MONITORING THE PRESENCE AND LEVELS OF PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS) IN WATER: WESTERN CAPE CASE

Mbuso Kingdom Dludlu and Peter Mallon

WATER RESEARCH COMMISSION

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Monitoring the presence and levels of per- and polyfluoroalkyl substances (PFAS) in water: Western Cape case study

Report to the
Water Research Commission

by

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WATER
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EXECUTIVE SUMMARY

BACKGROUND

Widespread occurrence of per/polyfluoroalkyl substances (PFAS) has raised global concerns because of their toxic effects on the environment and human health, which stem from their use in non-stick cookware, food packaging, surfactants, cosmetics, firefighting foams, paints, waterproof products, and inks. A variety of other industrial applications include the manufacture of paper, leather, textiles, medical aids, pesticides, minerals, oils, and metal plating. Per- and polyfluoroalkyl substances (PFAS) are human-made and pervasive chemicals that have been widely used over the last 60 years. They are essentially fluorinated aliphatic molecules (carbon-fluorine bonds) which pollute water, and because of their inert and non-degradable nature, they appear to be a challenging problem for environmental researchers, as they are easily spread in numerous ways. The use of these products leads to the contamination of drinking water as well as treated wastewater, which is commonly used for agricultural purposes. Studies have shown alarming levels of certain groups of PFAS in the blood and urine of humans and animals. Previous studies have linked perfluorooctanoic acid (PFOA) and perfluorooctanoate sulfonate (PFOS) to certain health effects, including kidney cancer, thyroid problems, and high cholesterol. There is a need for scientists and environmental researchers to develop models for predicting the levels of PFAS to estimate how much PFAS migrate to the environment, impacting people and ecosystems, as well as running analytical detection methods to understand the occurrence of PFAS in general food.

Although PFAS-treated products play an important role in extending their service life and durability, they result in prolonged exposure of humans, wildlife, and the environment to PFAS. Humans and animals are exposed to PFAS through drinking water and dietary intake, which can have detrimental consequences such as acute and chronic diseases, including thyroid, asthma, anxiety, obesity, paediatric allergies, hyperuricaemia, peroxisome proliferation, immune toxicity, kidney disorders, liver damage, and cardiovascular diseases. South Africa, especially the Western Cape, suffers from a water shortage, and the security of this scarce resource is threatened because water sources are contaminated every day in various ways. To date, no comprehensive study has been conducted to determine PFAS concentrations in different water sources, and there is no data on PFAS in the Western Cape in South Africa; however, Kibambe et al. reported the detection of the following contaminants in Gauteng Province: PFBA, PFPeA, PFHxA, PFOA, PFDA, PFHxS, and PFOS from three wastewater treatment plants (WWTPs). The presence of PFAS in water resources is of particular concern because conventional water treatment processes do not effectively remove these compounds. For PFAS screening and method development, samples collected from various aquatic matrices, such as major dams, rivers, drinking water treatment plants, and wastewater treatment plants around the Western Cape, will be used. The province will serve as a comparative study for the other eight provinces, namely, Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape and North-West provinces, for identifying and detecting PFAS in water samples, with Gauteng being the most industrialized province in the country.

PROJECT AIMS

The aim of this project is as follows:

1. Monitor the concentrations of legacy and emerging PFAS in Western Cape Province from various aquatic sources.
2. Develop a provincial database that will add to the overall nationwide database on PFAS concentrations in different water sources in the Western Cape.

METHODS

a. Sampling Method

It has been noted that water sampling for PFAS studies has often not been reported in detail. This is an oversight because the collection and sampling processes must be contaminant-free to obtain accurate PFAS concentrations. PFAS samples must be measured at environmentally relevant concentrations (ng/L); hence, the sampling, laboratory, and analytical components must be cleaned thoroughly. PFAS can be absorbed from the analyte to the glass surface when using glass containers for sampling and from the fluoropolymer surface to the analyte when using fluoropolymer containers. Hence, it is best to avoid glass and fluoropolymer containers for sampling and to use either polypropylene or high-density polyethylene (HDPE) bottles for the collection of samples. All the sampling equipment and containers were first cleaned using tap water, followed by triple rinsing with ultrapure water, and finally washing with methanol. To minimise sample contamination, the sampling bottles were pre-rinsed with analytical grade methanol and rinsed with Milli-Q water. The samples were then transported to the laboratory, physicochemical parameters were measured, and the samples were stored in a fridge at -20 ºC until processing.

The two sampling methods employed in this study were as follows:

- Grab sampling – Samples were collected from seventeen (17) different water sites in the Western Cape province comprising: three (3) major dams (DM), three (3) rivers (RV), five (5) drinking water treatment plants (DWTP) with raw and final samples collected in each plant) and six (6) wastewater treatment plants (WWTP) with influent and effluent samples collected in each plant. Water samples were collected from various water sources at each site in clean high-density polyethylene bottles. Once collected, the samples were stored on ice, transported to the laboratory, and prepared for analysis. A total of one hundred and sixty-eight samples were collected and analysed for PFAS over the 36-month period.
- Passive sampling: With this method, a Polar Organic Chemical Integrated Sampler (POCIS) was used. The POCIS was deployed in the influent and effluent of two different wastewater treatment plants for two weeks, and POCIS was extracted after 14 days. This was because of the high PFAS concentration observed in wastewater treatment plants. Grab samples were also collected from the same location where the POCIS was deployed.

b. Solid Phase Extraction and LC-MS Analysis Method

A 1.2 mL native standard mix of 2000 ng/mL containing PBFA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFUdA, PFDoA, PFHxDA, PFDOA, L-PFBS, L-PFHxS, L-PFOS, L-PFDS, LPFpS, FHEA, FOET, FHET, 4:2FTS, 6:2FTS, 8:2FTS and isotopically labelled internal (MPFDA_13C2, MPFHxA_13C2 and M2PFOA_13C2) and surrogate (MPFNA) standards (50 mg/L in methanol), purchased from Wellington Laboratories (Guelph, Ontario, Canada) were used for this exercise. A previously developed multiple reaction monitoring method (MRM) analysis of the calibration standards at a full scan of ions was carried out. Quantitation of the target compounds was based on the internal standard method calibration with concentrations ranging from 0.1-1000 ng/L. The limit of detection (LOD) and limit of quantification (LOQ) were determined. The USEPA Solid Phase Extraction Method 537.1 was used for water samples from five (5) drinking water treatment plants, six (6) wastewater treatment plants, three (3) major dams and three (3) rivers. SPE SupelcoTM Envi18 cartridges purchased from SIGMA Aldrich Ltd were used for all PFAS extractions from the water samples. Cartridges were first conditioned. Thereafter, the cartridges were dried under vacuum for 1 h. The solvent extract was concentrated under a gentle stream of nitrogen. The extracts were reconstituted to 1 mL and spiked with the internal standards M2PFOA 13C2, MPFDA_13C2, and MPFHxA_13C2; the reconstituted extract was then transferred to a 2 mL centrifuge tube, 950 µL of the extract and 50.0 µL of the internal standard was then added to a brown autosampler 1 ml vial ready for instrument analysis. A 10.0 µL of the sample was injected into the LCMS/MS for analysis.

RESULTS

Water Analysis and PFAS Quantification

Physiochemical parameters of the collected water samples were measured, and the screening, analysis, and quantification of PFAS concentrations in the water samples collected over six seasons (three wet seasons and three dry seasons) were performed. The percentage recoveries of the labelled surrogate standards were in the range 70-130%. The MRM ranged from 299-913 and 80.15-520 ion m/z for the precursor and product ions, respectively. The LOD and LOQ values were 0.005-0.395 and 0.016-0.868 ng/L, respectively. The mean concentrations of PFAS detected in the spiked and unspiked blanks ranged from <LOD-2.870 ng/L and <LOD-0.924 ng/L, respectively. All isomer calibration curves showed linearity, based on correlation coefficients (r) and correlation of determination (r^2) greater than 0.99, with good precision of the internal standard. The chromatograms showed good peak resolution. The LOD and LOQ were >0.001 ng/L. The percentage recoveries of the labelled surrogate standards were within the acceptable ranges.

PFAS Identification in water sources in the Western Cape – Grab Sampling

Carboxylic acids and fluorotelomers were the most dominant PFAS in WWTP, rivers, dams, and drinking water treatment plants. For Carboxylic acids, perfluoro-n-butanoic acid (PFBA) percentage detection ranges from 90 to 100%, perfluoro-n-pentanoic acid (PFPeA) from 80 to 100%, perfluoro-n-octanoic acid (PFOA) from 40 to 100%, perfluoro-n-heptanoic acid (PFHpA) from 33 to 100%, perfluoro-n-hexanoic acid (PFHxA) from 10 to 31% and 2-Perfluorohexyl ethanoic acid (FHEA) detection ranges from 67 to 100%. For Fluorotelomers, for all 8:2 fluorotelomer alcohols (FOET), the percentage detection was 100%, as well as for 6:2 Fluorotelomer Alcohol (FHET) and 6:2 fluorotelomer sulfonate (6:2 FTS), it was 100%.

PFAS Identification in water sources in the Western Cape – Passive Sampling

Of the 21 PFAS studied, 12 were detected, except for PFUdA, PFDoA, PFHxDA, 4:2 FTS, L-PFHpS, PFODA, L-PFDS, L-PFHxS, and 8:2FTS. FOET had the highest concentration of all the detected PFAS. A similar trend was observed with grab sampling. This trend is in line with that of the grab sampling over the duration of this study. The difference between the concentrations recorded for the two sampling methods was because grab samples provide only snapshot concentrations, whereas passive sampling provides time-weighted average concentrations. The higher PFAS concentrations observed in passive sampling indicate the ability of the sampler to adsorb more PFAS.

Statistical Analysis

Multivariate statistical analysis (PCA) was used to establish inter-relationships between different groups of PFAS and sample sites, and to establish possible sources. From the PCA analysis, some PFAS showed similar sources, whereas others showed different sources. This trend was also observed with the sampling sites. Therefore, based on the land use activities around the sampling sites, the presence of PFAS detected in the water samples may have originated from the current/historical usage of PFAS in various activities.

GENERAL

The progress of the project was hindered by the passing away of the project leader, Dr Rehana Malgas-Enus. However, despite this setback, we proceeded with sample collection and PFAS analysis. Stellenbosch University had to assign a new project leader in Mr Mbuso Kingdom Dludlu, with Prof Peter Mallon acting as a project advisor. There were also delays in the production and design of the passive-sampler canister. The canisters were not sold over the counter in South Africa, and we had to find a steel designer to make the canisters. The canisters were designed by Mbuso Dludlu, manufactured by Mr Lawrence Ashworth at the Physics Department Laser Workshop at Stellenbosch University, and are ready for passive sampler deployment.

CONCLUSIONS

Non-target and target methods for the identification and quantification of PFAS in various water sources were successfully developed and validated by the Tshwane University of Technology research team led by Prof Jonathan Okonkwo and were used to monitor the distribution and sources of PFAS in water in the Western Cape Province. The concentrations of PFAS observed in the present study were, in some cases, higher than those reported by other researchers in similar water samples. Four water sampling sources, drinking water treatment plants (DWTP), wastewater treatment plants (WWTP), dams (DM), and rivers (RV), were studied for the presence of selected 21 PFAS. Of the 21 PFAS, only three compounds, 6:2 FTS, FOET, and FHET, were prevalent throughout the sampling locations. The results showed detectable concentrations, especially for short-chain PFAS. Long-chain PFAS were detected at lower levels, suggesting that they were less prevalent in the collected samples. Another reason for the lack of detection of long chains may be their low solubility in water.

The impact of the restrictions and regulations placed on long-chain PFAS and the use of shorter chains as alternatives were visible in the results reported in the province. The wastewater treatment plant samples showed higher concentrations of PFAS than all other sources, followed by rivers, dams, and water treatment plants. These detected PFAS may have originated from domestic waste from the use of PFAS-containing products that are flushed into the sewage system ending up in wastewater treatment plants because there were no high PFAs concentrations detected in the dams and DWTP. The Western Cape Province is also known for cape fires, in which fire foams are widely used which might contribute to the high concentrations of PFAS. There is also an airport in the vicinity of the wastewater treatment plant. Commercial airports train with, calibrate equipment with, and use the best performing AFFF fire suppression systems. Traditional Aqueous Film-Forming Foam (AFFF), the Class B firefighting foam used to fight aviation, and other chemical fires typically contain PFAS. AFFF is required to be used at airports and must be certified to meet strict performance specifications.

For decades, AFFF containing PFAS have been used extensively at airports throughout the world to protect the safety of passengers, crews, and others. The chemical properties of PFAS make AFFF effective in suppressing fires. In effect, the AFFF forms a dense “foam blanket”, which prevents oxygen from reaching the fire and smothers it. The rivers contain a high concentration of PFAS because the wastewater after treatment is discharged to all three rivers. The percentage detection of PFAS ranged from 10% to 100%. Of the 21 PFAS, the detected PFAS ranged from 7 to 12.

PFAS were detected in both the grab and passive samples. Passive sampling was also carried out in selected water sources, particularly wastewater treatment plants, where, on previous occasions, it was discovered that PFAS concentrations were higher than those of the other water sources under study. However, the PFAS concentrations in the POCIS passive sampler were not the same as those in the grab samples collected on the same day. The observed difference suggests cumulative time-weighted concentrations of PFAS with passive samplers compared to the once-off grab sampling method. Water sampling over 36 months (3 dry and 3 wet seasons) was conducted successfully from 5 water treatment plants, 6 wastewater treatment plants, 3 major dams and rivers in the Western Cape. None of the banned (PFOA and PFOS) PFAS are found in the Western Cape drinking water treatment plants. These PFAS are below the maximum concentration level issued by the EPA. However, the fluorotelomers were detected in high concentration levels in the WWTP and rivers, an indication that most of the PFAS enter the water system post-consumer. The WWTP effluent containing fluorotelomers ends up in the ocean-marine environment (Petrik et al., 2024).

CONFIRMATION OF NEW KNOWLEDGE CONTRIBUTION

Method Development for PFAS monitoring and monitoring PFAS levels in Western Cape dams and rivers. Table 6.4 shows the students from Stellenbosch University who benefited from this project in terms of capacity building.

CAPACITY BUILDING REPORT

No	Student full names	Student surname	Qualification in 2024	Institute registered
1	Sihlumile	Mgada	BSc Chemistry	Stellenbosch University
2	David	Sibanda	PhD	Stellenbosch University
3	Mbuso	Dludlu	PhD	Stellenbosch University

COMMUNITY/INSTITUTIONAL EMPOWERMENT

We are working in collaboration with the TUT to develop a standardised analytical method for PFAS determination. The postgrad student completed LC-MS training and analysed seventy-two water samples at TUT with Prof J. Okonkwo. We also obtained approval for sampling from the City of Cape Town municipality. Career guidance for a high school that we adopted in eMalahleni, Mpumalanga Province. Mentorship for one of the technical process operators in one of the water treatment plants.

KNOWLEDGE DISSEMINATION UNDERTAKEN

Knowledge and information were shared at in two major international conferences and in one closed stakeholder engagement seminar on PFAS as shown below.

1. ISPAC 2023 - 34th International Symposium on Polymer Analysis and Characterization 24th – 26th April, 2023, Stellenbosch, South Africa
2. Dioxin 2024 – 44th International Symposium on Halogenated Persistent Organic Pollutants (POPs), held at Suntec Convention and Exhibition Centre in Singapore from 29th September to 3 October 2024.
3. Stakeholder Engagement Seminar on PFAS in water – WRC project C2022/2023-00725 at Borcherds Quarry Wastewater Treatment Works, Cape Town on the 10th December 2024.

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Reference Group	Affiliation
Dr Nonhlanhla Kalebaila	Water Research Commission
Ms Charmaine Dladla	Water Research Commission
Dr Buyisile Kholisa	Water Research Commission
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Dr Erika Jordaan	Tshwane University of Technology
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Professor Niki Bathori	Cape Peninsula University of Technology
Professor Henk Bouwman	Northwest University
Mr Luthando Nyaba	University of Johannesburg
Dr Caitlin Swiegelaar	National Metrology Institute of South Africa

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ACRONYMS & ABBREVIATIONS

AFFF	Aqueous Film Forming Foam
ASTM	Association of standardized test method
BFRs	Brominated Flame Retardants
DCM	Dichloromethane
DEA	Department of Environmental Affairs
DWS	Department of Water & Sanitation
EPA	U.S. Environmental Protection Agency
EtOH	Ethanol
HBWC	Health-Based Water Concentration
HDPB	High Density Polyethylene Bottles
HPLC	High pressure liquid chromatography
LC-MS	Liquid Chromatography-Mass Spectrometry
LLE	Liquid-Liquid Extraction
LOD	Limit of detection
LOQ	Limit of quantification
MCLs	maximum contaminant levels
MeOH	Methanol
MRM	Multiple Reaction monitoring
NPDWR	National Primary Drinking Water Regulation
PFAS	Per- and polyfluorinated alkyl substances
R^2	Correlation Coefficients
RQS	Resource quality services
SDWA	Safe Drinking Water Act
SD	Standard deviation
SPE	Solid Phase Extraction
SU	Stellenbosch University
TDS	Total Dissolved Solids
TIC	Total ion chromatogram
TUT	Tshwane University of Technology
USEPA	United States Environmental Protection Agency
DWTP	Drinking Water Treatment Plant
WWTP	Wastewater Treatment Plant

1 BACKGROUND

1.1 INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) are synthetic chemicals that are used in textiles, packaging, paper, carpets, and building and construction materials. They have also been used in cosmetic formulations, insecticides, paints, firefighting foams, hydraulic fluids, and wax. Their widespread use is attributed to their unique thermal stability and excellent surfactant capacity. These chemicals can be released into the environment during the use or disposal of products treated with PFAS. They can also be released during production, military and firefighting operations, the discharge of treated effluent and sludge, and leachate from landfills.

It is known that PFAS in source waters are, in most cases, not removed by conventional water treatment processes because of the design and treatment processes to effectively remove these contaminants during water purification or treatment. Therefore, water users and consumers can be unintentionally exposed to PFAS with their concomitant toxic effects in such instances. Therefore, monitoring of PFAS in South African water sources is particularly important. Therefore, conducting a large-scale monitoring programme that would provide a nationwide inventory of the concentrations of PFAS in South African source waters is a step in the right direction to safeguard public health. In addition, this exercise would not only contribute towards critically reviewing the current drinking water guidelines in order to address the challenges that may be posed by the presence of PFAS in South African source waters but also generate data on PFAS that are required for the National Toxicant Monitoring Programme (NTMP).

Two approaches are employed in this nationwide PFAS monitoring programme: targeted and non-targeted. Targeted analysis provides an unparalleled level of specificity and sensitivity for quantitative analysis. However, for new and emerging compounds, this approach is not effective in detecting species of interest, regardless of their chemistry or concentration. Non-targeted analysis leverages the power of modern high-resolution mass spectrometers to analyse both targeted and undiscovered chemicals.

The present report focuses on PFAS screening and quantification using water samples collected from the Western Cape Province in wet and dry seasons. The samples were collected from five (5) drinking water treatment plants (DWTP), six (6) wastewater treatment plants (WWTP), three (3) major dams (DM) and three (3) rivers (RV).

1.2 PROJECT AIMS AND OBJECTIVES

1.2.1 Aims

The main aims of this project were to study the concentration of PFAS in the Western Cape drinking water treatment plants, wastewater treatment plants, dams, and rivers every six months over 36 months, and to determine and monitor the increase in concentrations of legacy and emerging PFAS in different water sources in pre-selected sites in the Western Cape.

1.2.2 Objectives

The objectives were as follows:

1. Conduct sampling from several dams, rivers, drinking water treatment plants, and wastewater treatment plants in the Western Cape and analyse for PFAS every 6 months for 36 months and analyse samples using HPLC-MS.

2. Use an appropriate model to identify the PFAS sources and assess the amounts of pollution by resolving the measured mixture of chemical species into the contributions from the individual source types.
3. Develop a province database that will add to the overall nationwide database on PFAS concentrations in different water sources in the Western Cape.
4. To equip policy and decision makers and other stakeholders to identify potential areas of concern with respect to PFAS contamination in drinking water and other water sources.

1.3 PROJECT SCOPE AND LIMITATIONS

1.3.1 Scope

The overall project is on PFAS pollution of water in all the provinces in South Africa to present an overview of the presence and concentration levels of PFAS in water systems in the country using target and non-target approaches. However, the present report is a targeted analysis of water samples collected from selected water sources in the Western Province. Grab and passive sampling methods were used to collect water samples over three wet and dry seasons from November 2021 to May 2024.

1.3.2 Limitations

The study of concentration levels of per- and polyfluoroalkyl substances (PFAS) in this project was only focused on some of the dams, rivers, drinking water treatment plants, and wastewater treatment plants in the Western Cape province. The passing of the former project leader, Dr. Rehana Malgas-Enus, slightly affected the progress of the project, but after the assignment of the new project leader, the project progressed smoothly. Delays in passive-sampler canister design and production limit the number of passive samplings undertaken. There was a delay in the delivery of the internal and surrogate from our overseas suppliers which led to a delay in the analysis of the sixth water sampling batch; hence, the PFAS concentrations of these results are not presented in this report, even though the sampling was undertaken and completed. The project scope and funding are limited to the study of PFAS concentrations in different aquatic matrices in the Western Cape. It is desirable for the Stellenbosch research team to continue exploring novel methods for the removal and remediation of PFAS in water.

2 LITERATURE REVIEW

2.1 INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) represent a large group of synthetic chemicals that have been used in various industries worldwide since the 1940s. Their widespread use is attributed to their ability to repel oil and water, resist heat, and reduce friction, making them suitable for applications in non-stick cookware, water-repellent clothing, and firefighting foams. PFAS are often referred to as "forever chemicals" because of their persistence in the environment and human and animal bodies. However, their persistence in the environment and potential health risks have led to increased scientific scrutiny in recent decades. This literature review will provide an overview of PFAS, focusing on their occurrence globally and specifically in Africa, the environmental and human health impacts of PFAS, pathways of exposure, regulatory challenges, and current regulatory and mitigation strategies.

2.2 PFAS CHARACTERISTICS AND ENVIRONMENTAL PERSISTENCE

2.2.1 Chemical Structure

PFAS are a class of chemicals characterised by chains of carbon-fluorine bonds, which are one of the strongest bonds in organic chemistry. This unique structure renders PFAS resistant to degradation through natural processes such as photolysis, hydrolysis, and microbial activity. Consequently, PFAS are often referred to as "forever chemicals" because they remain in the environment for long periods. Commonly studied PFAS include perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), which are associated with environmental and health concerns due to their persistence and bioaccumulative properties (Sunderland et al., 2019).

2.2.2 Environmental Impact

Once released into the environment, PFAS accumulate in various ecosystems, particularly in water bodies. Their solubility in water means that PFAS can easily spread through groundwater and surface-water systems. The bioaccumulation of PFAS in aquatic organisms, such as fish and marine mammals, has been well documented. For example, Gewurtz et al. (2020) found elevated PFAS concentrations in fish species, posing risks to both wildlife and human consumers. The presence of PFAS in remote areas, such as the Arctic, also demonstrates the long-range transport potential of these substances (Sunderland et al., 2019).

2.2.3 Persistence and Mobility, Bioaccumulation and Ecotoxicity (Soil and Air Contamination)

PFAS are highly persistent in the environment because of the strength of the carbon-fluorine bond, which is one of the strongest bonds in organic chemistry. This persistence indicates that PFAS can remain in the environment for decades, if not longer. PFAS are also highly mobile and easily migrate through the soil and water, leading to widespread environmental contamination (Scheringer et al., 2014). PFAS can bioaccumulate in the tissues of living organisms. Studies have shown that PFAS can be found in fish, birds, mammals, and humans. The bioaccumulative nature of PFAS means that they can build up in food chains, leading to higher concentrations in top predators (Giesy & Kannan, 2001). PFAS have been shown to be toxic to various wildlife species. For example, PFOS causes liver damage, reproductive harm, and developmental issues in fish and birds (Letcher et al., 2010). The toxicity of PFAS to wildlife raises concerns about the broader ecological impacts of these substances. In addition to water, PFAS can accumulate in soil, posing risks to terrestrial ecosystems. Their deposition onto soil can occur via air emissions, as industrial processes release PFAS into the atmosphere, which

subsequently settle onto land. Studies have detected PFAS in the soil near manufacturing facilities, military bases, and landfills, often resulting in the contamination of nearby water sources (Xu et al., 2020).

2.3 HUMAN HEALTH EFFECTS AND RISKS OF PFAS EXPOSURE

Humans can be exposed to PFAS through several routes, including drinking contaminated water, consuming contaminated food (especially fish and shellfish), inhalation of dust containing PFAS, and use of consumer products that contain PFAS (ATSDR, 2018). Numerous studies have linked PFAS exposure with adverse health effects. According to the Agency for Toxic Substances and Disease Registry (ATSDR), PFAS exposure is associated with liver damage, thyroid disease, decreased fertility, increased cholesterol levels, obesity, hormone suppression, and cancer (ATSDR, 2018). Specifically, PFOA exposure has been linked to kidney and testicular cancer, whereas PFOS exposure has been associated with immune system effects (C8 Science Panel, 2012).

2.3.1 Endocrine Disruption and Reproductive Health

Several studies have linked PFAS exposure to endocrine disruption, particularly the regulation of thyroid hormones. The endocrine-disrupting properties of PFAS may lead to adverse effects on reproductive health, including reduced fertility and developmental issues. Ding et al. (2020) found that exposure to PFOA and PFOS was associated with increased risks of infertility and adverse birth outcomes, such as low birth weight and preterm birth.

2.3.2 Cancer Risks

One of the most alarming health risks associated with PFAS exposure is an increased risk of certain cancers. Barry et al. (2013) reported that long-term exposure to PFAS, particularly PFOA, is associated with a higher incidence of kidney and testicular cancers. These findings are supported by epidemiological studies in communities living near chemical plants and military installations, where PFAS contamination is prevalent.

2.3.3 Immune System Impacts

PFAS exposure has also been linked to immunotoxicity, with evidence suggesting that these chemicals can impair immune system function. Grandjean et al. (2012) found that children exposed to elevated levels of PFAS had reduced antibody responses to vaccines, indicating weakened immune function. This immunosuppressive effect raises concerns about the potential of PFAS to increase susceptibility to infectious diseases and reduce the effectiveness of vaccinations.

2.4 PFAS IN WATER SYSTEMS AS PATHWAYS OF HUMAN EXPOSURE

2.4.1 Drinking Water Contamination

Contamination of drinking water is one of the most critical concerns regarding PFAS. One of the most well-established pathways of PFAS exposure is through contaminated drinking water. Numerous studies have documented the presence of PFAS in drinking water supplies worldwide. Communities located near PFAS manufacturing facilities, firefighting training areas, and wastewater treatment plants are particularly at risk. A nationwide study in the United States by Hu et al. (2016) found that millions of people consumed drinking water with PFAS concentrations above the recommended safety limits set by the Environmental Protection Agency (EPA). Efforts to address this issue include the implementation

of water treatment technologies and establishment of regulatory limits for PFAS in drinking water (Bruton & Blum, 2017).

2.4.2 Wastewater Treatment

Wastewater treatment plants (WWTPs) are a significant source of PFAS in the environment. Contamination is often linked to industrial sites, military bases, and wastewater treatment plants (WWTPs). Traditional wastewater treatment processes are not effective in removing PFAS, leading to the release of these chemicals into surface waters and the application of contaminated biosolids to agricultural fields. Research is ongoing to develop more effective treatment methods to remove PFAS from wastewater (Guerra et al. 2014). Figure 2-1 below give an indication of the PFAS pathways to human exposure (source: National Academies of Sciences, Engineering, and Medicine, 2022.).

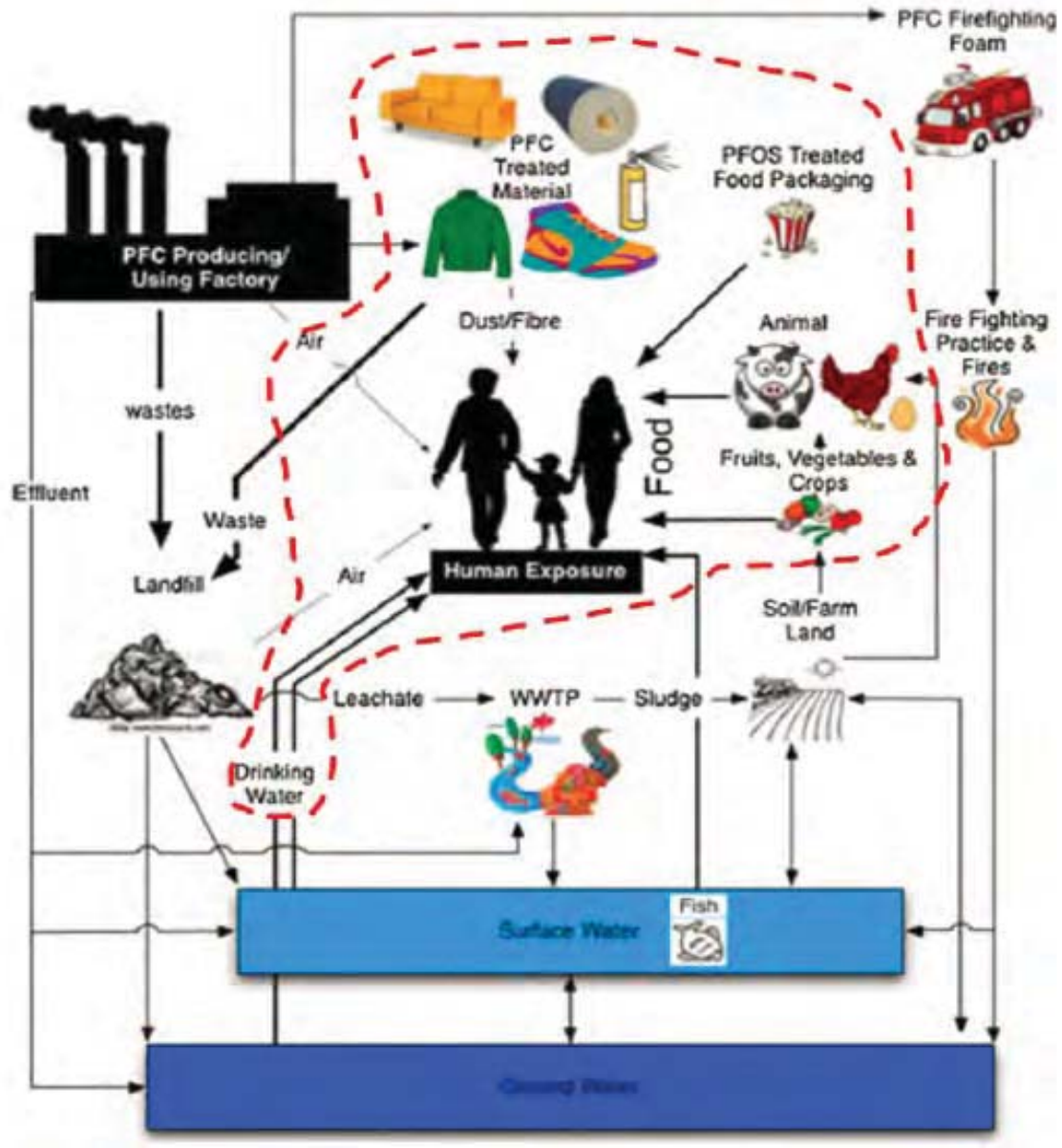

Figure 2-1: PFAS pathways to human exposure (source: National Academies of Sciences, Engineering, and Medicine, 2022).

2.4.3 Impact on Agriculture

PFAS contamination can adversely affect agriculture. Crops irrigated with contaminated water can accumulate PFAS, which then enter the food supply. Additionally, livestock exposed to PFAS through contaminated feed or water can also accumulate these chemicals in their tissues, posing risks to human health (Mörtberg et al., 2017). Contamination often occurs through the use of PFAS-containing pesticides, biosolids applied to agricultural fields, or contaminated irrigation water (Domingo and Nadal, 2019).

2.4.4 Contamination in Consumer Food Products

PFAS contamination in food products is a significant concern, particularly in foods that are exposed to contaminated water or packaging materials. PFAS are found in a wide range of consumer products, including non-stick cookware, water-repellent clothing, and food packaging materials. Frequent use of these products can result in the leaching of PFAS into the environment, contributing to human exposure through ingestion or dermal contact. Schaider et al. (2017) detected PFAS in various fast-food packaging materials, raising concerns regarding the potential of these chemicals to migrate into food. Studies have detected PFAS in a variety of food items, including dairy products, meat, and vegetables.

2.4.5 Dietary Sources

In addition to drinking water, dietary intake is an important source of PFAS exposure. Studies have shown that certain food items, particularly fish and seafood, can contain elevated PFAS levels owing to contamination in aquatic environments. Ericson et al. (2008) reported significant PFAS concentrations in fish samples from contaminated water bodies, highlighting the importance of diet as a pathway of exposure.

2.5 OCCURRENCE OF PFAS GLOBALLY

2.5.1 North America

PFAS contamination has been extensively documented in North America. A study by Hu et al. (2016) identified PFAS in the drinking water of over 16 million people in the United States. The most commonly detected compounds were perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Sources of contamination include industrial sites, military bases where aqueous film-forming foams (AFFFs) are used, and wastewater treatment plants.

2.5.2 Europe

Europe has also experienced significant PFAS contamination. A study by Gomis et al. (2018) reported widespread PFAS pollution in the surface waters of European rivers. This study highlighted that PFAS levels often exceeded the safety limits set by the European Food Safety Authority (EFSA). In addition, industrial sites in Belgium, Germany, and the Netherlands have been identified as the major sources of PFAS.

2.5.3 Asia

PFAS contamination has been reported in several countries in Asia. A study conducted by Yamashita et al. (2008) detected PFAS in river water samples from Japan, South Korea, and China. The primary

sources of contamination were industrial discharges and wastewater effluents. In China, the production and use of PFAS have led to significant environmental contamination, with levels in some areas exceeding those reported in North America and Europe (Wang et al., 2017).

2.5.4 Australia

Australia has also experienced PFAS contamination, particularly around sites where firefighting foams are used, such as airports and military bases. Heffernan et al. (2013) detected PFAS in groundwater near these sites, with levels of PFOA and PFOS exceeding health advisory limits. The Australian government has initiated extensive testing and remediation efforts in response to these findings.

2.5.5 Occurrence of PFAS in Africa

PFAS contamination in Africa is less documented than that in other continents, but recent studies indicate emerging concerns. Groffen et al. (2018) analysed PFAS in water, sediment, and biota from the Okavango Delta in Botswana. The findings revealed the presence of PFAS in all samples, with the highest concentrations in water and sediment near urban areas. Another study by Mbongwe et al. (2017) and Okonkwo et al. (2023) investigated PFAS levels in South African surface waters and highlighted significant contamination in urban and industrial regions. These sources are primarily attributed to industrial and urban runoff. These studies indicate that PFAS contamination in Africa is present and potentially growing, but not well documented.

2.6 REGULATORY CHALLENGES AND CURRENT MITIGATION STRATEGIES

2.6.1 Regulatory Landscape

Regulatory frameworks for PFAS are still being developed worldwide. In the United States, the EPA has established health advisory levels for PFOA and PFOS in drinking water; however, enforceable federal regulations are lacking. In contrast, the European Union has implemented more stringent regulations, including the restriction of certain PFAS under the Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulations (European Chemicals Agency, 2020). Several countries, including Canada and Australia, have established guidelines and limits for PFAS concentrations in drinking water and soil. Despite these efforts, the global nature of PFAS contamination poses significant regulatory challenges as these chemicals do not respect national borders and can spread through air and water.

2.6.2 Remediation Technologies and Techniques

Given the persistence of PFAS in the environment, effective remediation strategies are essential for reducing their impact. However, conventional water treatment technologies, such as filtration and chlorination, are ineffective in removing PFAS. Emerging remediation techniques include advanced oxidation processes (AOPs) and adsorption using activated carbon (AC) or ion-exchange resins. Rahman et al. (2014) demonstrated the potential of AOPs in degrading PFAS compounds in water, but widespread application of these methods is still limited due to high costs and technical challenges.

The remediation of PFAS-contaminated sites is challenging because of the chemical stability and persistence of these substances. Several technologies have been explored, including:

- Activated Carbon: Used for the adsorption of PFAS from water, although its effectiveness varies depending on the specific PFAS compound (Appleman et al., 2014).

- Ion-exchange resins: These resins can remove PFAS from water by exchanging ions with contaminants. They have shown promise in the treatment of PFAS-contaminated groundwater (Dudley et al., 2015).
- Advanced Oxidation Processes: Techniques such as ozonation and photocatalysis have been investigated for their ability to degrade PFAS in water (Rizzo et al., 2019).

One notable remediation effort is the cleanup of PFAS-contaminated sites around US military bases. The Department of Defence is actively working to identify and remediate PFAS contamination in hundreds of sites across the country. This includes the installation of granular activated carbon filters in drinking water systems and ongoing research on more effective remediation technologies (DOD, 2019). In Europe, cleanup of PFAS-contaminated sites has also been a priority. For example, the Dutch government has implemented a comprehensive strategy to address PFAS contamination in soil and water, which includes strict regulations and funding for remediation projects (RIVM 2016).

2.6.3 Innovative Degradation Methods

In recent years, research has focused on novel PFAS degradation methods, including microbial degradation and plasma-based technologies. Higgins and Luthy (2020) highlighted the potential of microbial degradation to break down certain PFAS under specific conditions, although this approach is still in the experimental stages. Plasma-based technologies, which use ionised gases to break chemical bonds, have also shown promise in degrading PFAS; however, further research is required to assess their scalability and long-term effectiveness.

2.6.4 Emerging Research on Short-Chain PFAS

As regulatory pressure mounts on long-chain PFAS, industries have shifted towards the production of short-chain PFAS as alternatives. These compounds are designed to be less bio-accumulative and potentially less toxic than their long-chain counterparts. However, recent studies have suggested that short-chain PFAS pose environmental and health risks. Wang et al. (2020) found that short-chain PFAS were detected in water bodies at comparable concentrations to long-chain PFAS, indicating that these alternatives may not fully resolve the persistence and toxicity issues associated with PFAS contamination.

2.7 SUMMARY

While the occurrence and impact of PFAS are well documented in regions such as North America, Europe, and Asia, emerging evidence indicates that PFAS contamination is also a growing concern in Africa. PFAS contamination is a significant environmental and public health concern owing to the persistent, bio-accumulative, and potentially toxic nature of these chemicals. They are persistent and pervasive environmental contaminants that have significant implications for human health and ecosystems. The widespread use of PFAS in consumer products and industrial applications, coupled with their resistance to degradation, has resulted in global contamination of water, soil, and air. The human health risks associated with PFAS exposure, particularly cancer, endocrine disruption, and immune system impairment, underscore the urgent need to address this issue. Furthermore, the shift towards short-chain PFAS as alternatives raises new concerns about their potential environmental and health impacts. Continued research and international collaboration are essential to manage the risks posed by PFAS and mitigate their long-term effects on the environment and human health. While regulatory frameworks are evolving, effective remediation strategies that address the challenges posed by PFAS require a coordinated global effort, including rigorous research, effective regulation, and the development of innovative remediation technologies for PFAS degradation. As awareness of the risks

associated with PFAS continues to grow, it is imperative to advance our understanding and management of these "forever chemicals" to safeguard the environment and public health.

3 DESCRIPTION OF STUDY SITES SAMPLING

3.1 DESCRIPTION OF STUDY AREA

Sources of information were selected based on their validity rather than on representativeness. The other criteria for selection were as follows:

- Hotspots (such as fire stations, airports, and industrial sites) – history of contamination.
- Major and minor water treatment plants.
- Location of wastewater treatment plants discharging into the river system.
- Location of the landfill sites.
- Location to agricultural activities and
- Location of industrial activity.

In the City of Cape Town, located in the Western Cape, there are 14 dams, 12 drinking water treatment plants, 620 pump stations, 180 reservoirs, and 23 wastewater treatment plants. The City of Cape Town (CoCT) maintains more than 20 000 km of pipelines and responds to more than 1 000 service requests daily (including pipe bursts, water leaks, and sewer blockages). The following water sources were selected for analysis in the Western Cape Province: Five (5) Drinking Water Treatment plants (DWTP), six (6) Wastewater Treatment Plants (WWTP) and three (3) Major Dams (DM) and three (3) Major Rivers (RV). To date, no comprehensive data on PFAS detection has been published for the Western Cape in South Africa. The province will serve as a comparative study for Gauteng province and other provinces under study to identify and detect PFAS in water samples; Gauteng is the most industrialised province in the country.

3.2 SAMPLING LOCATIONS

All samples were collected in duplicate in high-density polyethylene bottles (HDPB) pre-cleaned with methanol and ultrapure water using a bailer (Figure 3-3). As mentioned earlier, water samples from the Vaal River were used for the method development. Water samples were collected in clean high-density polyethylene bottles (HDPB) from five (5) water treatment plants, six (6) wastewater treatment plants, three (3) major dams and three (3) rivers.

3.2.1 Drinking water treatment plants

Figure 3-1 shows examples of points within the drinking water treatment plant where samples were collected. Table 3-1 gives a details on the 7 sampling cycle schedule for the drinking water treatment plant's raw and final water samples over the 36-month period. Table 3-2 gives detailed information about the drinking water treatment plants.

Data on the physicochemical properties of the drinking water treatment plant samples for both raw water samples and final water samples for each sampling cycle over the study period is provided in Appendix 1.

Figure 3-1: Drinking Water Treatment Plant sampling points.

Table 3-1: Drinking Water Treatment Plants Water Sampling Schedule over the 36-month period

Sampling cycles	**DWTP-F**		**DWTP-W**		**DWTP-V**		**DWTP-S**		**DWTP-H**	
Sample Quality:	Raw Water	Final Water	Raw Water	Final Water	Raw Water	Final Water	Raw Water	Final Water	Raw Water	Final Water
Cycle 1: 02 - 03 Nov 2021	WTP-F11	WTP - F12	WTP - W11	WTP - W12	WTP - V11	WTP - V12	WTP - S11	WTP - S12	WTP - H11	WTP - H12
Cycle 2: 02 - 08 May 2022	WTP - F21	WTP - F22	WTP - W21	WTP - W22	WTP - V21	WTP - V22	WTP - S21	WTP - S22	WTP - H21	WTP - H22
Cycle 3: 17 - 22 Nov 2022	WTP - F31	WTP - F32	WTP - W31	WTP - W32	WTP - V31	WTP - V32	WTP - S31	WTP - S32	WTP - H31	WTP - H32
Cycle 4: 08 - 10 June 2023	WTP - F41	WTP - F42	WTP - W41	WTP - W42	WTP - V41	WTP - V42	WTP - S41	WTP - S42	WTP - H41	WTP - H42
Cycle 5: 02 - 03 Nov 2023	WTP - F51	WTP - F52	WTP - W51	WTP - W52	WTP - V51	WTP - V52	WTP - S51	WTP - S52	WTP - H51	WTP - H52
Cycles 6&7: 02 - 08 May 2024	WTP - F61	WTP - F62	WTP - W61	WTP - W62	WTP - V61	WTP - V62	WTP - S61	WTP - S62	WTP - H61	WTP - H62

Table 3-2: Water Treatment Plants Water detailed information

Code	Constructed	Capacity (ML/day)	Treatment process and chemicals used	Water source	Site Coordinates
WTP - F	1994	500	Coagulation and pH level adjustment (hydrated lime), odour control (powder activated carbon), flocculation (ferric sulphate), settlement, filtration, stabilisation (hydrated lime and carbon dioxide), and chlorine disinfection	Theewaterskloof and Steenbras Upper dams	-34.040117, 18.801864
WTP - W	1958	250	Coagulation and pH level adjustment (hydrated lime), flocculation (aluminium sulphate), settlement, filtration, stabilisation (hydrated lime and carbon dioxide), and chlorine disinfection	Wemmershoek Dam (augmented from Theewaterskloof)	-33.834328, 19.072877
WTP - V	1971	230	Coagulation and pH level adjustment (hydrated lime), odour control (powder activated carbon), flocculation (aluminium sulphate/polyelectrolyte), settlement, filtration, stabilisation (hydrated lime and carbon dioxide), and chlorine disinfection	Voelvlei Dam (Klein Berg and Twenty-four rivers)	-33.386923, 19.033370
WTP - S	1946	150	Coagulation and pH level adjustment (hydrated lime), flocculation (aluminium sulphate/sodium aluminate), settlement, filtration, stabilisation (hydrated lime and carbon dioxide), and chlorine disinfection	Steenbras Lower and Upper Dam	-34.174547, 18.849335
WTP - H		15	pH level adjustment (hydrated lime), slow sand filtration and chlorination and chlorine disinfection	Land-en-Zeezicht Dam (Lourens River and boreholes)	-34.065058, 18.872518

3.2.2 Wastewater treatment plants

Table 3-3 gives a detailed sampling cycle schedule for the wastewater treatment plant for the influent and effluent water samples over the 36-month period. Table 3-4 gives detailed information about the wastewater treatment plants. Figure 3-2 show the wastewater treatment plant sampling point. Where it is indicated that there are no samples, it is because there were no water samples collected since sampling approval was not yet received from the City of Cape Town. Therefore, sampling was performed in only three wastewater treatment plants during that season.

Data on the physicochemical properties of the wastewater samples, both influent and effluent, for each sampling cycle over the study period are shown in Appendix 2.

Table 3-3: Wastewater Treatment Plant Water Sampling Schedule over the 36-month period

Sampling cycle	WWTP-C		WWTP-A		WWTP-Z		WWTP-P		WWTP-M		WWTP-V	
Sample Quality:	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Cycle 1: 02 - 03 Nov 2021	No Sample	No Sample	No Sample	No Sample	WWTP - Z11	WWTP - Z12	No Sample	No Sample	WWTP - M11	WWTP - M12	WWTP - V11	WWTP - V12
Cycle 2: 02 - 08 May 2022	WWTP - C21	WWTP - C22	WWTP - A21	WWTP - A22	WWTP - Z21	WWTP - Z22	WWTP - V21	WWTP - V22	WWTP - M21	WWTP - M22	WWTP - V21	WWTP - V22
Cycle 3: 17 - 22 Nov 2022	WWTP - C31	WWTP - C32	WWTP - A31	WWTP - A32	WWTP - Z31	WWTP - Z32	WWTP - P31	WWTP - P32	WWTP - M31	WWTP - M32	WWTP - V31	WWTP - V32
Cycle 4: 08 - 10 June 2023	WWTP - C41	WWTP - C42	WWTP - A41	WWTP - A42	WWTP - Z41	WWTP - Z42	WWTP - P41	WWTP - P42	WWTP - M41	WWTP - M42	WWTP - V41	WWTP - V42
Cycle 5: 02 - 03 Nov 2023	WWTP - C51	WWTP - C52	WWTP - A51	WWTP - A52	WWTP - Z51	WWTP - Z52	WWTP - P51	WWTP - P52	WWTP - M51	WWTP - M52	WWTP - V51	WWTP - V52
Cycle 6&7: 02 - 08 May 2024	WWTP - C61	WWTP - C62	WWTP - A61	WWTP - A62	WWTP - Z61	WWTP - Z62	WWTP - P61	WWTP - P62	WWTP - M61	WWTP - M62	WWTP - V61	WWTP - V62

Table 3-4: Wastewater Treatment Plants Water detailed information

WWTP	Treated effluent capacity (Ml/d)	Km of pipe network	Number of customer meters	Date commissioned	Capacity (Ml/d)	DWS licence (Ml/d)	Site Coordinates
WWTP - C	16.1	10.9	3	1960	200.0	161.0	-34.080819, 18.521743
WWTP - A	15.3	44.6	58	1923	105.0	110.0	-33.955240, 18.512890
WWTP - Z	6.1	0	1	1989	72.0	73.6	-34.052811, 18.712765
WWTP - P	46.6	110	44	1957	47.0	43.9	-33.840378, 18.522071
WWTP - M	11.1	32.3	17	1978	38.0	30.7	-34.074422, 18.766837
WWTP - V	N/A	0	0	1971	14.0	5.8	-33.386923, 19.033370

Figure 3-2: Wastewater Treatment Plant sampling point

3.2.3 Freshwater resources

Figure 3-3 shows the maps of the dams and river sampling sites across the Western Cape and Figure 3-4 shows one of the dams and river water sampling sites. Table 3.16 gives a detailed sampling cycle schedule for the dams and river water samples over the 36-month period. Table 3.17 gives some information about the dams and rivers.

Data on the physicochemical properties of the dams and river water samples for each sampling cycle over the study period are shown in Appendix 3.

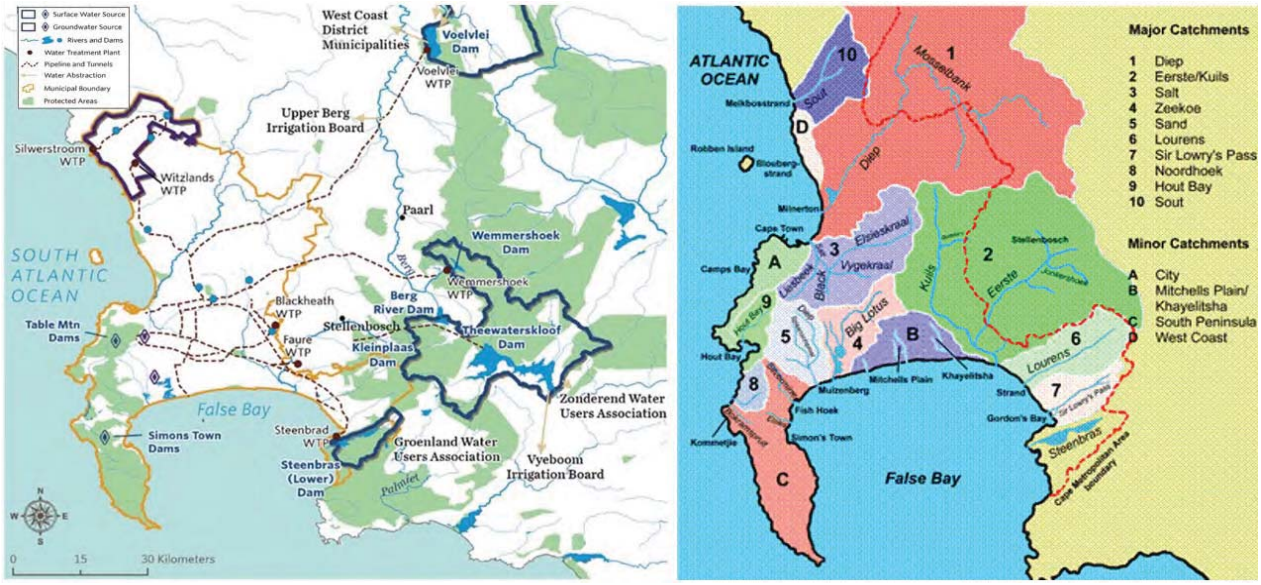

Figure 3-3: Map showing dams and rivers sampling sites. (Stafford et al., 2018).

Figure 3-4: Dam and River water Sampling Site – Dam (top two pictures same dam during wet and dry season) and bottom two pictures are two different rivers.

Table 3-5: Water source (Major Dams and Major Rivers) Sampling Schedule over the 36-month period

Water source/ Sampling Cycle	Dam-T	Dam-V	Dam-N	Diep River	Eerste River	Salt River
Cycle 1: 02 - 03 November 2021	DM-T1	DM-V1	DM-N1	RV-D1	RV-E1	RV-S1
Cycle 2: 02 - 08 May 2022	DM-T2	DM-V2	DM-N2	RV-D2	RV-E2	RV-S2
Cycle 3: 17 - 22 November 2022	DM-T3	DM-V3	DM-N3	RV-D3	RV-E3	RV-S3
Cycle 4: 08 - 10 June 2023	DM-T4	DM-V4	DM-N4	RV-D4	RV-E4	RV-S4
Cycle 5: 02 - 03 November 2023	DM-T5	DM-V5	DM-N5	RV-D5	RV-E5	RV-S5
Cycle 6&7: 02 - 08 May 2024	DM-T6	DM-V6	DM-N6	RV-D6	RV-E6	RV-S6

Table 3-6: Water source (Major Dams and Major Rivers) Sampling Schedule

Water source	Location	Ownership	Completed	Capacity (Ml)	Site Coordinates
DM - T	Villiersdorp	DWS	1978	480 250	-34.028142, 19.195741
DM - V	Gouda	DWS	1971	164 122	-33.348227, 19.025529
DM - N	Viljoen Pass, Grabouw	DWS			-34.088388, 19.055267
RV - D	Table View	DWS			-33.881756 , 18.489722
RV - E	Eerste River	DWS			-34.043593 , 18.738042
RV - S	Raapeneberg Depot	DWS			-33.935677 , 18.481618

3.3 SAMPLE COLLECTION METHODS

Grab and passive sampling were the chosen sampling methods (Figure 3-5).

Figure 3-5: Grab sampling and passive sampler.

3.3.1 Grab sampling

Water samples were collected at the same spot, time of day, and months. The physicochemical parameters of the water samples which may influence the results, were also measured at room temperature and recorded using a physicochemical multimeter. PFAS samples need to be measured at environmentally relevant concentrations (ng/L), hence the sampling, laboratory and analytical components need to be cleaned thoroughly. PFAS can be absorbed from the analyte to the glass surface when using glass containers for sampling, and from the fluoropolymer surface to analyte when using fluoropolymer containers. Hence, it is best to avoid using glass and fluoropolymer containers for sampling. High-density polyethylene (HDPE) bottles were used for grab sampling, as shown in Figure 3-5. All sampling equipment and containers were first cleaned using tap water, followed by triple rinsing with ultra-pure water and finally washing with methanol. To minimise sample contamination, sampling bottles were pre-rinsed with analytical grade methanol and thereafter rinsed with Milli-Q water. Samples were then transported to the laboratory, physiochemical parameters were measured, and the samples were stored in the fridge at -20 ºC until processing.

3.3.2 Passive sampling

3.3.2.1 Procedure

Passive sampling was carried out using passive samplers at suspected hotspots in wastewater treatment plants. Pre-cleaned Polar Organic Chemical Integrated Sampler (POCIS) containing an Oasis hydrophilic-lipophilic balance (HLB) purchased from EST – Environmental Sampling Technologies (USA) was used in this study as shown in Figure 3-6. Before field deployment, the sampling rates were determined in the laboratory in a tap water-filled 50-L aquarium under dark conditions at 20.5±2°C. The calibration study was conducted according to Gobelius et al. (2019) with minor modifications over 14

days in the laboratory using a modified flow-through system consisting of a test and reservoir 20-L glass tanks. Both tanks were wrapped in aluminium foil and a black lid to prevent UV light penetration.

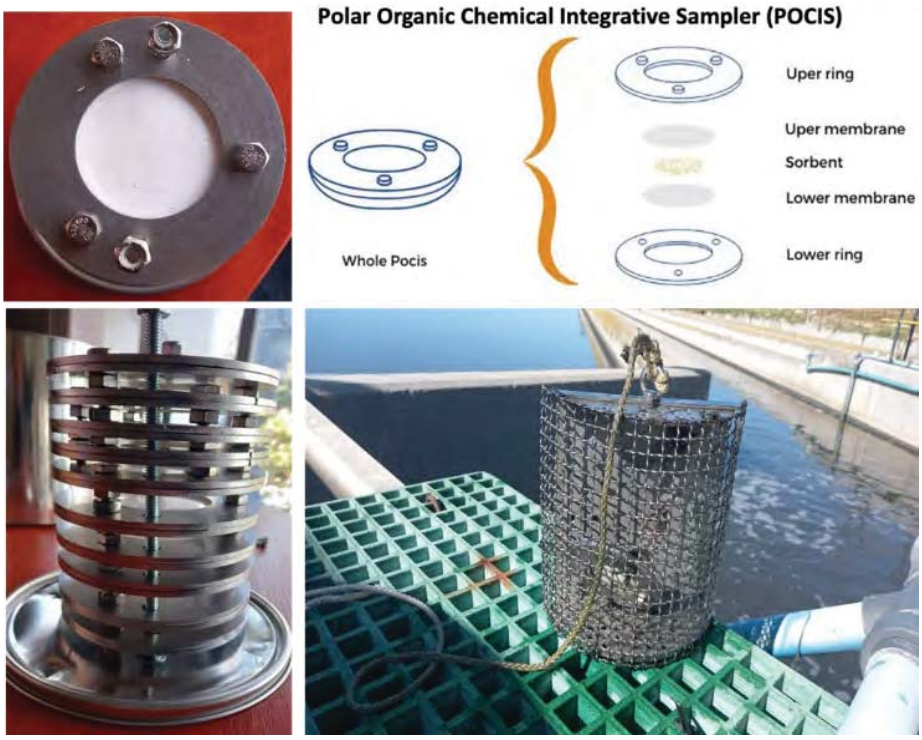

Figure 3-6: Passive sampler and passive sampler canister

The two glass tanks were fitted with two air pumps to ensure uniform distribution of PFAS and continuous circulation of the water body. The water temperature was controlled by maintaining the room temperature using air conditioning. Tap water in the test and reservoir tanks was spiked with 21 mixed PFAS at a concentration of 100 ng/L. Before starting the uptake experiment, the tank reservoir and tank passive samplers were left to equilibrate overnight to stabilise the sorption of PFAS onto the glass walls of the tanks. Every day, 3 L of the spiked water sample was removed from the test tank and replaced with the same volume from the reservoir on days 1, 7, and 14, using a peristaltic pump. Three POCIS-HLBs were placed in the test tank. The blank POCIS was exposed to the laboratory environment as a laboratory blank. All POCIS-HLB samples were vacuum-sealed in polypropylene bags and stored in a refrigerator (4°C) until analysis.

3.3.2.2 Field deployment of Passive Samplers

Passive samplers were deployed for 14 days in the influent and effluent of a wastewater treatment plant in Cape Town, South Africa. The passive samplers were retrieved on day 14. Grab samples were collected from the same point on the same day. Samples were stored inside a cooler box and in a refrigerator (4°C) until analysis. The process of accumulation in POCIS is essentially adsorption on the internal solid phase after the contaminants passively diffuse through the hydrophilic membrane. To assess the time-averaged ambient concentration of POCIS available contaminants, the POCIS was exposed during the linear-phase (phase I) regime, after which a calculation was made based on Equation 3-1:

$$C_{water} = C_{pocis} \cdot M_{pocis} / R_{s.t} \quad \text{(Equation 3-1)}$$

Where:
C_{water} = mean contaminant concentration (over the sampling period) in the ambient water (µg/L)
C_{pocis} = concentration in the POCIS (µg/g);
M_{pocis} = mass of adsorbent phase in the POCIS (g);
R_s = sampling rate (L/d), which corresponds to the volume of water purified per unit-of-time; and
t is the total exposure time (d).

The samples (Figure 3-7) were then transported to the laboratory in a cooler box with ice and refrigerated at -20°C. Figure 3-8 show a general schematic diagram of the process followed from water sample collection until the samples were analysed for PFAS in the lab. As part of the project, water samples were collected every six (6) months during the dry and wet seasons. This enabled the monitoring of the differences in PFAS concentrations during the two seasons of the study period.

Figure 3-7: Water samples from different water sampling sites.

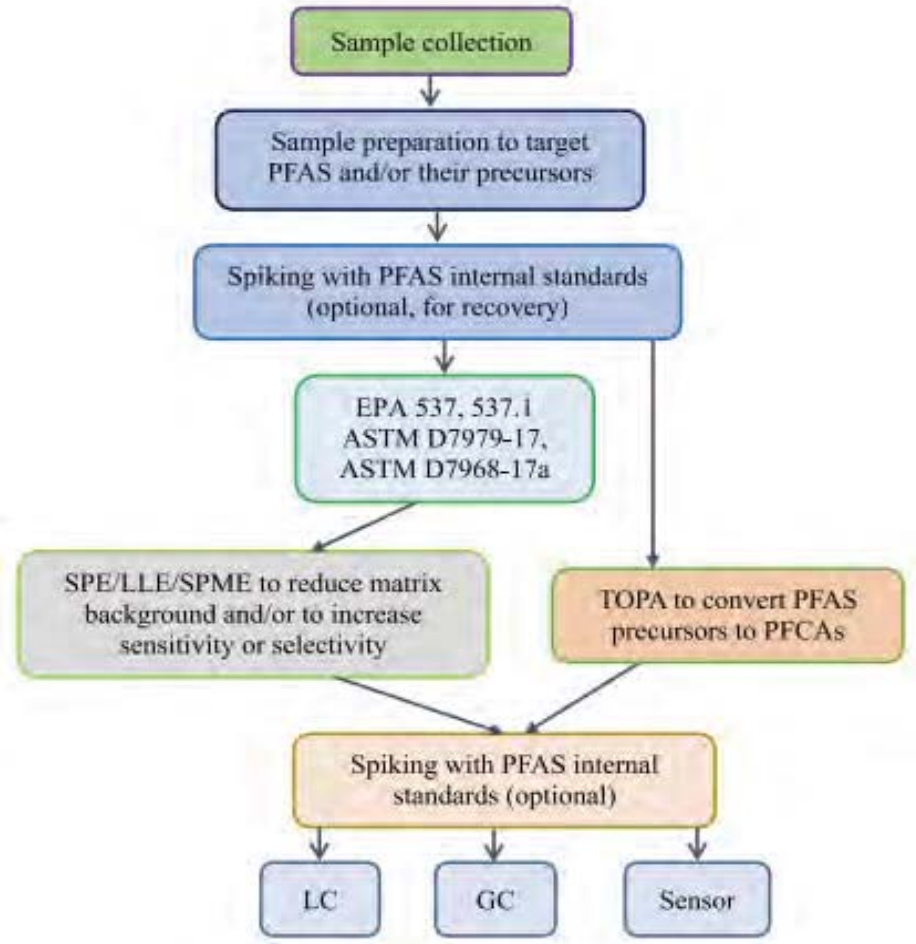

Figure 3-8: Schematic of the general procedure for PFAS analysis (Al Amin et al., 2020).

4 METHOD DEVELOPMENT AND SAMPLE ANALYSIS

4.1 INTRODUCTION

The design for monitoring the occurrence of toxic substances, such as PFAS, is particularly complex. Consequently, efforts are being made to devise a cost-effective means of monitoring such toxicants. Theoretically, there are several congeners and PFAS precursors of PFAS. Generally, analytical method development involves the use of analyte standards to determine the response of the analytical instrument to analyte standards. In this study, the analytical method was developed using PFAS standards for both calibration and multiple reaction monitoring. Water samples from the Gauteng Province were used for this exercise. Pretreatment and extraction methods need to be optimised, as they have a great impact on the determination of per- and polyfluorinated alkyl substances in different matrices. Depending on the type of sample, centrifugation and filtration methods are applied as pretreatment methods to minimise blockage in the subsequent extraction process and in the instrument.

Two sampling methods were employed in this study.

1. Grab sampling – Samples were collected from seventeen (17) different water sites in the Western Cape province in three (3) major dams (DM), three (3) rivers (RV), five (5) drinking water treatment plants (DWTP) with raw and final samples collected in each plant) and six (6) wastewater treatment plants (WWTP) with influent and effluent samples collected in each plant. Water samples were collected from various water sources at each site in clean high-density polyethylene bottles. Once collected, the samples were stored on ice, transported to the laboratory, and prepared for analysis. An overall total of one hundred and sixty-eight samples were collected and analysed for PFAS over the 36 months period.
2. Passive sampling: With this method, a Polar Organic Chemical Integrated Sampler (POCIS) was used. The POCIS was deployed in two wastewater treatment plants for two weeks (in the influent and effluent), and POCIS was extracted after 14 days. Grab samples were also collected from the same location where the POCIS was deployed.

4.2 SAMPLE EXTRACTION

4.2.1 Grab sample water samples

Prior to extraction, 100 µL of spiking surrogate (MPFNA) was added to 250 mL of all water samples (Figure 4-1), including the blanks, before passing them through SPE. For wastewater, samples were first filtered using a 0.45 µm glass fibre filter on a vacuum filtration unit before SPE extraction to remove suspended matter (Figures 4-2), which would otherwise block the cartridges. SPE SupelcoTM Envi18 cartridges were used for PFAS extraction. The cartridges were first conditioned with 5 mL of ultra-pure water, followed by 5 mL of LC-grade methanol. Without allowing the cartridges to dry, the samples were passed through the cartridges at a vacuum flow rate of 10-15 mL/min. The cartridges were then dried under vacuum for an hour (Figure 4-3). During elution, analytes were eluted from the cartridge by running 10.00 ml of methanol through the cartridges. The solvent was allowed to exit the cartridge under gravity. The solvent extract was concentrated under a gentle stream of nitrogen (Figure 4-4). After the addition of 1 mL of methanol to a 2 mL centrifuge tubes, the extract was centrifuged for 5 min. A 950 µL aliquot of the extract and 50.00 µL of the internal standard were added to an autosampler vial. A 10.00 µL sample was then injected into the LC-MS/MS for PFAS analysis.

Figure 4-1: Spiked Water samples before SPE process.

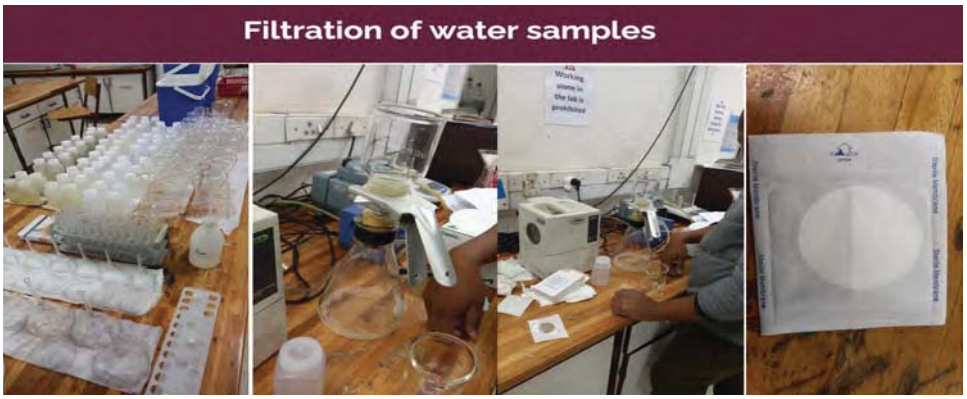

Figure 4-2: Filtration process of water samples.

Figure 4-3: Solid Phase Extraction of PFAS from water samples under vacuum.

Figure 4-4: Sample elution under the force of gravity, sample concentration under nitrogen, sample shaking and centrifuging.

4.2.2 Extraction of PFAS from POCIS

After deployment, passive samplers were retrieved for laboratory analysis. PFAS adsorbed on POCIS-HLB retrieved from the laboratory and field setup were extracted using a 6 mL SPE cartridge (Figure 4-5), which was fitted with polyethylene frits at the bottom. The HLB sorbent was transferred from the POCIS into cartridges through a glass funnel and rinsed with ultrapure water. Excess water was removed under vacuum for approximately 30 min, and another frit was placed on top of the sorbent. The cartridge was spiked with 100 µL of surrogate standard mixture. The HLB sorbent was eluted using methanol (10 mL). The eluent was collected in 50 mL polypropylene tubes (Figure 4-6). The POCIS-HLB field blanks were subjected to the same extraction procedure. The samples were concentrated under gentle nitrogen flow at room temperature, and 950 µL of the sample was transferred into 1 mL LC glass vials and spiked with 50 µL of the internal standard (Figure 4-6). The samples were then analysed using liquid chromatography-tandem mass spectrometry (LC-MS/MS) (Figure 4-6).

Figure 4-5: Passive sampling canisters at sampling site

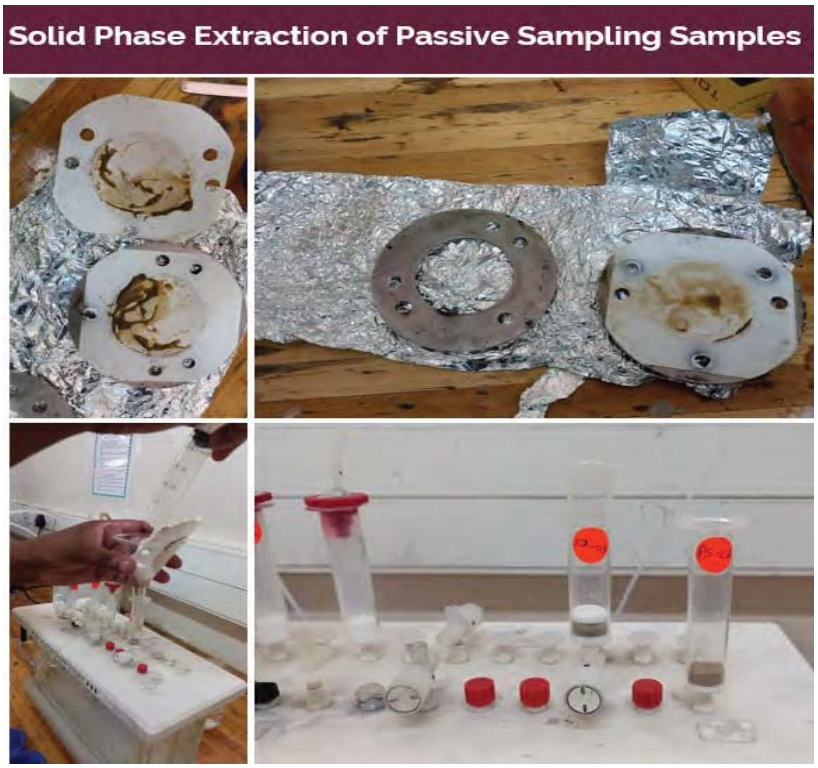

Figure 4-6: Solid Phase Extraction (SPE) of samples from passive sampling.

4.3 METHOD DEVELOPMENT

4.3.1 PFAS Compounds and labelled PFAS internal standards

The PFAS standards in methanol Tables 4-1 to 4-3 were purchased from Wellington Laboratories (Ontario, Canada). LC-MS-MS grade water, methanol, acetonitrile, and ammonium acetate were purchased from Sigma-Aldrich (Aston Manor, South Africa). Supelco ENVI-18™ SPE cartridges (500 mg, 6 mL) were purchased from Sigma-Aldrich (Aston Manor, South Africa).

Table 4-1: PFAS standards (internal and surrogate standards) used in this project for analysis.

Name of compound	Acronym
MPFHxA_13C2	MPFHxA_13C2
MPFNA_13C5	MPFNA_13C5
MPFDA_13C2	MPFDA_13C2
Perfluoro-n-butanoic acid	PFBA
Perfluoro-n-pentanoic acid	PFPeA
Perfluoro-n-hexanoic acid	PFHxA
Perfluoro-n-heptanoic acid	PFHpA
Perfluoro-n-octanoic acid	PFOA
Perfluoro-n-nonanoic acid	PFNA
Perfluoro-n-undecanoic acid	PFUdA

Perfluoro-n-dodecanoic acid	PFDoA
Perfluoro-hexadecanoic acid	PFHxDA
Perfluoro-octadecanoic acid	PFODA
Potassium perfluoro-1-butanesulfonate	L-PFBS
Sodium perfluoro-1-hexanesulfonate	L-PFHxS
Sodium perfluoro-1-octanesulfonate	L-PFOS
Sodium perfluoro-1-decanesulfonate	L-PFDS
Sodium perfluoro-1-heptanesulfonate	L-PFHpS
2-Perfluorohexyl ethanoic acid	FHEA
8:2 Fluorotelomer alcohol	FOET
6:2 Fluorotelomer Alcohol	FHET
8:2 Fluorotelomer sulfonate	4:2FTS
8:2 Fluorotelomer sulfonate	6:2FTS
8:2 Fluorotelomer sulfonate	8:2FTS

Table 4-2: Labelled PFAS internal standards

NAME OF COMPOUND	ACRONYM
perfluoro-n-[1,2-^{13}C2] octanoic acid perfluoro-n-[1,2-^{13}C2] decanoic acid perfluoro-n-[1,2-^{13}C2] hexanoic acid	M2PFOA MPFDA MPFHxA

Table 4-3: Surrogate standards

NAME OF COMPOUND	ACRONYM
perfluoro-n- [1,2,3,4, 5-$^{13}C_5$] nonanoic acid	MPFNA

4.3.2 Calibration curve standards preparations

Calibration curves were prepared by diluting a stock solution of 2,000 ng/mL PFAS mixture in methanol. A 10-point calibration curve was constructed with a range of 0.1-2000 ng/L for all PFAS analytes. Calibration curve for PFUdA, PFDoA, PFHxA, PFNA, PFPeA, PFBA, MPFNA, 4:2 FTS, 6:2 FTS, 8:2 FTS, FHET, FHEA and FOET ranged from 1-1000 ng/L, while that of L-PFBS, L-PFOS, PFOA, L-PFHpS, and L-PFHxS ranged from 100-1000 ng/L and that of MPFUdA, MPFHxS, L-PFDS, PFODA and PFHxDA ranged from 100-2000 ng/L. The Limit of Detection (LOD) was set as the instrument detection limit, which was different for each compound. LOD and LOQ were calculated from formulas 3σ and 10σ of the response/slope of the calibration curve, respectively.

4.3.3 Instrumental quantification

Ten microlitres (10 µL) of the standards were injected and analysed using liquid chromatography tandem mass spectrometry (Shimadzu LC-MS 8030 triple quadrupole system, Tokyo, Japan). The instrument was equipped with an electrospray ionisation (ESI) source, and the target compounds were separated on an Inert Sustain C18 (3µm, 2.1 i.d. x 150 mm) HPLC column (Tokyo, Japan). The instrument conditions for the target PFAS analysis on the LC-MS-8030 triple quadrupole system is shown in Tables 4.4, and the non-target PFAS identification using TripleTOF 6600 and SCIEX in Table 4-5. The quantitation of the target compounds was based on the internal standard method calibration with concentrations ranging from 1.0-1000 ng/L. An R^2=0.99 was achieved in all calibrations with good precision of the internal standard. Each method was then applied to the spiked water samples.

Table 4-4: Instrument conditions for PFAS analysis on LC-MS-8030 triple quadrupole system

LC-MS/MS instrument	Shimadzu, LCMS-8030
Analytical column	Kinetex® 2.6 µm XB-C18 100 Å, LC Column 50 x 4.6 mm
Column temperature	40 °C
Injection volume	10.00 µL
Flow rate	0.3000 mL/min
Mobile Phases	A. 20 mM Ammonium Acetate: B. 50:50 Methanol: Acetonitrile
Gradient conditions	**Time (min)** / **% Mobile phase B** 1 / 20 4 / 90 7 / 20 12 / 0
Acquisition time	12 min

Table 4-5: Instrument conditions for non-target PFAS identification on TOF-MSW

Instrument name	TripleTOF 6600, SCIEX
Analytical column	Luna Omega 3 µm polar C18 100Å LC column 100 x 2.1 mm, Phenomenex
Column temperature	40 °C
Injection volume	10.00 µL
Flow rate	0.5000 mL/min
Mobile Phases	A. 2 mM Ammonium Acetate, 0.1% Formic Acid : B. 100% Methanol
Gradient conditions	**Time (min)** / **% Mobile phase B** 1 / 5.0 16 / 95 20 / 5.0 26 / 0
Acquisition	Information Dependent Acquisition
Acquisition time	26 min

Emerging and legacy PFAS were identified using non-targeted analysis (Figure 4-7).

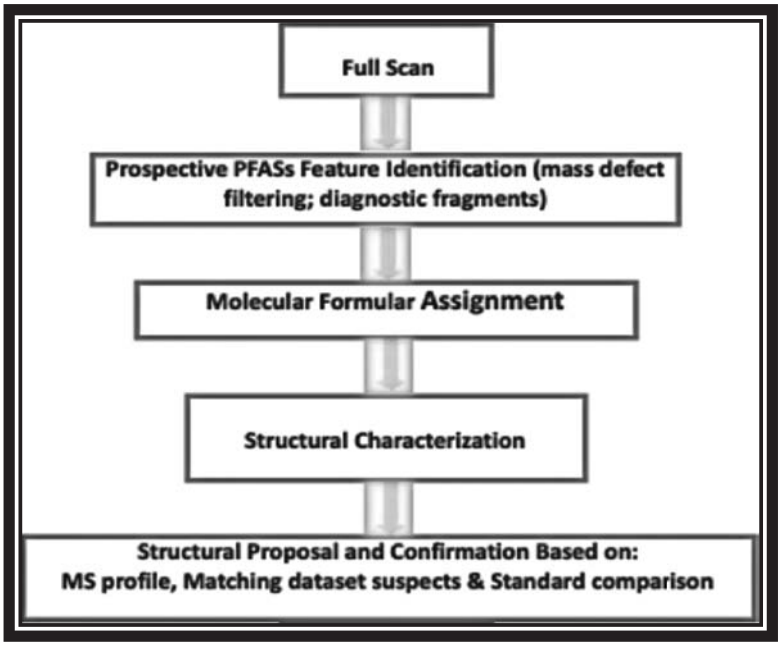

Figure 4-7: General schematic workflow for non-target PFAS by TOF-MS.

4.3.4 Method optimisation

When this method was developed, Multiple Reaction Monitoring (MRM) transitions were optimised using Flow Injection Analysis (FIA) for all compounds, bypassing the analytical column. A high concentration standard of 1000 ng/L containing a mixture of all PFAS compounds was used to optimise the MRM conditions. The mixture was then run under optimised LC-MS/MS conditions to determine the retention times of each analyte. A total of four methods, Table 4-6 below, were developed for the analysis of 21 PFAS compounds, namely:

- **Method 1** – for screening ten (10) carboxylic acids compounds
- **Method 2** - for screening six (6) sulfonates compounds
- **Method 3** – for screening four (4) telomers compounds
- **Method 4** – for screening ONE (1) Perfluoro-n-butanoic acid (PFBA)

Table 4-6: Methods 1 – 4: Instrument conditions for PFAS analysis on LC-MS-8030 triple quadrupole system

Method 1

LC-MS/MS instrument	Shimadzu, LCMS-8030
Analytical column	Kinetex® 2.6 µm Polar C18 100 Å, LC Column 100 x 2.1 mm
Column temperature	40 °C
Injection volume	10.00 µL
Flow rate	0.3000 mL/min
Mobile Phases	A. 10 mM Ammonium Formate B. 20:80 Methanol: Acetonitrile
Gradient conditions	

Time (min)	% Mobile phase B
1	45
3	50
4	60
4.5	70
5	65
5.5	68
6	80
7.5	70
10	0
16	Stop

Acquisition time	20 min

Method 2

LC-MS/MS instrument	Shimadzu, LCMS-8030
Analytical column	Kinetex® 2.6 µm Polar C18 100 Å, LC Column 100 x 2.1 mm
Column temperature	40 °C
Injection volume	10.00 µL
Flow rate	0.3000 mL/min
Mobile Phases	A. 10 mM Ammonium Formate B. 50:50 Methanol: Acetonitrile
Gradient conditions	

Time (min)	% Mobile phase B
1	
4	20
6.5	55
7	75
7.2	95
9	0
10	20
12	Stop

Acquisition time	12 min

Method 3

LC-MS/MS instrument	Shimadzu, LCMS-8030
Analytical column	Kinetex® 2.6 µm Polar C18 100 Å, LC Column 100 x 2.1 mm
Column temperature	40 °C
Injection volume	10.00 µL
Flow rate	0.3000 mL/min
Mobile Phases	A. 20 mM Ammonium Acetate B. 95:5 Methanol: Water
Gradient conditions	

Time (min)	% Mobile phase B
1	20
2	75
3	85
4	70
6	95
7.5	100
10	90
16	Stop

Acquisition time	16 min

Method 4

LC-MS/MS instrument	Shimadzu, LCMS-8030
Analytical column	Kinetex® 2.6 µm Polar C18 100 Å, LC Column 100 x 2.1 mm
Column temperature	40 °C
Injection volume	10.00 µL
Flow rate	0.3000 mL/min
Mobile Phases	A. 10 mM Ammonium Formate B. 20:80 Methanol: Acetonitrile
Gradient conditions	

Time (min)	% Mobile phase B
1	20
2	55
3.5	70
4	0
5	Stop

Acquisition time	10 min

4.3.5 Sample analysis

Figures 4-8 and 4-9 show the summarised version of the PFAS quantification workflow. The chromatographic conditions are listed in Table 4-6.

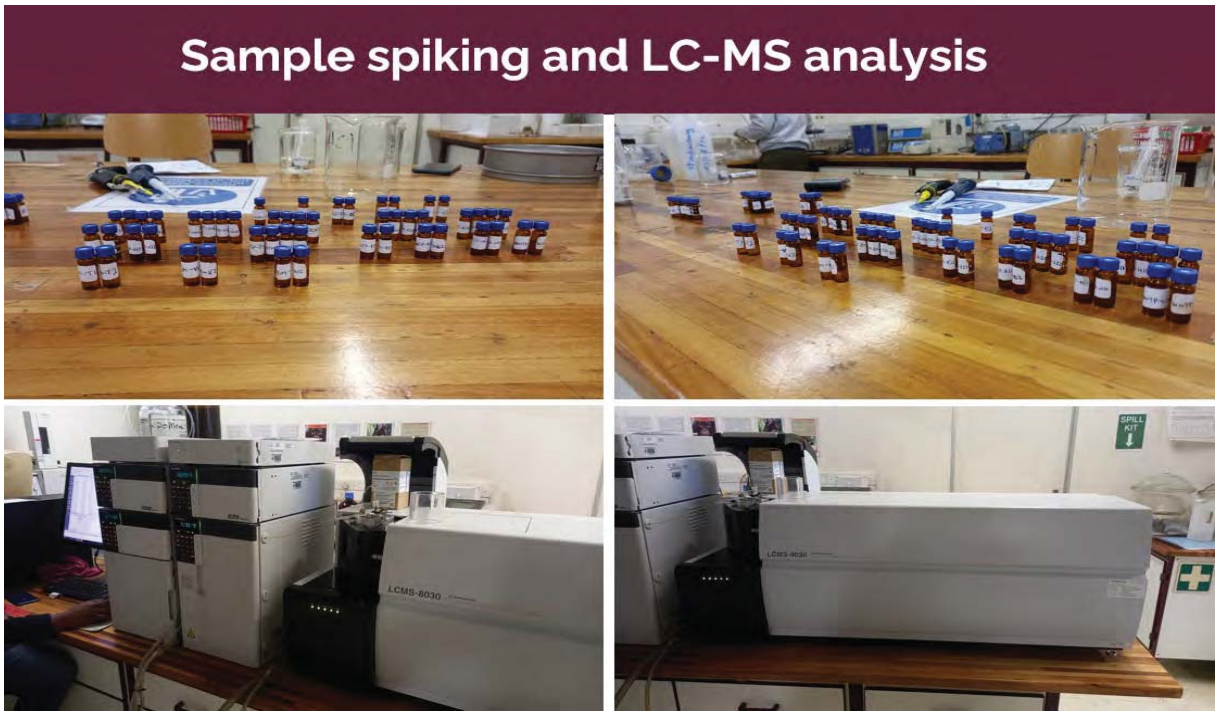

Figure 4-8: Sample vials ready for analysis run and LC-MS instrument.

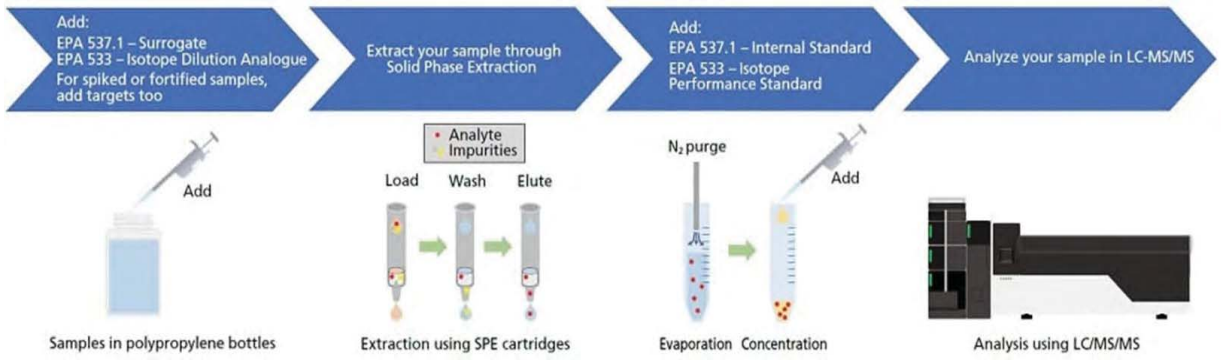

Figure 4-9: PFAS Quantification Workflow

These were used to analyse the extracted PFAS. The final concentrations of the samples were calculated using the following formula:
For water samples:

$$A_{nat}/A_{IS} \times 1/RRT \times M_{IS}/SS$$

where:
A_{nat} = area of surrogate standard A_{is} = area of internal standard
M_{IS} = mass of internal standard (ng)

The RRF is obtained when the ratio of the response for the unit amount of the contaminant of interest to the response of the IS.

RRF = slope or gradient in the calibration curves **SS** = sample size (mℓ)

and is expressed in equation below:

$$RRF = A_{NAT}/A_{IS} \times C_{IS}/C_{NAT}$$

where:

A_{NAT} is the peak area of the native ($^{13}C_2$) compound.

A_{IS} is the peak area of the internal standard in the standard.

C_{NAT} is the concentration of the native standard.

C_{IS} is the internal standard concentration.

4.3.6 Quality assurance

During sample preparation, sample blanks were prepared following the same procedure used for environmental samples to ensure that there was no contamination during sample preparation. During the analysis of the samples, solvent blanks (water and methanol) were analysed between samples after every tenth sample to avoid carryover, and a 100 ng/L standard was analysed after every 20th sample in the batch. The percentage relative standard deviation (%RSD) was calculated to determine the precision of the method. The water and blank samples were spiked with the surrogate standard and the recoveries of each sample were calculated.

4.4 RESULTS AND DISCUSSION

4.4.1 Instrument method development and optimization

The calibration curves and total ion chromatography (TIC) of the internal standards, surrogate and target compounds are shown in Figures 4-10 to 4-31.3. All isomers calibration curves showed linearity, based on correlation coefficients (r) and correlation of determination (r^2) that were greater than 0.99 with good precision of the internal standard.

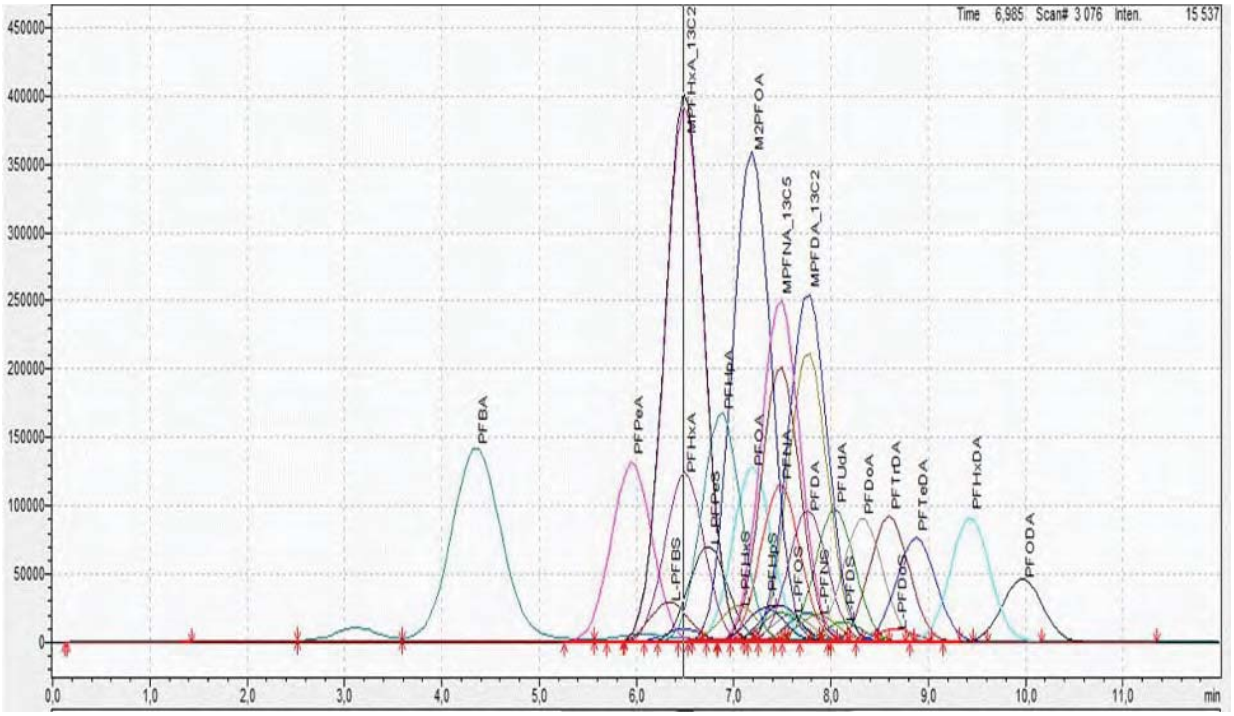

Figure 4-10: Chromatogram of overlaid peaks of mixed PFAS standard solution at 10 ng/mℓ.

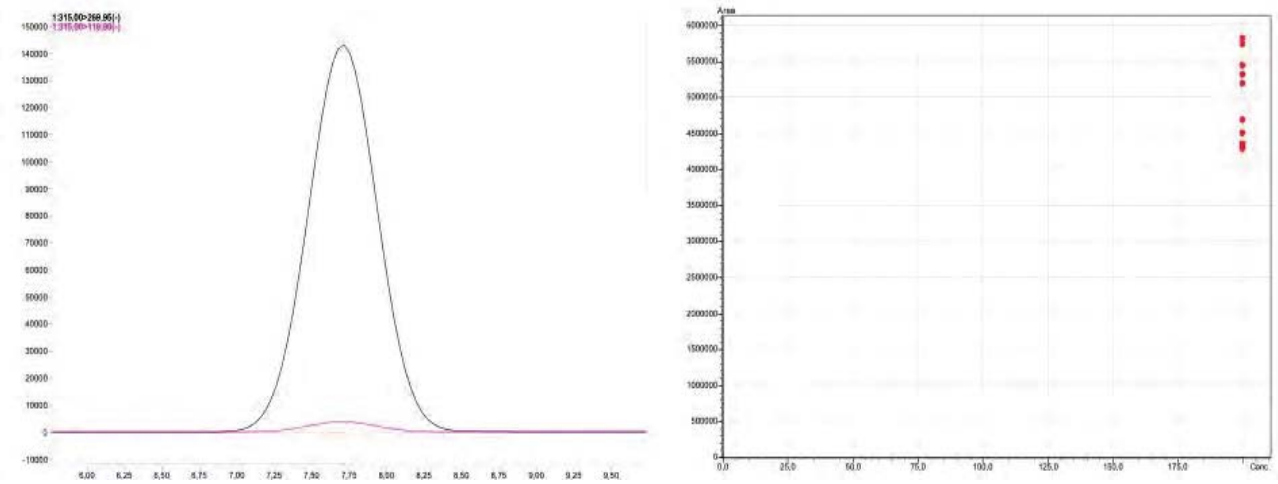

Figure 4-11: Perfluoro-n-[1,2-13C2] hexanoic acid (MPFHxA_13C2) calibration curve (right and TIC (left).

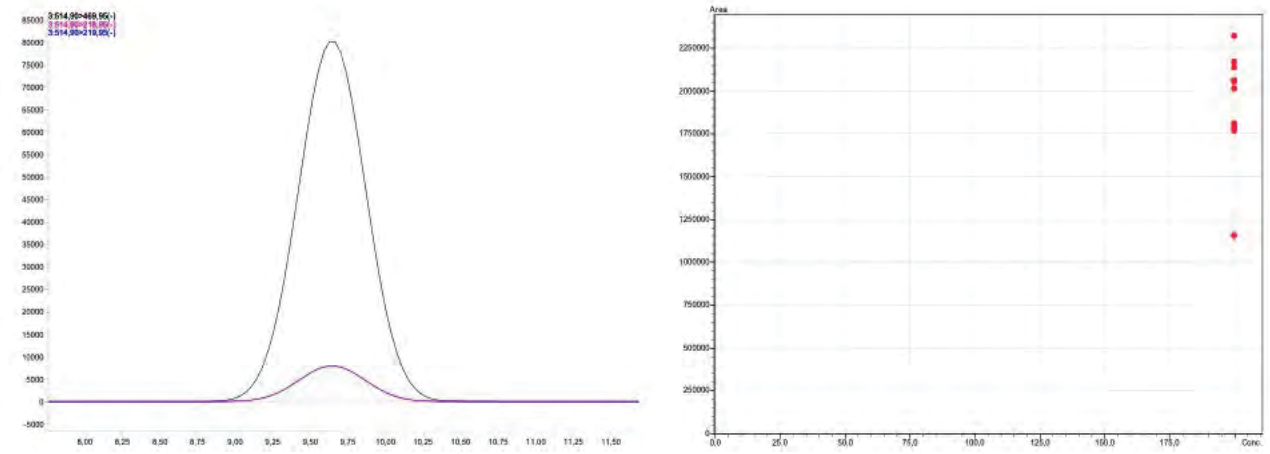

Figure 4-12: Perfluoro-n-[1,2-13C2] decanoic acid (MPFDA_13C2) calibration curve (left) and TIC (right).

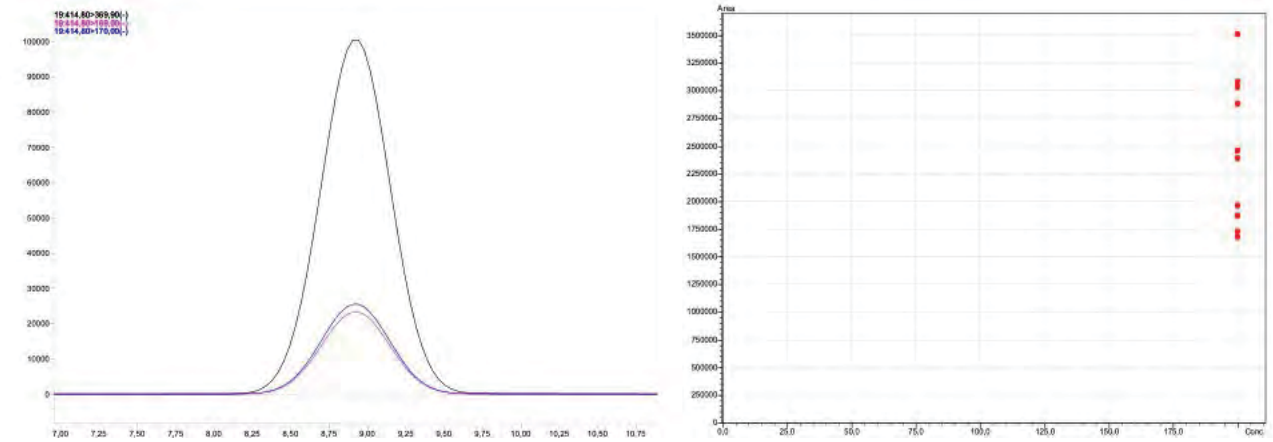

Figure 4-13: Perfluoro-n-[1,2-13C2] octanoic acid M2PFOA calibration curve (left) and TIC (right).

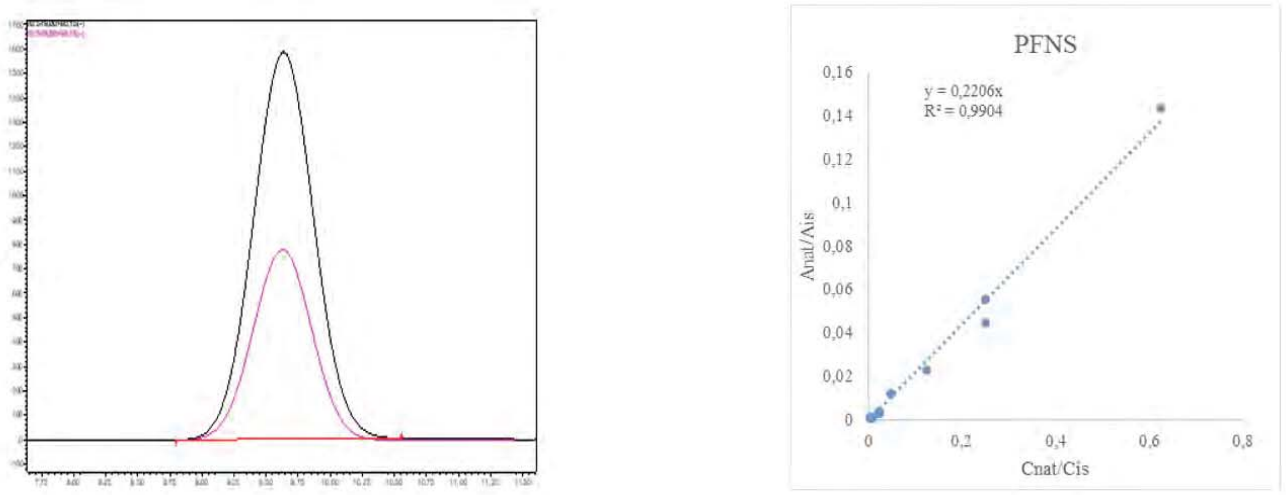

Figure 4-14: Perfluoro-n-nonanesulfonic acid (PFNS) with TIC (left) and calibration (right).

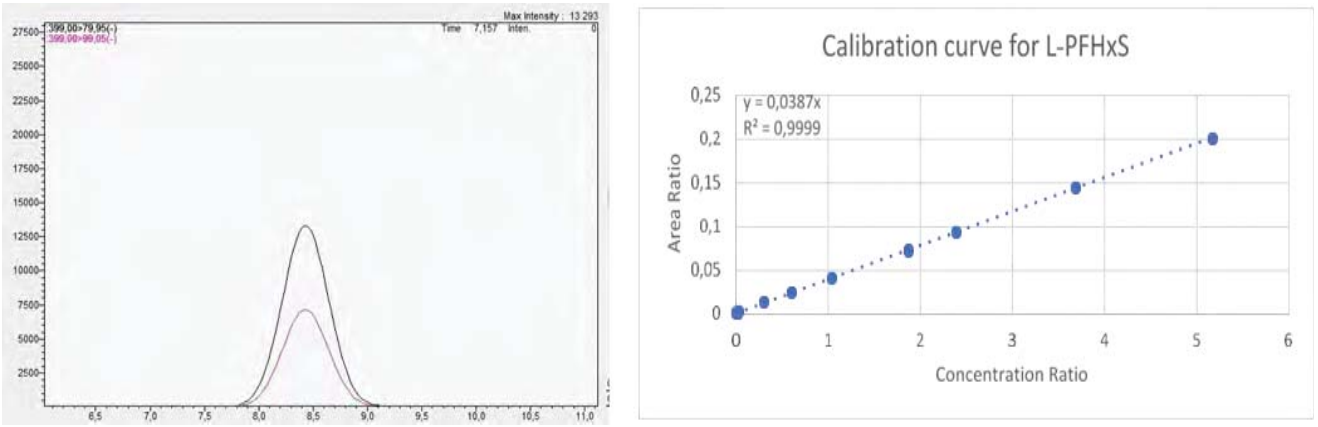

Figure 4-15: Total ion chromatogram (left) and calibration (right) for LPFHxS).

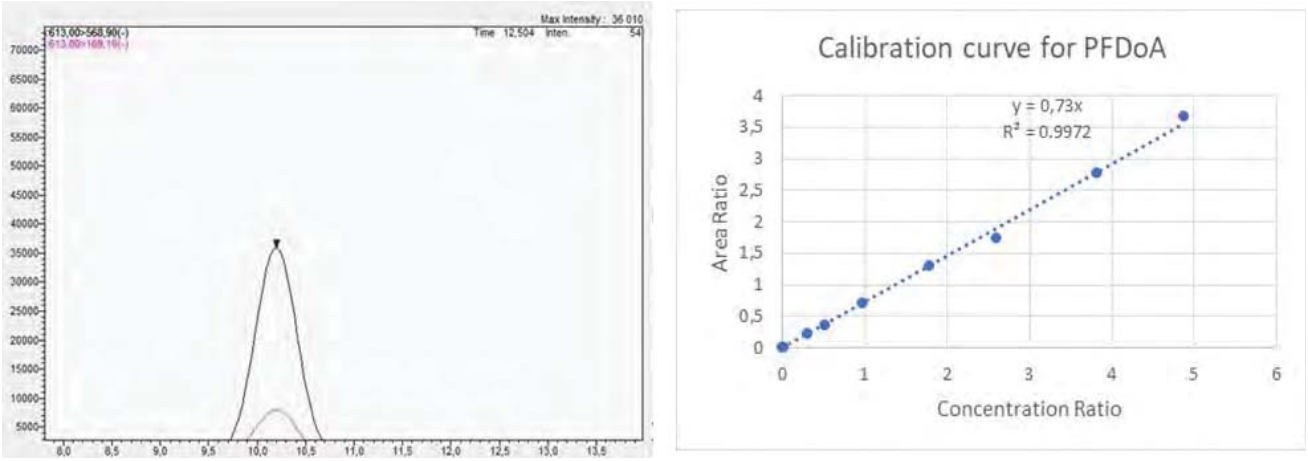

Figure 4-16: Total ion chromatogram (left) and calibration (right) for PFDoA.

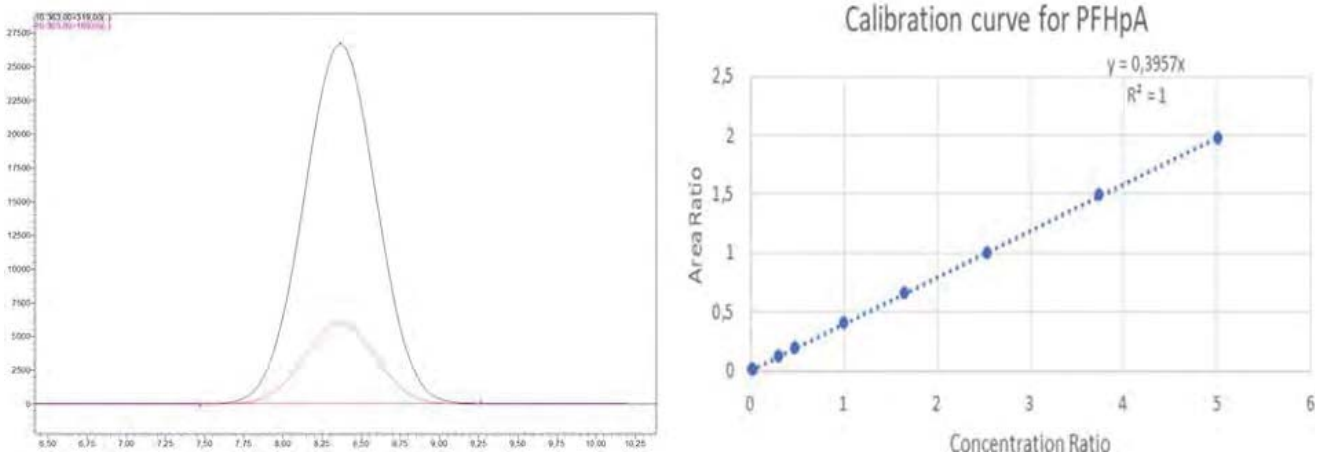

Figure 4-17: Total ion chromatogram (left) and calibration (right) for PFHpA.

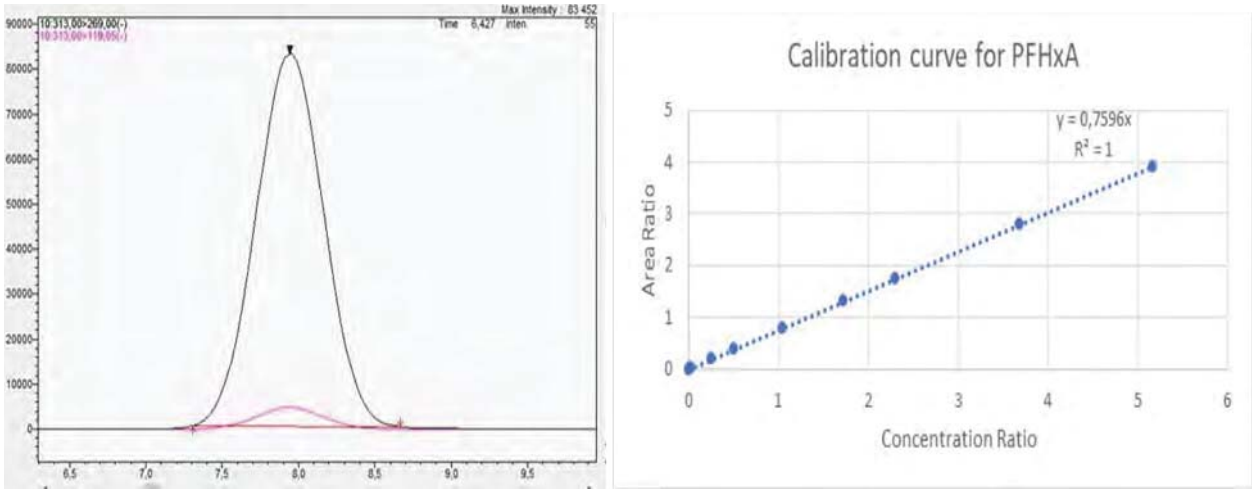

Figure 4-18: Total ion chromatogram (left) and calibration (right) for PFHxA.

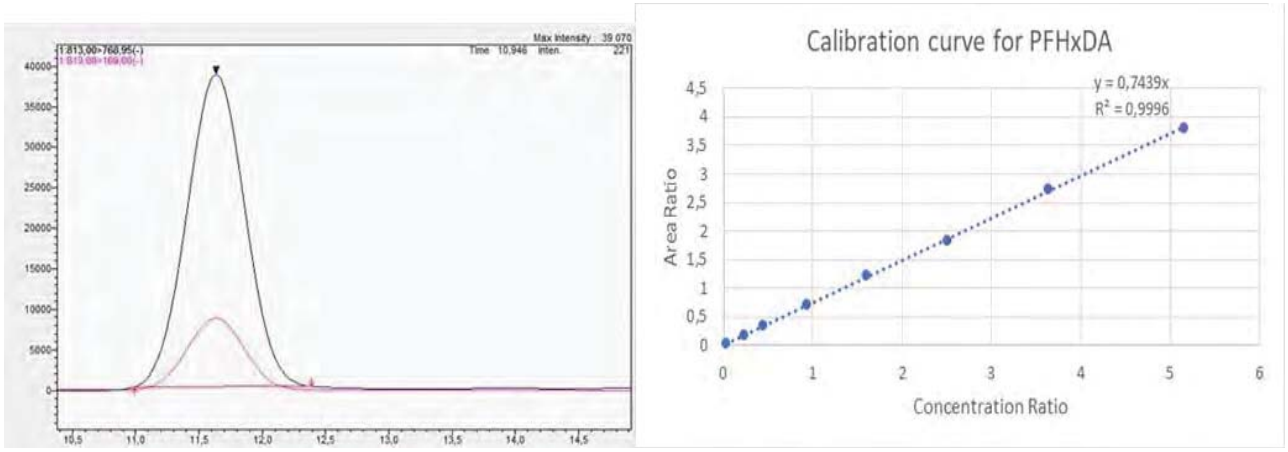

Figure 4-19: Total ion chromatogram (left) and calibration (right) for PFHxDA.

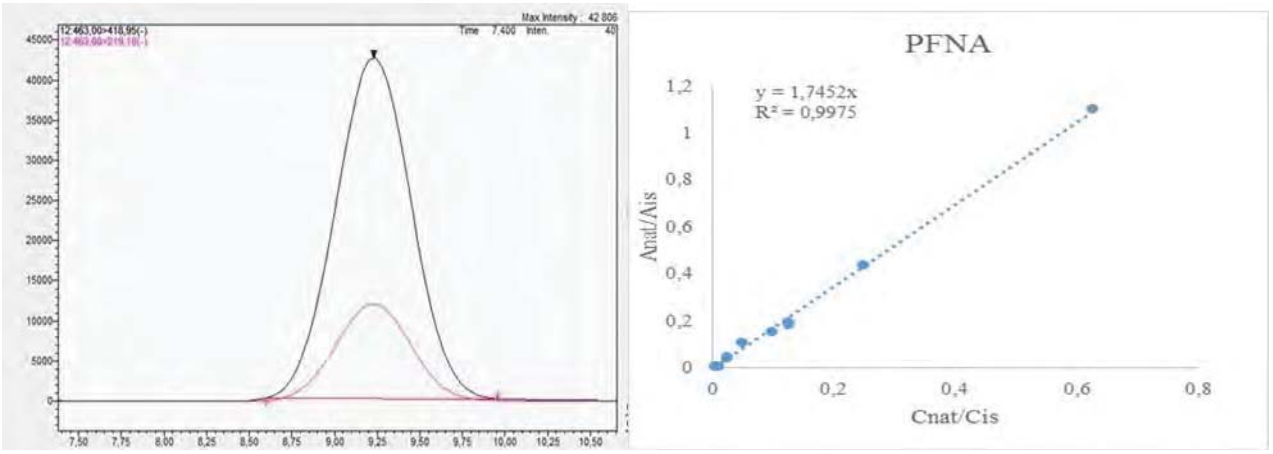

Figure 4-20: Total ion chromatogram (left) and calibration (right) for PFNA.

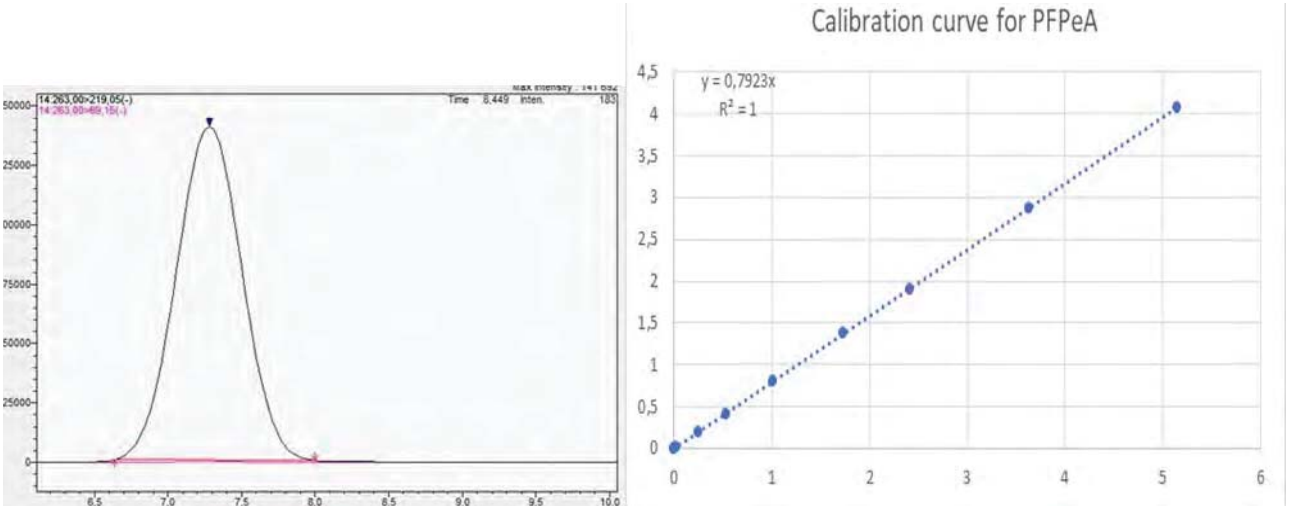

Figure 4-21: Total ion chromatogram (left) and calibration (right) for PFPeA.

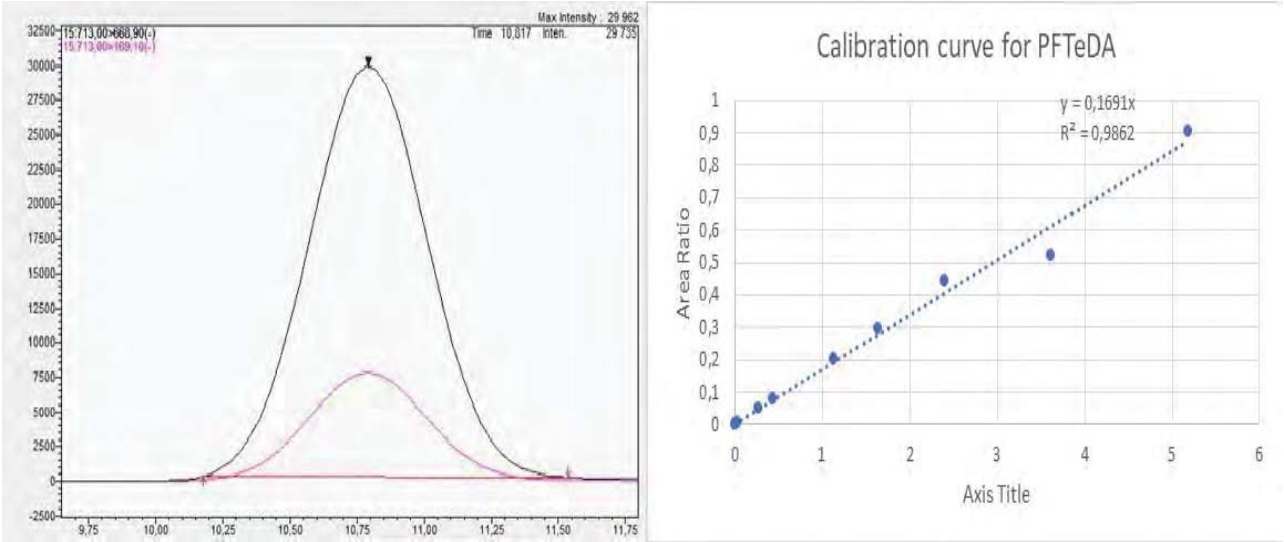

Figure 4-22: Total ion chromatogram (left) and calibration (right) for PFTeDA

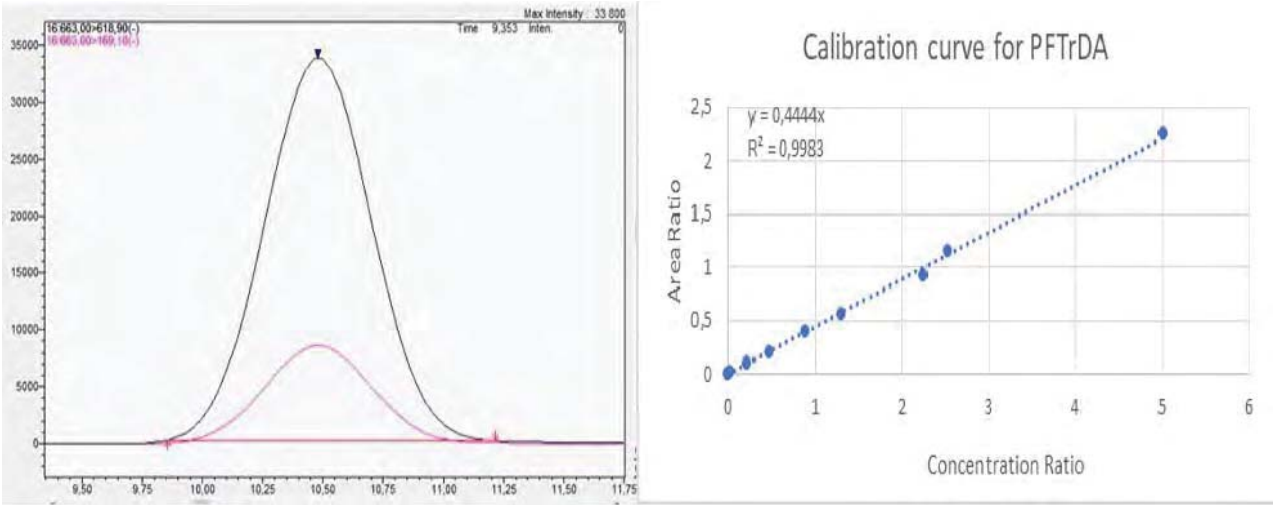

Figure 4-23: Total ion chromatogram (left) and calibration (right) for PFTrD.

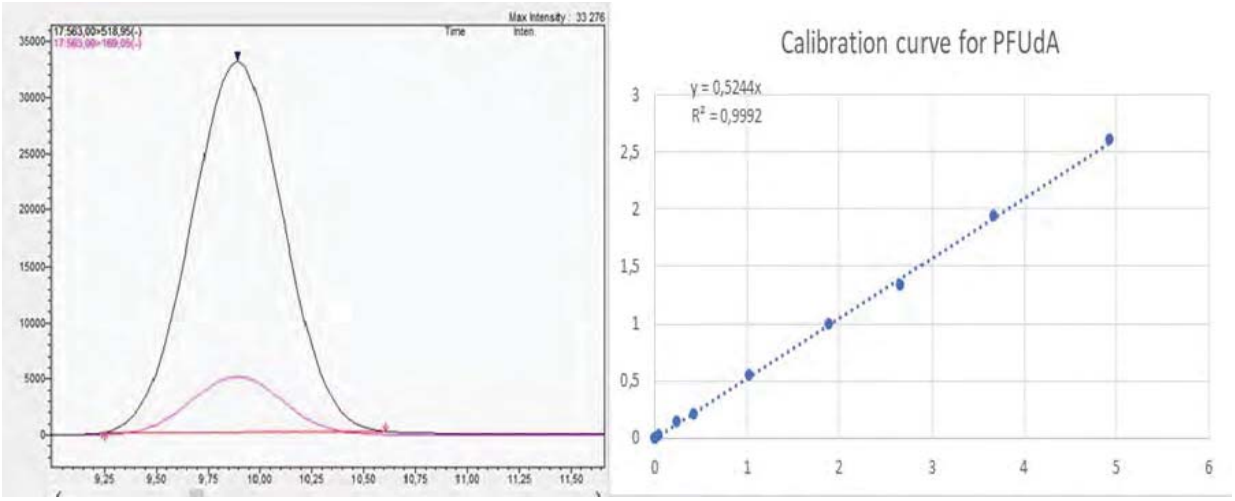

Figure 4-24: Total ion chromatogram (left) and calibration (right) for PFUdA.

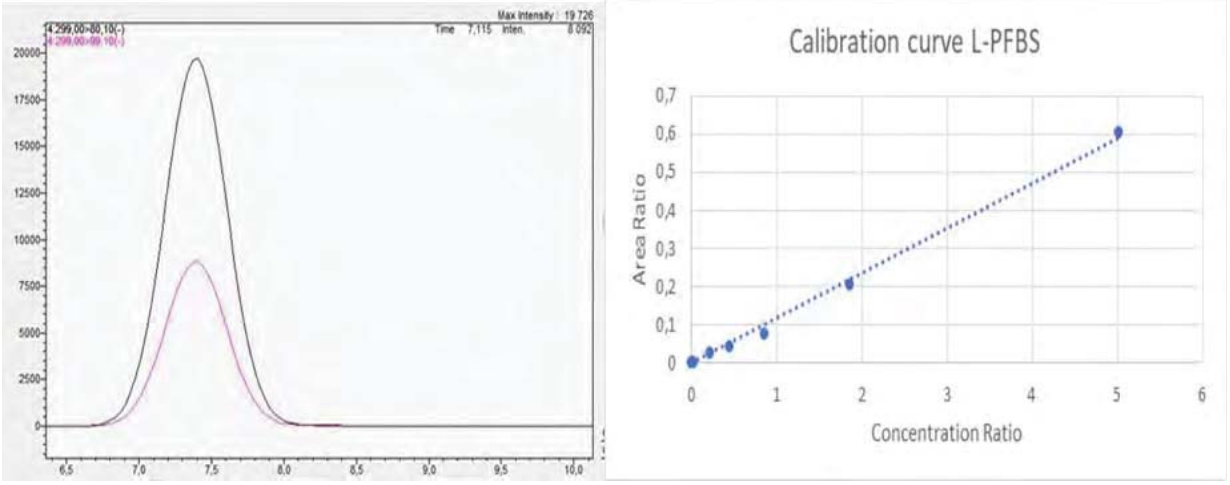

Figure 4-25: Total ion chromatogram (left) and calibration (right) for L-PFBS.

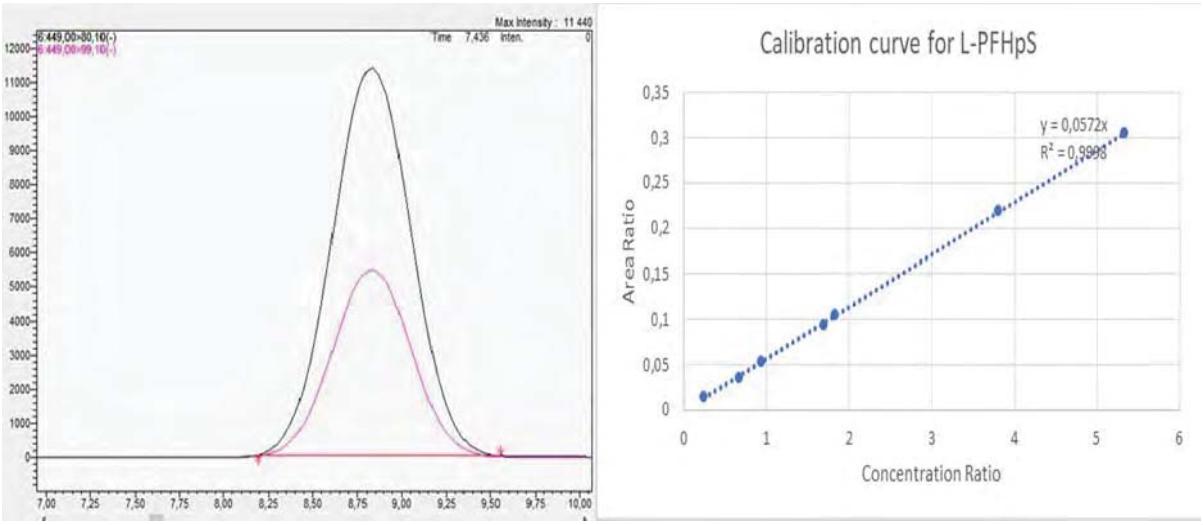

Figure 4-26: Total ion chromatogram (left) and calibration (right) for L-PFHpS.

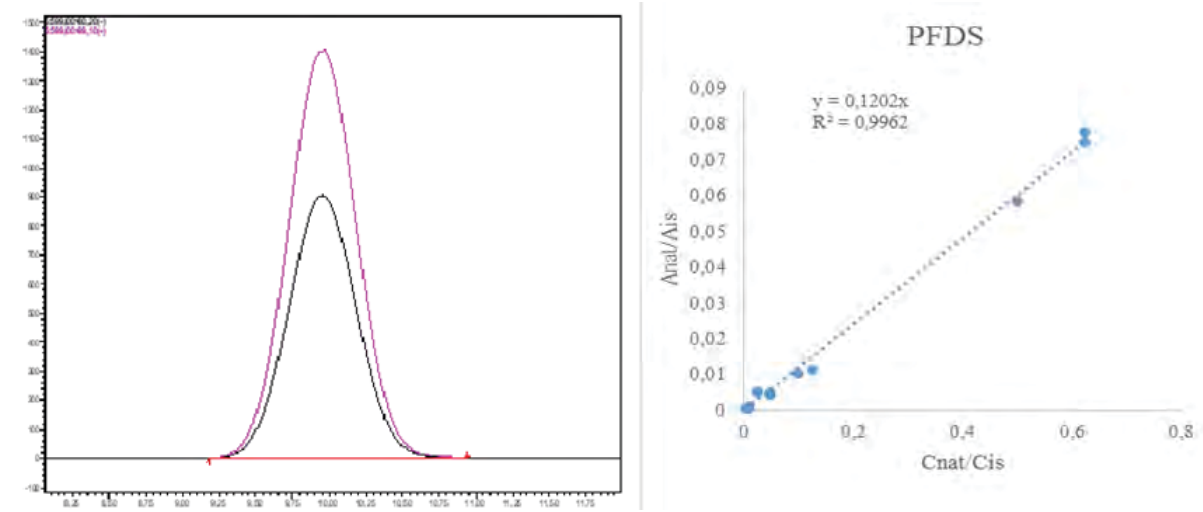

Figure 4-27: Total ion chromatogram (left) and calibration (right) for L-PFDS.

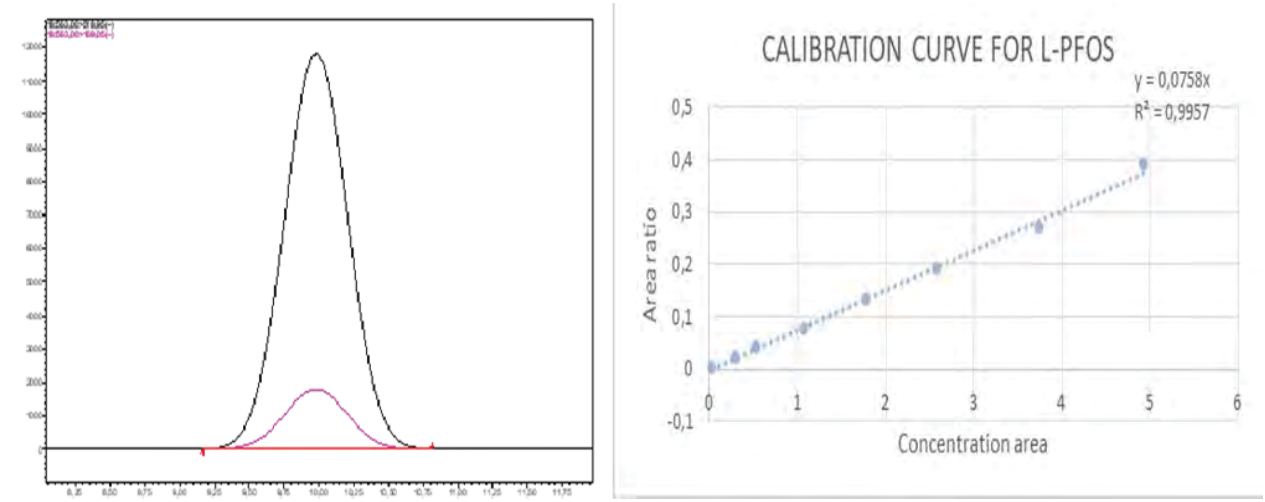

Figure 4-28: Total ion chromatogram (left) and calibration (right) for L-PFOS.

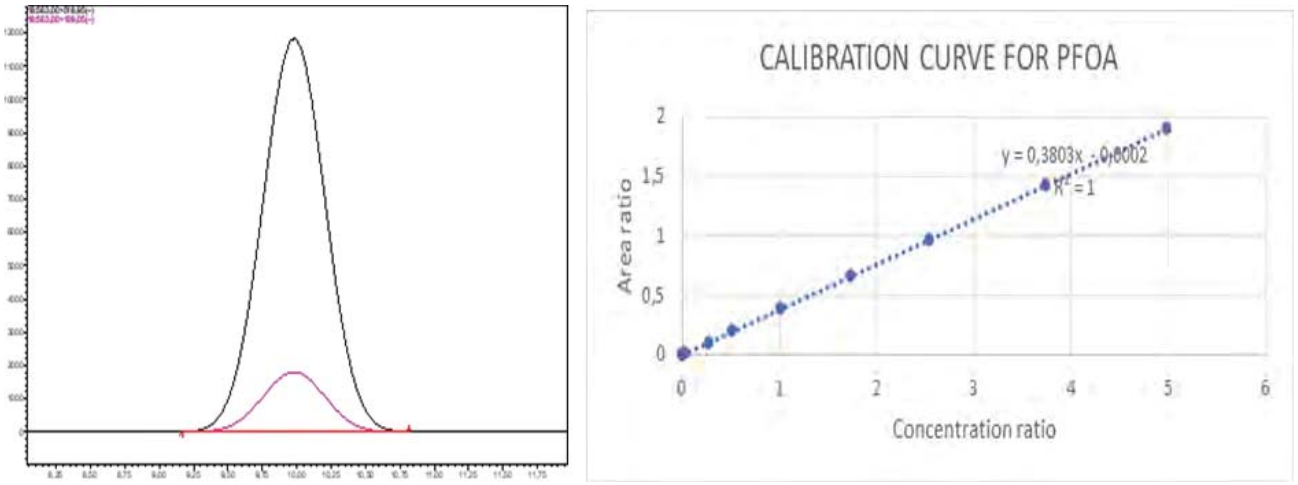

Figure 4-29: Total ion chromatogram (left) and calibration (right) for PFOA.

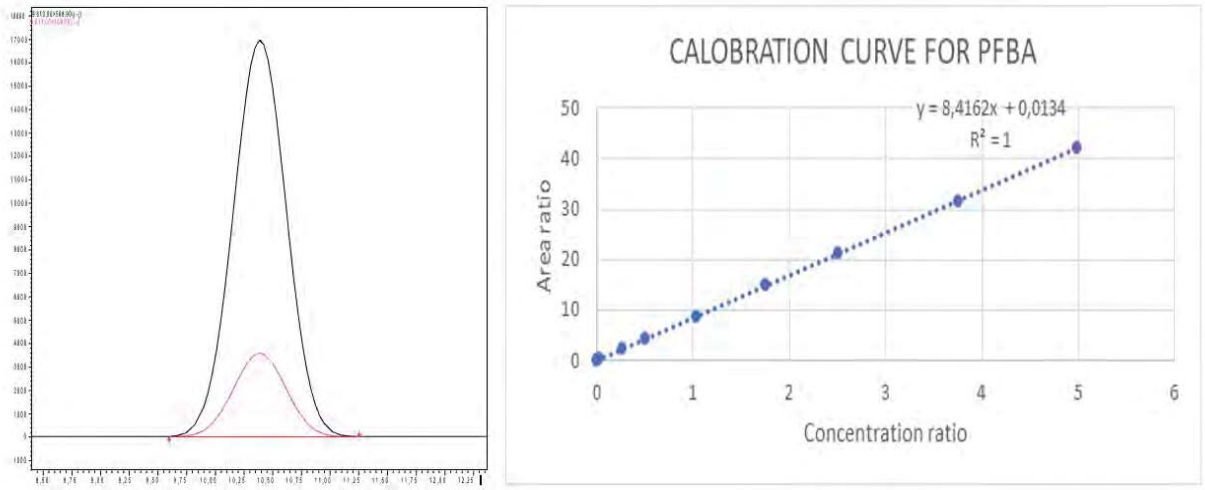

Figure 4-30: Total ion chromatogram (left) and calibration (right) for PFBA

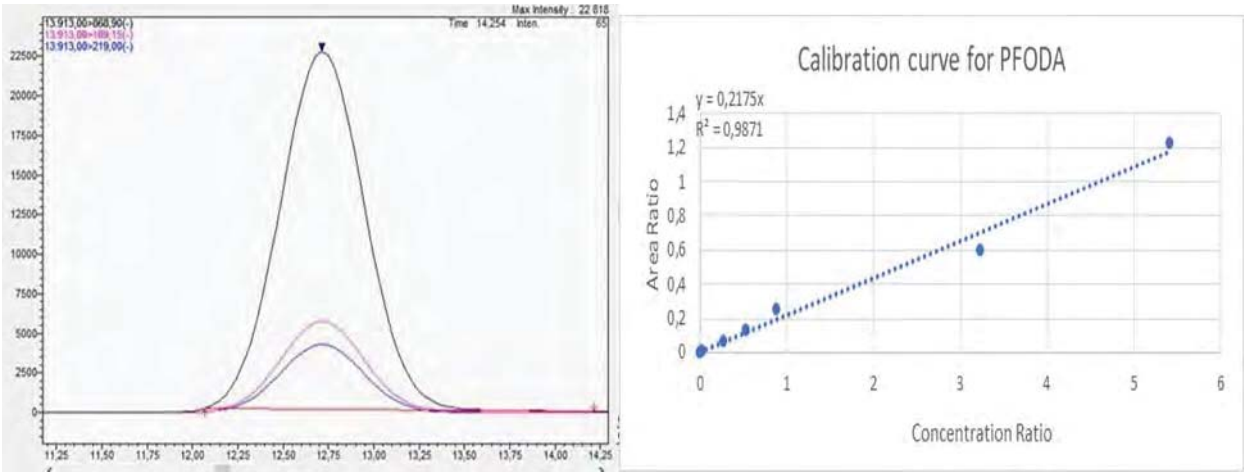

Figure 4-31: Total ion chromatogram (left) and calibration (right) for PFODA.

4.4.2 Multiple reaction monitoring (MRM)

During MRM selection, a full scan of the ions was performed. Ions corresponding to the compounds of interest were targeted, followed by fragmentation of the targeted ions, producing a range of daughter ions. The ions corresponding to the compounds of interest were selected and isolated from other ions within the mass spectrometer to quantify the method. The results of the multiple reaction monitoring are presented in Table 4-7.

Table 4-7: MRM of precursor and product ions.

Compound	Abbreviation	Precursor ion (m/z)	Product ion (m/z)	Retention time (min)
MPFHxA_13C2	MPFHxA_13C2	315.00	269.95	6.46
MPFNA_13C5	MPFNA_13C5	467.90	423.00	7.51
MPFDA_13C2	MPFDA_13C2	514.90	469.95	7.76
Perfluoro-n-butanoic acid	PFBA	213.00	169.05	4.15
Perfluoro-n-pentanoic acid	PFPeA	263.00	219.05	5.96
Perfluoro-n-hexanoic acid	PFHxA	313.00	269.00	6.49
Perfluoro-n-heptanoic acid	PFHpA	363.00	319.00	6.88
Perfluoro-n-octanoic acid	PFOA	413.00	368.95	7.186
Perfluoro-n-nonanoic acid	PFNA	463.00	418.95	7.50
Perfluoro-n-undecanoic acid	PFUdA	563.00	518.95	8.04
Perfluoro-n-dodecanoic acid	PFDoA	613.00	568.90	8.33
Perfluoro-hexadecanoic acid	PFHxDA	813.00	768.95	9.43
Perfluor-ooctadecanoic acid	PFODA	913.00	868.90	9.97
Potassium perfluoro-1-butanesulfonate	L-PFBS	299.00	80.10	6.34
Sodium perfluoro-1-hexanesulfonate	L-PFHxS	399.00	79.95	7.06
Sodium perfluoro-1-octanesulfonate	L-PFOS	499.00	80.15	7.60
Sodium perfluoro-1-decanesulfonate	L-PFDS	599.00	80.20	8.13
Sodium perfluoro-1-heptanesulfonate	L-PFHpS	449.00	80.10	7.34
2-Perfluorohexyl ethanoic acid	FHEA	376.90	292.90	5.053
8:2 Fluorotelomer alcohol	FOET	463.00	216.90	8.37
6:2 Fluorotelomer Alcohol	FHET	363.10	280.95	10.29
4:2 Fluorotelomer sulfonate	4:2FTS	327.00	307.00	8.12
6:2 Fluorotelomer sulfonate	6:2FTS	426.90	426.90	7.37
8:2 Fluorotelomer sulfonate	8:2FTS	526.90	507.05	14.94

4.4.3 Percentage recoveries of samples and blanks spiked with surrogate standards

The percentage recovery of the samples and blanks spiked with surrogate standards are shown in Tables 4-8 to 4-10. As shown in the Tables, the percentage recoveries of the labelled surrogate standards were in the range of 39–196%. It has been suggested that recoveries can and often have a wide range (50-200%) owing to matrix effects which can occur in water samples.

Table 4-10: % Recovery (Dams and Rivers)

Sample Name	MPFNA	MPFUnDA
DM-T1	147	122
DM-V1	136	76
DM-N1	141	70
RV-E1	139	132
RV-D1	188	88
RV-S1	138	77
DM-T2	187	93
DM-V2	132	113
DM-N2	146	112
RV-E2	156	110
RV-D2	170	115
RV-S2	135	85

Table 4-9: % Recovery (WWTP)

Sample Name	MPFNA	MPFUnDA
WWTP-Z11	39	150
WWTP-Z12	196	75
WWTP-V11	122	181
WWTP-V12	113	113
WWTP-Z21	49	65
WWTP-Z22	112	130
WWTP-V21	132	106
WWTP-V22	130	113
WWTP-C21	139	63
WWTP-C22	112	94
WWTP-A21	62	83
WWTP-A22	66	81
WWTP-P21	63	65
WWTP-P22	114	67
WWTP-M21	194	92
WWTP-M22	144	102
WWTP-S1	181	115

Table 4-8: % Recovery (WTP)

Sample Name	MPFNA	MPFUnDA
WTP-F11	91	90
WTP-F12	98	80
WTP-W11	101	87
WTP-W12	77	92
WTP-V11	72	112
WTP-V12	67	100
WTP-S11	119	80
WTP-S12	127	124
WTP-H11	95	103
WTP-H12	102	102
WTP-F21	125	134
WTP-F22	139	95
WTP-W21	101	96
WTP-W22	130	151
WTP-V21	147	120
WTP-V22	143	138
WTP-S21	123	124
WTP-S22	155	129
WTP-H21	144	100
WTP-H22	136	136
Blank (spiked)	120	85
Blank (unspiked)	132	126

4.4.4 LOD and LOQ

The LOD and LOQ are shown in Table 4-11, the LOD and LOQ values range from 0.0003 - 4.247and 0.0009 - 12.869ng/L respectively.

Table 4-11: LOD and LOQ values (ng/L) of the targeted standards

Compound	Abbreviation	LOD	LOQ
Perfluoro-n-butanoic acid	PFBA	0,055	0,166
Perfluoro-n-pentanoic acid	PFPeA	0,027	0,083
Perfluoro-n-hexanoic acid	PFHxA	0,062	0,187
Perfluoro-n-heptanoic acid	PFHpA	0,013	0,039
Perfluoro-n-octanoic acid	PFOA	0,005	0,016
Perfluoro-n-nonanoic acid	PFNA	1,195	3,621
Perfluoro-n-undecanoic acid	PFUdA	0,022	0,065
Perfluoro-n-dodecanoic acid	PFDoA	2,018	6,116
Perfluoro-hexadecanoic acid	PFHxDA	-	-
Perfluor-ooctadecanoic acid	PFODA	0,010	0,032
Potassium perfluoro-1-butanesulfonate	L-PFBS	0.023	0.070
Sodium perfluoro-1-hexanesulfonate	L-PFHxS	0,054	0,163
Sodium perfluoro-1-octanesulfonate	L-PFOS	0,006	0,018
Sodium perfluoro-1-decanesulfonate	L-PFDS	0,0003	0,0009
Sodium perfluoro-1-heptanesulfonate	L-PFHpS	0.020	0.063
2-Perfluorohexyl ethanoic acid	FHEA	0,233	0,707
8:2 Fluorotelomer alcohol	FOET	0,236	0,715
6:2 Fluorotelomer Alcohol	FHET	0,049	0,147
4:2 Fluorotelomer sulfonate	4:2FTS	0,041	0,125
6:2 Fluorotelomer sulfonate	6:2FTS	4,247	12,869
8:2 Fluorotelomer sulfonate	8:2FTS	0,041	0,124

4.4.5 PFAS concentrations (ng/L) detected blanks

The mean concentrations of the PFAS detected in the spiked and unspiked blanks are shown in Table 4-13 and Table 4-14. As can be seen, the mean concentrations of PFAS in spiked blanks were less than the limit of detection of 1.322–12 056.430 ng/L and in unspiked blanks were less than the limit of detection (LOD).

Table 4-12: Concentrations of PFAS in spiked blanks

Compound	Mean concentrations (ng/L) + SD			
	Abbreviation	SB	SB	SB
Perfluoro-n-butanoic acid	PFBA	<LOD	<LOD	<LOD
Perfluoro-n-pentanoic acid	PFPeA	<LOD	<LOD	<LOD
Perfluoro-n-hexanoic acid	PFHxA	<LOD	<LOD	<LOD
Perfluoro-n-heptanoic acid	PFHpA	<LOD	<LOD	<LOD
Perfluoro-n-octanoic acid	PFOA	<LOD	<LOD	<LOD
Perfluoro-n-nonanoic acid	PFNA	<LOD	<LOD	<LOD
Perfluoro-n-undecanoic acid	PFUdA	<LOD	<LOD	<LOD
Perfluoro-n-dodecanoic acid	PFDoA	<LOD	<LOD	<LOD

Perfluoro-hexadecanoic acid	PFHxDA	<LOD	<LOD	<LOD
Perfluor-ooctadecanoic acid	PFODA	<LOD	<LOD	<LOD
Potassium perfluoro-1-butanesulfonate	L-PFBS	<LOD	<LOD	<LOD
Sodium perfluoro-1-hexanesulfonate	L-PFHxS	<LOD	<LOD	<LOD
Sodium perfluoro-1-octanesulfonate	L-PFOS	<LOD	<LOD	<LOD
Sodium perfluoro-1-decanesulfonate	L-PFDS	<LOD	<LOD	<LOD
Sodium perfluoro-1-heptanesulfonate	L-PFHpS	<LOD	<LOD	<LOD
2-Perfluorohexyl ethanoic acid	FHEA	<LOD	<LOD	<LOD
8:2 Fluorotelomer alcohol	FOET	12056.430 ±4500	9769.816 ±2450	7110,621.430 ±2120
6:2 Fluorotelomer Alcohol	FHET	1.907±0.055	1.322±0.075	1.627±0.160
4:2 Fluorotelomer sulfonate	4:2FTS	<LOD	<LOD	<LOD
6:2 Fluorotelomer sulfonate	6:2FTS	15,524±5.50	21.859±5.55	23.875±4.65
8:2 Fluorotelomer sulfonate	8:2FTS	<LOD	<LOD	<LOD

Table 4-13: Concentrations (ng/L) of PFAS in unspiked blank

Compound	**Mean concentrations (ng/L) + SD**			
	Abbreviation	**USB**	**USB**	**USB**
Perfluoro-n-butanoic acid	PFBA	<LOD	<LOD	<LOD
Perfluoro-n-pentanoic acid	PFPeA	<LOD	<LOD	<LOD
Perfluoro-n-hexanoic acid	PFHxA	<LOD	<LOD	<LOD
Perfluoro-n-heptanoic acid	PFHpA	<LOD	<LOD	<LOD
Perfluoro-n-octanoic acid	PFOA	<LOD	<LOD	<LOD
Perfluoro-n-nonanoic acid	PFNA	<LOD	<LOD	<LOD
Perfluoro-n-undecanoic acid	PFUdA	<LOD	<LOD	<LOD
Perfluoro-n-dodecanoic acid	PFDoA	<LOD	<LOD	<LOD
Perfluoro-hexadecanoic acid	PFHxDA	<LOD	<LOD	<LOD
Perfluor-ooctadecanoic acid	PFODA	<LOD	<LOD	<LOD
Potassium perfluoro-1-butanesulfonate	L-PFBS	<LOD	<LOD	<LOD
Sodium perfluoro-1-hexanesulfonate	L-PFHxS	<LOD	<LOD	<LOD
Sodium perfluoro-1-octanesulfonate	L-PFOS	<LOD	<LOD	<LOD
Sodium perfluoro-1-decanesulfonate	L-PFDS	<LOD	<LOD	<LOD
Sodium perfluoro-1-heptanesulfonate	L-PFHpS	<LOD	<LOD	<LOD
2-Perfluorohexyl ethanoic acid	FHEA	<LOD	<LOD	<LOD
8:2 Fluorotelomer alcohol	FOET	<LOD	<LOD	<LOD
6:2 Fluorotelomer Alcohol	FHET	<LOD	<LOD	<LOD
4:2 Fluorotelomer sulfonate	4:2FTS	<LOD	<LOD	<LOD
6:2 Fluorotelomer sulfonate	6:2FTS	<LOD	<LOD	<LOD
8:2 Fluorotelomer sulfonate	8:2FTS	<LOD	<LOD	<LOD

4.4.6 Identification of PFAS in water samples

Figure 4-32 shows the XIC, MS and MS/MS chromatograms of PFBA showed 100% library score.

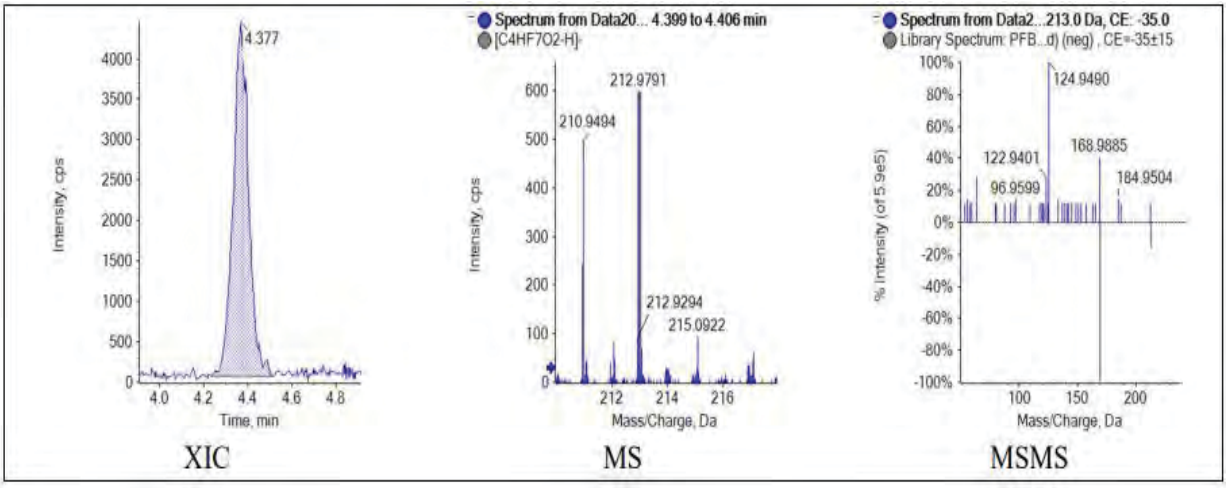

Figure 4-32: shows the XIC, MS and MS/MS chromatograms of PFBA.

Tables 4-14 to 4-43 show the targeted and non-targeted PFAS detected in drinking water treatment plants, wastewater treatment plants, dams, and rivers. During the first wet season, only two wastewater treatment plants were sampled because we were still waiting for approval from the City of Cape Town. As seen in the tables, carboxylic acids and fluorotelomers were the most dominant compounds detected, especially in wastewater treatment plants. Fluorotelomers are *poly*fluoroalkyl substances, and unlike many other PFAS, fluorotelomer alcohols are highly volatile. Consequently, volatilisation was the primary transport pathway for these compounds. As they oxidise in the atmosphere, they break down into perfluorinated carboxylic acids such as PFOA (Figure 4-33).

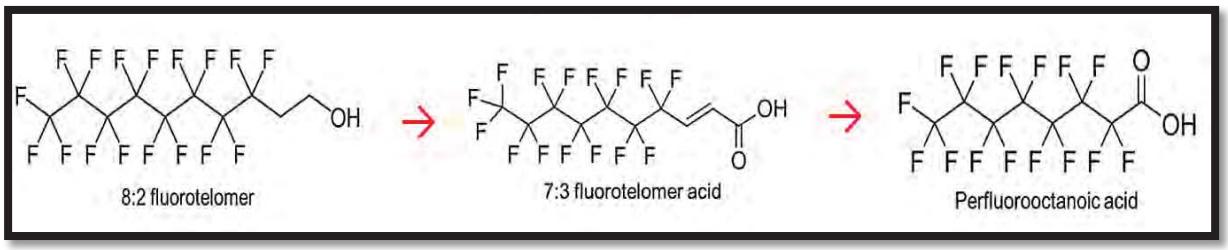

Figure 4-33: Typical Schematic of how Fluorotelomers oxidize in the atmosphere and break down into perfluorinated carboxylic acids such as PFOA.

As shown in the tables below Perfluoro-n-butanoic acid (PFBA), Perfluoro-n-pentanoic acid (PFPeA), Perfluoro-n-hexanoic acid (PFHxA), Perfluoro-n-heptanoic acid (PFHpA), Perfluoro-n-octanoic acid (PFOA) are the most prevalent carboxylic acids. The percentage detection ranges from 90 to 100% for Perfluoro-n-butanoic acid (PFBA), 80 – 100% for Perfluoro-n-pentanoic acid (PFPeA), 10 – 31% for Perfluoro-n-hexanoic acid (PFHxA), 33 – 100% for Perfluoro-n-heptanoic acid (PFHpA), and 40 – 100% Perfluoro-n-octanoic acid (PFOA). The dominant fluorotelomers are 2-Perfluorohexyl ethanoic acid (FHEA), 8:2 Fluorotelomer alcohol (FOET), 6:2 Fluorotelomer Alcohol (FHET), and 6:2 Fluorotelomer sulfonate (6:2 FTS). The percentage detection ranged from 50 to 100% for 2-Perfluorohexyl ethanoic acid (FHEA), 100% for 8:2 Fluorotelomer alcohol (FOET), 100% for 6:2 Fluorotelomer Alcohol (FHET), and 100% for 6:2 Fluorotelomer sulfonate (6:2 FTS). Fluorotelomer sulfonic acids (FTSA): The n:2

fluorotelomer sulfonic acids (n:2 FTSAs) are associated with aqueous film-forming foam (AFFF) in wastewater treatment plant effluents and landfill leachates. Fluorotelomer carboxylic acid (FTCA) compounds are formed through the biodegradation of fluorotelomer alcohols (Figure 5.24). Most of the detected PFAS were present in wastewater treatment plant samples. It must be noted that in each water and wastewater treatment plant, two samples were collected before and after treatment. In addition, in dams and rivers, two samples were collected from two different locations, and the reported results are the average of the two samples in the dams and rivers.

Table 4-14: PFAS Detection Results for Drinking Water Treatment Plant Samples Wet Season - First Sampling Cycle

Water Sample Source		WTP-F11	WTP-F12	WTP-W11	WTP-W12	WTP-V11	WTP-V12	WTP-S11	WTP-S12	WTP-H11	WTP-H12	Detection frequency %
Compound	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	NO	90
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	NO	√	NO	NO	NO	NO	NO	NO	NO	NO	10
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	NO	NO	NO	NO	NO	NO	√	NO	NO	NO	0
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	NO	NO	80
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	100

FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-15: PFAS Detection Results for Drinking Water Treatment Plant Samples Dry Season – Second Sampling Cycle

Water Sample Source		WTP-F21	WTP-F22	WTP-W21	WTP-W22	WTP-V21	WTP-V22	WTP-S21	WTP-S22	WTP-H21	WTP-H22	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	NO	√	√	NO	√	√	√	√	80
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	NO	NO	√	√	NO	√	NO	NO	NO	√	40
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	NO	√	NO	√	√	√	√	√	80
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-16: PFAS Detection Results for Drinking Water Treatment Plant Samples Wet Season – Third Sampling Cycle

Water Sample Source		WTP-F31	WTP-F32	WTP-W31	WTP-W32	WTP-V31	WTP-V32	WTP-S31	WTP-S32	WTP-H31	WTP-H32	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	NO	NO	√	√	√	√	NO	NO	60
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	√	√	√	√	√	√	√	√	√	√	100
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	NO	NO	√	√	√	√	√	√	√	√	80
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-17: PFAS Detection Results Water Drinking Treatment Plant Samples Dry Season – Fourth Sampling Cycle

Water Sample Source		WTP-F41	WTP-F42	WTP-W41	WTP-W42	WTP-V41	WTP-V42	WTP-S41	WTP-S42	WTP-H41	WTP-H42	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	NO	NO	√	√	√	√	√	NO	70
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	√	√	√	√	√	√	√	√	100
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	√	√	√	NO	90
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	√	√	NO	NO	√	NO	√	√	√	NO	60
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	50
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	10
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-18: PFAS Detection Results Drinking Water Treatment Plant Samples Wet Season – Fifth Sampling Cycle

Water Sample Source		WTP-F51	WTP-F52	WTP-W51	WTP-W52	WTP-V51	WTP-V52	WTP-S51	WTP-S52	WTP-H51	WTP-H52	Detection frequency
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	%
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	NO	NO	√	√	√	√	NO	NO	60
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	√	√	√	√	√	√	√	√	√	√	100
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	NO	NO	√	√	√	√	√	√	√	√	80
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-19: PFAS Detection Results for Wastewater Treatment Plant Sample Wet Season – First Sampling Cycle

Water Sample Source		WWTP-Z11	WWTP-Z12	WWTP-V11	WWTP-V12	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	NO	NO	NO	NO	0
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	√	√	100
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	0
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	√	√	50
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	√	√	√	√	100
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	0

Table 4-20: PFAS Detection Results for Wastewater Treatment Plant Samples Dry Season – Second Sampling Cycle

Water Sample Source		WWTP-C21	WWTP-C22	WWTP-A21	WWTP-A22	WWTP-P21	WWTP-P22	WWTP-Z21	WWTP-Z22	WWTP-M21	WWTP-M22	WWTP-V21	WWTP-V22	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	NO	√	√	√	√	NO	√	√	√	√	√	√	85
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	NO	NO	NO	NO	NO	√	√	√	NO	NO	√	31
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	NO	√	√	√	NO	NO	√	√	√	√	√	√	69
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	√	√	√	√	NO	NO	√	NO	NO	NO	√	√	54
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	√	√	√	√	√	√	√	NO	√	√	NO	NO	69
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	√	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-21: PFAS Detection Results for Wastewater Treatment Plant Samples Wet Season – Third Sampling Cycle

Water Sample Source		WWTP-C31	WWTP-C32	WWTP-A31	WWTP-A32	WWTP-P31	WWTP-P32	WWTP-Z31	WWTP-Z32	WWTP-M31	WWTP-M32	WWTP-V31	WWTP-V32	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	√	√	√	NO	NO	√	√	NO	√	√	75
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	√	√	√	NO	√	NO	NO	NO	NO	NO	NO	NO	33
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	√	NO	NO	NO	NO	NO	√	√	25
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	√	NO	√	NO	NO	NO	NO	NO	NO	NO	NO	NO	17
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	NO	NO	NO	75
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-22: PFAS Detection Results for Wastewater Treatment Plant Samples Dry Season – Fourth Sampling Cycle

Water Sample Source		WWTP -C41	WWTP -C42	WWTP -A41	WWTP -A42	WWTP -P41	WWTP -P42	WWTP -Z41	WWTP -Z42	WWTP -M41	WWTP -M42	WWTP -V41	WWTP -V42	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	NO	NO	√	√	√	√	√	NO	NO	NO	58
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	√	√	√	√	√	√	√	NO	NO	NO	√	67
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	√	√	√	√	NO	√	√	√	√	NO	√	√	83
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-23: PFAS Detection Results for Wastewater Treatment Plant Samples Wet Season – Fifth Sampling Cycle

Water Sample Source		WWTP-C51	WWTP-C52	WWTP-A51	WWTP-A52	WWTP-P51	WWTP-P52	WWTP-Z51	WWTP-Z52	WWTP-M51	WWTP-M52	WWTP-V51	WWTP-V52	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	√	√	√	NO	NO	√	√	NO	√	√	75
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	√	√	√	NO	√	NO	NO	NO	NO	NO	NO	NO	33
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	√	NO	NO	NO	NO	NO	√	√	25
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	√	NO	√	NO	NO	NO	NO	NO	NO	NO	NO	NO	17
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	√	√	√	NO	NO	NO	75
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0

Table 4-24: PFAS Detection Results for Dam and River Samples Wet Season – First Sampling Cycle

Water Sample Source		DM-T1	DM-V1	DM-N1	RV-E1	RV-D1	RV-S1	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	NO	NO	NO	NO	NO	NO	0
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	NO	NO	√	NO	√	NO	33
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	NO	√	NO	√	√	67
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	NO	NO	0
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	NO	√	17
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	NO	NO	√	67
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	0

Table 4-25: PFAS Detection Results for Dam and River Samples Dry Season – Second Sampling Cycle

Water Sample Source		DM-T2	DM-V2	DM-N2	RV-E2	RV-D2	RV-S2	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	NO	√	√	√	√	83
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	NO	NO	NO	NO	√	NO	17
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	NO	√	NO	√	NO	50
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	NO	NO	NO	√	√	50
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	NO	NO	0
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	√	NO	17
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	√	√	33
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	NO	NO	√	NO	√	√	50
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	0

Table 4-26: PFAS Detection Results for Dam and River Samples Wet Season – Third Sampling Cycle

Water Sample Source		DM-T3	DM-V3	DM-N3	RV-E3	RV-D3	RV-S3	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	NO	√	√	√	√	83
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	√	√	33
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	√	NO	17
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	√	√	33
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	NO	√	NO	√	√	67
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	NO	NO	√	√	√	67
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	0

Table 4-27: PFAS Detection Results for Dam and River Samples Dry Season – Fourth Sampling Cycle

Water Sample Source		DM-T4	DM-V4	DM-N4	RV-E4	RV-D4	RV-S4	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	√	√	√	√	√	100
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	NO	NO	√	NO	√	√	50
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	√	√	NO	NO	NO	33
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	√	√	NO	√	√	67
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	√	√	√	NO	√	√	83
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	√	√	√	√	√	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	√	√	√	√	√	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	0

Table 4-28: PFAS Detection Results for Dam and River Samples Wet Season – Fifth Sampling Cycle

Water Sample Source		DM-T5	DM-V5	DM-N5	RV-E5	RV-D5	RV-S5	Detection frequency %
Compound Abbreviation and Name	Formula	Detected	Detected	Detected	Detected	Detected	Detected	
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	√	√	√	√	√	√	100
PFPeA - Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	√	√	√	√	√	√	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	√	√	√	√	√	√	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	√	NO	√	√	√	√	83
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	√	√	√	√	√	√	100
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	NO	NO	NO	NO	√	√	33
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	NO	NO	NO	NO	NO	NO	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	NO	NO	NO	NO	NO	NO	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	NO	NO	NO	NO	NO	NO	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	NO	NO	NO	NO	NO	NO	0
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	NO	NO	NO	NO	√	NO	17
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	NO	NO	NO	NO	√	√	33
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	NO	NO	NO	NO	NO	NO	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	NO	NO	NO	NO	NO	NO	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	√	NO	√	NO	√	√	67
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	√	√	√	√	√	√	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	√	√	√	√	√	√	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	NO	NO	NO	NO	NO	NO	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	√	NO	NO	√	√	√	67
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	NO	NO	NO	NO	NO	NO	0

Table 4-29: PFAS Concentration (ng/L) Results for Drinking Water Treatment Plant Samples Wet Season – First Sampling Cycle

Compound Name	Formula	WTP-F11	WTP-F12	WTP-W11	WTP-W12	WTP-V11	WTP-V12	WTP-S11	WTP-S12	WTP-H11	WTP-H12	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	0.47	0.79	1.01	0.46	0.55	0.91	0.72	0.78	0.88	<LOD	90	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	0.79	0.23	0.11	0.31	0.12	0.14	0.28	0.47	0.16	0.49	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	<LOD	0.13	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	10	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	1.18	2.81	0.44	0.75	0.35	0.83	2.18	0.33	<LOD	<LOD	80	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	1 776.28	2 390.10	5 341.46	12 662.50	14 609.99	13 346.69	14 111.65	12 867.48	15 594.79	12 946.99	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	2.27	2.38	2.47	2.48	2.49	2.35	2.56	2.51	2.56	1.70	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	20.95	15.76	18.77	21.65	33.29	17.94	117.01	27.90	20.93	11.46	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-30: PFAS Concentration (ng/L) Results for Drinking Water Treatment Plant Samples Dry Season – Second Sampling Cycle

Compound Name	Formula	WTP-F21	WTP-F22	WTP-W21	WTP-W22	WTP-V21	WTP-V22	WTP-S21	WTP-S22	WTP-H21	WTP-H22	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	1.19	1.23	0.45	1.20	0.34	1.70	1.19	0.76	1.16	1.31	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	0.29	0.27	<LOD	0.09	0.17	<LOD	0.13	0.14	0.35	0.48	80	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	<LOD	<LOD	0.01	0.01	<LOD	0.01	<LOD	<LOD	<LOD	0.02	40	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	4.03	0.84	<LOD	1.27	<LOD	3.22	1.79	0.41	0.71	1.79	80	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	2 672.26	2 894.06	13 768.44	14 172.71	11 652.15	16 387.60	17 711.37	15 573.13	18 935.55	19 167.10	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	3.14	3.48	2.77	3.26	2.11	2.56	3.32	2.54	3.44	2.73	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	54.04	63.30	30.84	14.81	30.15	21.76	44.34	119.21	54.46	22.33	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-31: PFAS Concentration (ng/L) Results for Drinking Water Treatment Plant Samples Wet Season – Third Sampling Cycle

Compound Name	Formula	WTP-F31	WTP-F32	WTP-W31	WTP-W32	WTP-V31	WTP-V32	WTP-S31	WTP-S32	WTP-H31	WTP-H32	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	0.14	0.85	0.31	4.44	0.54	0.91	22.18	0.72	0.78	0.88	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	0.22	0.25	0.19	0.46	0.45	0.27	0.33	0.53	0.74	0.65	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.90	0.33	0.22	0.41	0.22	0.24	0.38	0.57	0.26	0.59	100	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.05	0.07	<LOD	<LOD	0.12	0.04	0.11	0.05	<LOD	<LOD	60	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	<LOD	0.0144	0.0091	<LOD	0.02	0.04	0.006	0.006	0.006	0.007	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	26.06	12.06	7.88	9.64	10.05	6.71	6.12	4.87	3.28	3.78	100	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	4.81	1.62	3.99	2.58	1.19	1.49	2.57	3.15	3.48	2.77	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	28.12	279.11	684.40	1019.6	1852.03	1953.24	2625.87	2758.22	2635.25	2292.20	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	0.91	1.26	1.37	1.38	1.97	1.87	2.79	3.85	2.81	2.04	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	<LOD	<LOD	10.04	9.62	12.21	12.82	28.18	31.29	13.17	5.28	80	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-32: PFAS Concentration (ng/L) Results for Drinking Water Treatment Plant Samples Dry Season – Fourth Sampling Cycle

Compound Name	Formula	WTP-F41	WTP-F42	WTP-W41	WTP-W42	WTP-V41	WTP-V42	WTP-S41	WTP-S42	WTP-H41	WTP-H42	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	17.98	22.73	21.40	7.61	49.11	52.57	61.81	71.14	12.40	57.48	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	8.19	1.84	9.58	0.59	5.99	8.26	48.70	16.92	19.78	2.49	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	1.08	0.25	<LOD	<LOD	0.60	0.31	1.53	1.65	1.97	<LOD	70	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	26.24	38.77	23.21	3.76	17.26	24.09	214.61	123.34	84.73	36.65	100	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.45	0.07	0.13	0.04	0.14	0.04	0.29	0.32	0.06	<LOD	90	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	1.04	14.38	<LOD	<LOD	40.85	<LOD	4.51	8.19	4.70	<LOD	60	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	<LOD	10	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	795.27	402.72	294.96	232.66	537.12	73.54	24.80	39.03	25.98	3.78	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	1 473.15	0.77	207.25	907.09	3 935.69	41 159.65	147 600.76	113 668.39	127 374.26	183 435.09	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	17.02	7.10	22.29	10.56	26.15	40.42	77.89	39.65	68.67	37.47	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	110.92	79.18	68.45	26.50	106.09	189.11	459.22	358.83	317.28	118.38	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-33: PFAS Concentration (ng/L) Results for Drinking Water Treatment Plant Samples Wet Season – Fifth Sampling Cycle

Compound Name	Formula	WTP-F51	WTP-F52	WTP-W51	WTP-W52	WTP-V51	WTP-V52	WTP-S51	WTP-S52	WTP-H51	WTP-H52	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	0.186	0.895	0.358	4.480	0.588	0.948	22.219	0.757	0.821	0.914	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	0.259	0.292	0.232	0.503	0.487	0.310	0.376	0.568	0.780	0.687	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.934	0.372	0.255	0.449	0.261	0.280	0.421	0.608	0.301	0.631	100	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.093	0.109	<LOD	<LOD	0.161	0.075	0.152	0.092	<LOD	<LOD	60	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.000	0.053	0.048	0.000	0.062	0.079	0.045	0.045	0.045	0.046	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	26.095	12.101	7.921	9.675	10.090	6.747	6.157	4.904	3.322	3.817	100	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	<LOD	10	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	4.85	1.66	4.04	2.61	1.23	1.53	2.61	3.1	3.52	2.81	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	29	280	685	1 020	1 852	1 954	2 626	2 759	2 636	2 293	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	0.95	1.30	1.41	1.42	2.01	1.91	2.83	3.89	2.85	2.08	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	<LOD	<LOD	10.08	9.66	12.25	12.86	28.22	31.32	13.21	5.31	80	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-34: PFAS Concentration (ng/L) Results for Wastewater Treatment Plant Samples Wet Season – First Sampling Cycle

Compound Name	Formula	WWTP-Z11	WWTP-Z12	WWTP-V11	WWTP-V12	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	2.09	0.43	1.80	1.60	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	0.13	0.09	0.16	0.17	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	<LOD	<LOD	<LOD	<LOD	0	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.13	0.08	0.15	0.06	100	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.35	0.04	1.02	0.22	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	0	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	0.03	0.03	50	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	0.10	0.00	0.05	0.01	100	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	58.99	1.18	6.04	7.48	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	73 157.46	13 256.62	41 581.14	21 077.76	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	10.94	2.14	14.26	10.06	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	391.57	48.48	122.09	120.83	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-35: PFAS Concentration (ng/L) Results for Wastewater Treatment Plant Samples Dry Season – Second Sampling Cycle

Compound Name	Formula	WWTP-C21	WWTP-C22	WWTP-A21	WWTP-A22	WWTP-P21	WWTP-P22	WWTP-Z21	WWTP-Z22	WWTP-M21	WWTP-M22	WWTP-V21	WWTP-V22	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	1.71	1.60	4.10	0.64	1.13	0.69	3.54	0.36	2.19	0.36	1.30	0.98	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	<LOD	0.14	0.07	0.13	0.15	<LOD	0.26	0.09	0.20	0.31	0.28	0.16	85	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.36	<LOD	<LOD	<LOD	<LOD	<LOD	0.29	0.89	0.35	<LOD	<LOD	0.49	31	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	<LOD	0.09	0.08	0.12	<LOD	<LOD	0.07	0.08	0.06	0.33	0.34	0.14	69	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	1.07	1.04	1.68	0.27	0.33	0.07	1.15	0.26	0.65	0.64	0.17	0.21	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	0.03	0.03	0.04	0.02	<LOD	<LOD	0.03	<LOD	<LOD	<LOD	1.06	0.37	54	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	0.04	0.25	0.17	0.20	0.11	0.02	0.02	<LOD	0.21	0.08	<LOD	<LOD	69	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	101.95	112.92	229.33	21.99	125.12	7.07	167.67	0.69	96.27	5.59	12.80	15.97	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	70 385.15	85 199.22	118 362.04	40 666.12	93 860.58	18 029.16	274 615.93	37 833.70	108 774.09	17 593.18	27 062.12	30 930.70	100	0.24	0.72

FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	14.58	16.81	23.12	9.42	27.06	4.53	27.95	4.07	17.27	4.72	8.78	6.63	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	278.94	356.10	722.96	153.03	336.70	133.97	780.18	94.35	503.82	204.80	177.49	209.81	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-36: PFAS Concentration (ng/L) Results for Wastewater Treatment Plant Samples Wet Season – Third Sampling Cycle

Compound Name	Formula	WWTP-C31	WWTP-C32	WWTP-A31	WWTP-A32	WWTP-P31	WWTP-P32	WWTP-Z31	WWTP-Z32	WWTP-M31	WWTP-M32	WWTP-V31	WWTP-V32	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	1.812	1.723	1.299	0.979	1.715	1.605	4.098	3.536	1.133	0.691	2.186	0.360	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	5.44	10.06	0.67	1.97	0.81	1.88	2.35	4.7	40.16	5.12	26.40	2.35	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.29	0.89	0.28	0.49	0.36	0.69	0.64	1.13	0.69	2.19	0.36	0.56	100	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.32	0.24	0.51	0.40	0.39	<LOD	<LOD	0.27	0.16	<LOD	0.36	0.46	75	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.02	0.03	0.02	0.03	0.01	0.02	0.01	0.01	0.01	0.02	0.09	0.06	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	3.10	3.10	2.14	<LOD	2.68	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	33	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	0.09	0.18	25	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	0.011	<LOD	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	17	0.01	0.02

L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	170.6	3.628	15.74	18.91	104.9	115.9	232.3	24.93	128.1	10.01	99.21	8.533	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	59 385	74 199	107 362	29 666	82 861	7 029	263 616	26 834	97 774	16 593	16 062	19 931	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	3.452	4.647	14.00	13.63	0.7998	0.2046	0.1270	0.0974	0.0560	<LOD	<LOD	<LOD	75	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	22.40	39.89	53.38	57.14	52.79	38.70	16.10	12.01	11.54	10.43	11.18	10.98	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-37: PFAS Concentration (ng/L) Results for Wastewater Treatment Plant Samples Dry Season – Fourth Sampling Cycle

Compound Name	Formula	WWTP-C41	WWTP-C42	WWTP-A41	WWTP-A42	WWTP-P41	WWTP-P42	WWTP-Z41	WWTP-Z42	WWTP-M41	WWTP-M42	WWTP-V41	WWTP-V42	Detecti frequer %
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	65.81	10.77	25.33	21.31	69.02	23.24	48.26	17.50	21.27	19.47	24.49	31.28	100
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	18.48	3.76	2.68	6.23	1422.05	33.34	249.93	9.37	5.91	7.57	85.36	6.72	100
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	4.32	0.74	6.63	3.62	359.56	8.40	2.90	3.92	1.93	3.53	2.96	15.01	100
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	1005.28	56.42	27.47	31.42	947.94	61.66	16.57	35.47	11.84	8.93	12.52	13.00	100
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	1.61	0.18	<LOD	<LOD	0.24	0.03	0.23	0.18	0.04	<LOD	<LOD	<LOD	58
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	6.92	1.36	2.35	8.69	2.55	10.37	4.45	<LOD	<LOD	<LOD	10.54	67
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0

L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	0.54	0.13	0.18	0.92	<LOD	0.35	0.27	0.41	0.17	<LOD	0.02	0.12	83
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	587.13	101.95	865.92	346.92	4846.99	333.14	523.09	382.04	498.05	453.01	349.43	460.92	100
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	196977.23	48833.68	468522.12	93363.21	1128680.13	63949.64	1661.32	11255.68	279098.43	376146.94	103391.40	95134.46	100
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	129.88	35.04	233.41	85.33	1249.21	28.59	27.90	34.90	79.98	101.68	71.26	27.63	100
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	862.83	265.86	2191.41	744.96	12831.03	250.39	571.94	386.35	556.44	1011.51	487.59	785.36	100
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0

Table 4-38: PFAS Concentration (ng/L) Results for Wastewater Treatment Plant Samples Wet Season – Fifth Sampling Cycle

Compound Name	Formula	WWTP-C51	WWTP-C52	WWTP-A51	WWTP-A52	WWTP-P51	WWTP-P52	WWTP-Z51	WWTP-Z52	WWTP-M51	WWTP-M52	WWTP-V51	WWTP-V52	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	2.06	1.97	1.55	1.23	1.97	1.86	4.35	3.79	1.3	0.94	2.44	0.61	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	5.69	10.31	0.92	2.22	1.06	2.13	2.60	4.98	40.41	5.37	26.65	2.60	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.54	1.14	0.53	0.74	0.61	0.94	0.89	1.38	0.94	2.44	0.61	0.81	100	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.57	0.49	0.76	0.65	0.64	<LOD	<LOD	0.52	0.41	<LOD	0.61	0.71	75	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.27	0.28	0.27	0.28	0.26	0.27	0.26	0.2	0.26	0.27	0.34	0.31	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	3.35	3.34	2.39	<LOD	2.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	33	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	0.29	<LOD	<LOD	<LOD	<LOD	<LOD	0.34	0.43	25	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	0.26	<LOD	0.27	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	17	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	173.1	6.128	18.24	21.41	107.4	118.4	234.8	27.43	130.6	12.51	101.71	11.033	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	59 635	74 449	107 612	29 916	83 111	7 279	263 866	27 084	98 024	16 843	16 312	20 181	100	0.24	0.72

FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	3.97	5.17	14.52	14.15	1.32	0.72	0.65	0.62	0.58	<LOD	<LOD	<LOD	75	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	24.90	42.39	55.88	59.64	55.29	41.20	18.60	14.51	14.04	12.93	13.68	13.48	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-39: PFAS Concentration (ng/L) Results for Dam and River Samples Wet Season – First Sampling Cycle

Compound Name	Formula	DM-T1	DM-V1	DM-N1	RV-E1	RV-D1	RV-S1	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	0.65	0.63	0.41	0.22	0.34	0.82	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	0.14	0.11	1.13	0.16	0.26	0.09	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	<LOD	<LOD	0.16	<LOD	0.13	<LOD	33	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.25	<LOD	0.01	<LOD	0.02	0.11	67	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	0.0501	17	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	0.61	0.38	1.95	<LOD	<LOD	1.09	67	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	6551.73	5698.38	5890.47	7023.89	7391.86	9865.10	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	2.64	2.40	2.86	2.60	2.76	3.85	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	23.89	49.44	44.01	36.71	65.77	89.66	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-40: PFAS Concentration (ng/L) Results for Dam and River Samples Dry Season – Second Sampling Cycle

Compound Name	Formula	DM-T2	DM-V2	DM-N2	RV-E2	RV-D2	RV-S2	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	0.51	0.41	0.7	0.42	0.95	0.78	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	0.13	<LOD	0.22	0.11	0.15	0.11	83	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	<LOD	<LOD	<LOD	<LOD	0.63	<LOD	17	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.06	<LOD	0.11	<LOD	0.31	<LOD	50	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.28	<LOD	<LOD	<LOD	0.08	0.11	50	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	0.02	<LOD	17	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	0.03	0.07	33	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	0.26	<LOD	0.75	<LOD	2.67	3.91	67	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	6729.99	4607.14	7676.78	9036.51	11550.81	13726.38	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	2.93	3.39	3.01	3.34	4.54	5.38	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	22.22	41.25	59.38	35.96	63.50	100.29	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-41: PFAS Concentration (ng/L) Results for Dam and River Samples Wet Season – Third Sampling Cycle

Compound Name	Formula	DM-T3	DM-V3	DM-N3	RV-E3	RV-D3	RV-S3	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	0.40	0.29	0.62	0.31	0.84	0.67	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	11.49	23.26	41.66	252.59	21.44	45.80	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.11	0.15	0.21	0.09	0.14	0.10	100	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.07	<LOD	0.30	2.93	1.62	0.42	83	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.01	<LOD	0.01	0.02	0.04	0.06	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	1.38	1.24	33	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	0.03	17	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	0.02	0.03	33	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	0.23	<LOD	0.72	<LOD	2.63	3.88	67	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	5150	3027	6096	7456	9970	12146	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	2.13	2.60	2.22	2.54	3.74	4.59	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	5.41	<LOD	<LOD	5.61	11.85	65.83	67	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-42: PFAS Concentration (ng/L) Results for Dam and River Samples Dry Season – Fourth Sampling Cycle

Compound Name	Formula	DM-T4	DM-V4	DM-N4	RV-E4	RV-D4	RV-S4	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	8.66	26.96	45.99	29.89	47.54	40.46	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	4.14	9.12	8.76	2.42	6.32	2.59	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.77	0.45	1.37	0.07	6.85	1.46	100	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	17.78	13.62	31.42	16.52	28.18	13.81	100	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	<LOD	<LOD	0.02	<LOD	0.04	0.19	50	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	66.93	1.441	<LOD	<LOD	<LOD	33	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	0.11	0.12	<LOD	0.03	0.03	67	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	0.026	0.28	0.05	<LOD	0.09	0.16	83	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	641.43	505.77	551.03	445.66	737.44	333.71	100	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	7381.89	196023	140387	89642	224075	105848	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	32.02	33.77	16.18	12.45	186.96	32.15	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	225.91	237.11	358.68	74.28	1626.18	367.09	100	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

Table 4-43: PFAS Concentration (ng/L) Results for Dam and River Samples Wet Season – Fifth Sampling Cycle

Compound Name	Formula	DM-T5	DM-V5	DM-N5	RV-E5	RV-D5	RV-S5	Detection frequency %	LOD	LOQ
PFBA - Perfluoro-n-butanoic acid	$C_4HF_7O_2$	0.55	0.44	0.77	0.46	0.99	0.82	100	0.06	0.17
PFPeA - Perfluoro-n-pentanoic acid	C_5HF9O_2	11.99	23.76	42.16	253.09	21.94	46.30	100	0.03	0.08
PFHxA - Perfluoro-n-hexanoic acid	$C_6HF_{11}O_2$	0.61	0.65	0.71	0.59	0.64	0.60	100	0.06	0.19
PFHpA - Perfluoro-n-heptanoic acid	$C_7HF_{13}O_2$	0.57	<LOD	0.80	3.43	2.12	0.92	83	0.01	0.04
PFOA - Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	0.51	<LOD	0.51	0.52	0.54	0.56	100	0.005	0.016
PFNA - Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	<LOD	<LOD	<LOD	<LOD	1.88	1.74	33	1.20	3.62
PFUdA - Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.02	0.07
PFDoA - Perfluoro-n-dodecanoic acid	$C_{12}HF_{23}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	2.02	6.12
PFHxDA - Perfluoro-hexadecanoic acid	$C_{16}HF_{31}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	-	-
PFODA - Perfluorooctadecanoic acid	$C_{18}HF_{35}O_2$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.01	0.03
L-PFBS - Potassium perfluoro-1-butanesulfonate	$C_4HF_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	0.53	17	0.023	0.070
L-PFHxS - Sodium perfluoro-1-hexanesulfonate	$C_6HF_{13}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.05	0.16
L-PFOS - Sodium perfluoro-1-octanesulfonate	$C_8HF_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	0.52	0.53	33	0.01	0.02
L-PFDS - Sodium perfluoro-1-decanesulfonate	$C_{10}HF_{21}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.00	0.00
L-PFHpS - Sodium perfluoro-1-heptanesulfonate	$C_7F_{15}SO_3H$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.020	0.063
FHEA - 2-Perfluorohexyl ethanoic acid	$C_8H_3F_{13}O_2$	0.73	<LOD	1.22	<LOD	3.13	4.38	67	0.23	0.71
FOET - 8:2 Fluorotelomer alcohol	$C_{10}F_{17}H_5O$	5200	3077	6146	7506	10020	12196	100	0.24	0.72
FHET - 6:2 Fluorotelomer Alcohol	$C_8H_5F_{13}O$	2.63	3.10	2.72	3.04	4.24	5.09	100	0.05	0.15
4:2FTS - 4:2 Fluorotelomer sulfonate	$C_6H_5F_9O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.13
6:2FTS - 6:2 Fluorotelomer sulfonate	$C_8H_5F_{13}O_3S$	10.41	<LOD	<LOD	10.61	16.85	70.83	67	4.25	12.87
8:2FTS - 8:2 Fluorotelomer sulfonate	$C_{10}H_4F_{17}O_3S$	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0	0.04	0.12

5 DISTRIBUTION OF PER- AND POLYFLUOROALKYL SUBSTANCE CLASSES IN DIFFERENT WATER SOURCES

5.1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) announced the National Primary Drinking Water Regulation (NPDWR) for six per- and polyfluoroalkyl substances (PFAS) under the Safe Drinking Water Act (SDWA) effective from 10 April 2024 as shown in Table 5-1 (EPA, 2024). The regulation, such as NPDWR for other chemicals, includes enforceable maximum contaminant levels (MCLs), as shown below. The new federal MCLs are considered to be the maximum allowable concentrations in parts per trillion (ppt) of selected PFAS in public drinking water systems. The new federal regulations established a common national threshold for allowable concentrations of PFAS in drinking water, moving away from the patchwork of state rules and regulations. Individual states are still allowed to establish their own drinking water rules and regulations for PFAS, provided they are lower than federal MCLs. However, if the current state-enforceable levels are higher than federal MCLs, public water systems within that state must abide by federal levels. Individual MCLs are set for five different PFAS, but an approach known as Hazard Index (HI) applies to three of these individual PFAS and includes a fourth PFAS called PFBS, which does not have a stand-alone MCL. The HI approach treats these PFAS as a mixture using an additive approach (graphic and Equation 1) and Health-Based Water Concentration (HBWC).

Table 5-1: New federal MCLs for selected PFAS in public drinking water systems (1ng/L = ng/kg = 1ng/L) (EPA, 2024)

Compound	MCGL	MCL	HBWC
PFOS - perfluorooctane sulfonic acid	0	4ng/L	
PFOA - perfluorooctanoic acid	0	4ng/L	
PFNA - perfluorononanoic acid	10ng/L	10ng/L	
PFHxS - perfluorohexane sulfonic acid	10ng/L	10ng/L	
HFPO-DA(GenX)- hexafluoropropylene oxide dimer acid	10ng/L	10ng/L	
PFNA	Hazard Index = 1	Hazard Index = 1	10
PFHxS			10
HFPO-DA(GenX)			10
PFBS			2000

$$\frac{[\mathbf{GenX}]_{\mathbf{water}}]}{\mathbf{10ng/l}} + \frac{[\mathbf{PFBS}]_{\mathbf{water}}]}{\mathbf{2000ng/l}} + \frac{[\mathbf{PFNA}]_{\mathbf{water}}]}{\mathbf{10ng/l}} + \frac{[\mathbf{PFHxS}]_{\mathbf{water}}]}{\mathbf{10ng/l}} = \mathbf{Hazard\ Index\ (HI)} - \mathbf{Equation\ 1}$$

In the Western Cape, three classes of water sources were sampled for this study: drinking water treatment plants (raw and final water samples), wastewater treatment plants (influent and effluent water samples), and major dams and river water samples.

5.2 PFAS CLASS CONTRIBUTIONS IN DIFFERENT WATER SOURCES

5.2.1 Class contribution of PFAS drinking water treatment plant

Out of the 21 PFAS in the analysis of drinking water treatment plant samples, both raw and final water samples, 7 to 10 PFAS were detected that seemed to be prevalent over the period under study, that is, PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, FHEA, FOET, FHET, and 6:2FTS, as shown below in Figures 5-1 to 5-5. During the fourth cycle (dry season), the concentrations were extremely high in the drinking water treatment plant, because of the high PFAs concentrations in the dams. This trend is also observed with wastewater treatment plants during that season.

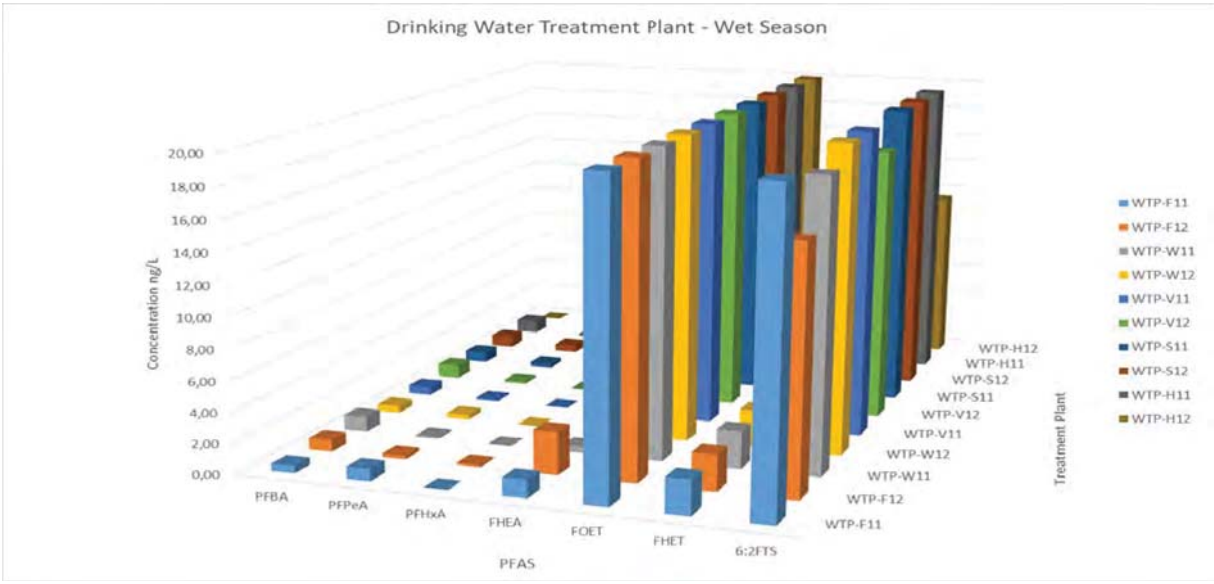

Figure 5-1: PFAS in drinking water treatment plant (raw and final water samples) wet season – first sampling cycle

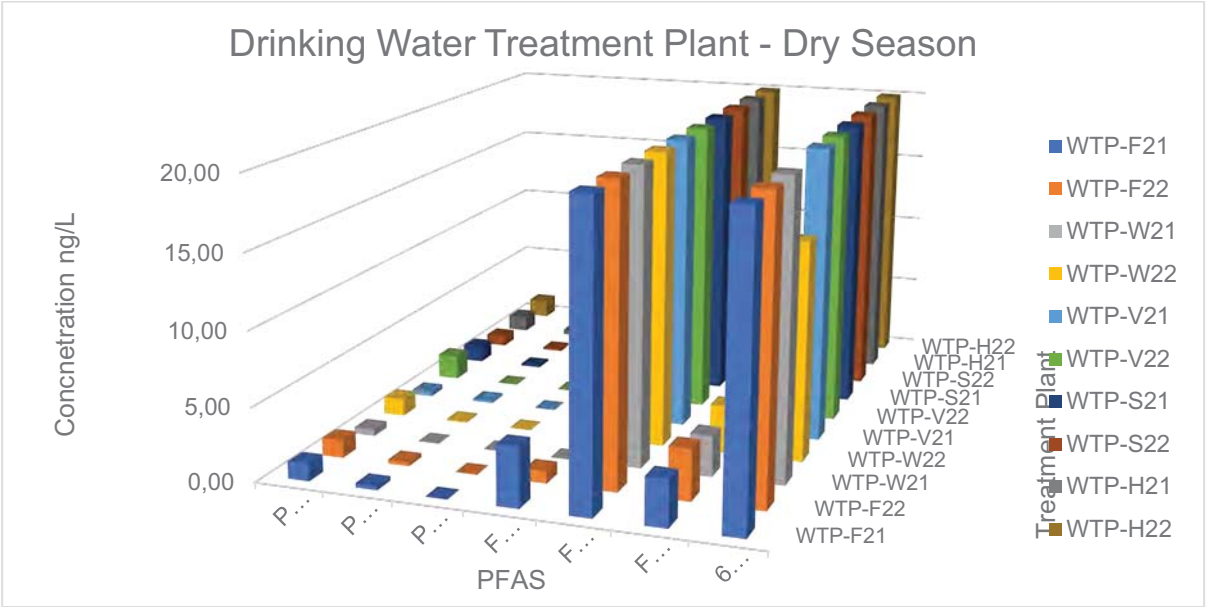

Figure 5-2: PFAS in drinking water treatment plant (raw and final water samples) dry season – second sampling cycle

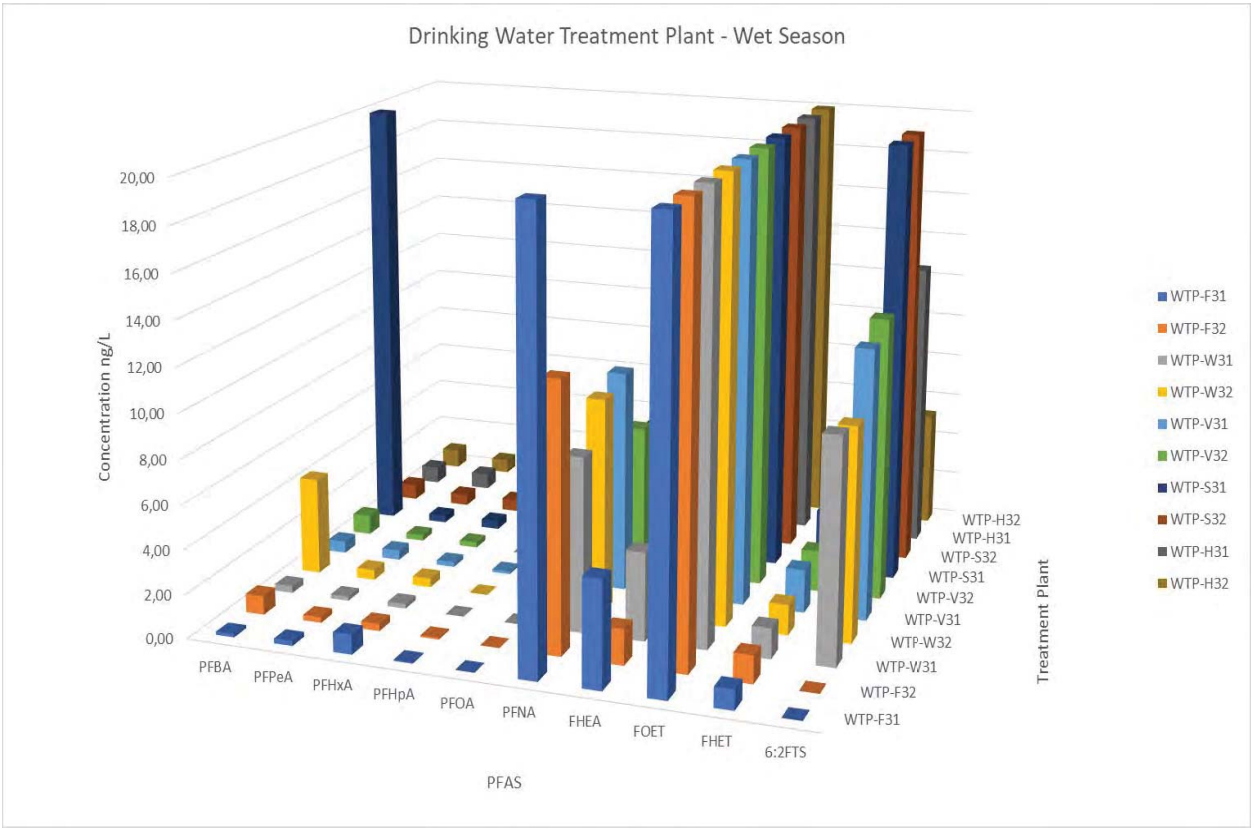

Figure 5-3: PFAS in drinking water treatment plant (raw and final water samples) wet season – third sampling cycle

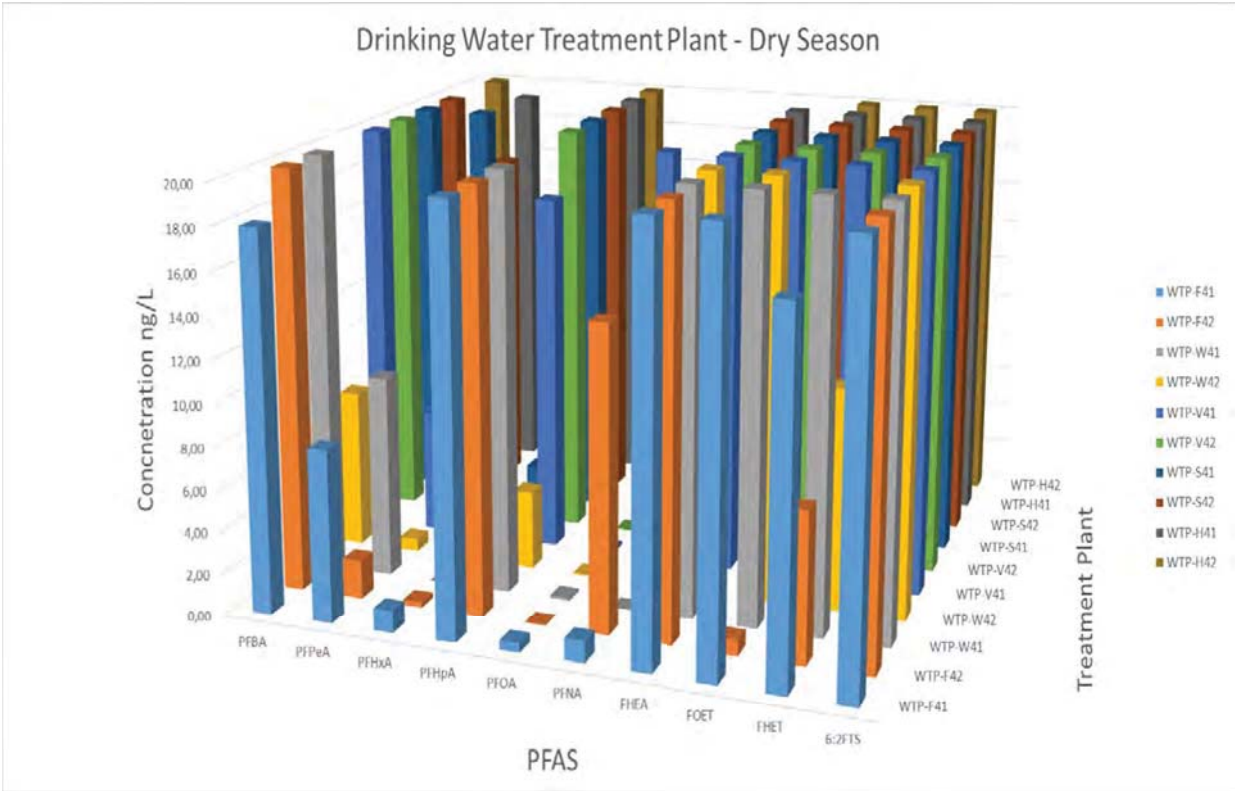

Figure 5-4: PFAS in drinking water treatment plant (raw and final water samples) wet season – fourth sampling cycle

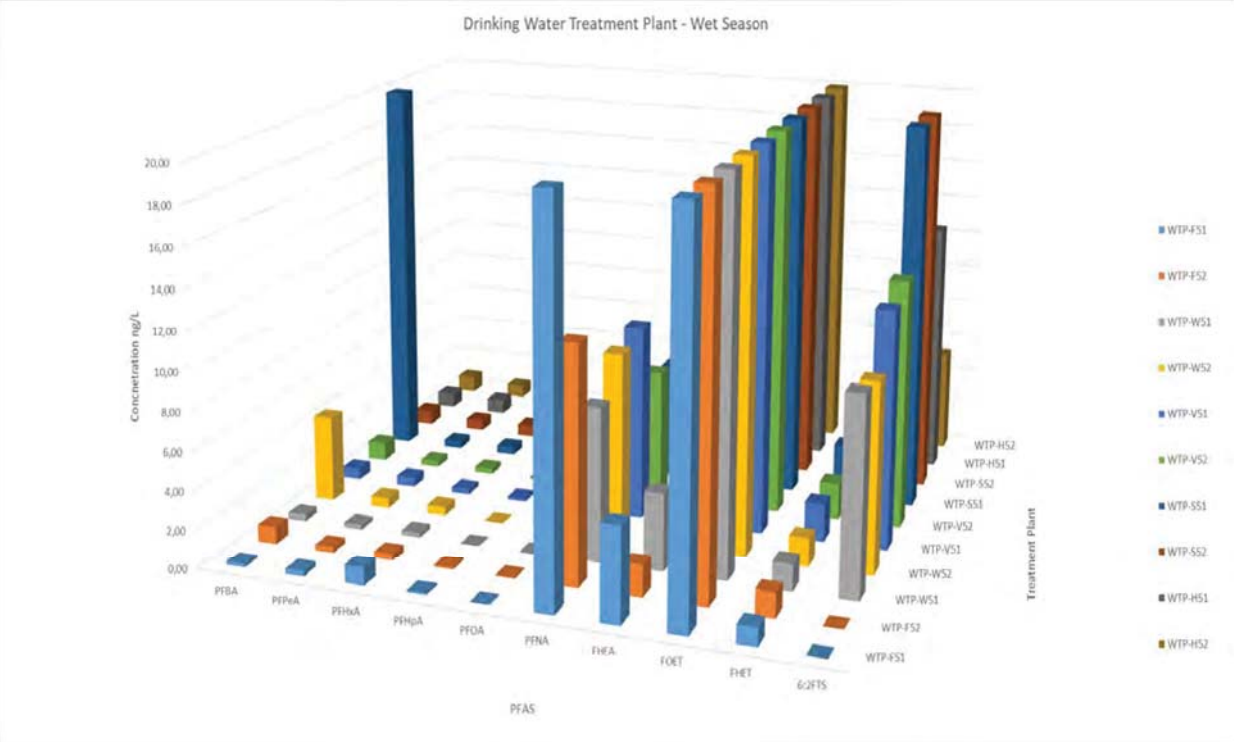

Figure 5-5: PFAS in drinking water treatment plant (raw and final water samples) wet season – fourth sampling cycle

5.2.2 Class contribution of PFAS major dams and rivers samples

The dams and rivers had the second highest PFAS concentrations detected after the wastewater treatment plant water samples. The detected PFAS ranged from 9 to 12, as shown in Figure 5-6 to 5-10. The following PFAS were detected PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, FHEA, FOET, FHET, 6:2FTS we also observed that L-PFBS and L-PFOS were also detected in the dams and rivers but not in the drinking water.

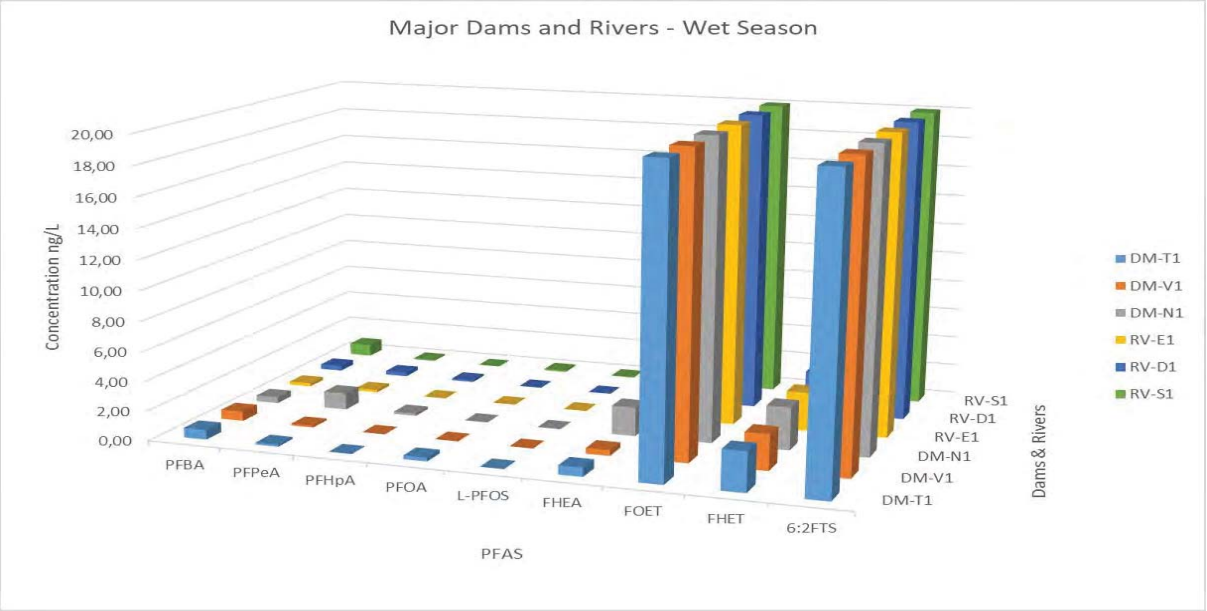

Figure 5-6: PFAS in major dams and rivers samples wet season – first sampling cycle

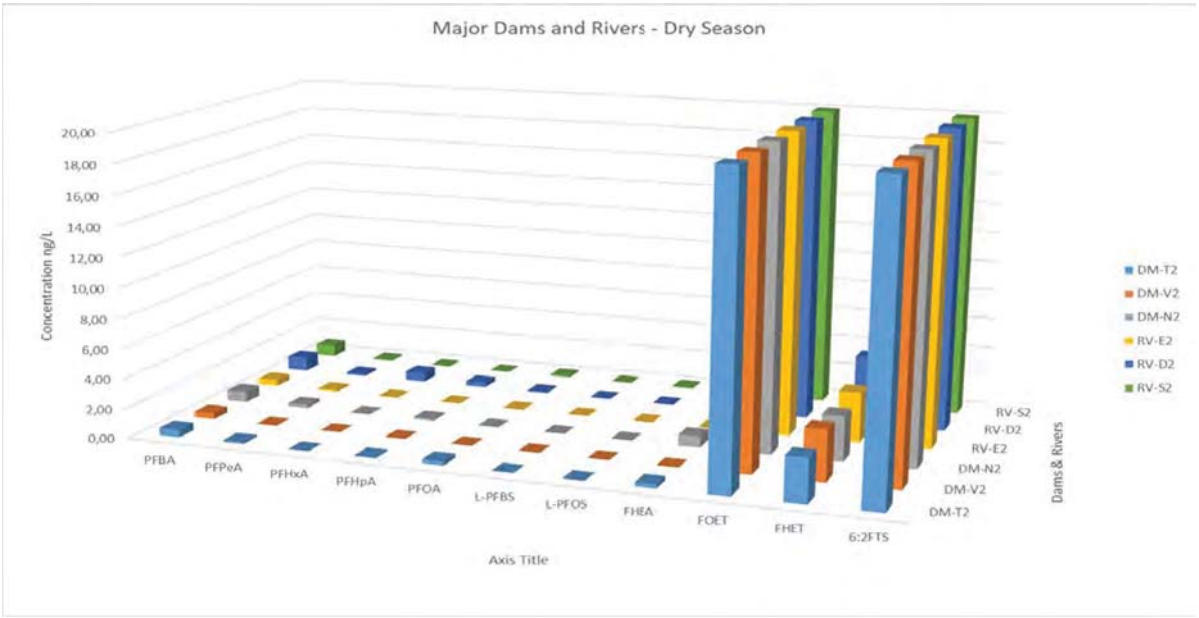

Figure 5-7: PFAS in major dams and rivers samples wet season – second sampling cycle

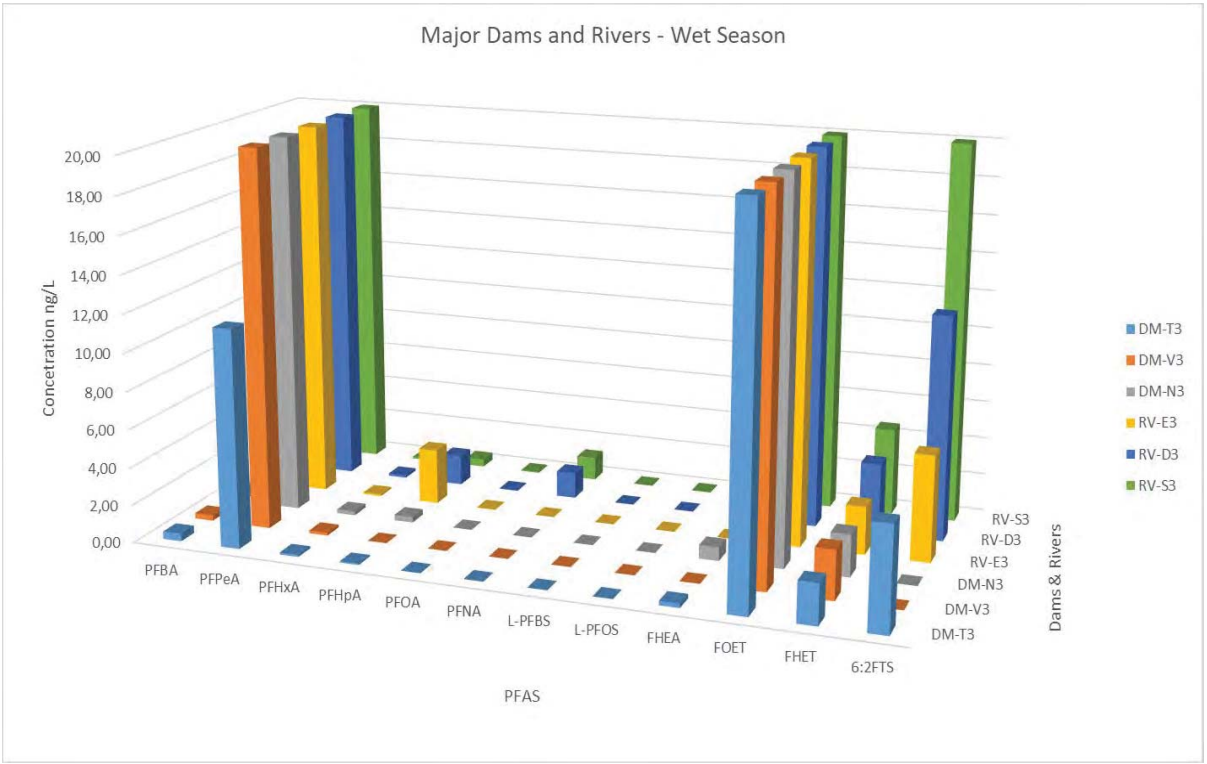

Figure 5-8: PFAS in major dams and rivers samples wet season – third sampling cycle

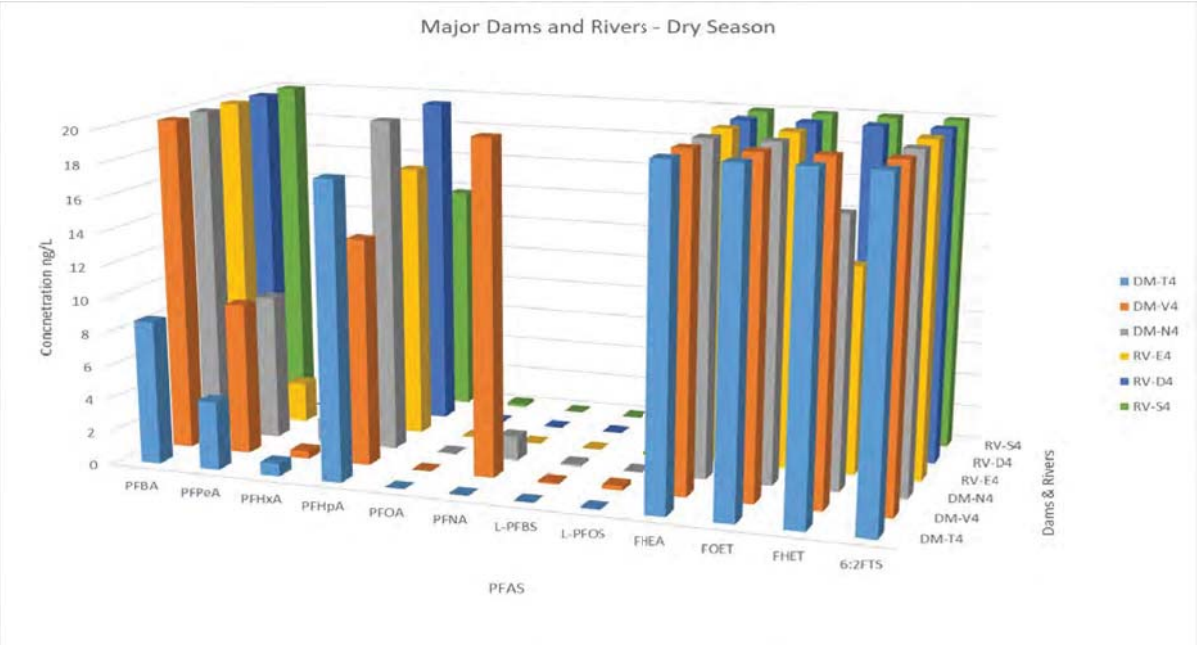

Figure 5-9: PFAS in major dams and rivers samples wet season – fourth sampling cycle

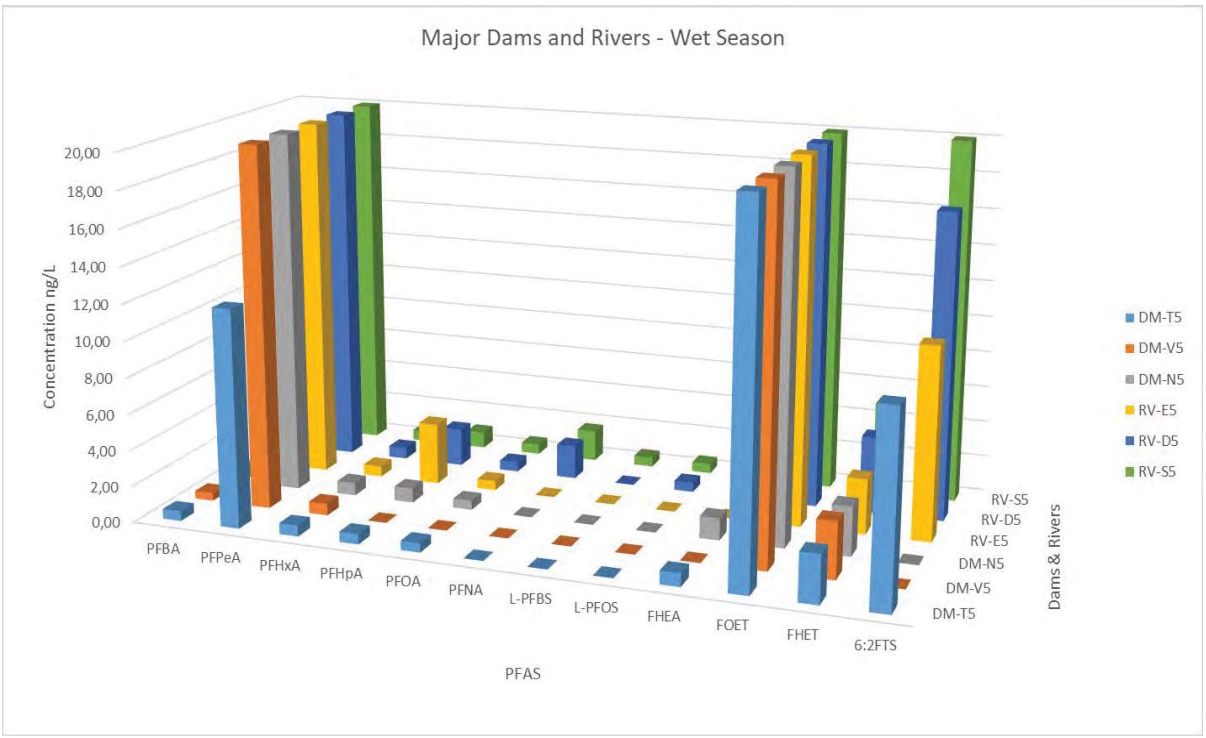

Figure 5-10: PFAS in major dams and rivers samples wet season – fifth sampling cycle

5.2.3 Class contribution of PFAS wastewater treatment plant (influent and effluent samples)

The number of PFAS detected for the different seasons ranged from 10 to 12 PFAS, namely PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, L-PFBS, L-PFOS, FHEA, FOET, FHET, and 6:2FTS, as shown below in Figure 5-11 to 5-15 for the different seasons.

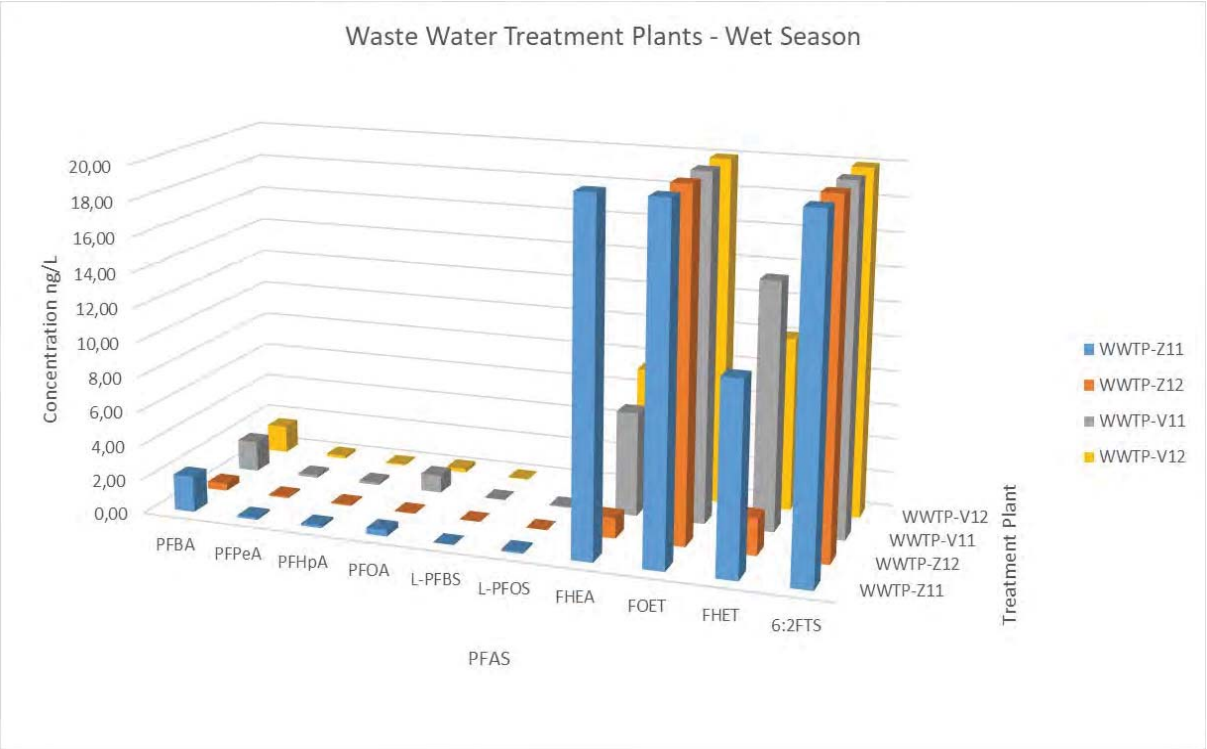

Figure 5-11: PFAS in wastewater treatment plant (influent and effluent samples) wet season – first sampling cycle.

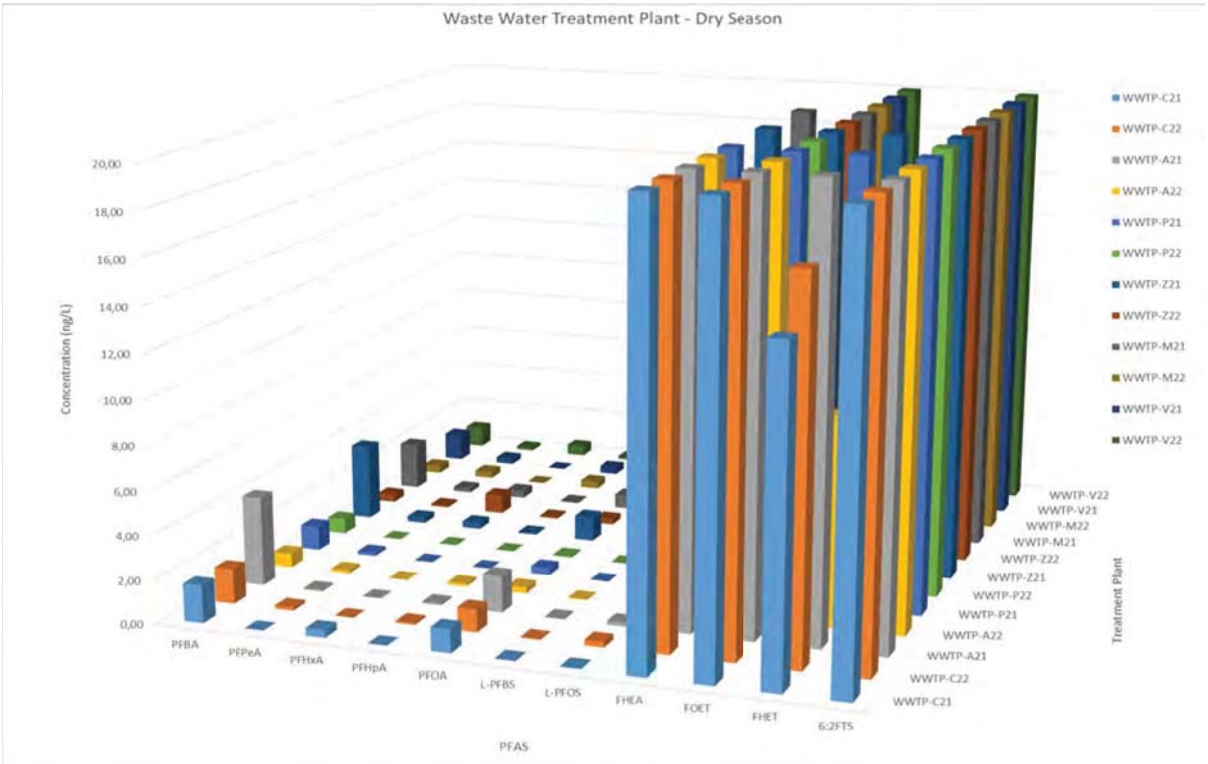

Figure 5-12: PFAS in wastewater treatment plant (influent and effluent samples) dry season – second sampling cycle.

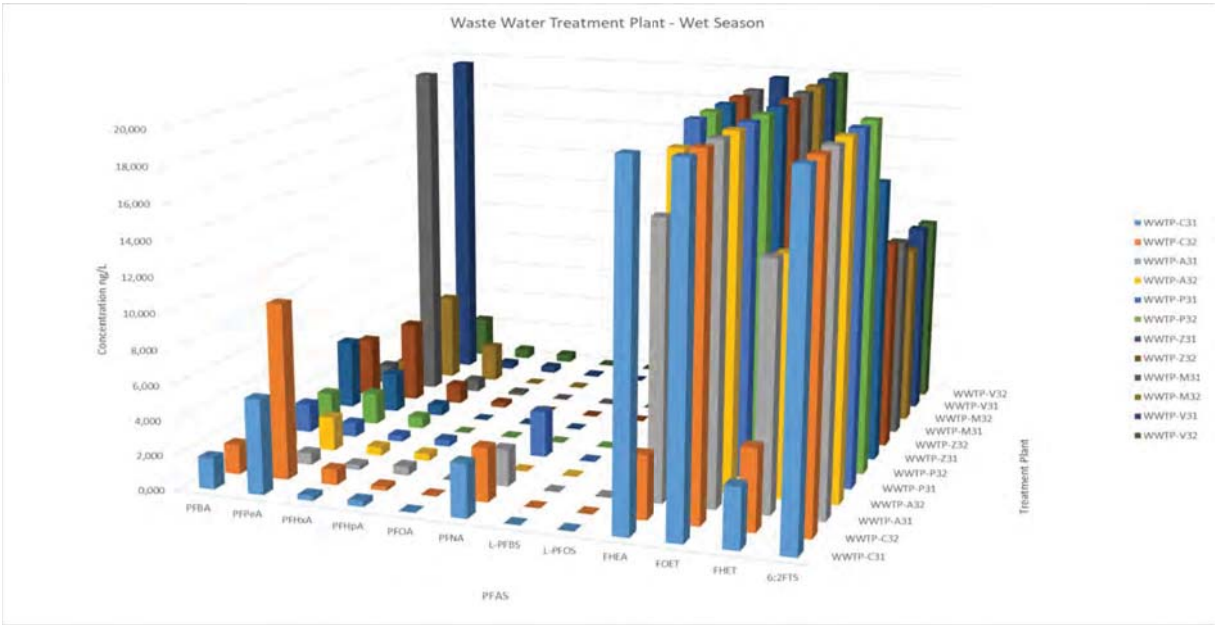

Figure 5-13: PFAS in wastewater treatment plant (influent and effluent samples) wet season – third sampling cycle.

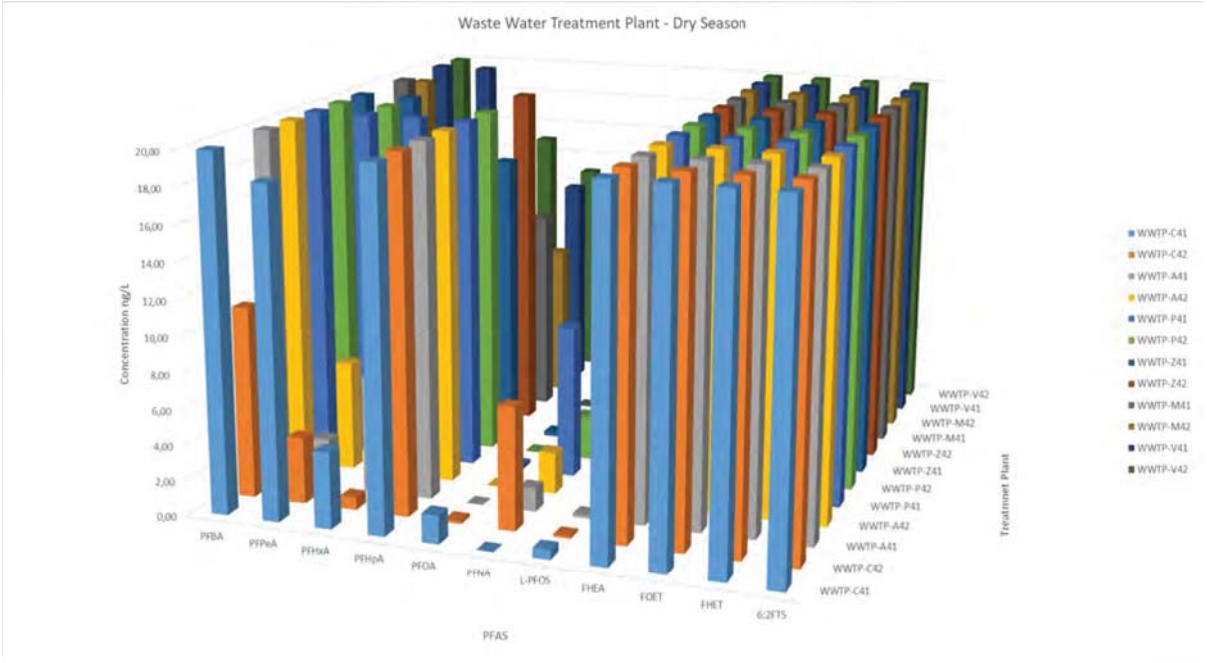

Figure 5-14: PFAS in wastewater treatment plant (influent and effluent samples) wet season – fourth sampling cycle.

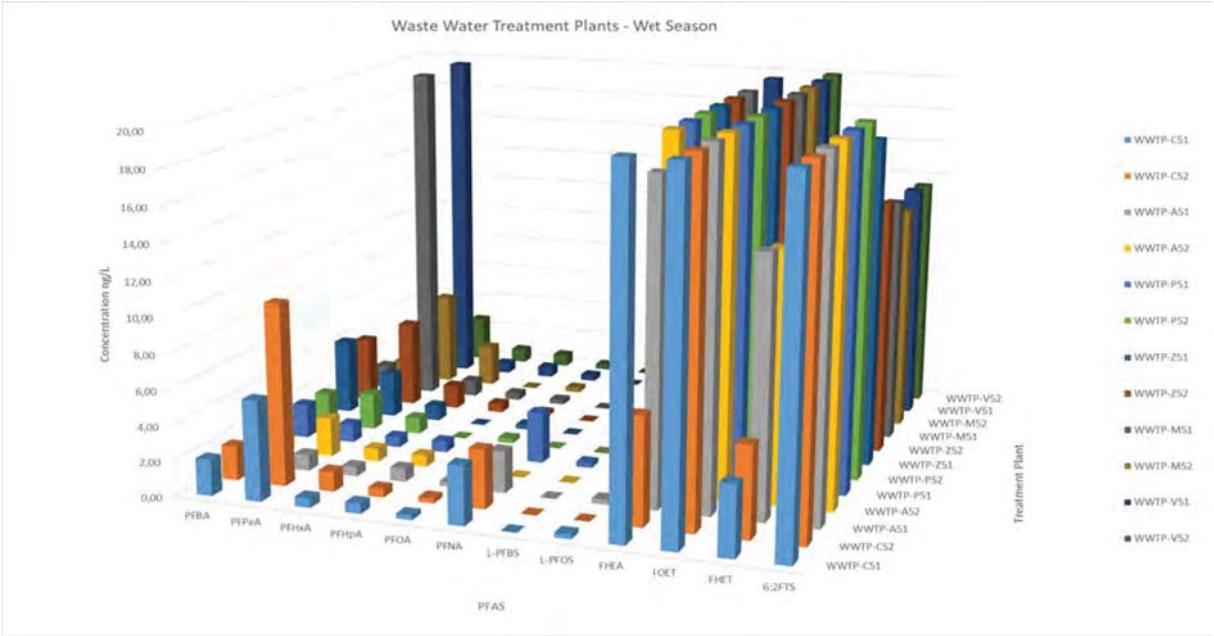

Figure 5-15: PFAS in wastewater treatment plant (influent and effluent samples) wet season – fifth sampling cycle.

5.2.4 Class contribution of PFAS in the Western Cape Province

Figure 5-16 and 5-17 illustrate the contributions of PFAS classes from various water sources in the Western Cape Province during the dry and wet seasons. As previously indicated, the WWTP has a high PFAS and is mainly dominated by telomers and PFCAs comprising FOET, 6-2 FTS, FHET, FHEA and PFBA, PFOA, PFPeA, and PFHpA. In the RV, most PFAS are telomers (FOET, 6-2 FTS, FHET, FHEA) and PFCAs (PFBA, PFOA, and PFPeA). In DWTP, the dominant PFAS are telomers (FOET, 6-2 FTS, FHET, FHEA) and PFCAs (PFBA, PFOA, and PFPeA). The dry- and wet-season PFAS were comparable in terms of occurrence. PFCAs had a lower % contribution than the telomers. The observed trend confirms that WWTP have the highest PFAS, followed by rivers, DWTP, and dams.

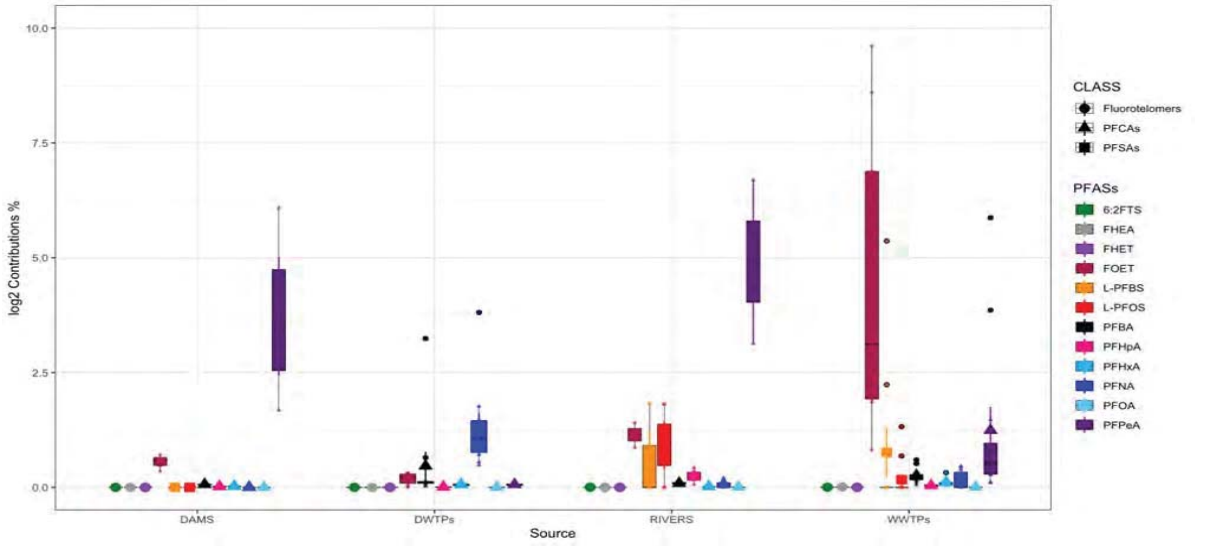

Figure 5-16: Spatial and temporal PFAS class contributions in various water sources in the Western Cape Province – wet season.

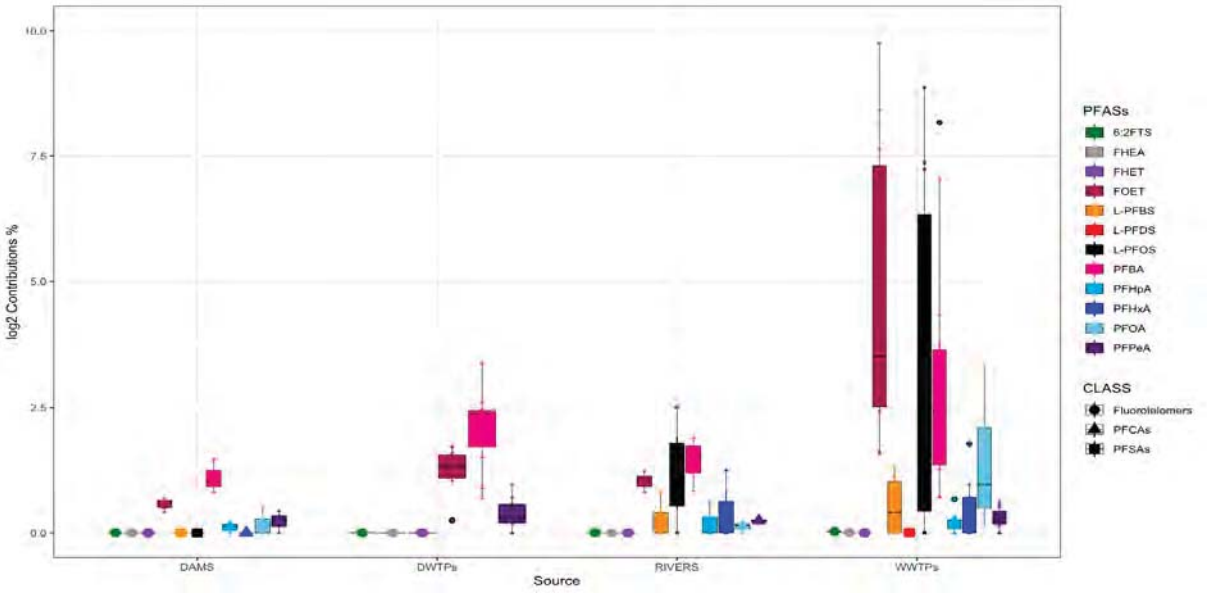

Figure 5-17: Spatial and temporal PFAS class contributions in various water sources in the Western Cape Province – dry season.

5.3 PFAS CONGENER CONTRIBUTIONS AND THEIR RELATIONSHIPS IN SOURCE APPORTIONMENT

In Western Cape, there was an observed correlation for the PFCAs (PFBA, PFHpA, PFHxA, and PFPeA) during the wet season, suggesting similar sources, as shown in Figures 5-18 and 5-19. There is also a close correlation between the fluorotelomers (6:2 FTS, FOET, FHEA, and FHET) which suggests a similar source. Since some fluorotelomers are known to be a source of PFCAs, the high detection of fluorotelomers may explain the prevalence of PFBA detected in all water sources, as they are also positively associated in the dry season. The PFNA, PFBS, and PFOS congeners were closely associated with each other during the dry season. During the dry season, the fluorotelomer FHET was closely associated with PFOA, PFHpS, and PFHxS, suggesting that it is a source of PFAS.

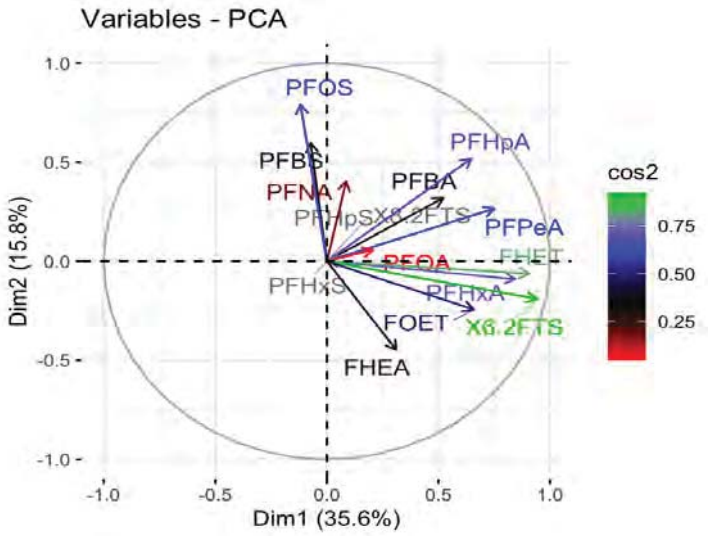

Figure 5-18: Sampling sites and their relationships in the Western Cape Province during the wet season.

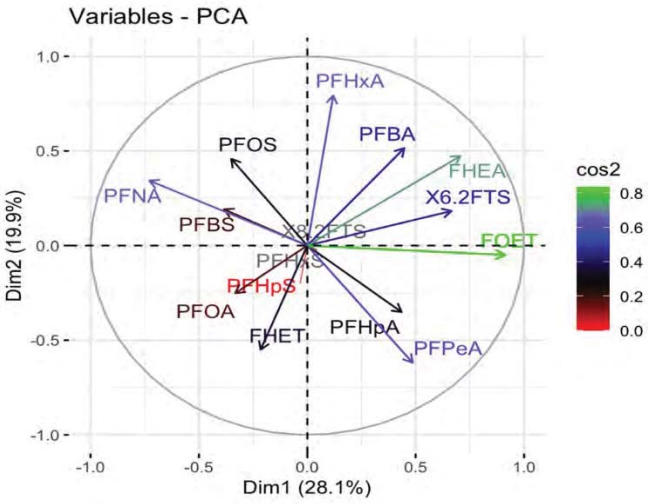

Figure 5-19: Sampling sites and their relationships in the Western Cape Province during the dry season.

5.3.1 Sampling Sites and their Relationships in Source Apportionment

As shown in Figures 5-20 and 5-21, the WWTP are clustered together, suggesting that they have similar PFAS across these water sources. The DWTP are also clustered together, and there are a few DWTP that share similar PFAS as the WWTP in both seasons and possibly similar sources. DM and RV also clustered together. Some WWTP are close to firefighting stations, while others are closer to airports which use firefighting forms which contain PAFAS. The WWTP also discharges to the rivers and contains PFAS that come from the WWTP.

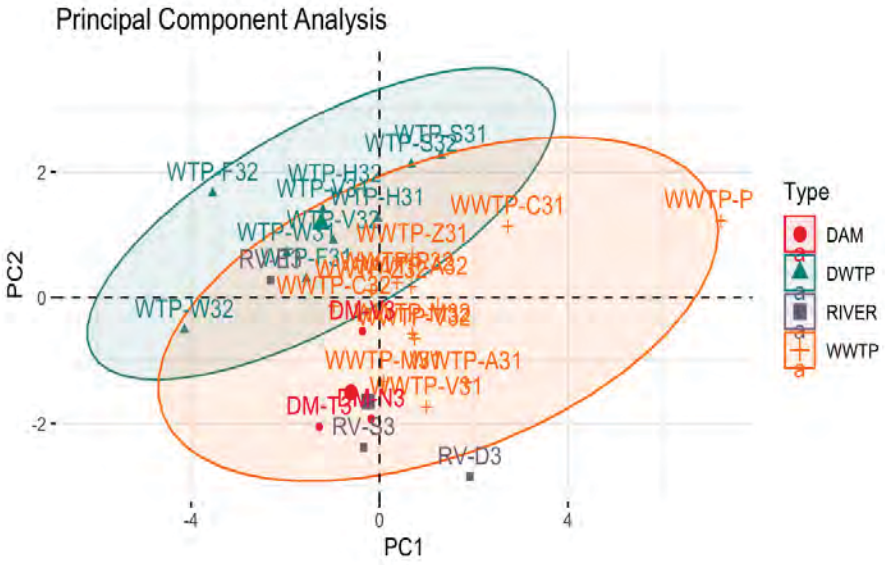

Figure 5-20: PFAS congener contributions and their relationships in source apportionment in the Western Cape Province during the wet season

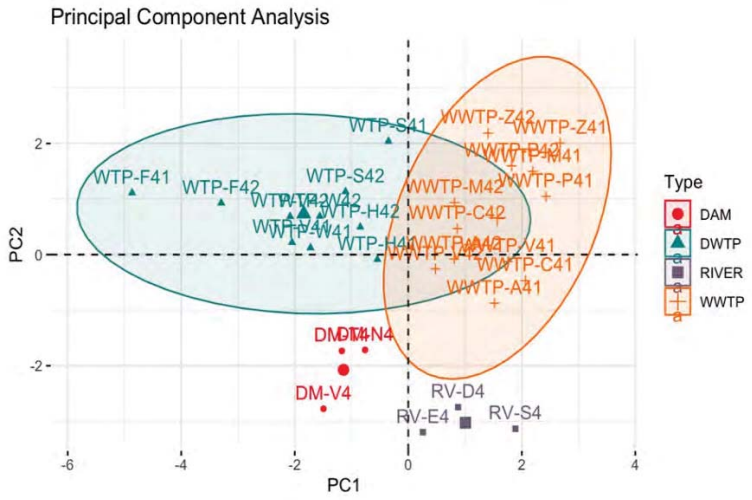

Figure 5-21: PFAS congener contributions and their relationships in source apportionment in the Western Cape Province during the dry season.

5.4 MONITORING PFAS IN WATER USING PASSIVE SAMPLING

Passive sampling is a useful technique for monitoring per- and polyfluoroalkyl substances (PFAS) in various environmental media including water. This allows for the continuous collection of PFAS over an extended period, providing valuable information on their presence and distribution. Before deployment, the POCIS-HLB used was calibrated using 21 PFAS mix standard compounds for 14 days. The calibration plots of POCIS-HLB adsorption of PFAS are shown in Figure 5-22. As can be seen, the uptake of PFAS was linear, except for PFPeA.

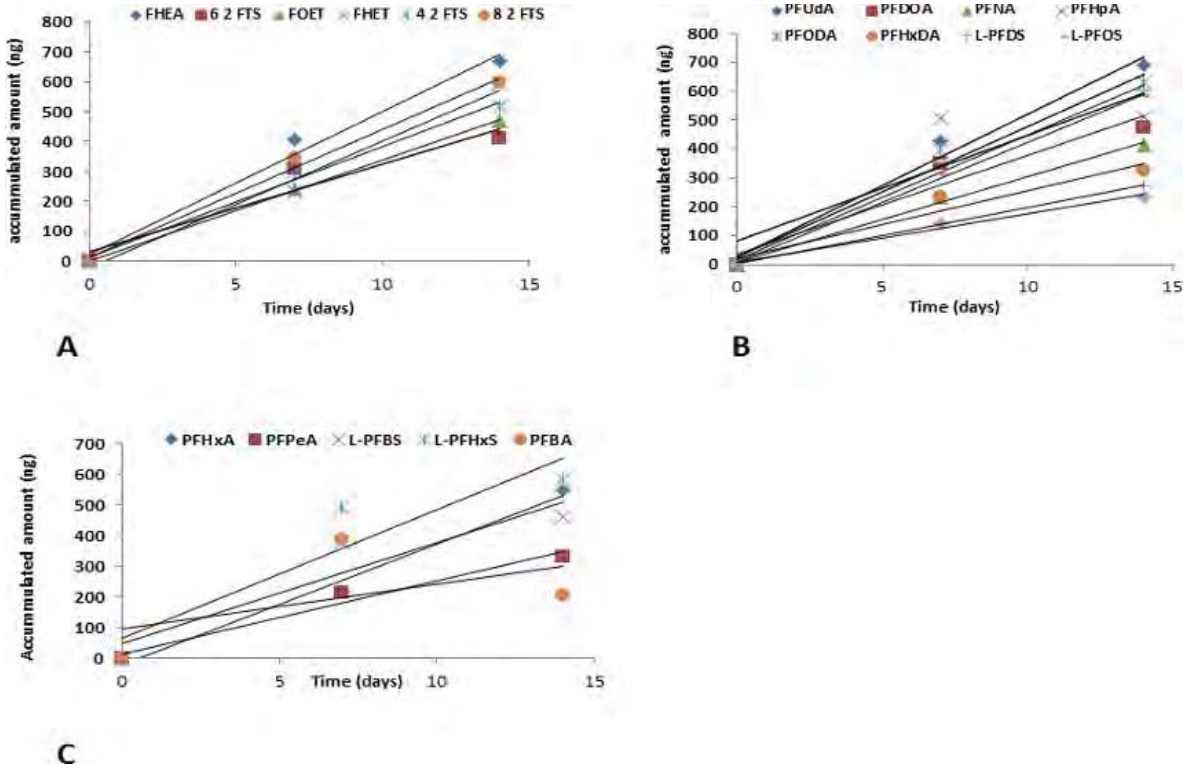

Figure 5-22: Uptake profile of individual PFAS for POCIS-HLB samplers over 14-day period (A) Fluorotelomers, (B) Long chain and (C) short chain PFAS

The sampling rates were determined from linear plots, as previously reported (Arditsoglou and Voutsa, 2008; Morin *et al.*, 2012; Weiss *et al.*, 2015). Sampling rates were calculated using the following equation:

$$C_w = C_s M_s / R_s t \quad \text{(Equation 6.1)}$$

where C_w and C_s are the concentrations of PFAS the water (ng/L) and in the POCIS (ng/g) respectively, M_s is the mass of the sorbent in the POCIS (g), Rs is the sampling rate (L/day) and t is the sampling period (days). The determined sampling rates range from 0.0029-0.099 L/day as shown in Table 5-2.

Table 5-2: Sampling rates for the calibration of POCIS-HLB samplers

Compound	*RS (L days^{-1})	*R^2
4:2 FTS	0.0523±0,066	0.9923
6:2 FTS	0.010±0,002	0.9239
8:2 FTS	0.041±0,033	0.9921
FHEA	0.099±0,023	0.9842
FHET	0.054±0,046	0.9843
FOET	0.044±0,184	0.9997
L-PFBS	0.036±0,043	0.8759
L-PFDS	0.0029±0,023	0.9995
L-PFHpS	0.018±0,632	0.9886
L-PFHxS	0.031±0,01	0.8654
L-PFOS	0.0081±0,14	0.9984
PFBA	0.004±0,14	0.9755
PFDOA	0.052±0,006	0,9299
PFHpA	0.077±0,043	0.7576
PFHxA	0.020±0,036	0.9850
PFHxDA	0.050±0,056	0.9410
PFNA	0.076±1,10	0.9941
PFOA	0.087±0,001	0.9892
PFODA	0.061±0,061	0.9806
PFPeA	0.084±0,045	0.2824
PFUdA	0.012±0,901	0.9817

*RS= sampling rate, R^2 = regression

Of the 21 PFAS studied, 14 were detected, except for 4:2 FTS, L-PFBS, L-PFDS, L-PFHxS, PFHxDA, and PFDOA. FOET had the highest concentration of 305 125.17±0.59 ng/L (Table 5-3). A similar trend was also observed with grab sampling. This trend is in line with grab sampling over the duration of this study. The difference between the concentrations recorded for the two sampling methods was because grab samples provide only snapshot concentrations, while passive sampling provides time-weighted average concentrations. The higher PFAS concentrations observed in passive sampling indicate the ability of the sampler to adsorb more PFAS.

Table 5-3: Mean concentrations of PFAS in passive samples and grab samples for three WWTPs after 14 days

	WWTP-C Influent	WWTP-C Effluent	WWTP-C Influent	WWTP-C Effluent	WWTP-M Influent	WWTP-M Effluent	WWTP-M Influent	WWTP-M Effluent
PFAS	Passive sample (ng/L)	Passive sample (ng/L)	Grab sample (ng/L)	Grab sample (ng/L)	Passive sample (ng/L)	Passive sample (ng/L)	Grab sample (ng/L)	Grab sample (ng/L)
4:2 FTS	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
6:2 FTS	975.11±0.07	378.11±0.07	751.62±0.17	229.32±0.17	638.22±0.15	1300.45±0.67	43512±0.06	305±0.06
8:2 FTS	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
FHEA	724.70±0.31	294.67±0.56	538.64±0.28	253.85±0.28	688.74±0.33	655.44±0.01	477.36±0.098	401.42±0.098
FHET	218.75±0.125	59.55±0.125	125.76±0.72	116.35±0.72	99.52±0.64	189.88±0.49	71.23±0.67	67.12±0.67
FOET	234875.08±0.64	55980.56±0.45	75489.23±0.55	47766.04±0.55	305125.17±0.59	419745.33±0.65	374012.78±0.76	350789.78±0.76
L-PFBS	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
L-PFDS	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
L-PFHpS	1.05.67±0.29	0.907.17±0.45	0.12±0.65	0.05±0.65	0.075±0.195	0.685±0.78	0.065±0.039	0.06±0.039
L-PFHxS	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
L-PFOS	1.07±0.75	0.419±0.53	0.27±0.90	0.19±0.90	0.38±056	0.22±0.42	<LOD	<LOD
PFBA	75.61±0.05	35.61±0.05	18.30±0.63	12.8±0.63	32.78±0.03	29.78±0.03	19.35±0.92	18.5±0.92
PFDoA	3.47±0.75	2.66±0.595	Not detected	Not detected	3.06±0.11	2.77±0.82	Not detected	Not detected
PFHpA	1103.56±0.78	73.69±1.9	95.11±1.3	53.61±1.3	22.03±0.76	19.87±0.35	15.17±0.75	10.77±0.75
PFHxA	8.16±0.03	1.72±0.45	5.22±0.15	3.82±0.15	2.77±0.22	5.63±0.05	4.75±0.57	3.55±0.57
PFHxDA	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
PFNA	14.54±0.61	9.14±0.16	<LOD	<LOD	9.88±0.33	7.64±0.32	<LOD	<LOD
PFOA	3.63±0.029	0.73±0.025	0.97±1.15	0.23±1.15	0.87±0.12	0.18±0.72	<LOD	<LOD
PFODA	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
PFPeA	35.34±0.12	15.86±0.26	11.12±0.97	7.81±0.97	16.84±0.76	11.55±0.96	8.13±0.62	7.17±0.62
PFUdA	0.327±0.96	0.409±0.36	<LOD	<LOD	0.27±0.65	0.21±0.56	<LOD	<LOD

5.5 POTENTIAL HUMAN HEALTH RISKS ASSOCIATED WITH EXPOSURE TO PER- AND POLYFLUOROALKYL SUBSTANCES IN WATER

Assessing human health risks from exposure to perfluoroalkyl substances (PFAS) in water is crucial because of their widespread use and persistence. These synthetic chemicals enter water sources via industrial discharge, runoff, and groundwater contamination. Chronic exposure to PFAS has been linked to health issues such as reproductive and developmental problems, immune system disruption, and a higher risk of certain cancers. Studies have linked perfluorooctanoic acid (PFOA) and perfluorooctanoate sulfonate (PFOS) to health effects, including kidney cancer, thyroid problems, and high cholesterol levels (Figure 5-23). A thorough assessment of human health risks associated with PFAS will aim to evaluate these risks to guide regulatory actions, improve water treatment strategies, and protect public health from PFAS contamination.

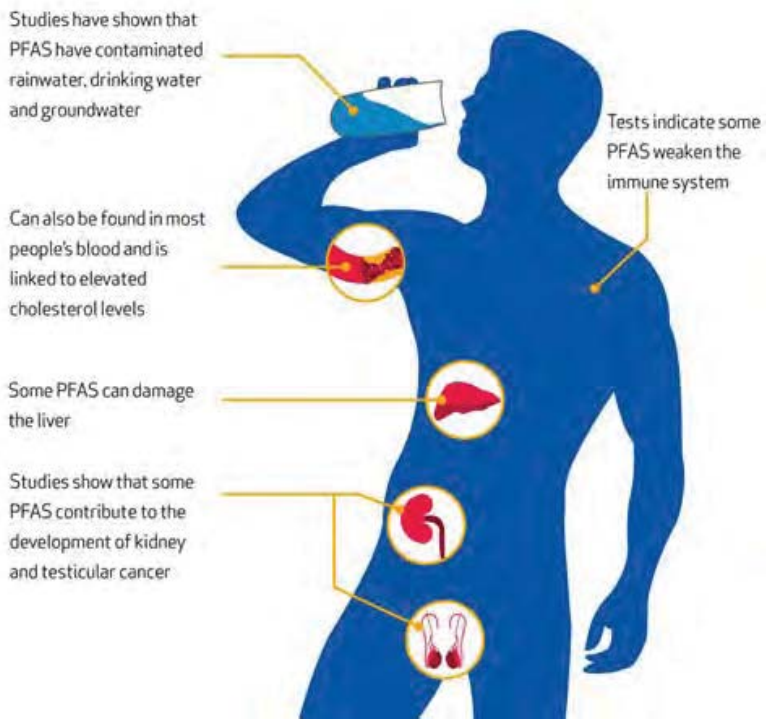

Figure 5-23: Health Effects of PFAS in a human body - https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

5.6 SUMMARY

Different water sources were sampled in the Western Cape: drinking water treatment plants (raw and final water samples), wastewater treatment plants (influent and effluent water samples), and major dams and river water samples. It was established that there was a high concentration of PFAS in wastewater treatment plants with comparable concentrations in the influent and effluent water samples. The second-highest PFAs concentration was found in rivers because most wastewater treatment plants discharge into rivers before the water goes to the ocean. The lowest PFAs concentrations were found in drinking water treatment plants and major dams. Carboxylic acids and fluorotelomers were the most dominant compounds, especially in WWTP, followed by rivers, dams, and drinking water treatment plants. Perfluoro-n-butanoic acid (PFBA), Perfluoro-n-pentanoic acid (PFPeA), Perfluoro-n-hexanoic acid (PFHxA), Perfluoro-n-heptanoic acid (PFHpA), Perfluoro-n-octanoic acid (PFOA) are the most prevalent carboxylic acids. Detection ranges from 90 – 100% for Perfluoro-n-butanoic acid (PFBA), 80 – 100% for

Perfluoro-n-pentanoic acid (PFPeA), 10 – 31% for Perfluoro-n-hexanoic acid (PFHxA), 33 – 100% for Perfluoro-n-heptanoic acid (PFHpA), and 40 – 100% Perfluoro-n-octanoic acid (PFOA). Dominant fluorotelomers are 2-Perfluorohexyl ethanoic acid (FHEA), 8:2 Fluorotelomer alcohol (FOET), 6:2 Fluorotelomer Alcohol (FHET), and 6:2 Fluorotelomer sulfonate (6:2 FTS). Fluorotelomer carboxylic acid (FTCA) compounds are known to form through biodegradation of fluorotelomer alcohols. Fluorotelomers are *poly*fluoroalkyl compounds. Unlike many other PFAS, fluorotelomer alcohols are highly volatile. Consequently, volatilisation is a primary transport pathway for these compounds. As they oxidize in the atmosphere, they break down into perfluorinated carboxylic acids, such as PFOA.

Percentage detection ranges from 50 – 100% for 2-Perfluorohexyl ethanoic acid (FHEA), 100% for 8:2 Fluorotelomer alcohol (FOET), 100% for 6:2 Fluorotelomer Alcohol (FHET), and 100% for 6:2 Fluorotelomer sulfonate (6:2 FTS).

Fluorotelomer sulfonic acids (FTSA): The n:2 fluorotelomer sulfonic acids (n:2 FTSAs) are associated with aqueous film forming foam (AFFF) in wastewater treatment plant effluents, and landfill leachate. The Western Cape is mostly known for its cape fires; as a result, fire foams are highly used. These aqueous film-forming foams (AFFF) are water-based and frequently contain hydrocarbon-based surfactants, such as sodium alkyl sulphate, and fluorosurfactants, such as fluorotelomers, perfluorooctanoic acid (PFOA), or perfluorooctanesulfonic acid (PFOS), giving rise to the high PFAS concentrations found in wastewater treatment plants.

Water samples were collected from different water sites. In the Western Cape, the water flows from the dams to the water treatment plants where it is treated and ready for household and industrial use. Once used, it is channelled to different wastewater treatment plants, where it is treated and discharged to the Salt, Diep, and Eerste Rivers. These three rivers end up in the Atlantic Ocean, where they discharge all their water, including treated water. The water in these rivers is not linked to any of the dams, which are sources of the Western Cape water treatment plants. Figure 5-24 shows the linear flow water system in the Western Cape. The Dams feed water to the drinking water treatment plant which is then treated and sent to the water reservoirs. From the water reservoirs, water is distributed for domestic, industrial, and other uses; from domestic and industrial use, it then goes to the sewage and is sent to the wastewater treatment plants for treatment. Once treated in a wastewater treatment plant, it is discharged into rivers which end in the ocean. For this reason, a high concentration of PFAS is found in wastewater treatment plants and rivers, but not in dams and water treatment plants.

Figure 5-24: A linear system water flow similar to the Western Cape Dams, Water Treatment Plants, Wastewater Treatment Plants and Rivers - https://watermanaustralia.com/sewage-treatment-plant-for-africa-to-eliminate-viral-and-parasitic-organisms/.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 OVERVIEW

PFAS are key components in aqueous film-forming foams (AFFF), which are used to fight petroleum-based fires in aviation and manufacturing facilities. Traditional Aqueous Film-Forming Foam (AFFF), the Class B firefighting foam used to fight aviation and other chemical fires, typically contains PFAS. After AFFF is used in an emergency or training exercise, it can seep into the ground to contaminate the local soil and groundwater (Figure 6-1). AFFF that enters the storm drainage system can also lead to contamination of the public water supply when it is sent to the local water treatment plant. For decades, AFFF containing PFAS has been used extensively at airports throughout the world to protect the safety of passengers, crew and others. The U.S. Federal Aviation Administration (FAA) requires commercial airports to train with, calibrate equipment with, and use the best-performing AFFF fire suppression systems. AFFF is required to be used at airports and must be certified to meet strict performance specifications, including the U.S. Department of Defence Military Specifications. The chemical properties of PFAS is what makes AFFF so effective at suppressing fires.

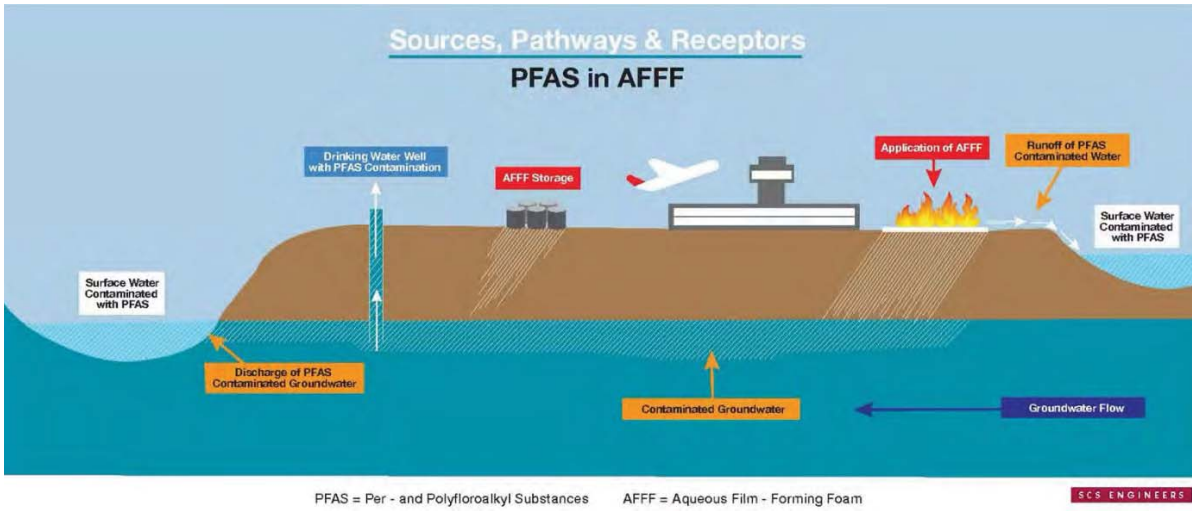

Figure 6-1: Sources, pathways and receptors of PFAS in AFFF in an Airports - https://www.aviationpros.com/aoa/aircraft-rescue-firefighting-arff/article/21092898/the-evolving-concern-of-pfas-at-airports.

In effect, AFFF forms a dense “foam blanket” that prevents oxygen from reaching the fire and smothers it. PFAS can travel long distances, move through soil, seep into groundwater, or be transported through the air. AFFF is released to the environment under various scenarios. At airports, AFFF are deployed intentionally for training, testing, and operational requirements or emergency response. It may also be accidentally released during delivery, transfer, and storage. In the past, the hazards to human health and the environment were not as well-known as they are today, and there were few guidelines for the handling and management of AFFF and wastewater contaminated with foam. Wastewater contaminated with AFFF (e.g. firefighting runoff) is often treated as storm water and is allowed to seep into soil or is discharged as surface water runoff. Storage tanks and drums containing AFFF sometimes leak and, in this case, can release PFAS into the subsurface. PFAS and PFAS contamination will migrate downward within the soil column. If the mass is sufficiently large, it can migrate and contaminate groundwater. Contaminated groundwater can then reach sensitive receptors by being extracted from drinking water

wells or by recharging surface water features, such as rivers or creeks. In both instances, PFAS become part of the food chain by being ingested by humans and wildlife.

6.2 CONCLUSIONS

In this project, six rounds of water sampling were completed during the wet and dry seasons over a period of thirty-six (36) months. Water samples were collected from five water treatment plants, six wastewater treatment plants (only two plants in season one because we had not received approval from the City of Cape Town), three dams, and three rivers. The physicochemical properties of these water samples have been reported. The two sampling methods that were used in this project were grab sampling and passive sampling. The four water sampling sources, namely water treatment plant, wastewater treatment plant, dams and rivers were studied for presence of selected 21 PFAS. Out of the 21 PFAS, only three compounds 6:2 FTS, FOET and FHET were found to be prevalent throughout the sampling locations. The results show detectable concentrations especially for the short chain PFAS. Long chain PFAS were detected at lower levels, suggesting that they are less prevalent in the samples collected.

Another reason for non-detection of long chain may be due to their low solubility in water. The impact of the restrictions and regulations placed on long chain PFAS and use of shorter chain as alternatives was visible in the results reported in the province. The wastewater treatment plant samples showed high concentrations of PFAS than all other sources, followed by rivers, dams and water treatment plants. These PFAS detected may have originated from domestic waste from the use of PFAS-containing products that are flushed into the sewerage system ending up in wastewater treatment plants. The Western Cape is also known for the cape fires in which fire foams are widely used which might contribute to the high concentrations of PFAS. Waste treatment plant water samples and river water samples contain a high concentration of PFAS because the wastewater after treatment is discharged to all three rivers. The percentage detection of the PFAS ranges from 10 – 100%. Out of the 21 PFAS the detected PFAS ranges from 7 to 12.

None of the banned (PFOA and PFOS) PFAS are found in the Western Cape drinking water treatment plants. These PFAS are below the maximum concentration level issued by the EPA. However, the fluorotelomers were detected in high concentration levels in the WWTP and rivers an indication that most of the PFAS enter the water system post-consumer. The WWTP effluent containing the fluorotelomers ends up in the ocean - marine environment (Petrik et al., 2024). Some of the data obtained from this study were presented at two conferences at the 34th International Symposium on Polymer Analysis and Characterization 24th – 26 April 2023 Stellenbosch, South Africa, and in the Dioxin 2024 – 44th International Symposium on Halogenated Persistent Organic Pollutants (POPs), which was held at the Suntec Convention & Exhibition Centre in Singapore from 29th September to 3 October 2024.

6.3 RECOMMENDATIONS

Based on the findings, the following is recommended:

- Measures for each Drinking Water Treatment Plant based on the seasons analysis for each plant
- Identify the PFAS sources and deal with them from the source
- Incorporate monthly PFAS analysis in drinking water treatment plants and wastewater treatment plants used for agricultural purposes
- Develop a circular water system for wastewater treatment plants

- Global Initiatives and Future Directions

  International efforts to address PFAS contamination include the Stockholm Convention on Persistent Organic Pollutants, which lists PFOS and its related compounds for elimination or restriction. Additionally, the Organization for Economic Co-operation and Development (OECD) has been working on harmonising PFAS regulations and promoting research into alternatives and remediation technologies (OECD, 2019).
- Alternatives to PFAS

  Given the environmental and health concerns associated with PFAS, there is a growing interest in finding safer alternatives. Research is being conducted on alternative chemicals and materials that can provide similar properties without any associated risks. For example, some companies are developing non-fluorinated alternatives for use in textiles and food packaging (KEMI 2015).
- Future Research Directions

  Future research on PFAS should focus on several key areas.
  - **Understanding Health Impacts:** Continued research on the health effects of PFAS exposure, particularly for less-studied compounds, is critical. These include long-term epidemiological and toxicological studies.
  - **Developing Alternatives:** Identifying and evaluating safer alternatives to PFAS for use in consumer products and industrial applications.
  - **Improving Remediation Technologies:** Advancing the development of more effective and cost-efficient technologies to remediate PFAS-contaminated sites.
  - **Enhancing Regulatory Frameworks:** Strengthening global regulatory frameworks to reduce PFAS emissions and protect public health and the environment.

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APPENDIX 1 – PHYSICOCHEMICAL PARAMETERS: DRINKING WATER TREATMENT PLANTS

Table 1: Water Treatment Plants Sample Second Cycle Physicochemical Data

Water Treatment Plant	WTP-F		WTP-W		WTP-V		WTP-S		WTP-H	
Site Coordinates	-34.040117, 18.801864		-33.834328, 19.072877		-33.386923, 19.033370		-34.174547, 18.849335		-34.065058, 18.872518	
Sample Quality:	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL
Sample ID:	WTP-F21	WTP-F22	WTP-W21	WTP-W22	WTP-V21	WTP-V22	WTP-S21	WTP-S22	WTP-H21	WTP-H22
Dissolved Oxygen (mg/L)	7.12	6.15	6.89	6.08	6.87	7.19	7.12	7.31	6.16	5.52
Temperature (°C)	19.8	19.8	20.1	20.0	19.7	19.8	19.8	19.9	19.8	19.8
pH	7.19	6.23	7.15	7.28	6.77	6.70	7.67	7.30	6.51	6.85
Redox potential (mV)	10.8	-42.6	-33.9	-62.0	-67.5	-73.8	-57.4	-97.0	-53.4	-135.2
Conductivity (µs/cm)	67.6	151.0	25.5	38.1	85.8	120.6	66.7	106.5	84.3	150.8
Total Dissolved Solids (ppm)	34.1	74.9	12.94	19.05	43.4	60.3	33.6	51.1	43.4	75.1

Table 2: Water Treatment Plants Sample Third Cycle Physicochemical Data

Water Treatment Plant	WTP-F		WTP-W		WTP-V		WTP-S		WTP-H	
Site Coordinates	-34.040117, 18.801864		-33.834328, 19.072877		-33.386923, 19.033370		-34.174547, 18.849335		-34.065058, 18.872518	
Sample Quality:	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL
Sample ID:	WTP - F31	WTP - F32	WTP - W31	WTP - W32	WTP - V31	WTP - V32	WTP - S31	WTP - S32	WTP - H31	WTP - H32
Dissolved Oxygen (mg/L)	5.1	5.1	5.4	5.4	5.7	5.2	5.3	5.2	5.2	5.3
Temperature (°C)	18.9	19.0	18.8	18.7	18.9	18.6	19.1	18.9	18.7	18.9
pH	6.78	7.0	6.54	7.25	7.52	7.54	6.91	6.87	6.97	7.01
Redox potential (mV)	12.8	-90.8	25.7	-14.1	-30.1	-32.4	58.6	9.0	1.7	-120.4
Conductivity (µS/cm)	74.8	149.4	28.2	86.8	92.7	129.0	74.1	118.5	82.9	148.3
TDS mg/L(ppm)	75	149	28	87	92	129	74	118	83	149
% Dissolved Oxygen (%)	56	56	61	59	69	56	58	56	56	57
Pressure mBar	115	114	124	121	141	115	118	116	115	118
ρ (KΩ*cm)	13.36	6.70	35.4	11.53	10.86	7.76	13.50	8.43	12.06	6.75
Salinity	0	0	0	0	0	0	0	0	0	0

Table 3: Water Treatment Plants Sample Fourth Cycle Physicochemical Data

Water Treatment Plant	WTP-F		WTP-W		WTP-V		WTP-S		WTP-H	
Site Coordinates	-34.040117, 18.801864		-33.834328, 19.072877		-33.386923, 19.033370		-34.174547, 18.849335		-34.065058, 18.872518	
Sample Quality:	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL
Sample ID:	WTP – F41	WTP – F42	WTP – W41	WTP – W42	WTP – V41	WTP – V42	WTP – S41	WTP – S42	WTP – H41	WTP – H42
Dissolved Oxygen (mg/L)	5.2	5.5	5.2	5.2	5.3	5.3	5.1	5.4	5.3	5.2
Temperature (°C)	19.7	19.4	19.3	19.4	19.5	19.3	19.2	19.3	19.4	19.4
pH	6.25	6.44	6.83	6.56	6.52	6.33	6.72	6.50	6.55	6.46
Redox potential (mV)	41.5	31.9	15.8	24.5	28.3	31.9	27.4	28.0	27.0	27.5
Conductivity (µS/cm)	59.3	94.8	34.2	58.7	107.5	144.4	94.1	132.8	118.4	148.5
TDS mg/L(ppm)	59.0	95.0	34.0	59.0	107.0	144.0	94.0	133.0	118.0	149.0
% Dissolved Oxygen (%)	57.0	61.0	58.0	59.0	58.0	59.0	57.0	59.0	57.0	58.0
Pressure mBar	121.0	126.0	118.0	119.0	117.0	121.0	116.0	120.0	121.0	117.0
ρ (KΩ*cm)	16.0	10.5	29.1	17.0	9.3	6.9	10.6	7.5	8.5	6.7
Salinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4: Water Treatment Plants Sample Fifth Cycle Physicochemical Data

Water Treatment Plant	WTP-F		WTP-W		WTP-V		WTP-S		WTP-H	
Site Coordinates	-34.040117, 18.801864		-33.834328, 19.072877		-33.386923, 19.033370		-34.174547, 18.849335		-34.065058, 18.872518	
Sample Quality:	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL
Sample ID:	WTP – F51	WTP - F52	WTP – W51	WTP – W52	WTP - V51	WTP – V52	WTP - S51	WTP – S52	WTP - H51	WTP – H52
Dissolved Oxygen (mg/L)	4.4	5.1	4.5	5.2	4.5	5.2	4.9	4.6	5.0	5.1
Temperature (°C)	22.4	22.0	22.2	22.1	22.2	22.0	22.3	22.3	22.3	22.4
pH	7.55	7.29	7.39	6.31	6.33	7.66	7.91	7.30	7.06	8.83
Redox potential (mV)	-28.1	-17.1	-23.1	31.1	14.9	-86.5	-51.1	-14.9	-5.5	-113.5
Conductivity (µS/cm)	70.2	124.5	32.9	115.3	97.6	152.4	76.3	116.1	119.3	187.7
TDS mg/L(ppm)	69	125	33.1	115	97	151.9	76	116	120	188
% Dissolved Oxygen (%)	51	59	55	60	53	60	56	54	57	58
Pressure mBar	108	118	110	120	110	120	112	108	116	117

ρ (KΩ*cm)	14.77	8.09	30.3	8.66	10.28	6.56	13.13	8.61	7.99	5.33
Salinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5: Water Treatment Plants Sample Sixth Cycle Physicochemical Data

Water Treatment Plant	WTP-F		WTP-W		WTP-V		WTP-S		WTP-H	
Site Coordinates	-34.040117, 18.801864		-33.834328, 19.072877		-33.386923, 19.033370		-34.174547, 18.849335		-34.065058, 18.872518	
Sample Quality:	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL	RAW	FINAL
Sample ID:	WTP – F61	WTP – F62	WTP – W61	WTP – W62	WTP – V61	WTP – V62	WTP – S61	WTP – S62	WTP – H61	WTP – H62
Dissolved Oxygen (mg/L)	3.9	4	4.1	3.9	3.8	3.8	3.7	3.8	3.8	3.9
Temperature (°C)	19.9	19.1	19.5	19.5	19.4	19.8	19.9	20.0	19.7	19.9
pH	5.82	6.07	5.89	5.90	6.18	6.59	6.06	8.85	7.12	7.73
Redox potential (mV)	54.1	53.1	59.3	36.7	44.8	-39.2	54.3	-91.2	-6.7	-48.4
Conductivity (µS/cm)	70.8	119.2	33.2	69.1	108.4	153.4	72.5	125.1	84.7	178.9
TDS mg/L(ppm)	71	119	33	69	109	153	73	125	85	179
% Dissolved Oxygen (%)	44	45	46	43	42	42	42	43	43	43
Pressure mBar	91	92	93	87	88	86	86	88	88	88
ρ (KΩ*cm)	14.1	8.38	30.3	14.14	9.20	6.52	13.81	8.03	11.83	5.63
Salinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX 2 - PHYSICOCHEMICAL PARAMETERS: WASTEWATER TREATMENT PLANTS

Table 1: Wastewater Treatment Plant Sample Second Cycle Physicochemical Data

Treatment Plant	WWTP-C		WWTP-A		WWTP-Z		WWTP-P		WWTP-M		WWTP-V	
Site Coordinates	-34.080819, 18.521743		-33.955240, 18.512890		-34.052811, 18.712765		-33.840378, 18.522071		-34.074422, 18.766837		-33.386923, 19.033370	
Sample Quality:	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Sample ID:	WWTP-C21	WWTP-C22	WWTP-A21	WWTP-A22	WWTP-Z21	WWTP-Z22	WWTP-P21	WWTP-P22	WWTP-M21	WWTP-M22	WWTP-V21	WWTP-V22
Dissolved O_2 (mg/L)	0.23	0.20	0.29	2.98	0.36	3.07	0.22	5.54	0.16	3.03	4.67	5.43
Temperature (°C)	18.4	18.1	18.5	18.5	20.0	19.5	18.2	19.1	18.6	18.5	19.3	19.5
pH	6.30	6.46	6.56	6.42	6.50	6.31	6.14	6.48	6.48	6.95	6.08	6.04
Redox Potential (mV)	2.1	-17.1	-4.2	-18.1	8.6	5.3	12.6	10.7	-1.4	-29.7	75.8	26.3
Conductivity (µS/cm)	1060	1063	1396	1222	1091	623	1484	977	1523	1523	930	944
TDS (ppm)	530	531	698	611	545	311	742	489	762	761	465	471

Table 2: Wastewater Treatment Plant Sample Third Cycle Physicochemical Data

Treatment Plant	WWTP-C		WWTP-A		WWTP-Z		WWTP-P		WWTP-M		WWTP-V	
Site Coordinates	-34.080819, 18.521743		-33.955240, 18.512890		-34.052811, 18.712765		-33.840378, 18.522071		-34.074422, 18.766837		-33.386923, 19.033370	
Sample Quality:	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Sample ID:	WWTP-C31	WWTP-C32	WWTP-A31	WWTP-A32	WWTP-Z31	WWTP-Z32	WWTP-P31	WWTP-P32	WWTP-M31	WWTP-M32	WWTP-V31	WWTP-V32
Dissolved O_2 (mg/L)	1.4	3.8	0.7	4.1	3.0	4.9	0.90	3.7	4.4	5.1	5.5	5.7
Temperature (°C)	19.5	19.7	19.3	19.1	19.0	19.1	19.0	20.0	19.6	19.8	19.6	19.0
pH	5.81	5.73	5.59	5.50	6.15	6.18	5.95	5.81	7.66	7.79	6.08	6.05
Redox Potential (mV)	-36.2	-27.6	-10.1	-36.1	-27.3	-41.4	-25.2	-41.1	-38.2	-45.8	-32.0	30.3
Conductivity (µS/cm)	1013	1031	1510	1435	891	946	1473	1310	850	1333	1003	1154
TDS (ppm)	1013	1031	1510	1435	890	946	1473	1310	850	1333	1003	1154
Dissolved Oxygen (%)	16	42	6	45	32	54	7	41	49	56	61	61
Pressure mBar	32	86	11	93	65	110	14	84	100	115	124	124
ρ (kΩ*cm)	0.987	0.969	0.662	0.697	1.122	1.057	0.679	0.763	1.177	0.750	0.997	0.867

Salinity	0.4	0.5	0.7	0.7	0.4	0.4	0.7	0.6	0.4	0.6	0.4	0.5

Table 4: Wastewater Treatment Plant Sample Fourth Cycle Physicochemical Data

Treatment Plant	WWTP-C		WWTP-A		WWTP-Z		WWTP-P		WWTP-M		WWTP-V	
Site Coordinates	-34.080819, 18.521743		-33.955240, 18.512890		-34.052811, 18.712765		-33.840378, 18.522071		-34.074422, 18.766837		-33.386923, 19.033370	
Sample Quality:	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Sample ID:	WWTP-C41	WWTP-C42	WWTP-A41	WWTP-A42	WWTP-Z41	WWTP-Z42	WWTP-P41	WWTP-P42	WWTP-M41	WWTP-M42	WWTP-V41	WWTP-V42
Dissolved O_2 (mg/L)	3.02	3.4	1.5	4.3	1.6	4.5	1.8	4.7	4.1	3.5	4.7	4.8
Temperature (°C)	19.3	19.1	19.1	19	19	19.1	19.6	19	19.1	19.1	19	18.9
pH	5.87	5.57	6.54	6.22	6.14	7.09	6.61	7.21	6.62	5.965	4.80	4.68
Redox Potential (mV)	65.4	82.6	26.2	45.3	49.9	-5.2	22.8	-12.8	22.4	60.8	131.2	134.8
Conductivity (µS/cm)	709	701	1314	833	875	657	1490	1011	796	1120	588	579
TDS (ppm)	709	701	1315	832	875	656	1492	1010	796	1120	590	581
Dissolved Oxygen (%)	32	37	16	47	18	50	30	52	46	38	53	50
Pressure mBar	68	72	33	95	36	102	45	106	93	75	106	104
ρ (kΩ*cm)	1.41	1.426	0.761	1.201	1.143	1.523	1	1	1	1	1.697	1.759
Salinity	0.3	0.3	0.6	0.3	0.4	0.2	1	0	0	1	0	0

Table 5: Wastewater Treatment Plant Sample Fifth Cycle Physicochemical Data

Treatment Plant	WWTP-C		WWTP-A		WWTP-Z		WWTP-P		WWTP-M		WWTP-V	
Site Coordinates	-34.080819, 18.521743		-33.955240, 18.512890		-34.052811, 18.712765		-33.840378, 18.522071		-34.074422, 18.766837		-33.386923, 19.033370	
Sample Quality:	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Sample ID:	WWTP-C51	WWTP-C52	WWTP-A51	WWTP-A52	WWTP-Z51	WWTP-Z52	WWTP-P51	WWTP-P52	WWTP-M51	WWTP-M52	WWTP-V51	WWTP-V52
Dissolved O_2 (mg/L)	1.7	3.9	0.9	2.6	3.3	4.6	1.2	4.4	1.7	3.5	4.8	5.0
Temperature (°C)	22.2	22.6	22.5	22.7	22.6	22.7	22.7	22.6	22.5	22.6	22.8	22.6
pH	7.52	7.72	7.48	7.48	7.59	7.34	7.82	7.36	7.63	7.81	6.98	6.89
Redox Potential (mV)	-42.9	-42.5	-26.8	-29.2	-34.8	-21.0	-48.4	-21.3	-36.1	-43.2	7.1	5.1
Conductivity (µS/cm)	1044	1117	1237	1202	995	681	1436	1055	1368	1613	873	866
TDS (ppm)	1049	1117	1238	1202	995	682	1436	1055	1369	1612	873	863

Dissolved Oxygen (%)	20	45	12	27	29	54	26	52	18	44	57	57
Pressure mBar	40	89	25	53	45	114	42	107	40	90	115	121
ρ (kΩ*cm)	0.956	0.885	0.808	0.832	1.005	1.460	0.696	0.948	0.731	0.620	1.145	1.166
Salinity	0.5	0.5	0.6	0.5	0.4	0.3	0.7	0.5	0.6	0.8	0.4	0.4

Table 6: Wastewater Treatment Plant Sample Sixth Cycle Physicochemical Data

Treatment Plant	WWTP-C		WWTP-A		WWTP-Z		WWTP-P		WWTP-M		WWTP-V	
Site Coordinates	-34.080819, 18.521743		-33.955240, 18.512890		-34.052811, 18.712765		-33.840378, 18.522071		-34.074422, 18.766837		-33.386923, 19.033370	
Sample Quality:	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Sample ID:	WWTP-C61	WWTP-C62	WWTP-A61	WWTP-A62	WWTP-Z61	WWTP-Z62	WWTP-P61	WWTP-P62	WWTP-M61	WWTP-M62	WWTP-V61	WWTP-V62
Dissolved O_2 (mg/L)	0.6	0.9	0.7	2.1	0.8	3.2	0.9	0.8	0.5	0.7	0.4	3.2
Temperature (°C)	18.5	18.5	18.6	18.5	18.6	18.6	18.6	18.7	18.6	18.7	18.9	19.0
pH	6.57	6.78	6.25	6.83	6.64	6.57	6.27	6.57	6.58	6.85	7.15	3.43
Redox Potential (mV)	25.0	14.7	43.5	9.4	21.0	20.5	42.6	22.9	24.2	8.0	-8.9	218.9
Conductivity (µS/cm)	1153	1066	1632	1420	1075	658	1403	1066	1865	1656	1315	1144
TDS (ppm)	1153	1067	1632	1421	1074	658	1403	1066	1864	1655	1315	1146
Dissolved Oxygen (%)	9	10	7	4	7	34	9	10	7	8	4	34
Pressure mBar	17	18	12	7	12	71	21	19	12	16	10	68
ρ (kΩ*cm)	0.867	0.938	0.614	0.70	0.931	1.521	0.713	0.938	0.538	0.606	0.760	0.813
Salinity	0.5	0.5	0.8	0.7	0.5	0.2	0.7	0.5	0.9	0.8	0.6	0.5

APPENDIX 3 - PHYSICOCHEMICAL PARAMETERS: FRESHWATER SOURCES

Table 7: Dams and Rivers Sample Second Cycle Physicochemical Data

Water source	Dam-T		Dam-V		Dam-N		Eerste River	Diep River	Salt River
Site	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 1	SITE 1
Site Coordinates	-34.028142, 19.195741	-34.036672, 19.170516	-33.348227, 19.025529		-34.088388, 19.055267		-34.043593, 18.738042	-33.881756, 18.489722	-33.935677, 18.481618
Sample ID:	DM-T21	DM-T22	DM-V21	DM-V22	DM-N21	DM-N22	RV-E2	RV-D2	RV-S2
Dissolved Oxygen (mg/L)	6.03	6.97	6.17	6.89	7.01	6.90	5.99	6.08	3.37
Temperature(°C)	19.9	20.0	20.2	20.2	19.8	19.8	18.8	18.7	18.8
pH	6.70	6.80	6.90	6.90	6.97	6.89	6.80	6.68	6.59
Redox Potential (mV)	6.5	7.3	11.5	0.3	31.6	38.6	-39.1	-36.6	-25.1
Conductivity (µS/cm)	74.1	66.5	86.0	85.9	33.4	34.8	474	4970	961
Total Dissolved Solids (ppm)	37.2	33.4	45.0	43.1	16.94	17.56	238	244	480

Table 8: Dams and Rivers Water Sample Third Cycle Physicochemical Data

Water source	Dam-T	Dam-V	Dam-N	Eerste River	Diep River	Salt River
Site Coordinates	-34.028142, 19.195741	-33.348227, 19.025529	-34.088388, 19.055267	-33.881756 , 18.489722	-34.043593 , 18.738042	-33.935677 , 18.481618
Sample ID:	DM - T3	DM - V3	DM - N3	RV - D3	RV - E3	RV - S3
Dissolved Oxygen (mg/L)	4.9	5.2	5.6	5.1	5.2	3.4
Temperature (°C)	19.4	19.5	19.3	19.6	19.9	19.3
pH	6.73	6.58	6.54	6.45	6.32	6.52
Redox Potential (mV)	22.2	-2.4	82.5	-54.2	-42.2	-29.2
Conductivity (µS/cm)	74.4	89.8	38.7	5100	666	1259
Total Dissolved Solids (ppm)	74	90	39	5100	666	1259
% Dissolved Oxygen (%)	54	58	61	56	58	37
Pressure mBar	111	118	120	114	118	75
ρ (kΩ*cm)	13.43	11.13	25.8	0.194	1.501	0.795
Salinity	0	0	0	2.7	0.3	0.6

Table 9: Dams and Rivers Sample Fourth Cycle Physicochemical Data

Water source	Dam-T	Dam-V	Dam-N	Eerste River	Diep River	Salt River
Site Coordinates	-34.028142, 19.195741	-33.348227, 19.025529	-34.088388, 19.055267	-33.881756, 18.489722	-34.043593, 18.738042	-33.935677, 18.481618
Sample ID:	DM – T4	DM – V4	DM – N4	RV – D4	RV – E4	RV – S4
Dissolved Oxygen (mg/L)	5.1	5.2	5.3	4.9	5.1	4.5
Temperature (°C)	18.9	18.8	19.2	19.3	19.1	19.2
pH	6.10	6.20	5.51	6.32	6.14	6.45
Redox Potential (mV)	55.1	42.2	86.6	31.6	50.3	27.2
Conductivity (µS/cm)	86.5	94.6	29.8	2700	38.8	712
Total Dissolved Solids (ppm)	87	95	30	2700	39	712
% Dissolved Oxygen (%)	56	57	58	55	58	49
Pressure mBar	114	116	121	111	116	101
ρ (kΩ*cm)	11.56	10.56	33.6	0.37	25.9	1.405
Salinity	0	0	0	1.4	0	0.3

Table 10: Dams and Rivers Sample Fifth Cycle Physicochemical Data

Water source	Dam-T	Dam-V	Dam-N	Eerste River	Diep River	Salt River
Site Coordinates	-34.028142, 19.195741	-33.348227, 19.025529	-34.088388, 19.055267	-33.881756, 18.489722	-34.043593, 18.738042	-33.935677, 18.481618
Sample ID:	DM – T5	DM – V5	DM – N5	RV – D5	RV – E5	RV – S5
Dissolved Oxygen (mg/L)	4.5	4.6	4.5	4.4	4.6	4.0
Temperature (°C)	22.5	22.6	22.5	22.6	22.6	22.6
pH	7.14	6.71	6.34	6.25	8.59	7.57
Redox Potential (mV)	-8.3	7.1	38.9	-4.3	-78.9	-33.8
Conductivity (µS/cm)	104.7	94.1	125.5	28900	106.7	1218
Total Dissolved Solids (ppm)	105	94.1	126	28900	107	1217
% Dissolved Oxygen (%)	52	53	54	52	54	57
Pressure mBar	104	108	114	105	109	96
ρ (kΩ*cm)	9.50	10.59	7.95	0.346	9.33	0.821
Salinity	0.0	0.0	0.0	17.5	0.0	0.6

Table 11: Dams and Rivers Sample Sixth Cycle Physicochemical Data

Water source	Dam-T	Dam-V	Dam-N	Eerste River	Diep River	Salt River
Site Coordinates	-34.028142, 19.195741	-33.348227, 19.025529	-34.088388, 19.055267	-33.881756 , 18.489722	-34.043593 , 18.738042	-33.935677, 18.481618
Sample ID:	DM – T6	DM – V6	DM – N6	RV – D6	RV – E6	RV – S6
Dissolved Oxygen (mg/L)	3.9	3.7	4.0	2.6	3.9	2.3
Temperature (°C)	18.4	18.4	18.4	18.3	18.4	18.3
pH	6.31	6.60	5.50	6.60	7.34	6.99
Redox Potential (mV)	38.9	24.8	86.6	14.1	-17.0	1.4
Conductivity (µS/cm)	72.1	106.0	40.2	36100	123	1357
Total Dissolved Solids (ppm)	72	106	40	36100	122	1357
% Dissolved Oxygen (%)	43	40	42	27	44	13
Pressure mBar	88	84	88	55	85	23
ρ (kΩ*cm)	13.86	9.43	24.9	0.277	8.11	0.737
Salinity	0.0	0.0	0.0	22.6	0.0	0.6