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SUSTAINABLE WATERS
EMPEREST

Draft framework for local PFAS risk assessment plan

EMPEREST – ELIMINATING MICRO-POLLUTANTS FROM EFFLUENTS FOR REUSE STRATEGIES

City of Riga, 2024

Imprint

This publication has been developed within the project **EMPEREST – Eliminating Micro-Pollutants from Effluents for Reuse Strategies,** co-financed by the Interreg Baltic Sea Region Programme 2021–2027, and helping to drive the transition to a green and resilient Baltic Sea region.

EMPEREST consortium: Union of the Baltic Cities Sustainable Cities Commission c/o City of Turku (UBC) (FI), Baltic Marine Environment Protection Commission – Helsinki Commission (HELCOM) (FI), University of Tartu (EE), Berlin University of Technology (DE), Turku University of Applied Sciences (TUAS) (FI), Gdańsk Water Utilities (PL), Water and Sewage Company Ltd of Szczecin (PL), Tartu Waterworks Ltd (EE), Tallinn Water Ltd (EE), "Kaunas water" Ltd (LT), Turku Region Wastewater Treatment Plant (FI), DWA German Association for Water, Wastewater and Waste DWA Regional group North-East (DE), Environmental Centre for Administration and Technology (LT), City of Riga (LV).

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Authors: Kamila Gruškeviča (City of Riga / Riga Technical University), Māra Reča (City of Riga) and Māris Zviedris (City of Riga / Riga Water Ltd).

Contributors: Mariia Andreeva (UBC), Agnieszka Ilola (UBC), Lotta Lehti (UBC), Piia Leskinen (TUAS), Denisa Martinkutė (ECAT), Vaiva Ramanauskienė (ECAT), Markus Raudkivi (HELCOM), Riikka Vainio (TUAS) and Siiri Velling (UT).

Layout: Laura Sarlin, City of Turku

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Project note

The EMPEREST project supports local authorities, service providers and policy-making community in finding ways to reduce PFAS (Per- and polyfluoroalkyl substances) and other organic micropollutants from the water cycle. The project has four activity strands to fulfil its aims. First, in close cooperation with HELCOM EMPEREST prepares methodological recommendations to monitor PFAS group in the aquatic environment. Second, local authorities address the subject on the city level by developing a PFAS risk assessment framework to identify and assess PFAS-related risks and propose relevant risk mitigation strategies. Third, EMPEREST supports water utilities in making informed decisions about cost-effective treatment strategies and investments for removing micropollutants from wastewater. Finally, capacity building takes place for both local authorities and public service providers to inform them about the recent developments in the field and train them with tailored materials and tools.

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1. Introduction

1.1. What are PFAS?

In 1938, while trying to create a new type of refrigerant gas, Roy J. Plunkett found that the sample had polymerized spontaneously into a white, waxy solid - polytetrafluoroethylene (PTFE) (Science History Institute Museum & Library n.d.). The chemical was registered under trademark Teflon in 1945 (Teflon.com n.d.). Starting in the 1950s, perfluoroalkyl and polyfluoroalkyl substances (PFAS) have been produced and used for a variety of both industrial and commercial purposes, including textile, carpet and leather treatment (water and dirt proofing), surfactants, firefighting foams, metal plating and paper grease-proofing treatments (Glüge, Scheringer, et al. 2020).

PFAS do not naturally occur in the environment and their presence is of anthropogenic origin (UBA 2022). PFAS are highly effective surfactants and surface protectors due to the presence of perfluorocarbon moieties which are both hydrophobic and oleophobic (Glüge, Scheringer, et al. 2020). These qualities, including mechanical strength, inertness, thermal stability, and resistance to degradation, have driven substantial demand and supply of PFAS on the global market. However, due to their extreme persistence (due to robust bond between carbon and fluorine) and inability to biodegrade in the environment (Glüge, London, et al. 2022), PFAS have earned the moniker "Forever chemicals" (Le Monde, et al. n.d.). Although certain complex molecules may degrade partially over time, they ultimately transform into persistent PFAS, like perfluorooctanoic acid (PFOA) or perfluorooctane sulfonic acid (PFOS), as well as smaller perfluorinated compounds, which linger in the environment (Directorate-General for Environment, European Commission 2020). Numerous PFAS compounds bioaccumulate in humans, animals, and plants (Cousins 2015). Among the limited number that have been extensively researched, the majority are regarded as toxic. The extensive use of PFAS since the 1950s has led to the accumulation of these substances in various environmental compartments, including groundwater, freshwater, seawater, rainwater, soil, sediment, wastewater treatment plant (WWTP) sludge and effluent, as well as in living organisms and food sources (Glüge, Scheringer, et al. 2020) (EFSA Panel on Contaminants in the Food Chain 2018) (Reinikainen, et al. 2022).

In this document, we refer to PFAS in accordance to a new OECD definition by (Wang, et al. 2021): "PFASs are defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e., with a few noted exceptions, any chemical with at least a perfluorinated methyl group ($-CF_3$) or a perfluorinated methylene group ($-CF_2-$) is a PFAS."

Currently there are more than 10000 known PFAS. To ensure that the information provided in this document is user-friendly we use the general term 'PFAS', instead of individual substances to provide a comprehensive overview.

1.2. Why PFAS are dangerous?

Several PFAS compounds bioaccumulate in humans, animals, and plants (Cousins 2015). Among the limited number that have been extensively researched, the majority are regarded as toxic. Humans get exposed to PFAS through breathing dust particles, consuming contaminated food and water, and absorbing substances through the skin. However, inhalation is considered a serious route in case of specific industry or location workers (Nilsson, et al. 2013). For example, workers in fluoropolymer facilities (Porter, et al. 2024), electroplaters (Göen, et al. 2024), professional ski waxers (Nilsson, et al. 2013) and firefighters (Tefera, et al. 2023). The general population get largest exposure to PFAS through their dietary habits and consumption of drinking water (Andrews and Naidenko 2020). Regardless of the exposure pathway, PFAS substances pose a significant risk to human health. They have the potential to cause changes in development, lipid metabolism, and the endocrine system, as well as to increase the risk of cancer, impair the immune system, damage the liver, and affect reproductive health (Panieri, et al. 2022). The known and potential impact of PFAS on human are shown in **Figure 1**.

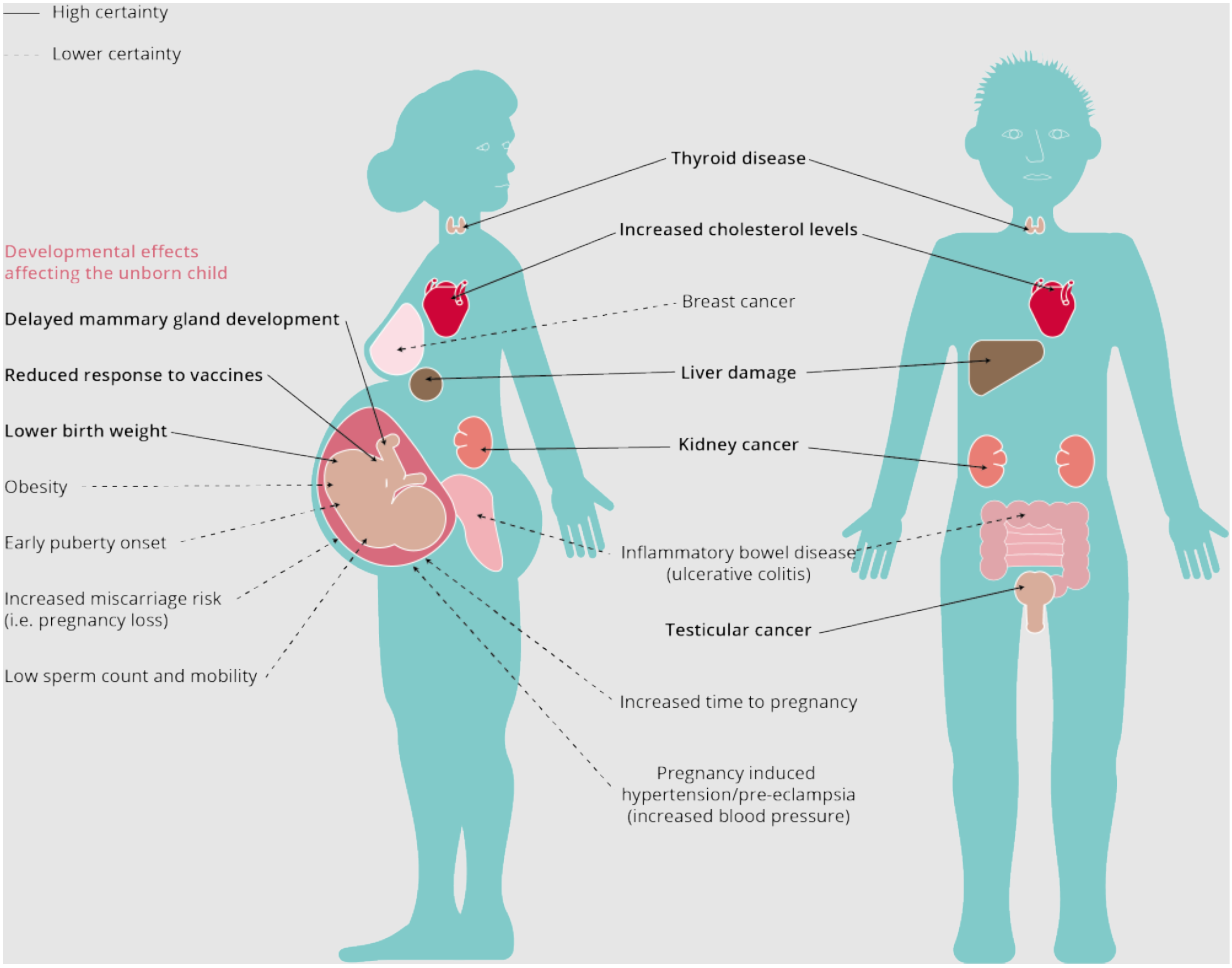

Figure 1 Effects of PFAS on human health (European Environment Agency n.d.) https://www.eea.europa.eu/publications/emerging-chemical-risks-in-europe/emerging-chemical-risks-in-europe

1.3. The aim

The aim of the current document is to provide local authorities with city-specific guidelines and tailor-made tools for the PFAS risk assessment in aquatic environments. With these guidelines and tools, it is possible to identify PFAS pollution sources and consequently better protect our waters (groundwater, river water, the Baltic Sea) from hazardous PFAS contamination.

The successful development and implementation of the risk assessment plan by local public authorities will improve the understanding of PFAS in the environment and especially in the water supply system, improve stakeholder collaboration and operational efficiency of the water utility as well as provide a robust framework to better target sustainable and long-term capital investments. The output, which is a comprehensive PFAS risk assessment plan, will contribute to the overall water utility risk management and thus strengthening safe and sustainable management of drinking water resources by municipalities. It will help local authorities to understand the complete system, identify where and how risks could arise, recognise barriers, determine control measures and monitoring plans as well as develop overall PFAS management system.

2. Review of potential PFAS contamination in municipalities

The traced sources of PFAS in contaminated groundwaters and surface waters are fluoropolymer producing facilities (Pitter, et al. 2020), firefighting training sites (Sörengård , et al. 2022) (Grung, et al. 2024), military (Sörengård , et al. 2022) and civil airports (Ahrens, et al. 2015), as well as sewage sludge applied to agricultural lands (Johnson 2022) and landfill leachate (Chen, et al. 2023), (Currell, Northby and Netherway 2024). The presence of PFAS in drinking water is associated with greater numbers of PFAS sources within watersheds (Liddie 2023). (Guelfo 2018) showed that PFAS in large public water systems (>10,000 customers) were found more than 5 times more often than in small water systems. However, average PFAS concentrations were more than two times higher in small public water systems than in large ones (Guelfo 2018). Contaminated groundwater poses a threat to human health when using individual drinking water wells in contaminated areas (Silver, et al. 2023). Several studies across the world linked higher level of PFAS in blood with fish and seafood consumption (Manzano-Salgado 2016) (Shu 2018), (Pirard 2020), (Augustsson, et al. 2021), (Richterová 2023). Exposure study showed that PFAS concentrations in teenage blood samples were significantly higher in North and West Europe than in South and East Europe (Richterová 2023).

WWTPs are considered one of the major PFAS environmental discharge channels, especially in the context of aquatic environments (Müller 2023). WWTP sludge accumulate PFAS (Stahl, et al. 2018) (Semerád , et al. 2020) (Fredriksson, et al. 2022), and composition of PFAS in sludge reflects tendencies to switch for more "modern" PFAS (Semerád , et al. 2020). However, now banned PFAS substances were also found in sludge samples (Semerád , et al. 2020) (Fredriksson, et al. 2022), indicating that sludge works as a sink for PFAS. If sludge is later used for fertilization or in green infrastructure the contamination may be spread on new areas and end up in soil and water bodies (Semerád , et al. 2020) (Silver, et al. 2023).

Apart from large contamination sources, PFAS come from various applications and products, including the production of coatings for stain and water repellence, and aqueous film-forming foams (specific type of firefighting foams) (Guelfo 2018). The industries generating PFAS pollution and typical applications for these industries are shown in **Table 1**.

Table 1 Industries and applications generating PFAS pollution (modified from (Croad 2022))

Industry	PFAS used in:
Chemical and energy storage	Piping, tubing and fittings, fluid-handling components, vessels, storage tanks, sensors, sealants, binders in energy storage devices (e.g. batteries).
Renewable energy	Front and back sheets for PV, paint and coating for wind turbines, coating for wires and cables, binders in lithium-ion batteries.

Industry	PFAS used in:
Metal plating	Chrome plating baths as fume suppressants, zinc plating to reduce the surface tension, corrosion reduction in finished products.
Consumer mixtures	Non-sticking coating, impregnation agents, polishes etc.
Cosmetics	Makeup (foundations, mascaras, lip products) for long-lasting properties.
Construction	Architectural membranes, windows and frames, cables, bearings, sealants, pipe linings, surface coatings.
Electronics	Semiconductor production, wires and cables.
F-gases	Air conditioning and heat pumps. Heat-transfer fluids/cooling agents.
Firefighting foams	Aqueous film-forming foams to fight fuel fires.
Food contact materials	Non-stick kitchen utensils, non-stick coating for cook and bakeware (pots, pans, baking trays).
Lubricants and ski wax	Various formulation to improve lubrication and slow wear-off.
Medical devices	Cardiovascular grafts, heart patches, ligament replacements, filtering membranes, dialysis membranes, catheters, surgical patches.
Petroleum and mining	Pipe linings, tanks, fluid handling components, seals, gaskets, cables.
Textiles and upholstery	Outdoor clothing (water, grease and chemical resistant clothes and footwear), upholstery, carpets, curtains etc.
Transportation	Fuel lines, hoses, hydraulic systems, O-rings, gaskets, electronic systems, coating for a variety of purposes (e.g. cables, wires, hoses, vents, sealants), fuel cell materials.

The finished products made with PFAS will end up on the market. PFAS release occurs in all stages: production, use and disposal. A review study of PFAS in domestic goods across the world identified the highest PFAS concentrations in household firefighting products, followed by textile finishing chemicals and household chemicals (Dewapriya 2023). Other study analysing PFAS in effluents from a variety of industries showed that the highest concentration of individual substance (PFHxS) - 79000 ng/L was found in mobile carpet cleaner wastewater (Payne 2023). Currently, there is no list that connects specific substances to particular industries (Lerch 2022). Thus, if a particular substance is present in wastewater, it is hard to trace the source.

It is estimated that around 230 000 tonnes of PFAS chemicals are placed on the market annually (Glüge, Scheringer, et al. 2020). The European industries that produce the largest quantities of PFAS (according to ECHA (ECHA, Proposal for a restriction 2023)) in descending order are listed in **Table 2** below.

Table 2 Industries in Europe producing the largest quantities of PFAS in 2020 (in descending order)

Application	Tonnes per year	Application	Tonnes per year
PFAS Manufacture	257 132	Petroleum and mining	5 507
TULAC*	91 938	Electronics and semiconductors	4 423
Medical devices	43 100	Energy sector	3 050
Applications of fluorinated gases	30 671	Lubricants	1 666
Food contact materials and packaging	24 185	Metal plating and manufacture of metal products	990
Transport	10 532	Cosmetics	32.1

* TULAC – Textile, upholstery, leather, apparel and carpets

A study about PFAS in home dust in Europe showed that higher concentrations were observed in houses: located in industrial areas, using floor carpets, containing PFAS in building materials (de la Torre 2019).

In sum, the largest PFAS pollution sources in the environment are fluoropolymer producing facilities, firefighting training sites, military polygons and civil airports, landfills, and wastewater treatment plants. But diffused pollution may come from various sources.

3. Local PFAS risk assessment plan for evaluating the potential exposure of residents to PFAS

The purpose of the EMPEREST tool is to provide local authorities with a guidance for the PFAS risk assessment. The risk assessment tool consists of 11 steps, based on 10 tables. When completed, local authorities will identify and assess PFAS related risks and can seek for relevant risk mitigation strategies. The final output – Risk assessment plan is tailor-made for your city/municipality.

Our first testing group (employees of municipalities and waterwork companies) indicated about 12 hours necessary to complete the document (excluding sampling part). They claimed the process was straightforward and no obstacles were identified, providing you are in a good contact with your stakeholder.

In the following (sections 3.1-3.11), we present the steps of the tool.

3.1. Identification of stakeholders

Current document specifically targets the assessment of local PFAS risks for the aquatic environments and general population. The primary route of exposure to PFAS for general population is consumption of contaminated food (not addressed in current document) and water. To identify PFAS risks in your city/municipality it is crucial to know what waterbody is used as source (sources) for drinking water production. To identify your drinking water sources please fill in **Table 3** below.

Table 3 Identification of stakeholders for water management

Water supply stage:	Stakeholder	Function:
Source		Water quality abstraction site.
Treatment and distribution		Abstracting water. Treating water. Supplying drinking water
Wastewater collection and treatment		Collecting wastewater. Treating wastewater.

3.2. Water source(s)

If you are not sure about drinking water sources (groundwater/surface water or the exact river/lake), contact your stakeholder.

Some cities may have several drinking water sources. In that case you will need to perform sampling and assess the PFAS risks for every source (or group the sources). If you have several groundwater wells, please group the sources by location (or contact our team for help). Please fill in **Table 4**.

Table 4 Sources of drinking water

Drinking water source 1: Groundwater or surface water?	Name of drinking water treatment plant	Water abstraction site
Groundwater		
	Amount, m^3	Amount, %
Well one		
Well two		
Drinking water source 2: Groundwater or surface water?	**Name of drinking water treatment plant**	**Water abstraction site**
Surface water		
	Amount, m^3	Amount, %
River one		
Lake two		

3.3. Individual drinking water wells

Potable drinking water is usually treated and municipal wells for abstraction of water are in protected areas. Therefore, individual wells are at higher risk of getting contaminated (including PFAS) water. Thus, the question is if and how many inhabitants use individual wells. Please answer how many inhabitants use individual wells Put X in the right place in **Table 5**.

Table 5 Individual wells users

More than 50 %	30 to 49 %	20 to 29 %	Less than 20%	No

3.4. PFAS producing facilities in EU

Fluoropolymers producing facilities affect the aquatic environment by excreting PFAS containing wastewaters to sewerage networks and gases to atmosphere. The largest known PFAS producing facilities are listed in **Table 6**. Please review the table (below) and determine if any of these facilities are located in your country and operate near your drinking water source watershed. Afterwards, fill in the last column in **Table 6**.

Table 6 Largest PFAS producing facilities in EU

Name	Location	Is current facility affecting your watersheds? (YES/NO)
Asahi Glass Chemicals Europe	Thornton-Cleveleys, UK	
Arkema France and Daikin Chemical	Pierre-Bénite, FR	
Chemours	Dordrecht, NL	
Dyneon (subsidiary of 3M)	Burgkirchen an der Alz, DE	
Solvay–Solexis	Tavaux, FR	

Name	Location	Is current facility affecting your watersheds? (YES/NO)
Solvay Specialty Polymers	Spinetta Marengo, IT	

3.5. Significant PFAS pollution sources in municipalities

The significant PFAS sources affecting surrounding aquatic environments are: airports, firefighters training sites, military polygons, landfills and wastewater treatment plants (WWTPs). Do you have these PFAS pollution sources and how far they are from water abstraction sites? Fill in **Table 7** according to the example (below).

Table 7 Significant PFAS pollution sources in municipalities

Content heading	No	Yes, how many?	Straight distance from the closest water source, km
Airport		1	10
Firefighters training site	x		
Military polygon	x		
Landfill		1	3
Wastewater treatment plant		1	8

3.6. Wastewaters

Ask your stakeholder responsible for wastewater collection and treatment what percentage of wastewater is domestic (communal) wastewater and what percentage is industrial wastewater. Knowing these numbers, you can justify where to put an effort. Please fill in **Table 8**. In case if you are unable to gain information regarding some particular categories, just leave it out for now.

Table 8 Classification of wastewaters

City	Amount, m^3/day	Amount, %
Domestic wastewater		
Rainwater		
Industrial wastewater		
Communal wastewater (mixed wastewater from both domestic and rainwater sources).		
Total amount		100

3.7. Largest wastewater producers

Ask your stakeholder responsible for wastewater collection and treatment what companies are the biggest contributors to amounts of wastewater (WW). 0,1% - 1 %, and others will be below 0,1%. Please see example below and fill in **Table 9**. Leave the last column unfilled for now. Add lines to the table if necessary.

Table 9 Largest wastewater producers

Company name	WW amount, m^3/day	Share of WW, %	NACE code
1 % and more of wastewaters:			
Company 1	100	1	
Company 2	99	1	
0,1 % to 1 % of wastewaters:			
Company 3	60	0,6	
Company 4	50	0,5	
Company 5	20	0,2	

3.7.1. Finding a database

To identify potential polluters among the biggest wastewater producers it is necessary to understand what kind of activities are made by companies from **Table 9**.

Common classification of economic activities in the EU helps to determine type of economic activity of institutional units engaged in manufacturing or other economic sectors. EU use NACE classification for the identification of economic activities:
https://ec.europa.eu/competition/mergers/cases/index/nace_all.html

If your country uses NACE, find the database allowing to identify enterprises related to a particular NACE code. (For example, C 20.52 Manufacture of glues). For your information: many enterprises have two or more NACE codes.

If your country does not use NACE, find an alternative database where enterprises are classified by economic activity codes. SIC codes (for UK) database can be used.

Poland uses PKD codes:

https://stat.gov.pl/en/metainformation/classifications/

3.8. Identifying potential polluters

Work with **Table 9**:

Identify NACE (or other) Codes:

- Use a database to identify the codes for all the companies listed in **Table 9**.
- Note that many enterprises might have two or more NACE codes.
- See the list of NACE codes associated with activities that generate potential PFAS pollution (see **paragraph 3.8.1**).
- Compare each company's NACE codes from Table 5 with the PFAS pollution related list.
- If at least one of the company's economic activities matches any code from the PFAS pollution list, mark that company's row in red.

If the whole number is mentioned (with no subcategories, e.g. 13) this means that all subcategories of this number also included foe example 13 Manufacture of textiles includes:

13 Manufacture of textiles

13.10 Preparation and spinning of textile fibres

13.20 Weaving of textiles

13.30 Finishing of textiles

13.91 Manufacture of knitted and crocheted fabrics

13.92 Manufacture of made-up textile articles, except apparel

13.93 Manufacture of carpets and rugs

13.94 Manufacture of cordage, rope, twine and netting

13.95 Manufacture of non-wovens and articles made from non-wovens, except apparel

13.96 Manufacture of other technical and industrial textiles

13.99 Manufacture of other textiles n.e.c.

In only some subcategories mentioned (for example 20.11), this means that only these subcategories are included and NOT the whole category (20).

3.8.1. PFAS pollution related list

Code	Name
C	MANUFACTURING
13	Manufacture of textiles
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
17	Manufacture of paper and paper products
19	Manufacture of coke and refined petroleum products
20.1	Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms
20.11	Manufacture of industrial gases
20.16	Manufacture of plastics in primary forms
20.17	Manufacture of synthetic rubber in primary forms
20.2	Manufacture of pesticides and other agrochemical products
20.3	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
20.4	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
20.52	Manufacture of glues
20.59	Manufacture of other chemical products n.e.c.

21.2	Manufacture of pharmaceutical preparations
22	Manufacture of rubber and plastic products
23.3	Manufacture of clay building materials
23.5	Manufacture of cement, lime and plaster
23.6	Manufacture of articles of concrete, cement and plaster
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28.25	Manufacture of non-domestic cooling and ventilation equipment
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
31	Manufacture of furniture
32.5	Manufacture of medical and dental instruments and supplies
32.99	Other manufacturing n.e.c.
D	ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY
35.11	Production of electricity
E	WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES
37	Sewerage
38	Waste collection, treatment and disposal activities; materials recovery

3.9. Voluntary firefighting brigades

Firefighting foams may contain PFAS. It is important to track all possible PFAS sources. Thus, please answer if voluntary firefighting brigades operate in your city/municipality. Put X in the corresponding place in **Table 10**.

Table 10 Voluntary firefighting brigades

Yes, several	Yes, one	No

3.10. Wastewater treatment sludge use for green infrastructure

Wastewater treatment plant sludge may accumulate PFAS. Is sludge from municipal wastewater treatment plants or its compost used for green infrastructure (parks, new green areas)? Put X in the corresponding place in **Table 11**.

Table 11 Sewage sludge use for green infrastructure

Yes, in most cases	Yes, sometimes	No

3.11. Existing pollution baseline

To evaluate if PFAS pollution already exists in drinking water it is important to know if any PFAS analyses were done. Currently in EU PFAS Total and Sum of PFAS analysis are proposed by Drinking Water Directive. Contact your stakeholder responsible for drinking water and ask if they have done any PFAS analyses for drinking water. Please fill in the **Table 12** (below) if any results are available. Add rows if necessary. If no analyses were done, please mark this in table.

Table 12 Results of PFAS analyses

Source	PFAS total, ng/L	Sum of PFAS, ng/L
Well one		
Well two		
Drinking water from drinking water treatment plant NAME		

4. Sampling of PFAS in drinking water

4.1. Extract from legislation on PFAS in drinking water

Article 25 in "Drinking Water Directive" DIRECTIVE (EU) 2020/2184 (THE EUROPEAN PARLIAMENT AND THE COUNCIL 2020) states (bolding added):

"1. By 12 January 2026, Member States shall take the measures necessary to ensure that water intended for human consumption complies with the parametric values set out in Part B of Annex I for Bisphenol A, Chlorate, Chlorite, Haloacetic Acids, Microcystin-LR, **PFAS Total, Sum of PFAS** and Uranium.

2. Until 12 January 2026, water suppliers shall not be obliged to monitor water intended for human consumption in accordance with Article 13 for the parameters listed in paragraph 1 of this Article."

Those substances shall be monitored when the risk assessment and risk management of the catchment areas for abstraction points carried out in accordance with Article 8 conclude that those substances are likely to be present in a given water supply.

Article 8: "Without prejudice to Articles 4 to 8 of Directive 2000/60/EC, Member States shall ensure that risk assessment and risk management of the catchment areas for abstraction points of water intended for human consumption are carried out."

Risk-based approach to water safety is described in same directive Article 7 (bolding added):

"1. Member States shall ensure that the supply, treatment and distribution of water intended for human consumption is subject to a **risk-based approach that covers the whole supply chain from the**

catchment area, abstraction, treatment, storage and distribution of water to the point of compliance specified in Article 6.

The risk-based approach shall entail the following elements:

(a) risk assessment and risk management of the **catchment areas for abstraction points** of water intended for human consumption in accordance with Article 8;

(b) risk assessment and risk management for **each supply system that includes the abstraction, treatment, storage and distribution of water** intended for human consumption to the point of supply carried out by the water suppliers in accordance with Article 9; and

(c) risk assessment of the **domestic distribution systems** in accordance with Article 10."

4.2. Extract from legislation on PFAS in wastewater

According to (Council of the European Union 2024): "Member States should monitor a broad spectrum of pollutants at the **inlets and outlets of the urban wastewater treatment plants**. To avoid unnecessary burden, only pollutants that can be expected to be found in urban wastewater should be monitored taking into account the high variety of pollutants which could reach urban wastewater treatment plants, including from non-domestic wastewater sources." ''It is (…) essential to better understand the pathways of PFAS into the environment and to monitor them in the inlet and outlet of the urban wastewater treatment plants. This monitoring should start in the first instance where the discharges reach catchment areas used for the abstraction of drinking water, due to high risks of being exposed to PFAS and their impact on health.''

4.3. Sampling

Currently (30. June 2024) there is no EU level legislation making PFAS analysis in drinking water obligatory. However, risk-based approach for the whole drinking water treatment and distribution process is mandatory for water intended for human consumption. Also, in a proposal for a Directive of the European Parliament and of the Council concerning urban wastewater treatment (Council of the European Union 2024) it is said that it is necessary to understand risks and spread of PFAS in the aquatic environment. This is why in current document we propose to make sampling in accordance to developed (in Local PFAS risk assessment plan for evaluating the potential exposure of residents to PFAS) risk assessment plan. Risk assessment for PFAS pollution covers all water cycle stages: source, treatment and distribution systems, and wastewater collection and treatment. After completing the risk assessment plan, you will know the points in the water cycle with the highest risks.

The PFAS monitoring strategy consists of three major parts: planning, sampling and analysis (**Figure 2**).

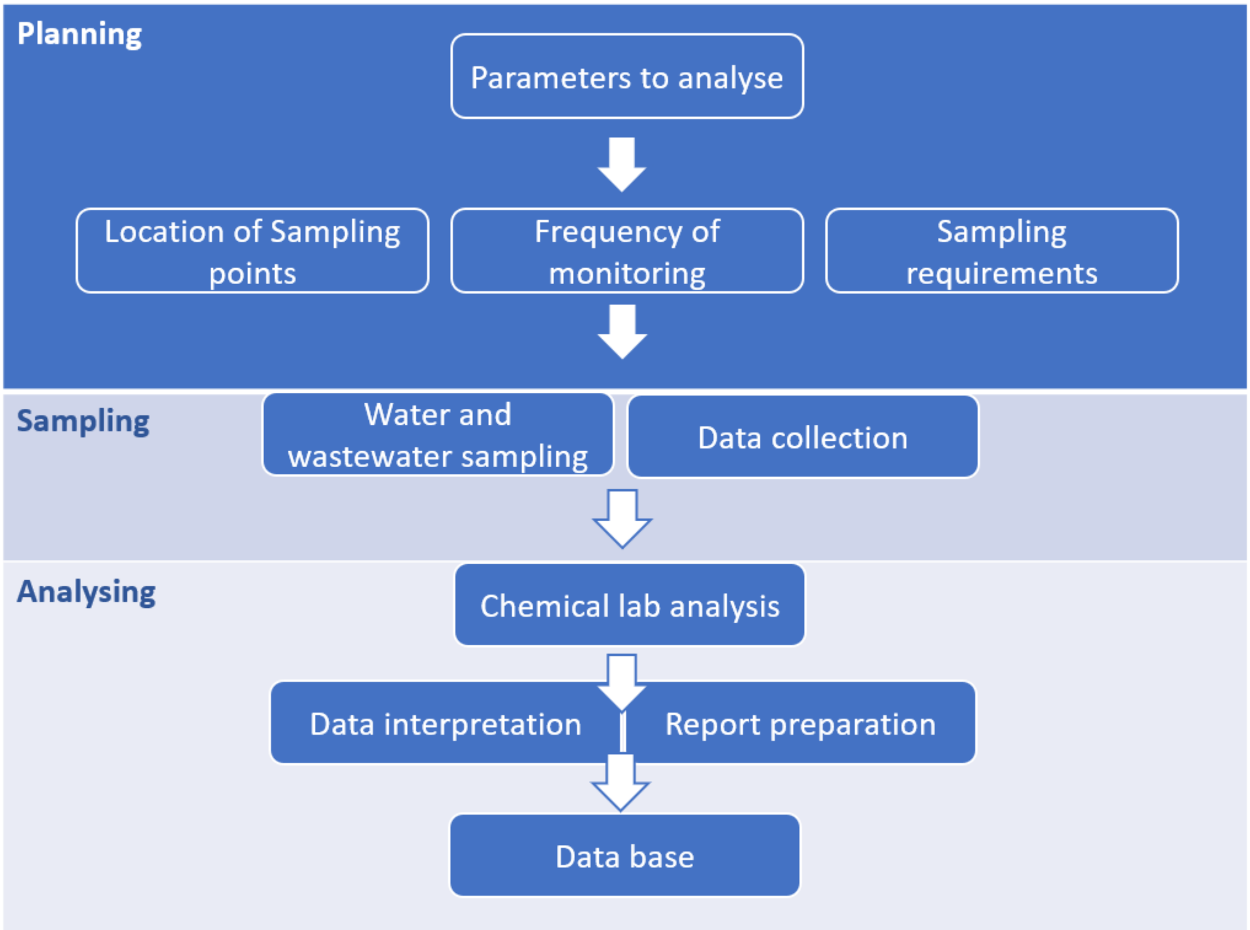

Figure 2. Proposed PFAS monitoring strategy in municipalities

4.3.1. Planning

Referring to the legislation (see Extract from legislation on PFAS in drinking water) we advise to analyse both **PFAS Total, Sum of PFAS** (if currently available, opt for PFAS20/PFAS24). However, if cost cutting is necessary, select **PFAS4** to have an indication of pollution.

Sampling should always be done at the source (see Water source(s)). If any PFAS pollution identified at the source, perform analysis also for treated water. This will help evaluate an effectiveness of drinking water treatment and understand if PFAS are present in drinking water. You will also be able to fill **Table 12** Results of PFAS analyses.

Sampling should be done at the inlet and outlet of wastewater treatment plant to evaluate PFAS contamination level in wastewater and PFAS release to the environment. We also advise to analyse wastewater treatment plant sludge for PFAS to understand if sludge can be safely used for fertilization of crops and for green infrastructure.

To evaluate potential pollution for aquatic environments, refer to **Table 7** Significant PFAS pollution sources in municipalities. If any significant pollution sources (airport, firefighters training site, military polygon, landfill, or wastewater treatment plant) are located in 6 km (straight) distance from drinking water source(s), sampling of water and/or soil should be done at the pollution source(s).

To evaluate identify PFAS polluters refer to **Table 9** Largest wastewater producers. We advise to take samples at least for companies contributing to 1 % and more of wastewaters with NACE codes corresponding to PFAS related activities.

4.3.2. Sampling and analysing

Detailed guidelines describing all aspects of water sampling strategies are available in standard ISO 5667-5:2006 Water quality — Sampling Part 5: Guidance on sampling of drinking water from treatment works and piped distribution systems (International Organization for Standardization 2006).

The standard advises to organise sampling for at least:

Drinking water source(s),

Treated drinking water,

Inlet and outlet of the wastewater treatment plant.

Afterwards analyse the obtained data and decide if additional monitoring (of potential pollution sources) is needed. If additional monitoring is needed, we propose 5-step approach to sampling:

Step 1: Identify and map potential pollution spots in sewerage network (in section 4.3.1).

Step 2: Identify which areas to monitor. Locate potential PFAS hotspots (from **Table 9** Largest wastewater producers).

Step 3: Prioritize the hotspots.

Prioritize the hotspots based on factors such as flow data, potential production scale etc.

Step 4: Collect data

Organise sampling and monitoring on chosen hotspots. It is advisable to sample each location in dry weather, but consult with a company to know if effluents may be diluted or concentrated depending on the activities before/during sampling. Composite samples covering the full working day should be taken. Data should be collected according to scale of the facilities and Directive (EU) 2020/2184 requirements on the quality of water intended for human consumption.

Step 5: Analyse the data

Compare PFAS concentrations in different spots, loads, peak loads, incidents above thresholds, to identify problem areas. If you have many pollution points in the system, consider basing the visualization on GIS charts or similar available maps, where different colours can be used to visualize historical data (such as short-term campaigns or permanent monitoring points) and critical PFAS pollution points. To create a PFAS mapping project, you'll need access to relevant data, geographic information system (GIS) software. In almost every city urban spatial data is maintained through the GIS environment and the most widespread programs for maintaining spatial data in the municipality are ArcGIS, QGIS.

5. Conclusion

The EMPEREST project will continue working on the PFAS risk-assessment framework and will publish the PFAS risk-assessment tool as an interactive excel file on the **project website** in 2025. Before the publication of the tool, the draft version will be tested by a network of cities in the Baltic Sea Region. We would already like to thank our colleagues in the cities of Kaunas, Jonava, Jurmala, Panevezys and Riga for their excellent collaboration in the testing of the first draft of the tool and the preparing of local PFAS risk-assessment plans in 2024.

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