PFAS Site Profile

PFAS Site Profiles were developed as part of the Environment Agency PFAS Risk Screening Project and represent an understanding of PFAS uses and occurrences from specific industry sectors at the time of writing in March 2024. This profile focuses on Metal Manufacturing and Finishing.

Metal Manufacturing and Finishing

1. INTRODUCTION

1.1 Overview

Per- and poly-fluoroalkyl substances (PFAS) are a broad group of more than 12,000 synthetic fluorinated organic chemicals. PFAS have been used in a wide variety of consumer products and industrial applications since the 1940s because of their unique chemical and physical properties, including oil, water and stain repellence, temperature and chemical resistance, and surfactant properties. These properties mean they are also extremely persistent in the environment. Some PFAS are bio-accumulative and toxic, and/or highly mobile.

Increasing awareness of the widespread presence of PFAS has heightened regulatory concerns about their potential risks to human health and the environment. To ensure effective actions are implemented the Environment Agency needs to better understand the potential sources of PFAS, the mechanisms of transport (pathways) and the relative significance of these substances in the environment.

As part of the Environment Agency PFAS risk screening project (Phases 1 to 4 carried out between 2020 to 2025) Jacobs developed individual site profiles for several potential high risk site types. They focus on specific industry sectors, representing potentially important sources of PFAS, whether from use or manufacture, with the potential for release into the environment.

The primary aim of these profiles is to help those parties involved in the regulation, investigation and remediation of sites where these problem chemicals present a risk to health and the wider environment. These are not definitive studies, but they introduce some of the technical considerations that need to be borne in mind when assessing a particular type of facility. Representing an understanding of PFAS at the time of writing (March 2024) and with published literature notably increasing continuously as practitioners and regulators seek to improve their understanding of PFAS, users must make their own appropriate assessments with current knowledge and specific to their site.

The reader is referred to Ross and Hurst (2019) and ITRC (2023) for more detailed information on PFAS chemistry, properties, fate and transport, risk assessment and remediation, to Glüge et al. (2020) for a review of the diversity of uses of PFAS, and to Ross (2023) for an overview of the uses of PFAS to assist with identification of sites of concern.

1.2 Site Profile Selection and Preparation

The site types for which site profiles have been developed in this project have been selected to represent potentially important users and sources of PFAS release to the environment in terms of quantity, frequency and historical records available.

Technical and scientific publications, fact-sheets, regulations, product websites, articles and online newspaper reporting interviews on the PFAS discussions were researched and reviewed to obtain information on the use of PFAS, with particular reference to the United Kingdom.

Each site profile includes site background information focused on PFAS use and identification of specific zones (where applicable), description of the processes involving PFAS, types of PFAS likely to be present, and an indication of the impact to water and soil. Brief examples and case studies from the literature are also provided.

For each site type a number of zones or activities have been identified where PFAS may be used. It should be recognised that not every site of this type will have all the activities identified. For example, a fire station site may be anything from a building where fire tenders containing Aqueous Film-Forming Foam (AFFF) are based (but filling, maintenance and training happen elsewhere) to a hub with a wide range of activities such as fire practice training, concentrate storage etc. in addition to vehicle storage.

Site profiles have been created for the following site types identified as potentially important potential sources of PFAS release to the environment:

- Civil and Military Airfields and Airports;
- Control of Major Accident Hazards (COMAH) Regulated Sites;
- Fire-fighting Grounds and Fire Stations;
- Landfills;
- Metal Manufacturing and Finishing;
- Military Bases (other than Air Transport Sites);
- Oil and Gas Industry (onshore exploration and extraction operations);
- Paper and Cardboard Manufacturing;
- Refineries and Fuel Sites;
- Textiles, Upholstery, Leather, Apparel and Carpets (TULAC) Manufacturing; and
- Waste Water Treatment Works.

Additional site profiles which do not relate directly to a particular site type have been developed for the following subject areas, which have potential applications within many different site types:

- Aqueous Film-Forming Foam (AFFF); and
- Fire Suppression Systems.

1.3 Methodology for Calculating Source Potential

For the purposes of the risk prioritisation project for which these site profiles were originally developed, an overall source potential has been developed for each site profile, based on professional judgment informed by the literature review. The source potential is constructed considering the magnitude and likelihood of PFAS presence and use in site profile zones.

The magnitude has been developed with a score of 1–5 (1 – low; 5 – high) based on the expected quantum of PFAS in the activity in the zone. For example, fire training practice using AFFF is recorded as high magnitude, because of the high volume and concentration of PFAS in this activity. Aircraft maintenance using hydraulic fluids containing PFAS is low magnitude because of the relatively low volume and concentration.

The likelihood for each activity is scored 1–5 (1 – low; 5 – high) based on the likelihood of a release to the environment occurring, taking into account frequency of activities where release may occur, and likelihood of loss of containment. For example, fire training practice using AFFF is likely to take place regularly at the same location over a period of years, with potential loss to ground or surface water, so is scored high. Although aircraft maintenance is likely to be undertaken all the time, significant accidental loss of containment is likely to be infrequent, so this is scored low.

The magnitude and likelihood are then multiplied to give the source potential (scored 1–25). It should be noted that these scores are generic and subjective and are based on professional judgment and should continue to be refined as more information becomes available. Further refinement could include expansion to consider changes in practice over the years as pollution prevention practices have improved.

2. BACKGROUND TO METAL MANUFACTURING AND FINISHING

This site profile refers to sites where both ferrous and non-ferrous metals are manufactured, finished, or surface treatments are applied. The uses of PFAS at industrial sites can generally be divided into direct uses associated with manufacturing processes (e.g. application of PFAS treatments), and indirect uses associated with the application of fire suppression systems and fire-fighting foams containing PFAS. The metal sector covers a very wide range of site types and activities, many of which do not involve the use of PFAS. There are however some very specialist uses of PFAS in metal manufacturing and finishing processes which have the potential to impact the wider environment, and they are the primary subject of this site profile.

This site profile has been developed based on desk studies only and this has not included any interviews or assessments of any specific UK sites.

2.1 Regulation of Metal Manufacturing and Finishing Sites in England

The regulation of the metals sector in England is complex, and some facilities which may be using PFAS may not be currently regulated, or may be being regulated based on different activities.

Depending on the scale and nature of activities and materials used, some sites may be regulated under Control of Major Accidents and Hazards Regulations (COMAH) which may be required to have fire prevention measures in place, which can include fire-fighting facilities on the site. Further details are described in the site profile for COMAH Regulated Sites (CL:AIRE, 2026b).

Metal manufacturing and finishing sites may also be regulated under the Environmental Permitting Regulations (EPR) 2016, as Part A(1) sites, Part A(2) sites and Part B sites. The application of these regulations is complex, and depending on the process involved, they can be regulated under different industrial sectors such as the inorganic chemical sector, as defined in EPR Schedule 1 Part II Section 4.2 Part A(1)(f) - Inorganic Chemical Sector (EPR, 2016).

The regulation of activities involving 'production and processing of metals' is detailed in EPR Schedule 1 Part II Chapter 2. Many sites with specialist PFAS uses will be regulated under the 'surface treating metals and plastics' sector, as defined in EPR Schedule 1 Part II Section 2.3. These may be permitted as:

- Part A(1) activities, regulated by the Environment Agency, include surface treating metals and plastic materials using an electrolytic or chemical process where the aggregated volume of the treatment vats is more than 30 m^3, but exclude activities defined as Part A(2) sites;
- Part A(2) activities, regulated by the Local Authority, also include surface treating metals and plastic materials using an electrolytic or chemical process where the aggregated volume of the treatment vats is more than 30 m^3 but where, on the same installation, other activities are undertaken as defined within EPR 2016; these activities comprise Part A(2) and Part (B) activities listed elsewhere under Section 2.1 (Ferrous metals), Section 2.2 (Non-ferrous metals) and Section 6.4 (Coating activities, printing and textile treatments);
- Part B activities, regulated by the Local Authority, include any process for the surface treatment of metal which is likely to result in the release into air of any acid-forming oxide of nitrogen and which does not fall within Part A(1) or Part A(2) of this Section; these will include small volume platers who have processes including nitric acid treatments.

This means that facilities with activities that meet the Part A(1) activities for regulation by the Environment Agency (generally expected to be higher risk activities) may actually be regulated under Part A(2) because of the co-location of other activities at the installation. Facilities which fall below the size threshold may be

regulated by the Environment Agency as Part A(1) under the chemicals sector due to the use of certain chemicals, or because of other ancillary A(1) processes such as effluent treatment plant which can also trigger Environment Agency regulation despite Part A(2)/B metals activities.

In practice in the UK, as well as the regulated metal manufacturing and finishing sites, there are believed to be many businesses (both large and small) offering metal finishing services which may be 'falling between the gaps' and operating without permits. Some of these sites may be operating with Trade Effluent Consents for effluent discharge to sewer, but others may be working without any consents at all.

2.2 PFAS Use Associated with Fire Suppression Systems and Fire-fighting Foams

Large manufacturing facilities including iron and steel manufacturing sites where dangerous substances are present, are likely to be regulated as COMAH sites (refer to the site profile for COMAH regulated sites (CL:AIRE, 2026b). These sites are required to have fire prevention measures in place, which can include fire-fighting facilities on the site. This may include fire station and fire training areas, where AFFF will have been stored and used (refer to the site profile for AFFF (CL:AIRE, 2026l)). Fire prevention and protection systems in large manufacturing facilities are likely to include installed fire suppression systems which may include automated sprinklers (refer to the site profile for Fire Suppression Systems (CL:AIRE, 2026m)). These may include foam systems, particularly where the fire hazard is related to flammable or combustible liquids. AFFF concentrate containing PFAS is stored in tanks and released through sprinklers in response to a fire. Systems need regular testing and maintenance. While current methodologies may have been developed to enable testing without release of PFAS, this is less likely to have been the case in the past. Accidental release may also occur, either through system failure or false alarm.

Upper Tier COMAH sites have a requirement for regular live training of emergency procedures, which may include demonstration of fire-fighting capability including foam. While such exercises are now likely to be undertaken using PFAS-free training foam, this is unlikely to have been the case in the past. Residual PFAS may also be present following emergency response to incidents.

Other large manufacturing sites with a long industrial history may also previously have had their own on-site fire services even if not regulated under COMAH or similar predecessor regulations.

2.3 PFAS Use Associated with Metal Manufacturing and Finishing Processes

The properties of PFAS that make them particularly useful in the metal sector include thermal and chemical stability, and surfactant properties, for example, to lower the surface tension of electrolyte solutions. Metal finishing such as electroplating, anodising, coating (phosphating, chromating, and colouring), chemical etching and milling may use PFAS (US EPA, 2021).

PFAS also have applications as specialist coatings in the metal industry. Polymeric poly-fluoroalkyl or fluoropolymers, for example PTFE are used in dip coating, aqueous dispersion and powder coatings for surface treatment of metals (STM). These coatings can be applied in the form of paint or coating at the metal manufacturing site or at the point of use. Anionic PFAS may be combined with the polymeric PFAS to aid in the application, and may also be present as residues in the finished product.

According to Glüge et al. (2020), the uses of PFAS within the metal sector can be categorised in two main branches: metal plating and the manufacturing of metal products.

PFAS used in metal plating, electroplating, for chrome and other metals such as nickel, copper, tin and zinc may have the following functions:

- Preventing the evaporation of chromium (VI) vapour (mist suppressant) with the property of lowering the surface tension of the electrolyte solution. PFAS are very stable in strongly acidic and oxidising conditions (see section 2.4);
- Lowering the surface tension acting as non-foaming surfactant and increasing the strength of the nickel electroplate by eliminating pinholes, cracks, and peeling;
- Preventing haze by regulating foam (mist suppressant) and improving stability and help to produce a plate of uniform thickness; and
- In zinc and steel finishing, cationic and amphoteric fluorinated surfactants impart a positive charge to fluoropolymer particles which facilitates the electroplating of the fluoropolymer.

Other PFAS uses in the finishing of metal products have the following functions:

- Promoting the flow of metal coatings, to prevent cracks in the coating during drying;
- Acting as a corrosion inhibitor on steel;
- Improving the efficient life of alkali baths;
- Fluoride-containing phosphating solutions help to dissolve the oxide layer of aluminium;
- Cleaning of metal surfaces, dispersing scum, speeding the runoff of acid when metal is removed from the bath, and increasing the bath life;
- Promote water removal from processed parts; and
- In electroless plating of copper, PFAS can be used to disperse pitch fluoride in the plating solution.

The composition and formulations of PFAS used in fluorosurfactants for these diverse applications are not clear. While Glüge et al. (2020) provide a long list of potential applications, they provide only limited information on product formulations. Exact formulations are generally protected by commercial sensitivity and Material Safety Data Sheets (MSDS) provide only generic information such as 'fluorinated surfactants'. Furthermore, the manufacturers typically maintain a product trade name but develop the formulation over time including in response to increasing environmental concerns.

One fluorosurfactant that has applications in surface coating is 3M Novec fluorosurfactant FC-4432 (3M, n.d.). Product information available on 3M website (3M, 2009) details its use in surface finishing, but does not provide compositional information. A product information sheet dated 2003 (3M, 2003) states "Novec FC-4432 fluorosurfactant is the first in a new line of fluorochemical surfactants from 3M based on perfluorobutane sulfonate (PFBS). PFBS refers collectively to perfluorobutane sulfonyl compounds including perfluorobutane sulfonates". In 2022, 3M announced it would exit PFAS manufacturing and work to discontinue the use of PFAS across its product portfolio by the end of 2025 (3M, 2022). This is just one example of fluorosurfactants being marketed for surface treatment applications, there are many other producers and suppliers in the UK and worldwide.

The use of polymeric PFAS in specialist coatings has been identified as an additional potential use of PFAS in the metal industry. These coatings can be applied in the form of a paint or coating at the point of use, or also at the manufacturing site. Anionic PFAS may be combined with the polymeric PFAS to aid in the application, and may also be present as residues in the finished product.

PFAS used by metal finishing facilities may be transferred to waste water streams generated by the facility and ultimately discharged to surface waters or WWTW. Based on studies conducted by the US EPA since 2007 (US EPA, 2021), chromium electroplating and chromium anodising operations (collectively referred to as "chromium electroplating facilities") were identified as the most significant source of PFAS, particularly PFOS, in the metal finishing point source category.

2.4 PFAS Use Specifically Associated with Chrome Plating

Historically, the metal plating industry has used, and continues to use PFAS in some metal plating applications. Chromium electroplating is the electrochemical deposition of chromium from aqueous electrolytes onto surfaces. There are two broad types of chrome plating:

- Hard chrome plating which is mainly used where hard-wearing, abrasion and corrosion resistant surfaces are required, such as hydraulic systems; and
- Decorative chrome plating to produce an optically attractive surface finish combining high hardness, chemical resistance and toxicological safety, for example sanitary fittings.

The process involves passing an electric current between two electrodes which are immersed in an electrolyte bath comprising chromic acid. During this process aerosols of chromic acid are released. This can lead to workers being exposed to releases of chromium (VI), sulfuric acid and chromo-sulfuric acid (German Environment Agency, 2017). The addition of polyfluorinated surfactants (such as PFOS) to the chromic acid both lowers the surface tension of the bath by forming a thin, foamy layer on the surface, thereby acting as a mist suppressant. PFOS began being used in mist suppressants in the 1980s to reduce worker exposure to toxic chromium (VI) ions. PFOS-based mist suppressants have also been used in the past during plastic etching, where chromic acid is used to prepare the surface of plastics for metallic electroplating.

The chromium electroplating industry had a special derogation from the EU Regulation on Persistent Organic Pollutants (EU, 2019/1021) which prohibits the use of PFOS and its derivatives, other than for "mist suppressants for non-decorative hard chrome (VI) plating in closed loop systems", due to its essential role in occupational health in this industry. The derogation applies until September 2025.

According to ECHA (2023), the restrictions on the use of PFOS have led to the substitution with 6:2 fluorotelomer sulfonate (6:2 FTS) in chrome plating processes. According to the German Environment Agency (UBA, 2022), a 2017 survey of chrome platers showed that only wetting agents containing 6:2 FTS were in use in functional chrome plating and plastic, while in decorative chrome plating, 6:2 FTS-containing (60%) as well as fluorine-free (40%) wetting agents were used. The use of fluorinated substances other than 6:2 FTS was not noted.

Improvements in technology associated with decorative chrome plating mean that chrome (III) can now be used rather than chrome (VI), rendering the use of PFOS or alternatives for mist suppression in this industry unnecessary. However, it is still required in hard chrome plating process. According to Posner (2020), the most common alternative in hard metal plating since 2016 is 6:2 FTS.

Literature indicates that the PFAS formulation with the trade name F-53B is used as an alternative to PFOS for chrome plating in China (Pan et al., 2018). F-53B is known to contain two PFAS: F-53B major, 6:2 chlorinated polyfluorinated ether sulfonate or 9Cl-PF3ONS; and F-53B minor, 8:2 chlorinated polyfluorinated ether sulfonate or 11Cl-PF3OUdS). The research by Pan et al. detected F-53B minor (9Cl-PF3ONS) at very low levels in surface water in the River Thames, suggesting that it may be in use in the UK. The Environment Agency (2020) stated that it was not known to be used in the UK at the time, but this may be because the volumes used fall below the REACH threshold (quantities below 1 tonne per year by individual companies).

In 2023, the Environment Agency published an environmental risk evaluation report for F-53B (Environment Agency, 2023), although there was no information about the actual quantities on the UK market (including from imported goods). It was recognised that F-53B could be being used as a replacement for PFOS, particularly within the chrome plating industry. For the purposes of this evaluation, the Environment Agency assumed that F-53B is used as a mist suppressant in chrome plating with a UK market volume of 0.5 tonnes/year (based on assumptions around the phaseout of PFOS).

As mentioned in the previous section, PFAS used by metal finishing facilities may be transferred to waste water streams generated by the facility and ultimately discharged to surface waters or WWTW. Based on studies conducted by the US EPA in 2007-2009, chromium electroplating and chromium anodising operations (collectively referred to as "chromium electroplating facilities") were identified as the most significant sources of PFAS, particularly PFOS, in the metal finishing point source category (US EPA, 2009). US EPA (2009) studied PFAS in waste water from eleven chrome plating sites in the USA and found varying PFAS substances, predominantly PFOS, PFBS, PFHxS and PFNA. PFCAs including PFOA were present but at much

lower concentrations. The 2009 study did not include fluorotelomers such as 6:2 FTS in the monitoring suite. The 2021 US EPA multi-industry study (US EPA, 2021), detailed in case studies below, provides a more up to-date view. Using available sampling data, the US EPA estimated the average waste water concentration of 6:2 FTS was more than 100 times greater than any other PFAS evaluated.

3. CASE STUDIES

Four case studies identified from literature review were reviewed with examples of PFAS contamination associated with metal manufacturing and finishing. The findings are listed in Table 1.

4. PROCESS

PFAS used in the manufacturing process may be lost to the ground and water environment through discharge in process waste water and through accidental loss. The German Environment Agency study (UBA, 2022) demonstrated that even with a state of the art closed loop system and effluent treatment for the closed loop process water, PFAS were still present in elevated concentrations in the final waste water discharge from the site. The nature of PFAS means that they readily adsorb to surfaces and are subsequently slowly desorbed, leading to continuous 'bleeding through' of PFAS long after their use within a facility. In the German example it was

Table 1. Case studies.

1. US EPA Multi-Industry Study – Metal Finishing Point Sources
This preliminary report (US EPA, 2021) summarises the manufacture, use, and discharge of PFAS from facilities in five industrial point source categories including metal finishing. The report presents the US EPA's estimates of the types and concentrations of PFAS, including legacy long-chain PFAS and replacement short-chain PFAS, present in waste water discharges from these facilities. The US EPA documented that PFAS are used by metal finishing facilities in the USA and chromium electroplating facilities were identified as the most significant source of PFAS in the sector. PFOS-based mist and fume suppressants were frequently used until 2015, when there was a regulatory requirement to phase out mist and fume suppressants containing more than 1 percent PFOS by weight. Chromium electroplating facilities were found to have adopted alternative technologies, including mist and fume suppressants containing fluorotelomer-based substances (e.g., 6:2 FTS) and chlorinated PFESAs (e.g., F-53B), to replace use of PFOS-based products. US EPA estimated that, at the time of the study, around half the chromium electroplating facilities in the USA were still applying some type of PFAS-based mist and fume suppressant. The study confirmed that the use of PFAS-based mist and fume suppressants may generate waste waters containing PFAS, and sampling and analysis demonstrated the presence of legacy long-chain PFAS and replacement PFAS in waste water discharges to surface water and WWTW. It was estimated the average waste water concentration of 6:2 FTS was more than 100 times greater than any other PFAS evaluated. Despite the phase out of PFOS-based mist and fume suppressants, it was noted that some chromium electroplating facilities still report detectable levels of PFOS in their waste water, although no detectable amounts of PFOS or its precursors were found in the mist and fume suppressants in use in the factory. The study found that no chromium electroplating facilities had PFAS effluent limitations or pretreatment standards in their waste water discharge permit and very few actually monitored for PFAS in discharges.
2. PFAS contamination in electroplating concrete floors
A case study of a site in Europe where the concrete floor in electroplating workshops was found to be impacted with PFAS contamination was presented at a conference (Held, 2021). Concrete up to 5 cm below the surface found to be impacted with up to 1.8 mg/kg PFOS, and leachable PFOS up to 75 µg/l. The contamination was predominantly PFOS with minor constituents of PFCAs and PFSAs. The contaminated concrete required special landfill disposal. It is not known if soil and groundwater were also impacted at this site (Held, 2021).
3. Study of PFOS Substitution in chrome plating, Germany
The German Environment Agency (UBA) published a detailed review of the use and substitution of PFOS in chrome plating (UBA, 2022). This includes an overview of the processes involved, substitutes currently in use (primarily 6:2 FTS) and the information available on the behaviour and toxicity of those substances. Detailed studies were undertaken of two facilities in which PFOS and 6:2 FTS were or are used, tracing the pathway of the 6:2 FTS from the point of use to the point of discharge. The most detailed study was undertaken at a plant which uses an automatic electroplating machine for nickel plating and decorative chromium plating of metal parts. The plant has a closed chromic acid circuit and is described as 'state of the art' where 6:2 FTS is used for mist suppression. PFOS was previously used at the site. Waste water from the closed system is collected separately and treated by ion exchange prior to mixing with other process water. The study found high concentrations of 6:2 FTS (910 µg/l) in the waste water, as well as PFOS (14 µg/l) which was interpreted as being related to residual 'bleeding through' from previous use of PFOS in the system. The ion exchange was effective at removing 6:2 FTS and PFOS. However, the waste water stream further down the process path was found to contain 6:2 FTS (61 µg/l) and PFOS (1.2 µg/l). It was deduced that the 6:2 FTS at this point was coming from adsorption and subsequent desorption of PFAS on to the plastic coated racks used to hold the articles being plated, both at the rack demetallisation stage and at the initial degreasing stage when new articles to be plated are placed on the racks. No transformation products of 6:2 FTS were detected in the process path within the factory, however they were detected in the effluent from the receiving municipal WWTW, together with reduced concentrations of 6:2 FTS. This study demonstrated that treatment of only the closed loop substream for PFAS was not sufficient to prevent waste water emissions of PFAS from the electroplating shop, and treatment of the whole waste water stream was necessary. It also demonstrates the continued 'bleeding through' of PFOS long after cessation of use. The UBA report also mentions that cases of groundwater contamination with 6:2 FTS caused by electroplating are known from North Rhine-Westphalia and Baden-Württemberg, but have not been published so far.

Table 1. Case studies (continued).

4. Former hard chromium plating site in Iggesund
A groundwater investigation was completed around a former hard chromium plating site in Iggesund, which is in the northern part of Sweden (Alnehem, 2016). The site was operational from the 1940s until 2009. The hard chromium plating activity was one of the registered exceptions where PFOS was still used. The substances analysed for were PFCAs: C4 – C14, C16 and C18, PFSAs: C4, C6, C8 and C10 and 6:2 FTS. No information is provided on PFAS formulations used in chrome plating at the site. Results from the water extraction analysis showed eight detected PFAS, with PFOS as the major contributor (72 - 9600 ng/l) with the sampling points located closest to the actual hard chromium plating having higher concentrations than the other samples. PFBS and PFHxS (which can be produced as an impurity during the production of PFOS) were also found in high concentrations. PFCAs in all samples were detected in lower concentrations. 6:2 FTS was found in a small number of samples with different characteristics to the majority of samples, but its presence was attributed to AFFF rather than chrome plating. Additional to the PFAS analysis, the groundwater was also measured for chromium since the hexavalent form is used in the chromic acid bath during hard chromium plating. Chromium was found in high concentrations in the same two samples that had the highest PFAS concentration. The report concluded that if the facilities are left to deteriorate, it will lead to continuous spreading of chromium and the highly water soluble PFAS downstream to the Iggesundsån river.

deduced that much of the PFAS in the final waste water was coming from adsorption to the plastic racks holding the articles being plated, as well as bleeding through of PFOS from previous use.

At sites with older systems and poorer housekeeping, potential pathways for PFAS loss include spills during manufacturing activities, chemical storage, filling and discharging of plating baths and other equipment, waste storage and disposal, process water discharge, wash water discharge, storm water discharge and runoff.

Even where PFAS are no longer used at the site (or where specific PFAS such as PFOS are no longer used), they may continue to be released in waste water and storm water due to the past adsorption and slow release from surfaces within the process system and facility. This includes semi-permeable surfaces such as concrete and other pavement, drainage infrastructure and ground. PFAS may be lost to ground and groundwater through soft ground, through cracks in hardstanding and through soakaways.

Even where facilities have processes in place for containment and treatment of contaminated process water, PFAS may be present in other waste water streams discharged from the site under consents or otherwise. Discharge consents in the UK are currently unlikely to have included PFOS or any other PFAS in the regulated substances.

In larger manufacturing sites with fire suppression systems, an on-site fire station and the need for test exercises, the use of fluorinated AFFF over the years is likely to have resulted in discharge to ground, adsorption to surfaces (including hardstanding and drainage systems), flushing of spent foam to soft ground, equipment washing, test discharge of extinguishers and other processes. Refer to the COMAH (CL:AIRE, 2026b), AFFF (CL:AIRE, 2026l) and Fire Suppression Systems (CL:AIRE, 2026m) site profiles for more details.

For sites which have been operational for chrome plating since before the restrictions on the use of PFOS, there is potential for residual release of PFOS associated with legacy use, including slow release of PFOS previously adsorbed onto equipment and infrastructure surfaces and porous media including concrete.

5. KEY PFAS CONTAMINANTS OF CONCERN

For metal sites in general, there is the potential for a wide range of processes to be currently active on the site, or to have been active in the past, where PFAS may be present, including at high concentrations in the industrial chemicals in use.

For the metal manufacturing sites regulated by the Environment Agency under Part A(1) of EPR 2016, many of these are large metal manufacturing sites which are also COMAH sites, where the major source of PFAS is likely to be AFFF use. The site profile for AFFF (CL:AIRE, 2026l) should be referred to for information on key PFAS of concern for this use.

For chrome plating sites, historically PFOS was the predominant PFAS used in fume and mist suppressant, although the formulations are likely to have contained other PFAS present as impurities from the ECF manufacturing process (refer to the site profile for AFFF for further detail (CL:AIRE, 2026l)).

The Stockholm Convention includes a derogation to the use of PFOS as a mist suppressant in closed loop systems in hard chrome plating until September 2025. Indications are that the majority of users have already transitioned to formulations that do not contain PFOS. However, it is noted that PFOS continues to be detected in the waste water of plants where PFOS was used, many years after the end of PFOS use, due to desorption processes from all surfaces that once came into contact with PFOS.

6:2 Fluorotelomers appear to be the common replacement chemistry for chrome plating. Formulations based on 6:2 FTS appear to be in widespread use in Europe while F-53B (including 6:2 chlorinated polyfluorinated ether sulfonate (9Cl-PF3ONS) and 8:2 chlorinated polyfluorinated ether sulfonate (11Cl-PF3OUdS)) is also used in China. The 6:2 fluorotelomers have the potential to degrade to short chain PFCAs include PFHxA, and they are also relatively stable in the environment, and persist in waste water effluent, surface waters and groundwater. Where it has been included in the testing suite, 6:2 FTS is frequently the most abundant PFAS detected in groundwater and surface water in England.

PFAS also have wide application in other surface plating activities as well as chrome plating, where they are used as degreasers and surfactants. As detailed above, there is very limited information available regarding the composition of fluorinated surfactants currently in use, and used in the past. Formulations in past use are likely to have included PFOS and other long chain PFAS. Current formulations are likely to be based on short chain PFAS and precursors including 6:2 FTS and PFBS.

6. SOURCE POTENTIAL FOR METAL MANUFACTURING AND FINISHING

Following the methodology set out in section 1.3, source potential has been developed for each site profile zone and detailed in Table 2.

ACKNOWLEDGEMENTS AND SUGGESTED CITATION

The PFAS Site Profiles were originally prepared by Jacobs for the Environment Agency PFAS Risk Screening Project (Phase 4) and have been edited for publication by CL:AIRE. The authors were Jane Thrasher, Francesca Giacomello, Hugh Masters-Williams, Yolande Macklin, Laura Richmond, Simon Tempest and Hannah Foster.

This bulletin should be cited as follows: CL:AIRE, 2026. Metal Manufacturing and Finishing. PFAS Site Profile 05. CL:AIRE, UK.

IMPORTANT NOTES FOR READERS OF THE PFAS SITE PROFILES

The PFAS Site Profiles are based on available online literature and review of readily available technical publications at the time of writing (2020-2024). The authors recognise that additional information may be available that has not been used in this study.

The published literature on PFAS occurrence and distribution is vast and continually expanding. For example, the Interstate Technology and Regulatory Council web resource cited in the PFAS Site Profiles as "ITRC (2023)" was substantially updated in January 2026.

Table 2. Site Profile Zone Source Potential.

Site Profile – Zones	Magnitude	Likelihood	Source Potential	PFAS presence and use
Former fire-fighting training activities (large metal manufacturing sites regulated under COMAH)	5	5	25	See site profile for COMAH regulated sites for further details (CL:AIRE, 2026b). Foam use when testing systems and practising emergency response. Historically, foams were used directly on the ground and pits where fire was staged for training. Large quantities of AFFF were used and released to the ground with high frequency. Currently this practice is improved and runoff likely to be contained, therefore the high source potential is related to the old practice and can be reduced for more recent fire training activities. Potential for adsorption to infrastructure including hardstanding and drainage systems, and ongoing slow release.
Process water	5	3	15	Potential release of process effluent. On-site treatment or containment may not capture all pathways; may be discharged via discharge consent to sewer or to surface water.
Waste water system	3	5	15	May include process waste water and drainage water from working areas. On-site effluent treatment processes for general waste water unlikely to reduce PFAS content. May be tankered for off-site disposal to WWTW.
Concentrates storage area including AFFF storage	5	1	5	Leaks can occur and if good practices are not in place PFAS can reach the drains via runoff.
Decommissioning and demolition of redundant plant	5	1	5	Due to adsorption PFAS may be present in all process plant. It has been found that PFAS persist in plant for several years after cessation of use. There will therefore be a risk of it being released to the environment at the end of the plant's life during disposal.
Surface water drainage systems and tanks, soakaways and effluent discharge points	1	3	3	Sediments likely to be contaminated by PFAS and to slowly release PFAS to the water environment.
Concrete areas and other semi-permeable surfaces where PFAS have been used	1	2	2	Past adsorption of PFAS to concrete surfaces. Slow release of PFAS from concrete can potentially impact surface water and groundwater.

PFAS Site Profile

The purpose of the PFAS Site Profiles is to provide regulators and other interested parties with researched advice on how to assess problem sites that may be impacted by legacy use or release of PFAS. The profiles do not seek to address the specific circumstances of each site as these will be unique. As such, the PFAS Site Profiles should be read with the following reservations in mind:

- Practices can vary between different sites and therefore individual sites may not have been exposed to the typical PFAS contaminants of concern as detailed in each site profile;
- Site exposure to PFAS contaminants of concern may vary based on practices and equipment used on site; and
- Given the longevity of PFAS in the environment, site profiles may refer to practices which are no longer followed, and subsequently may omit current practices which avoid contamination.

DISCLAIMER

The information, views and conclusions drawn concerning the PFAS Site Profiles are based, in part, on information supplied to Jacobs by third parties; and from publicly available information. Jacobs has proceeded in good faith on the assumption that this information is accurate and complete. Jacobs accepts no liability for any inaccurate conclusions, assumptions or actions taken resulting from any inaccurate information supplied to Jacobs by third parties or available from public sources.

All users must make their own appropriate assessments specific to their site (or group of sites).

For the avoidance of doubt none of CL:AIRE, Jacobs or the Environment Agency accept liabilities resulting from the use or interpretation of the contents of the PFAS Site Profiles.

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PFAS Site Profile

ACRONYMS AND ABBREVIATIONS

Note: this list of acronyms and abbreviations includes those used across all the site profiles and therefore may include some acronyms and abbreviations not used within this profile.

General Acronym / Abbreviation	Definition	General Acronym / Abbreviation	Definition
AFFF	Aqueous Film-Forming Foam	HSE	Health and Safety Executive
ALARP	As Low As Reasonably Practicable	ITRC	Interstate Technology and Regulatory Council
AR-FFFP	Alcohol resistant film-forming fluoroprotein foam	LCMS	Liquid Chromatography Mass Spectrometry
BOW	Bilge and oily waste water	LPG	Liquified Petroleum Gas
CA	Competent Authority	MAPP	Major accident prevention policy
CAS	Chemical Abstracts Service	MILSPEC	Military Specification
CAFS	Compressed Air Foam System	MSDS	Material Safety Data Sheets
CDOIF	Chemical and Downstream Oil Industries Forum	NAPL	Non Aqueous Phase Liquid
CIMAH	Control of Industrial Major Accident Hazards	NCM	Nordic Council of Ministers
CIP	Chemicals Investigations Programme	NIHHS	Notification of Installations Handling Hazardous Substances Regulations
CLP	Classification Labelling and Packaging	NORM	Naturally occurring radioactive material
CO_2	Carbon dioxide	OECD	Organization for Economic Cooperation and Development
COMAH	Control Of Major Accident Hazards	ONR	Office for Nuclear Regulation
CPI	Confederation of Paper Industries	PCM	Paper and Cardboard Manufacturing
DoD	Department of Defence (Australia)/Defense (USA)	PNEC	Predicted No-Effect Concentrations
DoE	Department of Environment	PPB	Parts Per Billion
DWS	Drinking Water Standards	PPE	Personal protective equipment
ECF	Electrochemical fluorination	RAAF	Royal Australian Air Force
EOF	Extractable Organic Fluorine	REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
EPA	Environmental Protection Agency (for Denmark)	STM	Surface treatment of metals
EPR	Environmental Permitting Regulations	TOP	Total Oxidisable Precursor
EQS	Environmental Quality Standard	TULAC	Textiles, Upholstery, Leather, Apparel and Carpets
EU	European Union	UBA	Umwelt Bundesamt (German Environment Agency)
FCM	Food Contact Material	UK WIR	United Kingdom Water Industry Research
FFF	Fire-Fighting Foam	UMD	University of Maryland
FFFP	Film-Forming Fluoroprotein	US EPA	United States Environmental Protection Agency
FP	Fluoroprotein	WWTP	Waste Water Treatment Plant
FPP	Fire Prevention Plans	WWTW	Waste Water Treatment Works
FRS	Fire and Rescue Service		

PFAS Site Profile

ACRONYMS AND ABBREVIATIONS

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PFAS Acronym / Abbreviation	PFAS Definition	PFAS Acronym / Abbreviation	PFAS Definition
10:2 FTOH	10:2 Fluorotelomer alcohol	HFPO-DA	Hexafluoropropylene oxide-dimer acid
10:2 FTS	10:2 Fluorotelomer sulfonate or sulfonic acid	HFPO-TA	Hexafluoropropylene oxide-trimer acid
10:2 FTUCA	10:2 Fluorotelomer unsaturated carboxylic acids	MeFOSAA	Methylperfluorooctanesulfonamidoacetic acid
11Cl-PF3OUdS	11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (F-53B Minor)	PAP	Polyfluorinated alkyl phosphates
12:2 FTS	12:2 Fluorotelomer sulfonate or sulfonic acid	PASF	Perfluoroalkane sulfonyl fluoride substances
14:2 FTS	14:2 Fluorotelomer sulfonate or sulfonic acid	PFA	Perfluoralkoxy polymer
12:2 FTAB	12:2 Fluorotelomer sulfonamido betaine	PFAA	Perfluoroalkyl acid
4:2 FTS	4:2 Fluorotelomer sulfonate or sulfonic acid	PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
5:3 FTCA	5:3 Fluorotelomer carboxylic acid	PFBA	Perfluorobutanoate or Perfluorobutanoic acid
6:2 FTAB	6:2 Fluorotelomer sulfonamidoalkyl betaine (see also CMDFPAH)	PFBS	Perfluorobutyl sulfonate or Perfluorobutyl sulfonic acid
6:2 FTCA	6:2 Fluorotelomer carboxylic acid	PFC	Perfluorinated Compound
6:2 FTOH	6:2 Fluorotelomer alcohol	PFCA	Perfluoroalkyl carboxylic acid
6:2 FTS	6:2 Fluorotelomer sulfonate or sulfonic acid (see also TDFOSA)	PFDA	Perfluorodecanoate or Perfluorodecanoic acid
6:2 FTUCA	6:2 Fluorotelomer unsaturated carboxylic acids	PFDoA	Perfluorododecanoate or Perfluorododecanoic acid
6:2 diPAP	6:2 Fluorotelomer phosphate diester	PFECA	Perfluoroalkyl ether carboxylic acid
8:2 Cl-PFESA	8:2 Chlorinated perfluoroalkyl ether sulfonic acid	PFECHS	Perfluoroethylcyclohexane sulfonate
8:2 FTOH	8:2 Fluorotelomer alcohol	PFESA	Perfluoroalkyl ether sulfonic acid
8:2 FTS	8:2 Fluorotelomer sulfonate or sulfonic acid	PFHpA	Perfluoroheptanoate or Perfluoroheptanoic acid
8:2 FTUCA	8:2 Fluorotelomer unsaturated carboxylic acids	PFHpS	Perfluoroheptane sulfonate or Perfluoroheptane sulfonic acid
9Cl-PF3ONS	9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (F-53B Major)	PFHxA	Perfluorohexanoate or Perfluorohexanoic acid
ADONA	4,8-Dioxa-3H-perfluorononanoic acid	PFHxS	Perfluorohexane sulfonate or Perfluorohexane sulfonic acid
CMDFPAH	Carboxymethyldimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)sulphonyl]amino]propylammonium hydroxide; a synonym of 6:2 FTAB used in UKWIR reports	PFNA	Perfluorononanoate or Perfluorononanoic acid
EtFOSA	N-ethyl-perfluorooctane sulfonamide	PFOA	Perfluorooctanoate or Perfluorooctanoic acid
EtFOSAA	N-ethyl-perfluorooctane sulfonamido acetic acid	PFOS	Perfluorooctane sulfonate or Perfluorooctane sulfonic acid
EtFOSE	N-ethyl-N-(2-hydroxyethyl) perfluorooctane sulfonamide	PFOSA	Perfluorooctane sulfonamide (FOSA)
F-53B	Trade name for chlorinated polyfluoroalkyl ether sulfonic acids (9Cl-PF3ONS and 11Cl-PF3OUdS)	PFOSE	Perfluorooctane sulfonamido ethanol
FASA	Perfluoroalkane sulfonamide	PFPA	Perfluoropentanoate or Perfluoropentanoic acid
FBSA	Perfluorobutane sulfonamide	PFPE	Phosphate ester salts
FOSA	Perfluorooctane sulfonamide	PFPeA	Perfluoropentanoic acid
FOSAA	Perfluorooctane sulfonamidoacetic acid	PFPeS	Perfluoropentane sulfonate or Perfluoropentane sulfonic acid
FOSE	Fluorooctane sulfonamido ethanol	PFPS	Perfluoropentane sulfonate
FTCA	Fluorotelomer carboxylic acid	PFSA	Perfluoralkane sulfonic acid
FTMAC	Fluorotelomer methacrylate	PFUnDA	Perfluoroundecanoate or Perfluoroundecanoic acid
FTOH	Fluorotelomer alcohol	POSF	Perfluorooctane sulfonyl fluoride
FTS	Fluorotelomer sulfonate	PTFE	Polytetrafluoroethylene
FTSA	Fluorotelomer sulfonic acid	TDFOSA	3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulfonic acid; a synonym for 6:2 FTS used in UKWIR reports
Gen-X	Trade name for HFPO-DA		