

Project output 2.2

PFAS risk assessment plan for local authorities

EMPEREST – ELIMINATING MICRO-POLLUTANTS FROM EFFLUENTS
FOR REUSE STRATEGIES

Kamila Gruškeviča et al, 2025



Imprint

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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

In recent years, the environmental pollution caused by hazardous substances has become increasingly significant. In particular, PFAS (Per- and polyfluoroalkyl substances) have been identified as a group of priority contaminants. PFAS, also known as forever chemicals (LeMonde, n.d.), are very useful because of their properties: they are repellent to water, oil and dirt and they are very durable under extreme conditions. Hence, they are used in e.g. teflon, gore-tex, cosmetics, construction products, and many more. However, they are harmful for health and the environment, and they are extremely persistent and mobile in nature. PFAS also pose a risk to circular economy: the presence of these chemicals in materials and resources complicates recycling systems.

In this document, we refer to PFAS in accordance to the OECD definition (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.

The objective of the EMPEREST project is to reduce the amount of PFAS in the water cycle. To do this, the project adopts a holistic approach, combining pollution monitoring, prevention and removal. Therefore, the first publication of the project (Methodological recommendations for the monitoring and assessment of PFAS in the aquatic environment, <https://interreg-baltic.eu/project/emperest/#output-0>) presents guidelines for assessing the status of PFAS pollution in the aquatic environment of the Baltic Sea and its catchment area. In this second publication, Output 2.2, we move on to the prevention of pollution: the document presents a tool for identifying PFAS pollution sources in urban areas, as well as subsequent mitigation strategies.

EMPEREST Deliverable 1.2, "Draft Framework for Local PFAS Risk Assessment Plan," presented the first version of our PFAS risk assessment tool, along with the framework around it, the reasons for selecting specific assessment parameters, and the relevant legal context.

This Output 2.2 builds on Deliverable 1.2. While the output includes some repeated content, the PFAS risk assessment tool in this document has been further developed based on feedback from 29 cities across the Baltic Sea Region that tested the tool in 2024 and 2025. Current document

describes the updated (interactive Excel-based) tool. It also includes five completed local risk assessment plans from participating cities, as well as proposed mitigation strategies. The tool is available online at Baltic Smart Water Hub: <https://www.balticwaterhub.net/tool/pfas-risk-assessment-tool>.

The aim of this document is to provide local authorities with city-specific guidelines and tailor-made tool for the PFAS risk assessment in aquatic environments. With these guidelines and the tool, 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.

1.1. Why PFAS are dangerous?

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". 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).

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 air and 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). In Europe, PFAS have been also found in house dust, with highest concentrations in houses located in industrial areas, using floor carpets, containing PFAS in building materials (de la Torre 2019). 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**.

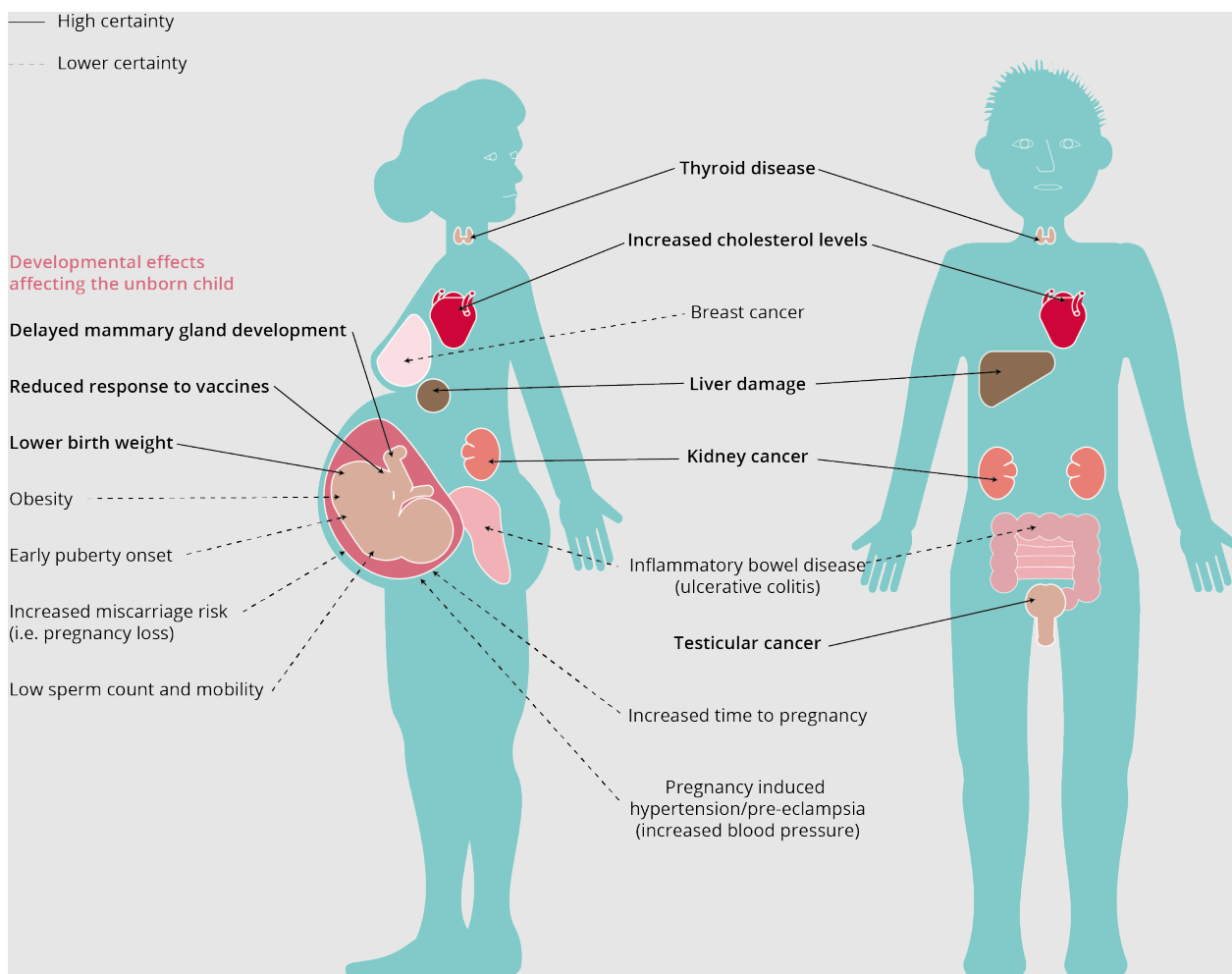


Figure 1 Effects of PFAS on human health (European Environment Agency n.d.)

<https://www.eea.europa.eu/publications/emerging-chemical-risks-in-europe/emerging-chemical-risks-in-europe>

2. Review of potential PFAS contamination in municipalities

The traced major 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, et al. 2024). The presence of PFAS in drinking water is associated with greater numbers of PFAS sources within watersheds (Liddie, et al. 2023). Several studies across the world linked higher level of PFAS in blood with fish and seafood consumption (Manzano-Salgado, et al. 2016; Shu, et al. 2018; Pirard, et al. 2020; Augustsson, et al. 2021; Richterová, et al. 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, et al. 2023).

Wastewater treatment plants (WWTPs) are considered one of the major PFAS environmental discharge channels, especially in the context of aquatic environments (Müller, et al. 2023). PFAS can accumulate into WWTP sludge (Stahl, et al. 2018; Semerád , et al. 2020; Fredriksson, et al. 2022), and composition of PFAS in sludge reflects industries' tendencies to switch for new, unregulated PFAS (Semerád , et al. 2020). However, now banned PFAS substances have also been found in sludge samples (Semerád, et al. 2020; Fredriksson, et al. 2022). 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, et al. 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.
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, et al. 2023). Currently, there is no list that connects specific substances to specific industries (Lerch, et al. 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 (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

In sum, the PFAS pollution hotspots include fluoropolymer producing facilities, firefighting training sites, military polygons and civil airports, landfills, and WWTPs. But diffuse pollution may come from various sources.

3. Local PFAS risk assessment tool for evaluating the potential risks to the aquatic environments

The purpose of the EMPEREST tool is to provide local authorities with a guidance for the PFAS risk assessment in a municipality. The tool covers the whole municipal water cycle starting from water abstraction, water treatment, water supply system, sewage collection, and sewage treatment to treated wastewater discharge. The tool is MS EXCEL based and contains the following parts: Disclaimer, Introduction, PFAS Definitions, 8 steps for risk assessment, More (links to our training material videos) and References sheets. It is available in English, Lithuanian, Estonian, Polish, Finnish, German, Latvian and Swedish languages. The language selection is available in the Disclaimer tab.

The core of the tool are the 8 steps (8 tables to fill). After completing the tables, the user will receive proposed mitigation strategies for the PFAS risks. Below you will find a synopsis of the tool and the proposed mitigation measures for each step are described.

Step 1: The user is asked to find out the source or sources for drinking water production and information about wastewater treatment. In order to do this, the user is asked to name the stakeholder of the 1) abstraction site, 2) water treatment, 3) drinking water distribution, 4) wastewater collection and 5) wastewater treatment. All this information is important because the tool covers the whole municipal water cycle starting from water abstraction, water treatment, water supply system, sewage collection, and sewage treatment to treated wastewater discharge, and collaboration and information collection from the relevant stakeholders might be needed.

Step 2: the user is asked to name the drinking water sources and indicate if the source is surface water, groundwater or artificially recharged water. This information is asked because contacting the drinking water suppliers might be useful for gaining information about local PFAS sources. The Drinking Water Directive (DWD) (THE EUROPEAN PARLIAMENT AND THE COUNCIL 2020) states that water suppliers are responsible for “risk assessment of the supply system”.

Step 3: the user is asked to provide information about significant PFAS pollution sources: airports, firefighting training sites, military training sites, landfills and WWTPs, as well as their distance to the closest drinking water source. This information is vital because the mentioned sites usually are significant PFAS sources affecting surrounding environment. Aqueous film forming foams used for extinguishing liquid fires (such as fuel fires) are often used in airports (even in small private airports), firefighting training sites, and military training sites. These types of foams often contain PFAS, which then travel through soil and contaminate groundwater and open water bodies in the surrounding areas. New formulations of firefighting foams may be PFAS-free, but if the site was used in previous years, there is a high probability that it is polluted with PFAS.

Landfills store various types of waste including building materials, textiles, upholstery and other items containing PFAS. When exposed to the sun, rain and temperature shifts those items degrade and release PFAS into runoff and landfill leachate, which is known to often contain high amounts of PFAS.

If there are above-mentioned risk activities found in municipalities and no PFAS have been analysed (existing PFAS data from the municipality is compiled in the next step), PFAS should be

analysed in the water source, drinking water and, if possible, wastewater, landfill leachate, and waterbodies and soils near the mapped risk activities. Regular monitoring of PFAS concentrations should be initiated, if it is not already established. When possible, PFAS-containing fire-fighting foams should be replaced with fluorine-free alternatives to prevent further exposure and contamination.

Step 4: the aim is to find out if any laboratory analyses of PFAS in drinking water or wastewater have been conducted in the municipality. The results could give crucial information about the state of PFAS pollution in the municipality. The user is asked to contact the stakeholders responsible for drinking water treatment and wastewater treatment and ask if they have done any PFAS analysis for drinking water and for wastewater effluent from WWTP. Possible PFAS analysis results could be interpreted according to the limit values of the DWD.

In case the results of PFAS analyses are higher than the existing limit values, but no clear PFAS sources are identified, it is suggested to contact experts in PFAS pollution and seek help for identification of possible pollution sources.

Step 5: this relates to wastewater profiles: the amounts of domestic wastewaters, rainwater, industrial wastewaters, and other communal wastewaters. Industrial wastewater may contain high concentrations of PFAS. Thus, higher risks for PFAS pollution arise if wastewater treatment plants receive industrial wastewaters. Regular monitoring of PFAS from influent and effluent should be established. If PFAS concentrations are elevated, investments in additional treatment technologies, such as granular activated carbon, anion exchange resins, and nanofiltration membrane systems could be considered.

Step 6: the focus is on the risks of WWTP sludge usage for green infrastructure. Since WWTP sludge may accumulate PFAS, it is important to know if the sludge or its compost is used for green infrastructure, such as parks or new green areas. If the answer is yes, PFAS concentrations should be assessed from the sludge to evaluate if the usage is safe.

Step 7: the user is asked about individual drinking wells. Individual drinking well users are at risk of harmful PFAS exposure through their drinking water if there are PFAS risk activities in the groundwater recharge or key aquifer area. To protect citizens, inform the authority on the risks of PFAS contamination. If wells are located in potentially polluted territory, we suggest contacting the national authority responsible and advising them to perform PFAS analyses.

Step 8: the focus is on voluntary firefighting brigades. Since firefighting foams may contain PFAS, the objective of this step is to track all possible firefighting training sites, in addition to the

ones identified at step three. To prevent unnecessary exposure to the PFAS-containing fire-fighting foams, inform voluntary firefighting brigades about health and environmental risks PFAS pose. Organizations that use PFAS-containing foams should assess if fire suppression foam can be replaced with a fluorine-free alternatives.

4. Preparing a local PFAS risk assessment plan

This PFAS risk-assessment tool may serve as a basis for a comprehensive plan for tackling the PFAS problem locally. As an example, this chapter contains fragments of the local PFAS risk-assessment plans by five cities with proposed mitigation strategies, completed as part of the EMPEREST project. The cities are: Riga (LV), Jūrmala (LV), Jelgava (LV), Kaunas (LT) and Panevezys (LT). All the persons who did the testing were representatives of local waterworks. In summary, the following outlines what the cities discovered about their PFAS risks using the EMPEREST tool. This information was used as a basis for the PFAS risk-assessment plan for each city.

- Drinking water sources: All cities use groundwater as drinking water source, only Riga utilizes both groundwater (partially artificially recharged) and surface water. Water abstraction volumes range from ~2.17 million m³/year in Jūrmala (60 378 people) to over 21.6 million m³/year in Riga (645 261 people).
- Significant pollution sources: All cities have at least one significant PFAS pollution source (airport, military or firefighting training sites, landfill, WWTP).
- PFAS analysis results: Out of 5 cities, only Riga and Jelgava made PFAS analyses for drinking water, with concentrations ranging from 0.057 to 0.866 ng/L (which is below current regulation threshold for PFAS total 0,50 µg/L or 500 ng/L).
- Industrial wastewater proportions: They vary, with Panevėžys (33%) and Riga (30.9%) having the highest, suggesting a need for tighter industrial source tracking. Jūrmala reported minimal industrial discharge (<1%). The amounts of industrial wastewater may indicate higher risks for PFAS in wastewaters (indirectly affecting drinking water sources and directly affecting water bodies, where treated wastewaters are discharged). This information might be useful if high concentrations of PFAS found in WWTP inlet. In this case detailed source tracking may be performed using method based on identification of potential PFAS sources in wastewater collection networks using NACE codes (proposed

in an earlier version of the tool, presented in EMPEREST Deliverable 1.2. Draft framework for local PFAS risk assessment plan).

- Individual water well use: In all cities, most of the population uses municipal drinking water, but some individual wells are in use. We asked to collect this information because individual wells may be located in potentially polluted areas (in vicinity of significant contamination sources, where contamination may spread in aquifer).
- Voluntary fire brigades: These are potential PFAS sources due to firefighting foam. Among the five cities, voluntary fire brigades are operating in Panevėžys and Kaunas region, absent in others.
- WWTP sludge reuse: Only Panevėžys reported reusing sludge from WWTPs for green infrastructure. WWTP sludge and its compost may serve as sinks for different contaminations including heavy metals, PFAS, and microplastics.

Overall, the persons testing the risk assessment framework indicated that 2-5 days were necessary to complete the tables, depending on the availability of the information. The most time-consuming part was completing the table with largest wastewater producers and corresponding NACE codes. After considering the feedback and our own evaluation, the NACE code identification was removed from the final version of the tool, to make it more user-friendly. The feedback from testers was overall positive, they indicated that gained new knowledge about PFAS, about potential PFAS sources in their municipality.

4.1. PFAS risk-assessment plan proposed for the city of Riga

Based on the completed risk assessment in Riga, three significant potential sources of PFAS pollution have been identified within the municipality: the landfill (located approximately 7 km from the nearest water source) and two airports (20+ km away). It is essential to evaluate if the landfill lies within the drainage basins or recharge areas of key aquifers.

Riga is the only city out of those who prepared a risk assessment plan that has PFAS analyses done for all the sources. Although all the results are below threshold value provided in DWD, we can see that results from surface water (Daugava) and artificially recharged groundwater (Baltezers) are higher than in other (groundwater) drinking water sources in Riga.

We suggest to:

- **Initiate PFAS monitoring** in drinking water sources in both influent and effluent at the WWTP. Monitoring should include total PFAS or the PFAS sum.

- Establish a regular monitoring programme for drinking water to see possible trends.
- Consider analyzing PFAS in influent and effluent of WWTP.
- Suspend sludge reuse until analysis confirms it is safe.
- Consider implementing **source tracking** to identify specific PFAS contributors within the wastewater network.
- **Analyse landfill leachate** for PFAS.
- Develop **risk mitigation plan** for **landfill leachate**.

If WWTP PFAS concentrations in treated effluent exceed recommended levels, the following **treatment technologies** should be considered to reduce PFAS before discharge into the environment:

- Granular Activated Carbon (GAC)
- Anion Exchange Resins
- Nanofiltration Membrane Systems

4.2. PFAS risk-assessment plan for the city of Jūrmala

Based on the completed risk assessment in Jūrmala, two significant potential sources of PFAS pollution have been identified within the municipality: the airport (located approximately 16 km from the nearest water source) and the WWTP, which is situated 6 km away. It is essential to evaluate whether these sites lie within the drainage basins or recharge areas of key aquifers. If they do, the following actions are recommended:

- **Initiate PFAS monitoring** in drinking water sources and in both influent and effluent at the WWTP. Monitoring should include PFAS total and/or PFAS sum.
- If concentrations exceed the **DWD limits**, a regular monitoring programme should be established.
- Consider implementing **source tracking** to identify specific PFAS contributors within the wastewater network.

While industrial inflows into the WWTP are minimal, available data suggest that the highest potential risk points are the **hospital, health centre, and a car wash**, based on wastewater volumes.

If PFAS concentrations in treated effluent exceed recommended levels, the following **treatment technologies** should be considered to reduce PFAS before discharge into the environment:

- Granular Activated Carbon (GAC)

- Anion Exchange Resins
- Nanofiltration Membrane Systems

In **Jūrmala**, no PFAS analysis results are currently available. Therefore, we strongly recommend conducting baseline PFAS testing in relevant environmental media.

If WWTP PFAS concentrations in treated effluent exceed recommended levels, the following **treatment technologies** should be considered to reduce PFAS before discharge into the environment:

- Granular Activated Carbon (GAC)
- Anion Exchange Resins
- Nanofiltration Membrane Systems

4.3. PFAS risk-assessment plan for the city of Jelgava

Based on the completed risk assessment, the significant potential source of possible PFAS contamination is WWTP (located approximately 6 km from the nearest water source). It is essential to evaluate if WWTP receiving water body lies within the drainage basins or recharge areas of key aquifers. Jelgava has had several PFAS analyses done in different seasons and all the results are below threshold provided by DWD.

We suggest to:

- **Initiate PFAS monitoring** in drinking water sources and in both influent and effluent at the WWTP. Monitoring should include total PFAS and/or the PFAS sum.
- A regular monitoring programme for drinking water should be established to see the trends.
- Consider analyzing PFAS in influent and effluent of WWTP.
- Consider implementing **source tracking** to identify specific PFAS contributors within the wastewater network.

If WWTP PFAS concentrations in treated effluent exceed recommended levels, the following **treatment technologies** should be considered to reduce PFAS before discharge into the environment:

- Granular Activated Carbon (GAC)
- Anion Exchange Resins
- Nanofiltration Membrane Systems

4.4. PFAS risk-assessment plan for the city of Kaunas

Based on the completed risk assessment in Kaunas, two significant potential sources of PFAS pollution have been identified within the municipality: the landfill (7 km away) and the airport (located approximately 9 km from the nearest water source). It is essential to evaluate whether these sites lie within the drainage basins or recharge areas of key aquifers. The inflow of industrial wastewaters to WWTP is 21 %, which may cause the risk of PFAS. As Kaunas has no results of PFAS analysis, we suggest testing at least for drinking water.

The following actions are recommended:

- **Initiate PFAS monitoring** in drinking water sources and in both influent and effluent at the WWTP. Monitoring should include PFAS total and/or PFAS sum.
- Conduct baseline PFAS analysis at all four drinking water sources and in WWTP influent.
- Consider implementing **source tracking** to identify specific PFAS contributors within the wastewater network.

If PFAS concentrations in treated effluent exceed recommended levels, the following **treatment technologies** should be considered to reduce PFAS before discharge into the environment:

- Granular Activated Carbon (GAC)
- Anion Exchange Resins
- Nanofiltration Membrane Systems

4.5. PFAS risk-assessment plan for the city of Panevėžys

Based on the completed risk assessment in Panevėžys, three significant potential PFAS pollution sources have been identified within the municipality: a military training site (1.54 km from water sources), a landfill (4.8 km away), a WWTP (11 km away from abstraction sources).

As PFAS analyses have not yet been conducted in Panevėžys, we recommend initiating testing, starting with drinking water sources. Also, it is crucial to determine whether these above-mentioned sites are situated within the drainage basins or recharge zones of local aquifers, particularly the military training site due to its close proximity. We recommend testing nearby surface water bodies for PFAS to evaluate potential contamination pathways. Additionally, the location of individual drinking water wells should be assessed in relation to these potential sources. If wells are situated nearby, local health or environmental authorities should be contacted to initiate PFAS monitoring.

Industrial wastewater accounts for 33% of total inflow to the WWTP, which presents an elevated risk of PFAS entering the wastewater stream. In light of this, we recommend the following actions:

- **Initiate PFAS monitoring** in drinking water sources, including both PFAS total and PFAS sum parameters.
- **Conduct baseline PFAS analysis** of both influent and effluent at the WWTP.
- **Implement PFAS source tracking** within the municipal wastewater network, using industrial discharge profiles (e.g. NACE codes) to identify likely contributors.

If PFAS levels in treated effluent are found to exceed recommended thresholds, the following advanced treatment technologies should be considered to reduce PFAS before environmental discharge:

- Granular Activated Carbon (GAC)
- Anion Exchange Resins
- Nanofiltration Membrane Systems

5. Conclusion

While working on the PFAS issue within the EMPEREST project, we discovered that many utility staff, environmental specialists, and policymakers initially had limited knowledge about PFAS—its sources, risks, and possible solutions. Most people were only familiar with PFAS in the context of Teflon pans or other consumer products, and had heard that it might pose health risks—but that was often the extent of their awareness.

Through the process of developing PFAS risk assessment plans, stakeholders—including municipal utility personnel and environmental managers—gained valuable insights. They came to understand PFAS as a serious environmental and public health concern, learning about its persistence, major sources, and regulatory background. They also deepened their understanding of local risks, including potential contamination sources in water abstraction zones.

Participants learned practical methods for identifying possible polluters. They also developed skills in organizing and interpreting environmental data. Completing the risk assessment tables

helped promote critical thinking about monitoring gaps and encouraged better collaboration across departments.

The development and testing of the PFAS risk assessment framework within the EMPEREST project has consequently been an important step in helping local authorities better understand and manage PFAS-related risks in their water systems. By engaging municipalities across the Baltic Sea Region, the initiative has not only raised awareness about PFAS pollution but has also built local capacity for risk assessment and environmental management.

The testing of the comprehensive PFAS risk assessment framework in five cities: Riga, Jūrmala, Jelgava, Kaunas, and Panevėžys, demonstrated the tool's value in helping municipalities understand their local PFAS sources. Despite varying levels of available data and analytical capacity, each city was able to identify potential sources of PFAS contamination, complete wastewater profiles, and collect all the necessary information.

The Excel-based PFAS risk assessment tool, which was tested in 24 municipalities, proved to be user-friendly and important for risk assessment. Feedback highlighted the tool's clarity and practicality, with users appreciating the pre-set mitigation strategies. Users emphasized the usefulness of the tool for broader applications beyond PFAS, suggesting its adaptability for assessing other pollutants.

One of the most significant outcomes of this process was the learning and collaboration it fostered among local stakeholders. Municipal utility staff, environmental managers, and public officials gained critical knowledge about PFAS, developed technical skills in source tracking, and improved their capacity to collect and interpret environmental data. The risk assessment process also stimulated interdepartmental cooperation—connecting water, waste, environmental, and emergency services around a shared environmental goal.

Moving forward, the PFAS risk assessment tool and the whole framework offer a solid foundation for municipalities seeking to strengthen their resilience against chemical pollution. Continued monitoring, regular updates to the framework based on regulatory developments, and expansion of the tool to other pollutants are recommended. Ultimately, these efforts contribute to safer water resources, informed public health strategies, and a more sustainable management of urban environments in the Baltic Sea Region.

6. References

- Ahrens, Lutz, Karin Norström, Tomas Viktor, Anna Palm Cousins, and Sarah Josefsson. 2015. "Stockholm Arlanda Airport as a source of per- and polyfluoroalkyl substances to water, sediment and fish." *Chemosphere* 129. doi:10.1016/j.chemosphere.2014.03.136.
- Andrews, D., and O. Naidenko. 2020. "Population-Wide Exposure to Per- and Polyfluoroalkyl Substances from Drinking Water in the United States." *Environmental Science & Technology Letters* 7 (12): 931-936. doi:10.1021/acs.estlett.0c00713.
- Augustsson, A., T. Lennqvist, C.M.G. Osbeck, P. Tibblin, A. Glynn, M.A. Nguyen, E. Westberg, and R. Vestergren. 2021. "Consumption of freshwater fish: A variable but significant risk factor for PFOS exposure." *Environmental Research* 192. doi:https://doi.org/10.1016/j.envres.2020.110284.
- Chen, Yutao, Hekai Zhang, Yalan Liu, John Bowden, Thabet Tolaymat, Timothy Townsend, and Helena Solo-Gabriele. 2023. "Evaluation of per- and polyfluoroalkyl substances (PFAS) in leachate, gas condensate, stormwater and groundwater at landfills." *Chemosphere*. doi:10.1016/j.chemosphere.2023.137903.
- Cousins, IT. 2015. "Per- and polyfluoroalkyl substances in materials, humans and the environment." *Chemosphere* (129): 1-3. doi:https://doi.org/10.1016/j.chemosphere.2014.08.036.
- Croad, B., Kreissig, J., Corden, C. 2022. "Update of market data for the socioeconomic analysis (SEA) of the European fluoropolymer industry." https://fluoropolymers.plasticseurope.org/application/files/1216/5485/3500/Fluoropolymers_Market_Dat.
- Currell, Matthew, Nathan Northby, and Pacian Netherway. 2024. "Examining changes in groundwater PFAS contamination from legacy landfills over a three-year period at Australia's largest urban renewal site." *Chemosphere* 352. doi:10.1016/j.chemosphere.2024.141345.
- de la Torre, A., Navarro, I., Sanz, P., de los Ángeles Martínez, M. 2019. "Occurrence and human exposure assessment of perfluorinated substances in house dust from three European countries." *Science of The Total Environment* 685: 308-314. doi:https://doi.org/10.1016/j.scitotenv.2019.05.463.
- Dewapriya, P., Chadwick, L., Ghorbani Gorji, S., Schulze, B., Valsecchi, S., Samanipour, S., Thomas, K., Kaserzon, S.L. 2023. "Per- and polyfluoroalkyl substances (PFAS) in consumer products: Current knowledge and research gaps." *Journal of Hazardous Materials Letters*.
- Directorate-General for Environment, European Commission. 2020. "Document 52020SC0249 COMMISSION STAFF WORKING DOCUMENT Poly- and perfluoroalkyl substances (PFAS) Accompanying the document COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN

PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE AND THE COMMITTEE OF THE REGIONS Chemicals Strategy for Sustainability Towards a Toxic-Free Environment .

ECHA. 2023. "Proposal for a restriction." <https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea>.

European Environment Agency. n.d. [eea.europa.eu](https://www.eea.europa.eu/publications/emerging-chemical-risks-in-europe/emerging-chemical-risks-in-europe). <https://www.eea.europa.eu/publications/emerging-chemical-risks-in-europe/emerging-chemical-risks-in-europe>.

Fredriksson, Felicia, Ulrika Eriksson, Anna Kärrman, and Leo Yeung. 2022. "Per- and polyfluoroalkyl substances (PFAS) in sludge from wastewater treatment plants in Sweden — First findings of novel fluorinated copolymers in Europe including temporal analysis." *Science of the Total Environment* 157406.

Glüge, J., M. Scheringer, IT. Cousins, JC. DeWitt, G. Goldenman, D. Herzke, R. Lohmann, CA. Ng, X. Trier, and Z. Wang. 2020. "An Overview of the Uses of Per-and Polyfluoroalkyl Substances (PFAS)." *Environ Sci Process Impacts* 2345–73.

Glüge, J., R. London, I. Cousins, J. DeWitt, G. Goldenman, D. Herzke, R. Lohmann, et al. 2022. "Information Requirements under the Essential-Use Concept: PFAS Case Studies." *Environmental Science and Technology* 6232-6242.

Göen, T., A. Abballe, R. Bousoumah, L. Godderis, I. Iavicoli, A.M. Ingelido, V. Leso, et al. 2024. "HBM4EU chromates study – PFAS exposure in electroplaters and bystanders." *Chemosphere* 346. doi:<https://doi.org/10.1016/j.chemosphere.2023.140613>.

Grung, Merete, Dag Hjermann, Thomas Rundberget, Kine Bæk, Cathrine Thomsen, Helle Katrine Knutsen, and Line Småstuen Haug. 2024. "Low levels of per- and polyfluoroalkyl substances (PFAS) detected in drinking water in Norway, but elevated concentrations found near known sources." *Science of the Total Environment* (947). doi:10.1016/j.scitotenv.2024.174550.

Guelfo, JL., Adamson, DT. 2018. "Evaluation of a national data set for insights into sources, composition, and concentrations of per- and polyfluoroalkyl substances (PFASs) in U.S. drinking water." *Environ Pollution* 505-513.

Johnson, Gwynn. 2022. "PFAS in soil and groundwater following historical land application of biosolids." *Water Research* 211. doi:10.1016/j.watres.2021.118035.

Le Monde, (France), (Germany) NDR, (Germany) WDR, (Germany) Süddeutsche Zeitung, (Italy) RADAR Magazine, (Italy) Le Scienze, (Netherlands) The Investigative Desk, et al. n.d. [Foreverpollution.eu](https://foreverpollution.eu/). <https://foreverpollution.eu/>.

Lerch, M., Nguyen, K.H., Granby, K. 2022. "Is the use of paper food contact materials treated with per- and polyfluorinated alkyl substances safe for high-temperature applications? – Migration study in real food and food simulants." *Food Chemistry*.

- Liddie, JM., Schaider, LA., Sunderland, EM. 2023. "Sociodemographic Factors Are Associated with the Abundance of PFAS Sources and Detection in U.S. Community Water Systems." *Environ Sci Technol* 57(21): 7902-7912.
- Manzano-Salgado, CB., Casas, M., Lopez-Espinosa, MJ., Ballester, F., Martinez, D., Ibarluzea, J., Santa-Marina, L., Schettgen, T., Vioque, J., Sunyer, J., Vrijheid, M. 2016. "Variability of perfluoroalkyl substance concentrations in pregnant women by socio-demographic and dietary factors in a Spanish birth cohort." *Environ Int.*
- Müller, V., Kindness, A., Feldmann, J. 2023. "Fluorine mass balance analysis of PFAS in communal waters at a wastewater plant from Austria." *Water Research* 244.
doi:<https://doi.org/10.1016/j.watres.2023.120501>.
- Nilsson, H., A. Karrman, A. Rotander, B. van Bavel, G. Lindstrom, and H. Westberg. 2013. "Professional ski waxers' exposure to PFAS and aerosol concentrations in gas phase and different particle size fractions." *Environ. Sci. Process Impacts* 15: 814–822.
- Panieri, E., K. Baralic, D. Djukic-Cosic, A. Buha Djordjevic, and Saso L. 2022. "PFAS Molecules: A Major Concern for the Human Health and the Environment." *Toxics* 10 (2).
doi:<https://doi.org/10.3390/toxics10020044>.
- Pirard, C., Dufour, P., Charlier, C. 2020. "Background contamination of perfluoroalkyl substances in a Belgian general population." *Toxicology Letters* 333: 13-21.
doi:<https://doi.org/10.1016/j.toxlet.2020.07.015>.
- Pitter, Gisella, Filippo Da Re, Cristina Canova, Giulia Barbieri, Maryam Zare Jeddi, Francesca Daprà, Flavio Manea, et al. 2020. "Serum Levels of Perfluoroalkyl Substances (PFAS) in Adolescents and Young Adults Exposed to Contaminated Drinking Water in the Veneto Region, Italy: A Cross-Sectional Study Based on a Health Surveillance Program." *Environ Health Perspect* 128 (2).
doi:10.1289/EHP5337.
- Porter, A., S. Kleinschmidt, K. Andres, C. Reusch, R. Krisko, O. Taiwo, G. Olsen, and M. Longnecker. 2024. "Occurrence of COVID-19 and serum per- and polyfluoroalkyl substances: A case-control study among workers with a wide range of exposures." *Global Epidemiology* 7.
doi:<https://doi.org/10.1016/j.gloepi.2024.100137>.
- Richterová, D., Govarts, E., Fábelová, L., Rausová, K., Rodriguez Martin, L., Gilles, L., Remy, S., Colles, A., Rambaud, L., Riou, M., Gabriel, C., Sarigiannis, D., Pedraza-Diaz, S., Ramos, J.J., Kosjek, T., Snoj Tratnik, J., Lignell, S., Gyllenhammar, I.,. 2023. "PFAS levels and determinants of variability in exposure in European teenagers – Results from the HBM4EU aligned studies (2014–2021)." *International Journal of Hygiene and Environmental Health* 247.
doi:<https://doi.org/10.1016/j.ijheh.2022.114057>.
- Semerád , Jaroslav, Nicolette Hatasová , Alena Grasserová, Tereza Černá, Alena Filipová, Aleš Hanč, Petra Innemanová, Martin Pivokonský, and Tomáš Cajthaml. 2020. "Screening for 32 per- and polyfluoroalkyl substances (PFAS) including GenX in sludges from 43 WWTPs located in the Czech Republic - Evaluation of potential accumulation in vegetables after application of biosolids." *Chemosphere* 261.

- Shu, H., Lindh, CH., Wikström, S., Bornehag, CG. 2018. "Temporal trends and predictors of perfluoroalkyl substances serum levels in Swedish pregnant women in the SELMA study." *PLoS One*.
- Silver, Matthew, William Phelps, Kevin Masarik, Kyle Burke, Chen Zhang, Alex Schwartz, Miaoyan Wang, et al. 2023. "Prevalence and Source Tracing of PFAS in Shallow Groundwater Used for Drinking Water in Wisconsin, USA." *Environmental Science & Technology* 57 (45): 17415–17426.
- Söregård , Mattias, Sofia Bergström, Philip McCleaf, Karin Wiberg, and Lutz Ahrens. 2022. "Long-distance transport of per- and polyfluoroalkyl substances (PFAS) in a Swedish drinking water aquifer." *Environmental Pollution* 311. doi:10.1016/j.envpol.2022.119981.
- Stahl, Thorsten, Matthias Gassmann, Sandy Falk, and Hubertus Brunn. 2018. "Concentrations and Distribution Patterns of Perfluoroalkyl Acids in Sewage Sludge and in Biowaste in Hesse, Germany." *Journal of Agricultural and Food Chemistry* 66 (39): 10147-10153.
- Tefera, Y.M., S. Gaskin, K. Mitchell, D. Springer, and S. Mills. 2023. "Temporal decline in serum PFAS concentrations among metropolitan firefighters: Longitudinal study on post-exposure changes following PFAS foam cessation." *Environment International* 179. doi:<https://doi.org/10.1016/j.envint.2023.108167>.
- THE EUROPEAN PARLIAMENT AND THE COUNCIL. 2020. "DIRECTIVE (EU) 2020/2184 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2020 on the quality of water intended for human consumption." <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX%3A32020L2184>.
- UBA. 2022. "Guidelines for PFAS assessment Recommendations for the uniform nationwide assessment of soil and water contamination and for the disposal of soil material containing PFAS."
- Wang, Zhanyun, Andreas Buser, Ian Cousins, Silvia Demattio, Wiebke Drost, Olof Johansson, Koichi Ohno, et al. 2021. "A New OECD Definition for Per- and Polyfluoroalkyl Substances." *Environ. Sci. Technol.* 55: 15575–15578.