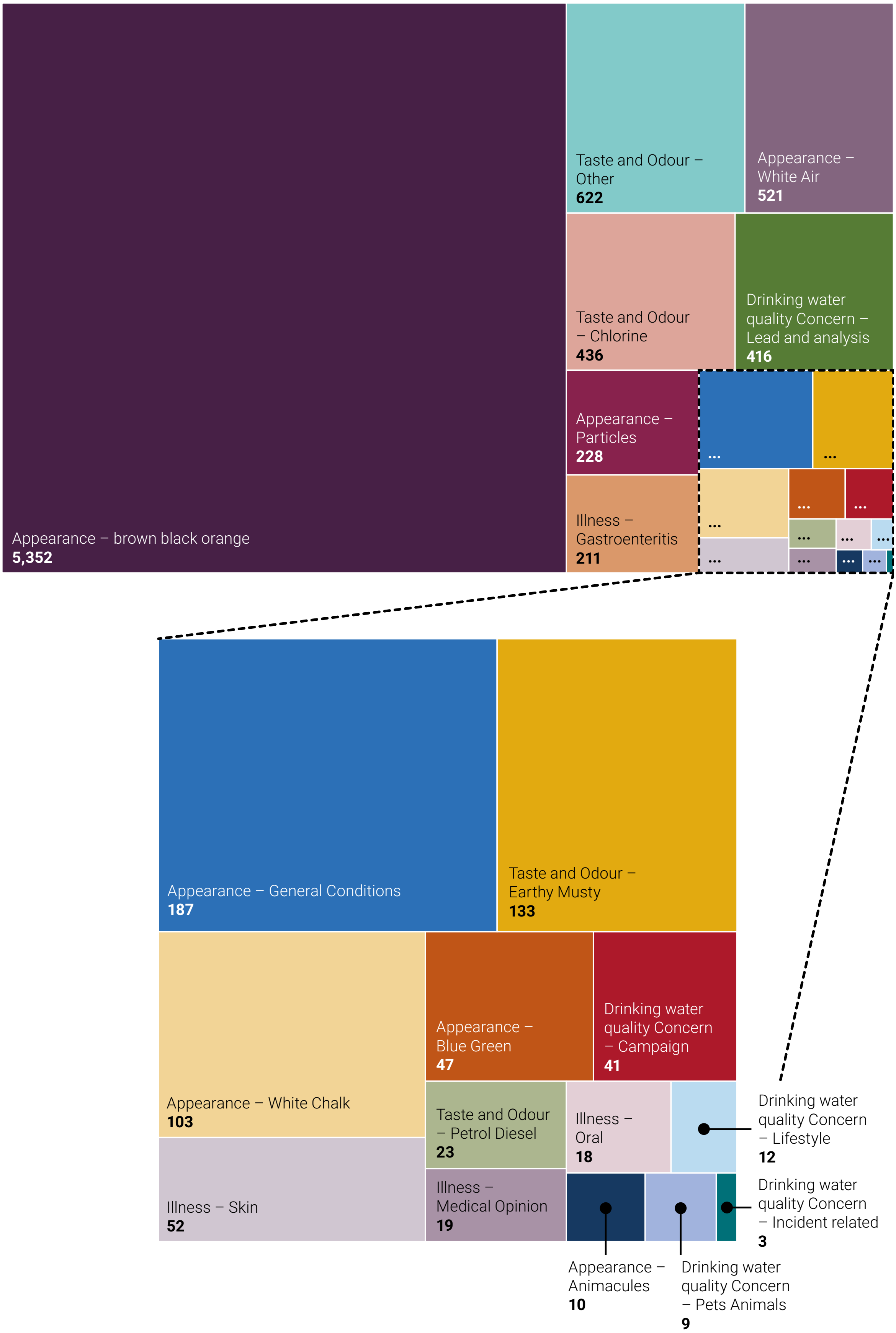
Consumer contacts

Acceptability of water

In 2022, there were 8,443 consumer contacts reported to companies wholly or mainly in Wales. This is a rate of 2.51 which is more than double the rate across the industry. The tree diagrams below shows the number of contacts received for each type of complaint for Welsh companies.

Figure 15.

Tree diagram of the split of acceptability contacts in Wales in 2022

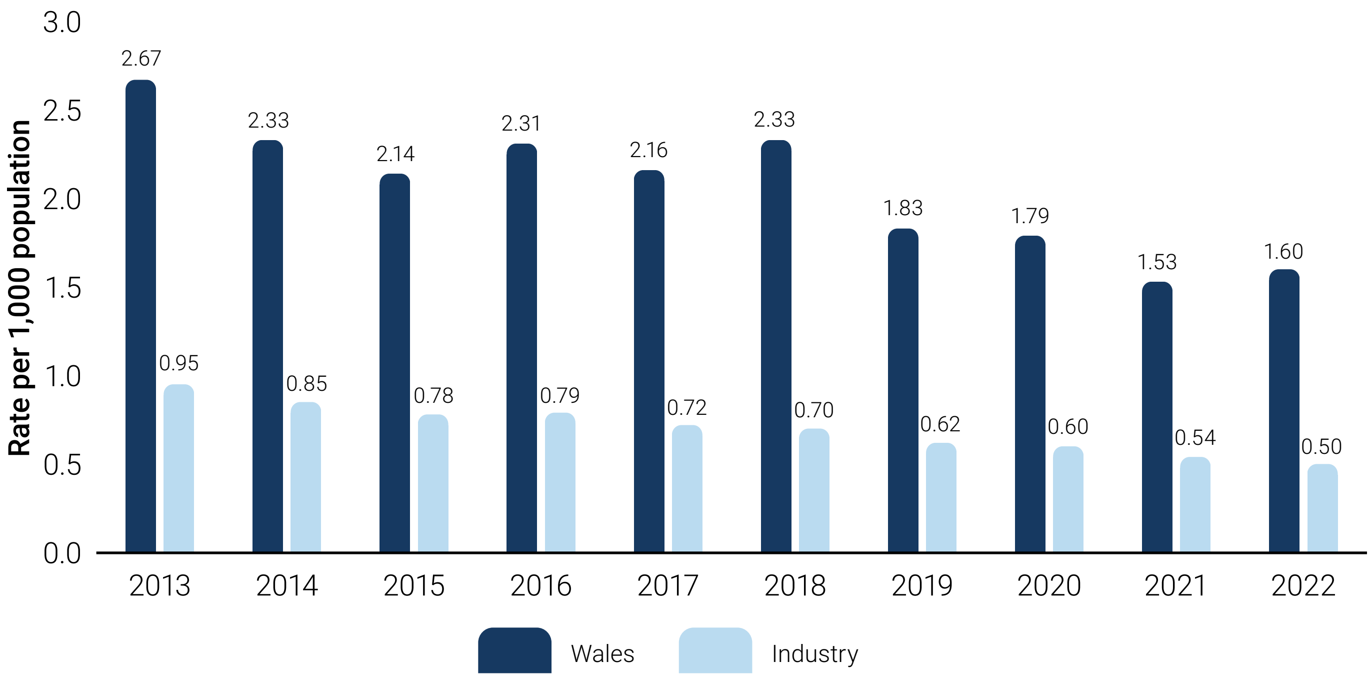


Discoloured water

A total of 5,352 consumers contacted Welsh companies in 2022 to report discolouration; a black/orange/brown colour to the water supply. As can be seen in Figure 16, whilst discolouration contacts in Wales increased by 3.7% in 2022, overall, the number across the industry fell by 7%, giving an average industry rate for 2022 of 0.50 per 1,000 population.

Figure 16.

Wales and industry discolouration rates across the years

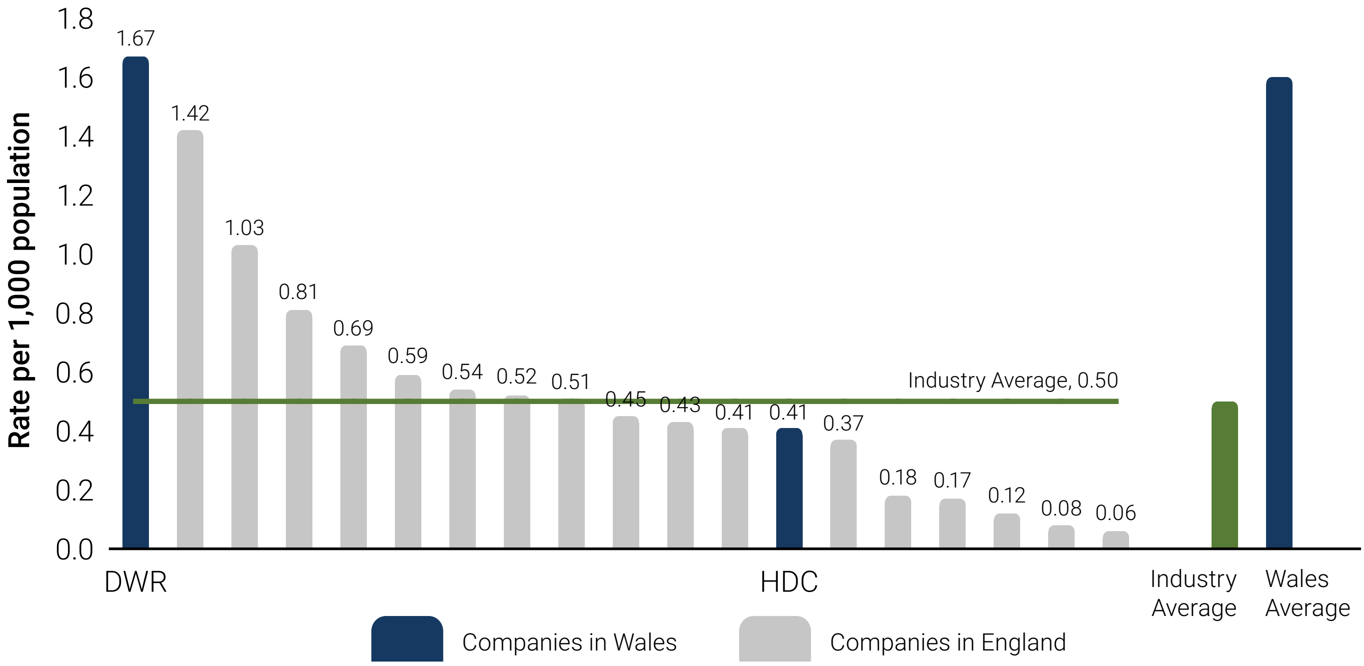


This reduction follows a year-on-year reduction for the industry, which is the result of the many initiatives which water companies employ to reduce their discolouration risk. Wales remains significantly higher than the industry, and although progress has been made, this is slower than the general industry trend and the rate has deteriorated in 2022. Industry good practice to reduce discolouration risks include novel, innovative and water saving approaches to flushing, contact cluster analysis to determine root causes, mains conditioning programmes, network flow optimisation, mains replacement, catchment management initiatives to improve raw water quality and optimisation of water treatment processes to reduce residual metals in treated water. Resuspension of existing mains sediment can be minimised by operating networks under calm network principles, employing standpipe management, minimising illegal hydrant use, cooperation with the fire services and other hydrant users and by the use of modelling and risk assessment to inform network operations. Proactive consumer engagement and communications prior to planned work which may impact consumers can reduce complaints. Consideration could also be given to inlet monitoring of service reservoirs for iron, manganese and aluminium to provide additional information on metal residuals in treated water storage.

Companies should be considering longer term solutions to discoloured water, and not relying solely on flushing programmes or filter installation on supply pipes as mitigation for individual consumer complaints. Drought poses a challenge to the completion of annual flushing programmes, which is another reason it cannot be relied upon as a long-term solution. Companies should be prepared to proactively bring forward mains flushing to avoid delay or incomplete annual flushing programmes during the warmer months. Discolouration does remain a risk for companies in Wales, see Figure 17.

Figure 17.

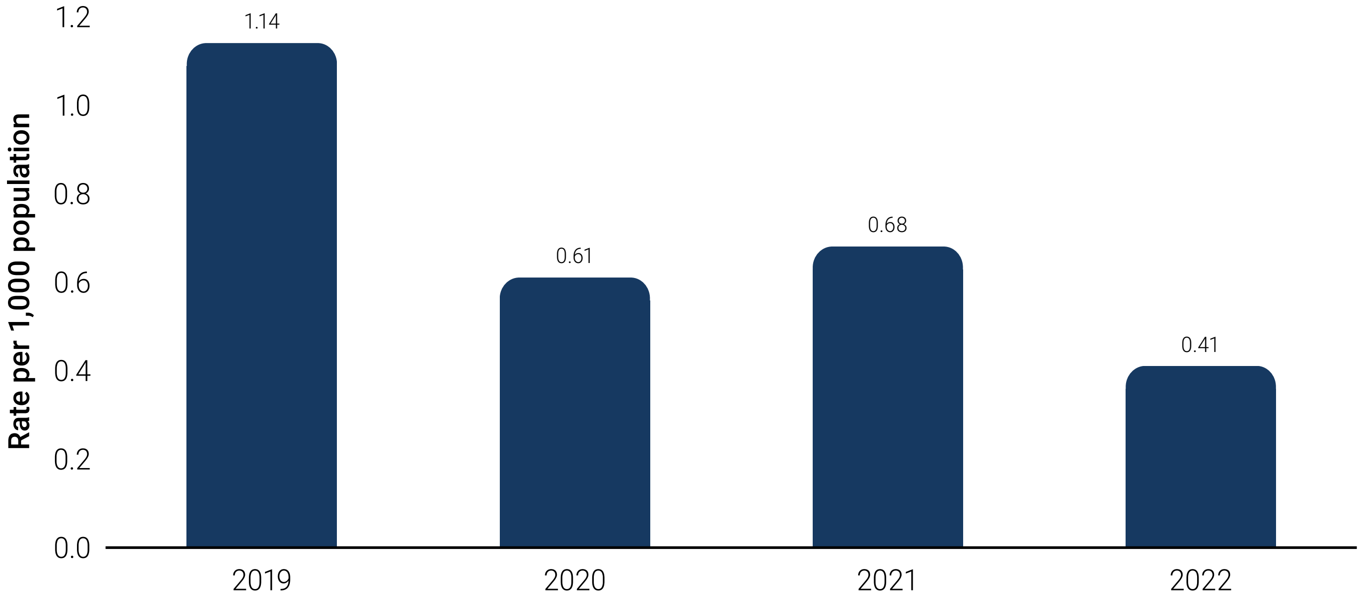
Discolouration rates for companies in 2022



Hafren Dyfrdwy has made significant progress over the past three years, reducing their contact rate for discolouration by 60% since 2019. A notice for discolouration in two zones; Legacy and Rhos was completed and closed in February 2022. These two zones have seen a notable improvement in the number of discolouration contacts received and will have contributed to the progress which can be seen in Figure 18.

Figure 18.

Rate of discolouration contacts for Hafren Dyfrdwy



The picture for Dŵr Cymru Welsh Water is less favourable, and the company remains the worst performing in the industry for discolouration contacts; a position it has held since 2014. Progress is generally being made, however the rate for 2022 is higher than the previous year. The change in rate over the past five years is shown in Figure 19. There are currently 15 discolouration regulation 28 notices in place for individual zones, which are due to be completed by 2027. The Inspectorate has been working with the company throughout 2022 to draft a new discolouration notice to cover zones which do not have these individual notices. This notice was served in early 2023.

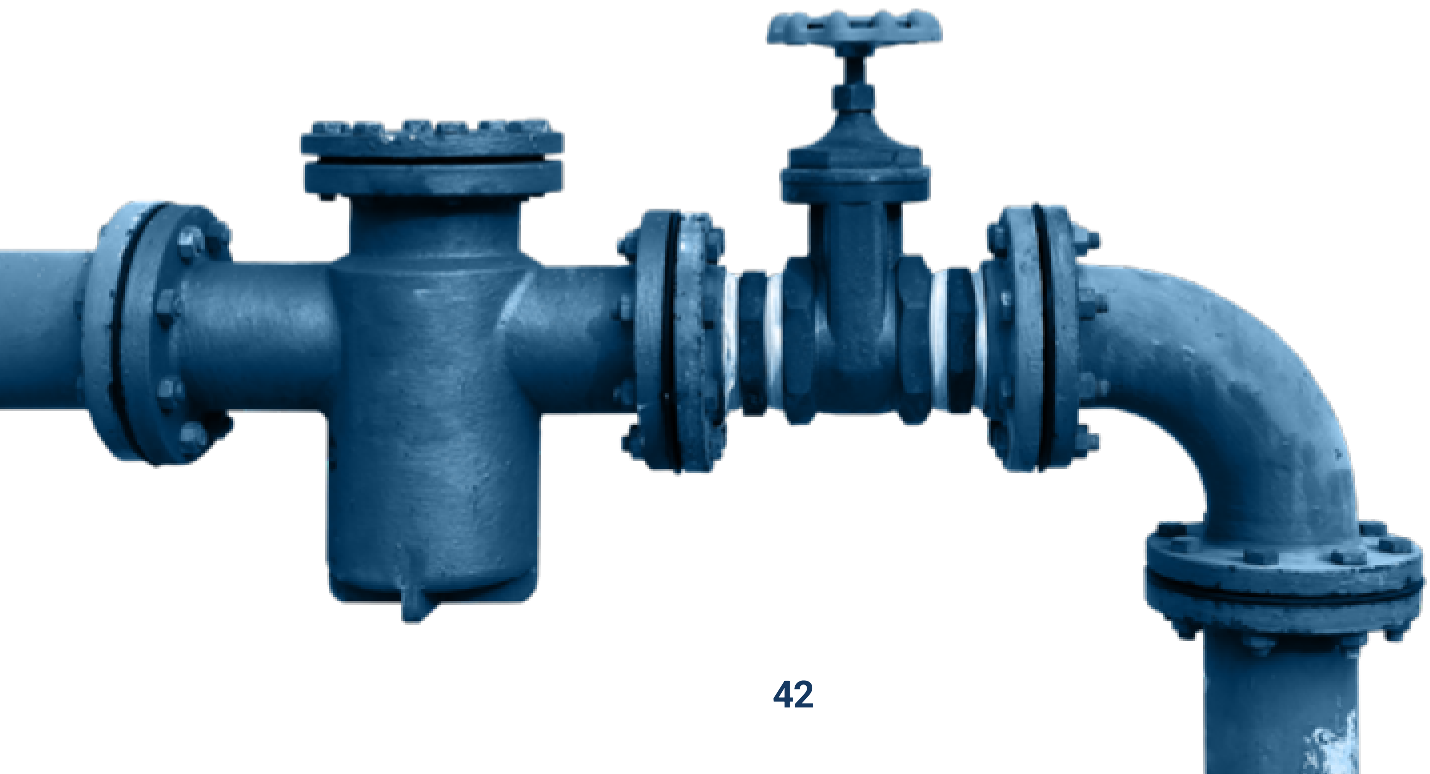


Figure 19.

Rate of discolouration contacts in Dŵr Cymru Welsh Water

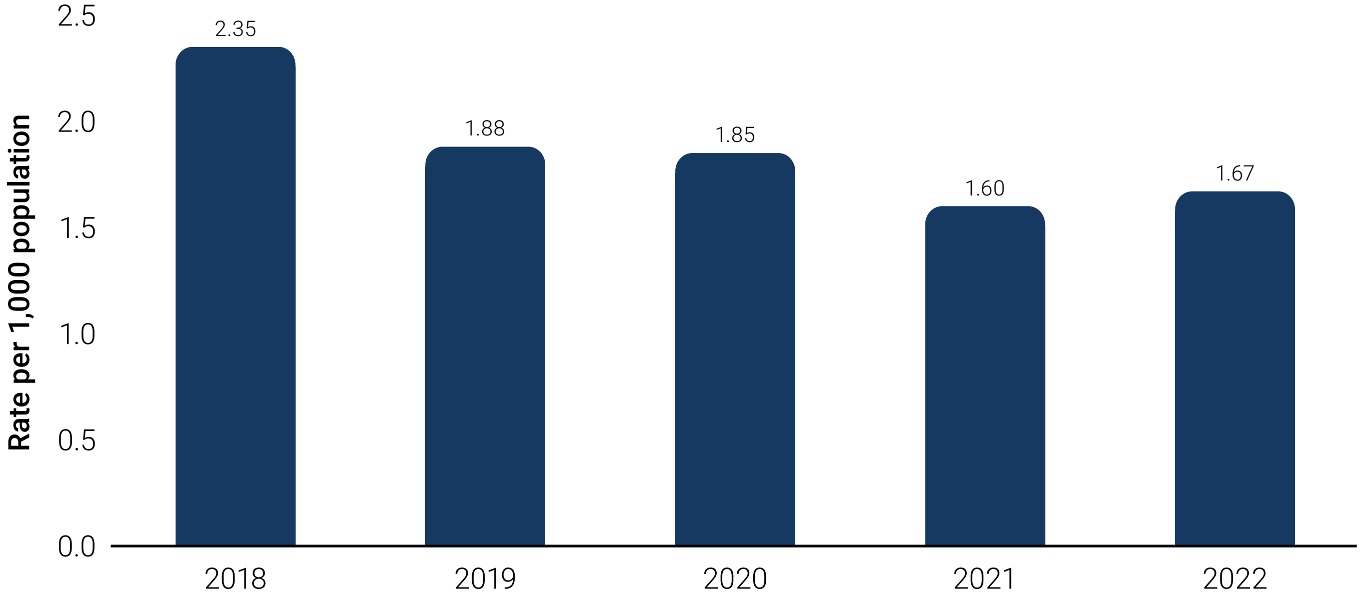
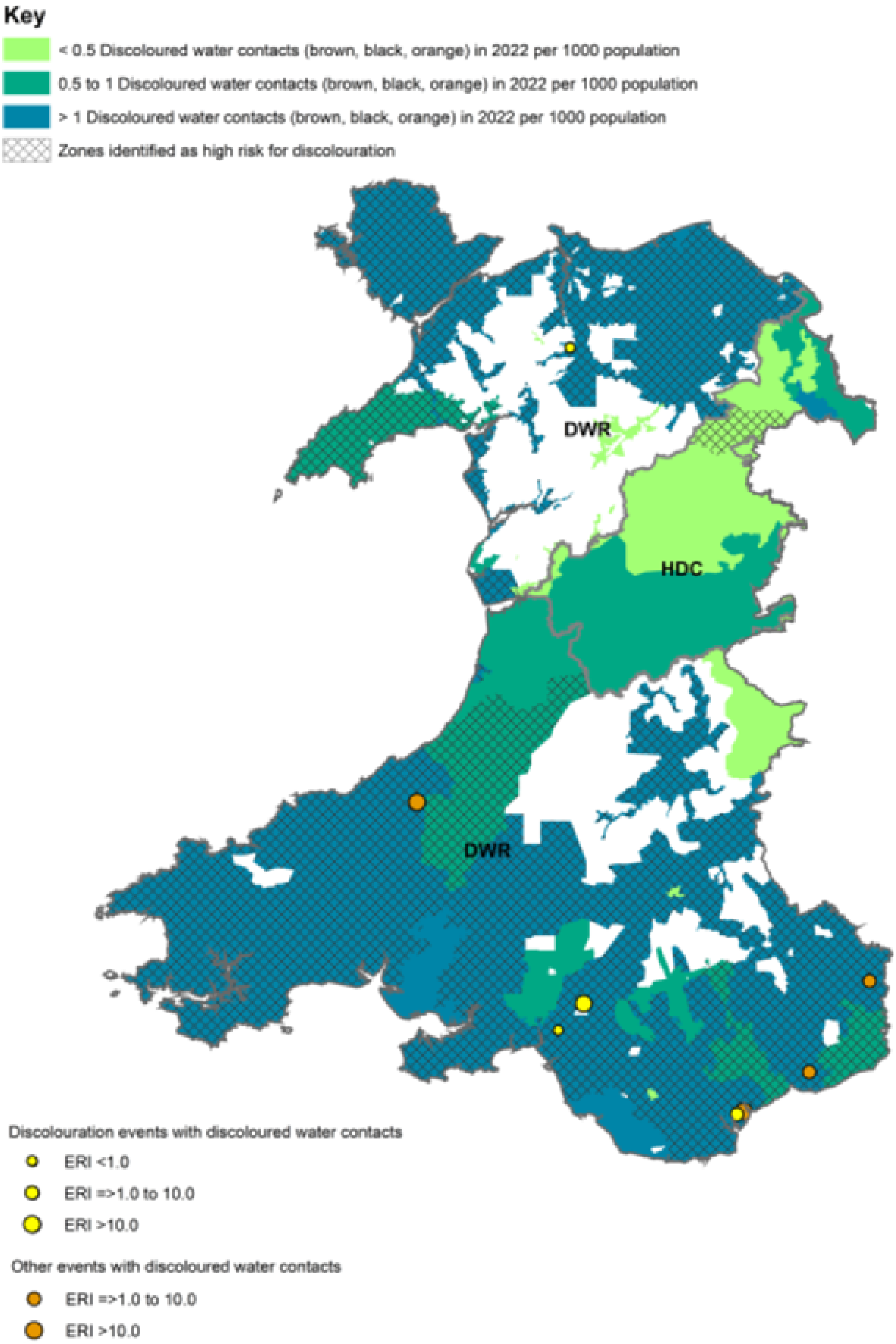


Figure 20 displays the rate of discolouration contacts in 2022, for each water quality zone in Wales. Zones which are considered high risk for discolouration are cross hatched and these zones are monitored by the Inspectorate, with further steps taken where necessary.

Figure 20.

Discolouration map

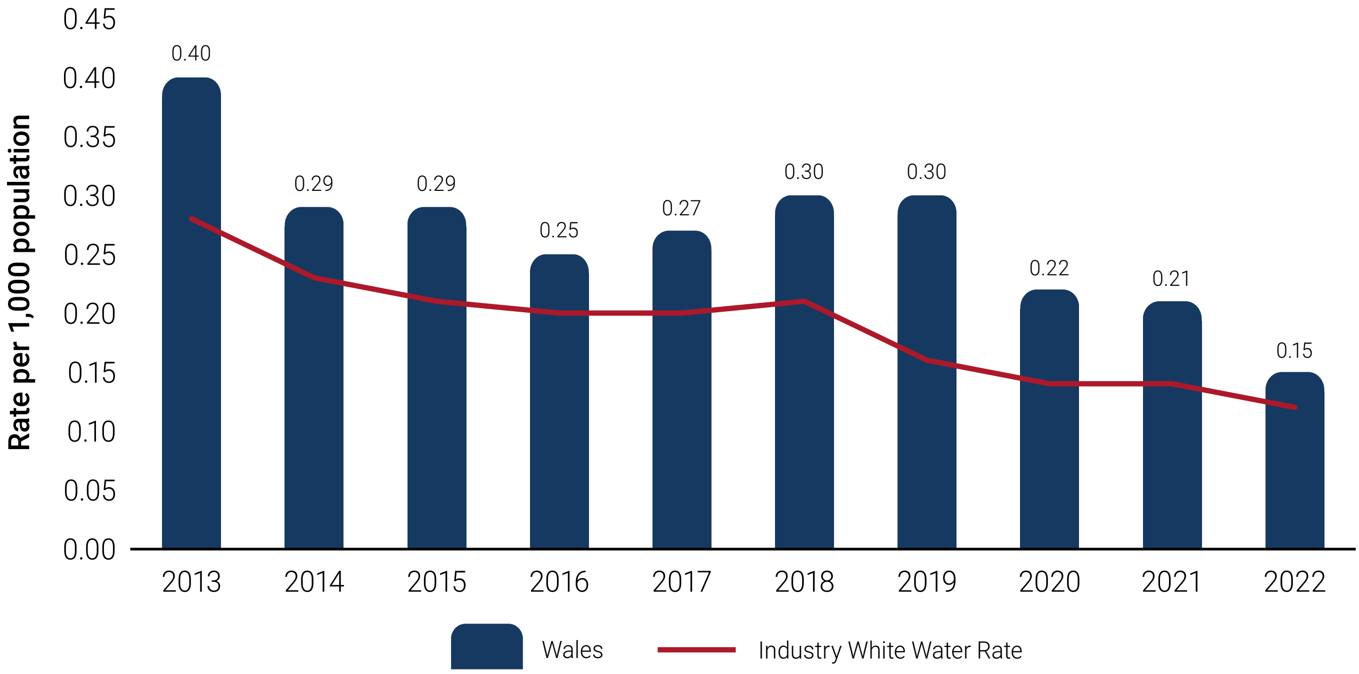


White water

The consumer contact rate for white water, for Welsh companies is higher than that of the industry, as shown in Figure 21. In Figure 22, the rate for 2022 for individual companies indicates that Hafren Dyfrdwy contributes the greatest proportion of these contacts in Wales, and in the industry, and was the worst performing in 2022.

Figure 21.

Rate of white-water contacts in Wales



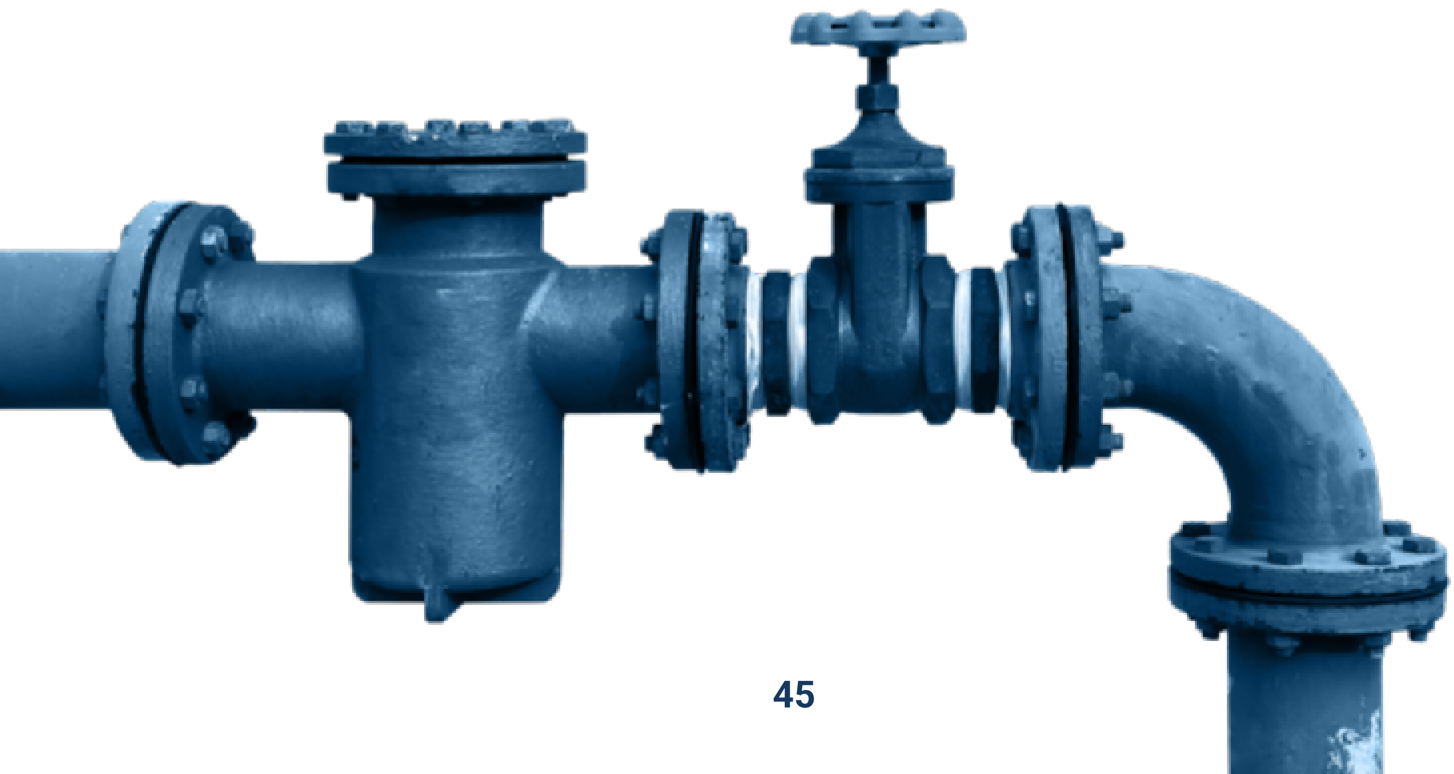
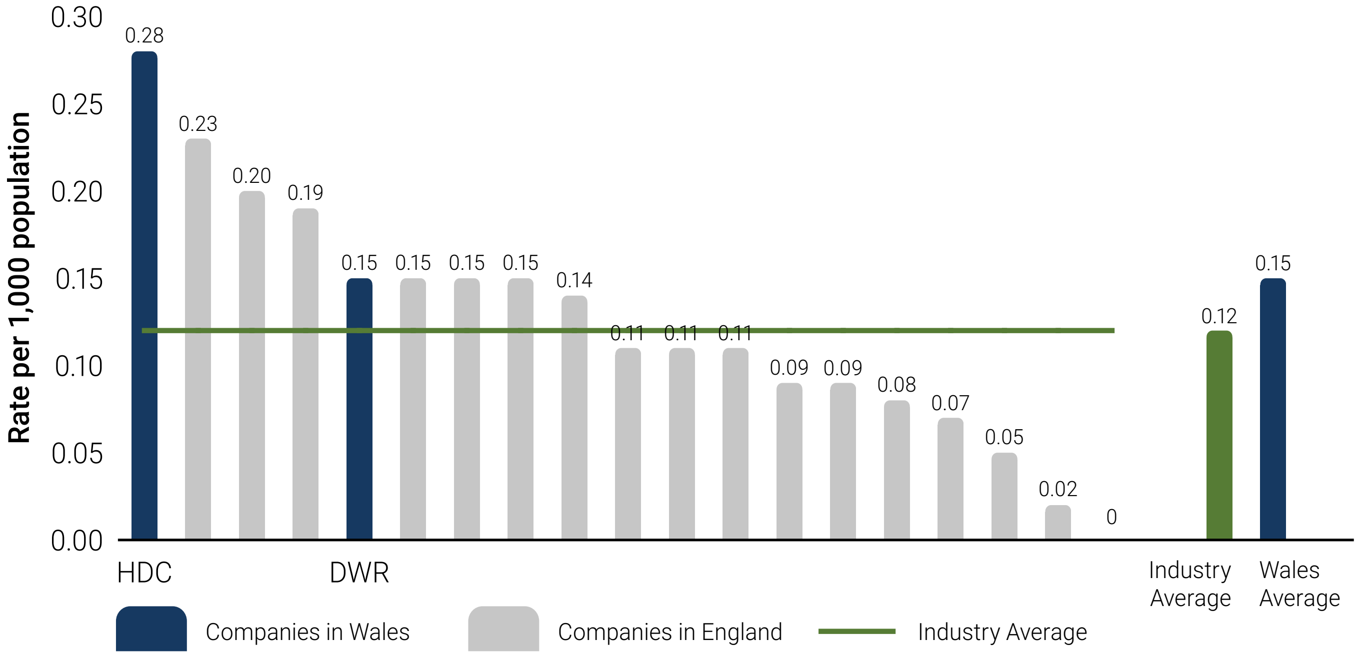


Figure 22.

Rate of white-water contacts in 2022



Taste and odour

Like discoloured water contacts, the contact rate for total taste and odour contacts for the industry has also been reducing year on year, but for Welsh companies remains persistently above the industry average by over 35%.

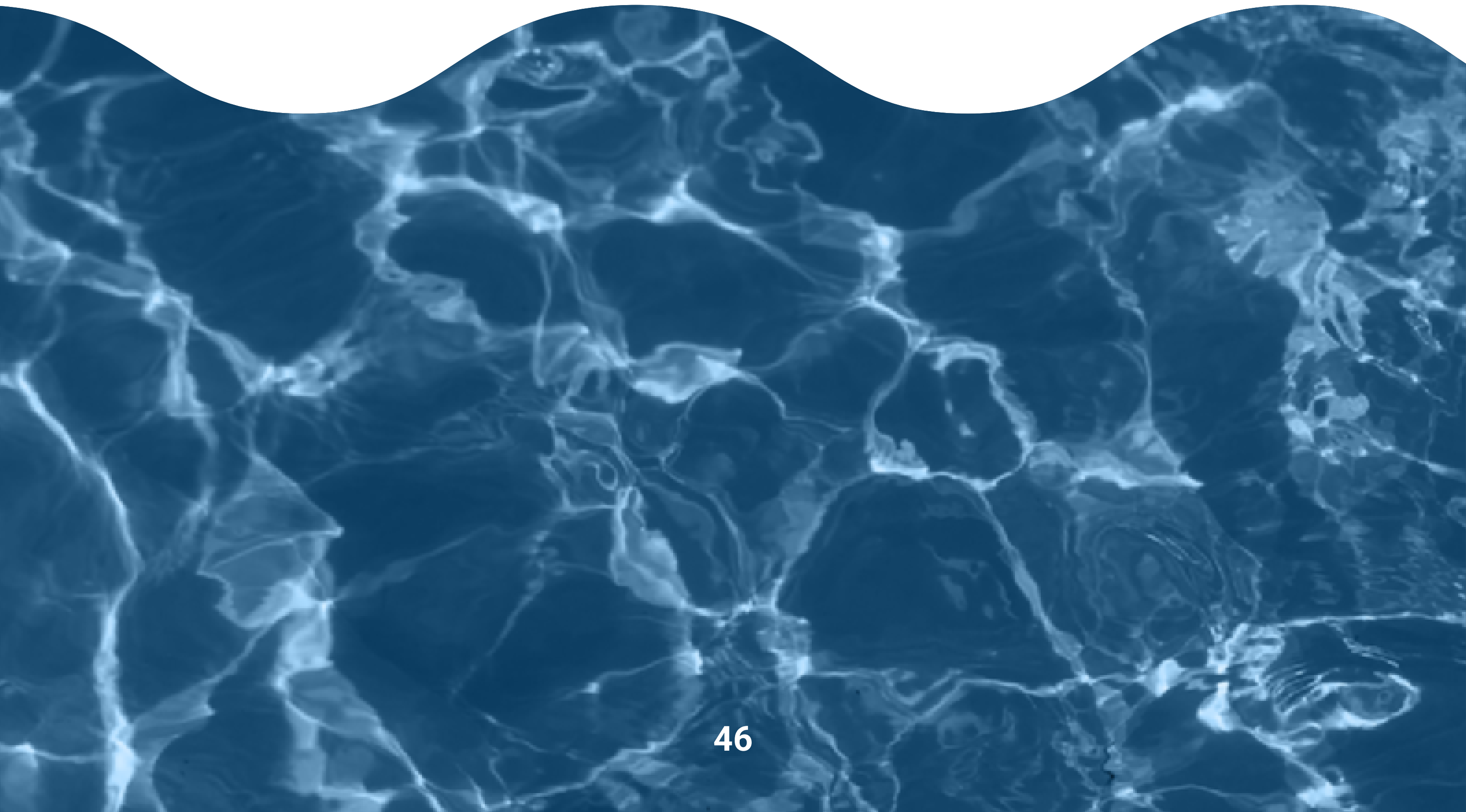


Figure 23.

Rate of taste and odour contacts in Wales

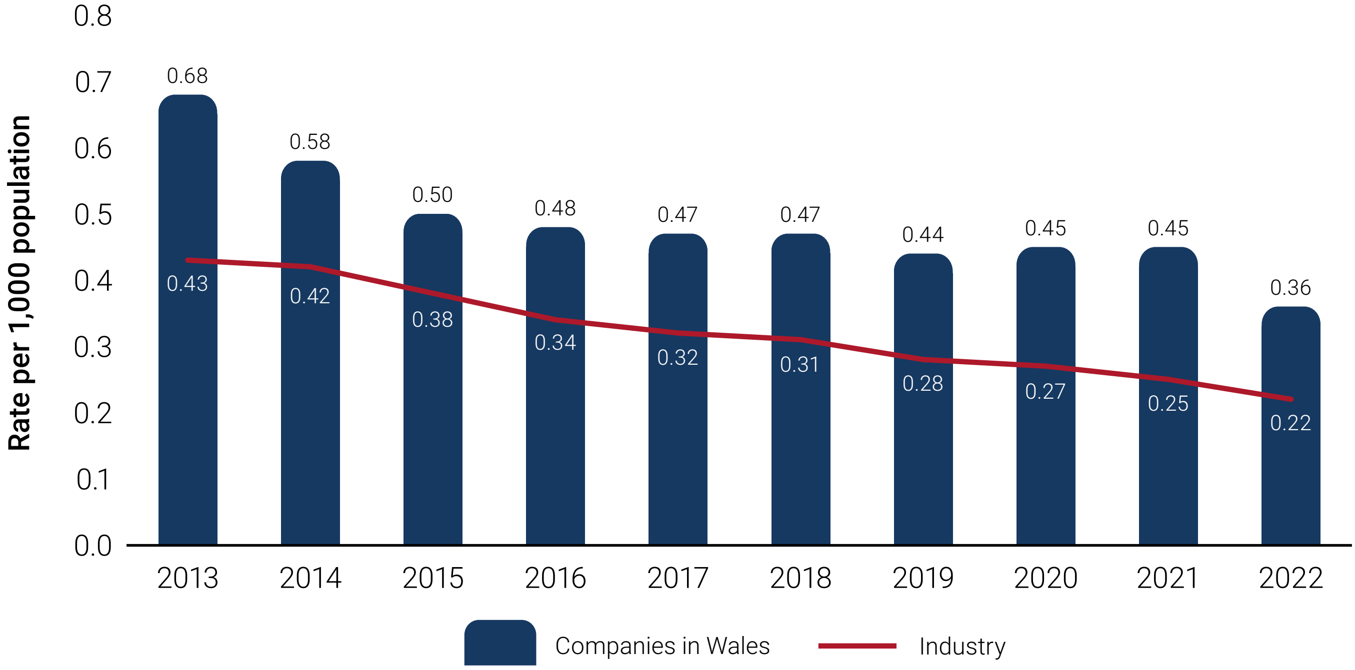
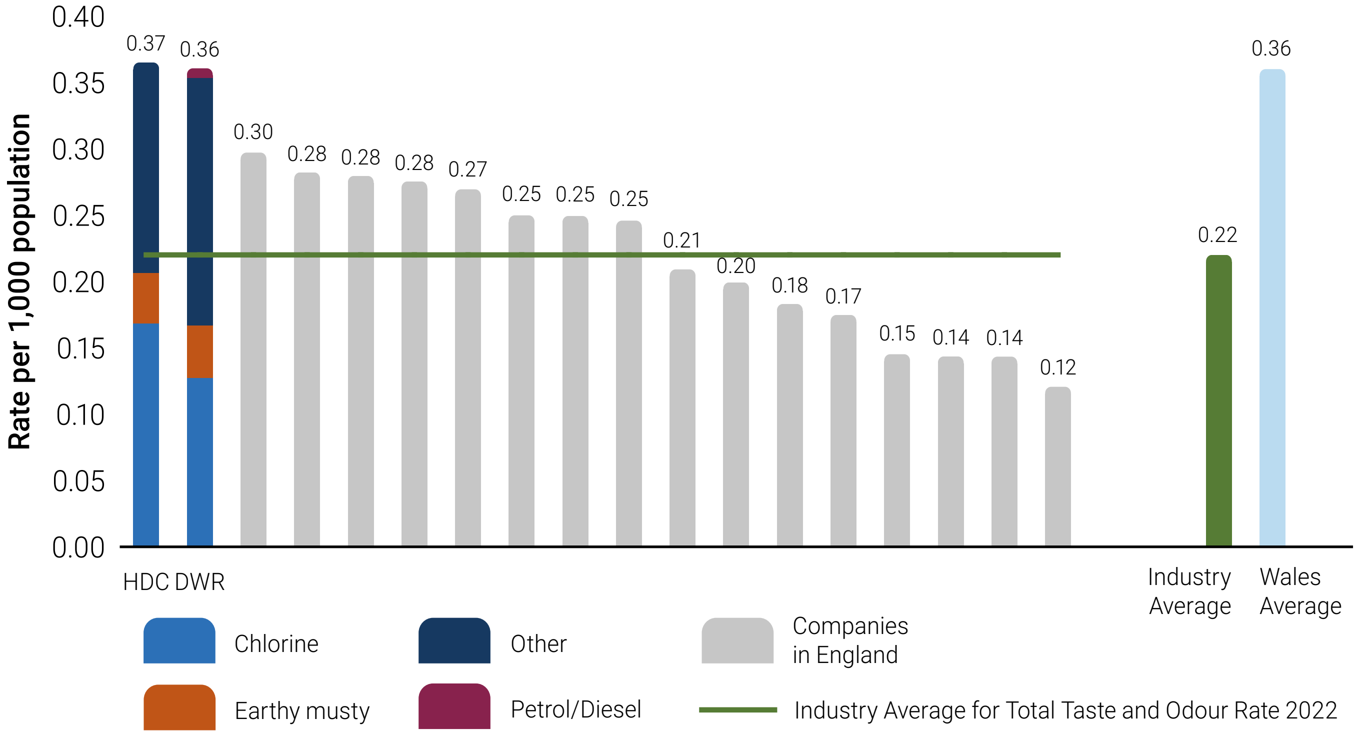


Figure 24.

Rate of taste and odour contacts in 2022



Water Safety Planning and risk assessment

Following the World Health Organisation's guidelines, The Inspectorate has adopted a water safety planning approach for drinking water quality. Companies are required to carry out adequate risk assessments of each supply system and submit this data to the Inspectorate. Hazards are identified and risks are assessed from source to tap (catchment, abstraction, treatment, storage, distribution and consumer stages) and actions are put in place to maintain safe and secure supplies and prevent problems from occurring.

Raw water risk assessments

Raw water sampling data targeted at hazards

As part of the water safety plans, raw (untreated) water data is submitted annually to the Inspectorate. Sampling is targeted at hazards to understand the presence and severity of the hazard. The data are used to inform work on catchment management and the design and operation of treatment processes. Raw water summary data is provided on the Inspectorate's website.

Working with the Natural Resources Wales (NRW)

Drinking water abstractions above 10 cubic metres per day are protected under the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 to ensure they are not polluted. Sources need to be protected, to avoid or minimise the need for additional purification treatment which can be costly and resource intensive. Water companies and NRW identify drinking water areas that are 'at risk' of deterioration and establish Safeguard Zones. These are non-statutory areas where measures are targeted to address contamination, identifying impacts, sources, actions, and measures in action plans which are periodically reviewed and updated. The raw water data collected by water companies contributes to the assessment of **drinking water protected areas** and **safeguard zones**, which are published by NRW.

Perfluoroalkyl and polyfluoroalkyl substances (PFAS)

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals that have been widely used in various industries since the 1950s. They are often found in products such as non-stick cookware, waterproof clothing, carpets, food packaging, and firefighting foam.

The dangers of PFAS have become a growing concern due to their persistence in the environment, ability to accumulate in the human body, and potential health effects. Regulators across the world have been setting their own national standards in what is a rapidly evolving arena, most countries are focusing on PFOS and PFOA which are the two most common derivatives, the USA have gone further to include an additional four compounds – PFHxS, PFNA, PFBS and HFPO-DA whilst leaving space to include more in the future.

In collaboration with the Environment Agency, the Inspectorate has identified 47 compounds of particular interest which companies should be monitoring (**Information letter 05/2021**). Companies were asked to monitor at the raw water abstraction points prioritising raw water which may be a higher risk of the presence of PFAS. Accordingly, if PFAS was detected in the raw water, then companies were expected to sample at the final water to determine if the risk was mitigated through any treatment or blending process. Samples may therefore have been taken multiple times to develop an understanding of risk. Consequently, data should be viewed as being a worse case analysis due to purposeful and repeated sampling methodology. In July 2022 the Inspectorate updated its guidance to cover any PFAS compounds, in final water.

Table 8.

Tiered actions for controlling risks from PFAS

Tier	Results or Result Risk Assessment	Escalating actions
Tier 1	<0.01 µg/L	Risk assessment and monitoring
Tier 2	<0.1 µg/L	Risk control and consultation
Tier 3	≥0.1 µg/L	Risk reduction and notification

During 2022 the water industry in Wales submitted 2,568 test results to start building a picture of PFAS risk in supply systems. Some test results were attributed to multiple sample points, therefore a test result may be repeated in the data set. Due to this nuance of the data, it is not possible to report total numbers of tests accurately at this time.

Table 9 shows the seven compounds detected in raw water, and the maximum concentrations found.

Table 9.

Raw water maximum test results

PFAS name	Maximum concentration in raw water μg/L	Number of results within Tier 2
PFOS	0.022	1
PFOA	0.018	1
PFPeA	0.006	0
THPFOS	0.001	0
PFHpA	0.002	0
PFBS	0.002	0
PFHxA	0.001	0

A number of companies and laboratory service providers are developing in-house analytical capability, and research into treatment technology is ongoing.

The most recent **Information Letter 02/2023** sets out expectations for companies to submit PFAS strategies for investigating risk, setting trigger levels, and taking action to mitigate PFAS risk from source to tap. Companies are required to offer section 19 undertakings to deliver their PFAS strategies over AMP8, where there is a likelihood of a contravention of section 68(1) of the Water Industry Act (1991). Tables 10 and 11 do not include tests results below the limit of detection.

Table 10.

Raw water PFAS tests

Company	Tier 1 <0.01	Tier 2 <0.1	Tier 3 ≥0.1
DWR	1,318	2	0
HDC	141	0	0

Table 11.

Treated water PFAS tests

Company	Treated sample results in tier 1	Treated sample results in tier 2	Treated sample results in tier 3
DWR	824	1	0
HDC	141	0	0

The single sample in Tier 2 was PFBA at 0.025 µg/L.

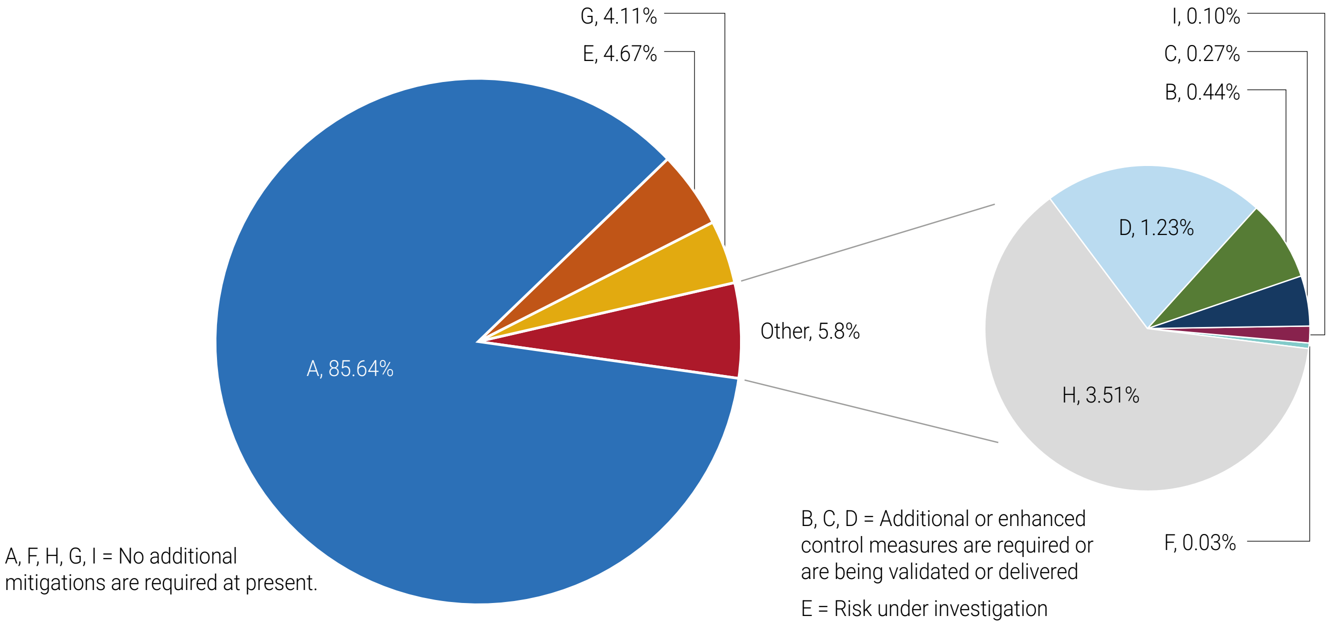
Water safety planning and risk assessment

Under regulation 27 and regulation 28 water companies are required to carry out adequate risk assessments of each supply system and submit this data to the Inspectorate.

The Inspectorate received 138,153 lines from Wales. Most of this data for Wales (93.38%) indicates that risks are either being effectively mitigated or fall into categories that indicate mitigations are not currently required.

Figure 25.

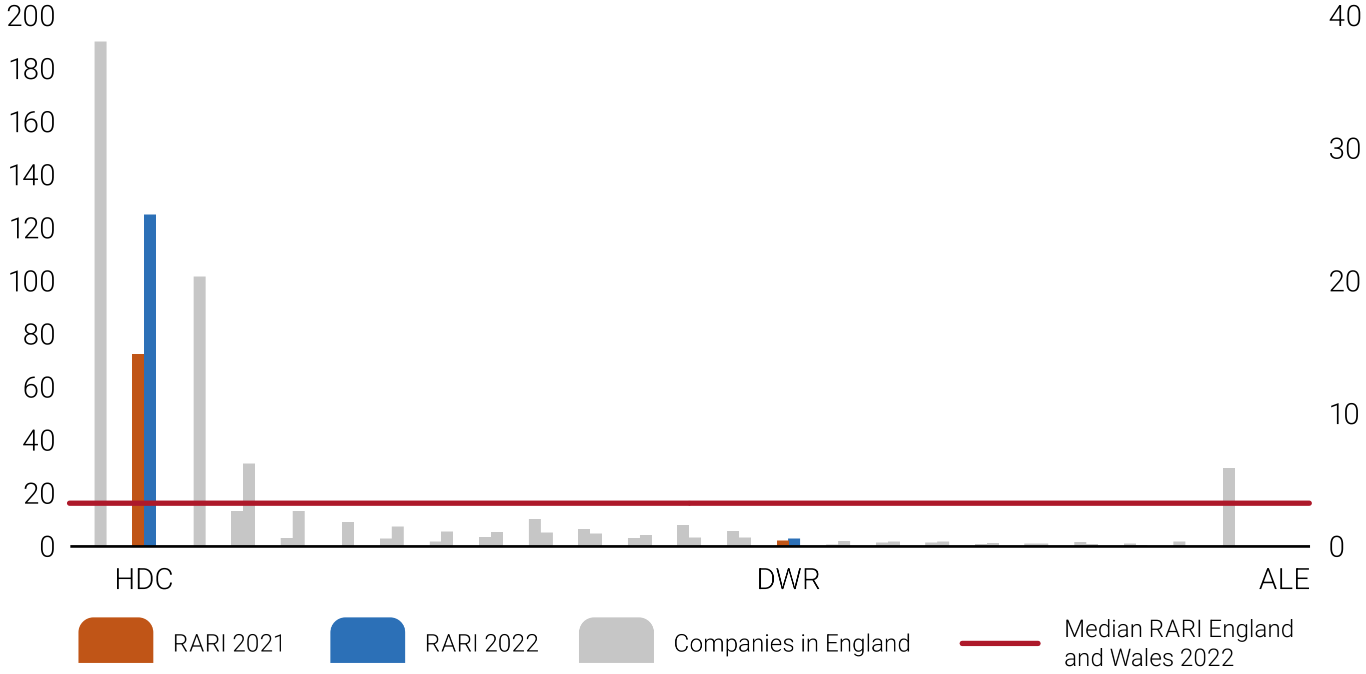
Breakdown of regulation 28 data for Wales by DWI risk category. Number of records and percentage of the total number are displayed.



Risk Assessment Risk Index Scores (RARI)

Figure 26.

RARI



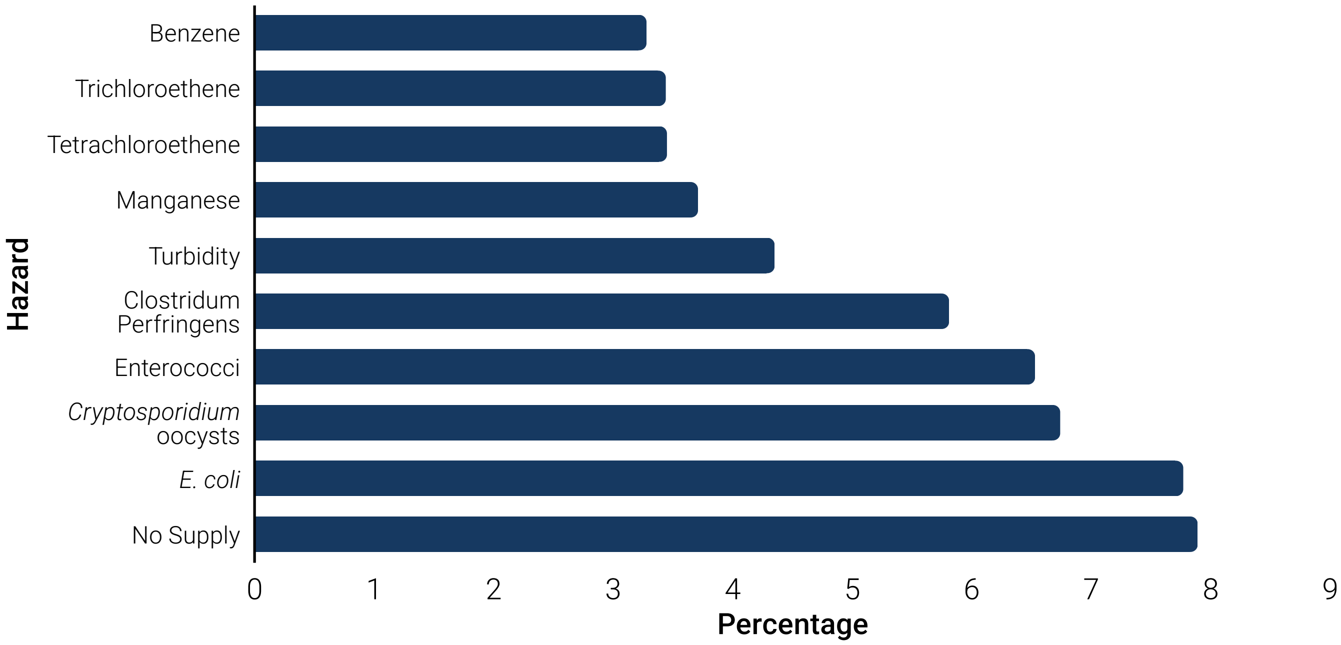
The purpose of RARI is to enable tracking of risks from an unmitigated to mitigated status. This is important to inform strategic action, to proactively keep water safe. As such, it is not a measure but an information tool. As examples of best use, Hafren Dyfrdwy reported a score of 124.830 in 2022 (compared to 72.35 in 2021). This is the third consecutive year that Hafren Dyfrdwy's risk score has increased, which shows the company is identifying more risks. Awareness of risks permits senior decision makers to understand where the company priorities are and keep water quality first. This year, the risk score rise was due to a higher proportion of lines that identified the need for new control measures to mitigate a risk (category D). Whilst it is legitimate for the company to increase its score due to new risk identification, the company needs to put in place mitigation of the large amount of risk lines under investigation (category E) and review other lines in which capital delivery is currently underway or complete (categories B and C).

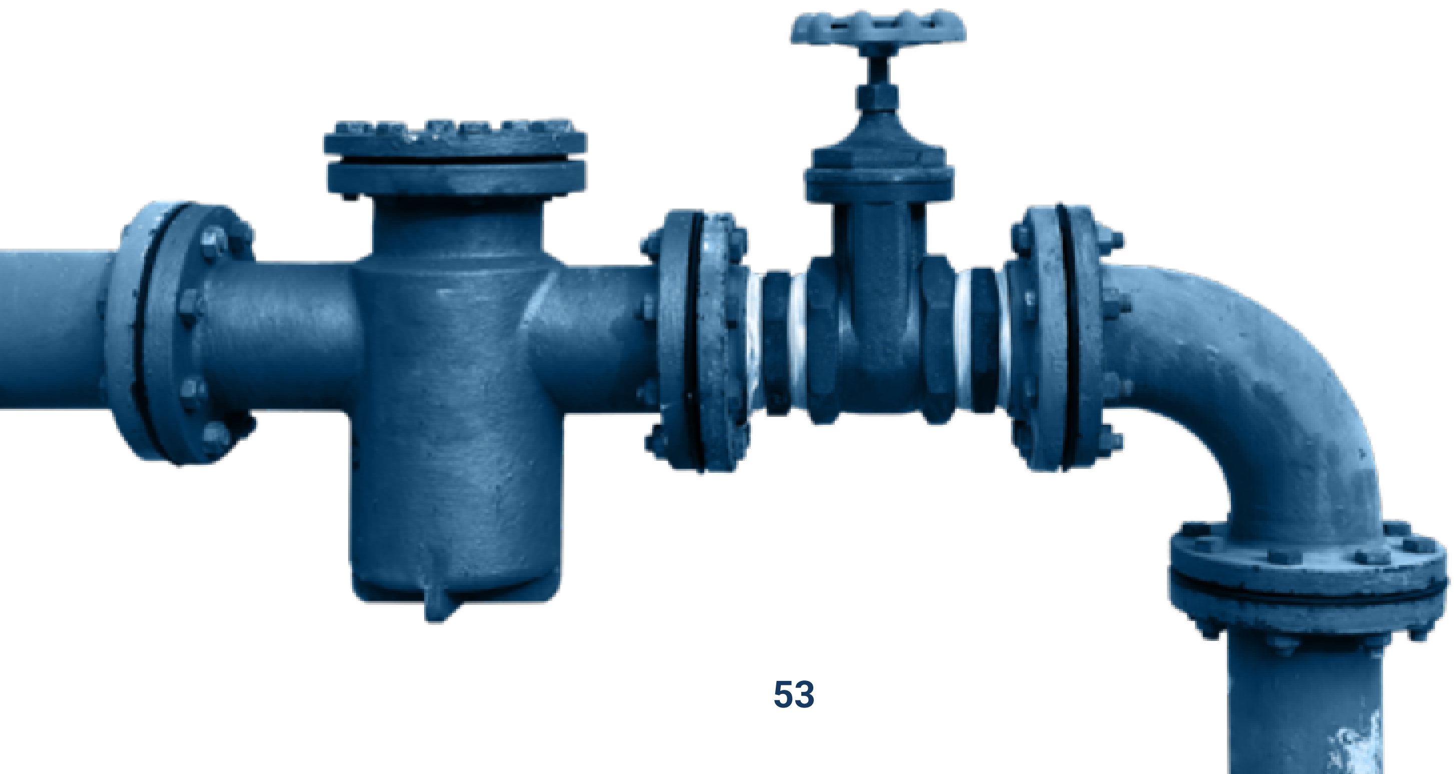
The Inspectorate audited the company's risk assessment methodology and system, and this attracted a number of recommendations to help the company focus on improving the methodology. It is now working to implement a new system, in which, risk identification, control, review and reporting will be an upgrade over the current system.

Dŵr Cymru Welsh Water's score is below the industry average, albeit higher than last year's. This is due to the rise of reporting of categories C, D and E, which means the company is investigating and finding a growing number of risks which need capital investment to control risks. Most high scoring hazards are still associated with no supply, *E. coli* or *Cryptosporidium*, where the company require a number of mitigations, particularly regarding asset condition and asset upgrades, as well as network mains which continue to challenge the company in delivering a quality service free of discoloration and taste and odour risks, both of which are top priorities for their customers.

Figure 27.

Percentage contribution of the top ten hazards to the overall Wales RARI score





Audit programme completed by the Inspectorate

Lead desk-top audit (Quarter 1) To understand the company's lead strategy, procedures for responding to lead sample failures and the stability and reliability of orthophosphoric acid dosing for plumbosolvency risks. The wider industry and Wales were audited. Both Dŵr Cymru Welsh Water and Hafren Dyfrdwy were subject to desk top audits. Common themes and learning were reported in CIR Quarter 1.

Works and service reservoir compliance failures (Quarter 2) To investigate known risks and associated compliance failures.

Reactive works audit (Quarter 3) To investigate hazards and risks identified in regulation 28 reports.

Contractor audit (Quarter 3) To investigate the management of contractors to ensure regulatory requirements are met and that risks to water quality are mitigated. All companies across England and Wales were audited.

Chlorate sampling audit (Quarter 3) Reactive audit to understand the management of chlorate risk at one site.

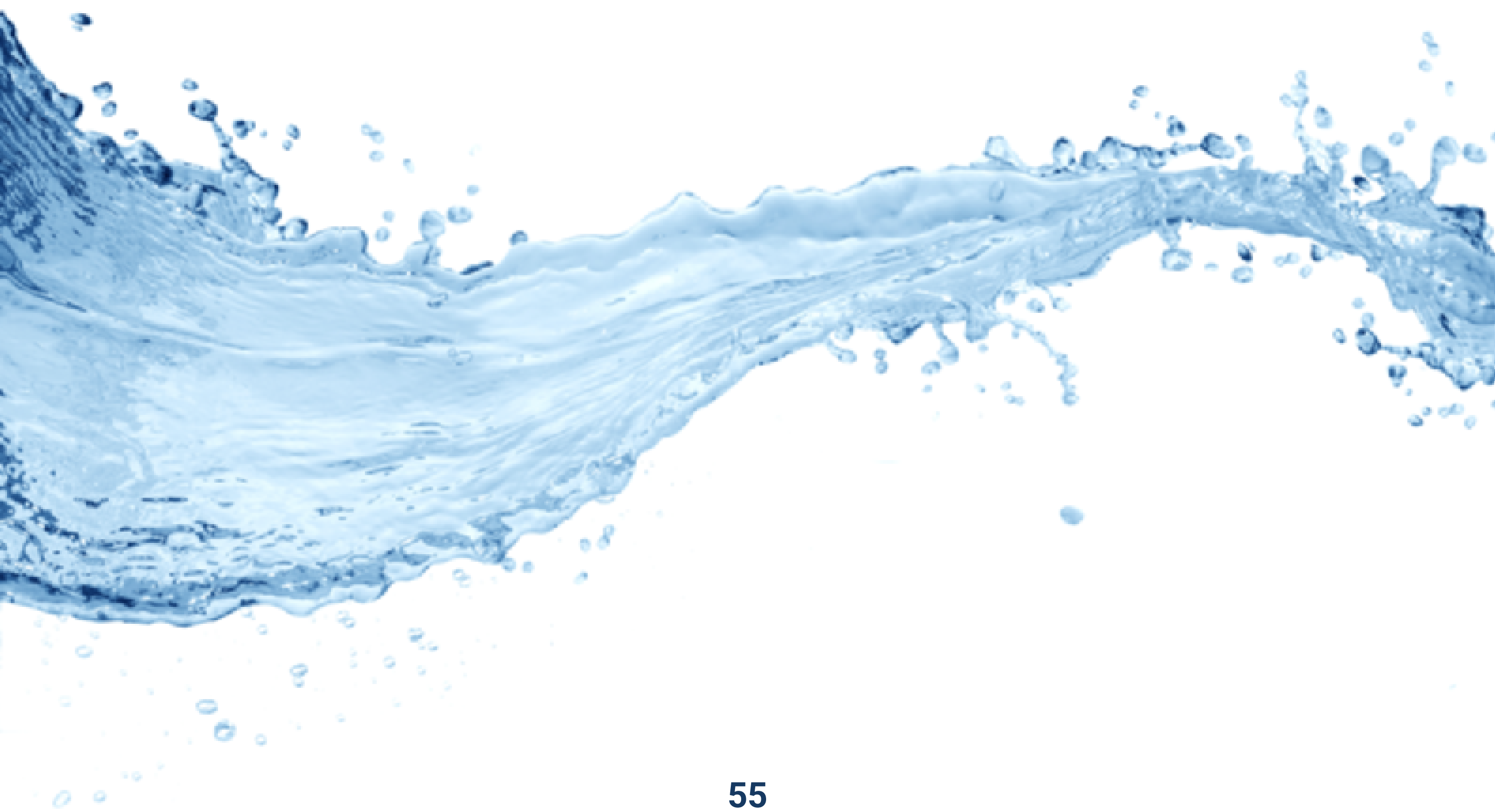
Sampling and laboratory data transfer audit (Quarter 4) National audit to understand water quality test data processing and reporting. Companies in Wales were not audited due to a level of confidence gained through other activities.

PFAS methodologies were audited to assess implementation of guidance provided by the Inspectorate.

Water Safety Plan – An in-depth audit for Hafren Dyfrdwy. Review of the methodology document and site audits at one catchment, one works and two service reservoirs.

Table 12.
Audits in Wales

Regulatory driver	Audit type	Number of audits
Risk Assessment	PFAS risk assessment	**2**
	Water safety planning	**1**
Water Quality	Asset health	**2**
	Management of contractors	**2**
	Event or audit follow up	**2**
	Lead	**2**
	Legal Instrument	**0**
	Competence	**0**
	Whistleblower	**0**
Enforcement	Regulation 27	**0**
Security and Emergencies Direction	Provision of alternative supplies and service to vulnerable consumers	**1**
Total		**12**



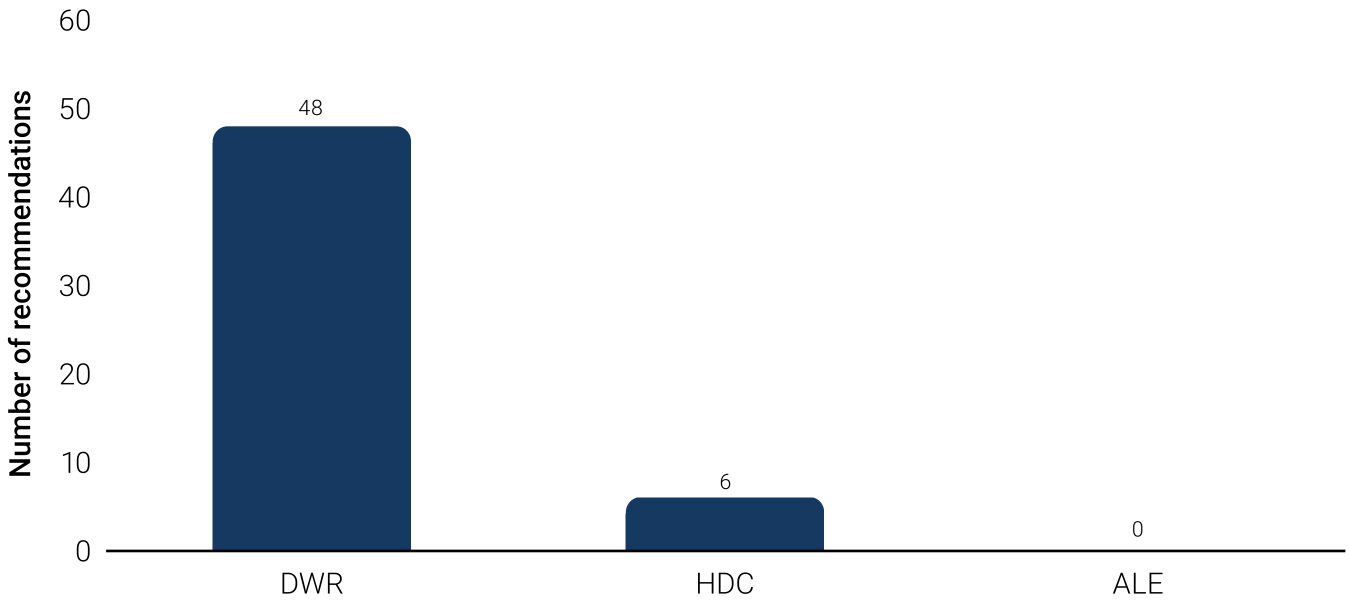
Recommendations

Where there is a breach of regulation or a likely breach and an Inspector is unable to conclude that the breach is unlikely to recur, they are obliged to make a formal recommendation to the company.

Inspectors made 54 recommendations to companies operating in Wales during 2022, see Figure 28.

Figure 28.

Number of recommendations per company in 2022



Dŵr Cymru Welsh Water continue to attract a high number of recommendations, albeit a reduction since last year. Forty-eight were received in 2022, compared with 57 in 2021. Hafren Dyfrdwy's have reduced from 11 in 2021 to 6 in 2022.

The national figure for Wales has therefore decreased in 2022 showing an overall reduced trend (Figure 29).

Figure 29.

Trend of recommendations in Wales

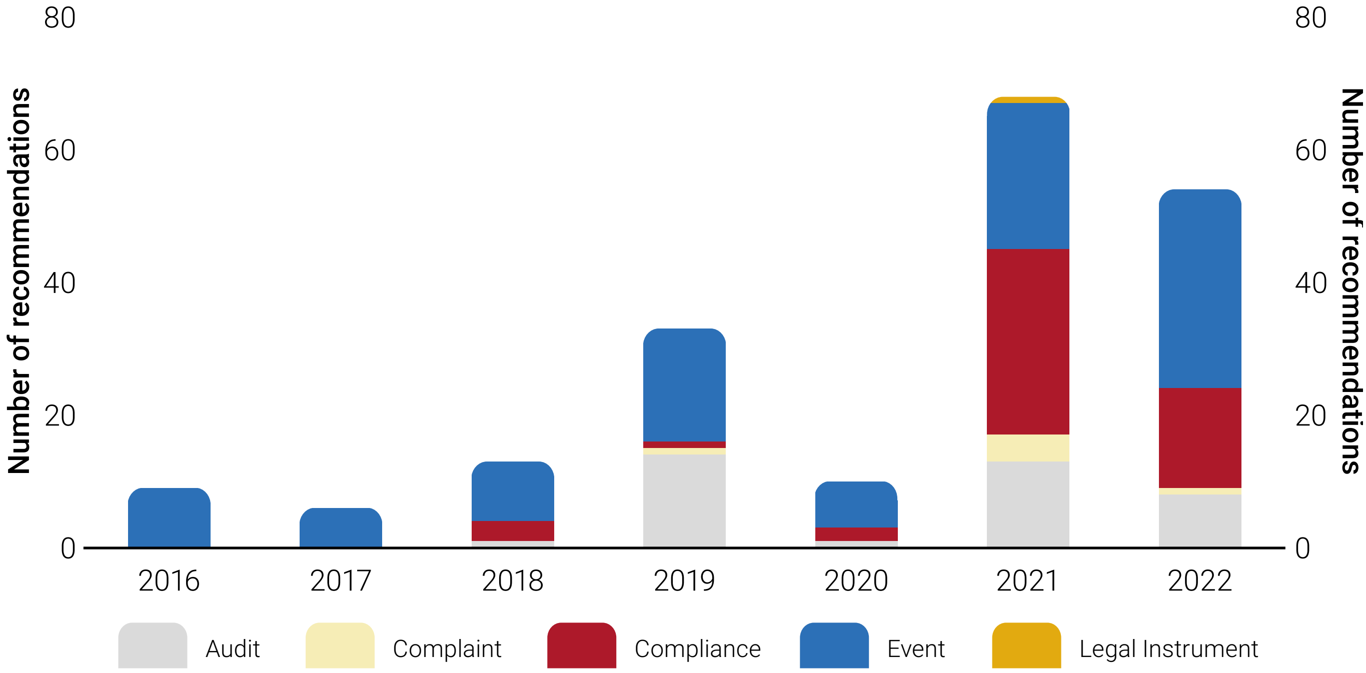
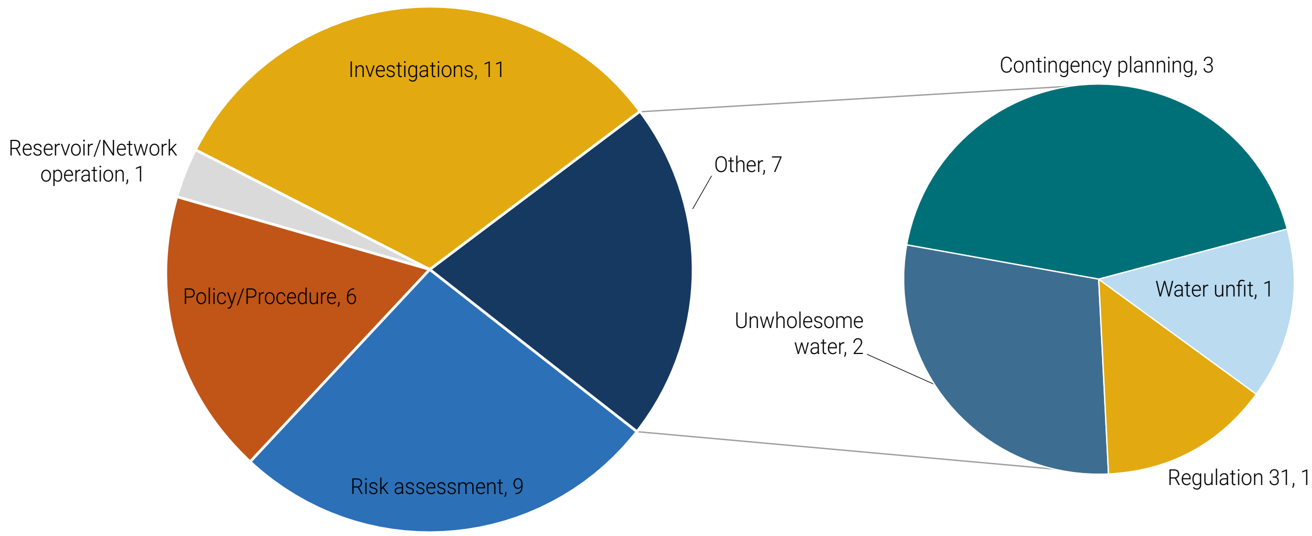


Figure 29 shows the division of recommendations made in each work area. Most recommendations made were related to water quality events.

Management deficiencies account for the largest share of recommendations, with 34 making up this portion. Sampling, storage and distribution and treatment deficiencies also attracted recommendations. Of the 34 recommendations in the management category, nine were for risk assessment and 11 were for inadequate investigations.

Figure 30.

Recommendations by type

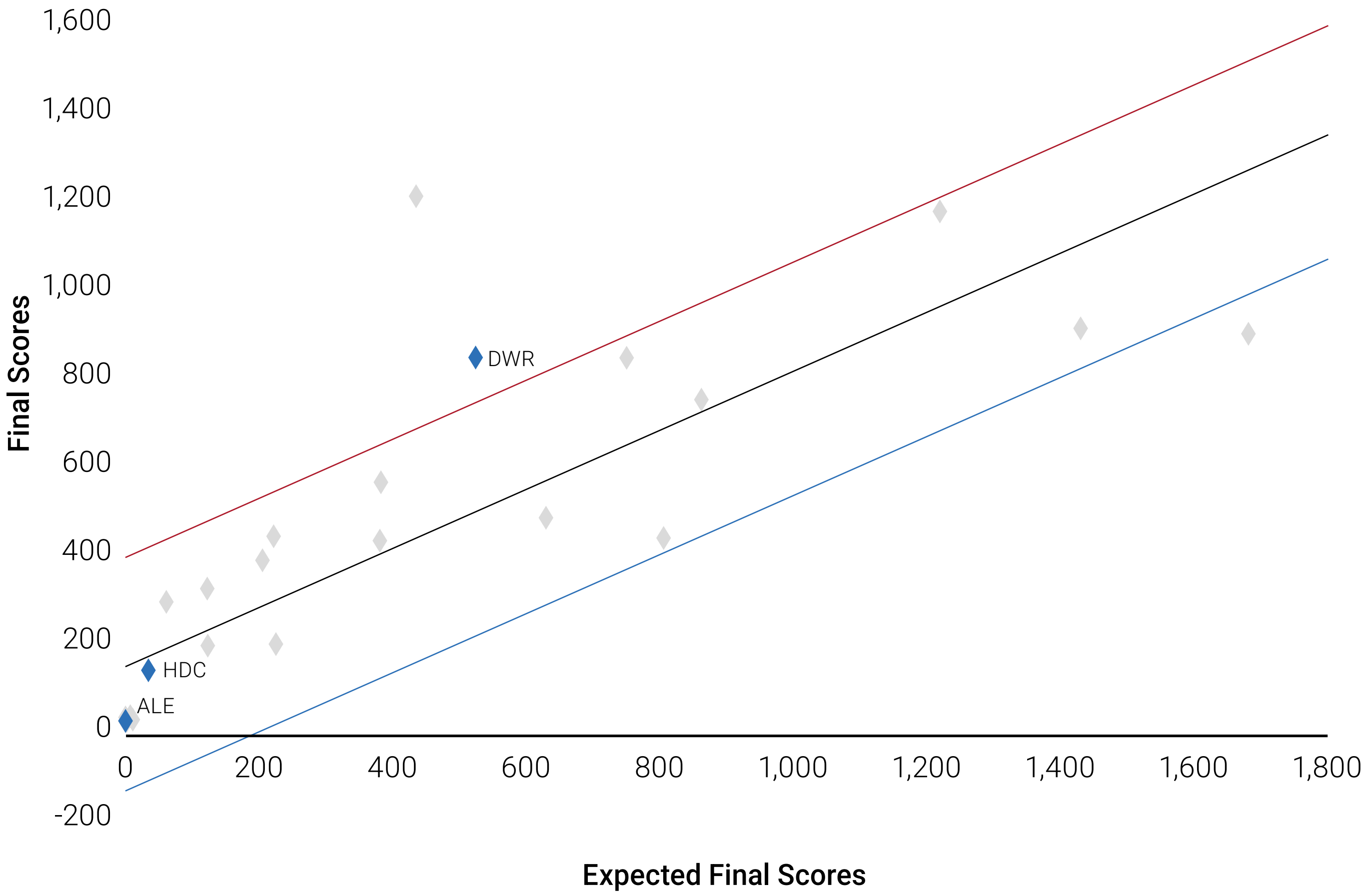


Both Dŵr Cymru Welsh Water and Hafren Dyfrdwy attracted recommendations for reportable events, with 30 recommendations given in total in 2022, between 12 events. Dŵr Cymru Welsh Water received 29 recommendations between 11 events and Hafren Dyfrdwy received one recommendation for one event.

The Recommendations Risk Index (Figure 31) measures all companies' performance in recommendations against the industry. Recommendations are the first level of regulatory intervention, in line with the Better Regulation framework. For the purposes of discussion, an equal distribution of recommendations by company size (population serviced) is assumed. Regression analysis can be seen in Figure 31 as the central black line. A position below this line means a company is receiving fewer recommendations and/or lower scores attached to those recommendations than would be expected. A position above the black line means the opposite. Any measure has a degree of uncertainty and so a 95% confidence interval is applied either side of the black line, represented by the red and blue lines.

Figure 31.

Recommendations Risk Index



The Recommendations Risk Index shows Dŵr Cymru Welsh Water and Hafren Dyfrdwy's position compared to the expected recommendation score for the company size. Whilst Hafren Dyfrdwy are within the expected scoring, Dŵr Cymru Welsh Water are again above the red line. There is an improvement when compared to 2021, however this position provides a corresponding backdrop against which the Inspectorate's regulatory activities in 2023 which are detailed in this report, can be viewed. New legal instruments have been put in place to resolves systematic problems that manifest across many regulated activities. The resulting improvements should have a direct positive effect on the Recommendations Risk Index, with the best outcome for Dŵr Cymru Welsh Water being that this impact is realised quickly.

Enforcement

Legal Instruments served in 2022

The Inspectorate publishes Legal Instruments on the website under **company improvement programmes**. A summary of the Legal Instruments issued in 2022 is in Table 13. Twenty Legal Instruments were closed/revoked for Dŵr Cymru Welsh Water, and six for Hafren Dyfrdwy during 2022.

Table 13.

Legal instruments issued in Wales, in 2022

Type of legal instrument	Number	Company
Regulation 27(4) notice for improvements to water safety plans	1 0	Dŵr Cymru Welsh Water Hafren Dyfrdwy
Regulation 28(4) notice relating to risks identified in water safety plans	1 4	Dŵr Cymru Welsh Water Hafren Dyfrdwy
Enforcement Order under section 18 of the Water Industry Act 1991.	0	
Undertaking under section 19 of the Water Industry Act	1 0	Dŵr Cymru Welsh Water Hafren Dyfrdwy

Dŵr Cymru Welsh Water – section 19 undertaking for regulation 18

In 2021 Dŵr Cymru Welsh Water received recommendations which started to form a common theme related to event investigations. This was discussed with the company at the time, and reviews were conducted internally with a view to making improvements. However, in 2022 this theme continued and following two ingress events, repeat recommendations regarding investigations, particularly the appropriateness of reactive and investigatory sampling, were given. In June 2022 the company received a minded to enforce letter, and the remainder of the year was spent formulating the programme of work included in the resulting section 19 undertaking.

The importance of a full investigation that meets the requirements of regulation 18, are twofold. The company must follow self-assurance principles to demonstrate that it has met its regulatory obligations in understanding the cause and extent of the event or breach. This is often proven through the investigation and appropriate sampling which provides the evidence and determines the root cause. It is the Inspectorate's duty to assess the investigation, and if the appropriate evidence is not available or provided by the company, the worst-case scenario must be assumed.

The undertaking will cause the company to critically review and improve its:

- Strategy for investigations to ensure it meets the requirements of regulation 18.
- Accompanying procedures. And,
- Provide training to staff to embed changes.
- Demonstrate that improved processes and procedures are followed.
- Cause to take representative samples in all cases apart from those which are exceptional and unforeseen.

The company accepted the undertaking in February 2023 and all work should be concluded by 31 March 2024.

Audit strategy reviews and guidance given

Most of the legal instruments the Inspectorate serve (all of the regulation 28(4) notices, section 18 enforcement orders served and the section 19 undertakings accepted) require the company to develop and maintain an audit strategy. This is a fundamental part of delivering the legal instrument successfully and should not merely be regarded as a report to produce for the Inspectorate's benefit. The purpose of the audit strategy is to outline how the company will monitor the success of measures being delivered, as well as to monitor the effectiveness of the interim mitigation measures put into place. It should include (as a minimum) the following sections;

- Governance – for example, a defined governance structure with board level visibility and sign off to ensure measures within a notice are delivered on time and as required under the legal instrument.

- Ownership – specific requirements outlined in the audit strategy should have named personnel/job roles responsible for delivery of measures. This is to aid clarity and provide accountability of delivering measures.
- Monitoring – monitoring can include enhanced sampling, consumer contact tracking and online monitoring. Monitoring should be clearly defined and tracked by the company to ensure sampling is not missed or sampling rescheduled where applicable.
- Measures of success – the audit strategy should define what successful delivery of the measures and successful mitigation of the original risk(s) looks like.
- Continuous review – the audit strategy should be a dynamic document which the company uses, reviews and updates throughout the lifetime of the legal instrument.

The Inspectorate recognised there was a divergence in the standards of audit strategies between companies and so, during 2022, inspectors completed an audit of the audit strategies submitted by companies. Where audit strategies were found to be poor, the Inspectorate sought to engage with companies, to educate and guide, following which, the Inspectorate required a review and resubmission of the affected audit strategies. The Inspectorate was pleased with the response from companies in rising to this challenge and has seen substantial improvements to these essential tools since.

Any company that would like a guidance session on audit strategies, please contact the Enforcement Team.

Security and Emergencies (SEMD)

The Inspectorate regulates the security and emergency measures direction (SEMD) on behalf of Welsh Ministers. After consultation with the industry, the direction was updated to a more risk-based approach.

The Inspectorate has been working with Welsh companies during a pilot year to set out expectations and drive improvement during the pilot year. Several companies are reviewing their reasonable worst case planning scenario, which is a good result for the consumer. The pilot ended March 2023. The Inspectorate will continue to work with the industry to drive improvement, and where necessary take enforcement action in line with the SEMD enforcement policy.

Two main challenges faced by the industry were the summer 2022 drought and the freeze/thaw experienced in December 2022. Both events demonstrated the challenge to make available minimum quantities of alternative supplies to consumers. The Inspectorate completed four audits in the wider industry during the year, focused on alternative water supplies and vulnerable consumers. Six recommendations were made to ensure companies have tested emergency plans and carry out emergency exercises.

Bottled water collection point (photo attributed to Water Direct).

Materials in contact with drinking water

During 2022, the Inspectorate continued to receive and process applications for approval of products in contact with drinking water (under regulation 31). The volume of applications processed was:

- 2022 – 145 total (32 new applications, 62 changes and 51 reapprovals)
- 2021 – 146 applications (23 new applications, 62 changes and 60 reapprovals)
- 2020 – 120 applications
- 2019 – 156 applications

During 2022, the Inspectorate has been working with its IT partners to design and build a new regulation 31 database. The system will replace the current Word document application forms, which are emailed into the team, with online, interactive application forms that will guide applicants in providing all the necessary information for an approval to be considered. The online process will have the benefit of meeting **Accessibility standards**, making them available to more people. The next phase of the project will see the approved products list transformed from a monthly, published PDF document to an interactive, searchable website which is updated in real-time. This will effectively become a live, online catalogue of approved products.

Laboratory capacity issues continue, with the sole approved regulation 31 testing laboratory temporarily closing its doors to samples to relocate. However, in more positive news, both NSF and ALS have made significant progress towards becoming recognised laboratories for product approval, and therefore testing facilities should be available again in the near future.

During the year there have been drinking water quality events caused by the inappropriate use of repair materials. A key part of the regulation 31 approval process is the assessment of the manufacturer's instructions for use (IFU), which must be provided when the product is supplied as a condition of approval. The IFU is a vital source of information to the end user of the product in using it correctly and appropriately to prevent risks to drinking water quality. Where applicable, compatible repair materials and repair techniques will be specified within the IFU. It is not appropriate to apply any other product as a repair material, even a separate, existing approved product. The interactions between the products will be unknown and untested, and could have an impact on drinking water quality.

Research publications

Four research projects were completed and published in 2022. The full research reports can be accessed on the Inspectorate's website at **Research – Drinking Water Inspectorate (dwi.gov.uk)**

- Organophosphorus Flame Retardants (OPFRs) – Risk to Drinking Water in England and Wales
- Method for the Determination of Concentrations of Perfluoroalkyl Substances (PFAS) in Drinking Water
- Research on Removal of Microplastics by Drinking Water Treatment Processes
- Public Perception of Water Recycling for Drinking Water Use

RAPID

The Regulators' Alliance for Progressing Infrastructure Development in Water (RAPID) was established to coordinate development and delivery of large-scale water resources infrastructure schemes, some of which will cross company boundaries, and improve resilience of supplies. Regional planning will inform water company water resource management plans in 2024, and companies should use the planning guidance published on the Inspectorate website to ensure risks to water quality are considered during the planning stages for all water resource schemes.

During 2022 the Inspectorate has continued to support RAPID to liaise with the Strategic Resource Options (SRO) sponsor companies and ensure that all drinking water quality risks are being appropriately considered, as the schemes are being progressed.

The Inspectorate worked with RAPID on the drinking water quality components during the publication of the draft and final decision documents for the accelerated Gate 2 and two new Gate 1 SROs, which were published in the first half of the year. In the second half of the year, the Inspectorate completed the assessment of 14 standard timeframe Gate 2 submissions which included the following drinking water quality considerations:

- Confirmation that company Water Quality teams have been engaged.
- Solutions are clearly explained, and options set out.
- Drinking water quality considerations for each option have been identified.
- Confirmation that key DWSP risks have been identified (catchment, source water, treatment, distribution, acceptability, materials in contact with drinking water, operability).
- Forward plan for investigation of key risks and further development of DWSPs including monitoring programmes.
- Confirmation as to how and when the Inspectorate will be engaged.

The assessments of the drinking water quality components feed into the cross-regulator assessment of how on track the solutions are. The Inspectorate will continue to work with the SRO sponsor water companies and partner regulators throughout the gated process, to ensure the solutions are appropriately identifying drinking water quality risks and putting suitable mitigation in place, to ensure they can provide wholesome supplies.

Whistleblowers

On the 15 December 2022 the Chief Inspector of Drinking Water and Inspectors appointed under section 86(1) of the Water Industry Act 1991 became 'prescribed persons' under the Prescribed Persons Order 2014 as amended (the Order).

Whilst the Inspectorate has historically received information from concerned employees, contractors or ex-employees of potential or known wrongdoing, by becoming a prescribed person somebody who is making a disclosure to the Inspectorate will afford certain protections under the Order and the Employment Rights Act 1996. In general terms, a person passing on information concerning wrongdoing (referred to as whistleblowing) should not suffer detriment or victimisation from their employers.

The type of disclosure that would typically qualify as a protected disclosure under the Order would be if it relates to the quality and sufficiency of water supplied by the water industry and the security of network and information systems within the supply and distribution sector. This will likely be information pertaining to a breach or potential breach of the Water Supply (Water Quality) Regulations 2016 (as amended), the Water Supply (Water Quality) Regulations 2018 (Wales), the Network and Information Systems Regulations 2018 or the company not meeting its obligations relating to water quality or sufficiency or potentially committing an offence under the Water Industry Act 1991.

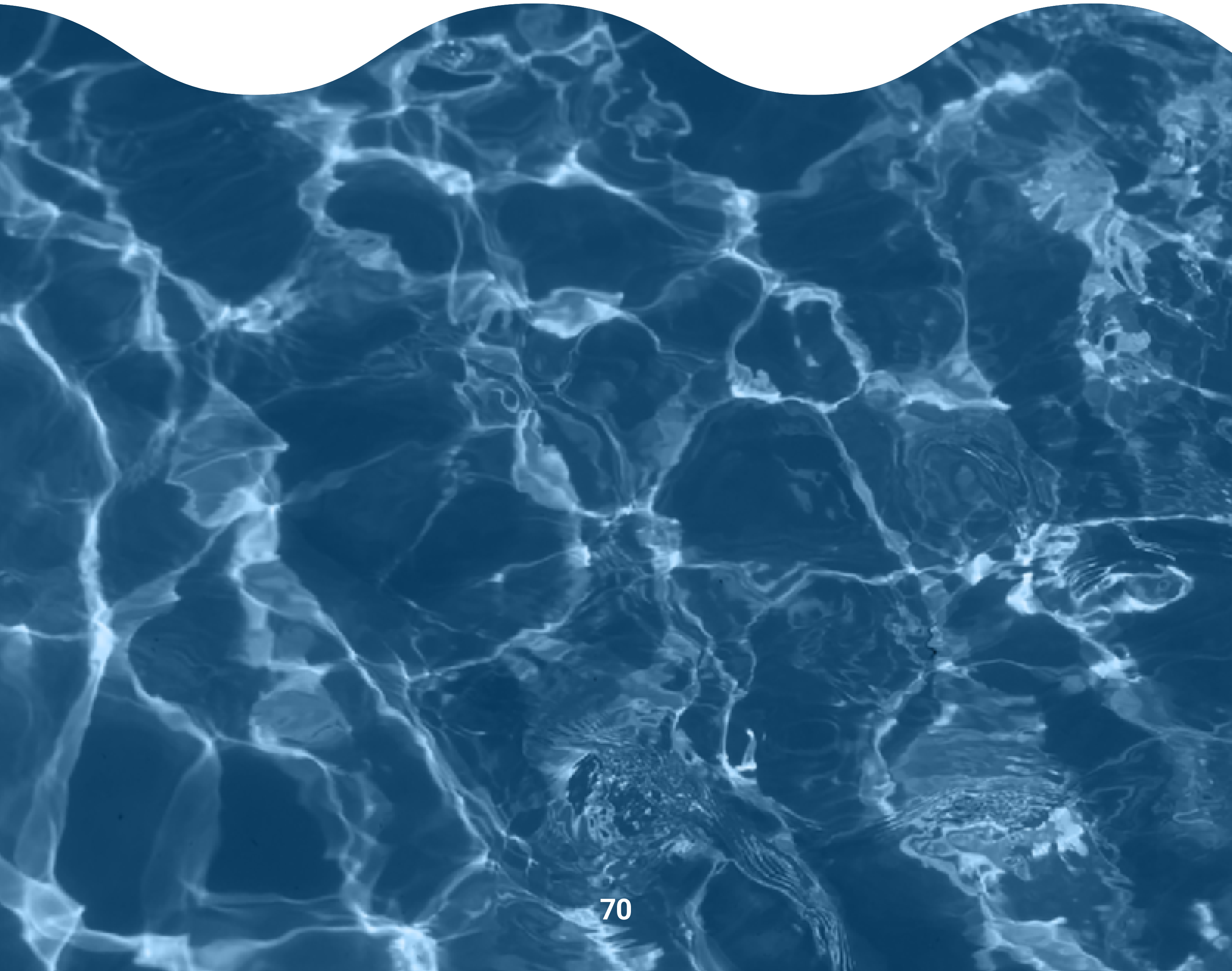
Any persons who are wishing to report a concern or potential concern regarding suspected or known wrongdoing which the Inspectorate can investigate should do so by contacting the DWI Enquiries line (**dwi.enquiries@defra.gov.uk** or 0330 041 6501).

The Inspectorate treats all disclosures made by whistleblowers sensitively and seriously. The Inspectorate follows up each disclosure with an appropriate investigation. The Inspectorate will protect the identity of an individual making an allegation wherever possible. However, in certain circumstances The Inspectorate may be required to reveal the identity, if required by law.

The Inspectorate will report the number of disclosures made during the reporting year (1 April – 31 March) annually in the Chief Inspector's Report. From the disclosures where the Inspectorate investigated further, it will report further action was taken, and a summary of the type of action taken (such as enforcement). The report will ensure that the anonymity of the whistleblower is protected and details of the company they work for is not reported.

Summary of disclosures made for the period 15 December 2022 – 31 March 2023

Number of disclosures made	Number of disclosures investigated further	Summary of action taken
0	0	N/A



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別添6：Environmental AgencyによるPFASの報告書

Per and Polyfluoroalkyl Substances (PFAS) in surface waters adjacent to UK airports

[redacted]

A dissertation submitted by [redacted] to the Department of Civil & Environmental Engineering, University of Strathclyde, in part-fulfilment of the requirements for the degree of Master of Science in Hydrogeology

I, [redacted] hereby states that this report is my own work and that all sources used are made explicit in the text

14,875 words

August 2023

Declaration of Author's rights

Confidentiality Statement

Abstract

Per- and poly-fluoroalkyl substances (PFAS) are a group of synthetic organofluorine chemicals produced for their oil and water-repellent characteristics. Due to the chemical structure of these compounds, they are persistent in the environment. This has led to a growing concern over their toxicity and potential risk to human health and the environment.

PFAS has been used in aqueous film forming foam (AFFF) since the 1960s. AFFF is used to extinguish hydrocarbon fuel fires and is used in many different industries. Due to firefighting training exercises undertaken in the aviation industry, airports have become synonymous with PFAS contamination associated with the use of AFFF. AFFF has been directly discharged to the ground during firefighting training exercises or emergency responses, which has left legacy contamination of the soils, wastewater, sediment, surface water, groundwater, seepage water and biota.

This research study attempts to assess whether sampling surface water adjacent to civilian airports in the UK can be used to determine if the airport is a source of PFAS contamination to waterways. Eight airports were targeted in the assessment, with all sample locations being outside of the airport boundaries in publicly accessible locations. Sample locations were selected based on water catchment geometry, with an upstream and a downstream sample relative to the airport's position. A suite of 17 PFAS were analysed from two rounds of surface water sampling.

Statistical testing was undertaken to determine whether there was a statistical difference between the PFAS concentrations in the upstream sample compared to the downstream sample. Four airports were identified to have statistically different results in both monitoring rounds indicating that between the two sample locations is contaminant source. Interpretation of the chemical data determined that there was a common signature of increasing perfluorooctane sulfonate (PFOS), 6:2 fluorotelomer sulfonate (6:2 FTS), perfluorohexane sulfonate (PFHxS), pentafluoropropionic acid (PFPA), and, to a lesser extent, perfluorooctanoic acid (PFOA) in the downstream samples relative to the upstream samples. These contaminants, with the exception of PFPA, are typical of PFAS based AFFF contamination indicating that the airports are a PFAS source.

The methodology does have limitations regarding access constraints and no onsite data with which to compare results. Further study could be to undertake onsite testing as a comparison and undertake more sampling rounds to make the data more reliable. Based on the available data, it was determined that this methodology could be used to evaluate a potential polluter and could be implemented on a wider scale.

Acknowledgements

I would like to acknowledge the Environment Agency for providing the information on which this assessment has been undertaken. In particular, I would like to acknowledge the time, guidance and support provided by Angela Haslam and Mark Sinton, as well as other Environment Agency staff for providing the required files and data.

I would like to acknowledge the work undertaken by Jacobs in collecting the data and providing the summary of the sampling undertaken which has enabled this dissertation to be progressed. In particular, I acknowledge the assistance of [redacted] who has provided valuable comment on the research assessment.

I acknowledge the guidance provided to me throughout this project by my dissertation supervisor [redacted] at the University of Strathclyde. Also, I acknowledge the support provided by [redacted] at Advisian for his guidance in using the QGIS software used in this dissertation.

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Acronyms

General Abbreviations	
AFFF	Aqueous Film-Forming Form
CSM	Conceptual site model
EA	Environment Agency
ECF	Electrochemical fluorination
FTA	Fire training area
FTF	Fire training facility
LIDAR	Light detection and ranging
LOD	Limit of detection
m AOD	Metres Above Ordnance Datum
OECD	Organisation for Economic Co-operation and Development
PCA	Principal component analysis
POP	Persistent organic pollutant
RPD	Relative percentage difference
RTD	River terrace deposits
SPZ	Source protection zone
WWTP	Wastewater treatment plants
Airport Abbreviations	
BHX	Birmingham Airport
BOH	Bournemouth Airport
EMA	East Midlands Airport
LBA	Leeds Bradford Airport
LGW	London Gatwick Airport
MAN	Manchester Airport

NCL	Newcastle International Airport
STN	London Stansted Airport
Chemical Abbreviations	
C	Carbon
PFAS	Per and polyfluoroalkyl substances
6:2 FTS	6:2 fluorotelomer sulfonate
FTSA	Fluorotelomer sulfonic acids
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutanesulfonic acid
PFCA	Perfluorocarboxylates
PFDA	Perfluorodecanoic acid
PFDoA	Perfluorododecanoic acid
PFDS	Perfluorodecane sulfonic acid
PFHpA	Perfluoroheptanoic acid
PFHpS	Perfluoroheptanesulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonate
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PFOSA	Perfluorooctanesulfonamide
PFPA	Pentafluoropropionic acid
PFPeS	Perfluoropentanesulfonic acid
PFSA	Perfluoroalkanesulfonates
PFUnA	Perfluoroundecanoic acid

1. Introduction

1.1 PFAS: A Growing Concern

Per- and poly-fluoroalkyl substances (PFAS) are a group of synthetic organofluorine chemicals first produced in the late 1940s for their oil and water-repellent characteristics (Balgooyen & Remucal, 2023; Carrizo *et al.,* 2023; Cui *et al.,* 2020; Vo *et al.,* 2020; Moller *et al.,* 2010). Despite being used commercially for five decades, awareness of the potential adverse effects of PFAS only emerged in the early 2000s (Sharifan *et al.,* 2021). Due to decades of use, PFAS are widespread in the environment, having been detected in surface water, groundwater, soil, air, dust and even in remote environments such as the polar regions (Hu *et al.,* 2016; Langberg *et al.,* 2022; Podder *et al.,* 2021; Johnson *et al.,* 2022; CRC CARE, 2018). PFAS contamination being detected in media far from a PFAS source, reflects the ability of PFAS to be transported long distances. This results in the existence of PFAS 'background' concentrations (Johnson *et al.,* 2022). The term 'forever chemicals' has been used to refer to PFAS due to their persistence in the environment (De Silva *et al.,* 2022; Manojkumar *et al.,* 2023). The persistence of this chemical group has led to a growing concern over their toxicity and potential risk to human health and the environment (East *et al.,* 2021; De Silva *et al.,* 2022; Moller *et al.,* 2010).

There are between 5,000 to 10,000 compounds within the PFAS group (Manojkumar *et al*., 2023), though this number is noted to vary across different studies and references. A simplified schematic of PFAS as a chemical group is presented in Figure 1 (HEPA, 2020). The early PFAS contamination studies mainly focused on the PFAS compounds perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), due to their potential toxicity to human health and the environment. These PFAS are also two of the most common PFAS detected in the environment (East *et al.,* 2021; CRC CARE, 2018). One of the main legacy uses of PFOS was to produce aqueous film foaming foam (AFFF) used to fight hydrocarbon fuel fires. The use of PFOS within AFFF started to be phased out in 2002 due to growing awareness of its toxicity (Balgooyen & Remucal, 2023; East *et al.,* 2021; Sims *et al.,* 2022).

In May 2009, PFOS was added to Annex B of the Stockholm Convention as a persistent organic pollutant (POP) due to its adverse effects on human health and the environment, bioaccumulation ability and persistence. This led to further global restrictions on its production and use (CRC CARE, 2018; Ahrens *et al.,* 2015; Hoisaeter *et al.,* 2019; Wei *et al.,* 2017); resulting in the phase-out of PFOS within AFFF. Generally, PFOA-containing AFFF became a replacement for PFOS-containing foams (EA, 2021), however in 2019, PFOA was added to Annex A of the Stockholm Convention to restrict the use of this compound (Sims *et al.,* 2022). The extent of PFAS contamination from legacy AFFF use is unknown (Anderson *et al.,* 2019).

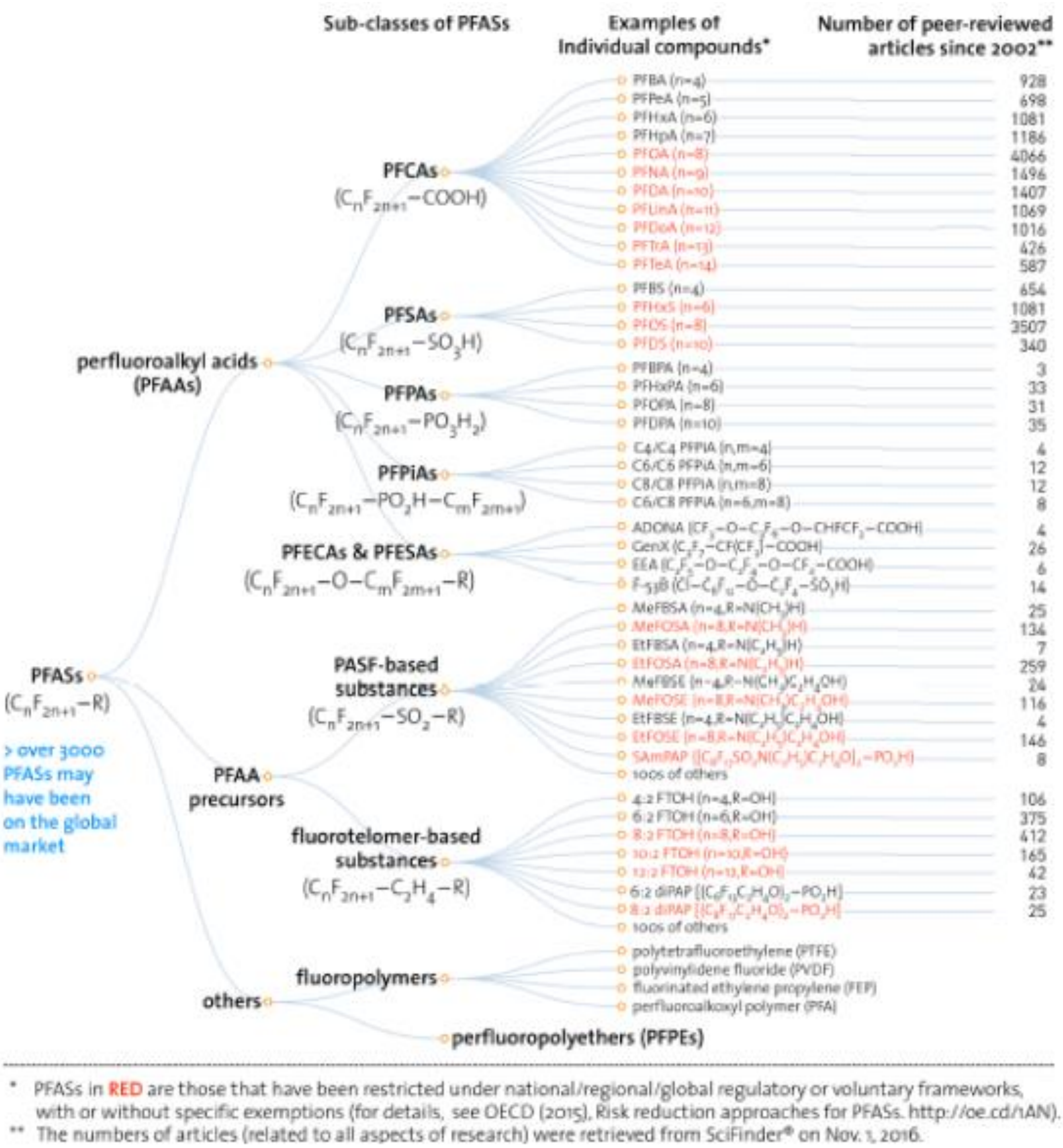


Figure 1: Simplified schematic showing the PFAS chemical group (HEPA, 2020)

1.2 Aqueous Film Foaming Foam – The Issue

Airports with fire training facilities have been identified as significant sources of PFAS contamination in the environment through AFFF use (De Silva *et al.*, 2022; Ahrens *et al.*, 2015). During fire training exercises or emergency use/during aviation fires, PFAS containing AFFF have been used directly on the ground and the environment. This direct discharge to the ground has left legacy contamination of the soils, wastewater, sediment, surface water, groundwater, seepage water and biota (Dauchy *et al.*, 2017; Carrizo *et al.*, 2023). Historically there was limited containment during these fire training exercises. Containment of AFFF is not considered to be a priority when used in an emergency response (Milley *et al.*, 2018; Lui *et al.*, 2022)

Fire training exercises at airports typically occur within a fire training area (FTA). FTAs are where AFFF has most likely been deployed and making these areas point sources of PFAS contamination (Milley *et al.,* 2018). FTAs can be observed from satellite imagery, as shown in Figure 2. A fire training area typically has a concrete pad, so the AFFF will not be directly discharged to the soil, though runoff from the concrete pad is likely. Runoff captured in stormwater drainage may eventually be discharged via a discharge point.

Airports have multiple PFAS sources, not just those associated with firefighting training practices. Other potential PFAS sources on an airport could be related to areas of material storage and handling as well as aircraft accident locations (Ross *et al.,* 2017; Solla *et al.,* 2012). During material storage there is the potential for loss of foam concentrate, there is also the potential for accidental discharge of fire suppression systems and the release to waste water treatment plants from discharge via stormwater (CL:AIRE, 2023). Fire suppression systems can be situated within tenant hangers. PFAS can also be present in aircraft hydraulic fluids (Anderson *et al.,* 2023).

Figure 2: Fire Training Area – Leeds Bradford Airport (Google Maps, 2023)

1.3 Aims and Objectives

PFAS has been identified as a potential risk to human health and the environment, with airports being a potential point source of PFAS due to using AFFF during fire training activities or aviation emergencies.

This research aims to determine if sampling surface water adjacent to airports can determine if an airport is a point source of PFAS and further understand whether civilian airports are an important/significant source of PFAS contamination within waterways.

In order to meet this aim, the following objectives are set:

- Undertake a literature review to develop an understanding of the:
    - potential commercial sources of PFAS and their fate and environmental transport mechanisms.
    - chemical signature of PFAS in AFFFs.
- Develop a conceptual understanding of each of the airport water catchments in terms of surface water, groundwater, geology, and areas where AFFF have been used in the airports and identify any other potential PFAS sources within the catchment area;
- Review the available upstream and downstream surface water PFAS analytical data concerning the airport and river sampling points;
- Evaluate the potential for the civilian airports to be a source of PFAS or assess why no PFAS signature is observed within the surface water samples; and
- To discuss the methodology implemented in terms of its performance and to discuss the data and methodology limitations;
- Elevate the potential to use the methodology as a widespread deployment technique to determine potential polluter sites.

1.4 Data Source and Study Areas

The Environment Agency has provided the data used in this research project. The data was obtained from freely accessible rivers by the environmental consultancy Jacobs on behalf of the Environment Agency.

Sample points were chosen based on the watershed geometry around eight civilian airports. One sample was collected from upstream of the airport and one sample from downstream of the airport over two sampling rounds.

1.5 Report Structure

This report's structure is as follows:

Section 1 – Introduction and aims and objectives

Section 2 – Focused literature review of PFAS sources, physical and chemical properties, fate and transport, AFFF environmental forensics and PFAS source attribution using surface-water case studies;

Section 3 – Details of the methodology undertaken for sampling and analysis;

Section 4 – Conceptualisation of the study areas, presenting the results of the study;

Section 5 - Discussion of the findings and the limitations of the study; and

Section 6 – Provides a conclusion of the study and recommendations for further work.

2. Literature Review

2.1 PFAS Sources

To undertake this study, it is necessary to understand the potential PFAS sources in a water catchment. This section will look at where PFAS is used and provide a general background to PFAS.

PFAS are encountered in firefighting foams and are associated with FTAs at airports which is the focus of this study. However, PFAS are also encountered in the following products: hydraulic fluids, grease repellents, carpet and rug surface treatments, textiles, coatings and adhesives, cookware, cosmetics, household and industrial cleaning products, semiconductors, food packaging, pesticides and herbicides (Balgooyen & Remucal, 2023; CRC CARE 2018; Carrizo *et al.,* 2023).

As well as products, certain industries are associated with PFAS contamination, including landfills, drilling, oil recovery, wastewater treatment facilities, the automotive industry, fire suppression systems, metal plating and electroplating (CRC CARE, 2018; Carrizo *et al.,* 2023; Cui *et al.,* 2020). Fire suppression systems can be employed in numerous industries such as manufacturing facilities, chemical, petrochemical and pharmaceutical plants, automotive workshops, rail yards, mining operations, commercial kitchens and many more (CL:AIRE, 2023).

A summary of the industries which use PFAS is presented in Table 1. The numbered brackets following the industry denotes the number of subcategories within that industry.

Table 1: Industries where PFAS are or have been employed (Gruge et al., 2020)

Industry branches	
Aerospace (7)	Mining (3)
Biotechnology (2)	Nuclear industry
Building and construction (5)	Oil & gas industry (7)
Chemical industry (8)	Pharmaceutical industry
Electroless plating	Photographic industry (2)
Electroplating (2)	Production of plastic and rubber (7)
Electronic industry (5)	Semiconductor industry (12)
Energy sector (10)	Textile production (2)
Food production industry	Watchmaking industry
Machinery and equipment	Wood industry (3)
Manufacture of metal products (6)	
Other use categories	
Aerosol propellants	Metallic and ceramic surfaces
Air conditioning	Music instruments (3)
Antifoaming agent	Optical devices (3)
Ammunition	Paper and packaging (2)
Apparel	Particle physics
Automotive (12)	Personal care products
Cleaning compositions (6)	Pesticides (2)
Coatings, paints and varnishes (3)	Pharmaceuticals (2)
Conservation of books and manuscripts	Pipes, pumps, fittings and liners
Cook- and bakingware	Plastic, rubber and resins (4)
Dispersions	Printing (4)
Electronic devices (7)	Refrigerant systems
Fingerprint development	Sealants and adhesives (2)
Fire-fighting foam (5)	Soldering (2)
Flame retardants	Soil remediation
Floor covering including carpets and floor polish (4)	Sport article (7)
Glass (3)	Stone, concrete and tile
Household applications	Textile and upholstery (2)
Laboratory supplies, equipment and instrumentation (4)	Tracing and tagging (5)
Leather (4)	Water and effluent treatment
Lubricants and greases (2)	Wire and cable insulation, gaskets and hoses
Medical utensils (14)	

Though the potential sources of PFAS are diverse, 95% of global PFAS is estimated to be sourced from AFFF (CRC CARE, 2018). Potential PFAS sources affecting surface water are shown Figure 3. Entry of PFAS into surface water and groundwater can result from runoff and/or leaching or direct discharges (CRC CARE, 2018). It should be noted that PFAS are almost always released into the environment via above-ground activities and is not released from underground tanks (Sharifan *et al.*, 2021).

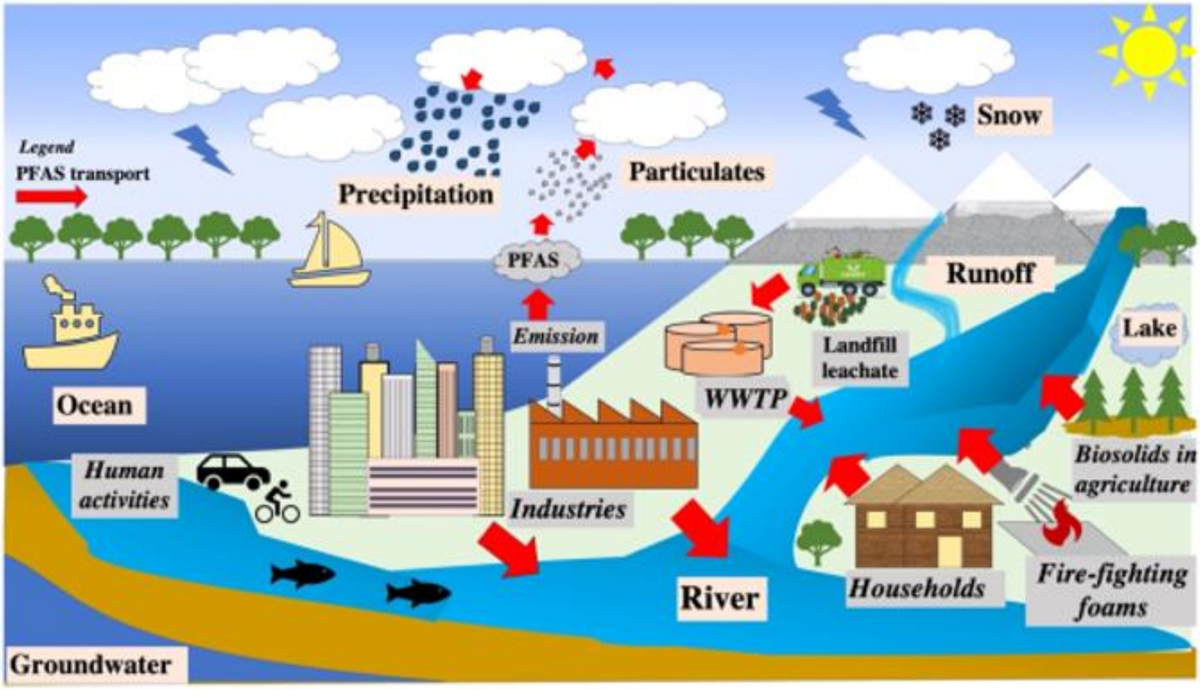


Figure 3: PFAS sources affecting surface water (Podder et al., 2021)

2.1 Physical and Chemical Properties

PFAS are a group of organic molecules with thousands of individual species which vary in ionisation state, functional group substitution, chain length and branching degree (Sharifan *et al.,* 2021; Reinikainen *et al.,* 2022; Ng *et al.,* 2021). The most common PFAS sub-classes are the perfluoroalkyl sulfonic acids (PFSAs), like PFOS, and perfluoroalkyl carboxylic acids (PFCAs), such as PFOA, as shown in Figure 1, which are part of the perfluoroalkyl acids (PFAAs) (Reinikainen *et al.,* 2022; Solla *et al.*, 2012).

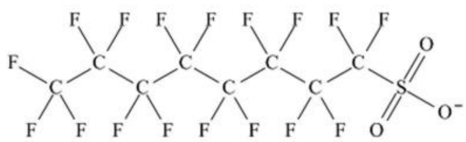
Another important group are the PFAA precursors, with the subclass fluorotelomers. The carbon-6 backbone fluorotelomers are considered to be better alternatives for the environment, than the carbon-8 PFAAs (such as PFOS and PFOA), due to their low bioavailability. In particular, 6:2 fluorotelomer sulfonate (6:2 FTS), is becoming a common alternative to PFOS and PFOA (Lu *et al.*, 2017).

The carbon-fluorine backbone is the defining feature of a PFAS molecule (East *et al.*, 2021). Fluorine atoms replace the hydrogen atoms on a carbon chain to varying degrees of saturation, resulting in the per- or poly- nomenclature (CRC CARE, 2018; Leeson *et al.*, 2021; East *et al.*, 2021; Sims *et al.*, 2022). PFOS and PFOA are examples of perfluorinated compounds with every carbon atom bonded to a fluorine atom, whereas 6:2 FTS is an example of a polyfluorinated compound (NASF, 2019).

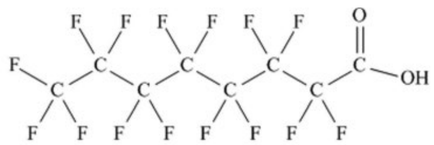
The strong carbon-fluorine bond makes PFAS biologically, chemically and thermally stable, making the molecules resistant to degradation and providing its lipophobic (lipid, grease repellent) and hydrophobic (water repellent) properties (CRC CARE, 2018; Cui *et al.,* 2020; East *et al.,* 2021; Vo *et al.,* 2020; Sims *et al.,* 2022; Koch *et al.,* 2019; Podder *et al.,* 2021). The hydrophobic properties result from the carbon backbone (tail). In contrast, the functional group part of the molecule, which comprises mainly the carboxylic group or sulfonates, is the hydrophilic head (lipophobic). These properties make PFAS relatively soluble (Cui *et al.,* 2020; Wei *et al.,* 2017). The molecular structures of PFOS, PFOA and 6:2 FTS are shown in Figure 4, where the carbon-fluorine backbone and functional groups can be identified. As indicated in the figure, the numbers on the fluorotelomer backbone relate to a 6-carbon fluorinated backbone and a 2-carbon non-fluorinated backbone.

PFAS are resistant to photo-oxidation, biodegradation, hydrolysis and photolysis (Leeson *et al.,* 2021). PFAS also have stability against bases, acids, reducing and oxidising agents (Manojkumar *et al.,* 2023) and bioaccumulate and biomagnify in food webs as they are metabolically and chemically inert, resisting chemical and biotic degradation. This makes them stable and persistent compounds in the environment (CRC CARE, 2018).

PFOS



PFOA



6:2 FTS

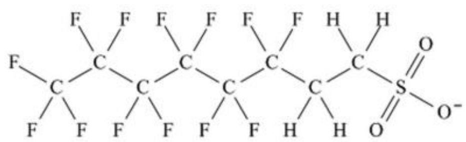


Figure 4 Molecular Structure of PFOS, PFOA and 6:2 FTS (Lu et al., 2017)

2.2 Fate and Transport

PFAS fate and transport are affected by the environmental transformation rate of the precursors and PFAS sorption and migration capabilities (Lui *et al.,* 2022). Precursors are larger PFAS molecules which can break down via biodegradation, oxidation, biotransformation or metabolism into more persistent PFAS such as PFOS and PFOA (CRC CARE, 2018; Vo *et al.,* 2020). Precursors are shown in Figure 1.

When released into the environment, PFAS undergo various transformations dependent on the environmental conditions and their physical and chemical properties. The shorter-chain PFAS molecules (<C8) are more water-soluble, whereas the longer-chain molecules (>C8) accumulate more in the food chain and bind more strongly to soil particles (Ahrens *et al.,* 2015). Therefore, the length of the hydrophobic carbon chain alters the fate and distribution of PFAS in the environment and in humans (Sims *et al.,* 2022).

PFAS leaching from soils into groundwater can result in contaminated surface or drinking water. Partitioning of PFAS between waters, soils and sediments depends on numerous factors, including bond strength, chain length, functional group, soil organic content, solution ionic composition/ion exchange capacity, other contaminants (such as hydrocarbons) and pH (CRC CARE, 2018; Wei *et al.,* 2017; Anderson *et al.,* 2021). The organic content of soil is one of the key parameters affecting fate and transport. The subsurface's geochemical conditions, particularly pH, affect the soil surface's cation/anion exchange capacity by altering the PFAS molecules or the charges on the soil particles (Anderson *et al.,* 2019). Higher organic and clay content and pH are linked to more PFOS absorption in soils (CRC CARE, 2018).

Sediments may act as a sink for PFOS but less so for PFOA, which is less strongly absorbed. Sorption onto sediments or soil can reduce the concentrations of PFAS in aqueous solution (CRC CARE, 2018).

Moisture content can be a key parameter governing how PFAS is sorbed to soils. Moisture content can be seasonally affected via drainage rate, infiltration and evaporation. The higher the soil moisture content, the less PFAS will be retained in the soil due to less air-water interfacial areas. Therefore, during periods of heavy rains, PFAS concentrations in soil water may be higher as less is retained by soil particles (Sharifan *et al.,* 2021). Once the PFAS retained in soils has leached it can be transported away from FTAs via groundwater. Continued impacts (elevated PFAS concentrations) can be seen many years after decommissioning an FTA (Ahrens *et al.,* 2015).

AFFF are not just formed from PFAS; the non-PFAS part of the AFFF could affect PFAS fate and transport in the environment. Non-PFAS components could affect PFAS by acting as a cosolvent and facilitating transport, sequestering PFAS, or competing for sorption/retention sites in soils. If the non-PFAS compounds are biodegradable, the altering electron conditions could delay the biodegradation/transformation of any precursors (Anderson *et al.,* 2021).

2.3 Environmental Forensics

2.3.1 Attributing Sources

Due to the diverse range of PFAS usage, it can be hard to identify the exact source of PFAS contamination in the environment (Ruyle *et al.,* 2021). PFAS contamination can be from either point or diffuse sources. Chemical fingerprinting, concentrations and relative distribution profiles are all techniques that could potentially differentiate the sources. Chemical fingerprinting of AFFF-impacted sources is dominated by PFOS and other PFSA. Looking at these 'fingerprints' by reviewing concentrations and relative distribution profiles of individual PFAS against the sum of targeted PFAS could help identify point sources. Point sources, such as the use of AFFF at airports, have been identified as having the highest PFAS concentrations (Langberg *et al.,* 2022).

PFAS enters WWTPs via discharge to sewers; the standard wastewater treatment process does not remove PFAS. PFAS can leave WWTPs in the effluent or the biosolids (CRC CARE, 2018). A study undertaken by Chen *et al.* (2020) in China identified a higher concentration of PFAS in river water samples collected from locations affected by WWTPs than in river water samples collected from parts of the river which were away from the city centre.

A study by Ruyle *et al.* (2021) in the USA, identified that catchment areas with an AFFF PFAS source identified precursors with a carbon chain length of six. In contrast, catchments with no AFFF PFAS source identified precursors with a carbon chain length of four. Also, the PFAS contamination associated with AFFF was identified to alter with distance down the hydrological flow path due to these precursors' degradation and preferential sorption.

Important considerations for determining PFAS sources are the geological and hydrological settings, such as soil type, groundwater depth and surface water and groundwater flow directions (Anderson *et al.,* 2023).

2.3.1 AFFF Legacy Contamination

Firefighting organisations have used AFFFs to extinguish hydrocarbon fuel fires since the 1960s, particularly for use in aircraft emergencies, but also used in FTA, oil industries and others (Ahrens *et al.,* 2015; D'Agostino & Mabury, 2017; Dauchy *et al.,* 2017; East *et al.,* 2021; Lui *et al.,* 2022). The surface-active characteristics of PFAS allow it to form an aqueous foam which is resistant to heat and high temperatures which spreads out as a thin film, creating a vapour barrier that causes the fire to extinguish and prevent reignition (Dauchy *et al.,* 2017; Leeson *et al.,* 2021; D'Agostino & Mabury, 2017; Milley *et al.,* 2018).

AFFFs historically contained the PFAS sub-classes PFSAs, PFCAs and fluorotelomer sulfonic acids (FTSAs) (Ahrens *et al.,* 2015). There is currently limited use of long-chain PFAS in AFFF mixtures, with current AFFF mixtures using short-chain PFAS (Leeson *et al.,* 2021). Stocks of AFFF concentrate containing PFOS are still present, even after the phase out initiated in 2002 and current use is prohibited under the Stockholm Convention. The United Nations Environment Programme (UNEP) reported in 2011 that there were 2,200-2,600 tons in Switzerland, 300 tons in Canada, 1,400 tons in Norway and 19,000 tons in Japan of PFOS containing AFFF stored (Zushi *et al.,* 2017). However, contamination issues related to these longer-chain compounds are often the result of legacy contamination rather than contemporary contamination from stockpiles. The ongoing legacy contamination is due to the continued breakdown of precursor compounds contributing to the PFAS load and the persistence of the compounds in the environment (CRC CARE 2018).

The Organisation for Economic Co-operation and Development (OECD) definition of a long-chain PFAS is the following:

- PFCAs with more than or equal to eight carbons; and
- PFSAs with more than or equal to six carbons (Buck *et al.,* 2011)

Precursors can take a long time to transform and have a long retention time in soils, leading to a long-term PFAS flux leaching out of soils and entering adjacent groundwater and/or surface water (Lui *et al.,* 2022; Anderson *et al.* 2019). A study undertaken by Hoisaeter *et al.* (2019) in Norway showed that 15 years after AFFF containing PFOS was used at a Norwegian airport, PFOS still formed 96% of the total PFAS concentration in the soils at the firefighting training facility (FTF), highlighting the persistence and strong attenuation of PFOS to the soil in the unsaturated zone. PFOS was also encountered in groundwater down gradient of the FTF, accounting for 71% of the total PFAS concentration. The leaching of PFAS from unsaturated soil indicates the long-term risk of groundwater contamination and subsequent surface water contamination from the migration of contaminants within the groundwater.

2.3.2 AFFF Chemical Fingerprint

The composition of AFFF formulations has varied over time with no defined standards. The parent compounds, or precursors, can transform, resulting in different PFAS distributions at different AFFF-impacted sites. Therefore, the full composition of the PFAS in the impacted areas is uncertain (Anderson *et al.,* 2021; Balgooyen & Remucal, 2023; Milley *et al.,* 2018). The different formulations used mean that understanding the environmental fate and transport of PFAS sourced from AFFF use is complicated due to the uncertainty in chemical structures, degree of branching, functional groups, precursors and isomers, plus the complexity of interactions with co-occurring chemicals within the AFFF formulations (Leeson *et al.,* 2021). The variety of PFAS used in these foams means that environmental samples tested report varied PFAS mixtures (East *et al.,* 2021).

From a global perspective, from the late 1960s to 2002, most AFFF-contaminated sites used a legacy electrochemical fluorination (ECF) AFFF produced by 3M called Lightwater. This brand of foam mostly contained PFOS and its precursors (Ahrens *et al.,* 2015; Balgooyen & Remucal, 2023; Carrizo *et al.*, 2023; Hoisaeter *et al.,* 2019; Reinikainen *et al.,* 2022). When 3M phased out production of 3M, they were producing approximately 80% of the global PFOS. The use of PFOS in AFFF is assumed to have occurred post-2002 due to buyers using up available stock (Solla *et al.,* 2012).

When 3M discontinued the Lightwater foam, a fluorotelomer AFFF called Ansul became the dominant foam used at fire training facilities. In the Ansul foam, the polyfluorinated precursors' breakdown to PFCAs, most notably PFOA (Balgooyen & Remucal, 2023; Reinikainen *et al.,* 2022; Lui *et al.,* 2022). From anecdotal information, Angus has been the most widely used AFFF brand within the United Kingdom rather than Lightwater or Ansul (*per comms.* EA & Jacobs, 2023). Though the foam is a different brand, it is assumed that legacy foam contained PFOS prior to the 2009 Stockholm Convention POP designation, with a move towards PFOA and fluorotelomer AFFF formulations

Though AFFF compositions have varied over time, as a generalisation, historic AFFF mixtures contained high percentages of PFOS and other PFSAs such as perfluorohexane sulfonate (PFHxS) (Leeson *et al.*, 2021; Ahrens *et al.,* 2015), with PFOS being typical of the 3M manufactured AFFF and the 6:2 FTS being a typical breakdown product of the PFAS encountered in the Ansul AFFF (Houtz *et al.,* 2016). Most of the current PFAS environmental impacts are related to these historic AFFF formulations (Leeson *et al.*, 2021). A history of the brand production of AFFF is shown in Figure 5.

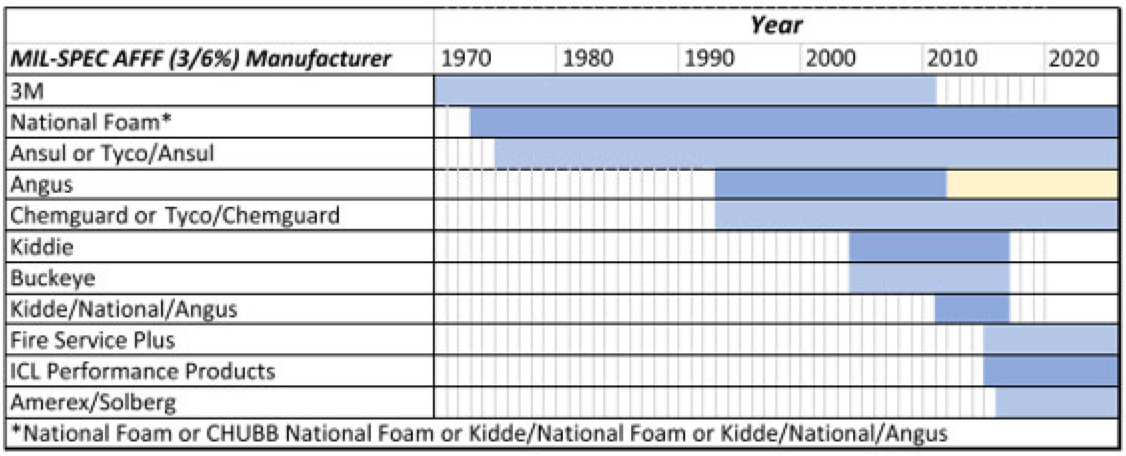


Figure 5: AFFF brand production (Leeson et al., 2021)

Houtz *et al.* (2013) undertook a study into the different precursors present in AFFF formulations per brand, both before and after oxidation. The results of this are presented in Figure 6. This figure shows that post oxidation, PFOS and PFHxA are the main contributors to the PFAS mix in the 3M formulations. Other brands had PFFeA and PFHxA as main contributors. Notably, PFOA was not recorded at high concentrations in the foam mixers.

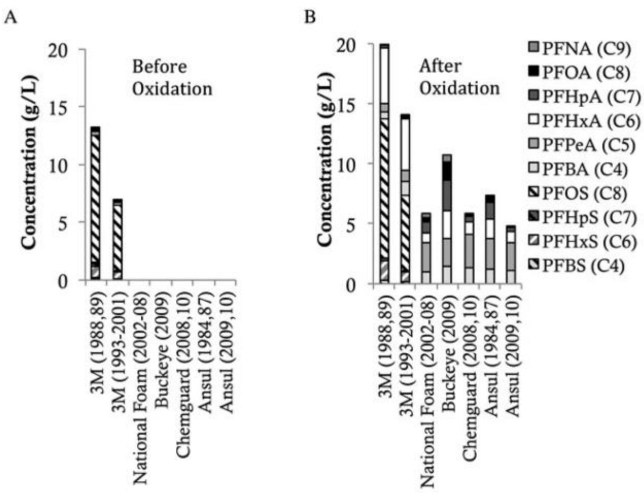


Figure 6: AFFF samples analysed for AFFF-related PFAA precursors, PFSAs and PFCAs before (A) and after (B) oxidation (Houtz et al., 2013)

Pre 2002, PFAS used in AFFF were generated by ECF, which resulted in 20-30% of the PFAS being branched isomers. Telomerisation manufacturing processes were used when PFOS was phased out, producing even carbon number PFAS chain lengths and linear molecules. Therefore, if branched isomer PFAS are detected, as well as a high proportion of PFHxS and PFOS, this indicates legacy AFFF contamination from the ECF manufacturing process 1980-2003. New-generation foams expect contamination associated with short-chain PFCAs and FTSAs (Koch *et al.,* 2019).

Anderson *et al.,* 2021 identified that PFHxS, 6:2 FTS, PFOS, PFPeA, PFOA, perfluorobutanoic acid (PFBA), perfluoroheptanoic acid (PFHpA) and perfluorobutanesulfonic acid (PFBS) were the most commonly detected PFAS in groundwater collected from within AFFF-impacted sites US Air Force bases as shown in Figure 7. Langberg *et al.* (2002) identified in a different study undertaken in Norway, that AFFF impacted sites produced a chemical signature that PFOS dominated, then to a less extent FOSA, perfluorodecane sulfonic acid (PFDS), perfluorohexanoic acid (PFHxA) and PFHxS.

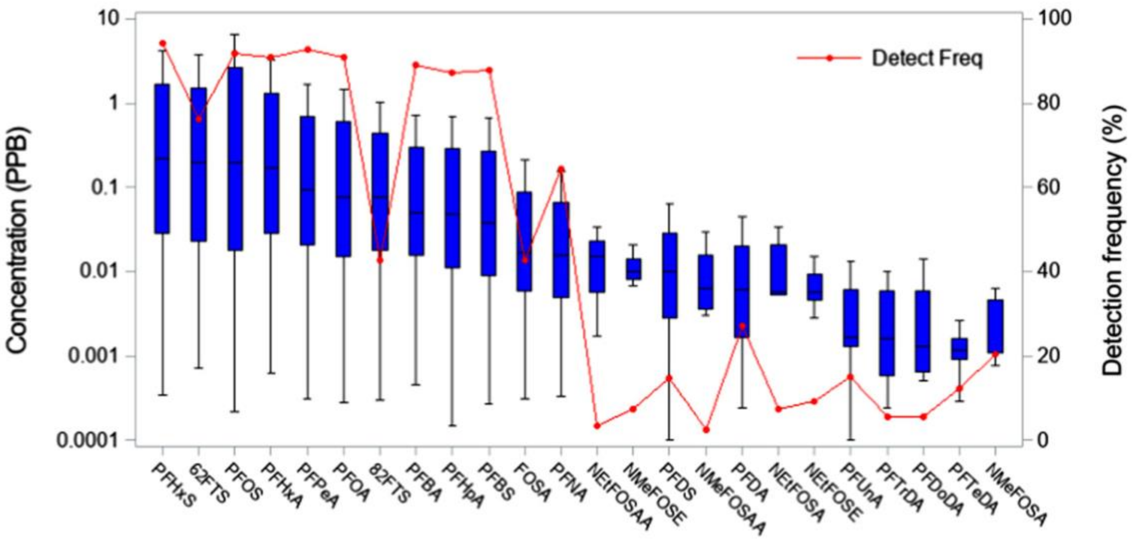


Figure 7: Detection frequency and concentrations of PFAS in groundwater within AFFF-impacted sites at US Air Force sites (Anderson et al., 2021)

2.3.1 PFAS Source Attribution Case Studies

Numerous studies have determined whether airports using AFFF are sources of PFAS contamination in surface waters. This section summarises a few studies, looking at the different methods for analysing source determination of PFAS contamination within surface waters.

Zhang *et al.,* (2016) undertook a study in the area of Rhode Island and New York Metropolitan. Surface water samples were collected from rivers, creeks and estuaries and analysed for 21 PFAS. The PFAS concentrations were looked at for spatial patterns, as well as undergoing principal component analysis (PCA) and hierarchical clustering. The geospatial analysis of the watersheds indicated that sources were potentially linked to the public airport and textile mills. The PCA identified three main statistical grouping of PFAS collected from surface water. These were point sources such as airports and textile mills, an atmospheric source and metal smelting industries. This study identified that knowing the river flow directions and hydrological distance from sources, i.e. understanding the aquatic transport pathway, was critical to determining the PFAS source.

Ruyle *et al*. (2021) analysed lakes and rivers in three water catchments with known AFFF source zones and three water catchments without known AFFF source zones, in the USA. The study identified that in catchments where there was not an AFFF PFAS source, then the molar fraction of PFBS and PFBA within the identified PFAS was statistically greater (26 ± 8%), whereas in a catchment within an AFFF PFAS source, then PFOS and PFOA accounted for 40 ± 14% of the PFAS identified. Therefore, catchments with an AFFF PFAS source are enriched with PFOS and PFOA in comparison to catchments where there is no AFFF PFAS source.

A study undertaken by Reinikainen *et al*. (2022) in Finland, analysed surface water taken from four different firefighting training sites; one at an emergency services academy, two at airports and one at an oil refinery. The concentration results identified perfluorononanoic acid (PFNA), PFOS and 6:2 FTSA as having the highest mean concentrations detected in surface water at airport sites, with PFOS contributing more than half of the total PFAS concentration. The study showed that although PFOS have no longer been in AFFF since the early 2000s, it will continue to be a long-term risk driver associated with legacy contamination.

A conceptual site model (CSM) of PFAS release at an airport using AFFF is shown in Figure 8. The dominant pathway shown in this figure for PFAS contamination of the surface water is via surface water runoff. The airport discharge point is not shown, which collects surface water runoff from across the airport and discharges it from a single point.

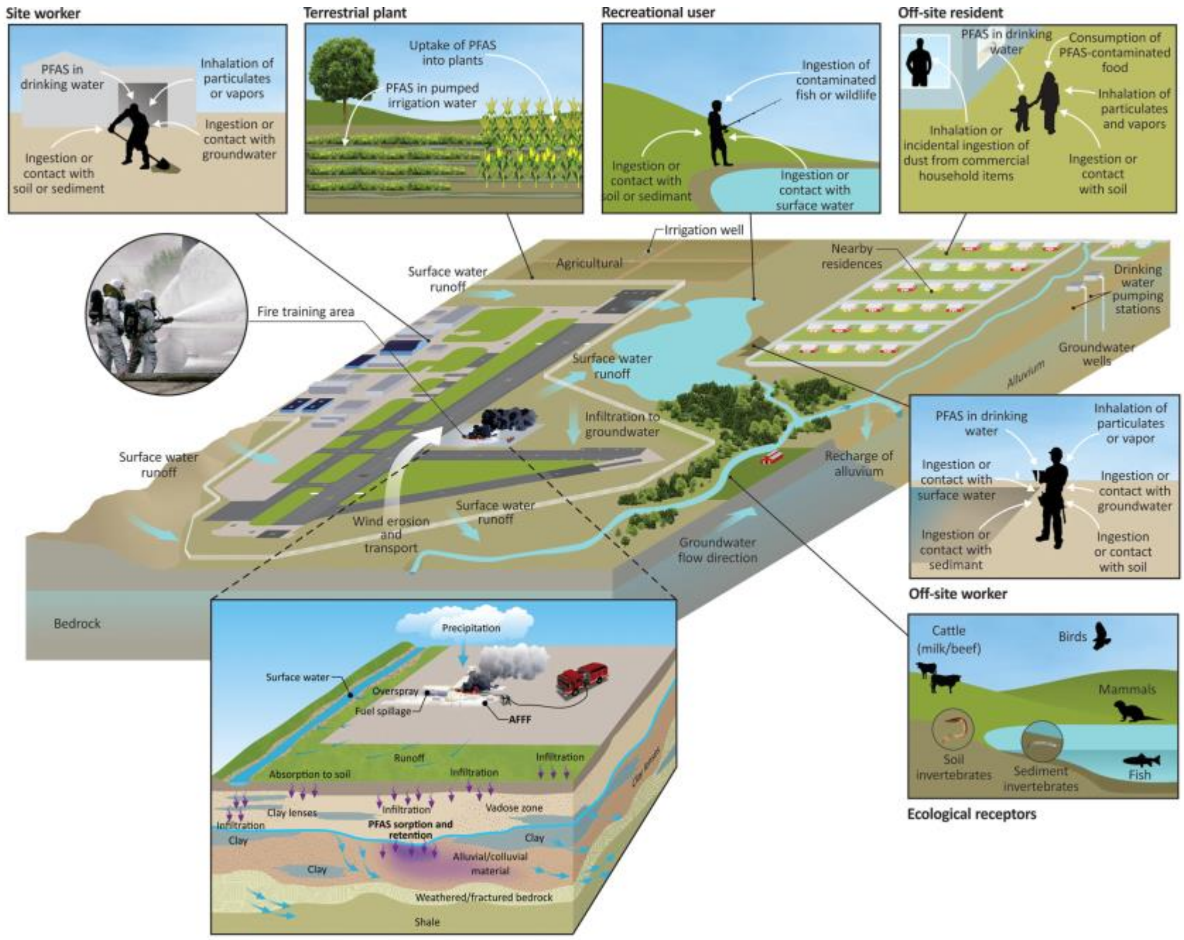


Figure 8: Conceptual Site Model of PFAS release at an airport by using AFFF (Leeson et al., 2021)

2.4 Expectations

Following the literature review, below are some expectations about AFFF contamination.

- The following PFAS are expected to be the dominant PFAS identified in surface water impacted by AFFF: PFHxS, 6:2 FTS, PFOS, PFPeA, PFOA, and PFHxA;
- The following PFAS are expected to be present to a lesser extent in surface water impacted by AFFF: PFBA, PFHpA, PFBS, FOSA and PFDS;
- PFOS is expected to be almost half of the PFAS total concentration;
- Branched isomer PFAS, as well as a high proportion of PFHxS and PFOS, would indicate legacy AFFF contamination;

- Short-chain PFCAs and FTSAs would indicate newer generation foams. Within industrial use of PFAS, the carbon-6 fluorotelomers, in particular 6:2 fluorotelomer sulfonate (6:2 FTS), are becoming common alternatives to PFOS and PFOA;

- Sites with more organic content in the soils are likely to have higher PFAS soil retention and, therefore, less likelihood of leaching into the surrounding surface waters;

- Sediments may act as a sink for PFOS so that PFOS may be reduced in concentration in turbid surface waters;

- Rainfall is anticipated to increase soil moisture content, reducing the soil retention of PFAS, potentially creating an increase in surface water concentrations; and

- Water catchment areas with an AFFF PFAS source likely have precursors with a carbon chain length of six, whereas water catchments with no AFFF PFAS source identified precursors with a carbon chain length of four.

When assessing the water catchments for the airports, the following other industries will be considered as potential PFAS sources, based on the literature review, which are considered for a UK setting: landfills, wastewater treatment facilities, automotive industry, metal plating, electroplating and buildings likely to have fire suppression systems such as hangers.

3. Methodology

3.1 Sampling

The sample locations aimed to achieve surface water samples from upstream and downstream of the eight civilian airports and their associated stormwater discharge points. If an upstream sample from the same river could not be obtained, a clean water sample from a stream close to the airport was collected as a background. Sample locations were agreed upon with the Environment Agency and selected based on the airports' position within the water catchment and accessibility. The dates of the sampling rounds are provided in Table 2.

Surface water samples from the rivers were collected using an extendable stainless-steel pole with a one-litre stainless steel container attached. The water was then decanted into 500-millilitre bottles provided by the laboratory.

Collected samples were placed in a cool box with ice packs whilst in transit to the laboratory under a Chain of Custody. Samples were recorded at the laboratory with temperatures ranging from 1.6 – 7.2 degrees Celsius. The laboratory used was ALS which is a UKAS-accredited laboratory. The tabulated surface water laboratory data is presented in appended Table A (Appendix A), and the laboratory certificates are presented in Appendix B.

Table 2: Surface Water Sampling Dates

Airport	**Sampling Round 1**	**Sampling Round 2**
Birmingham Airport (BHX)	9 Jan 2023	23 Jan 2023
Bournemouth Airport (BOH)	10 Jan 2023	24 Jan 2023
East Midlands Airport (EMA)	19 Jan 2023	2 Feb 2023
Leeds Bradford Airport (LBA)	17 Jan 2023	31 Jan 2023
London Gatwick Airport (LGW)	11 Jan 2023	25 Jan 2023
London Stansted Airport (STN)	12 Jan 2023	26 Jan 2023
Manchester Airport (MAN)	18 Jan 2023	1 Feb 2023
Newcastle International Airport (NCL)	16 Jan 2023	30 Jan 2023

Observations made regarding river depth, width, flow rate, flooding and turbidity at the time of sampling are presented in Table 3.

*Table 3: River Observations**

Airport & River	**Upstream**			**Downstream**			**Comments**
	River Depth (m)	**Width (m)**	**Flow**	**River Depth (m)**	**Width (m)**	**Flow**	
Birmingham – Low Brook	0.1 – 0.2	2-3	Slow	0.1	1.5	Fast	The river is narrower downstream, which could result in a faster flow. All samples were noted to be slightly turbid.
Bournemouth – Moors River	flooded	flooded	Stagnant (sampling round (SR) 1), fast (SR2)	1.5	8-9	Moderate	Flood waters sampled. No turbidity.
East Midlands – Ramset Brook (upstream) & unnamed minor stream (downstream)	0.2	3	Slow	0.1	0.5	Very slow flow	Downstream samples were noted to be slightly turbid.
Leeds Bradford – Carlton Beck (upstream) & Mosely Brook (downstream)	0.1	0.1	Slow	0.3	2	Fast	Slight turbidity on the downstream sample during sampling round 2
London Gatwick – River Mole	2	4-7	Moderate	0.3-0.5	3-4	Fast	Flooding was noted upstream in sampling round 1. Note that the water column depth in the downstream sample was lower than the upstream. Upstream samples were noted to be slightly turbid.

Airport & River	Upstream			Downstream			Comments
	River Depth (m)	**Width (m)**	**Flow**	**River Depth (m)**	**Width (m)**	**Flow**	
London Stansted – Stanstead Brook (upstream) & Pincey Brook (downstream)	0.25 - 1	2	Moderate	0.3 - 1	2 - 5	Slow	Samples were noted to be turbid in sampling round 1
Manchester – River Boling	2	1.5	Fast	1.5	10	Fast	Upstream samples were noted to be slightly turbid. Downstream samples were noted to have low turbidity.
Newcastle International – River Pont	0.2	10	Fast	0.4	6	Fast	The downstream sample in monitoring round 2 was noted to be turbid

** Observations provided by Jacobs (2023)*

3.2 Quality Assurance and Quality Control

The sampling equipment was washed before and after sampling with PFAS-free water to prevent cross-contamination.

Four trip blanks, three equipment blanks and three laboratory water samples were analysed as part of the study. To obtain the equipment blanks, PFAS-free water was rinsed over the sampling equipment and then collected for analysis. No PFAS was detected above the laboratory limit of detection (LOD) in any trip blank, equipment blank or laboratory water samples, as presented in the appended Table B (Appendix A).

Duplicates were also obtained and collected simultaneously as the parent sample in alternating 100 mL increments. Four duplicates were collected as part of the study from the downstream samples at Birmingham, Bournemouth, East Midlands and Newcastle International Airports. The relative percentage difference (RPD) between the parent and duplicate sample is presented in appended Table C (Appendix A).

The RPDs are all below 30%, indicating that the parent and duplicate samples were similar. East Midlands Airport had the highest variance between samples of 25.5 % for Linear PFOS. The sample was described as being slightly turbid. An increase in sediment in the sample could result in varying analytical results due to the ability of PFAS to partition between sediment and water. This variance is not considered to be a concern for laboratory quality.

Based on the above, the data obtained is considered to be fit for purpose.

3.3 Chemicals and Analysis

Due to analytical limitations, only a small number of PFAS can be commercially analysed (Chen *et al.*, 2020). The targeted analytes undertaken as part of this study included a total of 17 different PFAS, as indicated in Table 4. Note that PFOS was analysed three times to include total PFOS, branched PFOS and linear PFOS, totally 19 analytical results per sample. The tabulated surface water laboratory data is provided in Appendix A, and the laboratory certificates are provided in Appendix B.

Table 4: Targeted PFAS Analysis List

Analytes	**Carbon Chain Length**	**Short vs Long Chain***
Perfluorobutanoic acid (PFBA)	4	Short

Analytes	Carbon Chain Length	Short vs Long Chain*
Pentafluoropropionic acid (PFPA)	3	Short
Perfluorohexanoic acid (PFHxA)	6	Short
Perfluorobutanesulfonic acid (PFBS)	4	Short
Perfluoroheptanoic acid (PFHpA)	7	Short
6:2 fluorotelomer sulfonate (6:2 FTS)	8	N/A
Perfluorooctanoic acid (PFOA)	8	Long
Perfluorohexane sulfonate (PFHxS)	6	Long
Perfluorononanoic acid (PFNA)	9	Long
Perfluoroheptanesulfonic acid (PFHpS)	7	Long
Perfluorodecanoic acid (PFDA)	10	Long
Total Perfluorooctane sulfonate (PFOS)	8	Long
Linear PFOS	8	Long
Branched PFOS	8	Long
Perfluoroundecanoic acid (PFUnA)	11	Long
Perfluorododecanoic acid (PFDoA)	12	Long
Perfluorooctanesulfonamide (PFOSA)	8	Long
Perfluorodecane sulfonic acid (PFDS)	10	Long
Perfluoropentanesulfonic acid (PFPeS)	5	Short

** Based on the OECD definition – does not consider fluorotelomers in definition*

N/A – not applicable

3.4 Study Areas

Eight UK airports are the target of this investigation: Birmingham, Bournemouth, East Midlands, Leeds Bradford, London Gatwick, London Stansted, Manchester and Newcastle International Airports. The Environment Agency has provided the data. The sampling was undertaken by Jacobs, an environmental consultancy, in January and February 2023 and comprised two sampling rounds. The approximate outline of the airports is shown in the figures in the following sections as a solid polygon shape.

Sampling of surface water was undertaken both upstream and downstream of airports. The sampling locations were decided based on the following:

- Water catchment geometry within which the airport resides;
- Accessibility of the sampling location;
- Location of the airports' discharge point(s);
- Proximity to the airport to reduce the likelihood of a separate non-airport PFAS source impacting the surface water between the upstream and downstream samples; and
- Location of the FTAs.

3.5 Data Sources

To assist in the development of the conceptual models for the airports and in the interpretation of the results, Table 5 details the data sources used.

Table 5: Data Sources

Reference	Purpose
BGS (2023)	GeoIndex website - information on superficial and bedrock geology, as well as aquifer yields
DEFRA (2023a)	MAGIC website - information on the aquifer designations and source protection zones (SPZ)
Environment Agency (2023b)	Catchment Data Explorer website - provides information on the water catchment names and catchment shape files

Defra (2023b)	Defra Survey Data Download website – provided the LIDAR shapefiles to use in the QGIS 3.32.0, software which was used to generate the figures
Jacobs (2023)	Provided the location of discharge points for the airport, as well as information on sampling locations, dates and laboratory data

3.6 Generic Information

3.6.1 Aquifer Designations

Table 6 outlines the aquifer definitions are taken from the Environment Agency's guidance 'Protect groundwater and prevent groundwater pollution' (2017).

Table 6: Aquifer Designations

Aquifer Designation	**Description**
Principal aquifer	*'provide significant quantities of drinking water and water for business needs. They may also support rivers, lakes and wetlands'.*
Secondary A aquifer	*'comprise permeable layers that can support local water supplies and may form an important source of base flow to rivers'.*
Secondary B aquifer	'*mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers.'*
Secondary Undifferentiated aquifer	*'are aquifers where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value'.*
Unproductive Strata	*'largely unable to provide usable water supplies and are unlikely to have surface water and wetland ecosystems dependent on them'*

For the purpose of this assessment, if a FTA is located on a Principal or Secondary A aquifer, it is likely that any PFAS soil source could leach into the groundwater and be transported long distances and provide baseflow to any adjacent surface water feature. A PFAS groundwater plume is less likely to provide river baseflow for a Secondary B or undifferentiated aquifer due to discontinuous groundwater and slow migration. Groundwater migration of a PFAS plume is not considered a potential surface water PFAS source for unproductive strata. An unproductive stratum is likely to increase the amount of surface water runoff as the ground will be less permeable.

3.6.1 Source Protection Zones

A SPZ protects a groundwater abstraction borehole, and if an airport is within an SPZ, groundwater flow may be influenced by the groundwater abstraction, altering natural flow patterns. The EA (2023a) state '*Source Protection Zones (SPZs) are defined around large and public potable groundwater abstraction sites. The purpose of SPZs is to provide additional protection to safeguard drinking water quality through constraining the proximity of an activity that may impact upon a drinking water'*;

Following a search on Defra's MAGIC website (2023a), no airport is located within one kilometre of an SPZ. Therefore, it is unlikely that groundwater flow direction will be altered by groundwater abstraction.

3.6.1 LIDAR Figures

For the figures within Section 4, the base maps used were sourced from Google Satellite within the QGIS software. For the LIDAR data, topographically highs are coloured red and topographical lows are coloured green. The legend for the topography is in metres Above Ordnance Datum (m AOD).

4. Conceptual Models & Results

4.1 Birmingham Airport (BHX)

4.1.1 Geology, Hydrogeology and Hydrology

There is no continuous superficial geology underneath Birmingham Airport. Alluvium, described as clay, silt, sand and gravel, is identified in the eastern and northern areas, with River Terrace Deposits (RTD) (sand and gravel) also noted in the northern area of the airport (BGS, 2023). The superficial geology is not a classified aquifer (DEFRA, 2023a).

Bedrock comprises the Sidmouth Mudstone Formation across the majority of the site, described as a mudstone. The southern and eastern areas of the airport are underlain by either the Arden Sandstone Formation, described as sandstone, siltstone and mudstone or the Branscombe Mudstone Formation, described as a mudstone (BGS, 2023). These formations are classified as Secondary B aquifers with low productivity of less than 0.5 L/s (DEFRA, 2023a).

The FTA is located in the western part of the airport. No superficial deposits are located under the FTA; any runoff will be to Made Ground and then the bedrock (the Secondary B aquifer). Due to the bedrock classification, groundwater migration is anticipated to be slow. Surface water adjacent to the airport is more likely to be affected by surface water runoff and discharge from drainage rather than contaminated baseflow. The airport's discharge point is located in the eastern part of the airport and discharges into the Low Brook, just upstream from the downstream sample.

The majority of Birmingham Airport is located within the Hatchford-Kingsburst Brook to River Cole water catchment, shown in Figure 9 by the blue dashed line. A small portion of the airport in the east is located in the Blythe to River Tame water catchment, shown by the dashed red line (EA, 2023b). The water catchment indicates that runoff from the majority of the airport will be to the north or northeast.

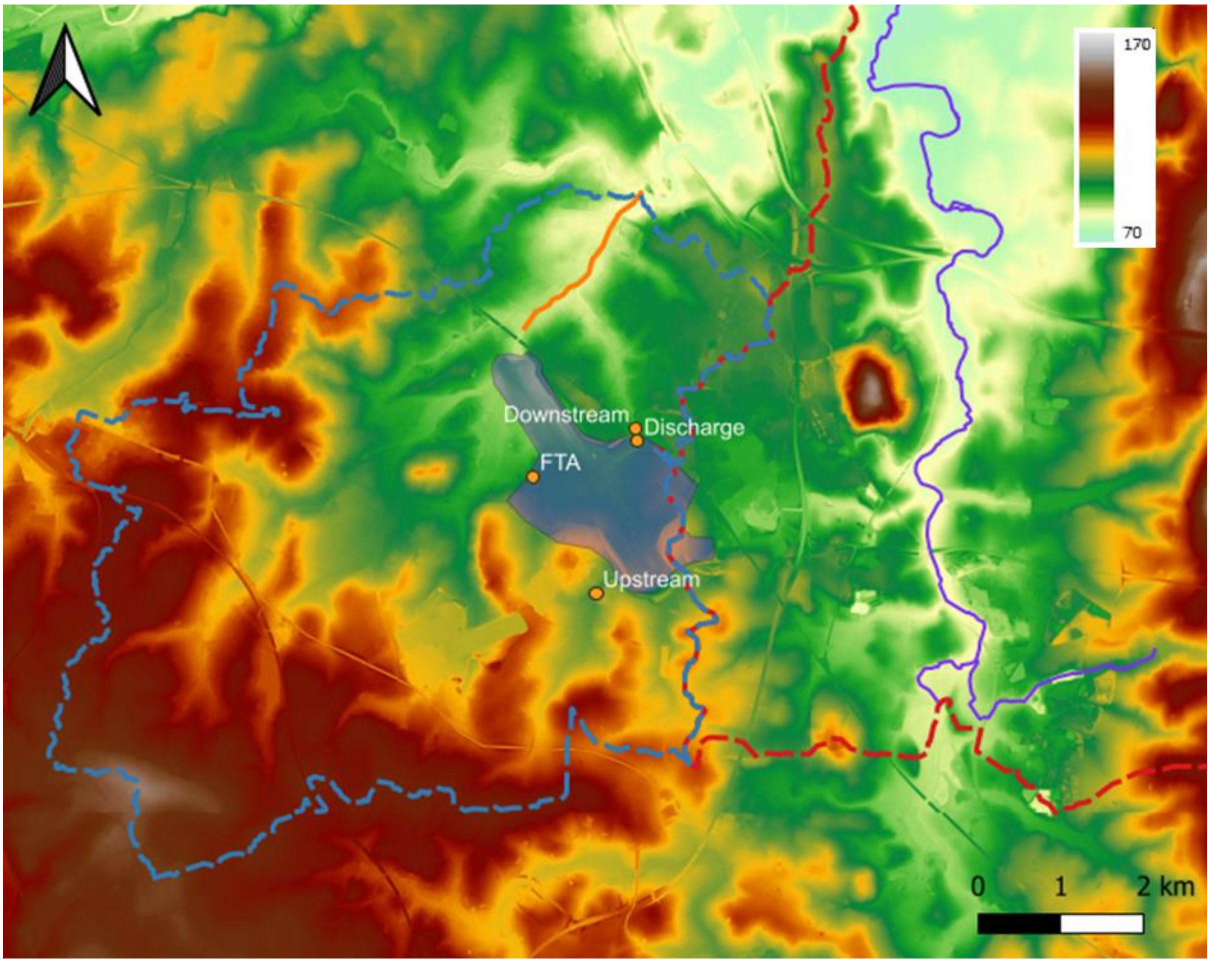


Figure 9: Birmingham Airport Water Catchment (Google Satellite, QGIS output)

4.1.1 Sampling Observations

The stream being sampled is called the Low Brook. The Low Brook is a shallow river with dimensions presented in Table 3. The Low Brook enters the airport from the south and exits the airport in the north, flowing roughly from south to north. The airport discharge point is located in the eastern part of the airport just prior to the brook exiting the airport.

Figure 10 shows an aerial image of Birmingham Airport. Based on the water catchments and the brook position, the sample locations are well located to analyse the potential PFAS loading from the airport source. There are no other potential PFAS sources between the upstream and downstream sample locations apart from the airport. The observed industry to the east is in another water catchment (indicated by the red/blue line), so runoff would flow to the east rather than to the downstream sampling location. Any increase in PFAS concentration in the downstream sample can be attributed to the airport.

The following pertinent observations, in addition to those made in Table 3, were made during sampling:

- The downstream sample in sampling round 1 was noted to be frothing. This could be an indication of PFAS contamination; and
- Oil was noted on the riverbank on the upstream sample during the second sampling round.

Figure 10: Aerial imagery of Birmingham Airport (Google Satellite, QGIS output)

4.1.2 Results

Figure 11 shows an increase in PFAS concentrations between the upstream and downstream samples for both sampling rounds. The graph indicates that PFOS and PFHxS concentrations contribute a large proportion of the total measured PFAS concentrations. These compounds are both indicative of legacy AFFF use. For the purpose of the assessment of the results, thereported concentrations that were below the laboratory LOD have not been included in Figure 11. Tabulated data is presented in Table A in Appendix A.

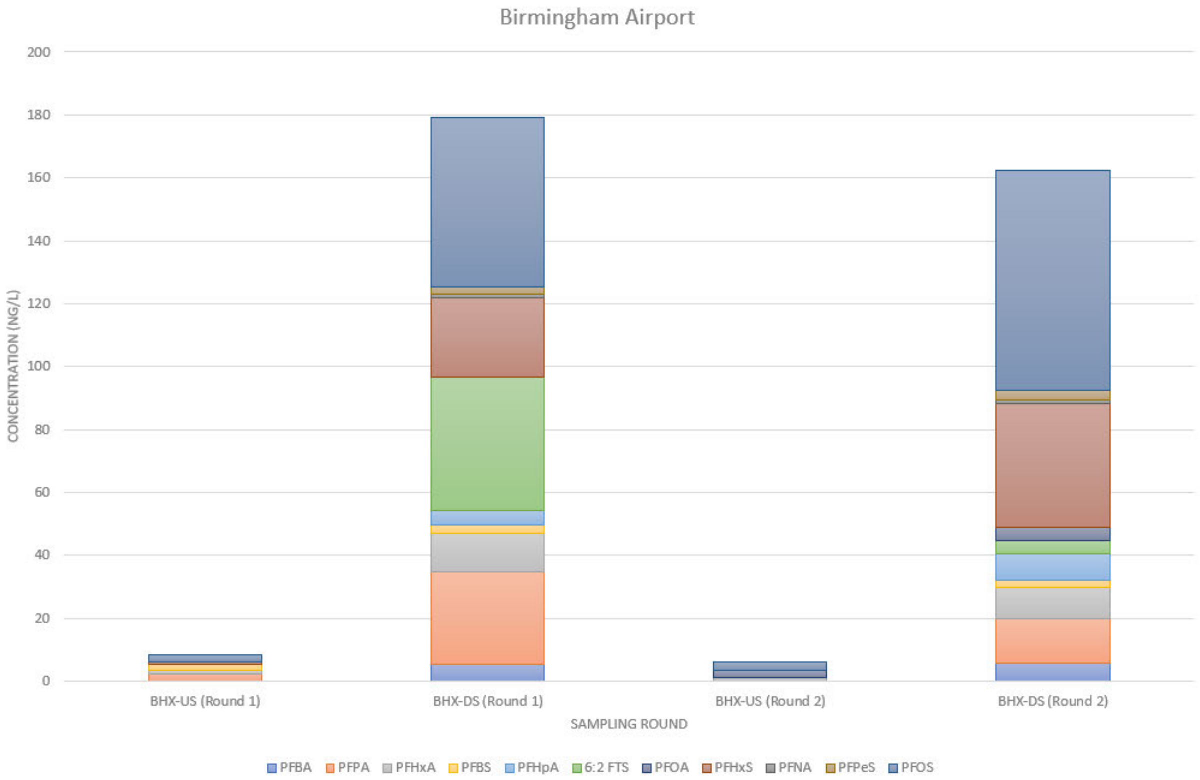


Figure 11: Birmingham Airport Surface Water PFAS Concentrations

The largest percentage increase between the upstream and downstream samples has been calculated as a 4140% increase in the downstream sample concentration of 6:2 FTS in sampling round 1, as presented in Figure 12. During sampling round 2, the percentage increase in 6:2 FTS was calculated as 300%. During sampling round 1, Low Brook was noted to be frothing which could be a reason for the larger percentage increase observed in the 6:2 FTS concentration.

Large percentage increases are identified for 6:2 FTS, PFHxS and PFOS, which does potentially indicate legacy AFFF use impacts within the surface water. Tabulated percentage differences are presented in Table D in Appendix A.

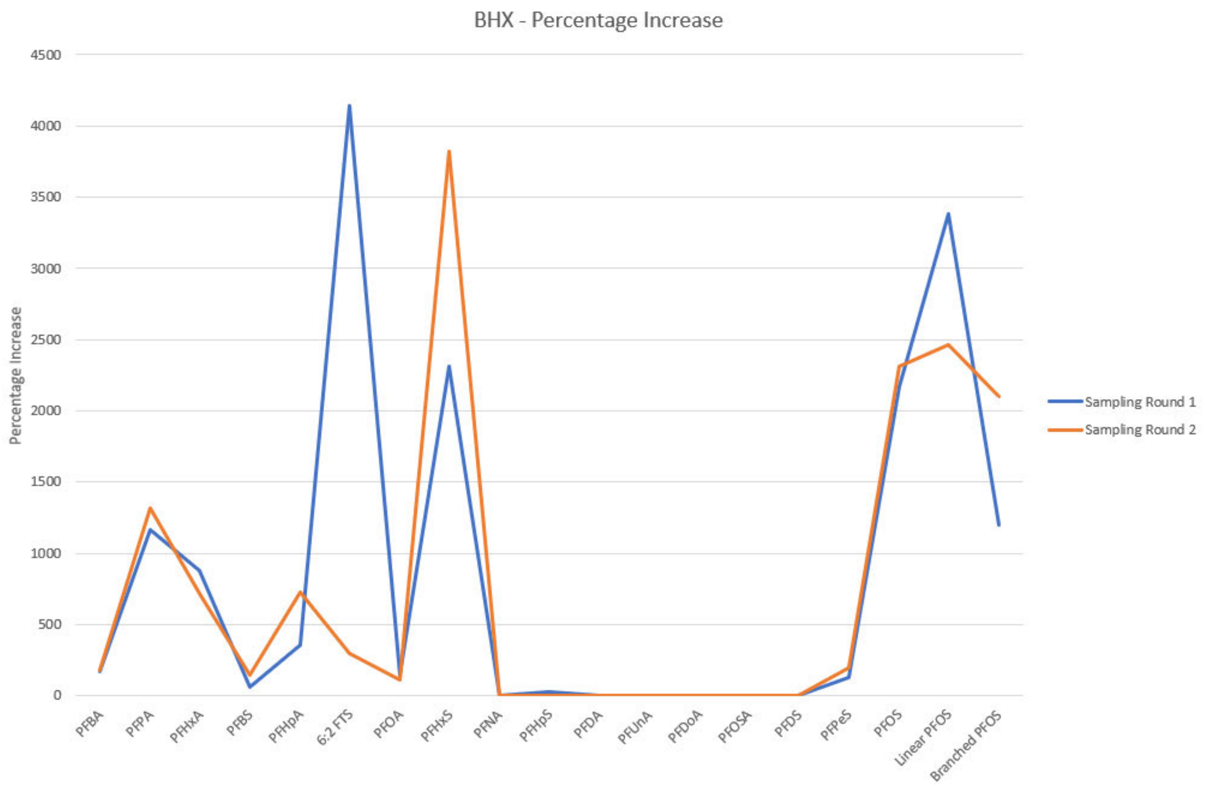


Figure 12: Birmingham Airport Percentage Increase in PFAS Concentrations

A p-value was calculated to determine the statistical significance between the upstream and downstream samples in each monitoring round. A p-value of less than 5 % indicates that the differences in the results are significant. The calculated p-values for the two sampling rounds at Birmingham Airport are presented in Table 7. The one and two-tail p-values calculated for the samples collected from adjacent to Birmingham Airport indicate that there is a statistical difference between the upstream and downstream PFAS concentrations.

Table 7: P-value Birmingham Airport (t-test: paired two samples for means)

	BHX-US-R1	*BHX-DS-R1*	*BHX-US-R2*	*BHX-DS-R2*
Mean concentration of total PFAS	1.37	12.87	1.32	12.59
Variance between PFAS concentrations within a sample	0.25	271.89	0.30	359.29
Observations (no. of PFAS sampled)	19	19	19	19
Pearson Correlation	0.32		0.57	
Hypothesized Mean Difference between upstream and downstream samples	0		0	

	BHX-US-R1	*BHX-DS-R1*	*BHX-US-R2*	*BHX-DS-R2*
Df	18		18	
t Stat	-3.07		-2.63	
P(T<=t) one-tail	**0.3%**		**0.8%**	
t Critical one-tail	1.73		1.73	
P(T<=t) two-tail	**0.7%**		**1.7%**	
t Critical two-tail	2.10		2.10	

4.2 Bournemouth Airport (BOH)

4.2.1 Geology, Hydrogeology and Hydrology

Bournemouth Airport is underlain by superficial deposits of River Terrace Deposits (RTD), described as sand and gravel. Alluvium deposits are present in the eastern part of the airport, described as clay, silt, sand and gravel (BGS, 2023). The FTA is in the western part of the airport, underlain by the RTD. The superficial deposits are classified as a Secondary A aquifer (DEFRA, 2023a). Groundwater within the RTD is likely to provide baseflow into the river, and the RTD are unlikely to have a high organic content; therefore, PFAS are more likely to partition to the aqueous phase.

The Branksome Sand Formation, described as sand, is in the northern portion of the airport and the Poole Formation, described as sand, silt and clay is in the southern portion of the airport. The bedrock aquifer is moderately productive with variable yields due to the aquifer being multi-layered (BGS, 2023). The bedrock aquifer is classified as a Secondary A aquifer (DEFRA, 2023a).

The majority of Bournemouth Airport is located within the Moor Water catchment, shown in Figure 13 by the blue dashed line. A small portion of the airport in the southwest is located in the Stour (Lower) water catchment shown by the dashed red line (EA, 2023b). The water catchment indicates that runoff from the airport and FTA will be southeast towards the River Moor, whereas the airport discharge point is located in a different water catchment.

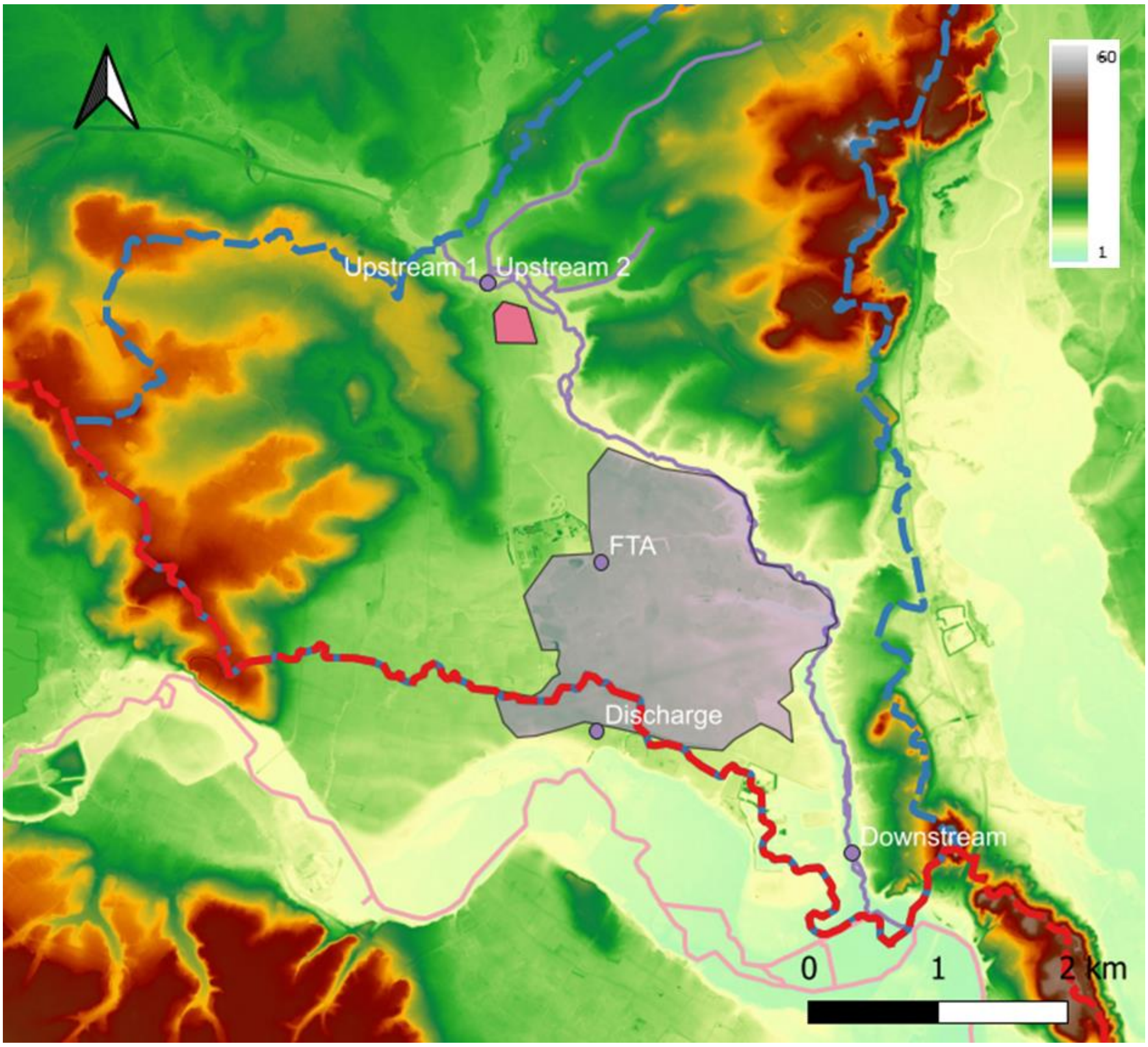


Figure 13: Bournemouth Airport Water Catchment (Google Satellite, QGIS output)

4.2.2 Sampling Observations

The stream being sampled is called the Moors River (shown as a solid purple line in Figure 14), with observations provided in Table 3. The Moors River borders the airport's eastern boundary flowing from northwest to southeast.

The airport discharge point is located in the western part of the airport into a tributary of the River Stour. The collected surface water samples on the downstream part of the Moors River will not be affected by the airport discharge, as the discharge is into a different water catchment, and the River Stour joins the Moors River farther downstream than sampled.

The upstream samples are located to the north of a wastewater treatment plant (WWTP), shown as a pink polygon in Figure 14, which is a potential other source of PFAS. This upstream location was selected due to access issues closer to the airport.

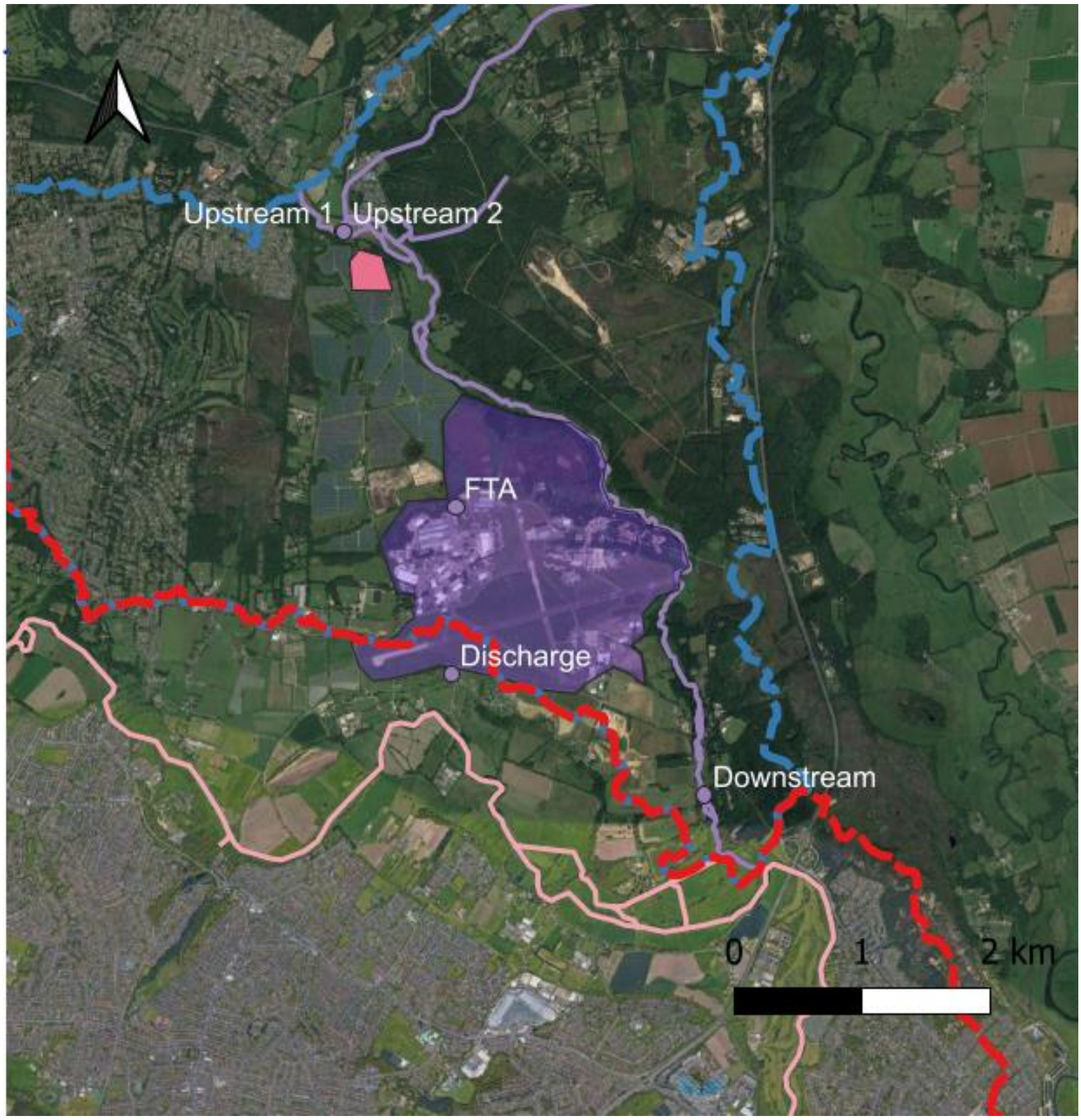


Figure 14: Aerial imagery of Bournemouth Airport (Google Satellite, QGIS output)

4.2.3 Results

The Moors River was noted to be flooded and stagnant in the upstream location during sampling round 1. The flooding does not appear to have made an impact on the results.

The graph presented in Figure 15 shows an increase in PFAS concentrations between the upstream and downstream samples for both sampling rounds, though the upstream sample concentrations are relatively high. The increase in 6:2 FTS in the downstream samples is the most notable difference between the sample locations. For the purpose of the assessment of the results, the reported concentrations that were below the laboratory LOD have not been included in Figure 15. Tabulated data is presented in Table A in Appendix A.

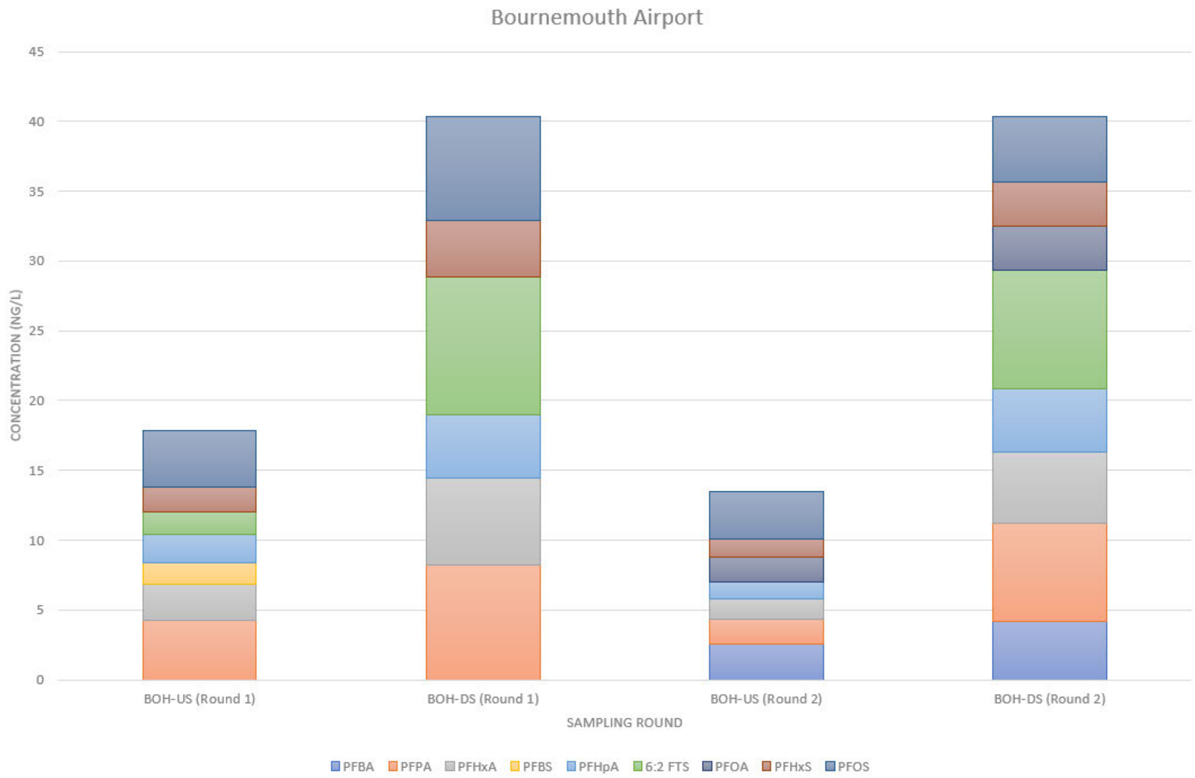


Figure 15: Bournemouth Airport Surface Water PFAS Concentrations

There was an increase of 756% in the concentration of 6:2 FTS in the downstream sample relative to the upstream sample in sampling round 2, as presented in Figure 16. Though other PFAS concentrations observed an increase, these increases were not as large. There is an observed increase in PFOS in the downstream samples, which may indicate that the airport is a potential source, as well as increases in PFPA and PFHxS. Tabulated percentage differences are presented in Table D in Appendix A.

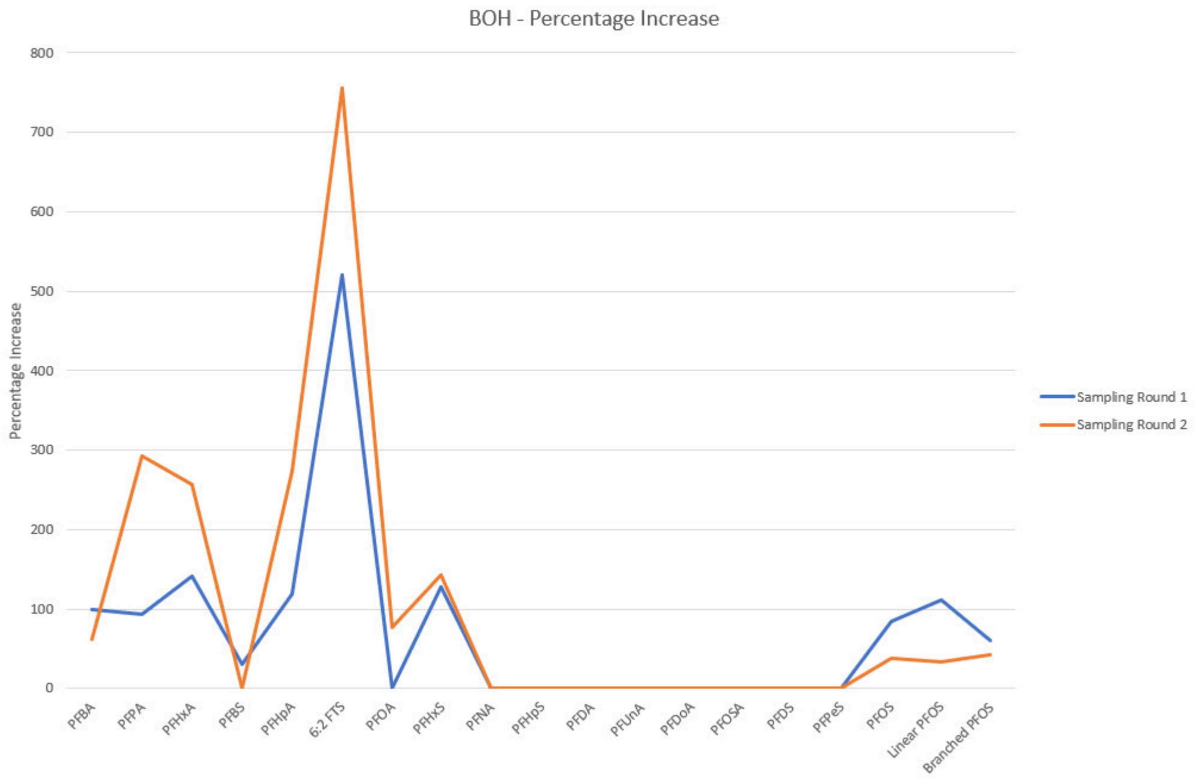


Figure 16: Bournemouth Airport Percentage Increase in PFAS Concentrations

The one and two-tail p-values calculated for the samples collected from Bournemouth Airport are below 5%, as shown in Table 8. This indicates that there is a statistical difference between the upstream and downstream PFAS concentrations.

Table 8: P-value Bournemouth Airport (t-test: paired two samples for means)

	BOH-US-R1	*BOH-DS-R1*	*BOH-US-R2*	*BOH-DS-R2*
Mean concentration of total PFAS	1.15	2.51	0.89	2.37
Variance between PFAS concentrations within a sample	2.01	11.29	1.13	7.36
Observations (no. of PFAS sampled)	19	19	19	19
Pearson Correlation	0.85		0.57	
Hypothesized Mean Difference between upstream and downstream samples	0		0	
Df	18		18	
t Stat	-2.60		-2.83	

	BOH-US-R1	*BOH-DS-R1*	*BOH-US-R2*	*BOH-DS-R2*
P(T<=t) one-tail	**0.9%**		**0.6%**	
t Critical one-tail	1.73		1.73	
P(T<=t) two-tail	**1.8%**		**1.1%**	
t Critical two-tail	2.10		2.10	

4.3 East Midlands Airport (EMA)

4.3.1 Geology, Hydrogeology and Hydrology

There are no superficial deposits at the airport and bedrock comprises the Gunthorpe Member, described as a mudstone with parts described as siltstone and dolomitic, in the northern and eastern areas of the airport. The Diseworth Sandstone Formation, described as a sandstone, is present in the east and west of the airport. The bedrock is described as a low-productivity aquifer with yields of less than 0.5 L/s of water (BGS, 2023). The FTA is underlain by the siltstone and dolomitic part of the Gunthorpe Member, located in the northern part of the airport.

The bedrock aquifer is classified as a Secondary B aquifer (DEFRA, 2023a). Based on the aquifer designation, the groundwater migration pathway is not considered to be a significant pathway. Runoff or direct discharge are considered more important pathways for East Midlands Airport's conceptual model.

The airport is located on a water catchment divide, as shown in Figure 17. The majority of the airport is located in the Long Whatton Brook Catchment, shown by the blue dashed line, within which the airport discharge occurs. The upstream sample was collected from the Ramsley Brook from Source to Carr-New Brook catchment (orange dashed line), whereas the downstream sample was collected from the Hemington Brook Catchment (red dashed line) (EA, 2023b). The latter is also the catchment upon which the FTA is just located.

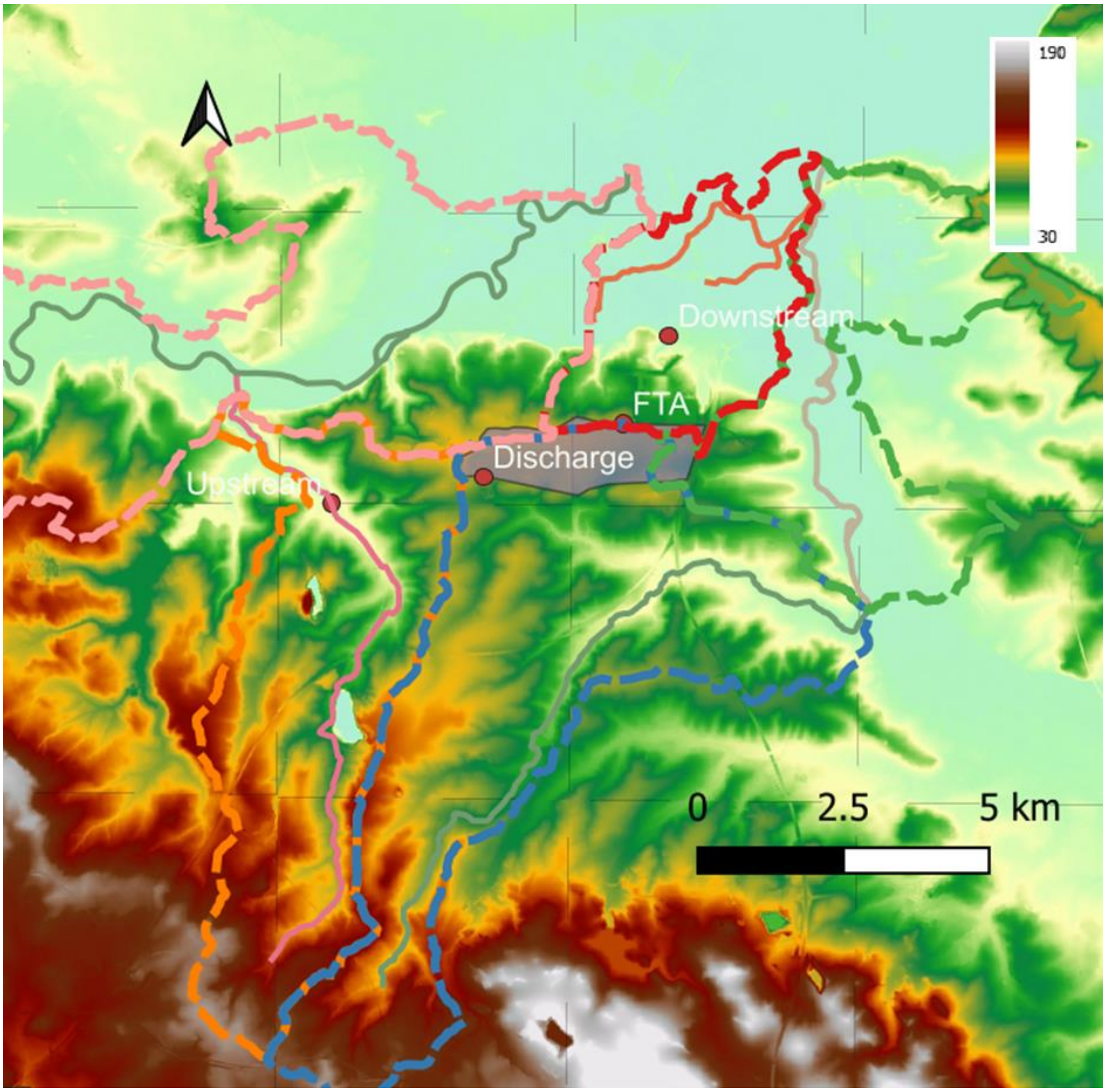


Figure 17: East Midlands Airport Water Catchments (Google Satellite, QGIS output)

4.3.2 Sampling Observations

The upstream surface water sample was collected from Ramsey Brook, and the downstream surface water sample was collected from an unnamed minor stream. Observations are presented in Table 3. The streams are not connected and are located within different water catchments. The discharge point is in the southwestern part of the airport and discharges into a stream which is in a different water catchment to the upstream and downstream samples. The sampling locations are shown in Figure 18.

Drainage outflows were noted at both the upstream and downstream sampling locations, though where the outflows drain from is unknown.

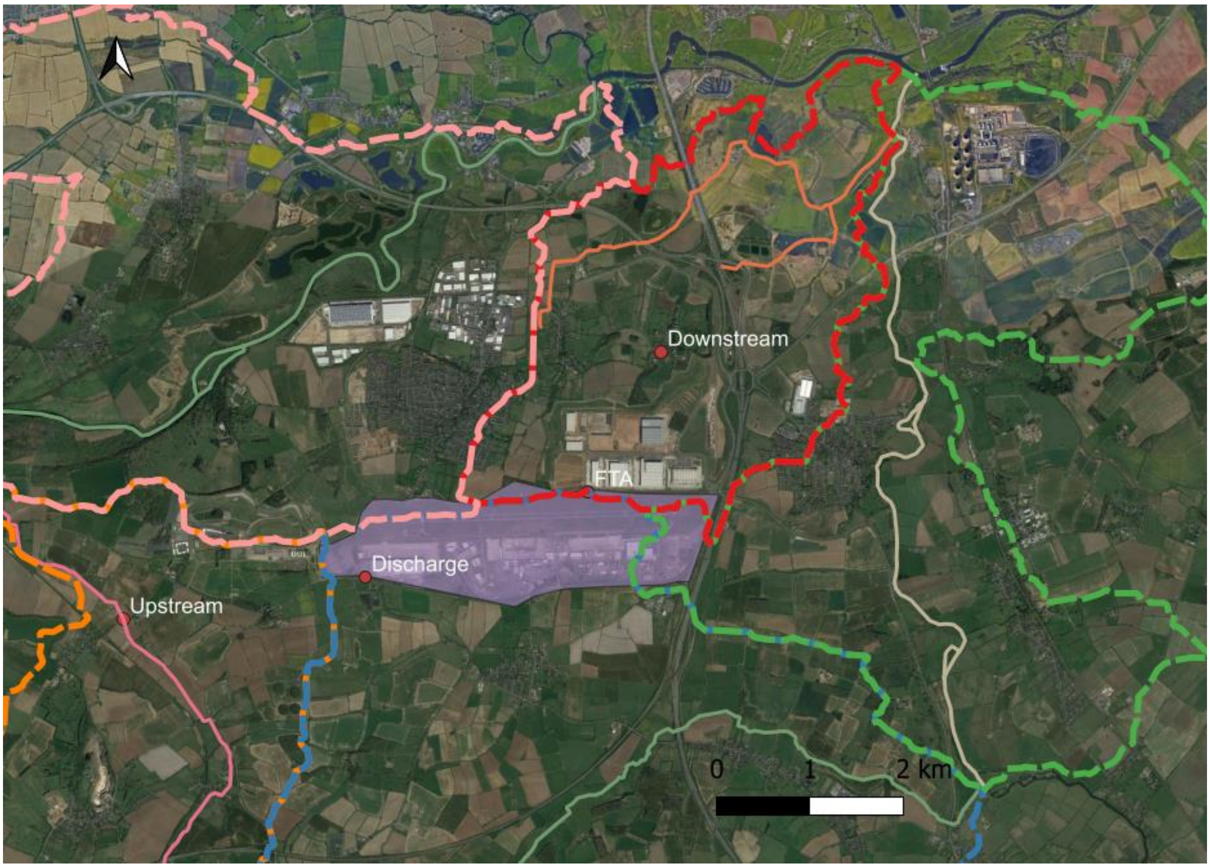


Figure 18: Aerial imagery of East Midlands Airport (Google Satellite, QGIS output)

4.3.3 Results

The upstream and downstream samples are not collected from the same stream or water catchment; therefore, without knowing the upstream PFAS concentration from the same stream, attributing the airport's contribution of PFAS to the stream is more difficult. The upstream sample location should have minimal runoff from the airport so it could be representative of the background in the area. The downstream unnamed surface water feature appears to originate from the airport, so any PFAS contamination is most likely sourced from the airport.

The airport is the topographical high for the Hemington Brook Catchment, therefore further reducing the likelihood of another PFAS source contributor for downstream surface water. Any runoff associated with the FTA should migrate to the north towards the downstream sample location. The industry present between the FTA and the downstream sample location appears to be delivery depots which should not be a PFAS source. It is unknown what the drainage outflows noted near the sampling locations are related to.

The airport discharge point is discharging into a different water catchment to the upstream sample location, so it should not be affecting the PFAS upstream/background concentrations.

Figure 19 shows the PFAS concentrations detected in surface water. A large difference is observed between the upstream and downstream samples, as well as between the two downstream sampling rounds. Nothing in the sampling notes indicates why the downstream sample concentrations might be so different between the two sampling rounds. The difference between the two downstream samples could be due to heavy rainfall prior to sampling round 1 causing an increase in soil moisture content and PFAS partitioning into the aqueous phase, though nothing in the sampling notes suggests that heavy rainfall had occurred prior to sampling. There is also a limited amount of PFOS in the downstream samples with 6:2 FTS forming a large percentage of the total tested PFAS in sampling round 1. The fluorotelomer 6:2 FTS is used in newer foam formulations, as a replacement for PFOS and PFOA (Lu *et al.,* 2017) so the large percentage of 6:2 FTS could indicate more contemporary AFFF contamination. However, there is an inconsistency between sampling rounds and the difference in apparent PFAS chemistry than other airports does suggest that there may be a different PFAS source that is not from AFFF use during firefighting activities.

For the purpose of the assessment of the results, the reported concentrations that were below the laboratory LOD have not been included in Figure 19. Tabulated data is presented in Table A in Appendix A.

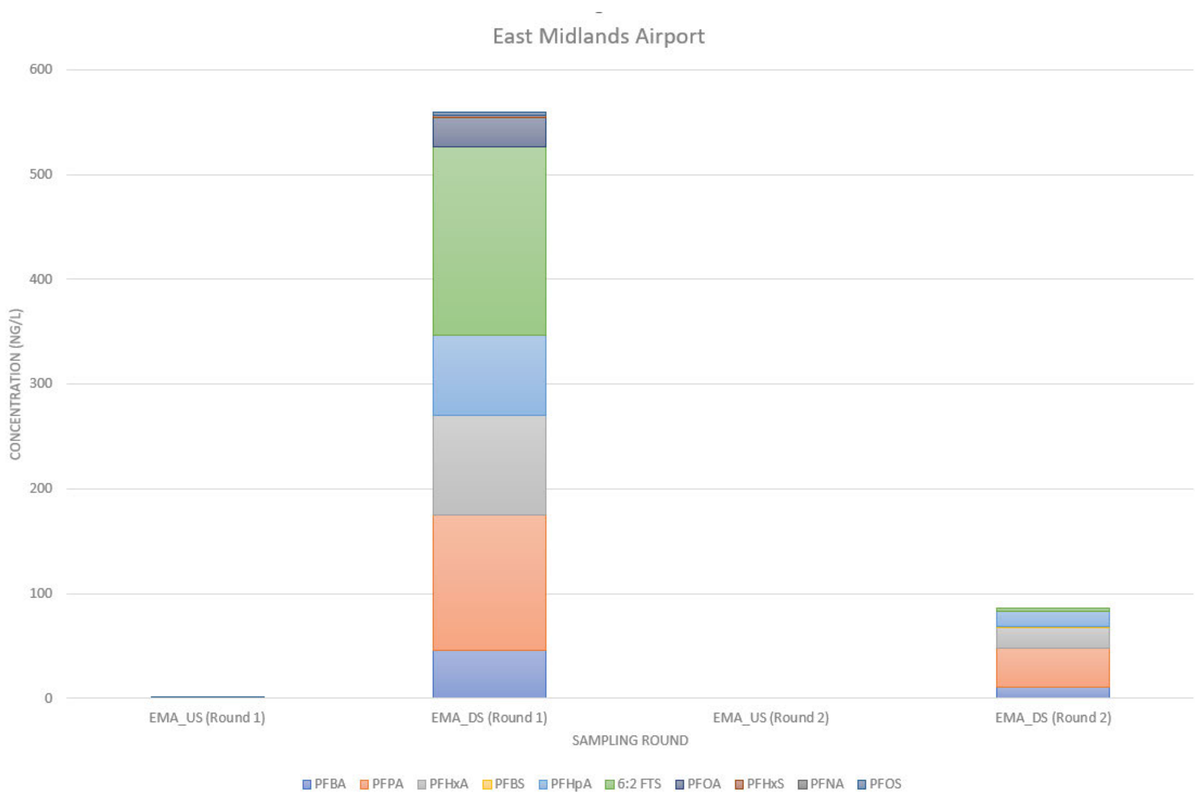


Figure 19: East Midlands Airport Surface Water PFAS Concentrations

The observed percentage increases between the downstream and upstream samples are presented in Figure 20. Within the first sampling round, large increases are seen in PFPA and 6:2 FTS. The second sampling round indicates increases in PFPA and PFHxA. It is unclear if the chemical fingerprint indicates an AFFF source as only small amounts of PFOS, PFHxS and PFOA are encountered, which are expected to be dominant compounds within legacy AFFF. Tabulated percentage differences are presented in Table D in Appendix A.

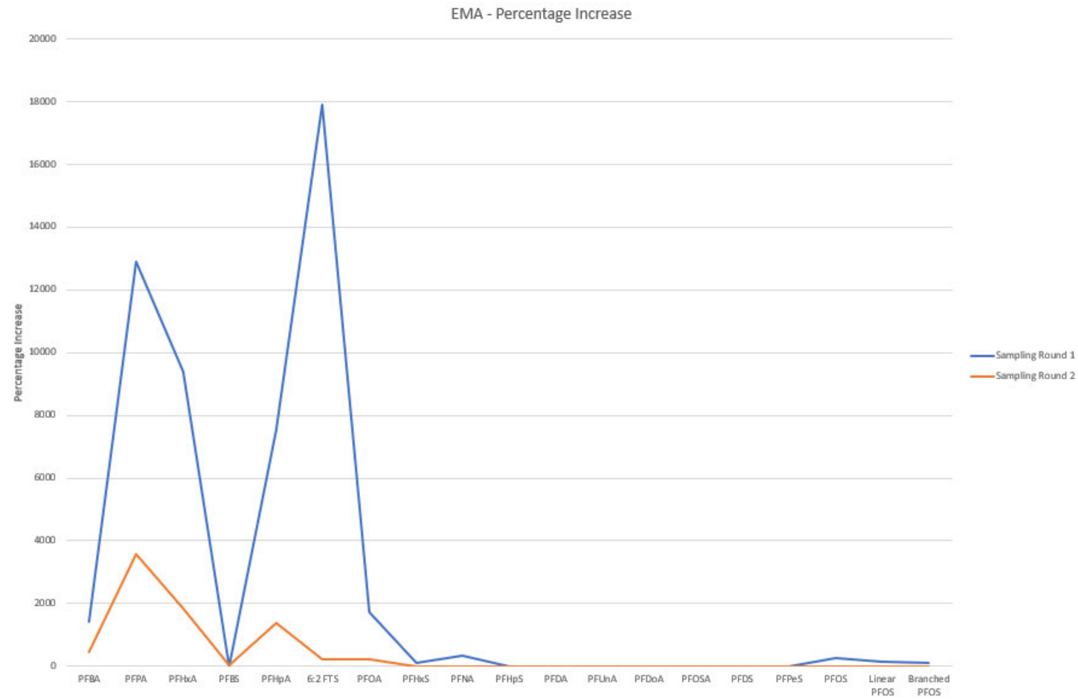


Figure 20: East Midlands Airport Percentage Increase in PFAS Concentrations

The one-tail p-values calculated for the samples collected from East Midlands Airport, presented in Table 9, indicate that there is a statistical difference between the upstream and downstream PFAS concentrations. However, on the second sampling round, the two-tail p-value indicates that the results may not be significantly different as the p-value is greater than 5%. This correlates with the difference in concentrations observed between the two different downstream samples collected.

Table 9: P-value East Midlands Airport (t-test: paired two samples for means)

	EMA-US-R1	*EMA-DS-R1*	*EMA-US-R2*	*EMA-DS-R2*
Mean concentration of total PFAS	1.16	30.34	1.06	5.40
Variance between PFAS concentrations within a sample	0.27	2752.07	0.13	87.32
Observations (no. of PFAS sampled)	19	19	19	19
Pearson Correlation	0.03		0.11	
Hypothesized Mean Difference between upstream and downstream samples	0		0	
df	18		18	
t Stat	-2.43		-2.03	

	EMA-US-R1	*EMA-DS-R1*	*EMA-US-R2*	*EMA-DS-R2*
P(T<=t) one-tail	**1.3%**		**2.9%**	
t Critical one-tail	1.73		1.73	
P(T<=t) two-tail	**2.6%**		**5.7%**	
t Critical two-tail	2.10		2.10	

4.4 Leeds Bradford Airport (LBA)

4.4.1 Geology, Hydrogeology and Hydrology

Superficial deposits of Till (diamicton) underly the majority of the southern and western portions of the airport. In the north, there are superficial deposits of Hummocky (Moundy) Glacial Deposits, also described as a diamicton (BGS, 2023). The FTA is underlain by the Till, located in the southeastern part of the airport. The superficial aquifer is classified as a Secondary (undifferentiated) aquifer (DEFRA, 2023a). It is likely that the Till will be clay-based and have a high organic content which could increase the amount of PFAS within the soil.

Pennine Lower Coal Measures, described as sandstone, mudstone and siltstone, underly the southern part of the airport. The northern part of the airport is underlain by Rough Rock, described as a sandstone, with a small portion of Millstone Grit Group described as a mudstone, siltstone and sandstone. The bedrock is described as a moderately productive multi-layered aquifer, typically yielding 5-10 L/s in the northern part of the site. The southern part of the site is also described as a moderately productive aquifer though no yield rates are provided (BGS, 2023). The bedrock aquifer is classified as a Secondary A aquifer (DEFRA, 2023a).

The Till is unlikely to have a continuous groundwater body; therefore, groundwater migration is an unlikely pathway for a PFAS plume to a surface water receptor. Therefore, any PFAS impacts likely to be caused by the airport in surface water would be sourced from runoff or direct discharge.

The majority of LBA is situated in the Carlton Beck water catchment (dashed red line), as shown in Figure 21. The western corner of the airport is located in the Gill Beck Guisley water catchment (dashed blue line) (EA, 2023b). For this airport, the upstream, downstream, discharge point and FTA are all located within the same catchment.

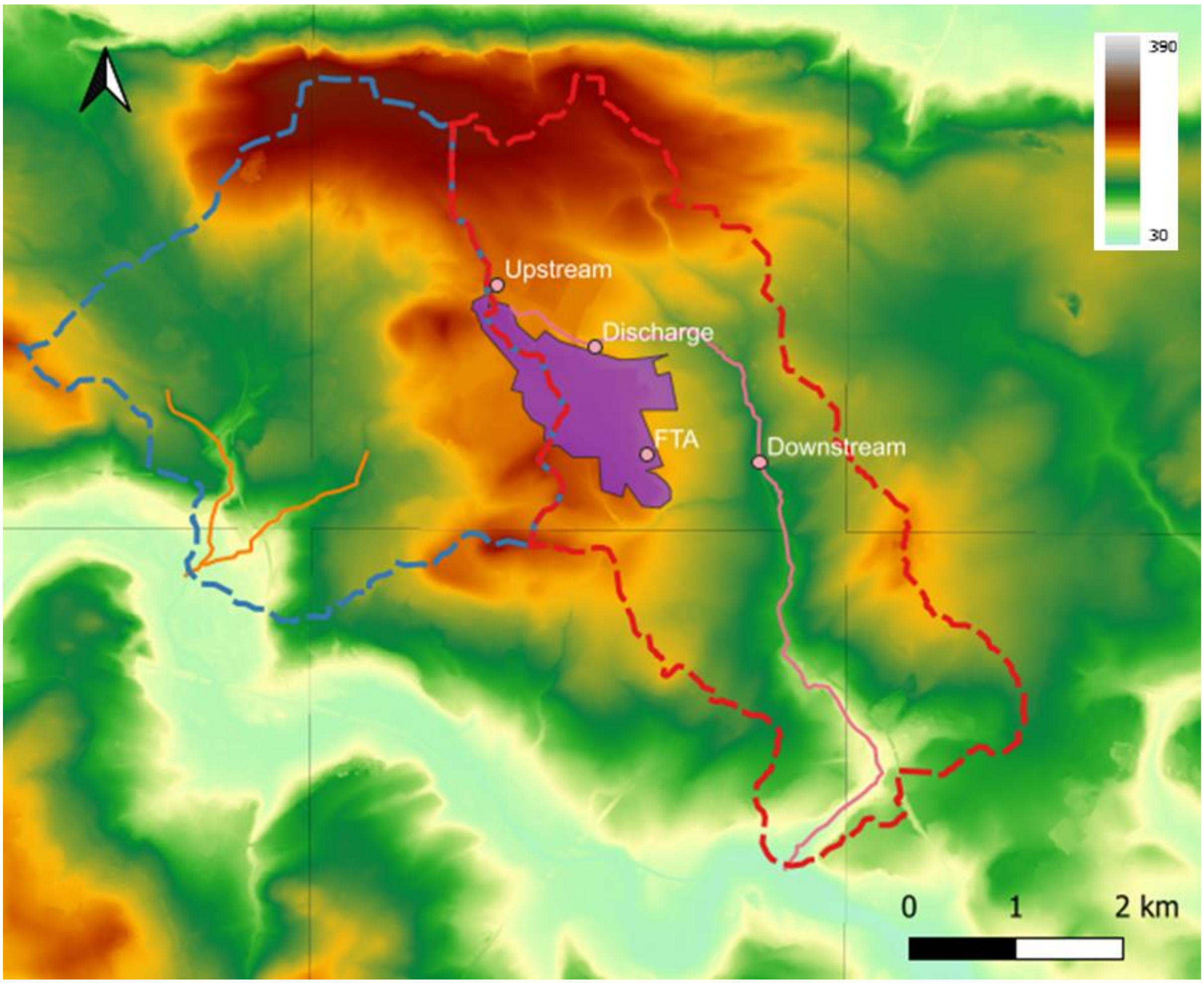


Figure 21: Leeds Bradford Airport Water Catchments (Google Satellite, QGIS output)

4.4.2 Sampling Observations

The upstream samples were collected from the Carlton Beck, which borders the airport's northern boundary flowing from northwest to southeast. The Carlton Beck flows into the Mosely Brook, which is where the downstream samples were collected. The Moseley Brook is to the east of the airport flowing from north to south, with the sampling location in an artificial brick-built channel. The airport discharge point is located in the northern part of the airport into the Carlton Beck. The brick-built channel is not considered to be an issue as the discharge point is to the river, and runoff can still occur. The sampling locations are shown in Figure 22, and river observations are provided in Table 3.

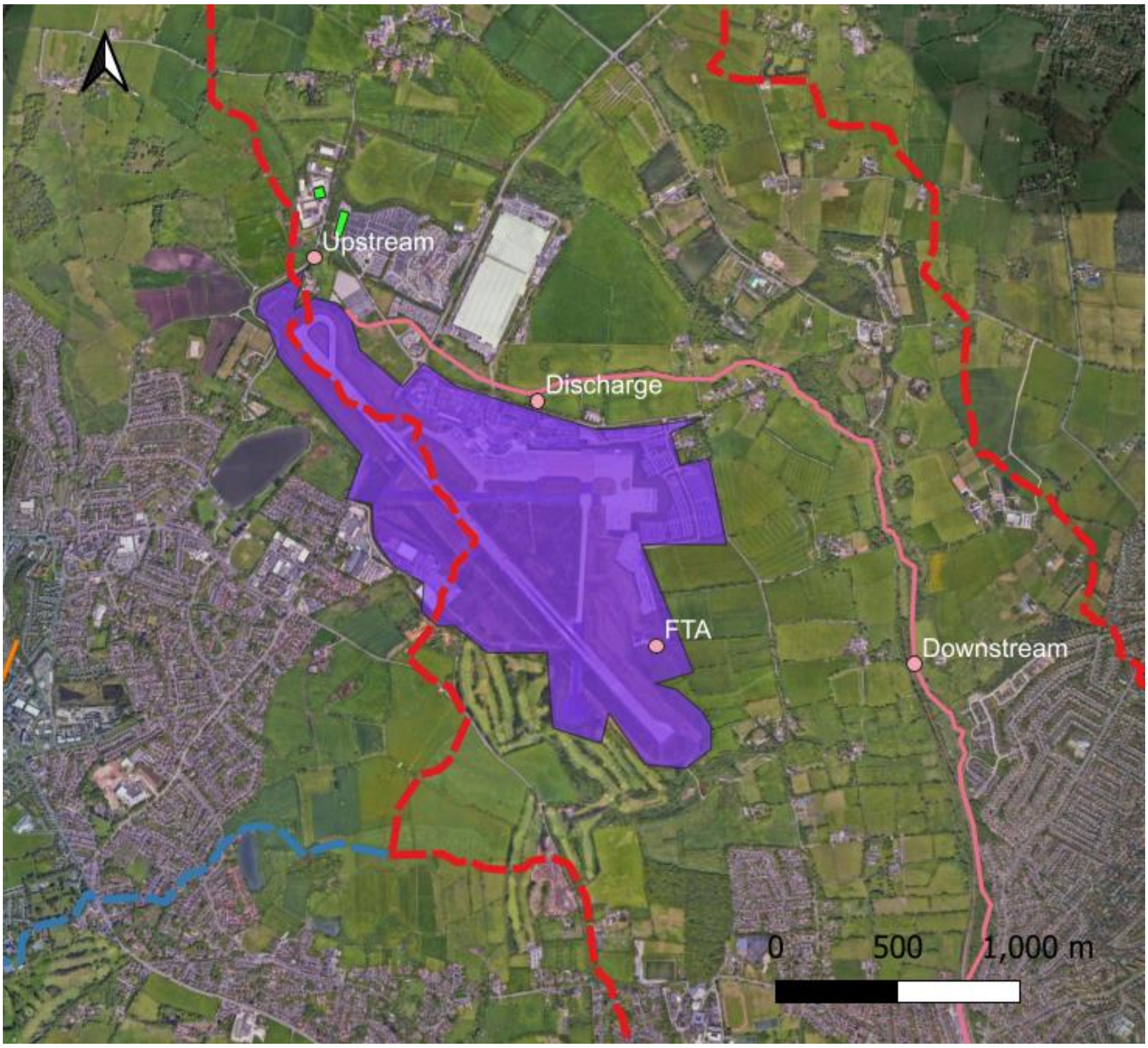


Figure 22: Aerial imagery of Leeds Bradford Airport (Google Satellite, QGIS output)

4.4.3 Results

The difference between the upstream and downstream samples at Leeds Bradford Airport is shown in Figure 23. The literature review indicated that PFAS could partition into sediment; however, the observation regarding the downstream sample in the second sampling round being slightly turbid does not appear to have increased the PFAS sample concentration. It is likely that the sample was filtered prior to analysis. During transit, PFAS within the aqueous phase could have partitioned to sediment in the sampling container, which could have resulted in the lower concentrations observed in the second monitoring round.

The upstream samples in both sampling rounds appear to be elevated. Two potential PFAS sources have been identified close to the upstream sample location, which have been highlighted in green in Figure 22. These are a metal finisher and Jet2 stores. As well as AFFF being used at the FTA on airports, it is typically also stored and used in aircraft hangers and stores for other fire suppression systems and well as in metal finishing.

For the purpose of the assessment of the results, the reported concentrations that were below the laboratory LOD have not been included in Figure 23. Tabulated data is presented in Table A in Appendix A.

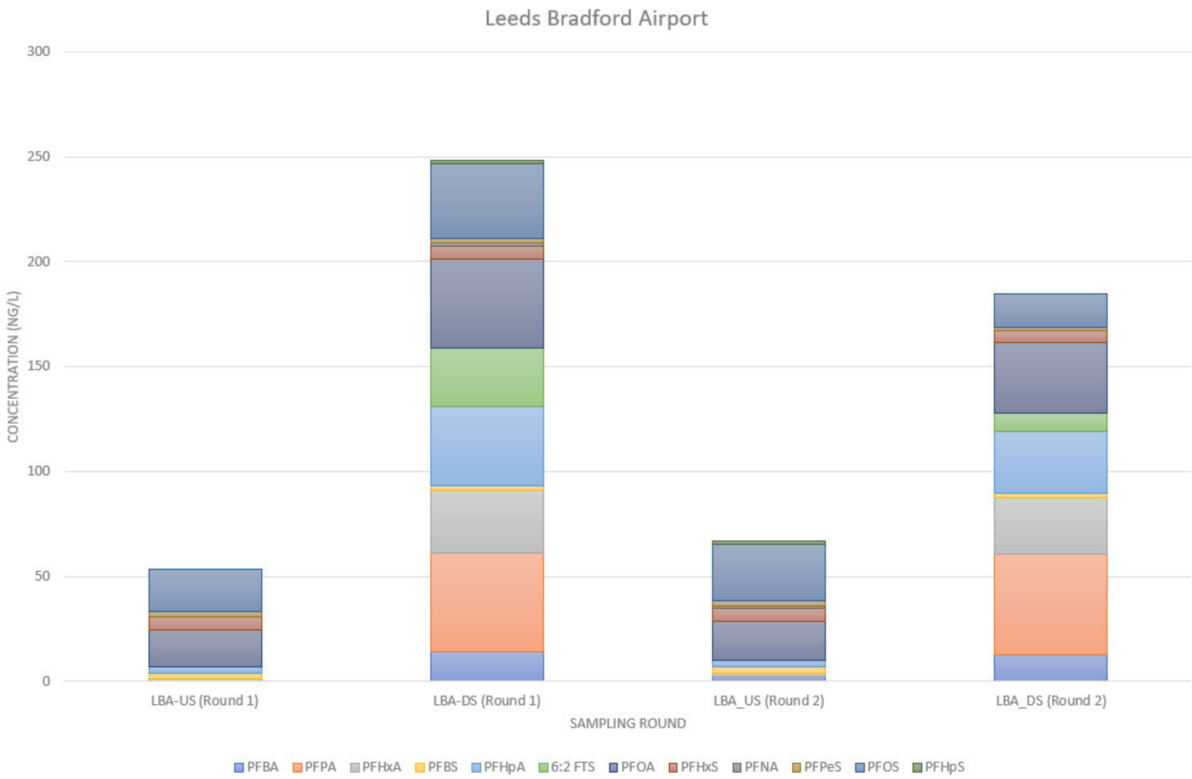


Figure 23: Leeds Bradford Airport Surface Water PFAS Concentrations

The largest percentage increases between the downstream and upstream samples are for PFPA, PFHxA and 6:2 FTS, as shown in Figure 24. The second monitoring round reports a decrease in PFOS between the upstream and downstream samples. PFOS and PFOA appear not to have increased much in the downstream samples due to high concentrations in the upstream samples. Tabulated percentage differences are presented in Table D in Appendix A.

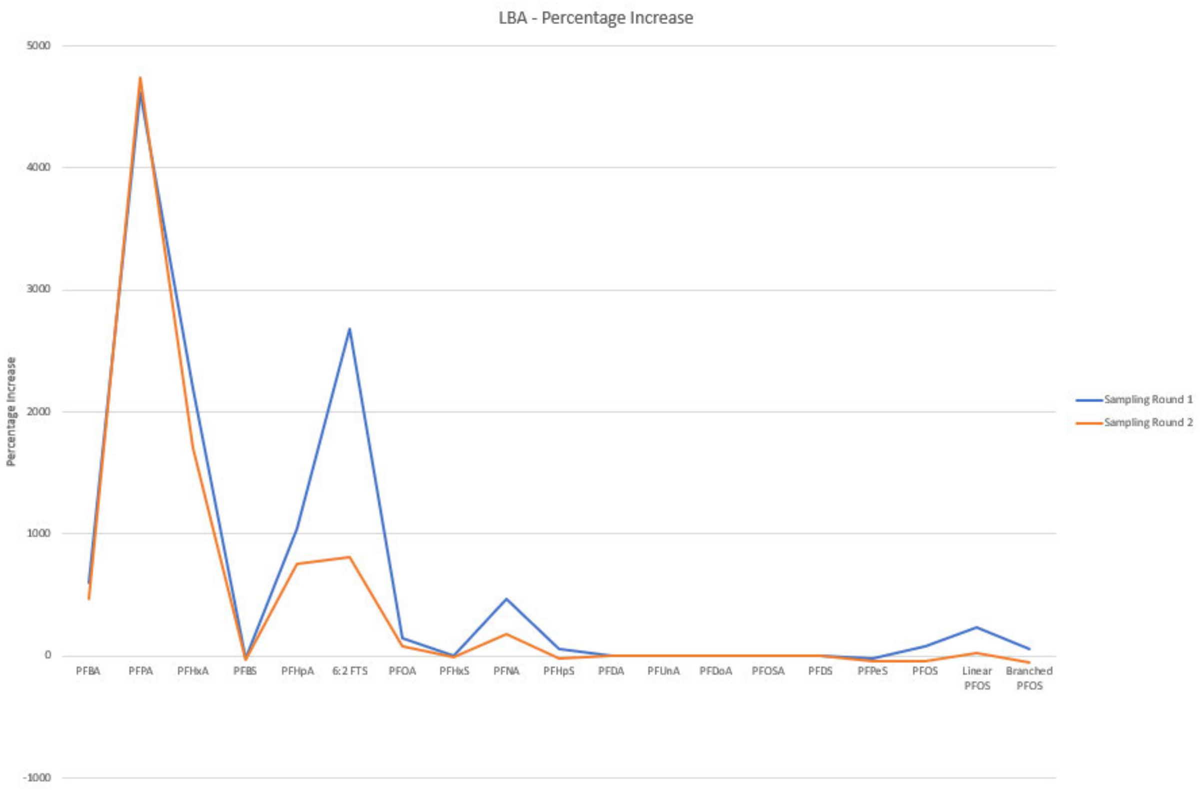


Figure 24: Leeds Bradford Airport Percentage Increase in PFAS Concentrations

Table 10 presents the p-values calculated between the upstream and downstream samples for Leeds Bradford Airport. The one-tail p-values calculated indicate that there is a statistical difference between the upstream and downstream PFAS concentrations. However, on the second sampling round, the two-tail p-value is over 5% and indicates that the results may not be significantly different. This could be due to a potential upgradient PFAS source.

Table 10: P-value Leeds Bradford Airport (t-test: paired two samples for means)

	LBA-US-R1	*LBA-DS-R1*	*LBA-US-R2*	*LBA-DS-R2*
Mean concentration of total PFAS	4.50	15.48	5.34	11.09
Variance between PFAS concentrations within a sample	41.07	279.43	66.64	189.61
Observations (no. of PFAS sampled)	19	19	19	19
Pearson Correlation	0.52		0.25	
Hypothesized Mean Difference between upstream and downstream samples	0		0	

	LBA-US-R1	*LBA-DS-R1*	*LBA-US-R2*	*LBA-DS-R2*
df	18		18	
t Stat	-3.32		-1.77	
P(T<=t) one-tail	**0.2%**		**4.7%**	
t Critical one-tail	1.73		1.73	
P(T<=t) two-tail	**0.4%**		**9.3%**	
t Critical two-tail	2.10		2.10	

4.5 London Gatwick Airport (LGW)

4.5.1 Geology, Hydrogeology and Hydrology

There is no continuous layer of superficial deposits underlying London Gatwick Airport. Parts of the airport are underlain by either Alluvium (clay, silt, sand and gravel), RTD (sand and gravel) or Head (clay, silt, sand and gravel) (BGS, 2023). The superficial deposit aquifers are classified as either Secondary A, Secondary B or Secondary (undifferentiated) aquifers (DEFRA, 2023a). No superficial deposits underly the FTA, which is located in the western part of the airport.

The bedrock comprises the Weald Clay Formation, described as a mudstone with occasional ironstone bands (BGS, 2023). The Weald Clay Formation is classified as unproductive strata (DEFRA, 2023a).

The superficial aquifers are described as having very small yields, and the bedrock is described as having no groundwater (BGS, 2023). Baseflow to the river is considered to be unlikely; therefore, runoff and direct discharge are considered to be the most significant pathways. A soil created from the Weald Clay Formation is likely to have a high organic content; therefore, the soils are likely to have a high PFAS retention capacity.

The main water catchment within which London Gatwick Airport is situated is the Mole (upstream of Horley) which is outlined in Figure 25 by the blue dashed line. The Tilgate Brook and Gatwick Stream water catchment are outlined in dashed orange on the airport's eastern edge, with the Mole (Horley to Dorking) catchment downstream to the north of the airport dashed in green (EA, 2023b). Based on the catchment, the majority of runoff across the airport would flow to the west and north towards the River Mole.

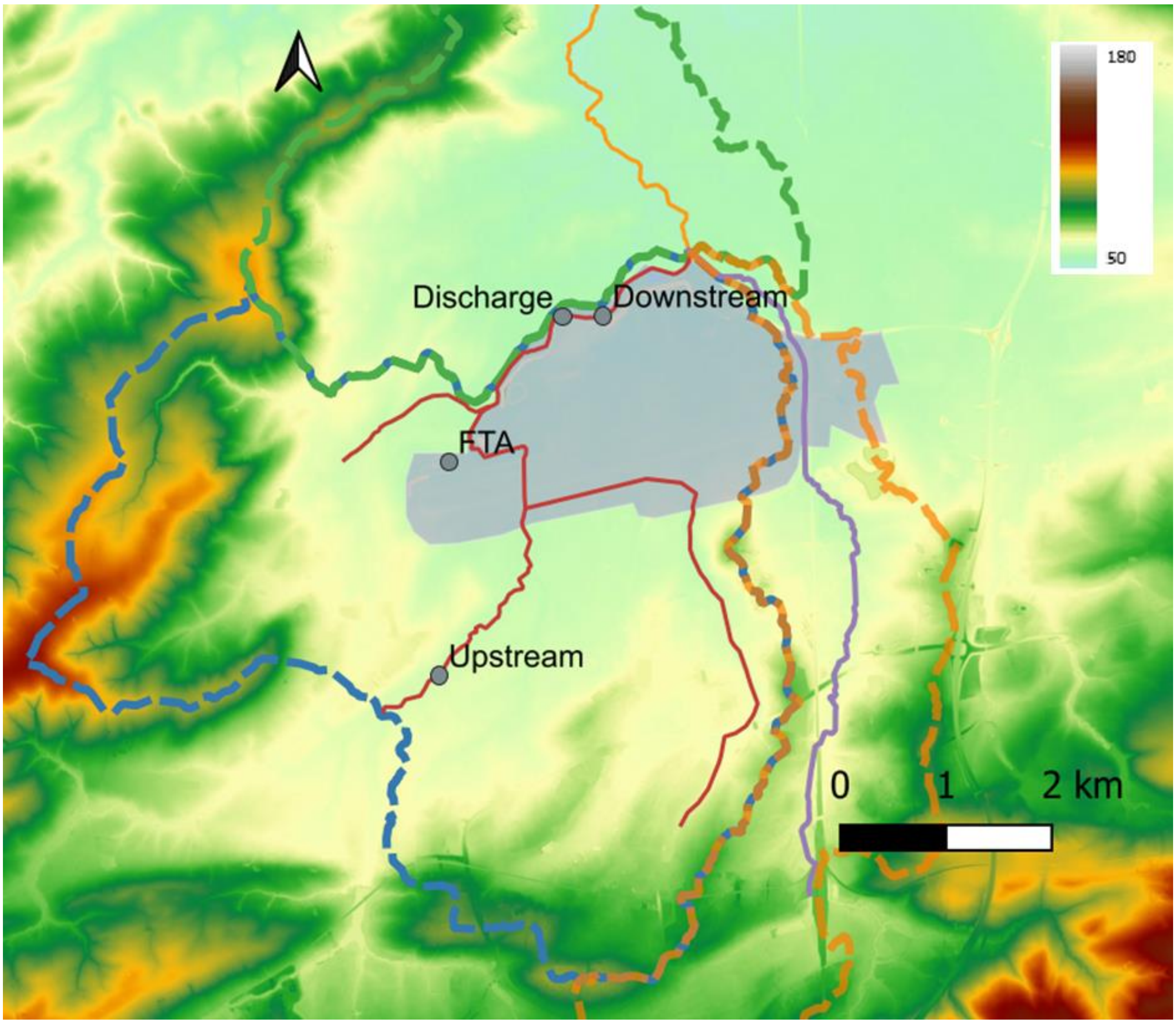


Figure 25: London Gatwick Airport Water Catchments (Google Satellite, QGIS output)

4.5.2 Sampling Observations

The samples were collected from the River Mole, which passes through the airport on the western side, flowing from south to north. The airport discharge point is located to the north of the airport adjacent to the downstream sampling location. The FTA is adjacent to the River Mole. The upstream sample is located away from the airport land boundaries, though there is no obvious PFAS source between the upstream sample and the airport. Sampling locations are shown on Figure 26 and river observations are presented in Table 3.

Oil was noted in the mud on the bank at the downstream location on both monitoring rounds. The literature review indicated how other contaminants could alter the partitioning ability of PFAS between the aqueous and solid phases.

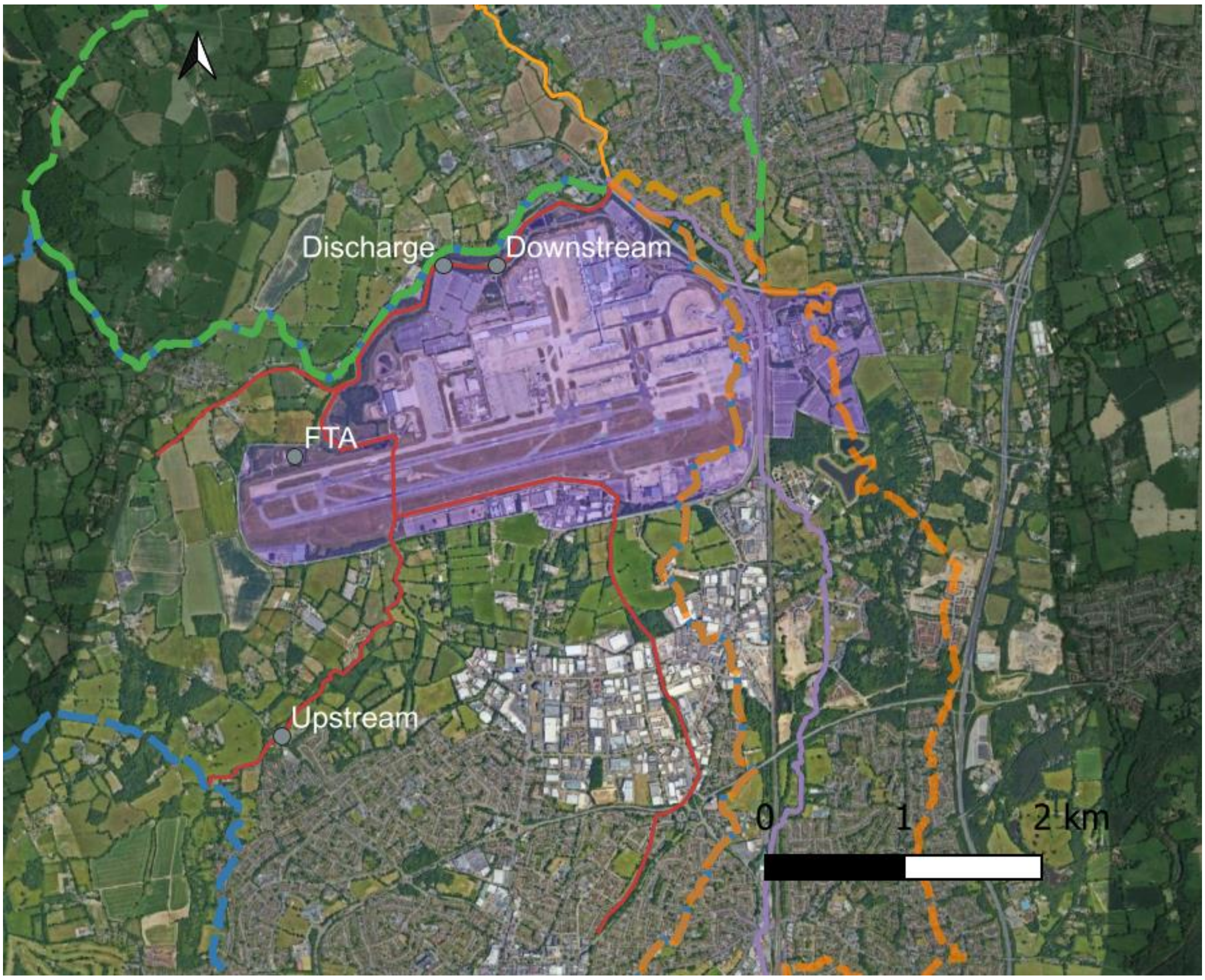


Figure 26: Aerial imagery of London Gatwick Airport (Google Satellite, QGIS output)

4.5.3 Results

The difference between the upstream and downstream samples at London Gatwick Airport is shown in Figure 27. The upstream samples in both sampling rounds appear to be elevated, though aside from the upstream sample being adjacent to an urban area, there is no obvious PFAS source for the upstream location. There is an increase observed in the downstream sample PFAS concentrations relative to the upstream samples.

For the purpose of the assessment of the results, the reported concentrations that were below the laboratory LOD have not been included in Figure 27. Tabulated data is presented in Table A in Appendix A.

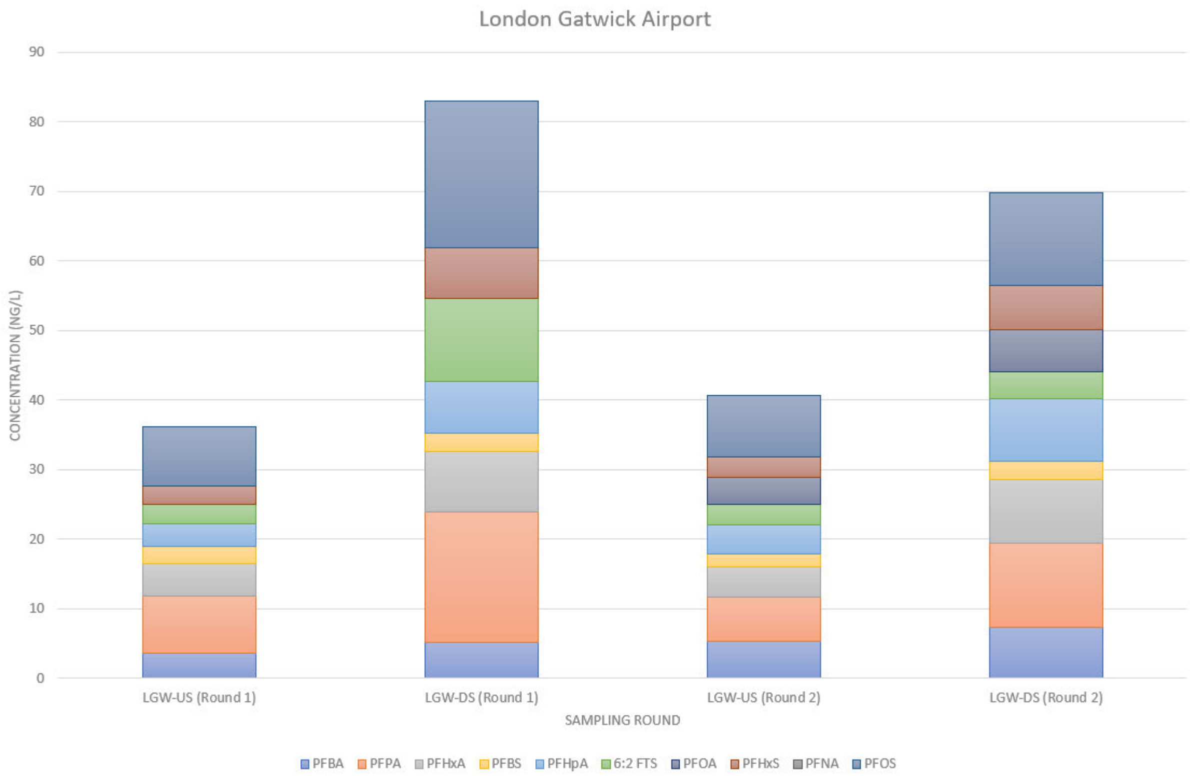


Figure 27: London Gatwick Airport Surface Water PFAS Concentrations

The largest percentage increases between the downstream and upstream samples are for 6:2 FTS, PFHxS and PFOS, as shown in Figure 28. The second sampling round increases were not as large between the upstream and downstream samples as the first sampling round. Tabulated percentage differences are presented in Table D in Appendix A.

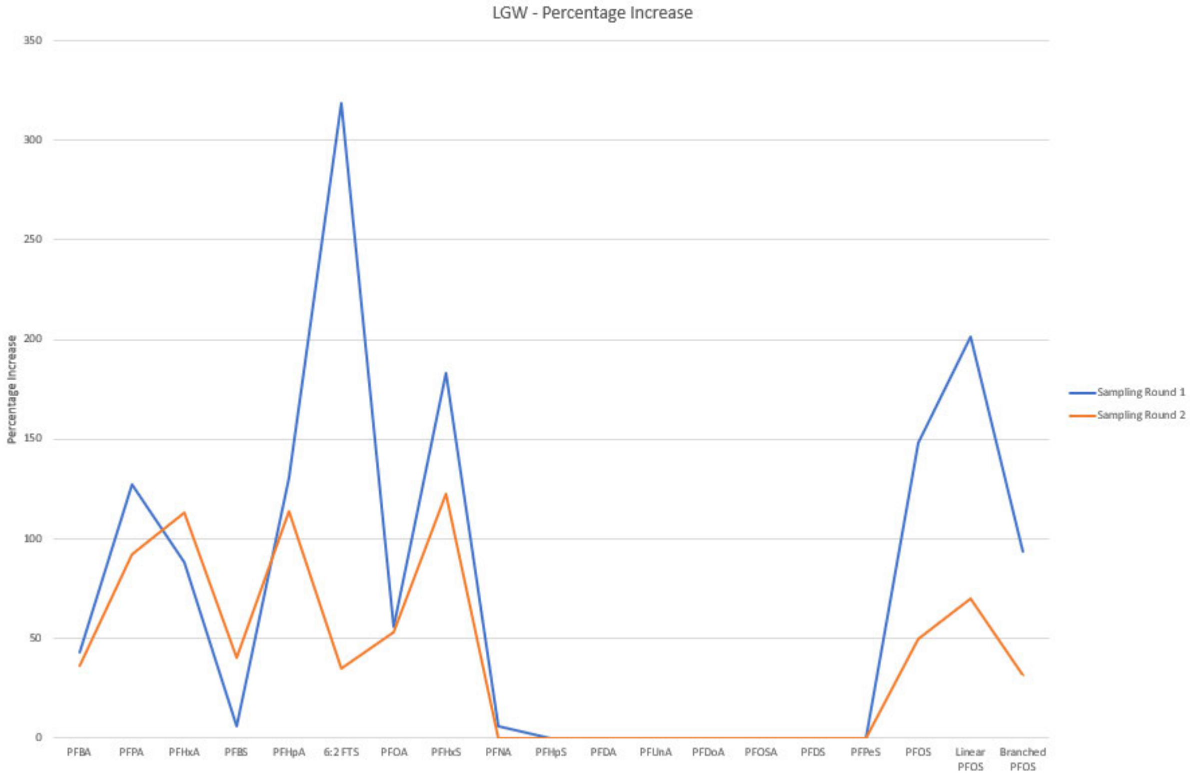


Figure 28: London Gatwick Airport Percentage Increase in PFAS Concentrations

Table 11 presents the p-values calculated between the upstream and downstream samples for London Gatwick Airport. Both the one and two-tail p-values calculated for both sampling rounds indicate that there is a statistical difference between the upstream and downstream PFAS concentrations.

Table 11: P-value London Gatwick Airport (t-test: paired two samples for means)

	LGW-US-R1	*LGW-DS-R1*	*LGW-US-R2*	*LGW-DS-R2*
Mean concentration of total PFAS	3.06	6.32	3.09	4.86
Variance between PFAS concentrations within a sample	5.26	38.11	5.03	16.38
Observations (no. of PFAS sampled)	19	19	19	19
Pearson Correlation	0.94		0.97	
Hypothesized Mean Difference between upstream and downstream samples	0		0	
df	18		18	

	LGW-US-R1	*LGW-DS-R1*	*LGW-US-R2*	*LGW-DS-R2*
t Stat	-3.46		-3.83	
P(T<=t) one-tail	**0.1%**		**0.1%**	
t Critical one-tail	1.73		1.73	
P(T<=t) two-tail	**0.3%**		**0.1%**	
t Critical two-tail	2.10		2.10	

4.6 London Stansted Airport (STN)

4.6.1 Geology, Hydrogeology and Hydrology

Lowestoft Formation, described as a diamicton (a chalky till with outwashes of sand, gravel, silt and clay), underlies the majority of the airport. There are also occasional deposits of Alluvium and Head, both described as clay, silt, sand and gravel (BGS, 2023). The superficial deposits are classified as a Secondary (undifferentiated) aquifer (DEFRA, 2023a). The FTA is underlain by the Lowestoft Formation, located in the eastern part of the airport. Soils created from the Lowestoft Formation are likely to have a high organic content; therefore, it is likely that the soils have a high PFAS retention capacity.

The bedrock is the London Clay Formation which is described as clay, silt and sand. The London Clay is described as *'rocks with essentially no groundwater'* (BGS, 2023). The bedrock is classified as unproductive strata (DEFRA, 2023a).

The water catchments around STN airport are shown in Figure 29. The airport is located on a topographical high with three water catchment divides. The downstream sample was collected from the Pincey Brook water catchment, which is dashed in dark blue. The upstream sample and the FTA are located within the Stanstead Brook catchment (red dashed). The proximity of the FTA to the water catchment boundary is shown in Figure 30. The airport discharge point is within the Great Hallingbury Brook catchment (green dashed). There is another water catchment adjacent to the east of the airport called the Upper Roding (to Cripsey Brook) Water Body dashed in light blue (EA, 2023b).

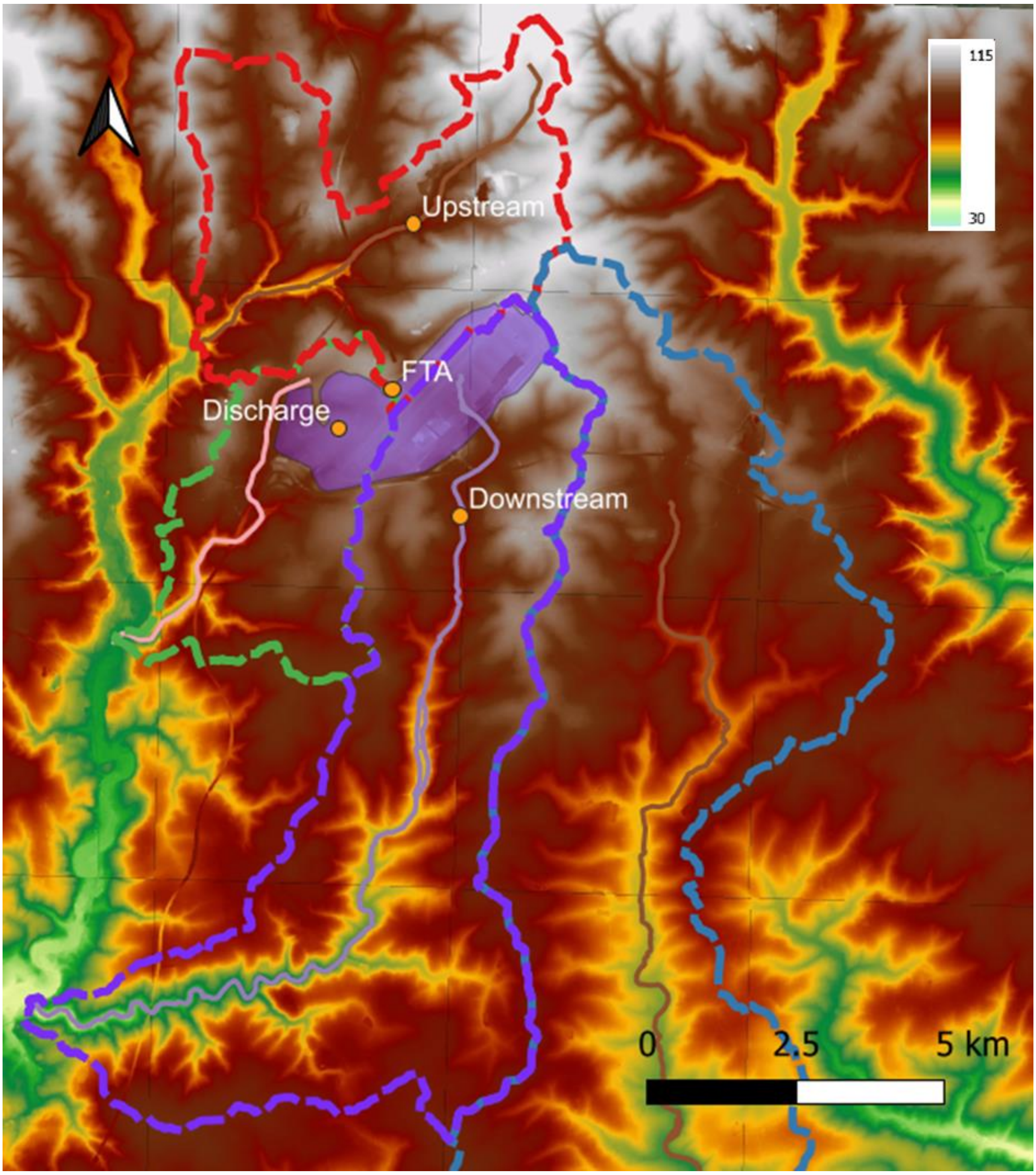


Figure 29: London Stansted Airport Water Catchments (Google Satellite, QGIS output)

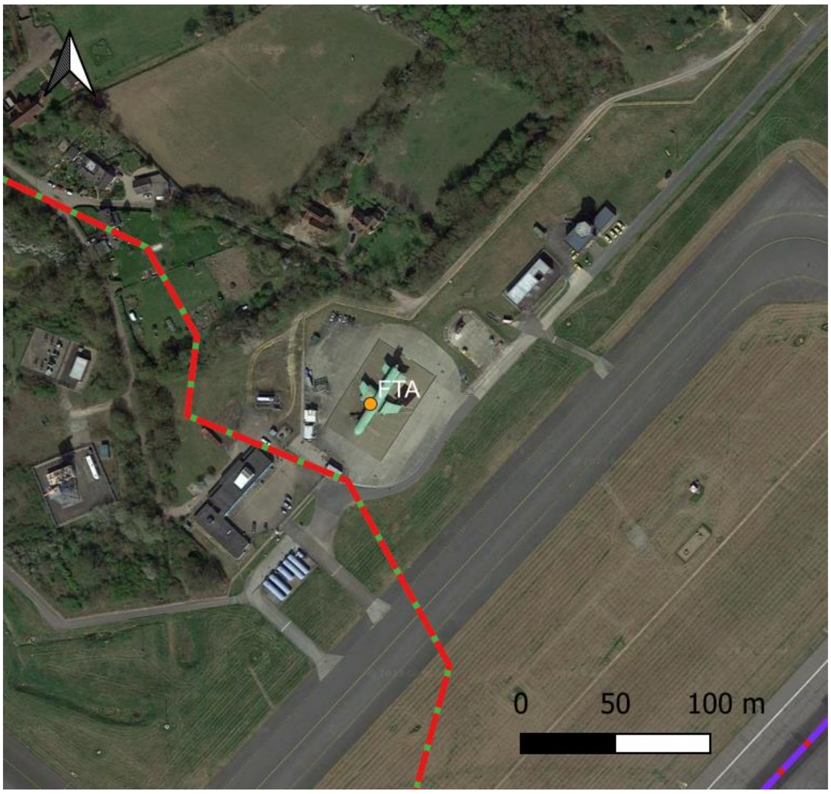


Figure 30: London Stansted FTA & Water Catchment Boundary (Google Satellite, QGIS output)

4.6.2 Sampling Observations

The upstream sample was collected from Stansted Brook, and the downstream sample was collected from Pincey Brook. The Stansted Brooks flows to the west, and the Pincey Brook flows to the south. The upstream and downstream sampling locations are not located in the same brook and are not connected. The Pincey Brook appears to originate from the airport. River observations are noted in Table 3, and an aerial image of the airport is shown in Figure 31.

The airport discharge point is located in the eastern part of the airport, discharging into a different brook than where the downstream sample was collected. Minor drainage outfalls were noted upstream of the downstream sampling location on Pincey Brook (though these outfalls are not noted in the same place as the airport discharge point). The source of the outfalls is unknown.

In between the airport and the downstream sample, there appears to be a settling pond, but the purpose of this is unknown. A wastewater treatment works is located approximately 130 m downstream of the downstream sampling location.

The Pincey Brook was a second-choice location for the downstream sample, which was originally proposed from an unnamed stream near the airport's discharge point within the Great Hallingbury Brook catchment. This was not chosen due to access issues.

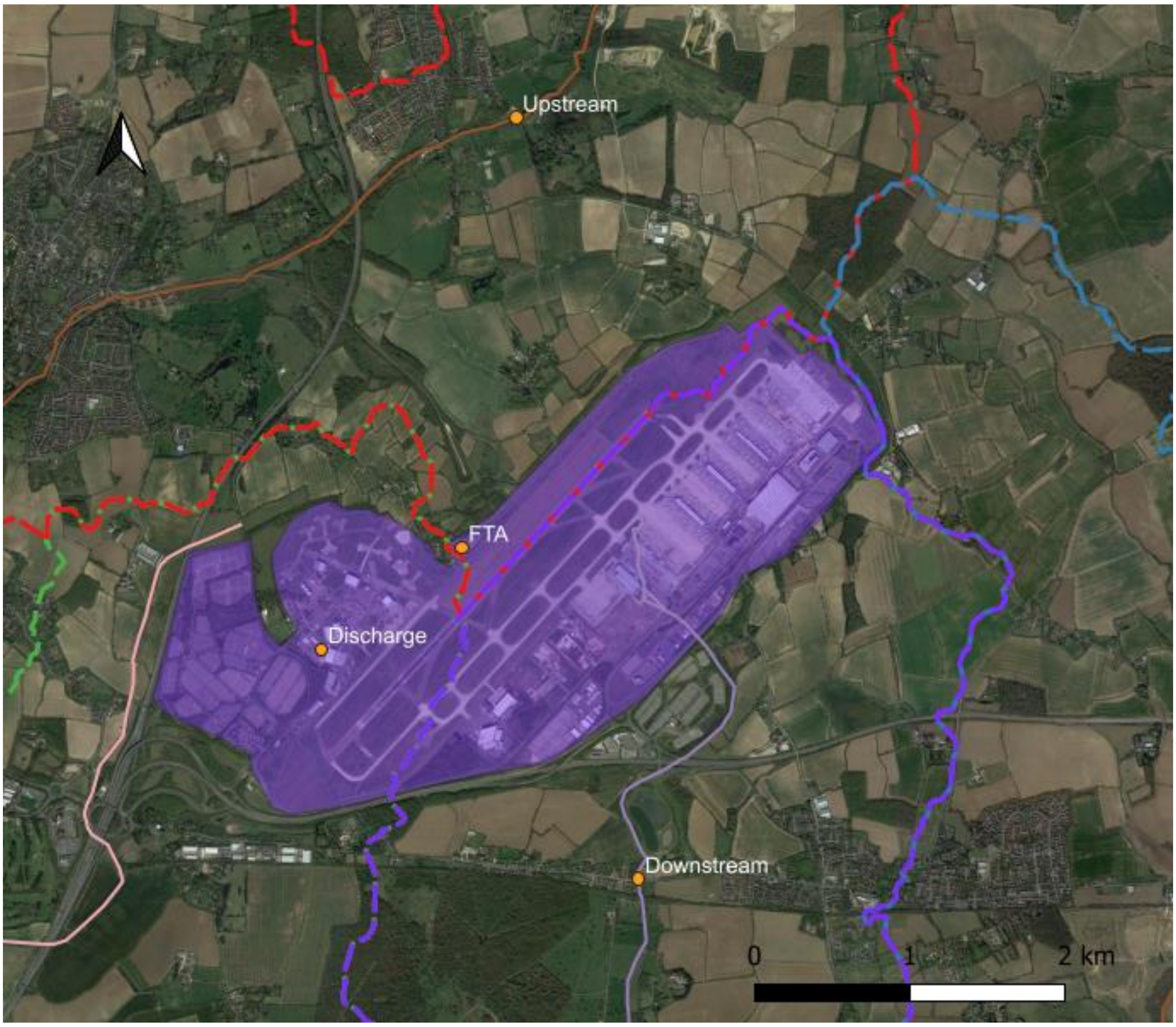


Figure 31: Aerial imagery of London Stansted Airport (Google Satellite, QGIS output)

4.6.3 Results

The PFAS concentration difference between the upstream and downstream samples at London Stansted Airport is shown in Figure 32. There is an increase observed in the downstream sample PFAS concentrations relative to the upstream samples. The second sampling round downstream sample has much higher PFAS concentrations than the first monitoring round.

The upstream sample and downstream sample are not connected via a stream, and as the airport is on a topographical high, both samples are technically downstream samples. It is noted that the upstream sample may receive some runoff from the airport (especially as the FTA is within the water catchment), though due to the brook's distance from the airport, it is likely to represent background concentrations. The majority of runoff from Stansted Airport would be within the Pincey Brook water catchment, which feeds the Pincey Brook from which the downstream sample was collected.

For the purpose of the assessment of the results, the reported concentrations that were below the laboratory LOD have not been included in Figure 32. Tabulated data is presented in Table A in Appendix A.

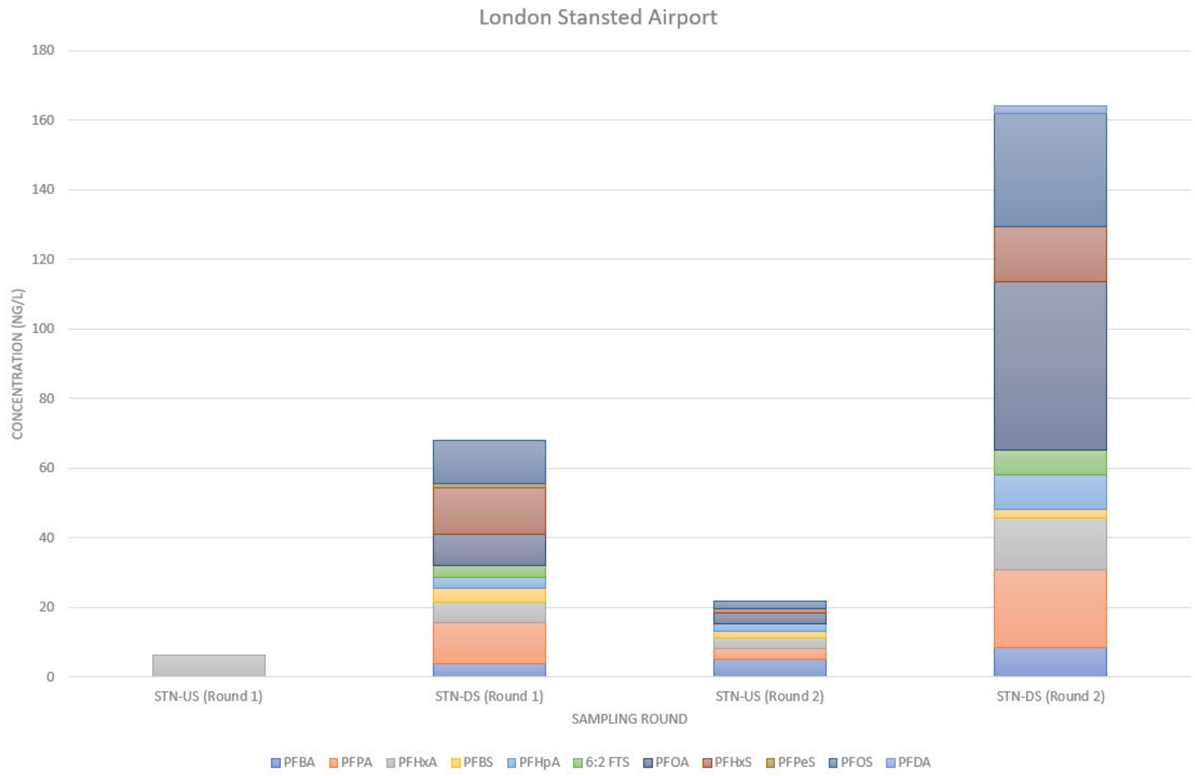


Figure 32: London Stansted Airport Surface Water PFAS Concentrations

This is one of the few airports which has noted a large percentage increase in the downstream samples for PFOA. Other large increases were noted for PFPA, 6:2 FTS, PFHxS and PFOS, which are all representative of legacy AFFF use. The graph showing the percentage increases between the downstream and upstream samples is shown in Figure 33. Tabulated percentage differences are presented in Table D in Appendix A.

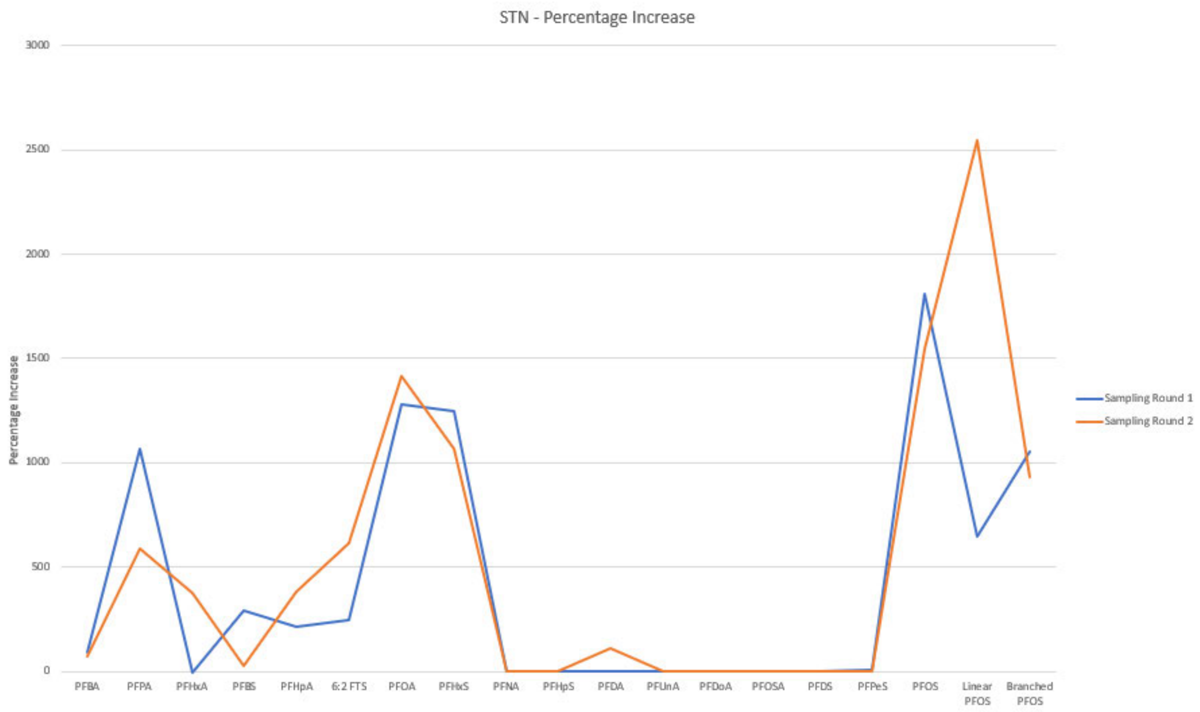


Figure 33: London Stansted Airport Percentage Increase in PFAS Concentrations

Table 12 presents the p-values calculated between the upstream and downstream samples for London Stansted Airport. The one and two tail p-values calculated indicate that there is a statistical difference between the upstream and downstream PFAS concentrations.

Table 12: P-value London Stansted Airport (t-test: paired two sample for means)

	STN-US-R1	*STN-DS-R1*	*STN-US-R2*	*STN-DS-R2*
Mean concentration of total PFAS	0.33	4.23	1.25	10.35
Variance between PFAS concentrations within a sample	2.05	21.23	2.27	173.60
Observations (no. of PFAS sampled)	19	19	19	19
Pearson Correlation	0.09		0.59	
Hypothesized Mean Difference between upstream and downstream samples	0		0	
df	18		18	

	STN-US-R1	STN-DS-R1	STN-US-R2	STN-DS-R2
t Stat	-3.62		-3.21	
P(T<=t) one-tail	**0.1%**		**0.2%**	
t Critical one-tail	1.73		1.73	
P(T<=t) two-tail	**0.2%**		**0.5%**	
t Critical two-tail	2.10		2.10	

4.7 Manchester Airport (MAN)

4.7.1 Geology, Hydrogeology and Hydrology

The majority of the site is underlain by Till, described as a diamicton. Three pockets of Glaciofluvial Deposits, described as sand and gravel, are present in the southwest, central and eastern areas of the airport (BGS, 2023). The FTA is underlain by Till, located in the eastern part of the airport. The superficial deposits are classified as Secondary (undifferentiated) and Secondary A aquifers (DEFRA, 2023a). Soils created from the Till are likely to have a high organic content; therefore, it is likely that the soils have a high PFAS retention capacity.

The bedrock is the Bollin Mudstone Member, which is described as a mudstone. The aquifer is described as having low productivity, with yields of less than 0.5 L/s of water (BGS, 2023). The bedrock aquifer is classified as a Secondary B aquifer (DEFRA, 2023a).

The airport is on a topographical high, with the water catchments shown in Figure 34. The central portion of the airport is located within the Bollin (River Dean to Ashley Mill) water catchment (light blue dashed), within which the upstream and downstream samples were collected, as well as one of the airport discharge points, discharging into this water catchment. The north-western section of the airport is located in the Timperley Brook Water Body catchment (dark blue dashed line) within which the second airport discharge point is located.

The FTA is located within the Sinderland Brook (Fairywell Bk and Baguley Bk) Water Body catchment (red dashed line) in the north-eastern portion of the site, also adjacent to the Mersey (upstream of Manchester Ship Canal) Water Body (pink dashed line). The southern portion of the airport is divided between the Birkin Brook - Mobberley Brook to River Bollin (including Rostherne Brook) Water Body (orange dashed line) and the Sugar Brook catchment (green dashed line) (EA, 2023b).

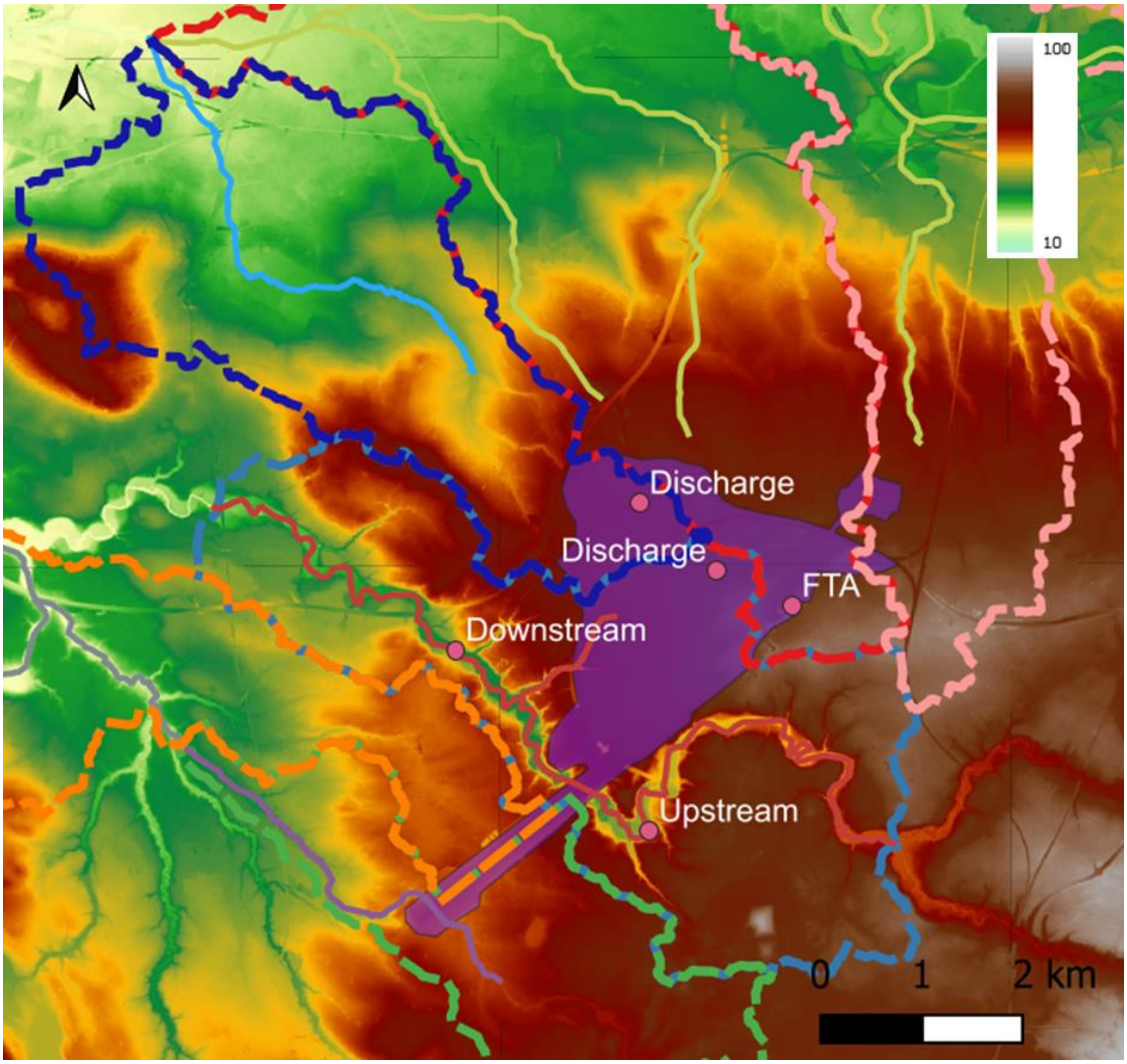


Figure 34: Manchester Airport Water Catchments (Google Satellite, QGIS output)

4.7.2 Sampling Observations

The samples were collected from the River Bollin, which crosses the airport's western runway, flowing from southeast to northwest. The airport discharge points are located in the northeastern part of the airport near the FTA and are not located near the River Bollin. Sampling locations are shown in Figure 35 and river observations are noted in Table 3.

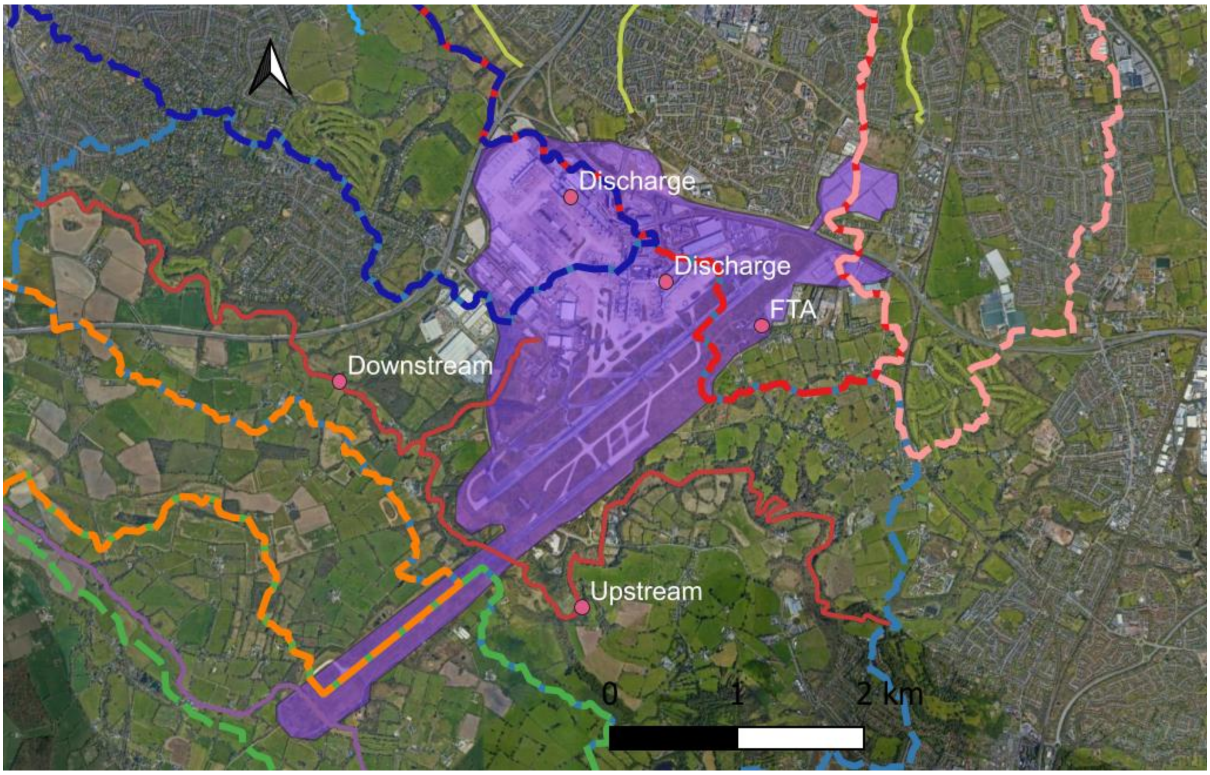


Figure 35: Aerial imagery of Manchester Airport (Google Satellite, QGIS output)

4.7.3 Results

The PFAS concentration difference between the upstream and downstream samples at Manchester Airport is shown in Figure 36. In the first sampling round, there is an increase observed in the downstream sample PFAS concentrations relative to the upstream samples. In the second sampling round, the total PFAS detected was less than the upstream sample, though some individual PFAS concentrations had increased and others decreased; however, there was still a net loss in concentration.

The River Bollin is situated to allow upstream and downstream samples to be collected from the airport; however, the river is not located near the airport's potential PFAS sources, which are the FTA, the discharge points and the aircraft hangers, which are all located in the northern portion of the airport. The FTA is located in a different water catchment.

There was a crash during takeoff on the runway in 1985 which could be a cause of the PFAS observed in the River Bollin adjacent to the runway (UK Aviation News, 2017).

For the purpose of the assessment of the results, the reported concentrations that were below the laboratory LOD have not been included in Figure 36. Tabulated data is presented in Table A in Appendix A.

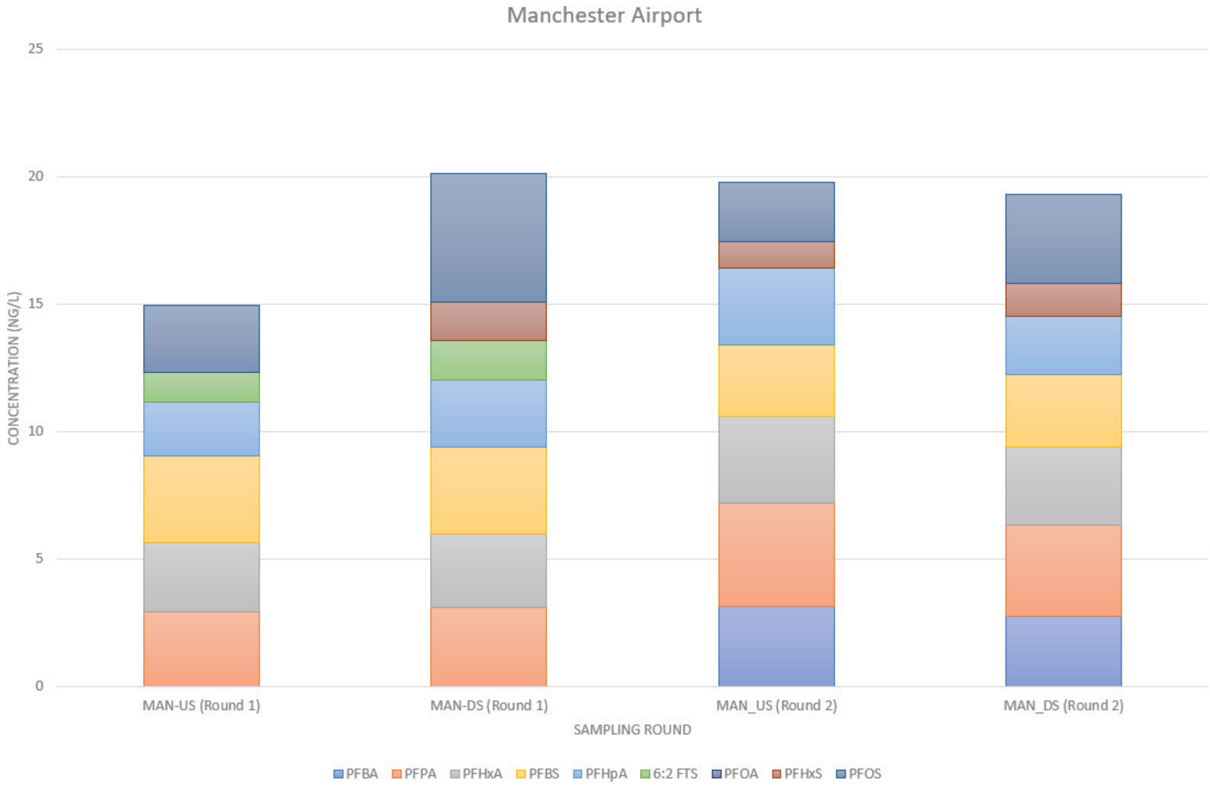


Figure 36: Manchester Airport Surface Water PFAS Concentrations

The largest percentage increases between the downstream and upstream samples are for PFHxS and PFOS as shown in Figure 37. The second monitoring round reports a percentage decrease in PFBA, PFPA, PFHxA, PFHpA and PFOA in the downstream samples relative to the upstream samples as indicated on the graph by the line going below the x-axis. Tabulated percentage differences are presented in Table D in Appendix A.

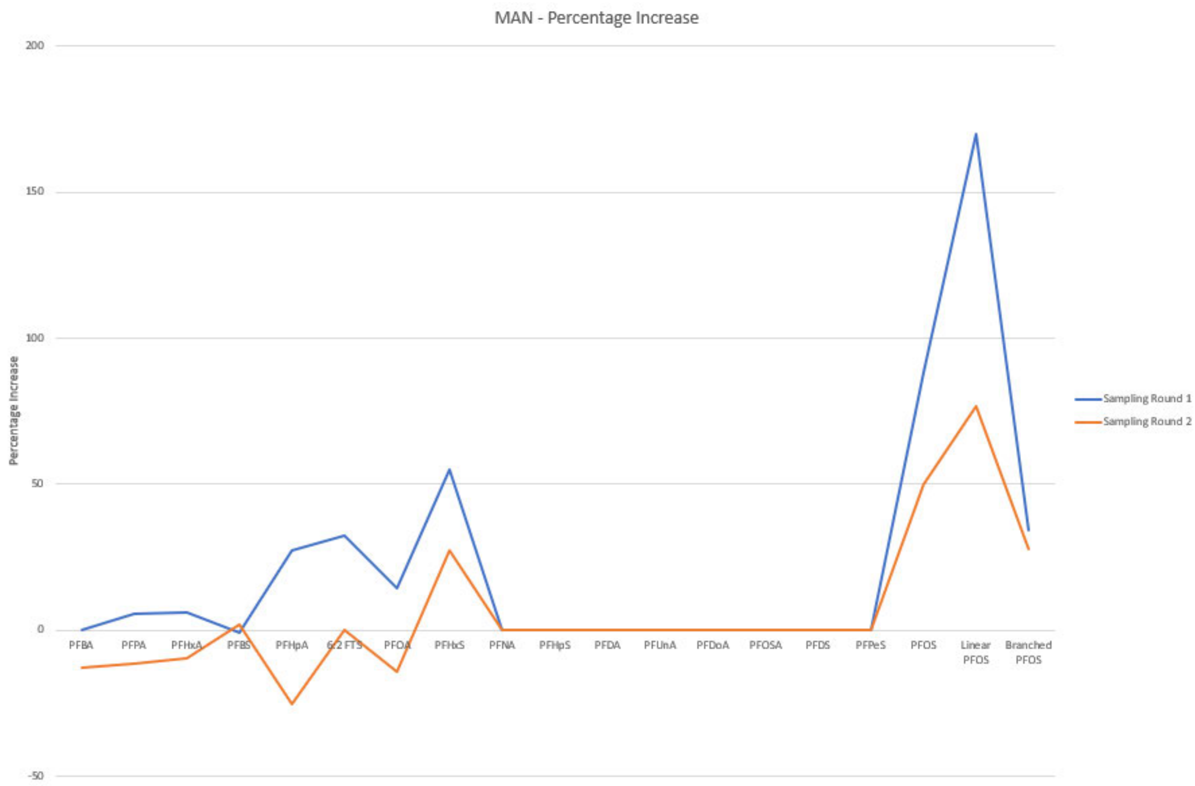


Figure 37: Manchester Airport Percentage Increase in PFAS Concentrations

Table 13 presents the p-values calculated between the upstream and downstream samples for Manchester Airport. The p-values calculated indicate that there is a statistical difference between the upstream and downstream PFAS concentrations in sampling round 1 but not sampling round 2.

Table 13: P-value Manchester Airport (t-test: paired two samples for means)

	MAN-US-R1	*MAN-DS-R1*	*MAN-US-R2*	*MAN-DS-R2*
Mean concentration of total PFAS	1.74	2.11	1.87	1.88
Variance between PFAS concentrations within a sample	0.81	1.41	1.20	0.92
Observations (no. of PFAS sampled)	19	19	19	19
Pearson Correlation	0.84		0.91	
Hypothesized Mean Difference between upstream and downstream samples	0		0	
df	18		18	
t Stat	-2.48		-0.11	

	MAN-US-R1	*MAN-DS-R1*	*MAN-US-R2*	*MAN-DS-R2*
P(T<=t) one-tail	**1.2%**		**46%**	
t Critical one-tail	1.73		1.73	
P(T<=t) two-tail	**2.3%**		**91%**	
t Critical two-tail	2.10		2.10	

4.8 Newcastle International Airport (NCL)

4.8.1 Geology, Hydrogeology and Hydrology

The entire airport is underlain by Till, described as a diamicton (BGS, 2023). The FTA is located in the eastern part of the airport on the Till. The Till is classified as a Secondary (undifferentiated) aquifer (DEFRA, 2023a). Soils created from the Till are likely to have a high organic content; therefore, it is likely that the soils have a high PFAS retention capacity.

The bedrock comprises the Pennine Lower Coal Measures and Pennine Middle Coal Measures Formations, which are described as sandstone and siltstone. The aquifer is described as being moderately productive and multi-layered (BGS, 2023). The bedrock is classified as a Secondary A aquifer (DEFRA, 2023a). Due to the overlying Till, the most likely PFAS migration pathway to surface water is via runoff rather than baseflow.

The water catchments around the airport are shown in Figure 38. The FTA is located in the Seaton Burn (from Source to Tidal Limit) catchment (red dashed line), with the airport's discharge located in the Ponteland to Dinnington Catchment Area (green dashed line). The upstream sample was collected from the Pont from Med Burn to Small Burn catchment (pink dashed line), with the downstream sample collected from the Pont from Small Burn to Blyth Water Body (blue dashed line). The southern portion of the airport is located in the Ouse Burn (from Source to Tyne) catchment (orange dashed line) (EA, 2023b).

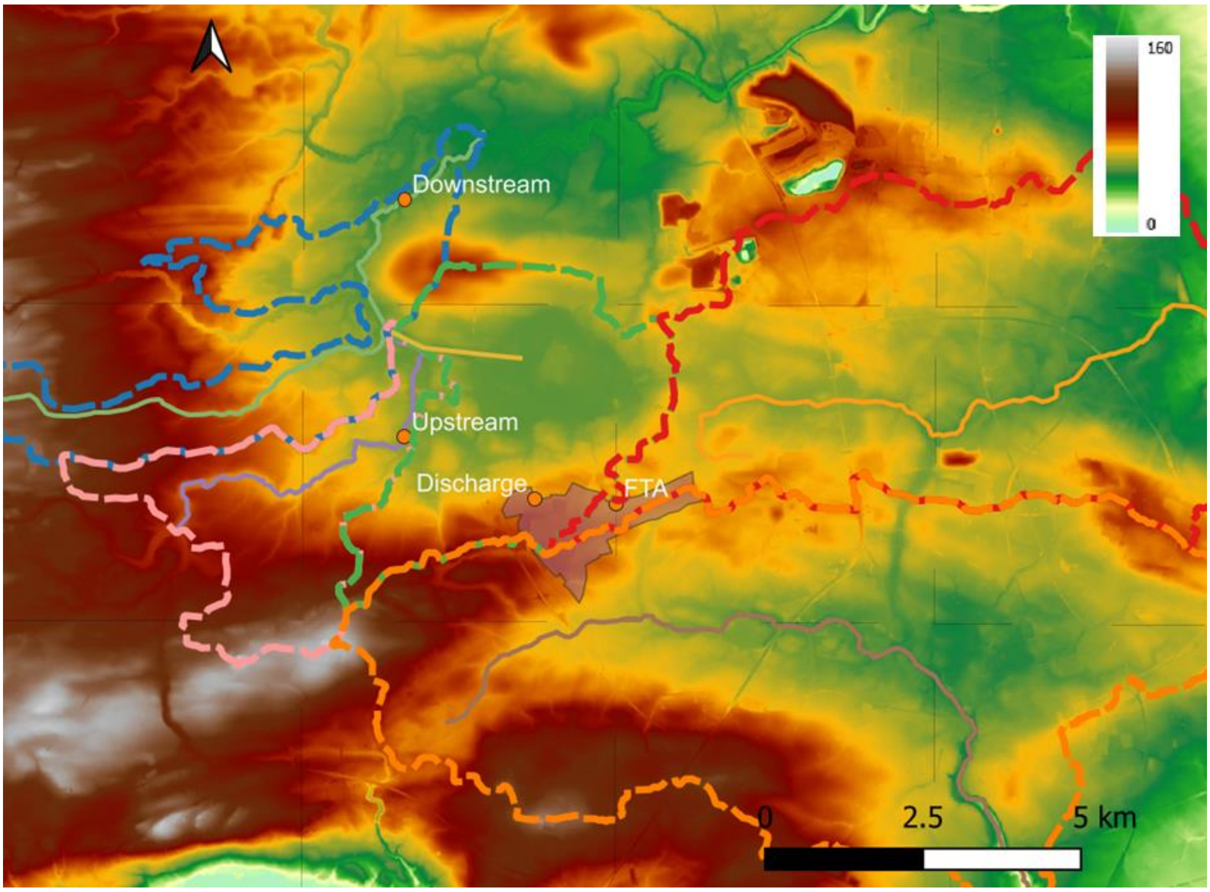


Figure 38: Newcastle International Airport Water Catchments (Google Satellite, QGIS output)

4.8.2 Sampling Observations

The samples were collected from the River Pont, which is located to the west of the airport and flows from south to north. The airport discharge point is located in the western part of the airport, discharging into a drainage channel of the River Pont. The drainage channel does appear to join the River Pont in between the upstream and downstream sampling locations; however, the river is located over 2.5 km from the site. Sampling locations are presented on Figure 39.

Oil was noted on the water during monitoring round 2 at the downstream sample location. Other observations made during sampling are presented in Table 3.

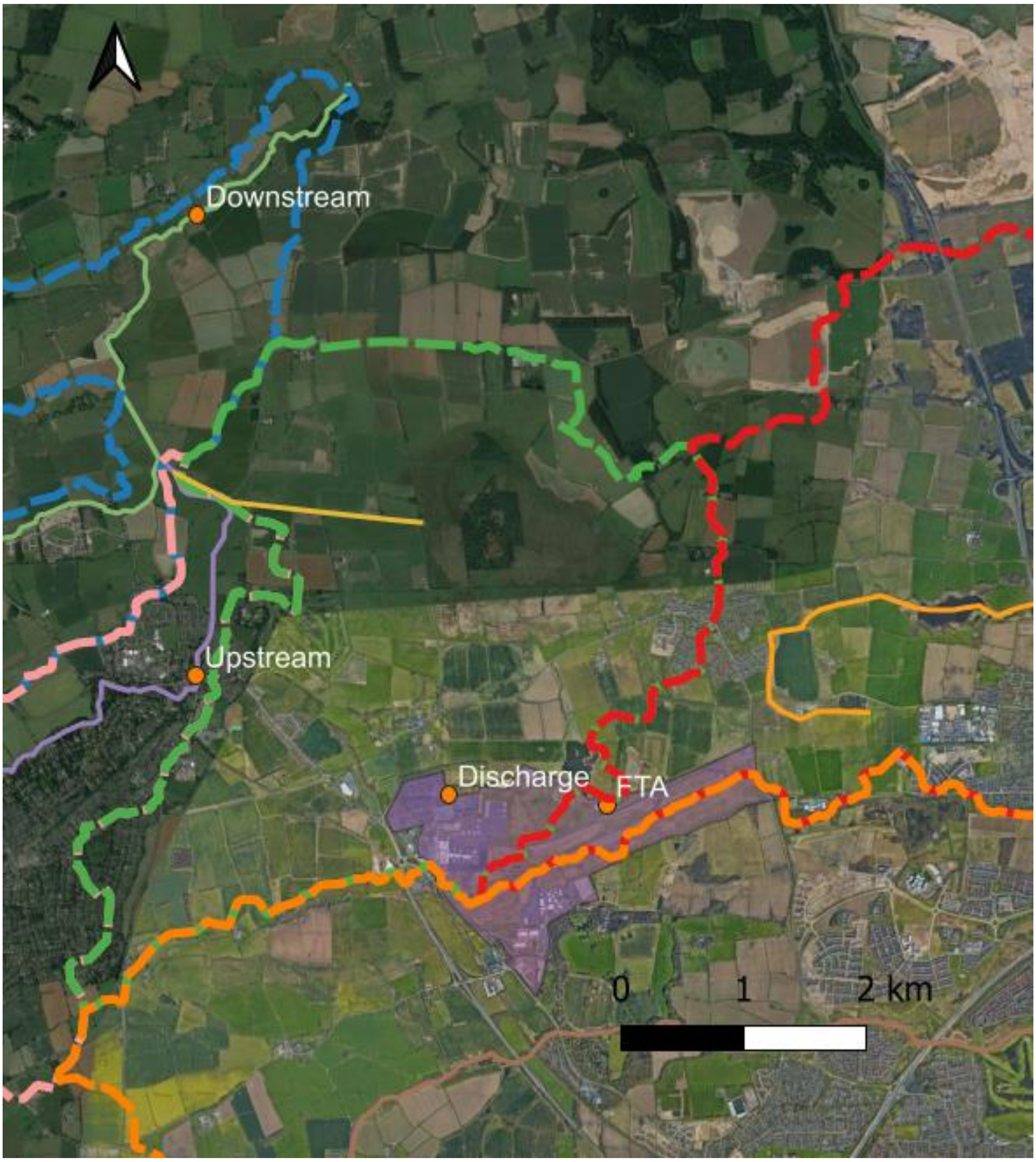


Figure 39: Aerial imagery of Newcastle International Airport (Google Satellite, QGIS output)

4.8.3 Results

During both sampling rounds, there was only one detection across the four samples collected. PFHxA was detected at 1.18 $ng.L^{-1}$ in the downstream sample in sampling round 1. All other PFAS results were below the laboratory limit of detection (LOD). It is possible that, due to the sample positions, any runoff from the airport is unlikely to reach the surface water. The Till in the area will limit baseflow to the river, therefore limiting PFAS migration. For a new potential downstream location, the Seaton Burn to the north of the airport could be sampled, depending on accessibility. This is downstream of the FTA and closer to the airport. Tabulated data is presented in Table A in Appendix A.

5. Discussion

5.1 Site Summaries

Based on the conceptual models of the airports, Birmingham and London Gatwick airports have the best positioning with regard to sample locations, water catchments, discharge points, FTAs and limited input from other potential PFAS sources. Potential PFAS sources, not related to the airports, have been identified at Bournemouth and Leeds Bradford airports.

Inconsistency was noted in the East Midlands Airport sampling rounds, though no additional PFAS source contributor, apart from the airport, has been identified. Newcastle Airport samples appear not to show any PFAS impacts associated with the airport in surface waters. Manchester Airport does not show a clear distinction between upstream and downstream samples which could be due to the position of the sample locations, potential source locations, a previous emergency response on the runway and water catchment geometry.

There does not appear to be a distinction between whether PFAS concentrations are affected by either slow, moderate or fast surface water flow. Comments on how each airport's site setting could affect the soil retention of PFAS and its mobilisation in groundwater are presented in Appendix C. Due to only two sampling rounds undertaken and no onsite data, a correlation between potential soil retention and groundwater migration has not been undertaken.

5.2 Data Summary

A summary of the p-values calculated between the PFAS concentrations in the upstream versus downstream samples is presented in Table 14. Results that are determined not to be statistically different between upstream and downstream samples are shaded in grey. Analytical data collected has been tabulated and is presented in Table A (Appendix A).

Table 14: Summary of the one and two-tail p values calculated between the upstream and downstream PFAS sample concentrations

Airport & Sampling Round Number	one-tail p value	two-tail p value
BHX Round 1	0.3%	0.7%
BHX Round 2	0.8%	1.7%
BOH Round 1	0.9%	1.8%

Airport & Sampling Round Number	one-tail p value	two-tail p value
BOH Round 2	0.6%	1.1%
EMA Round 1	1.3%	2.6%
EMA Round 2	2.9%	5.7%
LBA Round 1	0.2%	0.4%
LBA Round 2	4.7%	9.3%
LGW Round 1	0.1%	0.3%
LGW Round 2	0.1%	0.1%
STN Round 1	0.1%	0.2%
STN Round 2	0.2%	0.5%
MAN Round 1	1.2%	2.3%
MAN Round 2	45.7%	91.5%

Summarising the downstream data, Figure 40 shows the PFAS concentrations detected at Birmingham, Bournemouth, London Gatwick and Stansted Airports to allow direct comparison of the magnitude of the concentrations. These airports have been compared due to the results showing a statistical difference on both sampling rounds between the upstream and downstream samples. Of these airports, Birmingham Airport has the highest concentrations of PFAS.

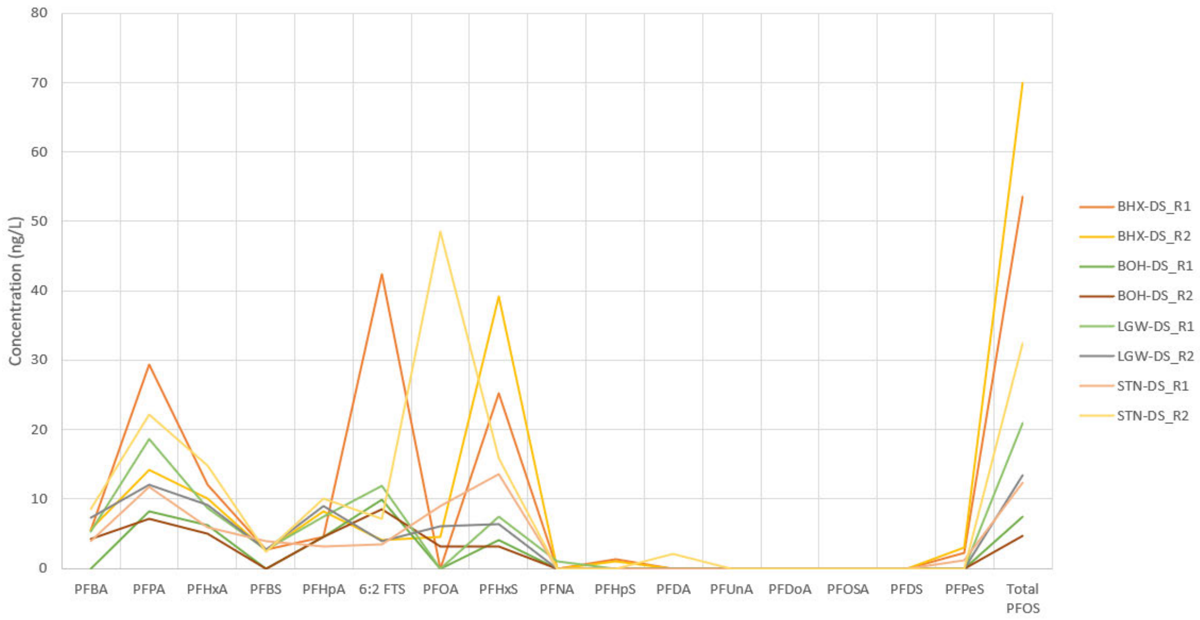


Figure 40: Downstream PFAS concentrations at BHX, BOH, LGW and STN

For the airports where a statistical difference was not observed in both sampling rounds; East Midlands, Leeds Bradford and Manchester, the comparison of the results are presented in Figure 41. Newcastle International Airport is not included as only one PFAS was detected above the laboratory LOD in two sampling rounds. For both Figure 40 and Figure 41, when a PFAS is less than the laboratory LOD, the value has been taken as a non-detect. Comparing the scales, the concentrations at East Midlands Airport in sampling round 1 are an order of magnitude larger than other airport samples. Table A (Appendix A) shows the sample results, with a summary showing the maximum recorded concentrations of each PFAS tested. The maximum concentration of any PFAS was 6:2 FTS (180 ng.L^{-1}) recorded in the downstream sample from East Midlands Airport. East Midlands Airport and Birmingham Airport recorded the highest concentrations typically across the sampling rounds.

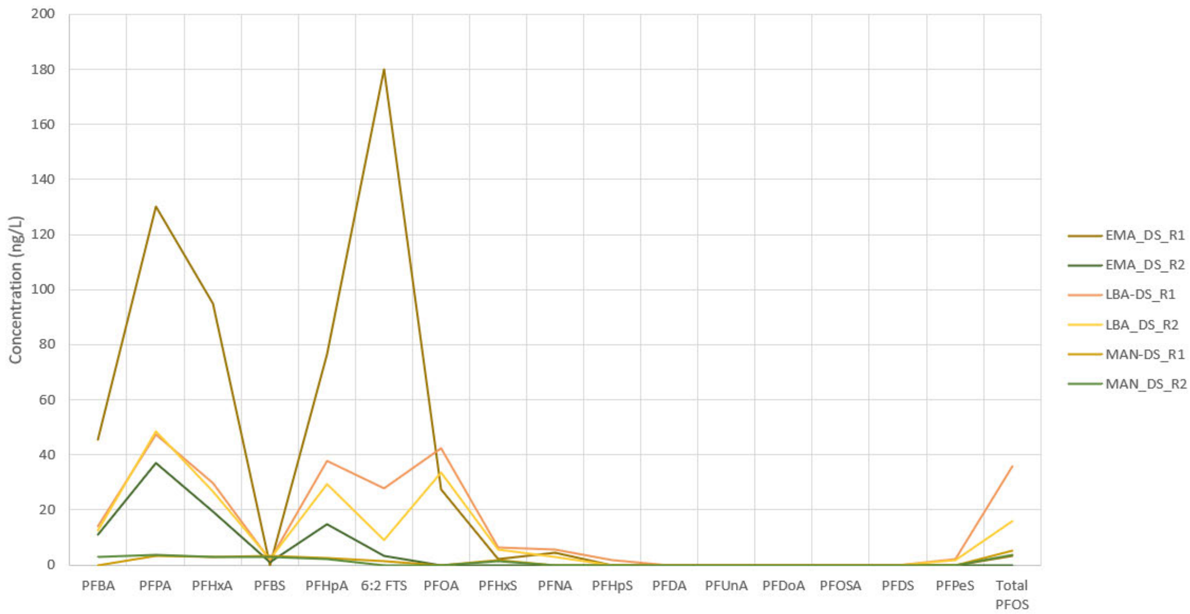


Figure 41: Downstream PFAS concentrations at EMA, LBA and MAN

Figure 42 shows graphs of the average concentration of PFAS for the downstream surface water samples for each airport, along with the cumulative frequency. The graphs are arranged so that the highest PFAS concentration is on the left. If a concentration was below the laboratory LOD, then the concentration used was the LOD. This figure highlights a few differences between the airports as follows:

- Leeds Bradford Airport is the only airport where PFPA was the PFAS with the highest concentration in the downstream samples;
- PFPA was not highlighted as a PFAS expected to be in AFFF formulations, though it is the second most concentrated PFAS in downstream samples at Bournemouth, East Midlands and London Gatwick Airports;
- PFOA does not appear as a main PFAS compound detected, apart from at Leeds Bradford and Stansted Airports; and
- Most airports show high concentrations of PFOS and 6:2 FTS.

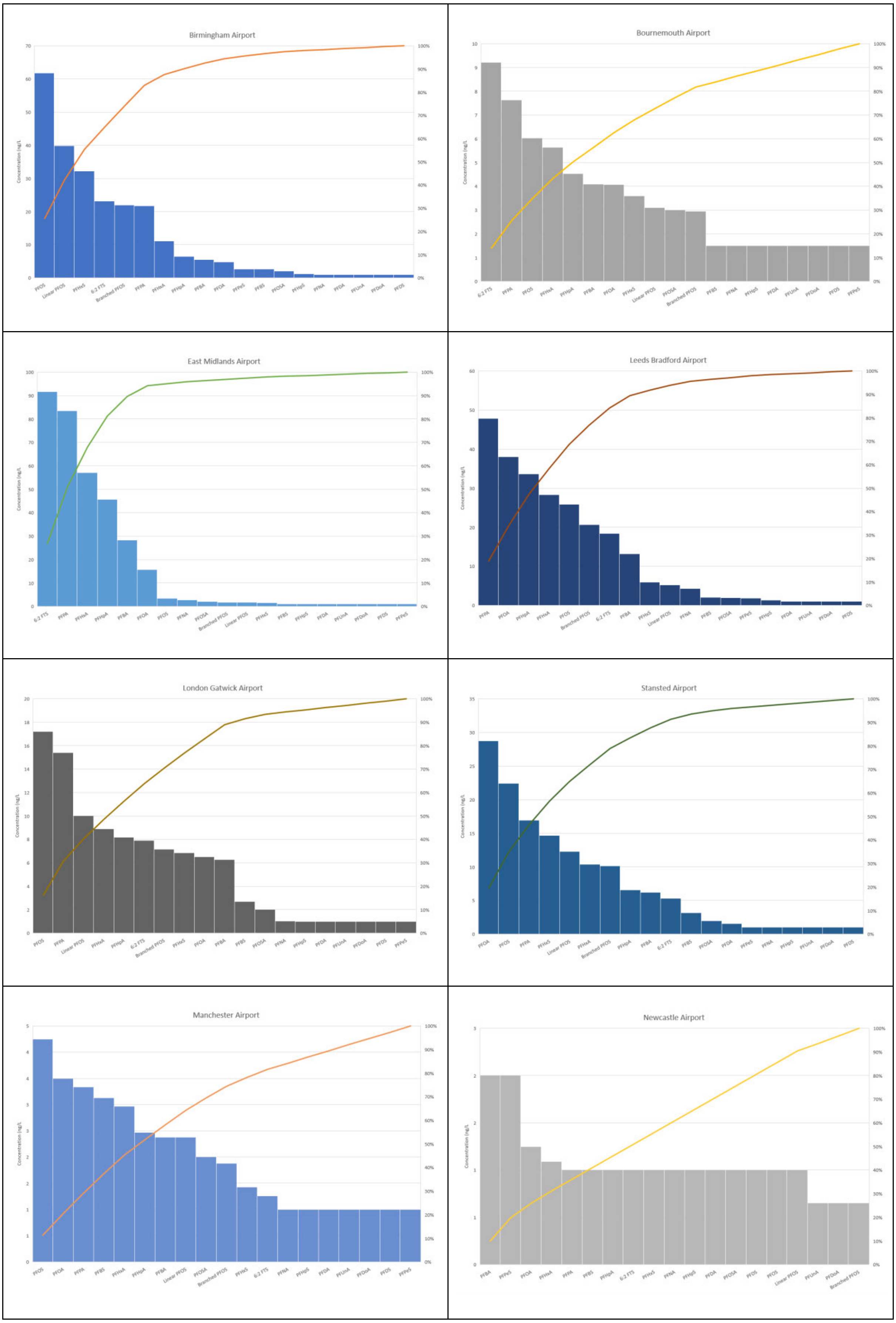


Figure 42: Airport downstream surface water PFAS concentration averages

5.3 Chemical Signature

5.3.1 Magnitude

Airports that reported a statistically significant difference between the upstream and downstream samples in both sampling rounds were Birmingham, Bournemouth, London Gatwick and London Stansted.

The individual PFAS from the upstream and downstream samples across these four airports were summed and presented in Figure 43. Within both the upstream and downstream samples, PFOS, PFPA and PFHxA are the most dominant PFAS within background concentrations. The difference in the downstream samples is the increase in the summed amount for PFHxS and 6:2FTS. As per the expectations listed in Section 2.4, the increase in PFOS, PFHxS and 6:2 FTS detected in the downstream samples could indicate PFAS contamination sourced from AFFF use at airports, both legacy and current use, as 6:2 FTS is used as an alternative for PFOS and PFOA in more contemporary foams. Though PFPA is detected in downstream samples and is not expected from AFFF formulations. Figure 43 shows that PFPA is also present in the upstream samples at a high relative magnitude to other PFAS. Therefore, this could be related to background concentrations. It could also be formed from a precursor within the AFFF formulation.

a) Upstream b) Downstream

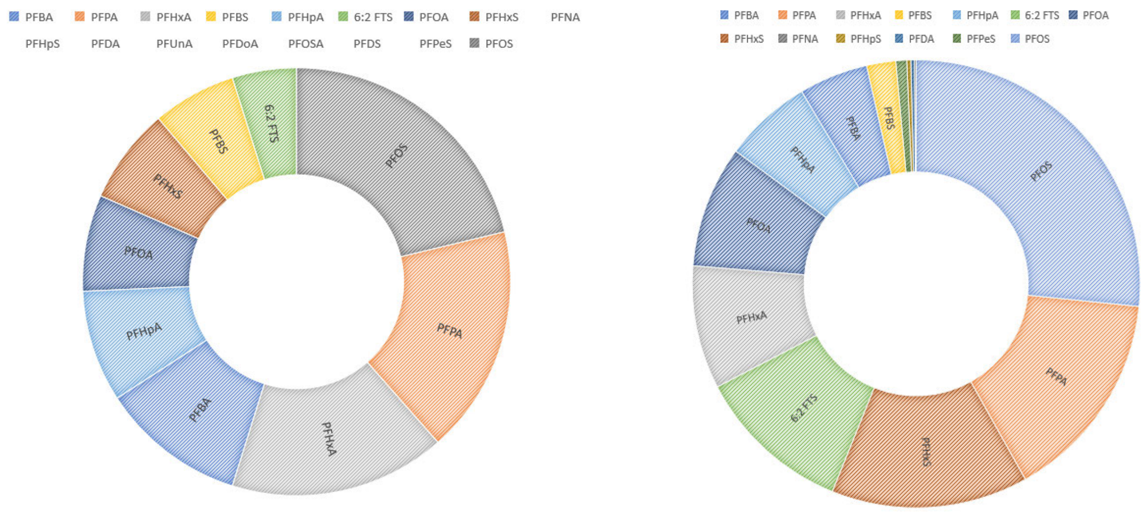


Figure 43: Summed PFAS across Birmingham, Bournemouth, London Gatwick and London Stansted Airports

5.3.2 Percentage Differences

For the four airports, where the results were determined to be statistically different between the upstream and downstream samples, Birmingham and London Stansted had the largest percentage differences between the upstream and downstream samples, as presented in Figure 44. This figure indicates that the main increases in concentration were for PFOS, PFHxS and 6:2 FTS, with smaller increases for PFOA and PFPA.

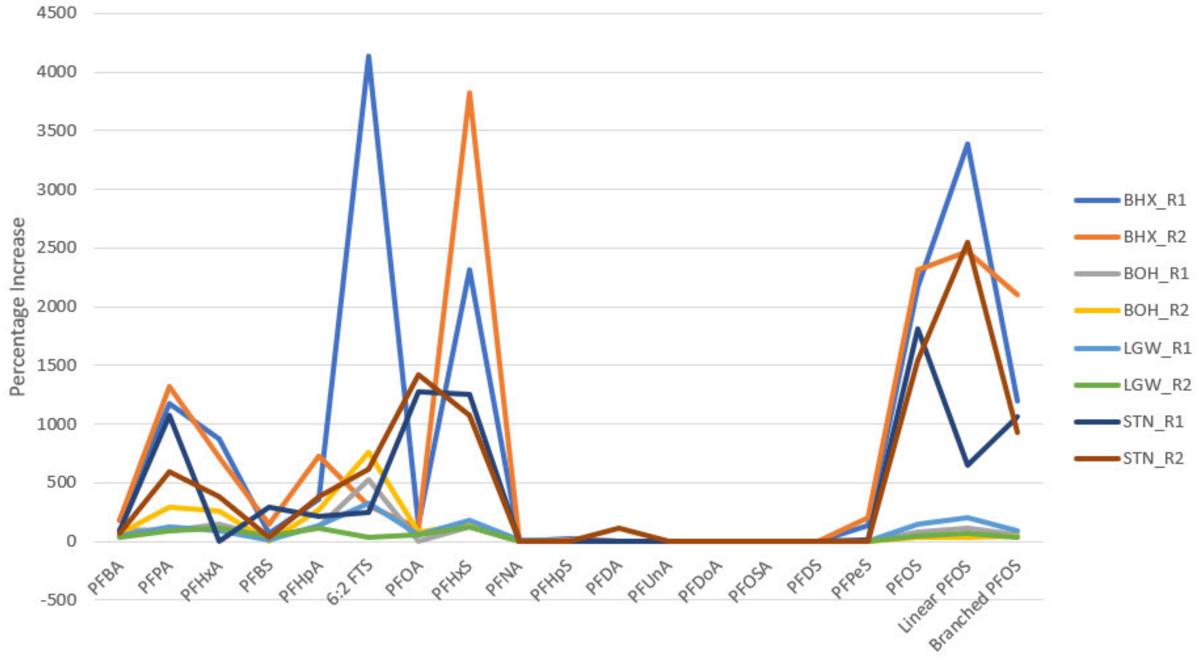


Figure 44: Percentages increases of PFAS in the downstream samples at Birmingham, Bournemouth, London Gatwick and London Stansted Airports

Figure 45 shows the percentage differences for the four airports where the results were not determined to be statistically different. The increases in PFHxS, PFOS and PFOA seen in the previous four airports are not observed in the latter four airports. As these PFAS are considered to be key contributors to AFFF formulations, this is further evidence that other PFAS sources (not AFFF) could be contributing to PFAS in surface waters at East Midlands and Leeds Bradford Airports. Though there is the possibility that EMA and LBA are showing contamination signatures common of newer foams using 6:2 FTS and are not showing the same legacy contamination signature of PFOS, PFHxS and PFOA of the old AFFF formulations. Manchester and Newcastle Airports' sampling locations were probably not positioned to obtain accurate results regarding the PFAS sources at the airport; therefore, that is more likely the reason why these airports are different, rather than non-AFFF PFAS sources.

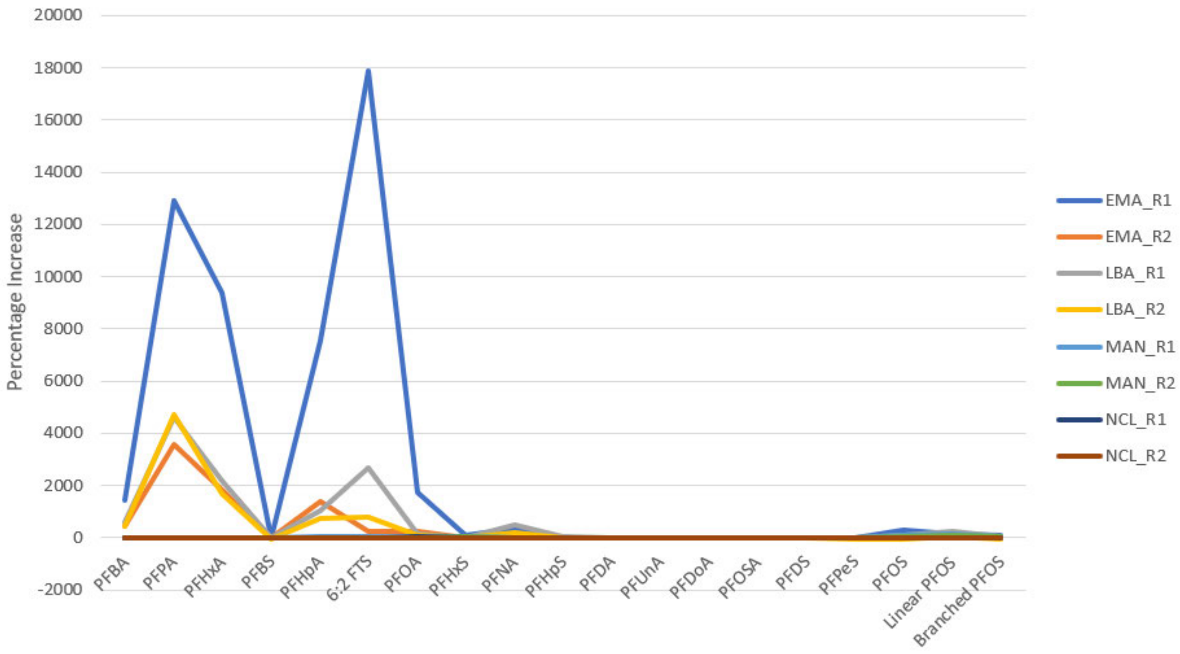


Figure 45: Percentages increases of PFAS in the downstream samples at East Midlands, Leeds Bradford, Manchester and Newcastle Airports

Another way to look at the chemical signature is to group the PFAS into the sub-class groups, precursors, PFSAs, PFPAs and PFCAs to allow comparison between the samples from across the different airports to get a general trend of the main constituents that could have been in the AFFF formulations. This technique creates homologue profiles of PFAS and was used by Koch *et al.,* (2019) to look at the contaminant mixture associated with historical AFFF products.

From the analytical suite undertaken, the following groupings have been used in this assessment:

- Precursors – 6:2 FTS and PFOSA;
- PFSAs – PFBS, PFHxS, PFHpS, PFDS, PFPeS and PFOS;
- PFPAs – PFPA;
- PFCAS – PFBA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnA and PFDoA

Figure 46 shows the homologue chart of these groupings for BHX, BOH, LGW and STN airports. The homologue profiles show that for the downstream samples, the percentage of precursors has increased, and generally, the percentage of PFCAs has decreased in the PFAS total load. The downstream samples in Figure 46(b) show a similar profile between the different airports, which could be the chemical signature observed from the AFFF used at the airports.

a) b)

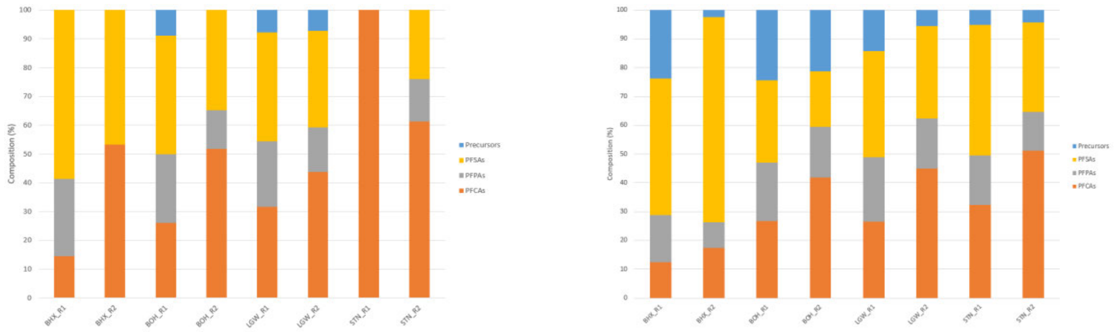


Figure 46: Homologue profiles of PFAS in upstream (a) and downstream (b) surface water samples from Birmingham, Bournemouth, London Gatwick and London Stansted Airports

Undertaking the same exercise for EMA, LBA, MAN and NCL airports, presented in Figure 47, it can be observed that the profile for East Midlands Airport downstream sample is very different from the profiles shown in Figure 46(b), with only a small proportion of the detected PFAS being from the PFSAs subclass. This is further indication that impacts observed at EMA may not be fully attributable to legacy AFFF products. Leeds Bradford Airport's downstream surface water samples present a PFAS homologue similar to the four airports shown in Figure 46, which were calculated as having a significant difference between the upstream and downstream samples. Leeds Bradford Airport may, therefore, still show evidence of legacy AFFF use at the airport, but the significance of the results could be influenced by the elevated upstream surface water PFAS concentrations which could be due to potential sources on the airport's upstream sampling location.

There is not much difference between the upstream and downstream samples at Manchester Airport, potentially indicating that these are background concentrations.

a) b)

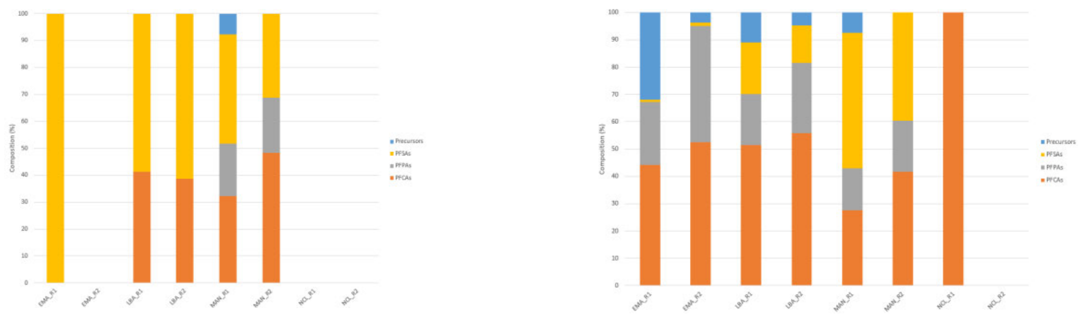


Figure 47: Homologue profiles of PFAS in upstream (a) and downstream (b) surface water samples from East Midlands, Leeds Bradford, Manchester and Newcastle International Airports

5.3.3 Branched vs Linear Isomers

Following the literature review, it was expected that if a legacy ECF AFFF was used than 20-30% of the PFAS would be branched isomers. In the analysis undertaken, only PFOS was split into linear and branched isomers. Figure 48 shows the percentage of linear vs branched PFOS isomers out of the total PFOS reported. There is typically over 30% branched isomers which is consistent with literature indicating that this PFAS contamination in the surface waters is related to legacy AFFF use. The downstream samples typically have a lower percentage of branched PFOS than the upstream samples. The background source of the upstream samples is unknown.

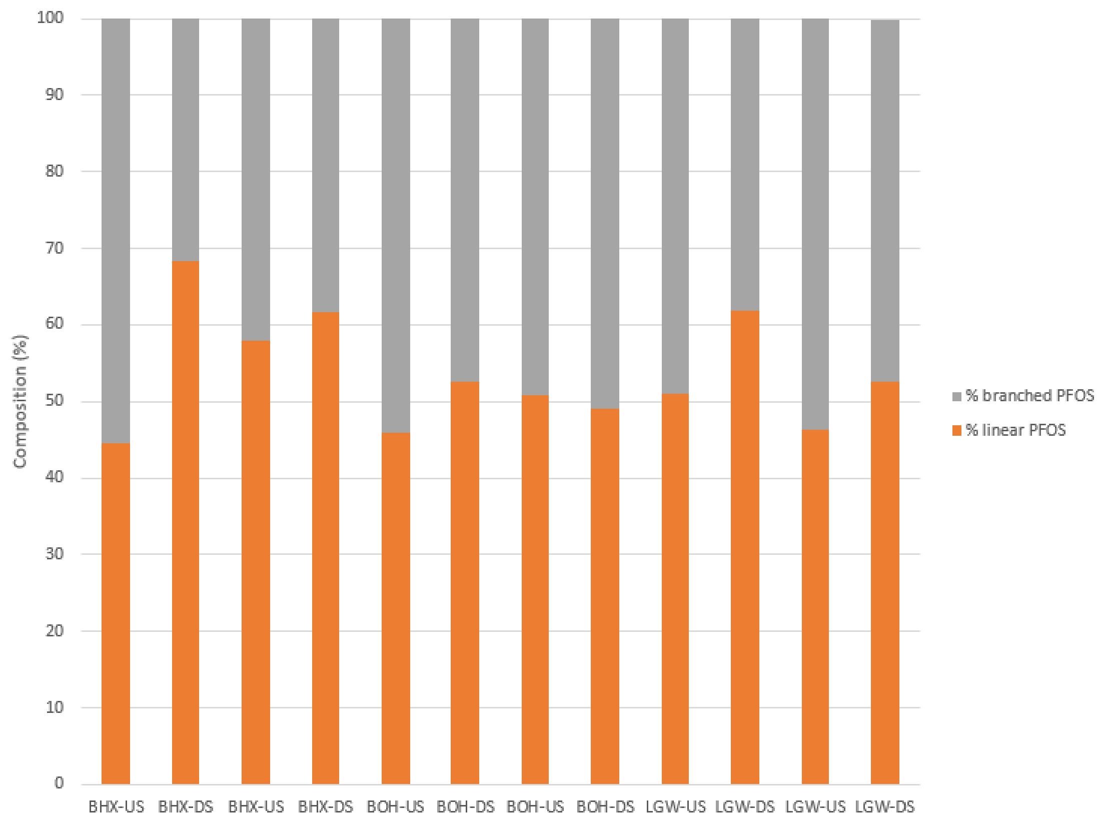


Figure 48: Branched vs Linear PFOS isomers in surface water samples from upstream and downstream of four UK airports

5.4 Limitations

Where surface water samples could be collected was limited due to access constraints and health and safety concerns for the sampler. Samples also had to be obtained from public land, which restricted some access to the rivers. Based on this, some preferable sampling locations could not be utilised.

The number of sampling rounds is limited to two rounds. The initial two sampling rounds allowed an initial assessment of the data, though more sampling rounds would have allowed for any inconsistency between rounds, such as for East Midlands Airport, to be assessed more adequately. It is unknown if the inconsistency between East Midlands Airport downstream samples across the two rounds is due to a rainfall event, a discharge event or even cross-contamination during sampling. The latter is considered unlikely due to the comparison between the parent and daughter samples collected during the first monitoring round.

There are no point source soil samples from the airport FTAs with which to compare the surface water samples. Therefore, this assessment of whether AFFF use has impacted surface waters is based on a literature review of what is expected from AFFF formulations with regard to PFAS contamination. It is unknown whether PFAS contamination from the airport is via drainage discharge as well as runoff. A sample from the discharge points around the airports would help with this assessment.

Information from the airports regarding the type of foam formulations used currently and historically would have helped this assessment. This would have allowed a direct comparison study rather than relying on literature sources for common chemical signatures of AFFF contamination.

Within the literature review, a potential AFFF signature within water catchment was that six carbon fluorotelomers were present in AFFF impacted water catchments and four carbon fluorotelomers were present in non-AFFF impacted water catchments. Four-carbon fluorotelomers where not analysed as part of the analytical suite in this study, though 6:2 FTS was encountered as a dominant PFAS indicating AFFF impacted water catchments.

6. Conclusions and Recommendations

The research aim of this study was to determine if sampling surface water adjacent to airports can determine if an airport is a point source of PFAS and further understand whether civilian airports are an important/significant source of PFAS contamination within waterways. This assessment has indicated that sampling of surface waters outside of a site can be used to determine if the site is a source of PFAS contamination. Four airports used in this assessment have been shown to have statistically different PFAS concentrations in surface waters located upstream and downstream of the airports.

The downstream samples have shown increases in precursors typical of more contemporary AFFF formulations, such as 6:2 FTS. There has also been observed increases in PFOS concentration downstream of airports which is typical of legacy AFFF formulations. The sum of PFSAs within the total PFAS targeted was found to increase downstream of airports, whilst the PFCAs decreased relative to the total PFAS sum. PFSAs are typical of legacy AFFF contamination.

PFOA was identified less than expected but was a higher relative percentage in surface waters from Leeds Bradford and London Stansted Airports. PFOA is associated with later AFFF formulation post-2002.

Branched PFOS isomers were encountered at ratios to linear PFOS isomers at greater than 20-30% which is expected for AFFF contamination. However, the percentage appears to decrease downstream of the airport relative to upstream. The source of the branched PFOS upstream within the background concentrations is unknown. The branching is a result of the electrochemical fluorination process undertaken to create the older AFFF formulations. The literature review relates to the formation of 3M Lightwater which, though dominant globally, may not have been the dominant AFFF formulation used in the UK, which may have been Angus. The fluorotelomer AFFF process used in later foams created fewer branching isotopes. Therefore, what is observed is dependent on the manufacturing process. Despite this, there are other lines of evidence which determine that the PFAS detected in the downstream samples is related to AFFF use at the airports.

Most surface water samples reported large increases in PFPA, which is not typically associated with legacy AFFF formulations based on the literature review. It is a short-chain PFAS and could be more associated with current AFFF formulations rather than legacy AFFF formulations, though without a study of current AFFF formulations; this has not been determined. PFPA forms a large percentage of the total PFAS concentration in the upstream samples, though does increase downstream of the airports indicating that the airports are also a source of the compound. As a short chain PFAS, it is possible that it could be the by-product of precursor breakdown.

Even knowing that airports are AFFF-impacted sites, the environmental sample contamination profiles differ from site to site. Though a common signature of increasing PFOS, 6:2 FTS, PFHxS, PFPA, and, to a lesser extent, PFOA has been observed. It can be determined from this study that it is possible to use surface waters outside of a site to determine if the site is a PFAS polluter. Using statistical analysis and environmental forensics, it can be determined from the data obtained that legacy AFFF use is a PFAS source within the surrounding surface waters. Based on the data, it is also potentially possible to observe contemporary AFFF contamination. This conclusion is due to the increase in 6:2 FTS observed in the downstream samples and how 6:2 FTS forms a large percentage of the total PFAS load at numerous airports. This six-carbon fluorotelomer is associated with new AFFF formulations as an alternative to PFOS and PFOA.

A limitation to the study when sampling outside of a potential polluting site is the distance of the sampling points from the source areas. This introduces unknowns such as the fate and transport mechanisms that occur along the source to sampling point pathway. The larger the distance between source and sampling point also introduces the potential for unknown non-AFFF PFAS sources. The accessibility of the sample locations is also a limitation as the more appropriate locationa may not be accessible. Though there are limitations to this methodology, it has provided data which can be evaluated and assessed to determine that airports are a source of PFAS within waterways. This methodology could be employed in a wider scale to determine polluter sites. It has shown that environmental samples do not need to be collected onsite to determine a source of pollution.

To take this study further, recommendations would be as follows:

- Undertake more sampling rounds to provide more confidence in the dataset. This could potentially reduce the inconsistency observed between monitoring rounds;
- Increase the number of sample locations to get a full spatial distribution around the airport. The airports have been observed to be in two or more water catchments, so ideally, samples will be collected from within each water catchment;
- Take samples at various points downstream to assess for degradation. This will help identify if the concentration of precursors decreases from the source and if the breakdown products increase further downstream;
- The study could be taken further into looking at the bacterial life in the water and sediments to determine how different microcosms affect the fate and transport of PFAS in waterways;
- Collect samples of the airport discharge points to allow a comparison to surface water samples;

- To determine if surface water turbidity has an effect, it is recommended to collect two water samples from the same location but send one to the laboratory filtered and one unfiltered. This will enable an assessment to see if PFAS partitions onto the sediment within the bottle during transit and whether this would affect the results; and

- Obtain the AFFF formulation records from the airports.

Further studies could expand into obtaining onsite soil samples and groundwater samples, as well as concrete samples from the FTAs.

7. References

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Appendix A

Tables

Table A - Surface Water Laboratory Data

NUMBER OF SAMPLES:	36						Sample Location	BHX-US	BHX-DS	BHX-DS-DUP	BHX-US	BHX-DS	BOH-US	BOH-DS	BOH-US	BOH-DS	BOH-DS-DUP	EMA_US	EMA_DS	EMA_DS_DUP	EMA_US
							Monitoring Round No.	1	1	1	2	2	1	1	2	2	2	1	1	1	2
							Date Sampled	09/01/2023	09/01/2023	09/01/2023	23/01/2023	23/01/2023	10/01/2023	10/01/2023	24/01/2023	24/01/2023	24/01/2023	19/01/2023	19/01/2023	19/01/2023	02/02/2023
							Stratum														
Analytical Parameter	Units	Limit of detection	No. Analyses	Min	Mean	Max	Max ID														
PFBA (375-22-4)	n.L^{-1}	<2	36	<2	<6.7	45.5	EMA_DS	<2	5.50	5.28	<2	5.57	<2	<4	2.57	4.17	3.92	<3	45.50	43.60	<2
PFPA (2706-90-3)	n.L^{-1}	<1	36	<1	<17.1	133	EMA_DS_DUP	2.31	29.30	35.60	<1	14.20	4.23	8.19	1.80	7.08	7.49	<1	130.00	133.00	<1
PFHxA (307-24-4)	n.L^{-1}	<1	36	<1	<11.2	97.8	EMA_DS_DUP	1.24	12.10	12.10	1.22	10.00	2.58	6.24	1.41	5.04	5.21	<1	94.80	97.80	<1
PFBS (375-73-5)	n.L^{-1}	<1	36	<1	<2	<5	STN-US	1.63	2.71	2.53	<1	2.50	1.54	<2	<1	<1	<1	<1	<1	<1	<1
PFHpA (375-85-9)	n.L^{-1}	<1	36	<1	<9.7	86.4	EMA_DS_DUP	<1	4.53	5.03	<1	8.25	2.08	4.56	1.21	4.52	4.74	<1	76.60	86.40	<1
6:2 FTS (27619-97-2)	n.L^{-1}	<1	36	<1	<15.8	180	EMA_DS	<1	42.40	40.30	<1	4.00	1.59	9.87	<1	8.56	8.93	<1	180.00	179.00	<1
PFOA (335-67-1)	n.L^{-1}	<0.65	36	<1	<8.71	48.5	STN-DS	<2	<5	<5	2.09	4.51	<3	<5	1.78	3.15	3.35	<1.5	27.50	25.00	<1.2
PFHxS (355-46-4)	n.L^{-1}	<1	36	<1	<5.6	39.2	BHX-DS	1.05	25.30	24.70	<1	39.20	1.78	4.05	1.29	3.14	3.05	<1	1.99	1.94	<1
PFNA (375-95-1)	n.L^{-1}	<1	36	<1	<1.5	5.7	LBA-DS	<1	<1	<1	<1	<1	<1	<2	<1	<1	<1	<1	4.39	4.76	<1
PFHpS (375-92-8)	n.L^{-1}	<1	36	<1	<1.2	<5	STN-US	<1	1.28	1.16	<1	1.07	<1	<2	<1	<1	<1	<1	<1	<1	<1
PFDA (335-76-2)	n.L^{-1}	<1	36	<1	<1.2	<5	STN-US	<1	<1	<1	<1	<1	<1	<2	<1	<1	<1	<1	<1	<1	<1
Linear PFOS (1763-23-1)	n.L^{-1}	<0.65	36	<0.65	<5.96	43.1	BHX-DS	1.05	36.60	31.80	1.68	43.10	1.85	3.90	1.72	2.29	2.40	<0.65	1.64	2.12	<0.65
Branched PFOS	n.L^{-1}	<0.65	36	<0.65	<6.17	29	LBA-DS	1.31	17.00	15.80	1.22	26.90	2.18	3.51	1.66	2.37	2.44	0.91	1.74	2.22	<0.65
PFUnA (2058-94-8)	n.L^{-1}	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<1	<1	<2	<1	<1	<1	<1	<1	<1	<1
PFDoA (307-55-1)	n.L^{-1}	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<1	<1	<2	<1	<1	<1	<1	<1	<1	<1
PFOSA (754-91-6)	n.L^{-1}	<2	36	<2	<2.3	<10	STN-US	<2	<2	<2	<2	<2	<2	<4	<2	<2	<2	<2	<2	<2	<2
PFDS (335-77-3)	n.L^{-1}	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<1	<1	<2	<1	<1	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	n.L^{-1}	<1	36	<1	<1.4	<5	STN-US	<1	2.29	1.98	<1	2.96	<1	<2	<1	<1	<1	<1	<1	<1	<1
Total PFOS	n.L^{-1}	<0.65	36	<0.65	<11.9	70	BHX-DS	2.36	53.60	47.70	2.90	70.00	4.03	7.41	3.38	4.66	4.84	0.91	3.39	4.33	<0.65

Table A - Surface Water Laboratory Data

NUMBER OF SAMPLES:	36						Sample Location	EMA_DS	LBA-US	LBA-DS	LBA_US	LBA_DS	LGW-US	LGW-DS	LGW-US	LGW-DS	MAN-US	MAN-DS	MAN_US	MAN_DS	NCL-US
							Monitoring Round No.	2	1	1	2	2	1	1	2	2	1	1	2	2	1
							Date Sampled	02/02/2023	17/01/2023	17/01/2023	31/01/2023	31/01/2023	11/01/2023	11/01/2023	25/01/2023	25/01/2023	18/01/2023	18/01/2023	01/02/2023	01/02/2023	16/01/2023
							Stratum														
Analytical Parameter	Units	Limit of detection	No. Analyses	Min	Mean	Max	Max ID														
PFBA (375-22-4)	n.L^{-1}	<2	36	<2	<6.7	45.5	EMA_DS	11.00	<2	14.00	2.19	12.40	3.65	5.23	5.39	7.33	<2	<2	3.16	2.75	<2
PFPA (2706-90-3)	n.L^{-1}	<1	36	<1	<17.1	133	EMA_DS_DUP	36.90	<1	47.20	<1	48.40	8.22	18.70	6.30	12.10	2.92	3.08	4.05	3.59	<1
PFHxA (307-24-4)	n.L^{-1}	<1	36	<1	<11.2	97.8	EMA_DS_DUP	19.50	1.30	29.90	1.48	26.70	4.61	8.67	4.27	9.09	2.72	2.89	3.37	3.05	<1
PFBS (375-73-5)	n.L^{-1}	<1	36	<1	<2	<5	STN-US	1.12	2.46	1.92	3.06	2.18	2.56	2.72	1.92	2.70	3.42	3.40	2.80	2.86	<1
PFHpA (375-85-9)	n.L^{-1}	<1	36	<1	<9.7	86.4	EMA_DS_DUP	14.90	3.30	37.90	3.42	29.30	3.20	7.38	4.20	8.98	2.10	2.67	3.04	2.27	<1
6:2 FTS (27619-97-2)	n.L^{-1}	<1	36	<1	<15.8	180	EMA_DS	3.23	<1	27.80	<1	9.09	2.84	11.90	2.90	3.91	1.14	1.51	<1	<1	<1
PFOA (335-67-1)	n.L^{-1}	<0.65	36	<1	<8.71	48.5	STN-DS	<4	17.40	42.50	18.20	33.50	<4.5	<7	3.94	6.03	<3.5	<4	<3.5	<3	<1.2
PFHxS (355-46-4)	n.L^{-1}	<1	36	<1	<5.6	39.2	BHX-DS	<1	6.04	6.22	6.33	5.71	2.61	7.39	2.85	6.34	<1	1.55	1.03	1.31	<1
PFNA (375-95-1)	n.L^{-1}	<1	36	<1	<1.5	5.7	LBA-DS	<1	<1	5.70	<1	2.84	<1	1.06	<1	<1	<1	<1	<1	<1	<1
PFHpS (375-92-8)	n.L^{-1}	<1	36	<1	<1.2	<5	STN-US	<1	<1	1.58	1.17	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFDA (335-76-2)	n.L^{-1}	<1	36	<1	<1.2	<5	STN-US	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Linear PFOS (1763-23-1)	n.L^{-1}	<0.65	36	<0.65	<5.96	43.1	BHX-DS	<0.65	2.02	6.69	2.96	3.71	4.31	13.00	4.15	7.06	1.06	2.86	1.07	1.89	<0.65
Branched PFOS	n.L^{-1}	<0.65	36	<0.65	<6.17	29	LBA-DS	<0.65	18.20	29.00	24.10	12.30	4.15	8.02	4.81	6.32	1.61	2.16	1.25	1.60	<0.65
PFUnA (2058-94-8)	n.L^{-1}	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFDoA (307-55-1)	n.L^{-1}	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFOSA (754-91-6)	n.L^{-1}	<2	36	<2	<2.3	<10	STN-US	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
PFDS (335-77-3)	n.L^{-1}	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	n.L^{-1}	<1	36	<1	<1.4	<5	STN-US	<1	2.56	2.02	2.52	1.62	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PFOS	n.L^{-1}	<0.65	36	<0.65	<11.9	70	BHX-DS	<0.65	20.20	35.70	27.10	16.00	8.46	21.00	8.95	13.40	2.67	5.02	2.32	3.48	<0.65

Table A - Surface Water Laboratory Data

NUMBER OF SAMPLES:	36						Sample Location	NCL-DS	NCL_US	NCL_DS	NCL_DS-DUP	STN-US	STN-DS	STN-US	STN-DS
							Monitoring Round No.	1	2	2	2	1	1	2	2
							Date Sampled	16/01/2023	30/01/2023	30/01/2023	30/01/2023	12/01/2023	12/01/2023	26/01/2023	26/01/2023
							Stratum								
Analytical Parameter	Units	Limit of detection	No. Analyses	Min	Mean	Max	Max ID								
PFBA (375-22-4)	$n.L^{-1}$	<2	36	<2	<6.7	45.5	EMA_DS	<2	<2	<2	<2	<10	3.87	4.97	8.58
PFPA (2706-90-3)	$n.L^{-1}$	<1	36	<1	<17.1	133	EMA_DS_DUP	<1	<1	<1	1.03	<5	11.70	3.21	22.20
PFHxA (307-24-4)	$n.L^{-1}$	<1	36	<1	<11.2	97.8	EMA_DS_DUP	1.18	<1	<1	1.05	6.24	5.94	3.09	14.80
PFBS (375-73-5)	$n.L^{-1}$	<1	36	<1	<2	<5	STN-US	<1	<1	<1	<1	<5	3.93	1.89	2.45
PFHpA (375-85-9)	$n.L^{-1}$	<1	36	<1	<9.7	86.4	EMA_DS_DUP	<1	<1	<1	<1	<5	3.15	2.07	10.00
6:2 FTS (27619-97-2)	$n.L^{-1}$	<1	36	<1	<15.8	180	EMA_DS	<1	<1	<1	<1	<5	3.44	<1	7.13
PFOA (335-67-1)	$n.L^{-1}$	<0.65	36	<1	<8.71	48.5	STN-DS	<1.5	<1	<1	<1.2	<6	8.96	3.20	48.50
PFHxS (355-46-4)	$n.L^{-1}$	<1	36	<1	<5.6	39.2	BHX-DS	<1	<1	<1	<1	<5	13.50	1.36	15.90
PFNA (375-95-1)	$n.L^{-1}$	<1	36	<1	<1.5	5.7	LBA-DS	<1	<1	<1	<1	<5	<1	<1	<1
PFHpS (375-92-8)	$n.L^{-1}$	<1	36	<1	<1.2	<5	STN-US	<1	<1	<1	<1	<5	<1	<1	<1
PFDA (335-76-2)	$n.L^{-1}$	<1	36	<1	<1.2	<5	STN-US	<1	<1	<1	<1	<5	<1	<1	2.08
Linear PFOS (1763-23-1)	$n.L^{-1}$	<0.65	36	<0.65	<5.96	43.1	BHX-DS	<0.65	<0.65	<0.65	<0.65	<3.25	4.87	0.75	19.70
Branched PFOS	$n.L^{-1}$	<0.65	36	<0.65	<6.17	29	LBA-DS	<0.65	<0.65	<0.65	<0.65	<3.25	7.52	1.24	12.80
PFUnA (2058-94-8)	$n.L^{-1}$	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<5	<1	<1	<1
PFDoA (307-55-1)	$n.L^{-1}$	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<5	<1	<1	<1
PFOSA (754-91-6)	$n.L^{-1}$	<2	36	<2	<2.3	<10	STN-US	<2	<2	<2	<2	<10	<2	<2	<2
PFDS (335-77-3)	$n.L^{-1}$	<1	36	<1	<1.1	<5	STN-US	<1	<1	<1	<1	<5	<1	<1	<1
PFPeS (2706-91-4)	$n.L^{-1}$	<1	36	<1	<1.4	<5	STN-US	<1	<1	<1	<1	<5	1.08	<1	<1
Total PFOS	$n.L^{-1}$	<0.65	36	<0.65	<11.9	70	BHX-DS	<0.65	<0.65	<0.65	<0.65	<3.25	12.40	1.98	32.50

Table B - QAQC Lab Data

NUMBER OF SAMPLES:	9						Sample Location	BHX - EQUIPMENT	BHX - TRIP BLANK	BOH - EQUIPMENT	BOH - TRIP BLANK	EMA -TRIP BLANK	EMA- EQUIPMENT	LAB WATER 1	LAB WATER 2	NCL- TRIP BLANK
							Monitoring Round No.	1	1	2	2	1	1	1	2	2
							Date Sampled	09/01/2023	09/01/2023	24/01/2023	24/01/2023	19/01/2023	19/01/2023	09/01/2023	24/01/2023	30/01/2023
							Stratum	SW	SW	SW	SW	SW	SW	SW	SW	SW
Analytical Parameter	Units	Limit of detection	No. Analyses	Min	Mean	Max	Max ID									
PFBA (375-22-4)	$n.L^{-1}$	<2	9	<2	<2	<2	n/a	<2	<2	<2	<2	<2	<2	<2	<2	<2
PFPA (2706-90-3)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFHxA (307-24-4)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFBS (375-73-5)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFHpA (375-85-9)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
6:2 FTS (27619-97-2)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFOA (335-67-1)	$n.L^{-1}$	<0.65	9	<0.65	<0.83	<1.3	EMA -TRIP BLANK	<0.65	<0.65	<0.65	<0.65	<1.3	<1.2	<1	<0.65	<0.7
PFHxS (355-46-4)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFNA (375-95-1)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFHpS (375-92-8)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFDA (335-76-2)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
Linear PFOS (1763-23-1)	$n.L^{-1}$	<0.65	9	<0.65	<0.67	0.872	LAB WATER 1	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	0.87	<0.65	<0.65
Branched PFOS	$n.L^{-1}$	<0.65	9	<0.65	<0.65	<0.65	n/a	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
PFUnA (2058-94-8)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFDoA (307-55-1)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFOSA (754-91-6)	$n.L^{-1}$	<2	9	<2	<2	<2	n/a	<2	<2	<2	<2	<2	<2	<2	<2	<2
PFDS (335-77-3)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	$n.L^{-1}$	<1	9	<1	<1	<1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PFOS	$n.L^{-1}$	<0.65	9	<0.65	<0.67	0.872	LAB WATER 1	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	0.87	<0.65	<0.65

Table C - Duplicate Analysis

Sample Location		BHX-DS-DUP	BHX-DS	RPD	BOH-DS-DUP	BOH-DS	RPD	EMA_DS-DUP	EMA_DS	RPD	NCL_DS-DUP	NCL_DS	RPD
Monitoring Round No.		1	1		2	2		1	1		2	2	
Date Sampled		09/01/2023	09/01/2023	%	24/01/2023	24/01/2023	%	19/01/2023	19/01/2023	%	30/01/2023	30/01/2023	%
Analytical Parameter	Units												
PFBA (375-22-4)	n.L^{-1}	5.28	5.50	4.1%	3.92	4.17	6.2%	43.60	45.50	4.3%	<2	<2	0.0%
PFPA (2706-90-3)	n.L^{-1}	35.60	29.30	19.4%	7.49	7.08	5.6%	133.00	130.00	2.3%	1.03	<1	3.0%
PFHxA (307-24-4)	n.L^{-1}	12.10	12.10	0.0%	5.21	5.04	3.3%	97.80	94.80	3.1%	1.05	<1	4.9%
PFBS (375-73-5)	n.L^{-1}	2.53	2.71	6.9%	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%
PFHpA (375-85-9)	n.L^{-1}	5.03	4.53	10.5%	4.74	4.52	4.8%	86.40	76.60	12.0%	<1	<1	0.0%
6:2 FTS (27619-97-2)	n.L^{-1}	40.30	42.40	5.1%	8.93	8.56	4.2%	179.00	180.00	0.6%	<1	<1	0.0%
PFOA (335-67-1)	n.L^{-1}	<5	<5	0.0%	3.35	3.15	6.2%	25.00	27.50	9.5%	<1.2	<1	18.2%
PFHxS (355-46-4)	n.L^{-1}	24.70	25.30	2.4%	3.05	3.14	2.9%	1.94	1.99	2.5%	<1	<1	0.0%
PFNA (375-95-1)	n.L^{-1}	<1	<1	0.0%	<1	<1	0.0%	4.76	4.39	8.1%	<1	<1	0.0%
PFHpS (375-92-8)	n.L^{-1}	1.16	1.28	9.8%	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%
PFDA (335-76-2)	n.L^{-1}	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%
Linear PFOS (1763-23-1)	n.L^{-1}	31.80	36.60	14.0%	2.40	2.29	4.7%	2.12	1.64	25.5%	<0.65	<0.65	0.0%
Branched PFOS	n.L^{-1}	15.80	17.00	7.3%	2.44	2.37	2.9%	2.22	1.74	24.2%	<0.65	<0.65	0.0%
PFUnA (2058-94-8)	n.L^{-1}	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%
PFDoA (307-55-1)	n.L^{-1}	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%
PFOSA (754-91-6)	n.L^{-1}	<2	<2	0.0%	<2	<2	0.0%	<2	<2	0.0%	<2	<2	0.0%
PFDS (335-77-3)	n.L^{-1}	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%
PFPeS (2706-91-4)	n.L^{-1}	1.98	2.29	14.5%	<1	<1	0.0%	<1	<1	0.0%	<1	<1	0.0%
Total PFOS	n.L^{-1}	47.70	53.60	11.6%	4.84	4.66	3.8%	4.33	3.39	24.4%	<0.65	<0.65	0.0%

BLACK BOLD TEXT ON WHITE BACKGROUND - RPD > 20%
WHITE BOLD TEXT ON GREY BACKGROUND - RPD > 30%

Table D: Percentage Differences between Upstream and Downstream Surface Water Samples

	BHX	BHX	BOH	BOH	EMA	EMA	LBA	LBA	LGW	LGW	STN	STN	MAN	MAN	NCL	NCL
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
PFBA	175	179	100	62	1417	450	600	466	43	36	94	73	0	-13	0	0
PFPA	1168	1320	94	293	12900	3590	4620	4740	127	92	1070	592	5	-11	0	0
PFHxA	876	720	142	257	9380	1850	2200	1704	88	113	-5	379	6	-9	18	0
PFBS	66	150	30	0	0	12	-22	-29	6	41	293	30	-1	2	0	0
PFHpA	353	725	119	274	7560	1390	1048	757	131	114	215	383	27	-25	0	0
6:2 FTS	4140	300	521	756	17900	223	2680	809	319	35	244	613	32	0	0	0
PFOA	150	116	0	77	1733	233	144	84	56	53	1278	1416	14	-14	25	0
PFHxS	2310	3820	128	143	99	0	3	-10	183	122	1250	1069	55	27	0	0
PFNA	0	0	0	0	339	0	470	184	6	0	0	0	0	0	0	0
PFHpS	28	7	0	0	0	0	58	-15	0	0	0	0	0	0	0	0
PFDA	0	0	0	0	0	0	0	0	0	0	0	108	0	0	0	0
PFUnA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PFDoA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PFOSA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PFDS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PFPeS	129	196	0	0	0	0	-21	-36	0	0	8	0	0	0	0	0
PFOS	2171	2314	84	38	271	0	77	-41	148	50	1808	1541	88	50	0	0
Linear PFOS	3386	2465	111	33	152	0	231	25	202	70	649	2544	170	77	0	0
Branched PFO	1198	2105	61	43	90	0	59	-49	93	31	1057	932	34	28	0	0

Appendix B

Laboratory Certificates

Unit 7-8 Hawarden Business Park
Manor Road (off Manor Lane)
Hawarden
Deeside
CH5 3US
Tel: (01244) 528777
email: hawardencustomerservices@alsglobal.com
Website: www.alsenvironmental.co.uk

Jacobs Engineering UK Limited
1180 Eskdale Road
Winnersh
Wokingham
Berkshire
RG41 5TU

Attention: Andrew Davies

CERTIFICATE OF ANALYSIS

Date of report Generation:	23 January 2023
Customer:	Jacobs Engineering UK Limited
Sample Delivery Group (SDG):	230114-59
Your Reference:	B2449202
Location:	PFAS Surface Water Sampling
Report No:	675846
Order Number:	

We received 12 samples on Saturday January 14, 2023 and 12 of these samples were scheduled for analysis which was completed on Monday January 23, 2023. Accredited laboratory tests are defined within the report, but opinions, interpretations and on-site data expressed herein are outside the scope of ISO 17025 accreditation

Should this report require incorporation into client reports, it must be used in its entirety and not simply with the data sections alone.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden.

All sample data is provided by the customer. The reported results relate to the sample supplied, and on the basis that this data is correct.
Incorrect sampling dates and/or sample information will affect the validity of results.
The customer is not permitted to reproduce this report except in full without the approval of the laboratory.

Approved By:

Sonia McWhan
Operations Manager

1291

Received Sample Overview

Lab Sample No(s)	Customer Sample Ref.	AGS Ref.	Depth (m)	Sampled Date
27408980	BHX-DS			09/01/2023
27408981	BHX-DS-3			09/01/2023
27408975	BHX-US			09/01/2023
27408976	BHX-US-1			09/01/2023
27408977	BHX-US-2			09/01/2023
27408984	BOH-DS			10/01/2023
27408982	BOH-US			10/01/2023
27408986	LGW-DS			11/01/2023
27408985	LGW-US			11/01/2023
27408978	LW-1			09/01/2023
27408988	STN-DS			12/01/2023
27408987	STN-US			12/01/2023

Only received samples which have had analysis scheduled will be shown on the following pages.

CERTIFICATE OF ANALYSIS

Validated

SDG: 230114-59
Client Ref.: B2449202
Report Number: 675846
Location: PFAS Surface Water Sampling
Superseded Report:

Results Legend

- X Test
- N No Determination Possible

Sample Types -
S Soil/Solid
UNS - Unspecified Solid
GW - Ground Water
SW - Surface Water
LE - Land Leachate
PL - Prepared Leachate
PR - Process Water
SA - Saline Water
TE - Trade Effluent
TS - Treated Sewage
US - Untreated Sewage
RE - Recreational Water
DW - Drinking Water Non-regulatory
UNL - Unspecified Liquid
SL - Sludge
G - Gas
OTH - Other

Lab Sample No(s)			27408980	27408981	27408975	27408976	27408977	27408984	27408982	27408986	27408985	27408978	27408988	27408987
Customer Sample Reference			BHX-DS	BHX-DS-3	BHX-US	BHX-US-1	BHX-US-2	BOH-DS	BOH-US	LGW-DS	LGW-US	LW-1	STN-DS	STN-US
AGS Reference														
Depth (m)														
Container			500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)
Sample Type			SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
PFAS Liquids	All	NDPs: 0 Tests: 12	X	X	X	X	X	X	X	X	X	X	X	X

08:25:18 23/01/2023

Validated

CERTIFICATE OF ANALYSIS

SDG: 230114-59
Client Ref.: B2449202
Report Number: 675846
Location: PFAS Surface Water Sampling
Superseded Report:

Results Legend

#	ISO17025 accredited.
M	mCERTS accredited.
aq	Aqueous / settled sample.
diss.filt	Dissolved / filtered sample.
tot.unfilt	Total / unfiltered sample.
*	Subcontracted - refer to subcontractor report for accreditation status.
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
(F)	Trigger breach confirmed
1-4+§@	Sample deviation (see appendix)

Customer Sample Ref.			BHX-DS	BHX-DS-3	BHX-US	BHX-US-1	BHX-US-2	BOH-DS
Depth (m)				-	-	-	-	
Sample Type			Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)
Date Sampled			09/01/2023	09/01/2023	09/01/2023	09/01/2023	09/01/2023	10/01/2023
Sample Time			15:10:00	15:10:00	13:10:00	13:10:00	13:10:00	16:30:00
Date Received			14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023
SDG Ref			230114-59	230114-59	230114-59	230114-59	230114-59	230114-59
Lab Sample No.(s)			27408980	27408981	27408975	27408976	27408977	27408984
AGS Reference								
Component	**LOD/Units**	**Method**						
PFBA (375-22-4)	<2 ng/l	TM337	5.5 #	5.28 #	<2 #	<2 #	<2 #	<4 #
PFPA (2706-90-3)	<1 ng/l	TM337	29.3 #	35.6 #	2.31 #	<1 #	<1 #	.19 #
PFHxA (307-24-4)	1 ng/l	TM337	12 1 #	12 1 #	1 24 #	1 #	<1 #	6 24 #
PFBS (375-73-5)	<1 ng/l	TM337	2.71 #	2.53 #	1.63 #	<1 #	<1 #	<2 #
PFHpA (375-85-9)	<1 ng/l	TM337	4.53 #	5.03 #	<1 #	<1 #	<1 #	4.56 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337	42.4 #	40.3 #	<1 #	<1 #	<1 #	9.87 #
PFOA (335-67-1)	<0.65 ng/l	TM337	<5 #	<5 #	<2 #	<0.65 #	<0.65 #	<5 #
PFHxS (355-46-4)	<1 ng/l	TM337	25.3 #	24.7 #	1.05 #	<1 #	<1 #	4.05 #
PFNA (375-95-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<2 #
PFHpS (375-92-8)	<1 ng/l	TM337	.28 #	1.16 #	<1 #	<1 #	<1 #	<2 #
PFDA (335-76-2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<2 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	36.6 #	31.8 #	1.05 #	<0.65 #	<0.65 #	3.9 #
Branched PFOS	0 65 ng/l	TM337	17 #	15 8 #	1 31 #	0 65 #	<0 65 #	3 51 #
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<2 #
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<2 #
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #	<2 #	<4 #
PFDS (335-77-3)	<1 ng/l	TM337	<1	<1	<1	<1	<1	<2
PFPeS (2706-91-4)	<1 ng/l	TM337	2.29 #	1.98 #	<1 #	<1 #	<1 #	<2 #
Total PFOS	<0.65 ng/l	TM337	53.6 #	47.7 #	2.36 #	<0.65 #	<0.65 #	7.41 #

Validated

CERTIFICATE OF ANALYSIS

SDG: 230114-59 **Report Number:** 675846 **Superseded Report:**

Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

- # ISO17025 accredited.
- M mCERTS accredited.
- aq Aqueous / settled sample.
- diss.filt Dissolved / filtered sample.
- tot.unfilt Total / unfiltered sample.
- * Subcontracted - refer to subcontractor report for accreditation status.
- ** % recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
- (F) Trigger breach confirmed
- 1-4+§@ Sample deviation (see appendix)

Customer Sample Ref.			BOH-US	LGW-DS	LGW-US	LW-1	STN-DS	STN-US
Depth (m)				-	-	-	-	
Sample Type			Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)
Date Sampled			10/01/2023	11/01/2023	11/01/2023	09/01/2023	12/01/2023	12/01/2023
Sample Time			15:25:00	13:20:00	11:25:00	11:45:00	10:10:00	08:50:00
Date Received			14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023
SDG Ref			230114-59	230114-59	230114-59	230114-59	230114-59	230114-59
Lab Sample No.(s)			27408982	27408986	27408985	27408978	27408988	27408987
AGS Reference								
Component	**LOD/Units**	**Method**						
PFBA (375-22-4)	<2 ng/l	TM337	<2 #	5.23 #	3.65 #	<2 #	3.87 #	<10 #
PFPA (2706-90-3)	<1 ng/l	TM337	4.23 #	18.7 #	8.22 #	<1 #	11.7 #	<5 #
PFHxA (307-24-4)	1 ng/l	TM337	2 58 #	8 67 #	4 61 #	1 #	5 94 #	6 24 #
PFBS (375-73-5)	<1 ng/l	TM337	.54 #	2.72 #	2.56 #	<1 #	3.93 #	<5 #
PFHpA (375-85-9)	<1 ng/l	TM337	2.08 #	7.38 #	3.2 #	<1 #	3.15 #	<5 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337	.59 #	11.9 #	2.84 #	<1 #	3.44 #	<5 #
PFOA (335-67-1)	<0.65 ng/l	TM337	<3 #	<7 #	<4.5 #	<1 #	8.96 #	<6 #
PFHxS (355-46-4)	<1 ng/l	TM337	.78 #	7.39 #	2.61 #	<1 #	13.5 #	<5 #
PFNA (375-95-1)	<1 ng/l	TM337	<1 #	1.06 #	<1 #	<1 #	<1 #	<5 #
PFHpS (375-92-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<5 #
PFDA (335-76-2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<5 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	.85 #	13 #	4.31 #	0.872 #	4.87 #	<3.25 #
Branched PFOS	0 65 ng/l	TM337	2 18 #	8 02 #	4 15 #	0 65 #	7 52 #	3 25 #
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<5 #
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<5 #
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #	<2 #	<10 #
PFDS (335-77-3)	<1 ng/l	TM337	<1	<1	<1	<1	<1	<5
PFPeS (2706-91-4)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	1.08 #	<5 #
Total PFOS	<0.65 ng/l	TM337	4.03 #	21 #	8.46 #	0.872 #	12.4 #	<3.25 #

Table of Results - Appendix

Method No	Reference	Description
TM337	PFAS in Environmental Water Matrices	Analysis of PFAS

NA = not applicable.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden (Method codes TM).

Test Completion Dates

Lab Sample No(s)	27408980	27408981	27408975	27408976	27408977	27408984	27408982	27408986	27408985	27408978
Customer Sample Ref.	BHX-DS	BHX-DS-3	BHX-US	BHX-US-1	BHX-US-2	BOH-DS	BOH-US	LGW-DS	LGW-US	LW-1
AGS Ref.										
Depth										
Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
PFAS Liquids	20 Jan 2023	20 Jan 2023	20 Jan 2023	23 Jan 2023	23 Jan 2023	23 Jan 2023	23 Jan 2023	23 Jan 2023	20 Jan 2023	20 Jan 2023

Lab Sample No(s)	27408988	27408987
Customer Sample Ref.	TN D	TN U
AGS Ref.		
Depth		
Type	Surface Water	Surface Water
PFAS Liquids	20-Jan-2023	23-Jan-2023

ASSOCIATED AQC DATA

PFAS Liquids

Component	Method Code	QC 2742	QC 2702
Perfluoro 1 butanesulfonate	TM337	**84.0** 58.95 : 133.73	**86.5** 58.95 : 133.73
Perfluoro-1-heptanesulfonate	TM337	**87.63** 54.69 : 144.16	**87.88** 54.69 : 144.16
Perfluoro-1-hexanesulfonate	TM337	**87.13** 70.93 : 121.48	**90.63** 70.93 : 121.48
Perfluoro-1-octanesulfonate	TM337	**86.13** 70.55 : 122.23	**92.88** 70.55 : 122.23
Perfluoro-n-butanoic acid	TM337	**91.0** 70 30 127 94	**95.5** 70 30 127 94
Perfluoro n decanesulfonate	TM337	**62.0** 45.01 : 118.66	**58.13** 45.01 : 118.66
Perfluoro-n-decanoic acid	TM337	**82.25** 69.46 : 122.34	**86.0** 69.46 : 122.34
Perfluoro-n-dodecanoic acid	TM337	**87.38** 60.49 : 120.04	**93.38** 60.49 : 120.04
Perfluoro-n-heptanoic acid	TM337	**98.75** 68.75 : 133.93	**101.0** 68.75 : 133.93
Perfluoro-n-hexanoic acid	TM337	**88.13** 69 13 124 63	**95.25** 69 13 124 63
Perfluoro n nonanoic acid	TM337	**84.25** 70.31 : 115.61	**91.63** 70.31 : 115.61
Perfluoro-n-octanoic acid	TM337	**89.75** 73.16 : 120.05	**91.5** 73.16 : 120.05
Perfluoro-n-pentanesulfonate	TM337	**87.63** 68.86 : 120.91	**92.0** 68.86 : 120.91
Perfluoro-n-pentanoic acid	TM337	**97.25** 55.25 : 127.03	**94.0** 55.25 : 127.03
Perfluoro-n-undecanoic acid	TM337	**78.5** 68 19 119 41	**92.25** 68 19 119 41
Perfluoro octane sulfonate 6 2	TM337	**93.88** 64.89 : 123.09	**99.25** 64.89 : 123.09
Perfluoro-octanesulfonamide	TM337	**81.25** 53.38 : 111.80	**87.75** 53.38 : 111.80

The above information details the reference name of the analytical quality control sample (AQC) that has been run with the samples contained in this report for the different methods of analysis.
The figure detailed is the percentage recovery result for the AQC.
The subscript numbers below are the percentage recovery lower control limit (LCL) and the upper control limit (UCL). The percentage recovery result for the AQC should be between these limits to be statistically in control.

Appendix

General

1. Results are expressed on a dry weight basis (dried at 35ºC) for all soil analyses except for the following: NRA and CEN Leach tests, flash point LOI, pH, ammonium as NH4 by the BRE method, VOC TICs and SVOC TICs.

2 If sufficient sample is received a sub sample will be retained free of charge for 30 days after analysis is completed (e-mailed) for all sample types unless the sample is destroyed on testing. The prepared soil sub sample that is analysed for asbestos will be retained for a period of 6 months after the analysis date. All bulk samples will be retained for a period of 6 months after the analysis date. All samples received and not scheduled will be disposed of one month after the date of receipt unless we are instructed to the contrary. Once the initial period has expired, a storage charge will be applied for each month or part thereof until the client cancels the request for sample storage. ALS reserve the right to charge for samples received and stored but not analysed.

3. With respect to turnaround, we will always endeavour to meet client requirements wherever possible, but turnaround times cannot be absolutely guaranteed due to so many variables beyond our control.

4. We take responsibility for any test performed by sub-contractors (marked with an asterisk). We endeavour to use UKAS/MCERTS Accredited Laboratories, who either complete a quality questionnaire or are audited by ourselves. For some determinands there are no UKAS/MCERTS Accredited Laboratories, in this instance a laboratory with a known track record will be utilised.

5. If no separate volatile sample is supplied by the client, or if a headspace or sediment is present in the volatile sample, the integrity of the data may be compromised. This will be flagged up as an invalid VOC on the test schedule and the result marked as deviating on the test certificate.

6. NDP - No determination possible due to insufficient/unsuitable sample.

7. Results relate only to the items tested.

8. LoDs Limit of Detection) for wet tests reported on a dry weight basis are not corrected for moisture content.

9. **Surrogate recoveries** - Surrogates are added to your sample to monitor recovery of the test requested. A % recovery is reported, results are not corrected for the recovery measured. Typical recoveries for organics tests are 70-130%. Recoveries in soils are affected by organic rich or clay rich matrices. Waters can be affected by remediation fluids or high amounts of sediment. Test results are only ever reported if all of the associated quality checks pass; it is assumed that all recoveries outside of the values above are due to matrix affect.

10. Stones/debris are not routinely removed. We always endeavour to take a representative sub sample from the received sample.

11. In certain circumstances the method detection limit may be elevated due to the sample being outside the calibration range. Other factors that may contribute to this include possible interferences. In both cases the sample would be diluted which would cause the method detection limit to be raised.

12. For dried and crushed preparations of soils volatile loss may occur e.g volatile mercury.

13. For leachate preparations other than Zero Headspace Extraction (ZHE) volatile loss may occur.

14. For the BSEN 12457-3 two batch process to allow the cumulative release to be calculated, the volume of the leachate produced is measured and filtered for all tests. We therefore cannot carry out any unfiltered analysis. The tests affected include volatiles GCFID/GCMS and all subcontracted analysis.

15. Analysis and identification of specific compounds using GCFID is by retention time only, and we routinely calibrate and quantify for benzene, toluene, ethylbenzenes and xylenes (BTEX). For total volatiles in the C5-C12 range, the total area of the chromatogram is integrated and expressed as ug/kg or ug/l. Although this analysis is commonly used for the quantification of gasoline range organics (GRO), the system will also detect other compounds such as chlorinated solvents, and this may lead to a falsely high result with respect to hydrocarbons only. It is not possible to specifically identify these non-hydrocarbons, as standards are not routinely run for any other compounds, and for more definitive identification, volatiles by GCMS should be utilised.

16. We are accredited to MCERTS for sand, clay and loam/topsoil, or any of these materials - whether these are derived from naturally occurring soil profiles, or from fill/made ground, as long as these materials constitute the major part of the sample. Other coarse granular material such as concrete, gravel and brick are not accredited if they comprise the major part of the sample.

17 Data retention. All records, communications and reports pertaining to the analysis are archived for seven years from the date of issue of the final report.

18. **Tentatively Identified Compounds (TICs)** are non-target peaks in VOC and SVOC analysis. All non-target peaks detected with a concentration above the LoD are subjected to a mass spectral library search. Non-target peaks with a library search confidence of 75% are reported based on the best mass spectral library match When a non target peak with a library search confidence of <75% is detected it is reported as "mixed hydrocarbons". Non-target compounds identified from the scan data are semi-quantified relative to one of the deuterated internal standards, under the same chromatographic conditions as the target compounds. This result is reported as a semi-quantitative value and reported as Tentatively Identified Compounds (TICs). TICs are outside the scope of UKAS accreditation and are not moisture corrected.

19. **Sample Deviations**

If a sample is classed as deviated then the associated results may be compromised.

1	**Container with Headspace provided for volatiles analysis**
2	**Incorrect container received**
3	**Deviation from method**
4	**Matrix interference**
♦	**Sample holding time exceeded in laboratory**
@	**Sample holding time exceeded due to late arrival of instructions or samples**
§	**Sampled on date not provided**

20 **Asbestos**

When requested, the individual sub sample scheduled will be analysed in house for the presence of asbestos fibres and asbestos containing material by our documented in house method TM048 based on HSG 248 (2021), which is accredited to ISO17025. If a specific asbestos fibre type is not found this will be reported as "Not detected". If no asbestos fibre types are found all will be reported as "Not detected" and the sub sample analysed deemed to be clear of asbestos. If an asbestos fibre type is found it will be reported as detected (for each fibre type found). Testing can be carried out on asbestos positive samples, but, due to Health and Safety considerations, may be replaced by alternative tests or reported as No Determination Possible (NDP). The quantity of asbestos present is not determined unless specifically requested.

Identification of Asbestos in Bulk Materials & Soils

The results for identification of asbestos in bulk materials and soils are obtained from supplied bulk materials addd soils which have been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining, based on HSG 248 (2021).

The results for identification of asbestos in soils are obtained from a homogenised sub sample which has been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining.

Asbestos Type	Common Name
Chrysotile	White Asbestos
Amosite	Brown Asbestos
Crocidolite	Blue Asbestos
Fibrous Actinolite	-
Fibrous Anthophyllite	-
Fibrous Tremolite	-

Visual Estimation Of Fibre Content

Estimation of fibre content is not permitted as part of our UKAS accredited test other than: - Trace - Where only one or two asbestos fibres were identified.

Respirable Fibres

Respirable fibres are defined as fibres of <3 μm diameter, longer than 5 μm and with aspect ratios of at least 3:1 that can be inhaled into the lower regions of the lung and are generally acknowledged to be most important predictor of hazard and risk for cancers of the lung.

Further guidance on typical asbestos fibre content of manufactured products can be found in HSG 264.

The identification of asbestos containing materials and soils falls within our schedule of tests for which we hold UKAS accreditation, however opinions, interpretations and all other information contained in the report are outside the scope of UKAS accreditation.

Unit 7-8 Hawarden Business Park
Manor Road (off Manor Lane)
Hawarden
Deeside
CH5 3US
Tel: (01244) 528777
email: hawardencustomerservices@alsglobal.com
Website: www.alsenvironmental.co.uk

Jacobs Engineering UK Limited
1180 Eskdale Road
Winnersh
Wokingham
Berkshire
RG41 5TU

Attention: Andrew Davies

CERTIFICATE OF ANALYSIS

Date of report Generation:	01 February 2023
Customer:	Jacobs Engineering UK Limited
Sample Delivery Group (SDG):	230120-108
Your Reference:	B2449202
Location:	PFAS Surface Water Sampling
Report No:	676938
Order Number:	

We received 11 samples on Friday January 20, 2023 and 11 of these samples were scheduled for analysis which was completed on Wednesday February 01, 2023. Accredited laboratory tests are defined within the report, but opinions, interpretations and on-site data expressed herein are outside the scope of ISO 17025 accreditation

Should this report require incorporation into client reports, it must be used in its entirety and not simply with the data sections alone.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden.

All sample data is provided by the customer. The reported results relate to the sample supplied, and on the basis that this data is correct.
Incorrect sampling dates and/or sample information will affect the validity of results.
The customer is not permitted to reproduce this report except in full without the approval of the laboratory.

Approved By:

Sonia McWhan
Operations Manager

UKAS TESTING
1291

Received Sample Overview

Lab Sample No(s)	Customer Sample Ref.	AGS Ref.	Depth (m)	Sampled Date
27437832	EMA_DS			19/01/2023
27437833	EMA_DS_3			19/01/2023
27437831	EMA_US			19/01/2023
27437829	EMA_US_1			19/01/2023
27437830	EMA_US_2			19/01/2023
27437826	LBA-DS			17/01/2023
27437825	LBA-US			17/01/2023
27437828	MAN-DS			18/01/2023
27437827	MAN-US			18/01/2023
27437823	NCL-DS			16/01/2023
27437822	NCL-US			16/01/2023

Only received samples which have had analysis scheduled will be shown on the following pages.

CERTIFICATE OF ANALYSIS

SDG: 230120-108 **Report Number:** 676938 **Superseded Report:**

Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

X Test

N No Determination Possible

Sample Types -

- S Soil/Solid
- UNS - Unspecified Solid
- GW - Ground Water
- SW - Surface Water
- LE - Land Leachate
- PL - Prepared Leachate
- PR - Process Water
- SA - Saline Water
- TE - Trade Effluent
- TS - Treated Sewage
- US - Untreated Sewage
- RE - Recreational Water
- DW - Drinking Water Non-regulatory
- UNL - Unspecified Liquid
- SL - Sludge
- G - Gas
- OTH - Other

Lab Sample No(s)			27437832	27437833	27437831	27437829	27437830	27437826	27437825	27437828	27437827	27437823	27437822
Customer Sample Reference			EMA_DS	EMA_DS_3	EMA_US	EMA_US_1	EMA_US_2	LBA-DS	LBA-US	MAN-DS	MAN-US	NCL-DS	NCL-US
AGS Reference													
Depth (m)													
Container			500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)
Sample Type			SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
PFAS Liquids	All	NDPs: 0 Tests: 11	X	X	X	X	X	X	X	X	X	X	X

Validated

CERTIFICATE OF ANALYSIS

SDG: 230120-108 **Report Number:** 676938 **Superseded Report:**

Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

#	ISO17025 accredited.
M	mCERTS accredited.
aq	Aqueous / settled sample.
diss.filt	Dissolved / filtered sample.
tot.unfilt	Total / unfiltered sample.
*	Subcontracted - refer to subcontractor report for accreditation status.
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
(F)	Trigger breach confirmed
1-4+§@	Sample deviation (see appendix)

		Customer Sample Ref.	EMA_DS	EMA_DS_3	EMA_US	EMA_US_1	EMA_US_2	LBA-DS
		Depth (m)		-	-	-	-	
		Sample Type	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)
		Date Sampled	19/01/2023	19/01/2023	19/01/2023	19/01/2023	19/01/2023	17/01/2023
		Sample Time	12:45:00	12:45:00	11:30:00	11:15:00	11:15:00	12:45:00
		Date Received	20/01/2023	20/01/2023	20/01/2023	20/01/2023	20/01/2023	20/01/2023
		SDG Ref	230120-108	230120-108	230120-108	230120-108	230120-108	230120-108
		Lab Sample No.(s)	27437832	27437833	27437831	27437829	27437830	27437826
		AGS Reference						
Component	**LOD/Units**	**Method**						
PFBA (375-22-4)	<2 ng/l	TM337	45.5 #	43.6 #	<3 #	<2 #	<2 #	14 #
PFPA (2706-90-3)	<1 ng/l	TM337	130 #	133 #	<1 #	<1 #	<1 #	47.2 #
PFHxA (307-24-4)	1 ng/l	TM337	94 8 #	97 8 #	1 #	1 #	<1 #	29 9 #
PFBS (375-73-5)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	.92 #
PFHpA (375-85-9)	<1 ng/l	TM337	76.6 #	86.4 #	<1 #	<1 #	<1 #	37.9 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337	180 #	179 #	<1 #	<1 #	<1 #	27.8 #
PFOA (335-67-1)	<0.65 ng/l	TM337	27.5 #	25 #	<1.5 #	<1.3 #	<1.2 #	42.5 #
PFHxS (355-46-4)	<1 ng/l	TM337	.99 #	1.94 #	<1 #	<1 #	<1 #	6.22 #
PFNA (375-95-1)	<1 ng/l	TM337	4.39 #	4.76 #	<1 #	<1 #	<1 #	5.7 #
PFHpS (375-92-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	.58 #
PFDA (335-76-2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	.64 #	2.12 #	<0.65 #	<0.65 #	<0.65 #	6.69 #
Branched PFOS	0 65 ng/l	TM337	1 74 #	2 22 #	0 914 #	0 65 #	<0 65 #	29 #
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #	<2 #	<2 #
PFDS (335-77-3)	<1 ng/l	TM337	<1	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	2.02 #
Total PFOS	<0.65 ng/l	TM337	3.39 #	4.33 #	.914 #	<0.65 #	<0.65 #	35.7 #

Validated

CERTIFICATE OF ANALYSIS

SDG: 230120-108 **Report Number:** 676938 **Superseded Report:**

Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

#	ISO17025 accredited.
M	mCERTS accredited.
aq	Aqueous / settled sample.
diss.filt	Dissolved / filtered sample.
tot.unfilt	Total / unfiltered sample.
*	Subcontracted - refer to subcontractor report for accreditation status.
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
(F)	Trigger breach confirmed
1-4+§@	Sample deviation (see appendix)

Customer Sample Ref.	LBA-US	MAN-DS	MAN-US	NCL-DS	NCL-US
Depth (m)		-	-	-	-
Sample Type	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)
Date Sampled	17/01/2023	18/01/2023	18/01/2023	16/01/2023	16/01/2023
Sample Time	10:50:00	13:00:00	11:40:00	14:05:00	12:55:00
Date Received	20/01/2023	20/01/2023	20/01/2023	20/01/2023	20/01/2023
SDG Ref	230120-108	230120-108	230120-108	230120-108	230120-108
Lab Sample No.(s)	27437825	27437828	27437827	27437823	27437822
AGS Reference					

Component	LOD/Units	Method	LBA-US	MAN-DS	MAN-US	NCL-DS	NCL-US
PFBA (375-22-4)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #	<2 #
PFPA (2706-90-3)	<1 ng/l	TM337	<1 #	3.08 #	2.92 #	<1 #	<1 #
PFHxA (307-24-4)	1 ng/l	TM337	1 3 #	2 89 #	2 72 #	1 18 #	<1 #
PFBS (375-73-5)	<1 ng/l	TM337	2.46 #	3.4 #	3.42 #	<1 #	<1 #
PFHpA (375-85-9)	<1 ng/l	TM337	3.3 #	2.67 #	2.1 #	<1 #	<1 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337	<1 #	1.51 #	1.14 #	<1 #	<1 #
PFOA (335-67-1)	<0.65 ng/l	TM337	7.4 #	<4 #	<3.5 #	<1.5 #	<1.2 #
PFHxS (355-46-4)	<1 ng/l	TM337	6.04 #	1.55 #	<1 #	<1 #	<1 #
PFNA (375-95-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #
PFHpS (375-92-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #
PFDA (335-76-2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	2.02 #	2.86 #	1.06 #	<0.65 #	<0.65 #
Branched PFOS	0 65 ng/l	TM337	18 2 #	2 16 #	1 61 #	0 65 #	<0 65 #
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #	<2 #
PFDS (335-77-3)	<1 ng/l	TM337	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	<1 ng/l	TM337	2.56 #	<1 #	<1 #	<1 #	<1 #
Total PFOS	<0.65 ng/l	TM337	20.2 #	5.02 #	2.67 #	<0.65 #	<0.65 #

Table of Results - Appendix

Method No	Reference	Description
TM337	PFAS in Environmental Water Matrices	Analysis of PFAS

NA = not applicable.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden (Method codes TM).

Test Completion Dates

Lab Sample No(s)	27437832	27437833	27437831	27437829	27437830	27437826	27437825	27437828	27437827	27437823
Customer Sample Ref.	EMA_DS	EMA_DS_3	EMA_US	EMA_US_1	EMA_US_2	LBA-DS	LBA-US	MAN-DS	MAN-US	NCL-DS
AGS Ref.										
Depth										
Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
PFAS Liquids	01 Feb 2023	01 Feb 2023	01 Feb 2023	01 Feb 2023	01 Feb 2023	01 Feb 2023	01 Feb 2023	01 Feb 2023	01 Feb 2023	01 Feb 2023

Lab Sample No(s)	27437822
Customer Sample Ref.	NCL U
AGS Ref.	
Depth	
Type	Surface Water
PFAS Liquids	01-Feb-2023

ASSOCIATED AQC DATA

PFAS Liquids

Component	Method Code	QC 2729
Perfluoro 1 butanesulfonate	TM337	**87.0** 58.95 : 133.73
Perfluoro-1-heptanesulfonate	TM337	**107.25** 54.69 : 144.16
Perfluoro-1-hexanesulfonate	TM337	**94.0** 70.93 : 121.48
Perfluoro-1-octanesulfonate	TM337	**87.75** 70.55 : 122.23
Perfluoro-n-butanoic acid	TM337	**93.0** 70 30 127 94
Perfluoro n decanesulfonate	TM337	**82.62** 45.01 : 118.66
Perfluoro-n-decanoic acid	TM337	**95.12** 69.46 : 122.34
Perfluoro-n-dodecanoic acid	TM337	**83.25** 60.49 : 120.04
Perfluoro-n-heptanoic acid	TM337	**108.63** 68.75 : 133.93
Perfluoro-n-hexanoic acid	TM337	**92.88** 69 13 124 63
Perfluoro n nonanoic acid	TM337	**90.87** 70.31 : 115.61
Perfluoro-n-octanoic acid	TM337	**89.75** 73.16 : 120.05
Perfluoro-n-pentanesulfonate	TM337	**87.25** 68.86 : 120.91
Perfluoro-n-pentanoic acid	TM337	**81.13** 55.25 : 127.03
Perfluoro-n-undecanoic acid	TM337	**87.13** 68 19 119 41
Perfluoro octane sulfonate 6 2	TM337	**97.75** 64.89 : 123.09
Perfluoro-octanesulfonamide	TM337	**74.13** 53.38 : 111.80

The above information details the reference name of the analytical quality control sample (AQC) that has been run with the samples contained in this report for the different methods of analysis .
The figure detailed is the percentage recovery result for the AQC .
The subscript numbers below are the percentage recovery lower control limit (LCL) and the upper control limit (UCL). The percentage recovery result for the AQC should be between these limits to be statistically in control .

Appendix General

1. Results are expressed on a dry weight basis (dried at 35°C) for all soil analyses except for the following: NRA and CEN Leach tests, flash point LOI, pH, ammonium as NH4 by the BRE method, VOC TICs and SVOC TICs.

2 If sufficient sample is received a sub sample will be retained free of charge for 30 days after analysis is completed (e-mailed) for all sample types unless the sample is destroyed on testing. The prepared soil sub sample that is analysed for asbestos will be retained for a period of 6 months after the analysis date. All bulk samples will be retained for a period of 6 months after the analysis date. All samples received and not scheduled will be disposed of one month after the date of receipt unless we are instructed to the contrary. Once the initial period has expired, a storage charge will be applied for each month or part thereof until the client cancels the request for sample storage. ALS reserve the right to charge for samples received and stored but not analysed.

3. With respect to turnaround, we will always endeavour to meet client requirements wherever possible, but turnaround times cannot be absolutely guaranteed due to so many variables beyond our control.

4. We take responsibility for any test performed by sub-contractors (marked with an asterisk). We endeavour to use UKAS/MCERTS Accredited Laboratories, who either complete a quality questionnaire or are audited by ourselves. For some determinands there are no UKAS/MCERTS Accredited Laboratories, in this instance a laboratory with a known track record will be utilised.

5. If no separate volatile sample is supplied by the client, or if a headspace or sediment is present in the volatile sample, the integrity of the data may be compromised. This will be flagged up as an invalid VOC on the test schedule and the result marked as deviating on the test certificate.

6. NDP - No determination possible due to insufficient/unsuitable sample.

7. Results relate only to the items tested.

8. LoDs Limit of Detection) for wet tests reported on a dry weight basis are not corrected for moisture content.

9. **Surrogate recoveries** - Surrogates are added to your sample to monitor recovery of the test requested. A % recovery is reported, results are not corrected for the recovery measured. Typical recoveries for organics tests are 70-130%. Recoveries in soils are affected by organic rich or clay rich matrices. Waters can be affected by remediation fluids or high amounts of sediment. Test results are only ever reported if all of the associated quality checks pass; it is assumed that all recoveries outside of the values above are due to matrix affect.

10. Stones/debris are not routinely removed. We always endeavour to take a representative sub sample from the received sample.

11. In certain circumstances the method detection limit may be elevated due to the sample being outside the calibration range. Other factors that may contribute to this include possible interferences. In both cases the sample would be diluted which would cause the method detection limit to be raised.

12. For dried and crushed preparations of soils volatile loss may occur e.g volatile mercury.

13. For leachate preparations other than Zero Headspace Extraction (ZHE) volatile loss may occur.

14. For the BSEN 12457-3 two batch process to allow the cumulative release to be calculated, the volume of the leachate produced is measured and filtered for all tests. We therefore cannot carry out any unfiltered analysis. The tests affected include volatiles GCFID/GCMS and all subcontracted analysis.

15. Analysis and identification of specific compounds using GCFID is by retention time only, and we routinely calibrate and quantify for benzene, toluene, ethylbenzenes and xylenes (BTEX). For total volatiles in the C5-C12 range, the total area of the chromatogram is integrated and expressed as ug/kg or ug/l. Although this analysis is commonly used for the quantification of gasoline range organics (GRO), the system will also detect other compounds such as chlorinated solvents, and this may lead to a falsely high result with respect to hydrocarbons only. It is not possible to specifically identify these non-hydrocarbons, as standards are not routinely run for any other compounds, and for more definitive identification, volatiles by GCMS should be utilised.

16. We are accredited to MCERTS for sand, clay and loam/topsoil, or any of these materials - whether these are derived from naturally occurring soil profiles, or from fill/made ground, as long as these materials constitute the major part of the sample. Other coarse granular material such as concrete, gravel and brick are not accredited if they comprise the major part of the sample.

17 Data retention. All records, communications and reports pertaining to the analysis are archived for seven years from the date of issue of the final report.

18. **Tentatively Identified Compounds (TICs)** are non-target peaks in VOC and SVOC analysis. All non-target peaks detected with a concentration above the LoD are subjected to a mass spectral library search. Non-target peaks with a library search confidence of 75% are reported based on the best mass spectral library match When a non target peak with a library search confidence of <75% is detected it is reported as "mixed hydrocarbons". Non-target compounds identified from the scan data are semi-quantified relative to one of the deuterated internal standards, under the same chromatographic conditions as the target compounds. This result is reported as a semi-quantitative value and reported as Tentatively Identified Compounds (TICs). TICs are outside the scope of UKAS accreditation and are not moisture corrected.

19. **Sample Deviations**

If a sample is classed as deviated then the associated results may be compromised.

1	**Container with Headspace provided for volatiles analysis**
2	**Incorrect container received**
3	**Deviation from method**
4	**Matrix interference**
♦	**Sample holding time exceeded in laboratory**
@	**Sample holding time exceeded due to late arrival of instructions or samples**
§	**Sampled on date not provided**

20 **Asbestos**

When requested, the individual sub sample scheduled will be analysed in house for the presence of asbestos fibres and asbestos containing material by our documented in house method TM048 based on HSG 248 (2021), which is accredited to ISO17025. If a specific asbestos fibre type is not found this will be reported as "Not detected". If no asbestos fibre types are found all will be reported as "Not detected" and the sub sample analysed deemed to be clear of asbestos. If an asbestos fibre type is found it will be reported as detected (for each fibre type found). Testing can be carried out on asbestos positive samples, but, due to Health and Safety considerations, may be replaced by alternative tests or reported as No Determination Possible (NDP). The quantity of asbestos present is not determined unless specifically requested.

Identification of Asbestos in Bulk Materials & Soils

The results for identification of asbestos in bulk materials and soils are obtained from supplied bulk materials add soils which have been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining, based on HSG 248 (2021).

The results for identification of asbestos in soils are obtained from a homogenised sub sample which has been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining.

Asbestos Type	Common Name
Chrysotile	White Asbestos
Amosite	Brown Asbestos
Crocidolite	Blue Asbestos
Fibrous Actinolite	-
Fibrous Anthophyllite	-
Fibrous Tremolite	-

Visual Estimation Of Fibre Content

Estimation of fibre content is not permitted as part of our UKAS accredited test other than: - Trace - Where only one or two asbestos fibres were identified.

Respirable Fibres

Respirable fibres are defined as fibres of <3 µm diameter, longer than 5 µm and with aspect ratios of at least 3:1 that can be inhaled into the lower regions of the lung and are generally acknowledged to be most important predictor of hazard and risk for cancers of the lung.

Further guidance on typical asbestos fibre content of manufactured products can be found in HSG 264.

The identification of asbestos containing materials and soils falls within our schedule of tests for which we hold UKAS accreditation, however opinions, interpretations and all other information contained in the report are outside the scope of UKAS accreditation.

Unit 7-8 Hawarden Business Park
Manor Road (off Manor Lane)
Hawarden
Deeside
CH5 3US
Tel: (01244) 528777
email: hawardencustomerservices@alsglobal.com
Website: www.alsenvironmental.co.uk

Jacobs Engineering UK Limited
1180 Eskdale Road
Winnersh
Wokingham
Berkshire
RG41 5TU

Attention: Andrew Davies

CERTIFICATE OF ANALYSIS

Date of report Generation:	03 February 2023
Customer:	Jacobs Engineering UK Limited
Sample Delivery Group (SDG):	230128-36
Your Reference:	B2449202
Location:	PFAS Surface Water Sampling
Report No:	677403
Order Number:	

We received 13 samples on Saturday January 28, 2023 and 13 of these samples were scheduled for analysis which was completed on Friday February 03, 2023. Accredited laboratory tests are defined within the report, but opinions, interpretations and on-site data expressed herein are outside the scope of ISO 17025 accreditation

Should this report require incorporation into client reports, it must be used in its entirety and not simply with the data sections alone.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden.

All sample data is provided by the customer. The reported results relate to the sample supplied, and on the basis that this data is correct.
Incorrect sampling dates and/or sample information will affect the validity of results.
The customer is not permitted to reproduce this report except in full without the approval of the laboratory.

Approved By:

Sonia McWhan
Operations Manager

1291

Received Sample Overview

Lab Sample No(s)	Customer Sample Ref.	AGS Ref.	Depth (m)	Sampled Date
27474487	BC-1			24/01/2023
27474479	BHX-DS			23/01/2023
27474478	BHX-US			23/01/2023
27474484	BOH-DS			24/01/2023
27474485	BOH-DS-3			24/01/2023
27474482	BOH-US			24/01/2023
27474480	BOH-US-1			24/01/2023
27474481	BOH-US-2			24/01/2023
27474489	LGW-DS			25/01/2023
27474488	LGW-US			25/01/2023
27474486	LW-2			24/01/2023
27474491	STN-DS			26/01/2023
27474490	STN-US			26/01/2023

Only received samples which have had analysis scheduled will be shown on the following pages.

Validated

CERTIFICATE OF ANALYSIS

SDG: 230128-36 **Report Number:** 677403 **Superseded Report:**

Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

- X Test
- N No Determination Possible

Sample Types -

S Soil/Solid
UNS - Unspecified Solid
GW - Ground Water
SW - Surface Water
LE - Land Leachate
PL - Prepared Leachate
PR - Process Water
SA - Saline Water
TE - Trade Effluent
TS - Treated Sewage
US - Untreated Sewage
RE - Recreational Water
DW - Drinking Water Non-regulatory
UNL - Unspecified Liquid
SL - Sludge
G - Gas
OTH - Other

Lab Sample No(s)			27474487	27474479	27474478	27474484	27474485	27474482	27474480	27474481	27474489	27474488	27474486	27474491	27474490
Customer Sample Reference			BC-1	BHX-DS	BHX-US	BOH-DS	BOH-DS-3	BOH-US	BOH-US-1	BOH-US-2	LGW-DS	LGW-US	LW-2	STN-DS	STN-US
AGS Reference															
Depth (m)															
Container			500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)
Sample Type			SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
PFAS Liquids	All	NDPs: 0 Tests: 13	X	X	X	X	X	X	X	X	X	X	X	X	X

15:16:55 03/02/2023

Validated

CERTIFICATE OF ANALYSIS

SDG: 230128-36 **Report Number:** 677403 **Superseded Report:**
Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

- # ISO17025 accredited.
- M mCERTS accredited.
- aq Aqueous / settled sample.
- diss.filt Dissolved / filtered sample.
- tot.unfilt Total / unfiltered sample.
- * Subcontracted - refer to subcontractor report for accreditation status.
- ** % recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
- (F) Trigger breach confirmed
- 1-4+§@ Sample deviation (see appendix)

Customer Sample Ref.			BC-1	BHX-DS	BHX-US	BOH-DS	BOH-DS-3	BOH-US
Depth (m)				-	-	-	-	
Sample Type			Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)
Date Sampled			24/01/2023	23/01/2023	23/01/2023	24/01/2023	24/01/2023	24/01/2023
Sample Time			13:00:00	15:30:00	14:10:00	14:30:00	14:30:00	13:00:00
Date Received			28/01/2023	28/01/2023	28/01/2023	28/01/2023	28/01/2023	28/01/2023
SDG Ref			230128-36	230128-36	230128-36	230128-36	230128-36	230128-36
Lab Sample No.(s)			27474487	27474479	27474478	27474484	27474485	27474482
AGS Reference								
Component	**LOD/Units**	**Method**						
PFBA (375-22-4)	<2 ng/l	TM337	<2 #	5.57 #	<2 #	4.17 #	3.92 #	2.57 #
PFPA (2706-90-3)	<1 ng/l	TM337	<1 #	14.2 #	<1 #	7.08 #	7.49 #	1.8 #
PFHxA (307-24-4)	1 ng/l	TM337	1 #	10 #	1 22 #	5 04 #	5 21 #	1 41 #
PFBS (375-73-5)	<1 ng/l	TM337	<1 #	2.5 #	<1 #	<1 #	<1 #	<1 #
PFHpA (375-85-9)	<1 ng/l	TM337	<1 #	8.25 #	<1 #	4.52 #	4.74 #	.21 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337	<1 #	4 #	<1 #	8.56 #	8.93 #	<1 #
PFOA (335-67-1)	<0.65 ng/l	TM337	<0.65 #	4.51 #	2.09 #	3.15 #	3.35 #	.78 #
PFHxS (355-46-4)	<1 ng/l	TM337	<1 #	39.2 #	<1 #	3.14 #	3.05 #	.29 #
PFNA (375-95-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFHpS (375-92-8)	<1 ng/l	TM337	<1 #	1.07 #	<1 #	<1 #	<1 #	<1 #
PFDA (335-76-2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	<0.65 #	43.1 #	1.68 #	2.29 #	2.4 #	.72 #
Branched PFOS	0 65 ng/l	TM337	0 65 #	26 9 #	1 22 #	2 37 #	2 44 #	1 66 #
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #	<2 #	<2 #
PFDS (335-77-3)	<1 ng/l	TM337	<1	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	<1 ng/l	TM337	<1 #	2.96 #	<1 #	<1 #	<1 #	<1 #
Total PFOS	<0.65 ng/l	TM337	<0.65 #	70 #	2.9 #	4.66 #	4.84 #	3.38 #

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Validated

CERTIFICATE OF ANALYSIS

SDG: 230128-36
Client Ref.: B2449202
Report Number: 677403
Location: PFAS Surface Water Sampling
Superseded Report:

Results Legend

- # ISO17025 accredited.
- M mCERTS accredited.
- aq Aqueous / settled sample.
- diss.filt Dissolved / filtered sample.
- tot.unfilt Total / unfiltered sample.
- * Subcontracted - refer to subcontractor report for accreditation status.
- ** % recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
- (F) Trigger breach confirmed
- 1-4+§@ Sample deviation (see appendix)

		Customer Sample Ref.	BOH-US-1	BOH-US-2	LGW-DS	LGW-US	LW-2	STN-DS
		Depth (m)		-	-	-	-	
		Sample Type	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)
		Date Sampled	24/01/2023	24/01/2023	25/01/2023	25/01/2023	24/01/2023	26/01/2023
		Sample Time	13:00:00	13:00:00	13:15:00	11:30:00	13:00:00	10:30:00
		Date Received	28/01/2023	28/01/2023	28/01/2023	28/01/2023	28/01/2023	28/01/2023
		SDG Ref	230128-36	230128-36	230128-36	230128-36	230128-36	230128-36
		Lab Sample No.(s)	27474480	27474481	27474489	27474488	27474486	27474491
		AGS Reference						
Component	**LOD/Units**	**Method**						
PFBA (375-22-4)	<2 ng/l	TM337	<2 #	<2 #	7.33 #	5.39 #	<2 #	.58 #
PFPA (2706-90-3)	<1 ng/l	TM337	<1 #	<1 #	12.1 #	6.3 #	<1 #	22.2 #
PFHxA (307-24-4)	1 ng/l	TM337	1 #	1 #	9 09 #	4 27 #	<1 #	14 8 #
PFBS (375-73-5)	<1 ng/l	TM337	<1 #	<1 #	2.7 #	1.92 #	<1 #	2.45 #
PFHpA (375-85-9)	<1 ng/l	TM337	<1 #	<1 #	8.98 #	4.2 #	<1 #	10 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337	<1 #	<1 #	3.91 #	2.9 #	<1 #	7.13 #
PFOA (335-67-1)	<0.65 ng/l	TM337	<0.65 #	<0.65 #	6.03 #	3.94 #	<0.65 #	48.5 #
PFHxS (355-46-4)	<1 ng/l	TM337	<1 #	<1 #	6.34 #	2.85 #	<1 #	5.9 #
PFNA (375-95-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFHpS (375-92-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFDA (335-76-2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	2.08 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	<0.65 #	<0.65 #	7.06 #	4.15 #	<0.65 #	9.7 #
Branched PFOS	0 65 ng/l	TM337	0 65 #	0 65 #	6 32 #	4 81 #	<0 65 #	12 8 #
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #	<2 #	<2 #
PFDS (335-77-3)	<1 ng/l	TM337	<1	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
Total PFOS	<0.65 ng/l	TM337	<0.65 #	<0.65 #	13.4 #	8.95 #	<0.65 #	32.5 #

15:16:55 03/02/2023

Validated

CERTIFICATE OF ANALYSIS

SDG: 230128-36
Client Ref.: B2449202
Report Number: 677403
Location: PFAS Surface Water Sampling
Superseded Report:

Results Legend

- \# ISO17025 accredited.
- M mCERTS accredited.
- aq Aqueous / settled sample.
- diss.filt Dissolved / filtered sample.
- tot.unfilt Total / unfiltered sample.
- * Subcontracted - refer to subcontractor report for accreditation status.
- ** % recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
- (F) Trigger breach confirmed
- 1-4+§@ Sample deviation (see appendix)

		Customer Sample Ref.	STN-US
		Depth (m)	
		Sample Type	Surface Water (SW)
		Date Sampled	26/01/2023
		Sample Time	09:00:00
		Date Received	28/01/2023
		SDG Ref	230128-36
		Lab Sample No.(s)	27474490
		AGS Reference	
Component	**LOD/Units**	**Method**	
PFBA (375-22-4)	<2 ng/l	TM337	4.97 #
PFPA (2706-90-3)	<1 ng/l	TM337	3.21 #
PFHxA (307-24-4)	1 ng/l	TM337	3 09 #
PFBS (375-73-5)	<1 ng/l	TM337	.89 #
PFHpA (375-85-9)	<1 ng/l	TM337	2.07 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337	<1 #
PFOA (335-67-1)	<0.65 ng/l	TM337	3.2 #
PFHxS (355-46-4)	<1 ng/l	TM337	.36 #
PFNA (375-95-1)	<1 ng/l	TM337	<1 #
PFHpS (375-92-8)	<1 ng/l	TM337	<1 #
PFDA (335-76-2)	<1 ng/l	TM337	<1 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	0.745 #
Branched PFOS	0 65 ng/l	TM337	1 24 #
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #
PFDS (335-77-3)	<1 ng/l	TM337	<1
PFPeS (2706-91-4)	<1 ng/l	TM337	<1 #
Total PFOS	<0.65 ng/l	TM337	.98 #

15:16:55 03/02/2023

Table of Results - Appendix

Method No	Reference	Description
TM337	PFAS in Environmental Water Matrices	Analysis of PFAS

NA = not applicable.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden (Method codes TM).

Test Completion Dates

Lab Sample No(s)	27474487	27474479	27474478	27474484	27474485	27474482	27474480	27474481	27474489	27474488
Customer Sample Ref.	BC-1	BHX-DS	BHX-US	BOH-DS	BOH-DS-3	BOH-US	BOH-US-1	BOH-US-2	LGW-DS	LGW-US
AGS Ref.										
Depth										
Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
PFAS Liquids	03 Feb 2023	03 Feb 2023	03 Feb 2023	03 Feb 2023	03 Feb 2023	03 Feb 2023	03 Feb 2023	03 Feb 2023	03 Feb 2023	03 Feb 2023

Lab Sample No(s)	27474486	27474491	27474490
Customer Sample Ref.	LW 2	TN D	TN U
AGS Ref.			
Depth			
Type	Surface Water	Surface Water	Surface Water
PFAS Liquids	03-Feb-2023	03-Feb-2023	03-Feb-2023

ASSOCIATED AQC DATA

PFAS Liquids

Component	Method Code	QC 2774	QC 2705
Perfluoro 1 butanesulfonate	TM337	**88.0** 58.95 : 133.73	**99.5** 58.95 : 133.73
Perfluoro-1-heptanesulfonate	TM337	**105.63** 54.69 : 144.16	**130.0** 54.69 : 144.16
Perfluoro-1-hexanesulfonate	TM337	**98.38** 70.93 : 121.48	**108.12** 70.93 : 121.48
Perfluoro-1-octanesulfonate	TM337	**96.25** 70.55 : 122.23	**109.13** 70.55 : 122.23
Perfluoro-n-butanoic acid	TM337	**102.0** 70 30 127 94	**112.88** 70 30 127 94
Perfluoro n decanesulfonate	TM337	**92.0** 45.01 : 118.66	**95.0** 45.01 : 118.66
Perfluoro-n-decanoic acid	TM337	**94.75** 69.46 : 122.34	**104.75** 69.46 : 122.34
Perfluoro-n-dodecanoic acid	TM337	**96.5** 60.49 : 120.04	**113.87** 60.49 : 120.04
Perfluoro-n-heptanoic acid	TM337	**113.63** 68.75 : 133.93	**128.75** 68.75 : 133.93
Perfluoro-n-hexanoic acid	TM337	**93.38** 69 13 124 63	**106.13** 69 13 124 63
Perfluoro n nonanoic acid	TM337	**106.63** 70.31 : 115.61	**107.13** 70.31 : 115.61
Perfluoro-n-octanoic acid	TM337	**104.13** 73.16 : 120.05	**115.13** 73.16 : 120.05
Perfluoro-n-pentanesulfonate	TM337	**91.5** 68.86 : 120.91	**100.5** 68.86 : 120.91
Perfluoro-n-pentanoic acid	TM337	**92.25** 55.25 : 127.03	**90.13** 55.25 : 127.03
Perfluoro-n-undecanoic acid	TM337	**88.75** 68 19 119 41	**114.37** 68 19 119 41
Perfluoro octane sulfonate 6 2	TM337	**110.38** 64.89 : 123.09	**119.63** 64.89 : 123.09
Perfluoro-octanesulfonamide	TM337	**92.0** 53.38 : 111.80	**99.63** 53.38 : 111.80

The above information details the reference name of the analytical quality control sample (AQC) that has been run with the samples contained in this report for the different methods of analysis .
The figure detailed is the percentage recovery result for the AQC .
The subscript numbers below are the percentage recovery lower control limit (LCL) and the upper control limit (UCL). The percentage recovery result for the AQC should be between these limits to be statistically in control .

Appendix

General

1. Results are expressed on a dry weight basis (dried at 35ºC) for all soil analyses except for the following: NRA and CEN Leach tests, flash point LOI, pH, ammonium as NH4 by the BRE method, VOC TICs and SVOC TICs.

2 If sufficient sample is received a sub sample will be retained free of charge for 30 days after analysis is completed (e-mailed) for all sample types unless the sample is destroyed on testing. The prepared soil sub sample that is analysed for asbestos will be retained for a period of 6 months after the analysis date. All bulk samples will be retained for a period of 6 months after the analysis date. All samples received and not scheduled will be disposed of one month after the date of receipt unless we are instructed to the contrary. Once the initial period has expired, a storage charge will be applied for each month or part thereof until the client cancels the request for sample storage. ALS reserve the right to charge for samples received and stored but not analysed.

3. With respect to turnaround, we will always endeavour to meet client requirements wherever possible, but turnaround times cannot be absolutely guaranteed due to so many variables beyond our control.

4. We take responsibility for any test performed by sub-contractors (marked with an asterisk). We endeavour to use UKAS/MCERTS Accredited Laboratories, who either complete a quality questionnaire or are audited by ourselves. For some determinands there are no UKAS/MCERTS Accredited Laboratories, in this instance a laboratory with a known track record will be utilised.

5. If no separate volatile sample is supplied by the client, or if a headspace or sediment is present in the volatile sample, the integrity of the data may be compromised. This will be flagged up as an invalid VOC on the test schedule and the result marked as deviating on the test certificate.

6. NDP - No determination possible due to insufficient/unsuitable sample.

7. Results relate only to the items tested.

8. LoDs Limit of Detection) for wet tests reported on a dry weight basis are not corrected for moisture content.

9. **Surrogate recoveries** - Surrogates are added to your sample to monitor recovery of the test requested. A % recovery is reported, results are not corrected for the recovery measured. Typical recoveries for organics tests are 70-130%. Recoveries in soils are affected by organic rich or clay rich matrices. Waters can be affected by remediation fluids or high amounts of sediment. Test results are only ever reported if all of the associated quality checks pass; it is assumed that all recoveries outside of the values above are due to matrix affect.

10. Stones/debris are not routinely removed. We always endeavour to take a representative sub sample from the received sample.

11. In certain circumstances the method detection limit may be elevated due to the sample being outside the calibration range. Other factors that may contribute to this include possible interferences. In both cases the sample would be diluted which would cause the method detection limit to be raised.

12. For dried and crushed preparations of soils volatile loss may occur e.g volatile mercury.

13. For leachate preparations other than Zero Headspace Extraction (ZHE) volatile loss may occur.

14. For the BSEN 12457-3 two batch process to allow the cumulative release to be calculated, the volume of the leachate produced is measured and filtered for all tests. We therefore cannot carry out any unfiltered analysis. The tests affected include volatiles GCFID/GCMS and all subcontracted analysis.

15. Analysis and identification of specific compounds using GCFID is by retention time only, and we routinely calibrate and quantify for benzene, toluene, ethylbenzenes and xylenes (BTEX). For total volatiles in the C5-C12 range, the total area of the chromatogram is integrated and expressed as ug/kg or ug/l. Although this analysis is commonly used for the quantification of gasoline range organics (GRO), the system will also detect other compounds such as chlorinated solvents, and this may lead to a falsely high result with respect to hydrocarbons only. It is not possible to specifically identify these non-hydrocarbons, as standards are not routinely run for any other compounds, and for more definitive identification, volatiles by GCMS should be utilised.

16. We are accredited to MCERTS for sand, clay and loam/topsoil, or any of these materials - whether these are derived from naturally occurring soil profiles, or from fill/made ground, as long as these materials constitute the major part of the sample. Other coarse granular material such as concrete, gravel and brick are not accredited if they comprise the major part of the sample.

17 Data retention. All records, communications and reports pertaining to the analysis are archived for seven years from the date of issue of the final report.

18. **Tentatively Identified Compounds (TICs)** are non-target peaks in VOC and SVOC analysis. All non-target peaks detected with a concentration above the LoD are subjected to a mass spectral library search. Non-target peaks with a library search confidence of 75% are reported based on the best mass spectral library match When a non target peak with a library search confidence of <75% is detected it is reported as "mixed hydrocarbons". Non-target compounds identified from the scan data are semi-quantified relative to one of the deuterated internal standards, under the same chromatographic conditions as the target compounds. This result is reported as a semi-quantitative value and reported as Tentatively Identified Compounds (TICs). TICs are outside the scope of UKAS accreditation and are not moisture corrected.

19. **Sample Deviations**

If a sample is classed as deviated then the associated results may be compromised.

1	**Container with Headspace provided for volatiles analysis**
2	**Incorrect container received**
3	**Deviation from method**
4	**Matrix interference**
♦	**Sample holding time exceeded in laboratory**
@	**Sample holding time exceeded due to late arrival of instructions or samples**
§	**Sampled on date not provided**

20 **Asbestos**

When requested, the individual sub sample scheduled will be analysed in house for the presence of asbestos fibres and asbestos containing material by our documented in house method TM048 based on HSG 248 (2021), which is accredited to ISO17025. If a specific asbestos fibre type is not found this will be reported as "Not detected". If no asbestos fibre types are found all will be reported as "Not detected" and the sub sample analysed deemed to be clear of asbestos. If an asbestos fibre type is found it will be reported as detected (for each fibre type found). Testing can be carried out on asbestos positive samples, but, due to Health and Safety considerations, may be replaced by alternative tests or reported as No Determination Possible (NDP). The quantity of asbestos present is not determined unless specifically requested.

Identification of Asbestos in Bulk Materials & Soils

The results for identification of asbestos in bulk materials and soils are obtained from supplied bulk materials andd soils which have been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining, based on HSG 248 (2021).

The results for identification of asbestos in soils are obtained from a homogenised sub sample which has been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining.

Asbestos Type	Common Name
Chrysotile	White Asbestos
Amosite	Brown Asbestos
Crocidolite	Blue Asbestos
Fibrous Actinolite	-
Fibrous Anthophyllite	-
Fibrous Tremolite	-

Visual Estimation Of Fibre Content

Estimation of fibre content is not permitted as part of our UKAS accredited test other than: - Trace - Where only one or two asbestos fibres were identified.

Respirable Fibres

Respirable fibres are defined as fibres of <3 µm diameter, longer than 5 µm and with aspect ratios of at least 3:1 that can be inhaled into the lower regions of the lung and are generally acknowledged to be most important predictor of hazard and risk for cancers of the lung.

Further guidance on typical asbestos fibre content of manufactured products can be found in HSG 264.

The identification of asbestos containing materials and soils falls within our schedule of tests for which we hold UKAS accreditation, however opinions, interpretations and all other information contained in the report are outside the scope of UKAS accreditation.

Unit 7-8 Hawarden Business Park
Manor Road (off Manor Lane)
Hawarden
Deeside
CH5 3US
Tel: (01244) 528777
email: hawardencustomerservices@alsglobal.com
Website: www.alsenvironmental.co.uk

Jacobs Engineering UK Limited
1180 Eskdale Road
Winnersh
Wokingham
Berkshire
RG41 5TU

Attention: Andrew Davies

CERTIFICATE OF ANALYSIS

Date of report Generation:	10 February 2023
Customer:	Jacobs Engineering UK Limited
Sample Delivery Group (SDG):	230203-97
Your Reference:	B2449202
Location:	PFAS Surface Water Sampling
Report No:	678294
Order Number:	

We received 10 samples on Friday February 03, 2023 and 10 of these samples were scheduled for analysis which was completed on Friday February 10, 2023. Accredited laboratory tests are defined within the report, but opinions, interpretations and on-site data expressed herein are outside the scope of ISO 17025 accreditation

Should this report require incorporation into client reports, it must be used in its entirety and not simply with the data sections alone.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden.

All sample data is provided by the customer. The reported results relate to the sample supplied, and on the basis that this data is correct.
Incorrect sampling dates and/or sample information will affect the validity of results.
The customer is not permitted to reproduce this report except in full without the approval of the laboratory.

Approved By:

Sonia McWhan
Operations Manager

UKAS TESTING 1291

Received Sample Overview

Lab Sample No(s)	Customer Sample Ref.	AGS Ref.	Depth (m)	Sampled Date
27507682	EMA_DS			02/02/2023
27507681	EMA_US			02/02/2023
27507677	LBA_DS			31/01/2023
27507676	LBA_US			31/01/2023
27507680	MAN_DS			01/02/2023
27507679	MAN_US			01/02/2023
27507675	NCL_DS			30/01/2023
27507673	NCL_DS_3			30/01/2023
27507674	NCL_US			30/01/2023
27507672	NCL_US_1			30/01/2023

Only received samples which have had analysis scheduled will be shown on the following pages.

CERTIFICATE OF ANALYSIS

SDG: 230203-97 **Report Number:** 678294 **Superseded Report:**
Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

- X Test
- N No Determination Possible

Sample Types -
S Soil/Solid
UNS - Unspecified Solid
GW - Ground Water
SW - Surface Water
LE - Land Leachate
PL - Prepared Leachate
PR - Process Water
SA - Saline Water
TE - Trade Effluent
TS - Treated Sewage
US - Untreated Sewage
RE - Recreational Water
DW - Drinking Water Non-regulatory
UNL - Unspecified Liquid
SL - Sludge
G - Gas
OTH - Other

Lab Sample No(s)			27507682	27507681	27507677	27507676	27507680	27507679	27507675	27507673	27507674	27507672
Customer Sample Reference			EMA_DS	EMA_US	LBA_DS	LBA_US	MAN_DS	MAN_US	NCL_DS	NCL_DS_3	NCL_US	NCL_US_1
AGS Reference												
Depth (m)												
Container			500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)	500ml Plastic (ALE208)
Sample Type			SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
PFAS Liquids	All	NDPs: 0 Tests: 10	X	X	X	X	X	X	X	X	X	X

10:48:30 10/02/2023

Validated

CERTIFICATE OF ANALYSIS

SDG: 230203-97 **Report Number:** 678294 **Superseded Report:**

Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend			Customer Sample Ref.	EMA_DS	EMA_US	LBA_DS	LBA_US	MAN_DS	MAN_US
# ISO17025 accredited. M mCERTS accredited. aq Aqueous / settled sample. diss.filt Dissolved / filtered sample. tot.unfilt Total / unfiltered sample. * Subcontracted - refer to subcontractor report for accreditation status. ** % recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery (F) Trigger breach confirmed 1-4+§@ Sample deviation (see appendix)			Depth (m)		-	-	-	-	
			Sample Type	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)
			Date Sampled	02/02/2023	02/02/2023	31/01/2023	31/01/2023	01/02/2023	01/02/2023
			Sample Time	11:45:00	10:15:00	12:30:00	11:30:00	14:00:00	11:20:00
			Date Received	03/02/2023	03/02/2023	03/02/2023	03/02/2023	03/02/2023	03/02/2023
			SDG Ref	230203-97	230203-97	230203-97	230203-97	230203-97	230203-97
			Lab Sample No.(s)	27507682	27507681	27507677	27507676	27507680	27507679
			AGS Reference						
Component	**LOD/Units**	**Method**							
PFBA (375-22-4)	<2 ng/l	TM337		11 #	<2 #	12.4 #	2.19 #	2.75 #	3.16 #
PFPA (2706-90-3)	<1 ng/l	TM337		36.9 #	<1 #	48.4 #	<1 #	3.59 #	4.05 #
PFHxA (307-24-4)	1 ng/l	TM337		19 5 #	1 #	26 7 #	1 48 #	3 05 #	3 37 #
PFBS (375-73-5)	<1 ng/l	TM337		.12 #	<1 #	2.18 #	3.06 #	2.86 #	2.8 #
PFHpA (375-85-9)	<1 ng/l	TM337		4.9 #	<1 #	29.3 #	3.42 #	2.27 #	3.04 #
6 2 FTS (27619 97 2)	<1 ng/l	TM337		3.23 #	<1 #	9.09 #	<1 #	<1 #	<1 #
PFOA (335-67-1)	<0.65 ng/l	TM337		<4 #	<1.2 #	33.5 #	18.2 #	<3 #	<3.5 #
PFHxS (355-46-4)	<1 ng/l	TM337		<1 #	<1 #	5.71 #	6.33 #	1.31 #	.03 #
PFNA (375-95-1)	<1 ng/l	TM337		<1 #	<1 #	2.84 #	<1 #	<1 #	<1 #
PFHpS (375-92-8)	<1 ng/l	TM337		<1 #	<1 #	<1 #	1.17 #	<1 #	<1 #
PFDA (335-76-2)	<1 ng/l	TM337		<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337		<0.65 #	<0.65 #	3.71 #	2.96 #	1.89 #	.07 #
Branched PFOS	0 65 ng/l	TM337		0 65 #	0 65 #	12 3 #	24 1 #	1 6 #	1 25 #
PFUnA (2058-94-8)	<1 ng/l	TM337		<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFDoA (307-55-1)	<1 ng/l	TM337		<1 #	<1 #	<1 #	<1 #	<1 #	<1 #
PFOSA (754 91 6)	<2 ng/l	TM337		<2 #	<2 #	<2 #	<2 #	<2 #	<2 #
PFDS (335-77-3)	<1 ng/l	TM337		<1	<1	<1	<1	<1	<1
PFPeS (2706-91-4)	<1 ng/l	TM337		<1 #	<1 #	1.62 #	2.52 #	<1 #	<1 #
Total PFOS	<0.65 ng/l	TM337		<0.65 #	<0.65 #	6 #	27.1 #	3.48 #	2.32 #

10:48:30 10/02/2023

Validated

CERTIFICATE OF ANALYSIS

SDG: 230203-97 **Report Number:** 678294 **Superseded Report:**

Client Ref.: B2449202 **Location:** PFAS Surface Water Sampling

Results Legend

#	ISO17025 accredited.
M	mCERTS accredited.
aq	Aqueous / settled sample.
diss.filt	Dissolved / filtered sample.
tot.unfilt	Total / unfiltered sample.
*	Subcontracted - refer to subcontractor report for accreditation status.
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
(F)	Trigger breach confirmed
1-4+§@	Sample deviation (see appendix)

		Customer Sample Ref.	NCL_DS	NCL_DS_3	NCL_US	NCL_US_1		
		Depth (m)		-	-	-		
		Sample Type	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)	Surface Water (SW)		
		Date Sampled	30/01/2023	30/01/2023	30/01/2023	30/01/2023		
		Sample Time	14:00:00	14:00:00	12:30:00	12:30:00		
		Date Received	03/02/2023	03/02/2023	03/02/2023	03/02/2023		
		SDG Ref	230203-97	230203-97	230203-97	230203-97		
		Lab Sample No.(s)	27507675	27507673	27507674	27507672		
		AGS Reference						
Component	**LOD/Units**	**Method**						
PFBA (375-22-4)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #		
PFPA (2706-90-3)	<1 ng/l	TM337	<1 #	1.03 #	<1 #	<1 #		
PFHxA (307-24-4)	1 ng/l	TM337	1 #	1 05 #	1 #	1 #		
PFBS (375-73-5)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
PFHpA (375-85-9)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
6 2 FTS (27619 97 2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
PFOA (335-67-1)	<0.65 ng/l	TM337	<1 #	<1.2 #	<1 #	<0.7 #		
PFHxS (355-46-4)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
PFNA (375-95-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
PFHpS (375-92-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
PFDA (335-76-2)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
Linear PFOS (1763-23-1)	<0.65 ng/l	TM337	<0.65 #	<0.65 #	<0.65 #	<0.65 #		
Branched PFOS	0 65 ng/l	TM337	0 65 #	0 65 #	0 65 #	0 65 #		
PFUnA (2058-94-8)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
PFDoA (307-55-1)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
PFOSA (754 91 6)	<2 ng/l	TM337	<2 #	<2 #	<2 #	<2 #		
PFDS (335-77-3)	<1 ng/l	TM337	<1	<1	<1	<1		
PFPeS (2706-91-4)	<1 ng/l	TM337	<1 #	<1 #	<1 #	<1 #		
Total PFOS	<0.65 ng/l	TM337	<0.65 #	<0.65 #	<0.65 #	<0.65 #		

Table of Results - Appendix

Method No	Reference	Description
TM337	PFAS in Environmental Water Matrices	Analysis of PFAS

NA = not applicable.

Chemical testing (unless subcontracted) performed at ALS Laboratories (UK) Limited Hawarden (Method codes TM).

Test Completion Dates

Lab Sample No(s)	27507682	27507681	27507677	27507676	27507680	27507679	27507675	27507673	27507674	27507672
Customer Sample Ref.	EMA_DS	EMA_US	LBA_DS	LBA_US	MAN_DS	MAN_US	NCL_DS	NCL_DS_3	NCL_US	NCL_US_1
AGS Ref.										
Depth										
Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
PFAS Liquids	09 Feb 2023	09 Feb 2023	09 Feb 2023	09 Feb 2023	10 Feb 2023	10 Feb 2023	10 Feb 2023	09 Feb 2023	09 Feb 2023	10 Feb 2023

ASSOCIATED AQC DATA

PFAS Liquids

Component	Method Code	QC 2758	QC 2732
Perfluoro 1 butanesulfonate	TM337	**106.0** 58.95 : 133.73	**89.75** 58.95 : 133.73
Perfluoro-1-heptanesulfonate	TM337	**109.5** 54.69 : 144.16	**97.12** 54.69 : 144.16
Perfluoro-1-hexanesulfonate	TM337	**109.88** 70.93 : 121.48	**100.63** 70.93 : 121.48
Perfluoro-1-octanesulfonate	TM337	**109.25** 70.55 : 122.23	**102.0** 70.55 : 122.23
Perfluoro-n-butanoic acid	TM337	**114.88** 70 30 127 94	**107.0** 70 30 127 94
Perfluoro n decanesulfonate	TM337	**82.88** 45.01 : 118.66	**74.5** 45.01 : 118.66
Perfluoro-n-decanoic acid	TM337	**106.38** 69.46 : 122.34	**106.13** 69.46 : 122.34
Perfluoro-n-dodecanoic acid	TM337	**106.75** 60.49 : 120.04	**96.75** 60.49 : 120.04
Perfluoro-n-heptanoic acid	TM337	**119.88** 68.75 : 133.93	**122.5** 68.75 : 133.93
Perfluoro-n-hexanoic acid	TM337	**113.5** 69 13 124 63	**104.5** 69 13 124 63
Perfluoro n nonanoic acid	TM337	**105.63** 70.31 : 115.61	**96.5** 70.31 : 115.61
Perfluoro-n-octanoic acid	TM337	**111.0** 73.16 : 120.05	**99.38** 73.16 : 120.05
Perfluoro-n-pentanesulfonate	TM337	**109.13** 68.86 : 120.91	**96.13** 68.86 : 120.91
Perfluoro-n-pentanoic acid	TM337	**107.25** 55.25 : 127.03	**90.5** 55.25 : 127.03
Perfluoro-n-undecanoic acid	TM337	**102.63** 68 19 119 41	**101.87** 68 19 119 41
Perfluoro octane sulfonate 6 2	TM337	**118.25** 64.89 : 123.09	**108.5** 64.89 : 123.09
Perfluoro-octanesulfonamide	TM337	**98.5** 53.38 : 111.80	**94.0** 53.38 : 111.80

The above information details the reference name of the analytical quality control sample (AQC) that has been run with the samples contained in this report for the different methods of analysis.
The figure detailed is the percentage recovery result for the AQC.
The subscript numbers below are the percentage recovery lower control limit (LCL) and the upper control limit (UCL). The percentage recovery result for the AQC should be between these limits to be statistically in control.

Appendix General

1. Results are expressed on a dry weight basis (dried at 35ºC) for all soil analyses except for the following: NRA and CEN Leach tests, flash point LOI, pH, ammonium as NH4 by the BRE method, VOC TICs and SVOC TICs.

2 If sufficient sample is received a sub sample will be retained free of charge for 30 days after analysis is completed (e-mailed) for all sample types unless the sample is destroyed on testing. The prepared soil sub sample that is analysed for asbestos will be retained for a period of 6 months after the analysis date. All bulk samples will be retained for a period of 6 months after the analysis date. All samples received and not scheduled will be disposed of one month after the date of receipt unless we are instructed to the contrary. Once the initial period has expired, a storage charge will be applied for each month or part thereof until the client cancels the request for sample storage. ALS reserve the right to charge for samples received and stored but not analysed.

3. With respect to turnaround, we will always endeavour to meet client requirements wherever possible, but turnaround times cannot be absolutely guaranteed due to so many variables beyond our control.

4. We take responsibility for any test performed by sub-contractors (marked with an asterisk). We endeavour to use UKAS/MCERTS Accredited Laboratories, who either complete a quality questionnaire or are audited by ourselves. For some determinands there are no UKAS/MCERTS Accredited Laboratories, in this instance a laboratory with a known track record will be utilised.

5. If no separate volatile sample is supplied by the client, or if a headspace or sediment is present in the volatile sample, the integrity of the data may be compromised. This will be flagged up as an invalid VOC on the test schedule and the result marked as deviating on the test certificate.

6. NDP - No determination possible due to insufficient/unsuitable sample.

7. Results relate only to the items tested.

8. LoDs Limit of Detection) for wet tests reported on a dry weight basis are not corrected for moisture content.

9. **Surrogate recoveries** - Surrogates are added to your sample to monitor recovery of the test requested. A % recovery is reported, results are not corrected for the recovery measured. Typical recoveries for organics tests are 70-130%. Recoveries in soils are affected by organic rich or clay rich matrices. Waters can be affected by remediation fluids or high amounts of sediment. Test results are only ever reported if all of the associated quality checks pass; it is assumed that all recoveries outside of the values above are due to matrix affect.

10. Stones/debris are not routinely removed. We always endeavour to take a representative sub sample from the received sample.

11. In certain circumstances the method detection limit may be elevated due to the sample being outside the calibration range. Other factors that may contribute to this include possible interferences. In both cases the sample would be diluted which would cause the method detection limit to be raised.

12. For dried and crushed preparations of soils volatile loss may occur e.g volatile mercury.

13. For leachate preparations other than Zero Headspace Extraction (ZHE) volatile loss may occur.

14. For the BSEN 12457-3 two batch process to allow the cumulative release to be calculated, the volume of the leachate produced is measured and filtered for all tests. We therefore cannot carry out any unfiltered analysis. The tests affected include volatiles GCFID/GCMS and all subcontracted analysis.

15. Analysis and identification of specific compounds using GCFID is by retention time only, and we routinely calibrate and quantify for benzene, toluene, ethylbenzenes and xylenes (BTEX). For total volatiles in the C5-C12 range, the total area of the chromatogram is integrated and expressed as ug/kg or ug/l. Although this analysis is commonly used for the quantification of gasoline range organics (GRO), the system will also detect other compounds such as chlorinated solvents, and this may lead to a falsely high result with respect to hydrocarbons only. It is not possible to specifically identify these non-hydrocarbons, as standards are not routinely run for any other compounds, and for more definitive identification, volatiles by GCMS should be utilised.

16. We are accredited to MCERTS for sand, clay and loam/topsoil, or any of these materials - whether these are derived from naturally occurring soil profiles, or from fill/made ground, as long as these materials constitute the major part of the sample. Other coarse granular material such as concrete, gravel and brick are not accredited if they comprise the major part of the sample.

17 Data retention. All records, communications and reports pertaining to the analysis are archived for seven years from the date of issue of the final report.

18. **Tentatively Identified Compounds (TICs)** are non-target peaks in VOC and SVOC analysis. All non-target peaks detected with a concentration above the LoD are subjected to a mass spectral library search. Non-target peaks with a library search confidence of 75% are reported based on the best mass spectral library match When a non target peak with a library search confidence of <75% is detected it is reported as "mixed hydrocarbons". Non-target compounds identified from the scan data are semi-quantified relative to one of the deuterated internal standards, under the same chromatographic conditions as the target compounds. This result is reported as a semi-quantitative value and reported as Tentatively Identified Compounds (TICs). TICs are outside the scope of UKAS accreditation and are not moisture corrected.

19. **Sample Deviations**

If a sample is classed as deviated then the associated results may be compromised.

1	**Container with Headspace provided for volatiles analysis**
2	**Incorrect container received**
3	**Deviation from method**
4	**Matrix interference**
♦	**Sample holding time exceeded in laboratory**
@	**Sample holding time exceeded due to late arrival of instructions or samples**
§	**Sampled on date not provided**

20 **Asbestos**

When requested, the individual sub sample scheduled will be analysed in house for the presence of asbestos fibres and asbestos containing material by our documented in house method TM048 based on HSG 248 (2021), which is accredited to ISO17025. If a specific asbestos fibre type is not found this will be reported as "Not detected". If no asbestos fibre types are found all will be reported as "Not detected" and the sub sample analysed deemed to be clear of asbestos. If an asbestos fibre type is found it will be reported as detected (for each fibre type found). Testing can be carried out on asbestos positive samples, but, due to Health and Safety considerations, may be replaced by alternative tests or reported as No Determination Possible (NDP). The quantity of asbestos present is not determined unless specifically requested.

Identification of Asbestos in Bulk Materials & Soils

The results for identification of asbestos in bulk materials and soils are obtained from supplied bulk materials andd soils which have been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining, based on HSG 248 (2021).

The results for identification of asbestos in soils are obtained from a homogenised sub sample which has been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining.

Asbestos Type	Common Name
Chrysotile	White Asbestos
Amosite	Brown Asbestos
Crocidolite	Blue Asbestos
Fibrous Actinolite	-
Fibrous Anthophyllite	-
Fibrous Tremolite	-

Visual Estimation Of Fibre Content

Estimation of fibre content is not permitted as part of our UKAS accredited test other than: - Trace - Where only one or two asbestos fibres were identified.

Respirable Fibres

Respirable fibres are defined as fibres of <3 μm diameter, longer than 5 μm and with aspect ratios of at least 3:1 that can be inhaled into the lower regions of the lung and are generally acknowledged to be most important predictor of hazard and risk for cancers of the lung.

Further guidance on typical asbestos fibre content of manufactured products can be found in HSG 264.

The identification of asbestos containing materials and soils falls within our schedule of tests for which we hold UKAS accreditation, however opinions, interpretations and all other information contained in the report are outside the scope of UKAS accreditation.

Appendix C

Site Summaries

Potential Soil Retention

Airport	Type of Superficial Deposit under FTA	Comments
Birmingham	None	Bedrock is mudstone so soils likely to have a high organic content if generated from weathered mudstone. Soil retention of PFAS is potentially high.
Bournemouth	RTD	RTD are comprised of sand and gravel. Even covered by topsoil, soil retention of PFAS is considered to be limited.
East Midlands	None	Bedrock is a siltstone so soils likely to have a high organic content if generated from weathered mudstone. Soil retention of PFAS is potentially high.
Leeds Bradford	Till	Till is likely to have a high organic content so soil retention of PFAS is potentially high.
London Gatwick	None	Bedrock is a clay so soils likely to have a high organic content if generated from bedrock. Soil retention of PFAS is potentially high.
London Stansted	Lowestoft Formation (chalky till)	Till is likely to have a high organic content so soil retention of PFAS is potentially high.
Manchester	Till	Till is likely to have a high organic content so soil retention of PFAS is potentially high.
Newcastle	Till	Till is likely to have a high organic content so soil retention of PFAS is potentially high.

Potential Baseflow Impact

Airport	Groundwater Comments
Birmingham	Unlikely baseflow input to surface water due to no superficial deposits and mudstone bedrock (Secondary B aquifer).
Bournemouth	Superficial deposits are RTD and a Secondary A aquifer. Groundwater baseflow to the rivers is considered to be likely.
East Midlands	Unlikely baseflow input to surface water due to no superficial deposits and siltstone/mudstone bedrock (Secondary B aquifer).
Leeds Bradford	The Till is unlikely to provide significant groundwater baseflow into the adjacent surface waters.
London Gatwick	Unlikely baseflow input to surface water due to no superficial deposits and clay bedrock (unproductive strata).
London Stansted	The Till is unlikely to provide significant groundwater baseflow into the adjacent surface waters.
Manchester	The Till is unlikely to provide significant groundwater baseflow into the adjacent surface waters.
Newcastle	The Till is unlikely to provide significant groundwater baseflow into the adjacent surface waters.