May 2024

PERSISTENT THREAT: PFAS IN TEXTILES AND WATER IN BANGLADESH

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for a toxics-free future

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About ESDO

Environment and Social Development Organization – ESDO is a non-profit and non-government action research organization in Bangladesh. It works to disseminate messages about the need for environmental health and nature conservation, committed to protecting biological diversity and ensuring ecological balance. Since the official formation of ESDO in 1990, we have focused on generating knowledge amongst the broader community about how anthropogenic activities negatively impact the environment. ESDO's mission is to promote and encourage an environmental movement through a participatory democratic framework involving diverse social groups, and to assist them with ideas, information, and leadership for addressing the triple planetary crisis; climate change, biodiversity loss and pollution (particularly plastic pollution) and promoting a safe, sustainable, and toxic-free world.

About IPEN

IPEN is a global network forging a healthier world where people and the environment are no longer harmed by the production, use, and disposal of toxic chemicals. Over 600 public interest NGOs in more than 120 countries, largely low- and middle-income nations, comprise IPEN and work to strengthen global and national chemicals and waste policies, contribute to ground-breaking research, and build a global movement for a toxics-free future.

Acknowledgements

IPEN and ESDO sincerely thank the analytic teams from Brown University, US, and University of Chemistry and Technology, Prague, Czech Republic.

IPEN and ESDO also acknowledge continuous support from the Cyclopure team, who provided training and advisory services regarding PFAS water test kits and the help of Arnika's intern Johana Kašparová with literature review.

IPEN and ESDO gratefully acknowledge the financial support provided by the Government of Sweden and German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection. The views herein do not necessarily reflect the official opinion of any of the institutions providing financial support. Responsibility for the content lies entirely with IPEN and ESDO.

Cite this report as: Hossain, S., Strakova, J., Sultana, S., Alam, S.F., Trisha, T.H., Rabbani, G., Brosche, S., Howard, R., DiGangi, J., 2024. Persistent Threat: PFAS in Textiles and Water in Bangladesh. ESDO and IPEN. 56 p.

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KEY FINDINGS

- PFAS, called "Forever Chemicals" due to their environmental persistence, are a threat to human health, with links to negative impacts on fertility, fetal development, and thyroid hormone function. Certain PFAS have been linked to weakened immunity, liver damage, and cancer.

- PFAS are widely used by the textiles industry, which accounts for about 50% of the total global use of PFAS and is the second largest PFAS emissions contributor.

- Bangladesh has a large textiles sector and an increasing number of textile factories. Residents of Bangladesh may face significant threats from PFAS pollution of their water and associated contamination of soils and food.

- Textile makers in Bangladesh near areas where water was found with high PFAS levels produce products for major global brands, including Benetton, C&A, Calvin Klein, H&M, Marks & Spencer, Sainsbury's, Zara and many others. These brand-name companies have tremendous market influence and should demand PFAS-free products. Some of the companies have publicly committed to ending their sales of products with PFAS.

- For this study, 31 surface water (river and lake water) samples and 4 tap water samples from areas in Bangladesh near textile manufacturing centers were analyzed.

- Samples with high PFAS levels were common in areas near textile producing facilities, adding to the evidence that the textiles industry may be a significant source of PFAS water pollution. In two waterways where samples were taken downstream and upstream from Export Processing Zones (the Dhaka and Adamjee EPZs), samples taken downstream from the facilities showed higher PFAS concentrations, reinforcing the conclusion that the textiles industry is the likely source of PFAS pollution.

- The results of the surface water testing showed:
  - PFAS were found in 27 of 31 surface water samples (87%).
  - In 18 samples (58%), PFAS that are listed for global elimination under the Stockholm Convention were detected.
  - In 19 samples (61%), PFAS were detected above proposed EU regulatory limits for surface water.
  - Several samples were found with very high PFAS levels. One sample contained PFAS at more than 310 times above a proposed EU regulatory limit. That sample also had the highest levels of globally-banned PFOA and PFOS at more than 1,700 times higher than a current Dutch advisory limit for PFOA and more than 54,000 times higher than a current Dutch advisory limit for PFOS.
  - Comparing the 2019 and 2022 results suggests that manufacturers may be shifting from PFAS to fluorinated polymers based on fluorotelomer side chains. However, this is not an improvement because these polymers can degrade into PFOA or other hazardous PFAS chemicals.

- The tap water samples also found PFAS in drinking water in Bangladesh.
  - Three of four samples contained PFAS (75%).
  - Three PFAS-containing samples tested above the US PFOA regulatory limit, and one also tested above the EU PFAS limit.
- The study also includes data on PFAS in clothing purchased from retailers in Bangladesh. PFAS were detected in all five clothing items tested, including clothing for men, women, and children. One item contained PFOA, which is banned globally and prohibited for use in consumer products in countries that have ratified the Stockholm Convention amendment on PFOA, including Bangladesh.
- Globally banned PFAS were found in surface water, tap water, and clothing.
- Safer alternatives to PFAS in textiles are available so there is no need for PFAS in textiles.
- The textiles industry should phase out the use of PFAS, and policymakers should develop comprehensive, class-based bans on the production and use of PFAS, including polymeric PFAS.

EXECUTIVE SUMMARY

In recent years, there has been increasing attention to per- and polyfluoroalkyl substances (PFAS), a large group of persistent, toxic chemicals used widely by several industries. There has been much attention given to PFAS in drinking water, and it is well known that PFAS are used by the textiles industry, with several studies finding PFAS in many products, including clothing, carpeting, furniture, and other textiles.

While PFAS in consumer products have drawn much attention, the toxic impacts of PFAS used in textile manufacturing have been less studied. This report provides new evidence linking textile-making facilities to PFAS water pollution.

PFAS, called "Forever Chemicals" due to their environmental persistence, pose serious threats to human health. PFAS are associated with negative impacts on fertility, fetal development, and thyroid hormone function. A 2022 review found chronic PFAS exposure in children was linked to elevated blood cholesterol levels, dyslipidemias (lipid imbalances related to cardiovascular disease), slightly lowered birth weight, and reduced antibody response to certain vaccines/infections. Studies have found that exposure to the PFAS chemical PFOS can cause liver damage, and the PFAS chemical PFOA is considered a likely carcinogen.

The textile industry accounts for about 50% of the total global use of PFAS and is the second largest PFAS emissions contributor. Alternatives to PFAS in textiles are available, so there is no need for their continued use.

Bangladesh has a large textiles sector and an increasing number of textile factories, mostly making products for export. Major brands, including Benetton, C&A, Calvin Klein, H&M, Marks & Spencer, Sainsbury's, Zara and many others, have manufactured products in the country's facilities, in particular in operations located in the growing number of Export Processing Zones, special economic areas that are duty-free and attract large concentrations of manufacturing plants. While the fashion products sold overseas pose PFAS-contamination threats to consumers globally, residents of Bangladesh may face the greatest threats from PFAS pollution of their water and associated contamination of soils and food.

In this study conducted by Environment and Social Development Organization (ESDO), a non-profit and non-governmental organization in Bangladesh, in partnership with IPEN, a global network of public interest groups working for a toxics-free world, 31 surface water (lake and river water) samples were collected in 2019 (9 samples) and 2022 (22 samples) from areas in Bangladesh near textile manufacturing facilities. Four tap water samples were also taken, and the study also includes data from PFAS testing of clothing purchased from Bengali retailers.

As Bangladesh does not yet have specific regulatory limits on PFAS, the surface water results are compared to the proposed EU limit of 4 nanograms per liter (ng/L), and to the Dutch advisory limit for PFOA in surface water of 0.3 ng/L. In addition, PFOA, PFOS, and PFHxS are persistent organic pollutants listed for global elimination by the Stockholm Convention (Bangladesh is a Party to the Convention).

Analysis by independent labs found that water samples (87%) contained PFAS. Of the 27 samples containing PFAS, 18 (67%) contained one or more PFAS listed for global elimination and 19 (70%) were found with total PFAS levels above the proposed EU limit.

The highest levels in the surface water samples were found in water collected in 2019 from the Karnatali River, with total PFAS content of 1,152.2 ng/L, greatly exceeding the currently proposed EU regulatory limit. That sample also had the highest PFOA and PFOS levels, 515.2 and 381.9 ng/L, respectively–many times higher than the current Dutch advisory limits. In 2019, very high total PFAS levels were also found in Tongi River water and Ashulia Lake water, well above the currently proposed EU limit. A sample from 2022, from Hatirjheel Lake, contained both PFOA and PFOS; the latter testing at 185 times higher than the current Dutch advisory level for PFOS, a globally banned PFAS chemical.

All surface water samples containing PFAS were collected from areas near textile manufacturing facilities. For example, the Karnatali River flows along the city of Savar, an industrial pollution hot spot that includes textile industry operations, footwear manufacturing companies, ready-to-wear (readymade) factories, and other industrial operations. The Tongi River flows through Tongi, a major township that hosts the garment, textile, and other industries. In addition, the Turag River may be a source of PFAS in Tongi River water, as it flows into the Tongi from an industrial pollution hot spot in Gazipur, a hub for the textile industry in Bangladesh. Ashulia Lake neighbors Savar and is located downstream from the Dhaka Export Processing Zone (DEPZ). The DEPZ hosts around 200 industries and is heavily saturated with textile industry operations. At Ashulia Lake, samples were taken upstream and downstream of the DEPZ, with results showing higher PFAS levels downstream from the facility, reinforcing the conclusion that the textile industry operations are the likely source of pollution.

Three tap water samples from 2019 were found to contain PFAS; a fourth sample taken in 2022 did not contain PFAS. We compared the tap water samples to the EU Drinking Water Directive limit of 100 ng/L and the US National Primary Drinking Water Regulation for PFOA, which sets a limit of 4 ng/L. All three of the PFAS-containing samples tested above the US PFOA threshold and one also tested above the EU PFAS limit.

Clothing purchased from retailers in Bangladesh were also tested, with results showing all samples of clothing tested contained PFAS expressed as Total Extractable Organic Fluorine (TEOF levels are a marker of PFAS). Samples included clothing for men, women, and children. One item contained PFOA, which is banned globally and prohibited in consumer products in countries that have ratified the Stockholm Convention amendment on PFOA, including Bangladesh.

The results demonstrate that PFAS contamination is common in waterways near textile producing regions in Bangladesh, and in many cases, the contamination is at high levels, above EU or other current or proposed regulatory levels. Some samples from waterways, tap water, and clothing were found with types of PFAS that are banned globally. The results add to the evidence that the textiles industry may be a significant source of PFAS water pollution, not only posing threats of PFAS exposures to residents of Bangladesh through water, food, and clothing, but also more widely due to their properties as global pollutants.

Based on the results of this study, ESDO and IPEN are calling on the textiles industry to phase out the use of PFAS, and on policymakers to develop comprehensive, class-based bans on the use of PFAS, including polymeric PFAS.

2. THE PFAS PROBLEM

2.1 INTRODUCTION TO PFAS

PFAS (per- and polyfluoroalkyl substances), also known as “Forever Chemicals,” are a large group of chemicals used ubiquitously in consumer and professional products, despite concerns about their health and environmental impacts. They are used to make products water-, grease-, and stain-resistant and are commonly found in waterproof rain gear and food packaging, non-stick cookware, firefighting foams, and other products. However, most uses of PFAS are not essential for the functioning of society and/or have safer alternatives.[1]

All PFAS contain very strong chemical bonds between carbon (C) and fluorine (F) atoms, making them very stable and resistant to decomposition. This is why they are sometimes referred to as “Forever Chemicals.” Studies have shown that PFAS are released into the environment at every stage of their life cycle, including production,[2,3,4] use,[5] and disposal.[6,7] This and their persistence leads to continuously increasing concentrations of PFAS in the environment.[8,9]

PFAS CAN BE FOUND IN VARIOUS PRODUCTS, SUCH AS:

- Cleaning products
- Water-resistant fabrics, such as rain jackets, umbrellas, and tents
- Grease-resistant paper
- Nonstick cookware
- Personal care products, like shampoo, dental floss, nail polish, and eye makeup
- Stain-resistant coatings used on carpets, upholstery, and other fabrics
- Leather
- Additives
- Pesticides
- Paints
- Protective sprays
- Food packaging and food wrappers
- Heat resistant tape Cleaning products

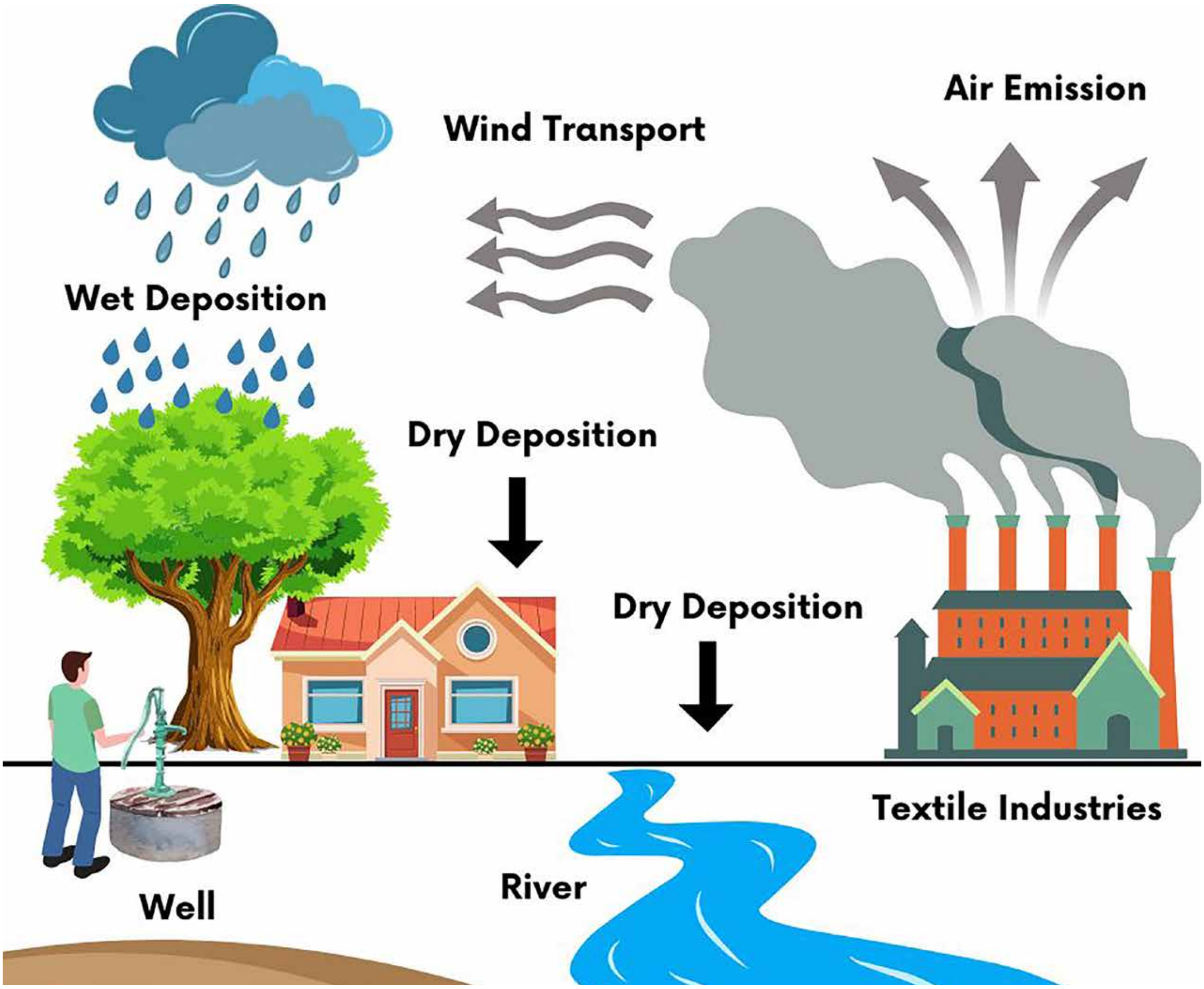
PFAS can be emitted into the air from industrial facilities that manufacture or use them, from landfills, and from incinerators. Once in the air, PFAS can travel long distances and eventually deposit onto land and water.[10]

PFAS have been detected in the air,[11] soil,[12] water[13] –including drinking water sources[14] – and household dust.[15,16] They have been found far from the places of their origin, including in the Arctic.[17,18]

Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) are the most commonly studied PFAS. Both PFOS and PFOA have been shown to bioaccumulate in the food chain, persist in the environment, persist in the environment, and travel long distances.[19] The time to reach 50% clearance in fish has been estimated to be around 100 days for PFOS. The elimination half-life of PFOS is estimated at approximately 4.8 years[20] and for PFOA at 3.5 years.[21]

PFOS (its salts and PFOSF), PFOA (its salts and PFOA-related compounds), and PFHxS (its salts and PFHxS-related compounds) are listed in the Stockholm Convention on Persistent Organic Pollutants for global restriction and elimination. Nevertheless, side-chain fluorinated polymers that can break down and form PFOA continue to be used as surfactants and surface treatment agents.[22] The most significant products for the fluorotelomer industry in terms of volume, the so-called "side chain" fluorotelomer-based polymers, have been shown to degrade to form PFOA.[23,24]

PFAS transport via air and deposition



Structures of PFOS and PFOA

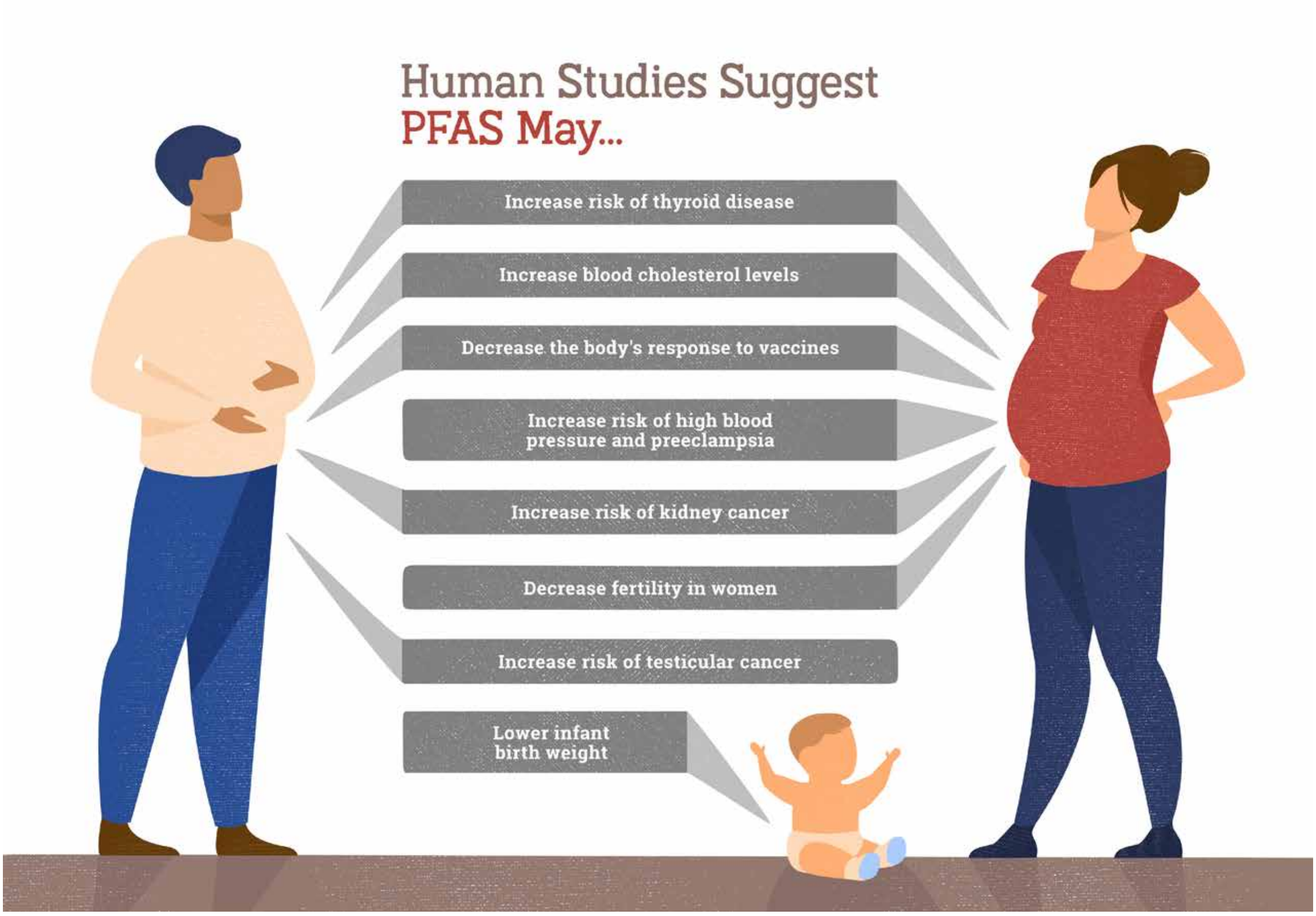
Among the long-chain PFAS are PFOA and PFOS, both of which consist of eight carbon atoms. Because of the gradual regulation of long-chain PFAS, they have increasingly been replaced with short-chain PFAS substitutes, mainly by PFHxA and PFHxS, both of which consist of six carbon atoms. Despite their lower bioaccumulation potential, short-chain PFAS are of increasing concern as they are ubiquitous in the environment, including in remote areas.[25] Short-chain PFAS are even more persistent and mobile in water than long-chain PFAS,[26] and thus may pose more risks for the environment and human health.[27]

2.2 PFAS EXPOSURE AND HEALTH CONCERNS

Humans are continuously exposed to PFAS. Food and drinking water have been established as the main exposure routes to PFAS. However, exposure from dust, indoor environments, and personal care and consumer products are also important.[28] Workers in the PFAS industry are exposed to greater amounts of PFAS than people in the general population.[29] Moreover, scientific studies of PFAS concentrations in human blood show that marginalized communities living in contaminated and industrialized areas are especially exposed to PFAS.[30] To date, human biomonitoring studies have detected PFAS in human breast milk, urine, and blood samples including serum, plasma, and whole blood.[31,32,33]

A recent study detected PFAS in breast milk of all 50 mothers studied from the United States.[34] Moreover, a 2022 review by the American Academy of Pediatrics (AAP) of a two-year study by the National Academies of Sciences, Engineering, and Medicine concluded that an association is likely between chronic PFAS exposure in children and medical concerns such as elevated blood cholesterol levels, dyslipidemias (lipid imbalances related to cardiovascular disease), slightly lowered birth weight, and reduced antibody response to certain vaccines/infections.[35] The AAP review noted that children are more vulnerable to PFAS because of lower body weight, differences in water and food intake, developing organ systems, breathing closer to the floor, and longer lifespans during which toxic effects might manifest.

Health concerns related to PFAS



PFAS have been shown to be associated with negative impacts on fertility, fetal development,[3] and thyroid hormone function.[45] PFOS has been found to disrupt hormone function, leading to concerns about its potential to interfere with hormone signaling pathways in humans. This could potentially impact reproductive health, thyroid function, and other hormone-regulated processes.[36] PFOS exposure is also associated with reduced fertility as well as adverse effects on fetal development.[37]

Some studies suggest that PFOS exposure may also suppress the immune system, making individuals more susceptible to infections and other immune-related disorders.[38] A National Toxicology Program review found that exposure to perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) is an immune hazard to humans based on a high level of evidence that PFOA and PFOS suppressed the antibody response of animals and a moderate level of evidence from studies in humans.[39] The negative impacts of PFAS on the immune system and their potential to make vaccines less effective[6] have been specifically highlighted in the context of the Covid-19 pandemic. Also, elevated levels of PFAS in blood were found to be associated with an increased risk of a more severe Covid-19 infection.[9]

In experimental animals, exposure to PFOS results in hepatotoxicity and increased mortality.[40] Studies have found that exposure to PFOS can cause liver damage, including liver tumors.[41] Similarly, based on studies in laboratory animals, PFOA is considered to be likely carcinogenic.[42]

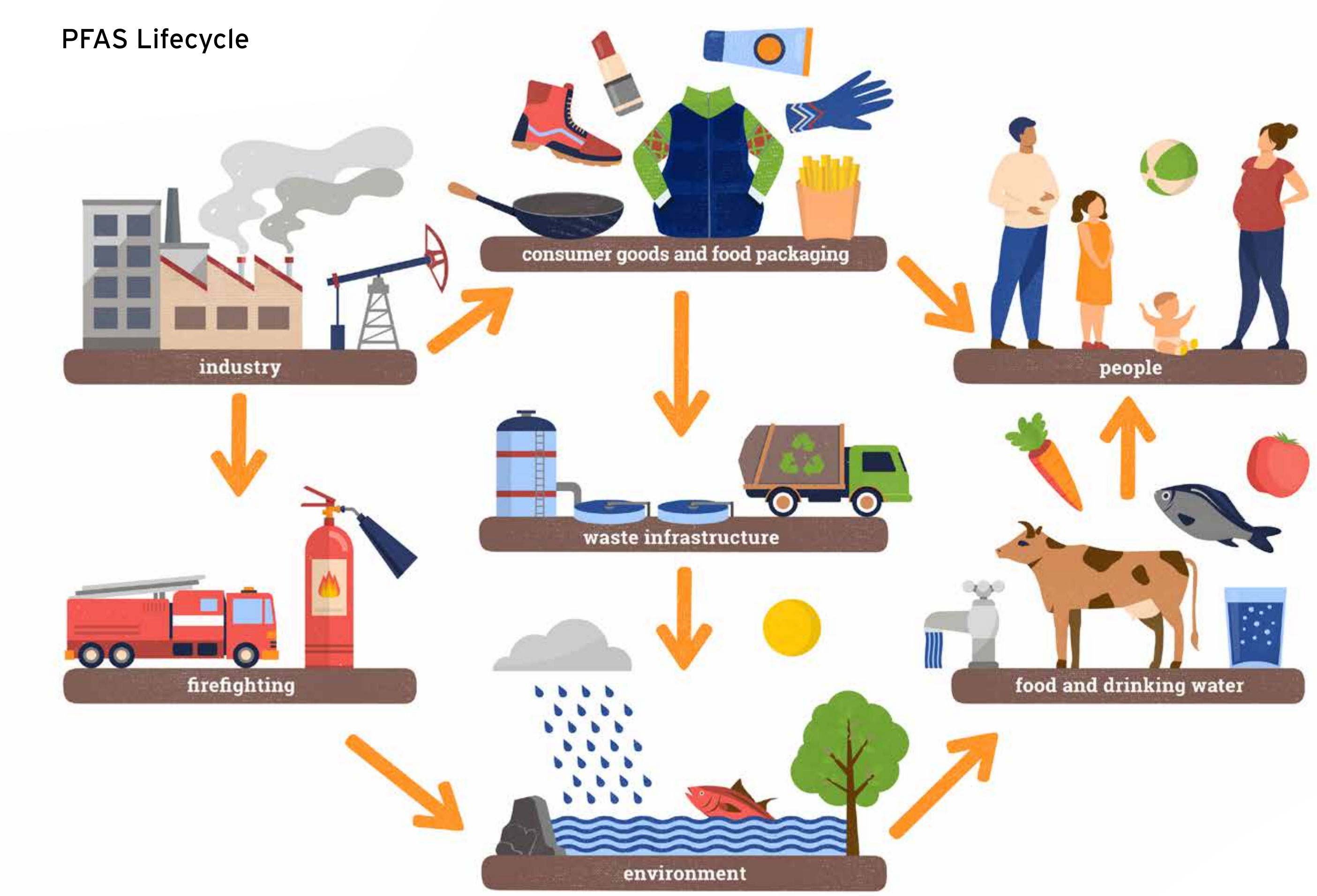
3. PFAS USE IN THE TEXTILE SECTOR

PFAS are used extensively in the textile and leather sectors, serving as surface coatings and waterproof membranes to provide resistance to water and stains. Surface treatments may occur either during the manufacturing process or as post-production applications.[43] PFAS also function as processing agents to facilitate dye and bleach application and to minimize foaming in textile treatment baths.[44]

During the production phase, textile factories pollute the surrounding environment through emissions into air and wastewater[45] and expose workers to PFAS.[46] PFAS are volatilized, weathered, and washed out from textile products during their use.[47,48] Concentrations of fluorotelomer alcohols (FTOHs), PFAS that are precursors to PFCAs including PFOA, inside sportswear stores selling outdoor clothing were found to be up to 30 times higher than in other working environments.[49] When PFAS-treated articles are disposed of at the end of life, PFAS migrate from waste into landfill leachates,[50] are emitted in incineration fumes and ashes, or are recycled into new products.[51]

To mitigate the use of PFAS, many companies are actively seeking alternative impregnating agents. Examples include substitutes based on paraffin, silicon, dendrimer, and polymer-based coatings. While these alternatives may have drawbacks, they present an opportunity to encourage industry players to move beyond the conventional use of PFAS in textiles. This proactive approach encourages the continual development of innovative solutions and safer alternatives, prioritizing the preservation and protection of both the environment and the population.[52]

PFAS Lifecycle



4. PFAS LEGISLATION

PFAS are increasingly regulated nationally, regionally, and internationally. The international ban or restriction on the production and use of PFOS, PFOA, and PFHxS are secured by the Stockholm Convention. The PFOS listing in Annex B of the Convention (restriction) entered into force for most countries in 2010. Bangladesh ratified the PFOS amendment in 2023. The listing of PFOA in Annex A of the Convention (global elimination) also entered into force in Bangladesh in 2023. The PFOA listing in Annex A of the Convention (global elimination) entered into force in Bangladesh in 2023. The amendment to list PFHxS, its salts, and PFHxS-related compounds in Annex A will enter into force for most Parties in 2024. Listing long-chain perfluorocarboxylic acids (PFCAs), their salts and related compounds in Annex A (global elimination) has been recommended to the next Conference of Parties to the Stockholm Convention in 2025 by the POPs Review Committee, a subsidiary body of the Convention that evaluates proposals for listing substances in the treaty.

There are no specific laws in Bangladesh related to PFAS chemicals. Bangladesh addresses persistent organic pollutants (POPs) through a multi-pronged approach rather than a single regulation. As Bangladesh is a party to the Stockholm Convention, it has restrictions on 16 POPs, including PFOS, its salts, and PFOSF. The National Implementation Plan of the Stockholm Convention outlines strategies for compliance with the Treaty–phasing out POPs use, managing existing POPs, and finding safer alternatives.[53] The Bangladesh Ecological Conservation Act partially addresses control over POPs in Bangladesh. While some POPs production and import are banned, potential loopholes exist.

See Annex PFAS Legislation in the EU and US for more information on regulation of PFAS in consumer products and drinking, underground, and surface waters in the EU, Netherlands, and the US.

5. SCOPE OF THE STUDY AND PFAS PROBLEM IN BANGLADESH

ESDO, a participating organization of IPEN, collaborated with IPEN on an extensive research study into the presence of PFAS in Dhaka's surface and drinking waters (from water sampling in 2019 and in late 2022) and in clothing purchased in Dhaka (from samples purchased in 2022).

As a developing country, Bangladesh has an increasing number of textile industries and factories. PFAS are released into the environment throughout the entire lifecycle of textiles: from production, use in textile products, to industrial and municipal wastewater treatment.[54] Their high solubility in water, persistence, and mobility enable them to contaminate various water sources, including groundwater basins and drinking water.[55] Moreover, polluted water is one of the main sources of PFAS found in plants, including agricultural crops, from where PFAS can transfer to humans through the food chain.[56] This adds to concerns as agriculture is the mainstay of the country's economy.

In addition to textile production and use, washing of PFAS-based textiles in laundry machines releases PFAS into wastewater, challenging wastewater treatment plants in Bangladesh, which often lack the technical capability to effectively address this issue.[57]

6. 2019 WATER SAMPLING

6.1 METHODOLOGY

6.1.1 Sample Collection

In April 2019, six water samples were collected in 50 mL spray bottles from locations in Dhaka, Bangladesh. Four samples were Karnatali River water samples (1, 3, Y, and 5), and two samples were tap water from Panpara and Lalmatia (T2 and T4). An empty spray bottle (B) was used as a control.

Water samples collected in April 2019

Water samples collected in September 2019

In September 2019, another eight samples of water from locations (surface water from the Tongi and Karnatali Rivers and from Ashulia Lake and tap water from Banani and Dagortoly village) in Bangladesh were collected in airtight rectangular food containers of various sizes. All containers were wrapped with wet cloth and sealed in ziplock bags. Two samples (sample "T1" from Turag River and sample "Dag-tap" from Dagortoly village) were excluded from the analysis due to technical problems.

6.1.2 Description of Sampling Locations

Karnatali Khal (River)

Four water samples (1, 3, Y, 5) were collected from the Karnatali Khal (river/canal) in April 2019 and two (BT1/3, BT2/3) were collected in September 2019.

The Karnatali Khal connects the Dhaleshwari and Buriganga Rivers. The river flows along Savar Upazila (sub-district) near densely populated residential areas and industrial zones.

Savar suffers from severe air, water, and land pollution. It is known for housing a concentration of heavy industries, including chemicals and pharmaceuticals, steel and metal fabrication, and readymade (ready-to-wear) garments.[58] In 2013, the New York Times noted that many waterways in Savar were "effectively retention ponds of untreated industrial waste."[59]

Pānpāra, Savar

One tap water sample (T2) was collected in April 2019.

Pānpāra is a densely populated place located in Savar Upazila. Savar is known for housing a concentration of heavy industries, including chemicals and pharmaceuticals, steel and metal fabrication, and readymade garments.

Lalmatia, Mohammadpur

One tap water sample (T4) was collected from Lalmatia, Mohammadpur, in April 2019.

Lalmatia is a vibrant and dynamic neighborhood settled in the Dhaka North City corporation. It is a small residential area with many educational institutions located in the area.

Tongi River/Khal, Abdullahpur, Uttara

One sample of river water (T2*) was collected in September 2019 from the Tongi River/Khal (canal) at Abdullahpur, Uttara.

The Tongi River at Abdullahpur is influenced by the water quality from the Turag River that flows from an industrial pollution hot spot in Gazipur and by the industrial hot spot in Tongi. Tongi is a major township in Gazipur, Bangladesh, with a population of 350,000 that hosts the garment, textile, steel fabrication, chemical, and plastics industries.

Ashulia Lake

Two samples of lake water (D1, D2) were collected in September 2019 in Ashulia Lake, located in a suburban area of Dhaka called Ashulia, neighboring Savar and Tongi.

Ashulia Lake plays a vital role in facilitating the drainage of water from the city of Dhaka in the wet season. The lake is also an important recreational area. In 2010, the government declared Ashulia Lake an Ecologically Critical Area (ECA), recognizing its importance and aiming to regulate activities within its vicinity. Moreover, the National Wetland Policy (2015) acknowledges the importance of wetlands like Ashulia Lake and outlines measures for their conservation and sustainable use. A management plan for Ashulia Lake was formulated in 2012, outlining strategies for conservation, pollution control, and community engagement. Based on petitions and evidence in 2012, the Bangladesh Environmental Court issued orders to protect the lake from illegal activities like sand mining and encroachment.

The Dhaka Export Processing Zone, or DEPZ, established in 1993, is situated upstream of Ashulia Lake. DEPZ is a special economic zone, oriented around duty-free production and export. It is one of ten export processing zones administered by the government designed to facilitate foreign investment. Around 200 registered industries are operating within the DPZ. It is heavily saturated with textile industry operations along with leather, chemicals, and the pharmaceutical industries.

Banani

One tap water sample (Dhaka_tap) was collected in September 2019 in Banani, a residential and commercial neighborhood and a thana (sub-district) of Dhaka.

Banani is often considered a part of the neighboring Gulshan area. It hosts upscale hotels, restaurants, shops, luxury apartments, schools, and the offices of many local and multinational companies.

The list of analyzed water samples with their coding is in **Table 1 below.**

6.1.3 Sample Analysis

The samples were placed in a 4°C dedicated sample storage refrigerator.

The samples were analyzed at an independent academic lab in the US as part of their work to develop specific PFAS testing protocols. The samples were processed by solid phase extraction (SPE) followed by analysis using the procedures described below. During phase 1 of April 2019, prior to extraction, 50 µL of an extraction standard containing ten isotopically labeled perfluorocarboxylic acids and three isotopically labeled perfluorosulfonic acids was added to each sample to demonstrate that these compounds could be recovered during SPE.

The concentration of the perfluorocarboxylic acids and perfluorosulfonic acids were determined using a Waters Acquity H-Class ultra-performance liquid chromatograph (UPLC) equipped with a Waters BEH C-18 column with an eluent gradient of ammonium acetate in water or methanol connected to a Waters Xevo TQ-S micro mass spectrometer (MS/MS). The Waters Xevo TQ-S micro was operated in negative electrospray ionization using multiple reaction monitoring mode tuned to unit mass resolution to isolate precursor and product ions for quantitation.

Table 1: 2019 water samples

Sample ID	Date	Location	Water source	GIS Coordinates
1	April 2019	Karnatali River/Khal, Savar	River water	23.818309, 90.257479
3	April 2019	Karnatali River/Khal, Savar	River water	23.822588, 90.257705
Y	April 2019	Karnatali River/Khal, Savar	River water	23.824554, 90.252066
5	April 2019	Karnatali River/Khal, Savar	River water	23.824554, 90.252066
T2	April 2019	Pānpāra, Savar	Tap water	23.81650, 90.252463
T4	April 2019	Lalmatia, Mohammadpur	Tap water	23.7554, 90.3690
BT1/3	September 2019	Karnatali River/Khal, Savar	River water	23.817940, 90.257147
BT 2/3	September 2019	Karnatali River/Khal, Savar	River water	23.817963, 90.257085
Dhaka_tap	September 2019	Banani	Tap water	23.789543, 90.402030
T2*	September 2019	Tongi River/Khal	River water	23.881850, 90.402162
D1	September 2019	Ashulia Lake	Lake water	23.947694, 90.249583
D2	September 2019	Ashulia Lake	Lake water	23.949106, 90.251686

6.1.4 Comparison of the Results with the US, EU, and Dutch Regulations

PFAS measurements were reported in nanograms per liter (ng/L). As there are no regulatory standards for PFAS in water in Bangladesh, we compared our findings with standards developed or in development in the EU, Netherlands, and USA (see Table 2).

Table 2: Legal standards used for comparison (see Annex PFAS Legislation in the EU and US for complete information on the existing standards in the EU and US)

Country	Drinking water	Surface water
European Union	Limit 100 ng/L for the sum of 20 PFAS	Proposed limit by the European Commission 4.4 ng/L for 20 PFAS expressed in PFOA toxic equivalent
Netherlands	--	Advisory limit 0.3 ng/L for PFOA and 7 pg/L (0.007 ng/L) for PFOS
United States	Limit 4 ng/L for PFOA	State of New York ambient water quality guidance values: PFOA 6.7 ng/L, PFOS 2.7 ng/L

6.2 RESULTS AND DISCUSSION

6.2.1 Surface Water

6.2.1.1 Results

The total PFAS concentration in surface waters of the Karnatali River, Tongi River, and Ashulia Lake ranged from 120 - 1,152; 788; and 152-420 ng/L, respectively, with the highest concentrations measured from the Karnatali River (1,152 ng/L) (see Table 3 for full results).

Table 3: Analytic results (ng/L) for river and lake water samples collected in 2019 (NA not analyzed; <below detection limit; *PFDoA, PFTeDA, PFPeS, PFNS, PFDS, and PFDoS were not detected in samples)

Locality	Sample code	PFBA	PFPeA	PF-HxA	PFH-pA	PFOA	PFNA	PFDA	PFUnA	PFBS	PF-HxS	PFHpS	PFOS	SUM*
April 2019														
Karnatali River	1	18.2	45.9	50.0	3.3	24.4	1.2	1.3	<1	48.9	15.8	<1	8.7	217.7
	3	17.6	34.8	43.0	<1	12.1	1.4	<1	<1	2.8	8.7	<1	<1	120.4
	Y	15.8	42.6	79.4	6.2	515.2	2.0	2.8	2.9	67.8	28.9	6.7	381.9	1152.2
	5	15.6	40.9	54.3	5.5	21.3	<1	1.4	<1	45.9	<1	<1	<1	184.9
September 2019														
Tongi River	T2*	<1	189.8	110.6	32.1	86.0	10.3	NA	NA	359.2	<1	<1	<1	787.9
Ashulia Lake	D1	<1	135.1	100.1	22.9	34.9	6.5	NA	NA	120.2	<1	<1	<1	419.7
	D2	<1	47.2	27.0	5.6	52.7	7.5	NA	NA	3.3	<1	<1	8.1	151.5
Karnatali R.	BT_1/3	<1	184.5	131.7	17.6	70.6	5.7	NA	NA	<1	<1	<1	<1	410.1
	BT_2/3	<1	149.1	103.8	22.1	55.9	30.4	NA	NA	<1	<1	<1	<1	361.4
Maximum		18.2	189.8	131.7	32.1	515.2	30.4	2.8	2.9	359.2	28.9	6.7	381.9	
Median**		16.7	47.2	79.4	11.9	52.7	6.1	1.4	2.9	48.9	15.8	6.7	8.7	

***Median was calculated from measurements over the limit of detection*

6.2.1.2 Comparison of the Results with Proposed or Current Advisory Limits

All surface water samples collected and analyzed in 2019 contained PFAS significantly over the currently proposed limit by the European Commission in the European Union of 4.4 ng/L (calculated as a sum of 20 PFAS expressed in PFOA toxic equivalent; see Annex Legislation).[60] The water samples from the Karnatali River exceeded the proposed limit by 8-310 times, the water samples from Ashulia Lake by 27-34 times, and the water samples from Turag River by 48 times. All surface water samples from 2019 also exceeded the Dutch advisory limit for PFOA (more than 40-1,700 times the limit of 0.3 ng/L) and three samples also exceeded the Dutch advisory limit for PFOS (more than 1,100-54,000 times the limit of 0.007 ng/L) developed in 2022.[61] All the surface water samples from 2019 exceeded the State of New York (USA) ambient water quality guidance value for protection of human health for PFOA (2 – 77 times the limit of 6.7 ng/L) and three samples also exceeded the value for PFOS (3 – 141 times the limit of 2.7 ng/L).[62]

6.2.1.3 Suspected Source of PFAS Pollution in Surface Water Samples

The suspected source of PFAS contamination in the water samples from the Karnatali River is the industrial pollution hot spot in Savar, which includes the textile industry, readymade garment makers, a footwear manufacturing company, and packaging industry operations. It is a major industrial hub known for housing a concentration of heavy industries contributing significantly to Bangladesh's export economy, including chemicals and pharmaceuticals, steel and metal fabrication, and textiles.

A water sample collected from the Tongi River at Abdullahpur likely gets its PFAS pollution from Tongi, which hosts garment, textile, steel fabrication, chemical, and plastics industries. An additional source of the PFAS contamination may be from the Turag River that flows from an industrial pollution hot spot in Gazipur (a hub for the textile industry in Bangladesh) and enters into the Tongi.

Ashulia Lake very likely receives polluted water from the Dhaka Export Processing Zone (DEPZ), which hosts export-oriented industries, with a concentration on garments and textiles as well as electronics and light manufacturing. The severe contamination of the lake was also confirmed in water samples collected in 2022 (the data follow below).

6.2.2 Tap Water

6.2.2.1 Results

PFAS contamination of tap water was confirmed in all three water samples collected in 2019 in three regions of Dhaka: Panpara Bazar, Lalmatia, and Banani. The total PFAS concentration in tap water ranged from 29 - 180 ng/L, with the highest concentrations measured in Banani, where the water was sourced from the surface (see Table 4 for full results).

Table 4: Analytic results for tap water samples (ng/L) collected in 2019 (<below detection limit; *PFPeS, PFHxS, PFHpS, PFDA, and PFUnA were not detected or analyzed in samples)

Location	Sample code	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFOS	SUM	Source of tap water
Panpara Bazar, Savar	T2	5.1	7.3	7.0	<1	6.8	<1	<1	2.6	28.8	Underground water
Lalmatia, Mohammadpur	T4	<1	13.5	11.8	<1	8.0	<1	2.7	2.3	38.3	Underground w.
Banani	Dhaka_tap	<1	157.2	<1	9.3	5.2	8.3	<1	<1	179.9	Surface w.

6.2.2.2 Comparison of the Drinking Water from the Tap Collected in 2019 with the Current Legal Limits

All three tap water samples collected in 2019 from Panpara Bazar, Lalmatia, and Banani exceeded the regulatory limit for PFOA (4 ng/L) under of the updated US National Primary Drinking Water Regulation. Tap water from Banani also exceeded the threshold set in the EU Drinking Water Directive (100 ng/L; expressed as a sum of concentrations of 20 PFAS).

6.2.2.3 Suspected Reasons for PFAS Contamination in the Drinking Water from the Tap Collected in 2019

Tap water in these areas is used for drinking after boiling, filtering, or purifying. According to an advisory from the US EPA, none of these methods used (boiling, water softeners, or iron filtration systems) are effective at removing PFAS from water. They found that filters should contain activated carbon or use reverse osmosis to be effective at removing PFAS from water.[63]

The highest total concentration of PFAS in the 2019 tap water samples was measured in Banani. Contrary to the other two underground-sourced water samples, the tap water in Banani is sourced from surface waters. The contamination of tap water from Banani may be the result of the discharge of PFAS-polluted municipal and industrial waters into the watershed that sources tap water for the area. The drinking water treatment process in 2019 included coagulation, filtration (without activated carbon), and disinfection. None of these methods remove PFAS from the water. Elevated levels of PFAS were identified on water samples collected in 2022 in Banani Lake as well as in two other neighboring lakes, Gulshan and Hatirjheel Lakes, confirming overall contamination of the area. The levels of PFAS in the tap water collected from Panpara Bazar (Savar) and Lalmatia in 2019 are no less concerning as the presence of PFAS in the tap water demonstrates contamination of underground water sources.

7. 2022 WATER SAMPLING

7.1 METHODOLOGY

7.1.1 Sample Collection

In December 2022, ESDO collected 23 water samples in Dhaka, Bangladesh, and its suburbs: 12 samples of river water, 10 samples of lake water, and 1 tap water sample from Lalmatia. There were also five control samples. Samples were collected using Cyclopure's PFAS Water Test Kit (WTK). Cyclopure is an independent lab based in the USA which has provided analytical PFAS testing and other services to the US Department of Defense, major industries, and other clients. Major elements of Cyclopure's WTK included a 250-mL collection cup and a DEXSORB (cyclodextrin-based adsorbent) extraction disc. DEXSORB is compatible with analytical applications like solid-phase extraction (SPE) used in the 2019 study. Testers filled collection cups with 250 mL of water taken from local surface waters. Each tester wore gloves during sampling. After filling, the WTK filters the sample through the open bottom of the cup, passing through the DEXSORB extraction disc. Sample filtration averaged 20-30 minutes, depending on water turbidity. After filtration, all PFAS in the water samples were adsorbed by and secured in the DEXSORB filter disc.

Sample collection and pouring by the ESDO Team in Dhaka, Bangladesh

7.1.2 Description of Sampling Locations

For each sampling location of interest (see description below and Table 5), a potential industrial point source(s) of PFAS pollution was identified and a blank control sample was taken. Sampling sites at lake and river waters in the vicinity of Dhaka and Adamjee Export Processing Zones, industrial pollution

Table 5: 2022 water samples

Sample ID	Date	Location	Description	GIS Coordinates
WTK_ID_1602	December 2022	Lake in Palashbari	Lake water, Baipail, upstream the DEPZ	23.935187, 90.267871
WTK_ID_1624	December 2022	Ashulia Lake	Lake water, downstream the DEPZ	23.949785, 90.253886
WTK_ID_1603	December 2022	Ashulia Lake	Lake water, Madhupur Para, down-stream the DEPZ	23.950884, 90.254636
WTK_ID_1604	December 2022	Ashulia Lake	Lake water, downstream the DEPZ	23.948758, 90.249936
WTK_ID_1620	December 2022	Shitalakshya River	River water, near the Kanchpur bridge, Siddhirganj subdistrict	23.702913, 90.516098
WTK_ID_1630	December 2022	Shitalakshya River	River water, near the Kanchpur bridge, Siddhirganj subdistrict	23.702002, 90.516768
WTK_ID_1619	December 2022	Shitalakshya River	River water, near the Kanchpur bridge, Siddhirganj subdistrict	23.701167, 90.517503
WTK_ID_1625	December 2022	Shitalakshya River	River water, near the Kanchpur bridge, Siddhirganj subdistrict	23.700843, 90.517755
WTK_ID_1605	December 2022	Shitalakshya River	River water, beside the Adamjee Export Processing Zone, Siddhirganj subdistrict	23.678780, 90.530206
WTK_ID_1611	December 2022	Shitalakshya River	River water, beside the Adamjee Export Processing Zone, Siddhirganj subdistrict	23.671928, 90.530619
WTK_ID_1613	December 2022	Shitalakshya River	River water, beside the Adamjee Export Processing Zone, Siddhirganj subdistrict	23.67159, 90.530019
WTK_ID_1601	December 2022	Shitalakshya River	River water, downstream the Adamjee Export Processing Zone, Siddhirganj subdistrict	23.669239, 90.527849
WTK_ID_1626	December 2022	Banani Lake	Lake water from Banani subdistrict, Gulshan	23.791097, 90.4101910
WTK_ID_1607	December 2022	Banani Lake	Lake water from Banani subdistrict, Gulshan	23.781290, 90.410283
WTK_ID_1618	December 2022	Gulshan Lake	Lake water from Gulshan Lake, Gulshan	23.781828, 90.418884
WTK_ID_1628	December 2022	Gulshan Lake	Lake water from Gulshan Lake, Gulshan	23.778748, 90.418961
WTK_ID_1606	December 2022	Hatirjheel Lake	Lake water from Gulshan, Hatirjheel subdistrict	23.754767, 90.402351
WTK_ID_1614	December 2022	Hatirjheel Lake	Lake water from Gulshan, Hatirjheel subdistrict	23.756976, 90.403487
WTK_ID_1612	December 2022	Buriganga River	River water from Dhaka central river port, Old Dhaka	23.710646, 90.399539
WTK_ID_1621	December 2022	Buriganga River	River water from Dhaka central river port, Old Dhaka	23.707363, 90.405796
WTK_ID_1623	December 2022	Buriganga River	River water from Dhaka central river port, Old Dhaka	23.707461, 90.405748
WTK_ID_1629	December 2022	Buriganga River	River water from Dhaka central river port, Old Dhaka	23.707430, 90.406008
WTK_PFAS_1609	December 2022	Lalmatia	Tap water from Lalmatia (ESDO office)	23.75613, 90. 37109

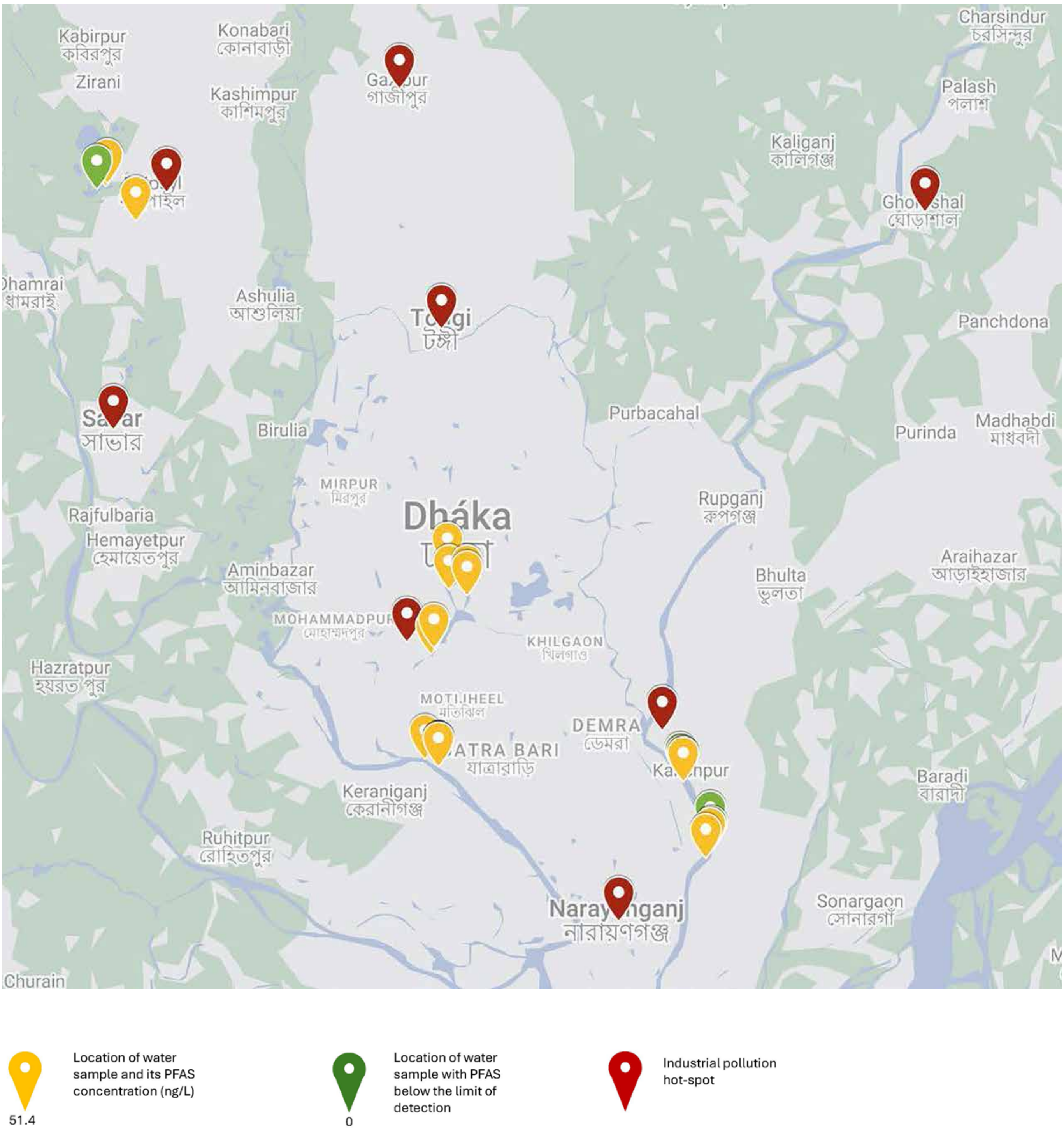
hot spots, were selected to include samples both upstream and downstream from the potential targeted pollution sources. The most prominent potential source of PFAS pollution in Dhaka was the textile manufacturing industry. See the overall map of sampling locations in 2022 and industrial pollution hot spots on Map 1 below.

Lalmatia, Mohammadpur

One tap water sample was taken in Lalmatia (WTK_PFAS_1609), Mohammadpur, in December 2022.

Lalmatia is a vibrant and dynamic neighborhood settled in the Dhaka North City corporation. It is a small residential area with many educational institutions.

Map 1: Overall map of sampling locations in 2022 and industrial pollution hot spots



Sampling at AEPZ

Shitalakshya River

Four river water samples were collected from the Shitalakshya River near the Kanchpur Bridge (WTK_ID_1620, 1630, 1619, 16925) and four samples near the Adamjee Export Processing Zone, AEPZ (WTK_ID_1605, 1611, 1613, 1601), Siddhirganj subdistrict, in December 2022.

The Shitalakshya River originates in Gazipur, a major hub for industrial activities (75% of the garment industries of Bangladesh are situated here), and flows through Ghorashal, another pollution hot spot (focused on textiles, garments, chemicals and plastics).

Small textile industries in Tarabo (textile and dyeing) are developed along the bank of the Shitalakhya (from Kanchan to Narayangonj), upstream from the sampling locations.

Adamjee Export Processing Zone (AEPZ) is a special economic zone, completely duty-free and oriented around production and export. It is one of ten export processing zones administered by the government designed to facilitate foreign investment. It consists of 229 industrial units across various sectors. Similar to the Dhaka Export Processing Zone, garment manufacturing and textile production dominate (including jute mills), but other sectors such as chemical and metal engineering are also present.

Another pollution hot spot is situated downstream from the sampling locations in Narayangonj (textiles, jute mills, river port, and commerce).

Moreover, the Shitalakshya River also serves as a recipient for residential waste waters from Gazipur, Tarabo, Narayangonj, and Dhaka districts.

Sampling at the Buriganga River

Buriganga River

Four river water samples were collected from Buriganga River - Sadarghat in December 2022.

The Buriganga River, flowing through the city including pollution hot spot Hazaribag, is heavily contaminated with industrial waste and sewage, threatening aquatic life and posing health risks.[64] Hazaribag is a hub for leather product manufacturing and tanneries.

Ashulia Lake and a Lake in Palashbari – Lakes Downstream and Upstream of the Dhaka Export Processing Zone (DEPZ)

Three lake water samples were collected in December 2022 from Ashulia Lake (WTK_ID_1624, 1603, 1604), an important recreational, nature conservation, and flood prevention area (see 2019 sampling site description (6.1.2) for more information about Ashulia Lake), downstream of the Dhaka Export Processing Zone. One more sample was collected at the same time at Baipail, in a small lake in Palashbari upstream of the DEPZ (WTK_ID_1602). DEPZ is a special economic zone, completely duty-free and oriented around production and export. Around 200 registered industries are operating within the DPZ. It is heavily saturated with textile and leather industries, along with chemical and pharmaceutical industries.

Banani, Gulshan, and Hatirjheel Lakes

Six lake water samples, two from each lake, were collected in Banani (WTK_ID_1626, 1607), Gulshan (WTK_ID_1618, 1628), and Hatirjheel Lakes (WTK_ID_1606, 1614). All three lakes are interconnected and surrounded by various commercial units and small textile industries. Hatirjheel Lake's surroundings host Tejgaon, a pollution hot spot and major commercial area of Dhaka, with many guest houses and hotels, showrooms and retail stores, office buildings, restaurants and cafes, and also electronics, glass and ceramic, chemical and pharmaceutical industries, and units of the health care sector.

Sampling at the Ashulia Lake

7.1.3 Sample Analysis

Fully-drained WTKs were placed back in the original packaging and sent for in-lab recovery and analysis at Cyclopure's analytical laboratory in the US. Methanol amended with ammonia acetate was used as eluent to recover PFAS compounds from the DEXSORB disc. Eluted PFAS samples were subsequently analyzed on a HPLC-MS/MS (QExactive hybrid quadrupole orbitrap, ThermoFisher) for target analysis of 55 compounds).

Analytical procedures used isotope dilution for PFAS measurement and quantification. The analysis of water samples has been validated to the requirements of EPA Methods 533, 537 and 1633 (draft), and follow instrument procedures for internal standardization and calibration. The limit of quantification (LOQ) for all 55 PFAS tested under Cyclopure analytical methods was 1.0 ppt (ng/L), other than GenX (HFPO-DA) which was 2.0 ppt (ng/L). Reporting limits have been validated to the accuracy criteria of EPA methods, including Minimum Reporting Limit (MRL) confirmation.

7.1.4 Comparison of the Results with the EU and Dutch Regulations

PFAS measurements were reported in nanograms per liter (ng/L). As there are no regulatory standards for PFAS in surface water in Bangladesh, we compared our findings with standards developed or in development in the EU and Netherlands (see Table 6 below).

Table 6: Legal standards used for comparison (see Annex PFAS Legislation in the EU and US for complete information on the existing standards in the EU and US).

Country	Surface water
European Union	Proposed limit by the European Commission 4.4 ng/L for 20 PFAS expressed in PFOA toxic equivalent
Netherlands	Advisory limit 0.3 ng/L for PFOA and 7 pg/L (0.007 ng/L) for PFOS

7.2 RESULTS AND DISCUSSION

7.2.1 Surface Water

7.2.1.1 PFAS in Surface Waters Overall in Dhaka

Of the 22 surface water samples collected in Dhaka, Bangladesh, and its suburbs, 18 samples contained PFAS above the limit of detection. Total PFAS concentrations in the 18 PFAS-positive samples ranged between 1.8 to 51.4 ng/L. The highest PFAS concentration (51.4 ng/L) was measured in Ashulia Lake, downstream from the Dhaka Export Processing Zone (DEPZ).

Out of the 55 tested PFAS, 12 PFAS chemicals, including globally- and EU-regulated PFOA and PFHxA, were measured in the samples.

FOUEA (8:2 FTUCA), 7:3 FTCA, PFBA, and PFOA were among the most frequently detected. The EU-restricted chemical PFHxA was measured in the highest concentration (15.3 ng/L) among the tested PFAS.

Two samples from Ashulia Lake exceeded both the Dutch advisory level for PFOA in surface waters (19-fold) and the threshold for PFAS in surface waters proposed in the European Union (34-fold). The Dutch advisory level for PFOA was also exceeded in the Shitalakshya and Buringanga Rivers and in Banani, Gulshan, and Hatirjheel Lakes. Moreover, water samples from Hatirjheel Lake exceeded the Dutch level not only for PFOA but also PFOS.

The PFOA/PFAS concentrations measured in surface waters in Dhaka, Bangladesh, were:

- Slightly higher than levels measured in surface water samples collected from 22 developing countries through the UNEP/Global Monitoring Plan 2 projects from 2017 until 2019.[65]
- Comparable to levels measured in urban river water samples during dry season in Vietnam[66] or in tributaries of the Pearl River in Guangzhou, China.[67]
- Slightly lower than the surface water affected by wastewater discharges in Las Vegas, US.[68]
- Lower than levels in the Qiantang River watershed, one of the most PFAS-contaminated rivers in China suffering from textile and leather[69] production emissions, and in Xiaoqing- River Basin, China, Yodo River Basin, Japan, and Keya River, Taiwan, surface waters heavily impacted by industrial activities or sewage treatment plant effluent discharges.[70]

Profiles of PFAS (prevalence of PFAA) in textile industry-impacted surface waters in Dhaka, Bangladesh, resemble the other textile industry-impacted waters in Asia analyzed previously (2014-2018).[71] However, PFOS and PFHxS in our water samples from Dhaka from 2022 have a lower detection frequency. This may be a result of textile manufacturers' shift from globally banned PFOS and PFHxS to fluorinated polymers based on fluorotelomer side chains, which are commonly used in textile and leather treatments.[72] This hypothesis is supported by findings of 5:3 and 7:3 FTCAs, FDUEA (10:2 FTUCA), and FOUEA (8:2 FTUCA) in water samples. Both FTCAs and FTUCAs are intermediate biodegradation products of fluorotelomer alcohols (FTOHs),[73] side-chain components of fluorinated polymers. As such, FTCAs and FTUCAs may further degrade into perfluorocarboxylic acids (PFCAs),[74] which are PFAS chemicals that were also quantified in the tested water. Identified PFAS in Dhaka waters are associated with developmental and hormonal effects, immunotoxicity, and tumor growth.[75]

7.2.1.2 PFAS in the Shitalakshya River

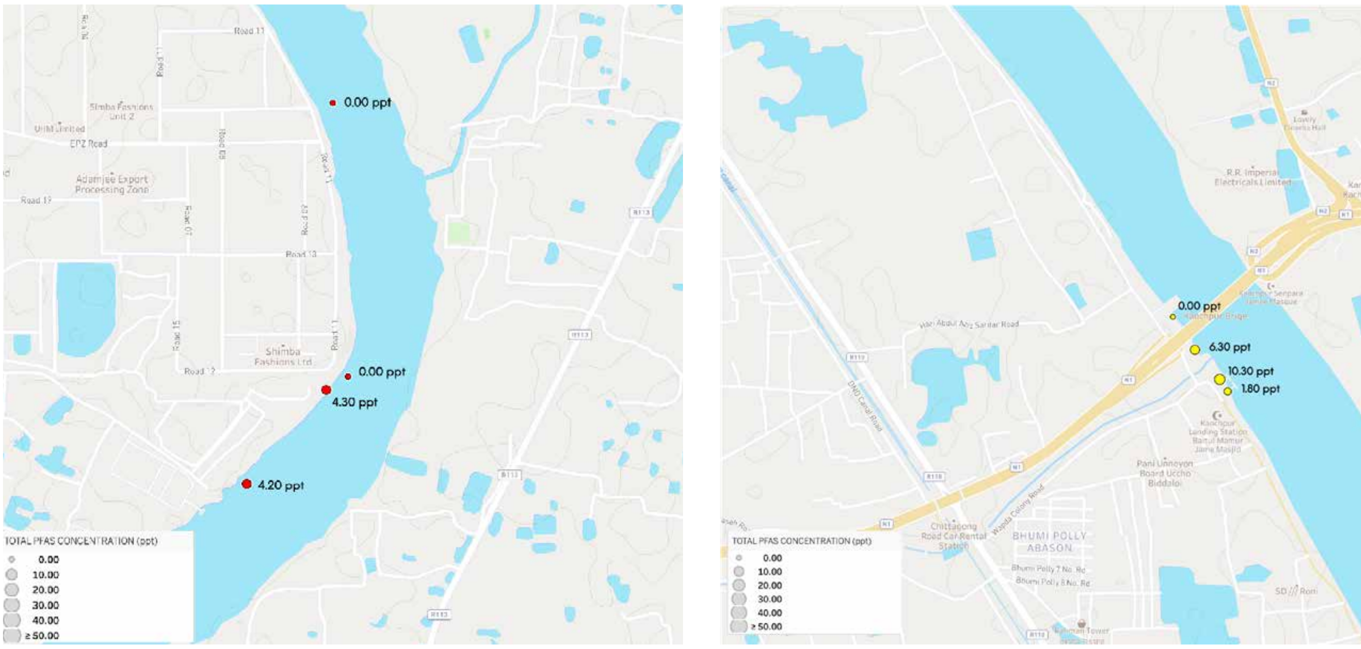
7.2.1.2.1 PFAS Concentrations in the Shitalakshya River

Concentration levels of individual PFAS in Shitalakshya River samples are summarized in Table 7, and total PFAS concentrations depicted on Map 2 below.

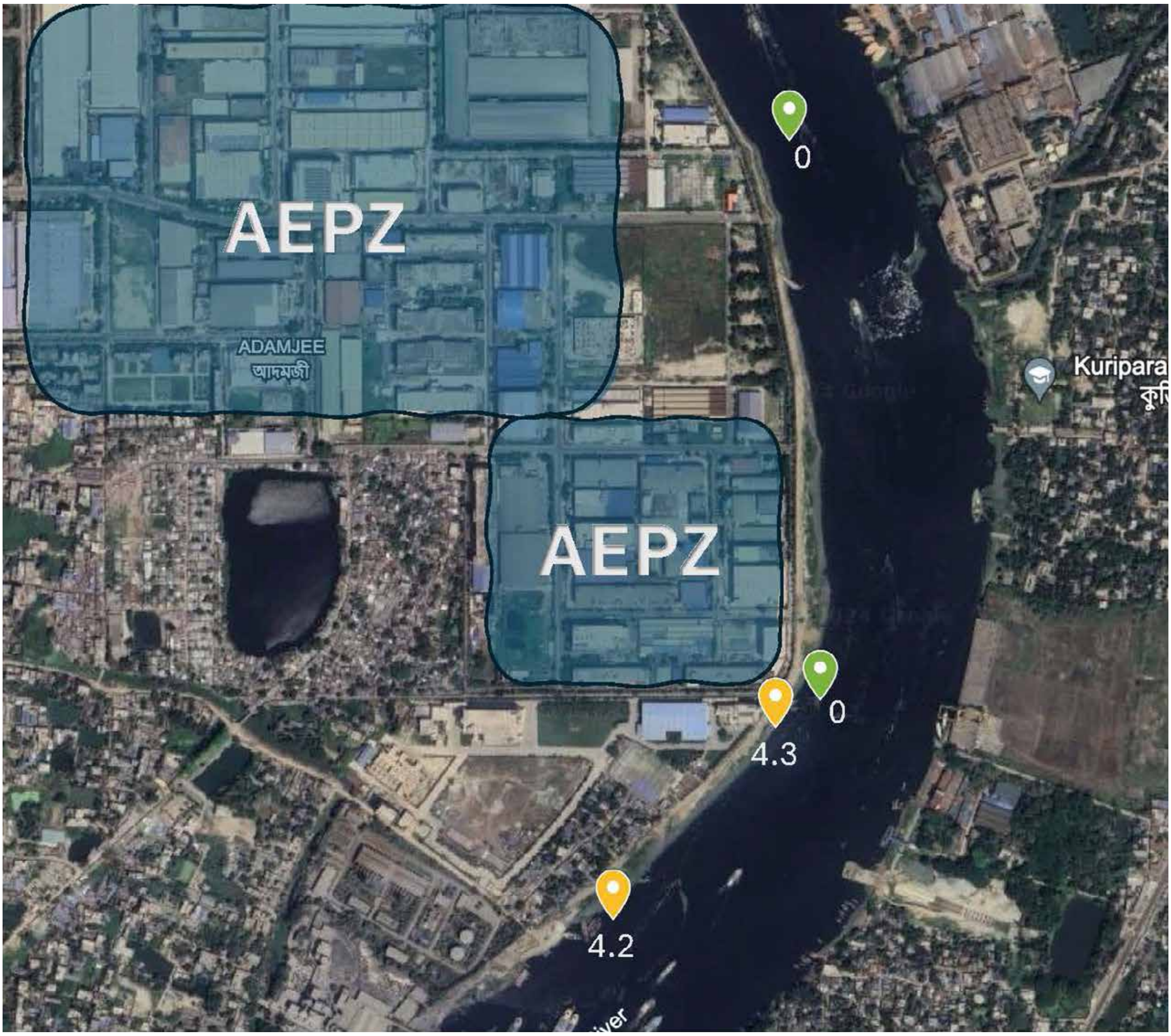
Table 7: PFAS concentrations in the Shitalakshya River (ng/L)

Location	WTK_ID	PFBA	PFHpA	PFOA	5:3 FTCA	7:3 FTCA	FDUEA (10:2 FTUCA)	FOUEA (8:2 FTUCA)	Total PFAS
Shitalakshya River near the Kanchpur Bridge (downstream from Gazipur and Tarabo)	1620	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< LOQ
	1630	< 1 ng/L	< 1 ng/L	< 1 ng/L	1.2	1.2	1	2.9	6.3
	1619	1.3	< 1 ng/L	1.2	1.7	1.7	1.1	3.3	10.3
	1625	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	1.8	1.8
Shitalakshya River beside and downstream from the Adamjee Export Processing Zone (AEPZ)	1605	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< LOQ
	1611	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< LOQ
	1613	1.4	1.3	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	1.6	4.3
	1601	3.1	< 1 ng/L	< 1 ng/L	< 1 ng/L	1.1	< 1 ng/L	< 1 ng/L	4.2

Map 2: PFAS concentrations in the Shitalakshya River



Map 3: PFAS concentrations upstream, beside and downstream of Adamjee Export Processing Zone (AEPZ)



7.2.1.2.2 Suspected Sources of PFAS in the Shitalakshya River

The Shitalakshya River bank near the Kanchpur Bridge reveals total PFAS concentrations ranging from below the level of detection to 10.30 ng/L. The water sample with the highest measured concentration exceeds the Dutch advisory limit for surface water for PFOA by four times.

The numerous industrial and factory units along the River banks, including numerous textile mills in Tarabo (upstream from the Kanchpur Bridge), are the likely sources of PFAS in the Shitalakshya River. Another industrial pollution hot spot likely contributing to PFAS levels in the River is Ghorashal, an area hosting factories involved in fabric production, clothing manufacturing, and chemicals and plastics production, and Gazipur, a major hub for garment manufacturing in Bangladesh. Residential sewage water from the city may also contribute to PFAS levels in the River.

Slightly lower levels of PFAS than sites near the Kanchpur Bridge were measured beside and downstream the Adamjee Export Processing Zone (AEPZ) that spans 245 acres with 229 industrial units including abundant textile factories. However, the differences between PFAS concentration upstream of the AEPZ (below LOD) and beside/downstream of the AEPZ (4.3 and 4.2 ng/L) demonstrates that AEPZ is the likely source of PFAS in the River (see Map 3 with depicted results). See Table 10 for more information on global brands manufacturing at AEPZ and Dhaka Export Processing Zone (DEPZ) .

7.2.1.3 PFAS in the Buriganga River

7.2.1.3.1 PFAS Concentrations in the Buriganga River

Concentration levels of individual PFAS in Buriganga River samples are summarized in Table 8, and total PFAS concentrations depicted on Map 4 below.

7.2.1.3.2 Suspected Sources of PFAS in the Buriganga River

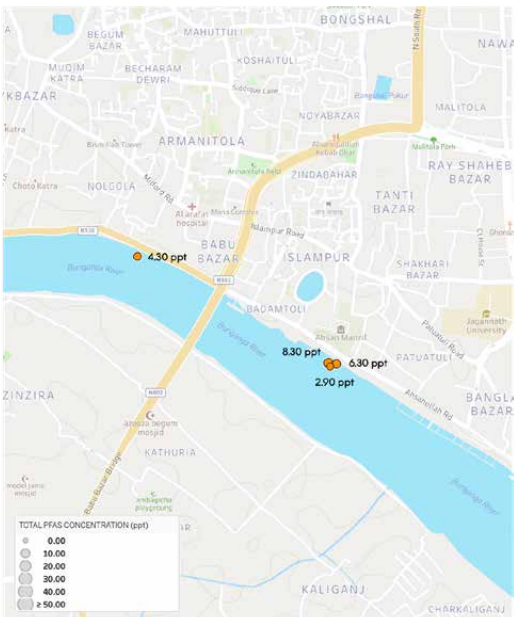
The results reveal elevated levels of PFAS pollution in the Buriganga River, ranging from 2.9 to 8.3 ng/L with one sample exceeding the Dutch advisory limit for PFOA in surface water by five times.

The heightened concentrations of PFAS in this area may be attributed to discharges from Hazaribag, a hub for leather product manufacturing and tanneries and from residential sources.

Table 8: PFAS concentrations in the Buriganga River (ng/L)

Location	WTK_ ID	PFBA	PF-HxA	PFOA	5:3 FTCA	7:3 FTCA	FOUEA (8:2 FTUCA	Total PFAS
Burig-anga River upstream Babubajar Bridge	1622	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	1.5	2.8	4.3
Buriganga River down-stream Babubajar Bridge	1621	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	1	1.9	2.9
	1623	1.1	< 1 ng/L	1.6	1.3	2	2.3	8.3
	1629	1.7	1	< 1 ng/L	< 1 ng/L	1.3	2.3	6.3

Map 4: PFAS concentrations in the Buriganga River



7.2.1.4 PFAS in the Ashulia Lake and Palashbari

7.2.1.4.1 PFAS Concentrations in the Ashulia Lake and Palashbari

Concentration levels of individual PFAS in the Ashulia Lake and Palashbari samples are summarized in Table 9, and total PFAS concentrations depicted on the Map 5 below.

7.2.1.4.2 Suspected Sources of PFAS in the Ashulia Lake and Palashbari

Ashulia Lake, with the Dhaka Export Processing Zone (DEPZ) upstream, stands out with the highest concentration of total PFAS among the collected water samples in 2022, ranging from below the limit of detection, to 46.3 and 51.4 ng/L at the localities closer to the influx of the Lake.

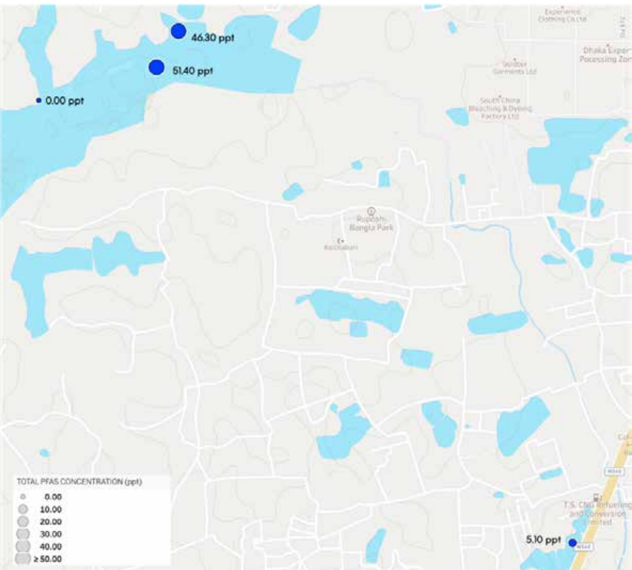
The DEPZ is heavily saturated with textile industries, suggesting a potential correlation between the high PFAS levels and textile-related pollutants. The absence of wastewater treatment processes in these industries raises concerns about the unchecked discharge of contaminated water into nearby water bodies.

Both PFAS-positive water samples from Ashulia Lake and Palashbari exceed the Dutch advisory level for PFOA in surface waters (19-fold). Moreover, the two water samples from Ashulia Lake also exceed the threshold for PFAS in surface waters proposed in the European Union (34-fold).

Table 9: PFAS concentrations in the Ashulia Lake and Palashbari (ng/L)

Location	WTK_ ID	Coordinates	PFBA	PF-PeA	PF-HxA	PFH-pA	PFOA	PFNA	PFDA	5:3 FTCA	7:3 FTCA	FDUEA (10:2 FTUCA	FOUEA (8:2 FTUCA	Total PFAS
Palashbari - Baipail (upstream from DEPZ	1602	23.935187, 90.267871	1.2	< 1 ng/L	< 1 ng/L	< 1 ng/L	1.5	< 1 ng/L	< 1 ng/L	1	1.4	< 1 ng/L	< 1 ng/L	5.1
Ashulia Lake	1624	23.949785, 90.253886	1.5	7.4	15.3	4.6	5.8	1.2	1.9	5.5	4.2	1.7	2.3	51.4
	1603	23.950884, 90.254636	2.1	6.3	14.1	4	5.6	1.2	2.1	4.2	3.2	1.6	1.9	46.3
	1604	23.948758, 90.249936	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< LOQ

Map 5: PFAS concentrations in the Ashulia Lake and Palashbari



Map 6: PFAS concentrations upstream and downstream Dhaka Export Processing Zone (DEPZ)

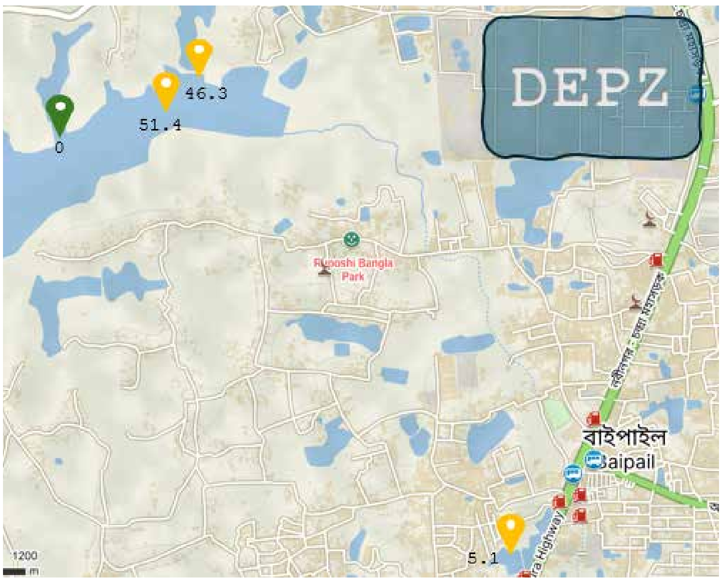


Table 10: Global brands in Bangladesh and their PFAS (=PFCs) phase-out commitments and actions

	Company	Location	PFAS phase-out	Source of the PFAS phase-out information
Alexon	FCI BD Ltd	https://www.google.com/maps/place/FCI+BD+Limited/@23.9493593,90.2708598,15z/data=!4m2!3m1!1s0x0:0x215b2e3559a3c5df?sa=X&ved=1t:2428&ictx=111	No PFAS phase-out information available	
Benetton	Benetton Asia Pacific Ltd Benetton Bangladesh Ltd	https://www.google.com/maps/place/Benetton+Asia+Pacific+Ltd.+Bangladesh+Branch/data=!4m7!3m6!1s0x3755c7a1eb5d98bd:0x321deecda322d000!8m2!3d23.787856!4d90.4164607!16s%2Fg%2F1tjddk1n!19sChIJvZhd66HHVTcRANAio83uHTI?authuser=0&hl=en&rclk=1 https://www.google.com/maps/place/Benetton+Bangladesh+Ltd./data=!4m7!3m6!1s0x3755c7dec57fc02d:0xb62df78dea6f5f5!8m2!3d23.7885266!4d90.4250195!16s%2Fg%2F11kpp2_33g!19sChIJLcB_xd7HVTcR9fWm3njfYgs?authuser=0&hl=en&rclk=1	*"Benetton almost reached the total elimination of PFCs from its production (being the compliance equal to 98%) and the few dections (sic: detections) are related to small unintentional contaminations in the production processes."*	https://www.benettongroup.com/site/assets/files/1143/benetton_pfcs_elimination_progress_dec_2021.pdf
C&A	C&A Sourcing Bangladesh	https://maps.app.goo.gl/kLGXRuZQME9E8dJt9	*"Globally, we eliminated PFCs from all products as of 2015."*	https://www.c-and-a.com/eu/en/corporate/company/sustainability/sustainability-strategy/innovate-lead/circular-fashion
Calvin Klein	Meerab Industries Ltd	https://www.google.com/maps/place/Calvin+Klein/data=!4m7!3m6!1s0x3755db7b36d6efdb:0x717967f03953de5a!8m2!3d23.98929!4d90.3809883!16s%2Fg%2F1pztd4xdt!19sChIJ2-_WNnvbVTcRWt5TOfBneXE?authuser=0&hl=en&rclk=1	No PFAS phase-out information available	
Charles Vögele	Charles Voegele Fashion HK Ltd. Bangladesh	https://www.google.com/maps/place/Charles+Voegele+Fashion+(HK)+Ltd./@23.8680571,90.3993131,15z/data=!4m2!3m1!1s0x0:0xeb020e7714a328d0?sa=X&ved=1t:2428&ictx=111	No PFAS phase-out information available	
Cubus	Masco Group	https://maps.google.com/maps/dir//Tongi+1712/@23.9209866,90.3908486,12z/data=!4m5!4m4!1m0!1m2!1m1!1s0x3755c493ae5303cd:0x3150042ea785ad07	No PFAS phase-out information available	
Gerry Weber	Gerry Weber Far East Ltd.	https://www.google.com/maps/place/Gerry+Weber/data=!4m7!3m6!1s0x3755c7004a4eb873:0x93d75ee32add656!8m2!3d23.803896!4d90.408724!16s%2Fg%2F11vpykvc1b!19sChIJc7hOSgDHVTcRVtatMu51PQk?authuser=0&hl=en&rclk=1	No PFAS phase-out information available	
H&M	HM TEXTILE MILL	https://www.google.com/maps/dir//h%26m+manufacturing+factories+bangladesh/data=!4m6!4m5!1m1!4e2!1m2!1m1!1s0x3755b7296f3af423:0x8de428f9916497bd?sa=X&ved=1t:3061&ictx=111	*"In the end of 2010, the first product with PFCs free finishing was introduced. From January 2013 the H&M Group put a global ban on Perfluorinated Compounds (PFCs)."*	https://hmgroup.com/wp-content/uploads/2020/10/HM_Case-Study-Phase-out-PFC.pdf
Kmart Australia	KAS Group Asia	https://www.google.com/maps/place/Kmart+Australia,+Dhaka+Office/@23.836244,90.418132,15z/data=!4m2!3m1!1s0x0:0xd9adbba040dc926f?sa=X&ved=1t:2428&ictx=111	No PFAS phase-out information available	
Lindex	Lindex Bangladesh Liaison Office	https://www.google.com/maps/place/Lindex+Bangladesh+Liaison+Office/@23.7939158,90.4143566,15z/data=!4m2!3m1!1s0x0:0x5f3ad41bad033108?sa=X&ved=1t:2428&ictx=111	*"Chemicals that are banned for the production of our garments, and in the finished garments, include PVC, phthalates, PFAS and APEO."*	https://about.lindex.com/files/documents/lindex-sustainability-report-2016.pdf
Mark and Spencer	Marks and Spencer	https://www.google.com/maps/place/Marks+and+Spencer/@23.7955226,90.4169158,15z/data=!4m2!3m1!1s0x0:0x92d4f11c1953c6a5?sa=X&ved=1t:2428&ictx=111	Certain PFAS are listed on the company's Manufacturing Restricted Substances List (MRSL)	https://corporate.marksandspencer.com/sites/marksandspencer/files/marks-spencer/policies/m-and-s-ecp-mrsl-and-rsl-2020.pdf
Primark	Primark trims bd Ltd	https://www.google.com/maps/place/Primark+trims+bd+Ltd/@23.706178,90.3966431,15z/data=!4m2!3m1!1s0x0:0x45443082c2404155?sa=X&ved=1t:2428&ictx=111	No PFAS phase-out information available	
Racing Green	Knittex Industries Ltd	https://www.google.com/maps/place/Knittex+Industries+Ltd./@23.8642289,90.4009224,15z/data=!4m2!3m1!1s0x0:0xbd475679d88c6efd?sa=X&ved=1t:2428&ictx=111	No PFAS phase-out information available	
Sainsburys	Sainsbury's Argos Asia Limited	https://www.google.com/maps/place/Simpletree+Anarkali/data=!4m7!3m6!1s0x3755c7a1e4908ff1:0x6f41fd24a2eef843!8m2!3d23.786843!4d90.4165483!16s%2Fg%2F11c1rfklpk!19sChIJ8Y-Q5KHHVTcRQ_juoiT9QW8?authuser=0&hl=en&rclk=1	No PFAS phase-out information available	
TM Lewin	T.M Lewin	https://www.google.com/maps/place/T.M+Lewin/@23.7796544,90.4154195,15z/data=!4m2!3m1!1s0x0:0xa5e21ff3f8c1d509?sa=X&ved=1t:2428&ictx=111	No PFAS phase-out information available	
Zara (Inditex)	Zara Style Ltd	https://www.google.com/maps/place/ZARA+STYLE+LTD/@23.6231685,90.4789908,15z/data=!4m2!3m1!1s0x0:0xaf474c47bb23b88f?sa=X&ved=1t:2428&ictx=111	*"Inditex has committed to eliminating the use of per- and polyfluoroalkyl sub-stances (hereinafter, PFAS) in their sup-ply chain, thus leading to the elimination of PFAS in their articles."*	https://www.inditex.com/itxcomweb/api/media/5b480a53-9437-4420-956e-e3c05372ac77/PFAS-free+Manufacturing+Guidance.pdf?t=1693235637676

The water sample collected in Palashbari, Baipail, the locality upstream from Ashulia Lake, shows one order lower levels of PFAS than the water samples near the Lake influx itself (see Map 6 with depicted results). Palashbari seems to be impacted by other textile industries and residential sources, but at a lower level than the DEPZ PFAS pollution hot spot.

The presence of high PFAS levels downstream of the Dhaka EPZ and the Adamjee EPZ indicates that PFAS substances are being used and released by Bangladesh suppliers making clothing for major US and EU brands. This links major global consumer clothing brands to PFAS pollution in Bangladesh. Table 10 shows that some of these brands have pledged to remove PFAS from their manufacturing processes.

7.2.1.5 PFAS in the Banani, Gulshan, and Hatirjheel Lakes

7.2.1.5.1 PFAS Concentrations in the Banani, Gulshan, and Hatirjheel Lakes

Concentration levels of individual PFAS in the Banani, Gulshan, and Hatirjheel Lakes are summarized in Table 11, and total PFAS concentrations depicted on Map 7 below.

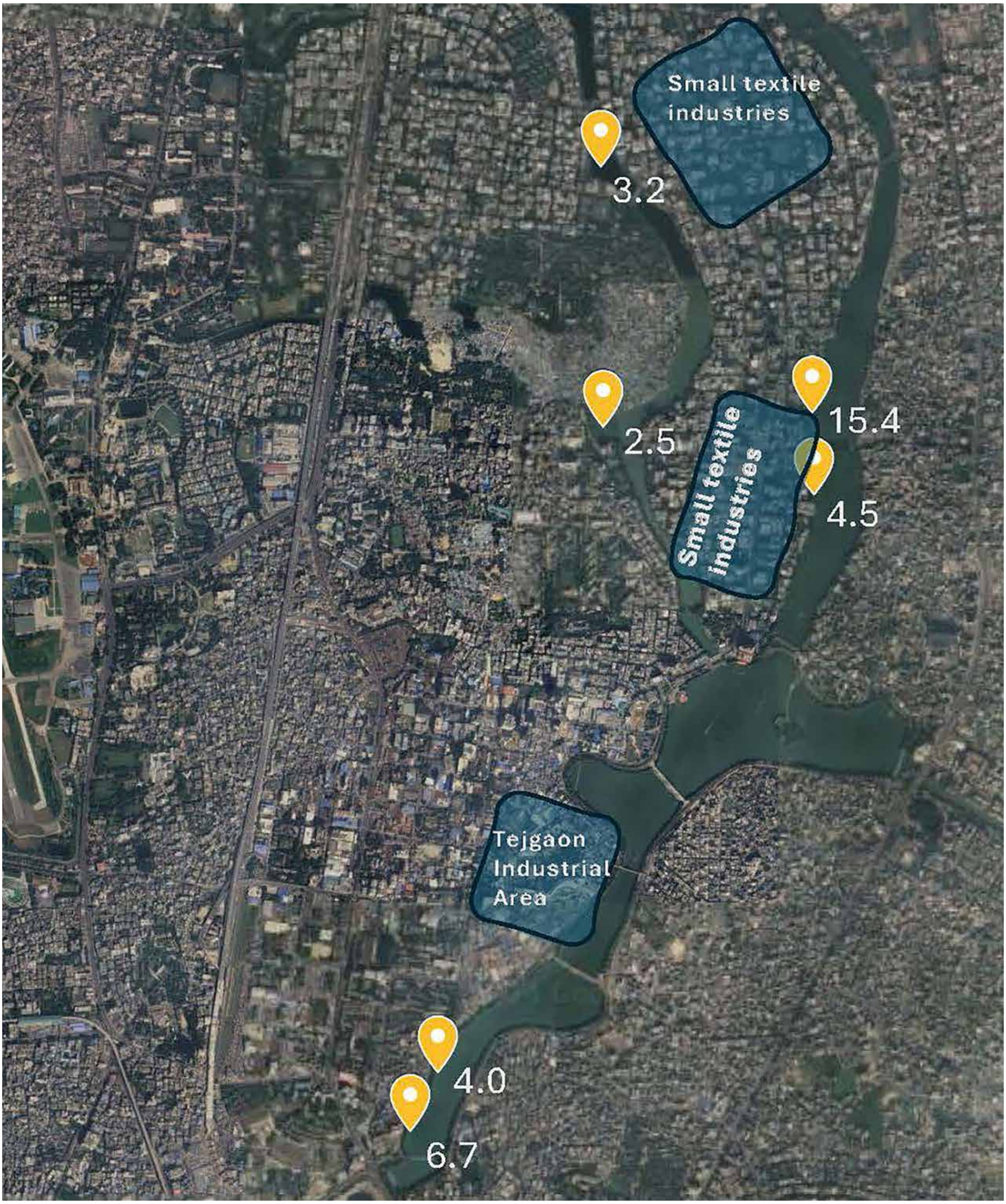
7.2.1.5.2 Suspected Sources of PFAS in the Banani, Gulshan, and Hatirjheel Lakes

Banani Lake registers PFAS concentrations ranging from 2.5 to 3.2 ng/L. Despite Gulshan's reputation as a clean area, Gulshan Lake displays PFAS concentrations ranging from 4.5 to 15.4 ng/L. Total PFAS concentrations of 4 and 6.70 ng/L have been identified in Hatirjheel Lake. Four of six water samples exceed the Dutch advisory level for PFOA in surface water by 3-5 times. The two water samples from Hatirjheel Lake exceed both the Dutch level for PFOA and for PFOS–the PFOS advisory level of 0.007 ng/L was exceeded by 171-185 times.

Table 11: PFAS concentrations in the Banani, Gulshan, and Hatirjheel Lakes (ng/L)

WTK_ID	Testing Location	Coordinates	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFOS	5:3 FTCA	7:3 FTCA	FDUEA (10:2 FTUCA	FOUEA (8:2 FTUCA	Total PFAS
1626	Banani Lake, Banani	23.791097, 90.4101910	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	1	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	2.2	3.2
1607	Banani Lake, Banani	23.781290, 90.410283	< 1 ng/L	1.5	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	1	< 1 ng/L	< 1 ng/L	< 1 ng/L	2.5
1618	Gulshan Lake, Gulshan	23.781828, 90.418884	3.7	< 1 ng/L	1.7	1.6	1.4	< 1 ng/L	1.7	1.5	1	2.8	15.4
1628	Gulshan Lake, Gulshan	23.778748, 90.418961	1.1	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	1	< 1 ng/L	< 1 ng/L	2.4	4.5
1606	Hatirjheel Lake, Gulshan	23.754767, 90.402351	< 1 ng/L	1.3	< 1 ng/L	< 1 ng/L	1.4	1.3	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 1 ng/L	4
1614	Hatirjheel Lake, Gulshan	23.756976, 90.403487	< 1 ng/L	1.2	1.1	< 1 ng/L	1.5	1.2	< 1 ng/L	< 1 ng/L	< 1 ng/L	1.7	6.7

Map 7: PFAS concentrations in the Banani, Gulshan, and Hatirjheel Lakes



Waters of all three lakes are interconnected, making the assumption of potential PFAS sources to individual spots problematic. Suspected sources of PFAS in all three lakes are numerous commercial establishments, including hotels and guest houses, particularly in Tejgaon commercial and port areas. In addition to municipal sources, PFAS can be emitted into the water from textile industries located between Banani and Gulshan Lakes and from the Tejgaon industrial area that hosts electronic, glass and ceramic, and chemical and pharmaceutical industries.

7.2.2 Tap Water

A tap water sample collected in 2022 from the ESDO office in Lalmatia, Dhaka, a meticulously planned residential area with no nearby industrial facilities that sources its tap from underground, was analyzed and found to have PFAS below the limit of detection. The tap water contamination from the same area in September 2019 was not confirmed in the sample taken in December 2022. This is likely partially thanks to reconstruction of the outdated piping system that was damaged with cracks and increased susceptibility to contamination from surrounding pollutants. Over the past few years, the Water Supply and Sewerage Authority (WASA) has been actively purifying and chlorinating the water in this locality; however, the purification does not include PFAS removal (neither filtration through activated carbon nor reverse osmosis). The known regular water treatment technologies used by WASA, i.e., pre-treatments (ozone chemical, floatation, neutralization, precipitation, aerated), coagulation, flocculation, sedimentation, filtration (without activated carbon), and disinfection by chlorine,[76] do not sufficiently remove PFAS from water. Monthly examinations of underground water include assessing levels of arsenic and other toxic elements such as chromium, cadmium, lead, mercury, zinc, and aluminum. Additionally, levels of ammonium nitrate, phosphate, sulfate, BOD, and COD are examined quarterly to ensure that water meets standards for consumption. Levels of PFAS are not monitored in the water. Therefore, the positive trend in PFAS contamination in tap water in Lalmatia will need to be confirmed in future investigations on a larger number of samples.

8. 2022 CLOTHING TESTING

In 2023, IPEN released a report on PFAS in clothing sold in 13 countries. The results include samples of clothing purchased in Dhaka, Bangladesh, in late 2022. The data from Bangladesh published in this previous report are included in this study since PFAS-treated clothing items can contribute to human exposure of Dhaka residents. PFAS can be released into laundry water and subsequently contaminate surface waters, as waste waters in Dhaka are not sufficiently treated to remove PFAS.

8.1 METHODOLOGY

8.1.1 Sample Collection

In total, nine clothing items were purchased in department stores in Dhaka. Five items, including jackets, trousers, and a hijab, which are potentially waterproof or stain resistant, were selected for lab analysis (see Table 12 with sample descriptions and sample photographs below).

Table 12: Clothing sample description

Sample ID	Product type	Product name	Brand	Store
BD-PFAS-01	jacket	Softshell Jacket and Water Repellent	Y. Haojin	GAP, Bashundhara City, Panthapath, Dhaka, Bangladesh.
BD-PFAS-02	hijab	Women's Ready Hijab	Al-Modina Borka Hijab	Bashundhara City, Panthapath, Dhaka, Bangladesh.
BD-PFAS-03	trousers	Kid's Spiderman Costume	Hakuchou, Marvel (Local brand of Thailand)	Mom's Angel, Rapa Plaza, 27 Dhanmondi, Dhaka, Bangladesh.
BD-PFAS-08	jacket	MEN´S Jacket 180 L	GRLGIMAP	GAP, Bashundhara City, Panthapath, Dhaka, Bangladesh.
BD-PFAS-09	jacket	MEN´S Jacket 175 A	GRLGIMAP	GAP, Bashundhara City, Panthapath, Dhaka, Bangladesh.

Analyzed samples

BD-PFAS-01

BD-PFAS-02

BD-PFAS-03

BD-PFAS-08

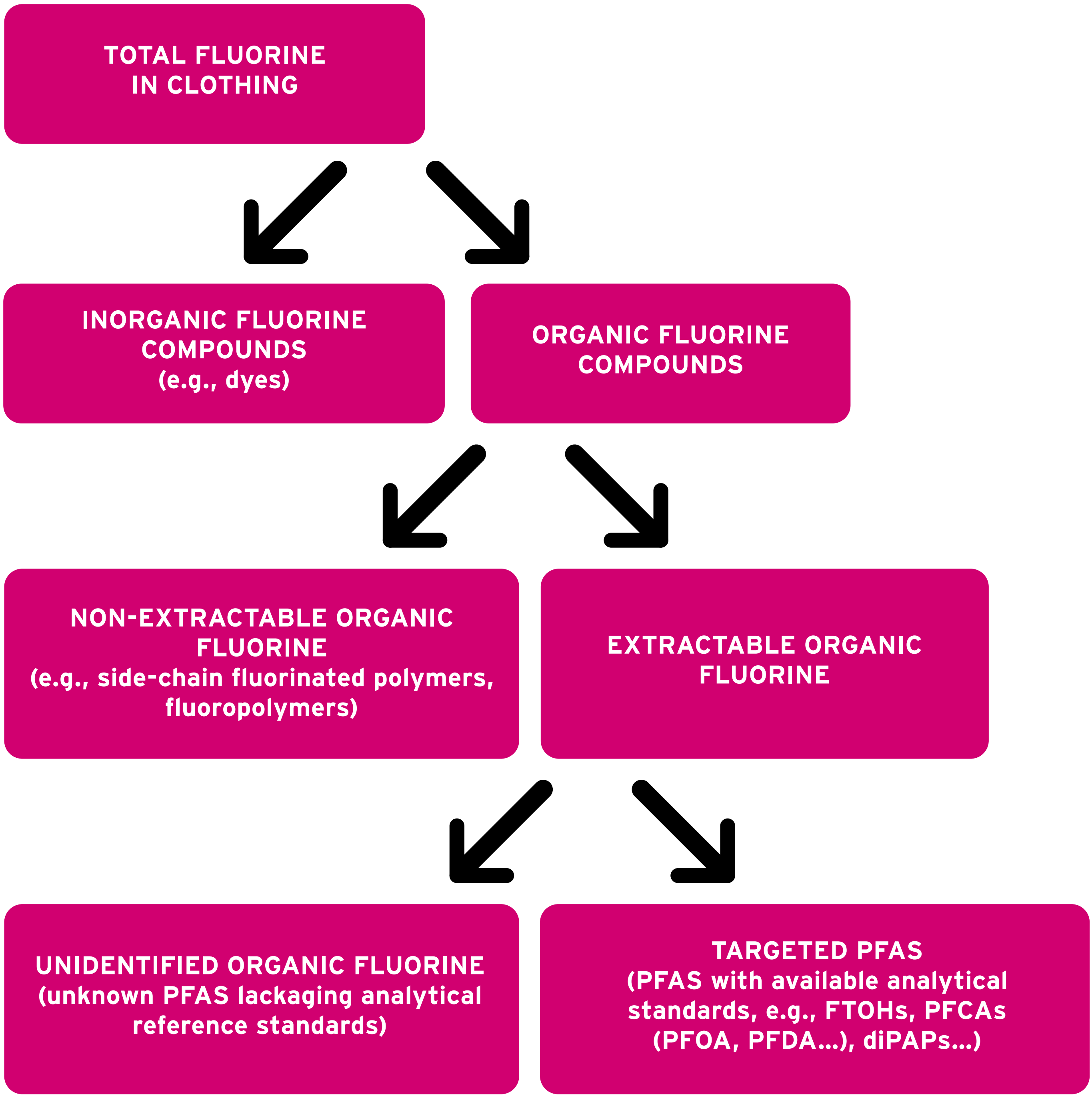
BD-PFAS-09

8.1.2 Sample Analysis

For the Extractable Organic Fluorine (EOF) and targeted PFAS analysis, the samples were prepared by cutting 100 cm^2 of fabric from the outer layer of each clothing item. After cutting, EOF/PFAS were extracted from the fabric with a mixture of methanol and ethyl acetate, and the extract obtained was subjected to the analysis

The EOF was determined by combustion ion chromatography (CIC). Fifty-eight targeted PFAS in sample extracts were determined using high-performance liquid chromatography with tandem mass detection with electrospray ionisation operating in negative mode (HPLC-ESI-MS/MS). The EOF and targeted PFAS amount determined in the extract was converted to the area of the fabric analysed and subsequently recalculated to weight concentration (ng/g). See Strakova et al. (2023)[77] for more details.

Different forms of EOF/PFAS in clothing



8.2 RESULTS

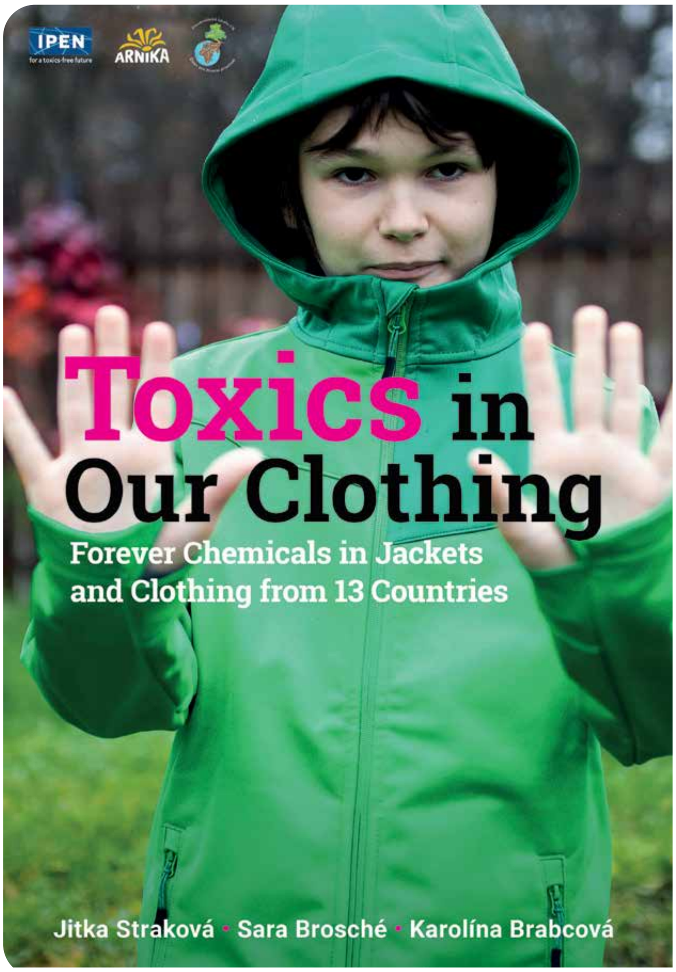
All five lab analyzed clothing were found to be PFAS-treated or -contaminated with EOF ranging from 251.3 to 770.9 ng/g. In the men's jacket from the "GRLGIMAP" manufacturer, 6.8 ng/g PFOA was detected.

See Table 13 below for detailed results.

Table 13: Results of the lab analysis

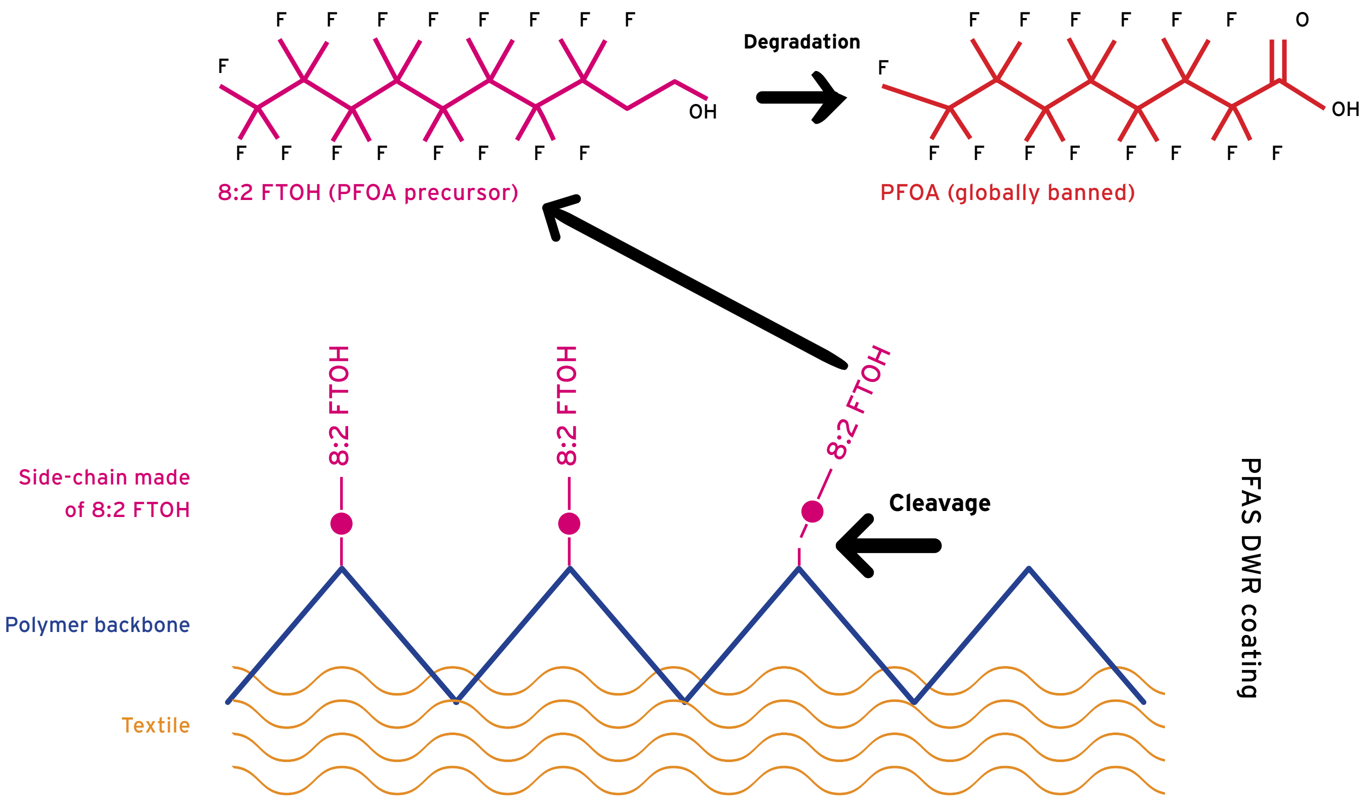
Sample ID	Product name	PFOA (ng/g)	EOF (Extractable Organic Fluorine) (ng/g)
BD-PFAS-01	Softshell Jacket and Water Repellent	<LOD	602.1
BD-PFAS-02	Women's Ready Hijab	<LOD	770.9
BD-PFAS-03	Kid's Spiderman Costume	<LOD	445.3
BD-PFAS-08	MEN´S Jacket 180 L	<LOD	251.3
BD-PFAS-09	MEN´S Jacket 175 A	6.8	263.2

Report on PFAS in clothing sold in 13 countries including Bangladesh



Tested Men's jacket BD-PFAS-08

A simplified example of PFOA formation from side-chain fluorinated polymer applied as durable water repellent (DWR) coating on textile surface



8.3 DISCUSSION

PFAS in clothing can be a source of human exposure to PFAS via inhalation, ingestion, and possibly also via dermal absorption.[78,79,80,81] Children are particularly sensitive to endocrine disrupting PFAS,[82, 83,84,85, 86] which is especially concerning as some of the clothing items investigated in this study were designed for children, whose skin may come into direct contact with the clothing.

PFOA detected in one of the men's jackets is listed in Annex A of the Stockholm Convention for global elimination. PFOA use is prohibited in consumer products in countries that have ratified the Stockholm Convention amendment on PFOA, including Bangladesh. The presence of PFOA in the jacket may be a result of side-chain polymer degradation, as water- and stain-repellency is often obtained by treating textiles with side-chain fluorotelomer-based polymers (SFPs).[87] For example, FTOH sidechains from SFPs degrade into PFOA.[88,89,90] SFPs can be released from items of clothing due to degradation and loss of textile fibers during the entire life cycle.[91, 92] SFPs are polymeric PFAS and not extractable, which means that they are not detectable by the method used in this study.

Since the use of PFAS in clothing is not essential[93] and alternatives already exist,[94,95] the use of PFAS should be banned and non-PFAS, safer alternatives should be used.

9. CONCLUSIONS

- Globally and/or EU regulated substances are present in Dhaka's waters and textiles in high concentrations, including PFOA, long-chain PFCAs, and PFHxA.
- Textile production for export is a source of PFAS releases into the environment.
- PFAS use in textiles leads to exposure in humans, including children, both directly and through drinking water.
- It is likely that there are ongoing releases of PFAS from the textile industry that leads to an accumulation of PFAS in the environment.
- There is a likelihood of broader environmental contamination by additional PFAS not detected by the targeted analysis.
- The textile sector has been estimated to account for about 50% of the total global use of PFAS. However, PFAS in textiles can be replaced with safer alternatives, so there is no need for their continued use.
- The most efficient control measure is to immediately ban the use of all PFAS, including their import/export.

10. RECOMMENDATIONS

FOR THE BANGLADESHI GOVERNMENT AS A PARTY TO THE STOCKHOLM AND BASEL CONVENTIONS:

- Support the listing of long-chain PFCAs and related substances for global elimination without exemptions.
- Work for a class-based approach of listing all PFAS for global elimination under the Stockholm Convention.
- Define all PFAS-contaminated waste as hazardous waste based on their H11 (delayed or chronic toxicity) characteristics.
- Work for PFAS waste limits ("low POPs content levels") no higher than 0.025 mg/kg for PFOS, PFOA or PFHxS and their salts and 10 mg/kg for the sum of PFOS, PFOA, PFHxS and their related compounds.
- Ratify the Basel Ban amendment, ensuring no export nor import of PFAS-contaminated hazardous waste to non-OECD countries.
- Acknowledge that polymeric fluorotelomer-based products (i.e., sidechain fluorinated polymers) as well as PFAS-contaminated products are non-recyclable, and hence non-circular, in the Technical guidelines on the identification and environmentally sound management (ESM) of plastic wastes and for their disposal.

FOR THE BANGLADESHI GOVERNMENT AND MINISTRIES:

- Implement Stockholm Convention amendments listing PFOA, PFOS and PFHxS in national regulations and support the removal of all exemptions and acceptable purposes.
- Prohibit manufacturing and importation of consumer goods containing PFAS, including textiles, textile products and toys, kitchen utensils, food packaging, and other product categories.
- Support the development of a universal (covering all PFAS, including fluorinated polymers and sidechain fluorinated polymers) restriction on PFAS and thereafter fully implement it.
- Require chemical and material transparency for products, i.e., adopt legislation requiring manufacturers to disclose their product ingredients to the public, retailers, and regulators.
- Monitor PFAS substances in the environment.
- Conduct human biomonitoring related to occupational health in paper, textile, firefighting, and other industries that potentially use PFAS in their processes.

- Determine a health-protective standard for PFAS content in drinking water, food, human biomarkers, and the environment.
- Concerned ministries need to initiate multi-stakeholders dialogue for awareness of PFAS and initiatives to phase out the use of PFAS in Bangladesh.

FOR TEXTILE INDUSTRIES:

- Immediately adopt public policies that quickly phase out the use of all PFAS with quantifiable goals and timelines and provide progress reports to the public on at least an annual basis.
- Assess any substitute chemicals for hazards to ensure that any replacement chemicals are the safest possible.
- Publicly disclose PFAS content in existing products with clear warning signs/labels/icons on products.
- Develop a swift and efficient plan for decontaminating soil and drinking water of affected communities living in the vicinity of production sites where PFAS are manufactured or used in textile production.

FOR CONSUMERS:

- Demand PFAS-free outdoor textiles and ask retailers for information about the PFAS content in their products.
- Purchase PFAS-free outdoor textiles that are clearly labeled as PFAS-free on the product.

ANNEX PFAS LEGISLATION IN THE EU AND US

REGULATORY FRAMEWORK IN THE EU

Consumer products

The EU POPs Regulation 2019/1021, which transposes the Stockholm Convention restrictions into European legislation, sets a maximum concentration for the use in consumer products, including textiles:

- PFOA and PFHxS (including their salts) individually: 0.025 mg/kg (25 ng/g or ppb)
- PFOA-related compounds: sum concentration of 1 mg/kg
- PFHxS-related compounds: sum concentration of 1 mg/kg
- PFOS and its derivatives: 10 mg/kg in substances or mixtures
- PFOS and PFOA may not be used in quantities of more than 1 $\mu g/m^2$ of the surface of the treated material.

In February 2023, a restriction covering about 200 long-chain PFCAs (C9-C14) and their precursors (chemicals that degrade into these) came into force in the EU. The threshold for restriction is 25 ppb for the cumulative sum of C9-C14 PFCAs and their salts, and 260 ppb for their related substances. There is also a proposal for restricting the PFAS chemicals PFHxA as well as their precursors.

Several PFAS are identified as substances of very high concern (SVHCs) under the EU REACH legislation (e.g., GenX, PFBS). This means that manufacturers, suppliers, and retailers have to communicate throughout the supply chain about the presence of these substances in products if they contain more than 0.1% of any SVHC substance. However, this threshold is not enough to be protective, since it is far too high and only comes with communication requirements and not additional measures.

In 2023, an EU-wide restriction proposal of all non-essential uses of the entire group of PFAS was published by the European Chemicals Agency (ECHA). When adopted, it will ban the manufacturing, placing on the market and use of PFAS as such, as constituent in other substances, in mixtures, and in articles above a set concentration limit. Almost no exemptions or transition periods are proposed for textiles, since there are viable alternatives available already on the EU market (a few minor exemptions are proposed for protective professional textile equipment). The proposal also describes the entire textile sector, which covers textiles, upholstery, leather, apparel and carpets as the second largest PFAS emissions contributor.

It proposes the following restriction limits:

- 25 ppb for any PFAS (except polymeric PFAS; measured by targeted PFAS analysis),
- 250 ppb for the sum of PFAS, optionally with prior degradation of precursors (measured, for example, by TOP assay), and
- 50 ppm for PFAS, including polymeric PFAS (measured as total organic fluorine).

Drinking water

The Drinking Water Directive (2020/2184/EU) sets two group thresholds for PFAS:

- 'sum of PFAS': 100 ng/L (0.1 µg/L) for a group of 20 PFAS (PFBA, PFPA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFBS, PFPS, PFHxS, PFHpS, PFOS, PFNS, PFDS, Perfluoroundecane sulfonic acid, Perfluorododecane sulfonic acid, Perfluorotridecane sulfonic acid)
- 'PFAS total': 500 ng/L (0.5 µg/L)

EU Member States have to take measures to ensure compliance with the PFAS thresholds by January 2026.

Surface water

Since 2013, PFOS has been one of the priority substances under the EU Water Framework Directive with associated environmental quality standards (EQS):

- annual average 6.5*10-4 µg/L (inland surface water) and 1.3*10-4 µg/L (other surface water),
- maximum allowable concentration: 36 µg/L (inland surface water) and 7.2 µg/L (other surface water)

In 2022, the European Commission proposed the group of 24 PFAS as new priority substances for surface water in a Directive that would amend the Water Framework Directive, the Environmental Quality Standards Directive and the Groundwater Directive. The threshold is 4.4 ng/L ((0.0044 µg/l) and is expressed as PFOA equivalents and makes use of a Relative Potency Factor approach of individual PFAS when setting the group threshold.

PFAS	Relative Potency Factor
PFOA	1
PFOS	2
PFHxS	0.6
PFNA	10
PFBS	0.001
PFHxA	0.01
PFBA	0.05
PFPeA	0.03
PFPeS	0.3005
PFDA	7
PFDoDA or PFDoA	3
PFUnDA or PFUnA	4
PFHpA	0.505
PFTrDA	1.65
PFHpS	1.3
PFDS	2
PFTeDA	0.3
PFHxDA	0.02
PFODA	0.02
HFPO-DA or Gen X	0.06
ADONA	0.03
6:2 FTOH	0.02
8:2 FTOH	0.04
C6O4	0.06

Dutch National Institute for Public Health and the Environment (RIVM) derived advisory surface water concentration limits are based on European Food Safety Authority's (EFSAs) health based limit which is protective for lifetime consumption of fish by humans (the limit was set for PFOA, PFOS, PFNA and PFHxS as tolerable weekly intake (TWI) to 4.4 ng per kilogram of body weight). For the three PFAS for which surface water quality standards are already in place in the Netherlands, the new risk limits are:

- 0.3 ng/L for PFOA;
- 7 pg/L for PFOS;
- 10 ng/L for HFPO-DA (GenX).

REGULATORY FRAMEWORK IN THE US

Consumer products

Although the United States has no federal legislation on PFAS, state governments are taking legislative and regulatory actions to phase out PFAS in products to prevent contamination in favor of safer alternatives. For example, laws in Maine, Minnesota, and Washington have given state agencies the authority to ban PFAS in a wide range of products. Maine and Minnesota's laws require manufacturers to disclose the presence of PFAS. Several states adopted restrictions on PFAS in textiles with California banning PFAS in almost all textiles, New York restricting them in apparel, Colorado and Minnesota banning them in upholstered furniture, and Washington moving forward on regulatory actions on many categories of textile products. Eight states (California, Colorado, Maine, Maryland, Minnesota, New York, Vermont, and Washington) adopted restrictions on PFAS in carpets, rugs, and aftermarket treatments. Twelve states (California, Colorado, Connecticut, Hawaii, Maryland, Maine, Minnesota, New York, Oregon, Rhode Island, Vermont, and Washington) have enacted state bans on PFAS in food packaging. Six states (California, Colorado, Maryland, Minnesota, Oregon, and Washington) adopted restrictions on PFAS in personal care products. Colorado also adopted restrictions on oil and gas products. Twelve states (California, Colorado, Connecticut, Hawaii, Illinois, Maine, Maryland, Minnesota, New Hampshire, New York, Vermont, and Washington) banned the sale of firefighting foam containing PFAS. With legislation adopted last year, Washington is evaluating safer alternatives for PFAS in products such as apparel, cleaners, coatings, floor finishes, firefighter turnout gear, and others with a timeline of adopting restrictions by 2025.

Drinking water

The United States Environmental Protection Agency (US EPA) agreed in April 2024 on the National Primary Drinking Water Regulation (NPDWR) to establish legally enforceable levels, called Maximum Contaminant Levels (MCLs), for six PFAS in drinking water. The EPA also proposed health-based, non-enforceable Maximum Contaminant Level Goals (MCLGs) for these six PFAS.

Compliance with the Hazard Index MCL is determined by a running annual average.[96]

The final rule requires:[97]

Public water systems must monitor for these PFAS and have three years to complete initial monitoring (by 2027), followed by ongoing compliance monitoring. Water systems must also provide the public with information on the levels of these PFAS in their drinking water beginning in 2027.

Public water systems have five years (by 2029) to implement solutions that reduce these PFAS if monitoring shows that drinking water levels exceed these MCLs.

Compound	Proposed MCLG	Proposed MCL (enforceable levels)
PFOA	Zero	4.0 ppt (ng/L)
PFOS	Zero	4.0 ppt
PFNA	10 ppt	10 ppt
PFHxS	10 ppt	10 ppt
PFBS	10 ppt	10 ppt
HFPO-DA (GenX)	10 ppt	10 ppt
Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS	1.0 (unitless) Hazard Index*	1.0 (unitless) Hazard Index*

* *The Hazard Index is calculated by the following equation:*

$$\text{Hazard Index (1 unitless)} = \left(\frac{[\text{HFPO}-\text{DA}_{\text{ppt}}]}{[10\ \text{ppt}]}\right) + \left(\frac{[\text{PFBS}_{\text{ppt}}]}{[2000\ \text{ppt}]}\right) + \left(\frac{[\text{PFNA}_{\text{ppt}}]}{[10\ \text{ppt}]}\right) + \left(\frac{[\text{PFHxS}_{\text{ppt}}]}{[10\ \text{ppt}]}\right)$$

Beginning in five years (2029), public water systems that have PFAS in drinking water which violates one or more of these MCLs must take action to reduce levels of these PFAS in their drinking water and must provide notification to the public of the violation.

Moreover, several US states set standards and guidance values for PFAS in drinking water.

Surface water

US EPA published its Draft 2022 Aquatic Life Ambient Water Quality Criteria for PFOA and PFOS.[98] When finalized, states and authorized tribes can adopt these criteria into their water quality standards or can adopt other criteria that are scientifically defensible based on local or site-specific conditions.

Criteria component	Maximum concentration (acute)	Continuous concentration (chronic)
PFOA	49 mg/L	0.094 mg/L
PFOS	3.0 mg/L	3.0 mg/L
Duration	1-hour average	1-hour average
Frequency	Not to be exceeded more than once in three years, on average	Not to be exceeded more than once in three years, on average

Several US states set standards and guidance values for PFAS in surface/effluent water. For example, the State of New York ambient water quality guidance values for protection of human health include PFOA (6.7 ng/L) and PFOS (2.7 ng/L).[99]

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