Output 1.1
Microplastic (MP) approach harmonised at EU and non-EU level

Drafted by Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Elaborated with input provided by all project partners

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Project MicroDrink

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Project partners:	HGI 1909 HRVATSKI GEOLOŠKI INSTITUT CROATIAN GEOLOGICAL SURVEY ZAVOD ZA JAVNO ZDRAVSTVO ZADAR UNIVERZA V LJUBLJANI University of Ljubljana KOVOD ENVIRONMENT AGENCY AUSTRIA VÚV TGM eurofins ZAVOD ZA JAVNO ZDRAVSTVO FBiH INSTITUTE FOR PUBLIC HEALTH FB&H ЈКП ДРУГИ ОКТОБАР ВРШАЦ FAU Friedrich-Alexander-Universität Erlangen-Nürnberg

Project Partner Institution	Contributors, name and surname
Croatian Geological Survey	Jasmina Lukač Reberski Mirna Švec Ana Selak Ivana Boljat
Institute of Public Health Zadar	Jadranka Šangulin Tajana Pijaca
University of Ljubljana	Mihael Brenčič Anja Torkar Ines Vidmar Mateja Jelovčan
Public company Kovod Postojna, water supply, sewerage, Ltd.	Edi Šibenik
Environment Agency Austria	Helga Lindinger Uta Wemhöner
T. G. Masaryk Water Research Institute	Zbyněk Hrkal Marek Polášek
Eurofins Analytical Services Hungary Kft	Gábor Bordós Bence Prikler
University of Belgrade, Faculty of Mining and Geology	Saša Milanović Ljiljana Vasić Branislav Petrović Veljko Marinović
Institute for Public Health of the Federation Bosnia and Herzegovina	Branimir Drinovac Nino Brajković Slađana Šarac
Public Utility Service Company "Drugi oktobar" Vršac	Aleksandar Šmit
Friedrich-Alexander-Universität Erlangen-Nürnberg	Gabriele Chiogna Mohammad Al-qadi

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1. Purpose, Scope & Policy Context

MicroDrink is a transnational project implemented under the Interreg Danube Region Programme and co-funded by the European Union. The project started in January 2024 and runs for two and a half years, until June 2026. It brings together 12 partners from 8 Danube Region countries: Austria, Germany, Slovenia, Hungary, Croatia, Serbia, Bosnia and Herzegovina, and the Czech Republic (Figure 1). The project aims to improve knowledge on microplastics in drinking water resources, strengthen cooperation between research and practice, and support the development of more comparable approaches for sampling, analysis, and interpretation across the region. As part of these efforts, the MicroDrink Knowledge Base was developed as an open-access platform that supports knowledge sharing by compiling information on sampling procedures, analytical methods, laboratory capacities, and instruments used for microplastic monitoring across the Danube River Basin.

Within this context, Output 1.1 presents a harmonised approach developed by project partners to support more consistent microplastic monitoring practices across EU and non-EU countries in the Danube River Basin (DRB). It is intended as a technical reference supporting coordination and knowledge exchange while respecting national and institutional competences.

Figure 1. MicroDrink project partner countries in the Danube Region.

The output does not establish legal limits, compulsory monitoring obligations, or binding implementation requirements. Instead, it provides a technical and methodological reference framework that supports preparedness and comparability across contexts without pre-empting future regulatory decisions or constraining national implementation choices.

The development of Output 1.1 is situated within the current EU regulatory framework on drinking water quality. The Directive (EU) 2020/2184 is a binding legal instrument, introducing a preventive, risk-based approach to drinking water safety. The Directive was adopted on 16 December 2020 as a recast of Directive 98/83/EC, with the objective of protecting human health by ensuring the safety and quality of drinking water and improving transparency and consumer access to information. It introduces a comprehensive risk-based approach covering the entire water supply chain, from abstraction through supply to the point of compliance. While the Directive does not currently define parametric values or mandatory monitoring requirements for microplastics in drinking water, it explicitly recognises microplastics as a group requiring further methodological development before regulatory implementation can be considered. Complementary technical guidance has also been developed by the Joint Research Centre (JRC) to support harmonised analytical approaches for microplastics in drinking water (Belz et al., 2024,).

The Directive also establishes a watch list mechanism for substances of emerging concern, enabling the European Commission to adopt delegated acts defining monitoring methodologies where appropriate. Member States are required to transpose the Directive into national legislation and implement its risk-based provisions, resulting in varying levels of preparedness and monitoring capacity across countries in the Danube River Basin. At EU level, no binding parametric value for microplastics in drinking water is currently in force. The first Drinking Water Watch List (January 2022) did not include microplastics. In this framework, Commission Delegated Decision (EU) 2024/1441 of 11 March 2024 establishes a harmonised methodology for the monitoring of microplastics in drinking water, which provide the technical basis for coordinated monitoring and potential future inclusion of microplastics under the watch list mechanism.

Additional EU legislation also addresses microplastics from a source-control perspective. Commission Regulation (EU) 2023/2055, adopted under the REACH framework by amending Annex XVII to Regulation (EC) No 1907/2006, restricts the placing on the market of synthetic polymer microparticles intentionally added to products such as cosmetics, detergents, and fertilisers, thereby aiming to reduce upstream emissions of microplastics. In addition, Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment seeks to reduce plastic litter and related environmental pressures, which may also indirectly contribute to limiting secondary microplastic generation and protecting drinking water resources.

This report outlines the sampling methods, instruments, and analytical procedures used across the Danube River countries, with the aim of establishing a future standardised approach that enables consistent comparison of results. It includes descriptions of each method, the tools used, preliminary laboratory sample preparation procedures, and information on instrument suppliers.

The report also identifies the types of water bodies sampled, the national contexts in which these methods are applied, the main user groups, and the advantages and limitations associated with each method. The harmonised approach was developed based on three main inputs:

(i) the transnational knowledge base compiled under Specific Objective 1, including identified challenges, state of the art and existing practices;
(ii) stakeholder feedback collected through interviews, questionnaires, national workshops, and roundtable discussions; and
(iii) findings from testing activities in the pilot areas carried out under Specific Objective 2. These testing activities enabled mapping of monitoring capacities and assessment of national preparedness in relation to evolving EU requirements.

Based on this combined evidence base, best practices were identified and the harmonised MP approach was progressively refined.

2. Overview of Sampling Procedures for Microplastics

Although research on microplastics has expanded rapidly over the last decade, methodological approaches remain highly diverse and are often developed in response to specific environmental compartments or research questions. Sampling strategies used in marine and freshwater environments have evolved earlier and are generally more established than those applied in drinking water systems. As a result, many existing protocols originate from environmental monitoring studies and have later been adapted to drinking water contexts, where lower particle concentrations, stricter contamination control requirements, and operational constraints present additional technical challenges. Differences in sampling volumes, filtration principles, pore sizes, and handling procedures can significantly influence reported results, making comparison across studies difficult. Understanding the range of available approaches and their respective limitations is therefore an important step toward identifying elements that can support more consistent and comparable monitoring practices.

This section provides an overview of internationally applied sampling approaches for microplastics, distinguishing between methods developed for environmental matrices and those specifically adapted for drinking water resources. This output highlights common technical principles of microplastic sampling in water, including filtration approaches, contamination control, and sample handling procedures as well as underlying methodological differences and key challenges associated with sampling design and analytical compatibility, serving as a basis for identifying methodological elements that may contribute to improved alignment of sampling practices in the Danube River Basin.

2.1. International Review of Sampling Protocols

2.1.1. Microplastic in the Environmental Matrices

Microplastics (MP) are now pervasive across all environmental matrices. From the Arctic (Obbard et al., 2014) to the Antarctic seawater (Cincinelli et al., 2017), to sediments (Van Cauwenberghe et al., 2013), rivers (Rodrigues et al., 2018), soil (Zhang & Liu, 2018) and even the air we breathe. This widespread presence has prompted extensive research into quantifying MP and their impact on various organisms (Barboza & Gimenez, 2015). However, the absence of standardised and validated methodologies has resulted in a diverse array of analytical approaches, which hinders the ability to interpret findings on a larger scale.

Connecting to the broader impact, Figure 2 illustrates the cycle of MP in the environment, starting with human littering and industrial waste disposal. Plastics, clothing, and personal hygiene products are discarded, ending up in water bodies where they break down into MP. These MP are ingested by fish and other marine animals, entering the food chain. As humans and animals consume these marine creatures, MP infiltrate their bodies, highlighting the widespread impact of plastic pollution on ecosystems and health. Expanding on the environmental trajectory of MP, it becomes clear that these pollutants eventually make their way into tap water, which is a primary concern of the MicroDrink project (see Figure 2).

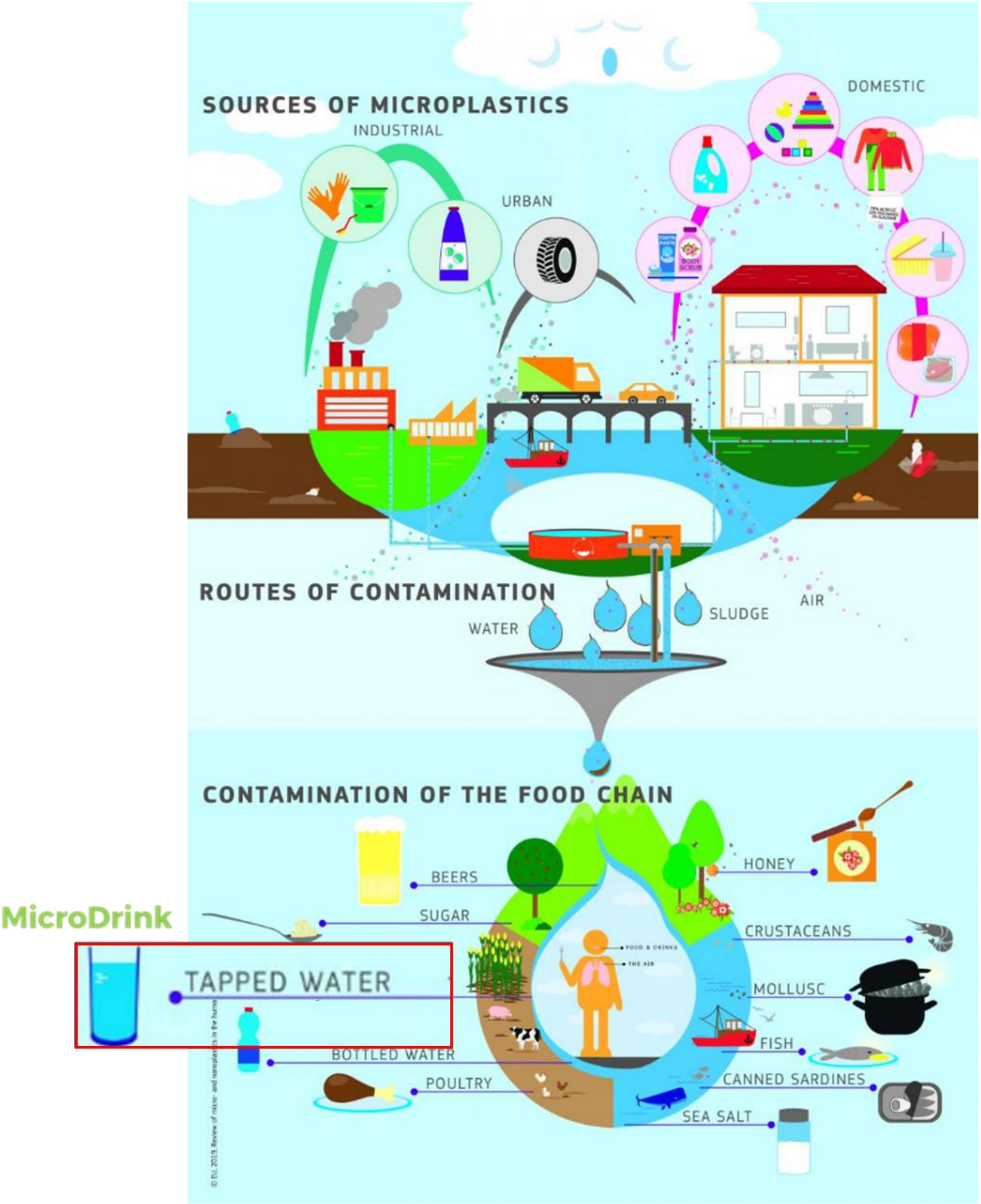
The distribution of MP in surface seawater has been extensively studied. In this process, sampling is the first step towards our basic understanding of the matter. However, a unified sample collection method is lacking due to the complex nature of sampling. Factors such as sampling site (geographical location), sampling conditions (wind, current, etc.), available instruments, and sampling time can all vary significantly. Common methods for sampling MP in water include direct filtration (Zheng et al., 2021), sieve pre-concentration (Mai et al., 2018), and trawling (Karlsson et al., 2020). These methods vary in their effectiveness, ease of use, and the size range of particles they can capture, which influences the reported concentrations and types of microplastics. Direct filtration and sieve pre-concentration are often used for the collection of samples with limited volumes from specific stations. Zheng et al. (2021) evaluated and compared different methods for sampling MP in surface seawater. The methods included: (i) direct filtration through a 0.45 µm membrane, (ii) 20 µm sieve pre-concentration followed by filtration through a 0.45 µm membrane, and (iii) Manta trawling using a 150 µm mesh net. This comparison aimed to provide technical guidance for effectively collecting MP from surface seawater. The study showed that no single method is suitable for all sampling objectives; rather, the methods can complement one another.

Freshwater surface waters, including rivers, lakes, and reservoirs, are also recognized as important transport pathways and accumulation zones for microplastics. Rivers play a particularly important role by transporting microplastics from terrestrial sources to downstream aquatic environments, while lakes and reservoirs can act as sinks where microplastics accumulate over time (Koelmans et al., 2019; Kye et al., 2023). Similar to seawater studies, reported concentrations in freshwater systems vary considerably due to differences in hydrological conditions and the lack of harmonized sampling and analytical methodologies.

The research by Huang et al. (2021) documents the presence of MP contamination in soil across several major continents including Asia, Europe, North America, Oceania, and South America. Significant concentrations of MP were recorded in various global locations. For example, agricultural soils in Madrid, Spain, amended with sludge, exhibited a mean microplastic abundance of 302,000 particles per kilogram (n/kg). In Wuhan, China, the abundance was quantified at 220,000 n/kg across woodland, vegetable, and vacant land soils. Similarly, in Denmark, agricultural soils not treated with sludge showed a microplastic abundance of 236,000 n/kg.

Groundwater, intricately linked to soils, plays a crucial role as one of the primary water resources and serves as a direct drinking water source for human consumption. Existing research highlights the vertical transport of MP from soils to groundwater (Bläsing & Amelung, 2018). The investigation into MP in groundwater remains underexplored compared to studies on soils. Several recent studies have documented the occurrence of MP in groundwater across various regions. Selvam et al. (2021) observed 4200 particles/m^3 in groundwater from coastal south India. In Germany, Mintenig et al. (2019) found MP levels ranging from 0 to 7 particles/m^3 in raw water or drinking water. Additionally, Panno et al. (2019) documented concentrations ranging from 860 to 15,200 particles/m^3 in karst groundwater. These findings collectively indicate the widespread occurrence of MP in groundwater sources. However, the number of available studies remains relatively limited, and their results are not based on harmonized sampling and analytical methods, making direct comparisons difficult. Consequently, significant knowledge gaps remain regarding the occurrence and behaviour of MP in groundwater systems. Further research using standardized methodologies is needed to better assess the extent and implications of MP contamination in groundwater environments.

Because these environmental matrices are deeply interconnected, the unchecked accumulation of microplastics in soils, surface waters, and groundwater inevitably cascades into the reservoirs and aquifers we rely on for human consumption. Consequently, as the presence of MP in drinking water becomes an increasing concern, the importance of advancing our sampling, analytical, and treatment methodologies cannot be overstated. Enhancing these methods will provide a clearer understanding of MP distribution and impact, facilitate the development of effective mitigation strategies and ensure the safety of our drinking water supplies. Existing studies show considerable variability in reported microplastic concentrations, which is partly influenced by differences in sampling strategies, sample handling procedures, and analytical approaches. This variability limits the comparability of results across studies and regions. Strengthening methodological consistency is therefore important for improving the reliability of monitoring data and supporting a better understanding of microplastic occurrence in drinking water systems. The following sections provide an overview of existing sampling approaches and methodological considerations relevant for microplastic detection in water resources, with particular attention to aspects that may influence comparability of results.



© EU, 2019, Review of micro- and nanoplastics in the huma

Figure 2. Various activities lead to the creation of microplastics in water bodies and their subsequent entry into food chains (modified after European Union (2020)).

2.1.2. Microplastic in Drinking Water Systems

Microplastics in drinking water have emerged as a significant environmental and public health concern due to their pervasive presence and potential adverse effects (Koelmans et al., 2019; Kumar et al., 2023). These minuscule plastic particles, equal to or less than 5 mm in size, originate from a variety of sources and are now found in diverse freshwater systems, ultimately making their way into our drinking water supplies (Kumar et al., 2023). Studies have detected MP in both raw and treated drinking water, with concentrations notably higher in untreated sources (Ferraz et al., 2020; Mintenig et al., 2019; Negrete Velasco et al., 2023). The majority of these particles are smaller than 10 µm and predominantly consist of materials like polyethylene terephthalate (PET), polypropylene (PP), and polyethylene (PE), each known for their wide usage in consumer products and packaging (Pivokonsky et al., 2018). Given that size of the particles, modern water treatment processes significantly reduce the levels of these particles, albeit they do not completely remove them (Negrete Velasco et al., 2023). This incomplete elimination leads to the inevitable presence of MP in drinking water consumed by the public and the persistence of MP in water highlights the urgency of developing more effective water treatment methods, pollution control and mitigation strategies. Further investigation is required to elucidate the biological fate and toxicity of MP in humans (Barboza et al., 2018; Carbery et al., 2018). However, existing evidence supports the adoption of a precautionary principle for the monitoring and mitigation of MP in drinking water (Danopoulos et al., 2020; Senathirajah & Palanisami, 2023). The global distribution of commonly reported microplastics across different water sources and geographical regions is illustrated in Figure 3.

No standardised protocols have been universally established to guide the collection and analysis of water samples for MP (Yuan et al., 2022). Protocols are needed to specify procedures for sample collection, preservation, preparation and analysis to ensure consistency and comparability across various studies. Integral to these protocols are quality assurance and quality control (QA/QC) measures, which are crucial for maintaining the reliability and accuracy of data (Prata et al., 2021). QA/QC procedures typically involve the use of blank samples, field blanks, and laboratory blanks to control and minimise potential contamination during sampling and analytical processes (Miller et al., 2021).

A significant challenge in sampling for MP contamination lies in the variability of sampling locations within drinking water systems (Pittroff et al., 2021). Variations in MP levels may occur at different points such as water intakes, treatment facilities, and distribution networks. Seasonal fluctuations in MP levels further complicate sampling efforts (Pivokonsky et al., 2018; Shan et al., 2021), influenced by factors like precipitation, runoff, and changes in water flow, which affect the transport and distribution of MPs. Additionally, the detection limits of sampling methods and analytical techniques are critical considerations in evaluating MP contamination in drinking water (Yuan et al., 2022), as lower detection limits allow for the identification of smaller MP particles, thereby yielding a more precise assessment of contamination levels.

Figure 3. World map showing some common MP identified in different water sources of the countries included in the study during 2015–2021 (modified after Chakraborty et al., 2023).

2.2. Importance of Standardised Sampling Procedures

Standardised sampling procedures are crucial for ensuring reliability, comparability, representativeness, minimization of bias, efficiency, and ethical considerations in research and data collection. Standardization is also essential in maintaining ethical standards throughout the research process, as it helps prevent contamination, reduces bias in data collection, and ensures that results are reliable and not misleading. Across Europe, the need for uniform sampling protocols is particularly important, as current methods for MP sampling in water vary widely (Baini et al., 2018; Koelmans et al., 2019). Recent advancements in sampling technologies and methodologies indicate a gradual move towards more harmonised approaches, emerging practices increasingly recommend the use of larger sampling volumes, cascade filtration systems (e.g. sequential pore sizes such as 100 µm followed by 20 µm), improved contamination control procedures, and the use of non-plastic sampling materials, especially in the context of drinking water. This shift is supported by a growing body of literature that documents the challenges of current sampling techniques and the benefits of developing more refined methods that improve the representativeness of samples and the comparability of results across studies.

The importance of standardised sampling methods extends beyond just scientific accuracy, as it can inform policies aimed at reducing environmental pollution (Schreiber et al., 2006). When policymakers trust that the data is comparable across different studies and regions, they are better equipped to design effective strategies to mitigate this environmental issue. For example, uniform sampling protocols can help in assessing the effectiveness of regulations banning certain plastic products. As the scientific and policy landscapes continue to evolve, the push for standardization in sampling methods will play an increasingly pivotal role in addressing this complex environmental challenge.

In addition to policy implications, standardised sampling procedures are crucial for public health research. Microplastics in drinking water are a growing concern, and understanding their prevalence and potential health impacts requires precise and consistent data (Kumar et al., 2023; Zhang et al., 2020). Researchers need to use comparable methods to accurately assess exposure levels and the associated risks. Studies have shown that variations in sampling methods can lead to vastly different estimates of MP concentrations (Koelmans et al., 2019; Mintenig et al., 2020), limiting the ability to reliably assess exposure and associated risks.

Harmonization efforts have already been undertaken by the EU. A sampling procedure was described in the recent Commission Delegated Decision (EU) 2024/1441 issued on 11 March 2024, supplementing Directive (EU) 2020/2184 of the European Parliament and of the Council by establishing a methodology for the assessment of microplastics in water intended for human consumption. In the methodology employed for the quantification of microplastics in water, the utilization of filtration techniques, specifically a filter cascade comprising filters with nominal pore sizes of 100 µm followed by 20 µm, is described. These filters are operated under an appropriate positive pressure regime to facilitate the collection of particulate matter and fibres present in water designated for human consumption. The sampling protocol mandates the extraction of a minimum volume of 1,000 Liters of water, with meticulous measurement and documentation of the total volume of water processed through the filter cascade.

Standardization should be implemented also for communication purposes. National reports describing the specific situation and approaches used in each country of the consortium displayed a very heterogeneous vocabulary, which sometimes impedes a direct comparison among the different sampling procedures collected in this study.

2.3. Current Status of Sampling Procedures for Microplastics in Drinking Water in the Danube River Basin

Sampling procedures for microplastics in drinking water across the Danube River Basin are still in an early phase. There is no standardised approach in place yet, and the methods being used differ quite a bit from one country or institution to the next, in terms of equipment, setup, and how sampling is actually carried out. For the most part, sampling takes place within the framework of research projects or pilot studies, not as part of routine drinking water monitoring. Sampling activities reported by project partners cover a range of water matrices including raw water, treated drinking water, groundwater and surface water

The technical capacity across the region is uneven. Some countries and institutions have put together dedicated sampling systems, while others have little or no access to the kind of equipment needed for this type of work. In Bosnia and Herzegovina, for example, stakeholders reported that there are currently no specific sampling procedures or equipment available at the national level.

One issue that came up repeatedly during the project is the limited availability of standardised, commercially produced sampling equipment. Most of the systems currently being used are custom-built, designed for research purposes, or still at a prototype stage. Stakeholders flagged this as a real barrier, without affordable, accessible, and validated equipment, it will be difficult to scale up monitoring, especially if regulatory obligations are introduced down the line.

Several sampling systems are currently being developed and tested within the region, notably in Austria, Slovenia, and the Czech Republic, along with the system applied as part of this project. These are generally based on filtration setups built to handle large volumes of water while keeping contamination risks low.

The system used in Austria (Carinthia) relies on pump-supported filtration with stainless steel filters of different pore sizes, which allows it to capture a broad range of particle sizes. It was designed for field use and has been tested in surface water settings (Figure 4). The following requirements were defined when designing the sampling system: sampling should be conducted directly on-site, the device should be applicable under a wide range of site conditions, and the device should be portable. The filtration system is a closed stainless-steel system, both the inlet and the outlet hoses are also made of stainless steel. The system contains a filter cascade consisting of several stainless-steel filter mesh. Low-cost stainless-steel mesh material sold by the meter was used instead of comparatively expensive prefabricated stainless-steel sieves. A wastewater pump with a power output of 1.2kW and maximum head of 17m and the maximum flow rate of 9.8 L/s was used to pump water through the system. For the filter cascade filters with mesh sizes of 50 µm and 500 µm were used. The mesh sizes can be adapted depending on characteristics of the sampling site.

At each sampling site, approx. 15 m^3 of water were filtered at a flow rate of about 0.5 to 1 L/s. After sampling, the filter mesh with the filter residue is carefully rolled up and transferred into a suitable container to the laboratory.

This method, although a prototype, offers significant advantages such as its flexibility in adapting to various water bodies and the use of filters with customizable pore sizes suitable for both environmental monitoring and drinking water analysis. However, being in the developmental phase, the method's full commercial and operational potentials are yet to be established. The cost of sampling and other specifics remain undetermined due to its prototype nature, underlining the need for further field testing and validation.

Figure 4. Filtration device (© Provincial government of Carinthia).

In Slovenia, a pump-based field filtration system has been developed and patented. It allows for simultaneous filtration of multiple samples through parallel branches and supports cascade filtration, meaning large sample volumes can be processed. The closed design helps reduce contamination. That said, equipment and filter membrane costs remain high, which limits wider adoption (Figure 5).

The main advantages of the system are the ease of use, the possibility of in-field filtration of large amounts of water, the possibility of simultaneous sampling of four subsamples, and the possibility of installing a cascade filtration in the case of clogging. The use of membranes suitable for FTIR or Raman microscopy allows the user to analyse the samples without pretreatment or manual separation of MP from the membrane. A drawback of this method is the high price of the membranes, and exposure of filter membranes to air during transfer from the system to storage containers.

Figure 5. Filtration system (Patent application SLO - P-202300155).

In the Czech Republic, the approach involves filtering water samples through membrane filters contained in plate stainless-steel housing (Figure 6). The filter containers can be connected into a vertical cascade, and after sampling, the filters are extracted and transferred to containers that will be transported to the laboratory. This method is used primarily for research purposes, but has been tested in various operational settings, including within drinking water treatment facilities. The system is robust and appropriate for cascade filtration, easy to transport with simple in-field handling. However, it is not commercially available, and the filters must be stored in a separate stainless-steel container after sampling before being transported to the laboratory for analysis.

Figure 6. Filtration system developed and used by T. G. Masaryk Water Research Institute, Czech Republic.

In Hungary, the on-site pressurised fractionated filtration system (Figure 7) is applied. This system was also used as part of MicroDrink project-related sampling activities. The system is designed to process large volumes of water directly at the sampling site, typically up to 1–2 m^3, enabling the concentration of microplastic particles present at low abundance. It operates through a sequence of filters with different mesh sizes, producing a concentrated sample that is transferred to the laboratory in closed filter units for further analysis.

The system can be used both in field conditions, supported by a pump and external power supply, and in pressurised environments such as drinking water facilities. To reduce contamination risks, the system is designed without the use of plastic materials, and the system is transported to the laboratory without air exposure. Sampled volumes are measured during operation.

Advantages of this system include its plastic-free design, ease of operation, and accurate volume measurement. It allows for flexibility in filter pore size and ensures that samples are transported safely in closed filter cartridges, reducing contamination risks. Despite its benefits, the system has limitations, a key one relating to the extraction of samples from cartridges and filters, and cleaning of the system prior to further use, presenting added complexity compared to simpler membrane filter methods.

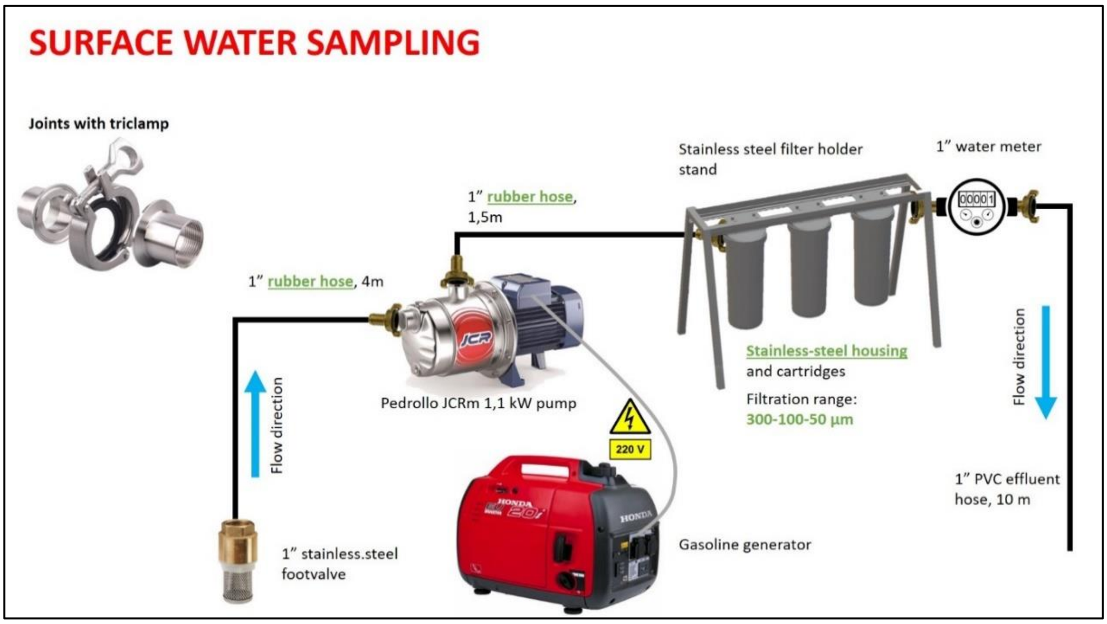


Figure 7. Overview of on-site pressurised fractionated filtration system.

Across all these approaches, filtration is the dominant principle (**Error! Reference source not found.**). But there is significant variation in filter materials, pore sizes, sampled volumes, and overall system design. This means the size range of particles that gets captured can differ considerably, and it makes it hard to compare data generated by different methods.

Contamination control is a major concern. Many systems use closed or semi-closed designs to limit airborne contamination, and operators take precautions such as using non-plastic materials, pre-cleaning equipment, and carefully controlling handling conditions. Even so, the risk of contamination during sampling, transport, and processing has not been fully eliminated and can affect the reliability of results.

There are also practical constraints that affect how feasible these methods are in day-to-day use. Equipment costs are high, specialised training is needed, and sampling and preparation take time. For smaller water utilities in particular, routine implementation is a challenge. On top of that, some filtration systems tend to clog when the water has a higher particulate load, which means sampling procedures have to be adjusted on the spot. The scientific literature describes a wide range of sampling methods, from bulk sampling to in situ filtration and cascade filtration techniques. However, these methods vary substantially in how they are designed and applied, and there is no universally accepted standard for microplastics sampling in drinking water. This makes it difficult to compare datasets from different studies or monitoring efforts.

- High cost of equipment (approx. 5.500 € + VAT)
- Difficult to clean
- Filter mesh prone to damage if water flow is too high
- SBR rubber hoses – may lead to filter clogging due to release of rubber
- Number of samples collected simulatenously is limtied (max. 4 filters in a row)

+ Completely closed system – minimized risk of contamination
+ Simple on-field handling
+ Cascade filtration in accordance with the prescribed methodology of Commission Delegated Decision (EU) 2024/1441
+ Rapid sampling (approx. 20 min for filtration of 1000 L)
+ Minimized risk of clogging
+ Relatively commercially available

- Less portable than other systems
- Filtration down to 50 µm
- Filter mesh must be removed, rolled up and sent to laboratory – potential contamination due to exposure to air
- Currently not commercially available

+ Comprised entirely of stainless steel
+ Economical compared to other systems

- Currently not commercially available
- Filters exposed to air on field – potential contamination risk
- Rapid clogging under increased water turbidity
- On-field handling may be more complex than other systems

+ Comprised entirely of stainless steel
+ Large number of samples may be collected simultaneously (min. 3 subsamples on each branch)
+ Cascade filtration possible
+ Sample volume can be controlled separately for each branch
+ Simple sample preparation

- Currently commercially unavailable
- Filtration slower than MicroDrink system
- Filters exposed to air on field – potential contamination risk

+ Comprised entirely of stainless steel
+ Large number of samples may be collected simultaneously
+ Cascade filtration possible
+ Simple on-field handling and portability

Figure 8. Advantages and disadvantages of alternative sampling systems identified within project MicroDrink. (a) MicroDrink system, (b) System employed by the Carinthian government, (c) Slovenian patented sampling equipment, (d) Equipment developed by T. G. Masaryk Water Research Institute, Czech.

Overall, the situation across the Danube River Basin reflects a transitional phase, moving from exploratory research towards what will eventually need to be operational monitoring. Technical solutions exist and are continuing to develop, but more work is needed to improve comparability between methods, align approaches across the region, and make implementation realistic under everyday operational conditions. What these findings point to is a clear need for harmonised minimum requirements for sampling, while still leaving room for the different technical and institutional realities that exist across partner countries. The information collected in the national reports drafted by MicroDrink project partners highlight that there is no homogeneity in the sampling methods used in the DRB region. Although some methods share important similarities, the way in which they are named differs. This may generate confusion among final users and stakeholders. Moreover, we can observe that while in some countries prototypes for effective sampling are under development or have been recently developed, in other countries there is a complete lack of expertise or the need for developing specific sampling methods for microplastic analysis is not recognised. The use of prototypes in different countries to optimise sampling procedures for microplastic analysis is very promising and highlights the interest in obtaining reliable samples; however, it does not yet facilitate the establishment of a standardised procedure throughout the Danube River Basin. Based on information gathered during national stakeholder interviews and feedback loops, it appears that each country leans toward methods tailored to its environmental monitoring needs and available resources. For instance, Croatia, Germany, Austria, and Hungary show a preference for on-site pressurised fractionated filtration systems, indicating a regional interest in direct, on-site techniques, while Slovenia utilises a unique, patented pump sampling method. In contrast, the approach in Bosnia and Herzegovina reflects a reliance on established European protocols rather than country-specific innovations. It is critical to stipulate, however, that much of this activity is currently conducted for research or investigative purposes and is not necessarily implemented as a national standard or widespread practice. Because these methodologies are still very novel and in a state of continuous development, the current landscape remains fragmented. This underscores the crucial role of the MicroDrink project, which provides the necessary input toward harmonised methodologies and open-access knowledge for future monitoring efforts across the region.

Filtration represents the core technical principle for the collection of microplastic particles from water matrices. The reviewed systems apply cascade filtration using sequential filter pore sizes, typically including 20 µm filtration. Systems are implemented as closed filtration configurations to minimise the risk of contamination during sampling and handling. Large water volumes can be processed depending on site conditions, although filtration time and potential clogging may influence operational feasibility. Filter pore sizes are selected according to sampling objectives and expected particle size ranges, and processed water volumes are measured during sampling. While technical configurations may differ in practical setup, the underlying sampling principles remain comparable across the reviewed systems.

At the same time, practical operational considerations were identified. Sampling systems typically require equipment such as pumps, pressure-resistant housings, or multi-stage filtration units, which may influence preparation time and operational effort depending on site conditions. Filtration performance may be influenced by particulate load in the sampled water, potentially leading to clogging or longer filtration duration. Sample extraction from filter cartridges or membranes may require careful handling to ensure reliable recovery of particles. Differences in selected pore size ranges may influence which particle fractions are captured, which can affect comparability between datasets generated using different systems.

Overall, the reviewed systems demonstrate that technically feasible approaches for sampling microplastics in drinking water exist and are continuing to develop. Although the systems are based on similar principles, small differences in their practical implementation highlight the importance of defining harmonised minimum technical requirements that support comparability of results across the Danube River Basin.

2.4. Sampling Challenges Across the DRB

Table 1 summarises the main challenges related specifically to sampling procedures for microplastics in drinking water identified across the Danube River Basin. National input, experiences of stakeholders from countries participating in MicroDrink project and experiences of project partners gained through conducting project activities show that technical challenges are largely similar across the DRB, although they may occur at different levels of intensity depending on available infrastructure and research capacity.

Across the region, sampling approaches are still mainly applied within research contexts, and many systems rely on custom-built or prototype equipment. Differences in filtration principles, pore sizes, sampled volumes, and system configurations influence the range of particle sizes captured and may affect comparability of results. Expected low counts of MP in drinking water require the processing of large water volumes to detect low concentrations of microplastics, which increases the complexity of field deployment and sample handling. Practical constraints were also identified, including the absence of commercially available devices specifically designed and standardized for microplastic sampling in groundwater and drinking water, the need for contamination control during sampling and transport, and the technical effort required for handling filtration units and sample preparation. In some cases, filtration systems may be sensitive to clogging when applied to water with higher particulate loads, requiring adjustments to sampling procedures in the field.

Project partner inputs indicate several recurring challenges affecting the implementation of sampling procedures for microplastics in drinking water across the Danube River Basin. Across the Danube River Basin, national legislation generally implements Directive (EU) 2020/2184 without introducing additional microplastics-specific parameters. Monitoring activities remain largely research-driven or pilot-based, and systematic integration into statutory drinking water surveillance is not yet established. Stakeholder consultations and questionnaire responses highlight limited baseline data, inconsistent sampling and analytical approaches, uneven laboratory capacity, and high analytical costs.

Table 1: Main sampling-related challenges identified across the Danube River Basin

Category	**Sampling-related challenges observed across DRB**
Lack of standardised technical approaches	Different filtration principles, pore sizes, sampled volumes, and system configurations limit comparability of results
Limited (absence) availability of commercially standardised equipment	Many sampling systems are custom-built, prototype-based, or developed within research projects
Large sample volume requirements	Detection of low microplastic concentrations often requires processing hundreds to thousands of litres of water
Risk of contamination	Need for strict contamination control measures during sampling, transport, and sample preparation
Technical complexity of sampling procedures	Field deployment may require pumps, pressure systems, or multi-stage filtration setups

Category	Sampling-related challenges observed across DRB
Clogging and matrix-related constraints	Higher particulate loads in some water types may affect filtration efficiency and require procedural adjustments
Handling and transport of samples	Maintaining sample integrity requires controlled handling conditions and appropriate storage materials
Operational feasibility	Some sampling approaches require specialised technical knowledge and preparation time

3. Overview of Analytical Methods (With Emphasis on Drinking Water Resources in DRB) – State of the Art

3.1. Overview of analytical methods used in the Danube River Basin

The global proliferation of MP across various environments has heightened the urgency for developing and refining analytical methods for their detection and quantification. The environmental impact of MP has been well-documented, leading to increased research in identifying and analysing these pollutants not only in aquatic settings but also in terrestrial ecosystems (Kirstein et al., 2021). Analytical methods for the detection of MP in environmental samples are diverse and complex, depending on the specifics of the sample matrix and the physical and chemical properties of the MP themselves. Once samples are prepared, analytical techniques are applied to detect, quantify, and classify microplastics. Laboratories in the Danube River Basin apply a range of analytical techniques for the identification and characterisation of microplastics in water samples. The most frequently applied analytical approaches are based on vibrational spectroscopy, including μFTIR microscopy and Raman microscopy, which allow identification of polymer types through analysis of molecular vibrations (Belz et al. 2024).

μFTIR microscopy enables automated particle analysis through infrared spectral imaging of particles collected on filters. Raman microscopy provides complementary capabilities and is often applied for smaller particles due to higher spatial resolution. Both techniques are widely used because they allow non-destructive particle-level identification of polymer composition. Additional analytical techniques include ATR-FTIR, laser direct infrared imaging (LDIR), fluorescence microscopy, and scanning electron microscopy (SEM), which may be applied depending on analytical objectives and laboratory capabilities. Thermo-analytical techniques such as Py-GC/MS and TED-GC-MS provide information on polymer composition based on thermal decomposition products and allow quantitative determination of polymer mass, although these methods require destruction of the analysed particles and do not provide direct information on particle size or morphology.

Fluorescence microscopy is frequently used as a screening technique, enabling rapid identification of potential plastic particles following staining procedures, although it cannot confirm polymer identity and may result in false positives. Scanning electron microscopy (SEM)-based approaches provide detailed information on particle morphology and surface characteristics, supporting particle classification and interpretation of environmental processes. The selection of analytical methods depends on laboratory capabilities, sample matrix characteristics, and required analytical outputs such as polymer identification, particle size distribution, or mass-based quantification. The main analytical characteristics of the commonly applied methods are summarised in Table 2**Error! Reference source not found.**.

Table 2. Analytical characteristics of methods used for microplastic analysis in the DRB.

Analytical method	Detection capability description (based on reported use in DRB)
µFTIR microscopy	Commonly detects particles in the range of approximately 10–20 µm; detection down to approximately 10 µm is reported, and down to approximately 5 µm under optimised conditions.
Raman microscopy	Commonly enables detection of smaller particles compared to FTIR microscopy, typically below 10 µm and in some cases down to a few micrometres depending on analytical conditions.
ATR-FTIR	Applied for targeted polymer identification of selected particles, typically after pre-selection or isolation.
LDIR	Enables rapid automated particle detection and identification.
SEM-based methods	Provide high-resolution particle morphology information.
Fluorescence microscopy	Used for screening and visualization of potential microplastic particles.
Py-GC/MS	Identifies polymer composition based on thermal decomposition products; does not provide particle size information.
TED-GC-MS	Destructive method; analysis requires thermal decomposition of the sample, therefore particle size, shape, and number of particles cannot be determined. In addition, a minimum polymer mass is required for reliable polymer identification and quantification, which may limit the detection of very low concentrations of microplastics.

Differences in detection capabilities between analytical techniques highlight the importance of clearly defining methodological approaches when comparing results across studies. The main advantages of analytical approaches described in the DRB are summarised in Table 3**Error! Reference source not found.**.

Table 3. Advantages of analytical methods used for microplastic detection in the DRB.

Analytical method	Main advantages
µFTIR microscopy	Non-destructive polymer identification and particle-level analysis.
Raman microscopy	High spatial resolution enabling analysis of smaller particles.
ATR-FTIR	Rapid confirmation of polymer composition.
LDIR	Rapid automated particle screening.
fluorescence microscopy	Fast screening of potential particles.
SEM	Detailed particle morphology information.
Py-GC/MS	Quantitative information on polymer composition.
TED-GC-MS	Quantitative information on polymer composition.

And the limitations of analytical approaches described in the DRB are summarised in Table 4**Error! Reference source not found.**.

Table 4. Limitations of analytical methods used for microplastic detection in the DRB.

Analytical method	Main limitations
µFTIR microscopy	Limited detection of smaller particles compared to Raman microscopy (typically below 10 µm depending on analytical setup).
Raman microscopy	Analysis may require longer measurement times compared to FTIR-based methods, depending on instrument configuration and sample characteristics.
ATR-FTIR	Limited suitability for automated large-scale particle screening due to manual or targeted analysis approach.
LDIR	The spatial resolution and the smallest detectable particle size vary depending on the instrument configuration and analytical settings used during analysis.
Fluorescence microscopy	Cannot confirm polymer identity.
SEM	Does not directly identify polymer composition.
Py-GC/MS	Destructive method, analysis requires thermal decomposition of the sample, therefore particle size, shape, and number of particles cannot be determined.
TED-GC-MS	Destructive method, analysis requires thermal decomposition of the sample, therefore particle size, shape, and number of particles cannot be determined.

The cost of microplastic analysis varies depending on analytical technique, instrumentation, sample preparation requirements, and analytical complexity. Reported costs typically range between approximately 350 € and 1000 € per sample, depending on detection limits, analysis time, and the level of quality assurance applied.

Differences in sampling and analytical methodologies can lead to variations in reported microplastic abundance, particle size, and polymer identification, which may affect comparability of results across studies and monitoring efforts. The application of harmonised analytical approaches, including consistent procedures for sample preparation, identification, and reporting, supports improved comparability and reliability of microplastic data across different laboratory settings.

3.2. Microplastic Detection in Drinking Water

The detection of MP in drinking water is an emerging area of concern that underscores the importance of reliable analytical methodologies to ensure water safety. The presence of MP in sources of drinking water, including tap, bottled water and groundwater, has led to increased scrutiny from both the scientific community and the public (Kosuth et al., 2018; Mintenig et al., 2019). The detection of microplastic in tap water is a worldwide issue and a concern for water suppliers (Figure 9).

The steps required for the analytical process of MP detection start with sampling and sample preparation (e.g., through digestion, separation and concentration). Then it is possible to perform imaging techniques (e.g., optical or fluorescence microscopy)). The identification of microplastics in drinking water is performed using a range of analytical methods (Figure 10). A typical example of this analytical workflow, including filtration, H_2O_2 treatment, and μFTIR microscopy for particle identification, is illustrated in Figure 11. Among these, FTIR and Pyrolysis Gas Chromatography-Mass Spectrometry (Py-GCMS) stand out due to their ability to provide detailed information about the chemical composition of MP (Primpke et al., 2020). These methods have been effectively utilised to assess the presence and concentration of MP in different water treatment stages and distribution systems (Kirstein et al., 2021). As stated in Schwaferts et al. (2019), FTIR spectroscopy is generally applied for bulk analysis of plastics, while μFTIR microscopy enables single-particle analysis, typically with a practical size detection limit of approximately 10 μM. Schymanski et al. (2018) specifically highlighted how FTIR has a major limitation in its inability to detect microparticle sizes below 20 μm (reduced to 10 μm since the original study thanks to the development of the technology), which is why Raman spectroscopy has been developed as an alternative method (Schymanski et al., 2018; Xu et al., 2020). Raman spectroscopy, similar to FTIR, identifies polymer composition based on molecular vibrations, but offers higher spatial resolution for smaller particles (Nava et al., 2021). Py-GCMS complements these techniques by providing a means to chemically characterize the types of plastics through the decomposition of the polymer into its monomers, allowing for precise identification (Kirstein et al., 2021). Additional analytical methods, including ATR-FTIR, laser direct infrared imaging (LDIR), fluorescence microscopy, and scanning electron microscopy (SEM), may be applied depending on analytical objectives and laboratory capabilities

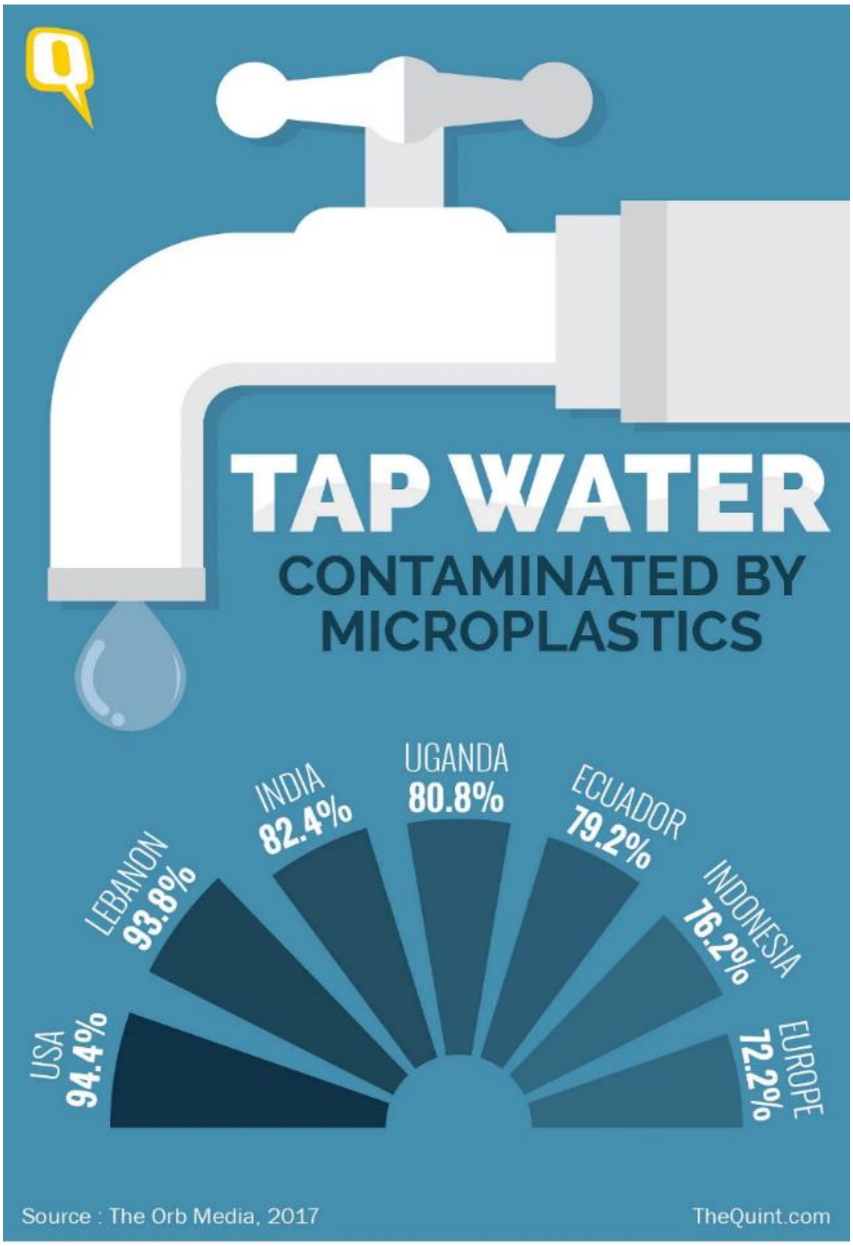


Figure 9. Detection of microplastic in tap water (source: https://images.thequint.com/).

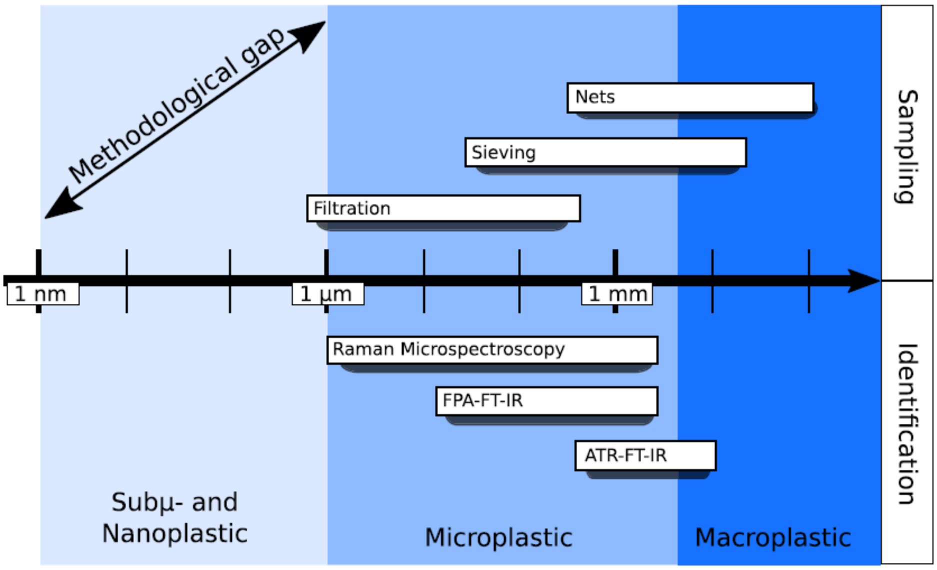
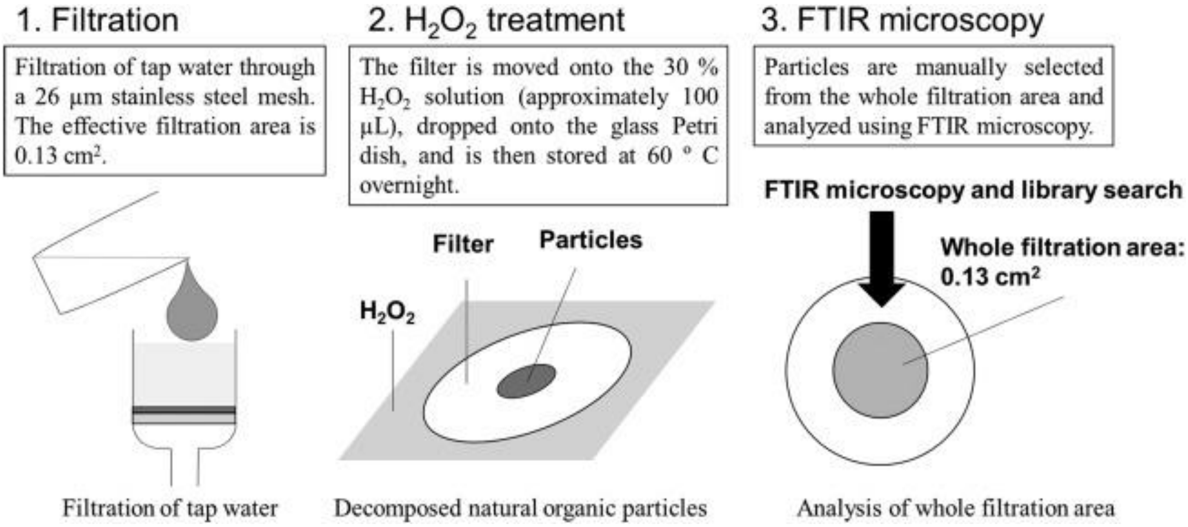


Figure 10. Analysis methods for microplastic down to 1 nm (Schwaferts et al., 2019).



Filtration of tap water through a 26 µm stainless steel mesh. The effective filtration area is 0.13 cm^2.

The filter is moved onto the 30 % H_2O_2 solution (approximately 100 µL), dropped onto the glass Petri dish, and is then stored at 60 ° C overnight.

Particles are manually selected from the whole filtration area and analyzed using FTIR microscopy.

Figure 11. Flowchart showing the steps for preparing and analysing microplastics in tap water using µFTIR microscopy (Mukotaka et al., 2021).

4. MicroDrink Knowledge Base, Challenges & Need for Harmonisation

The consortium of the MicroDrink project jointly developed the MicroDrink Knowledge Base, a user-friendly, open-access database containing an overview of the most commonly employed sampling and analytical methodologies for the detection of MP in water resources across the DRB, instruments capable of performing MP analysis, laboratories with adequate competency to analyse MP in water samples, regulations, legislations and policies related to microplastics in drinking water, and other EU and national projects researching microplastics in drinking water (Figure 12).

The Knowledge Base is informed by literature review and incorporates findings collected through national surveys, stakeholder questionnaires, and workshops conducted by partners participating in MicroDrink project across EU and non-EU partner countries (Austria, Bosnia and Herzegovina, Croatia, Czech, Germany, Hungary, Serbia, and Slovenia). Standardised questionnaires were circulated to project partners and stakeholders, focusing on awareness of MP, existing sampling and analysis practices, and perceptions of potential risks. In parallel, national workshops were organised in partner countries, where participants provided qualitative feedback on operational challenges and possible solutions.

The surveys generated more than 170 responses. When combined with discussions from national stakeholder workshops, these inputs provided a broad evidence base for the analysis presented in this section. Integrating questionnaire results with qualitative insights from water utilities, researchers, and public authorities ensured that the findings reflect diverse institutional perspectives across the Danube River Basin. Authorities and water suppliers report uncertainty in interpreting monitoring results due to the absence of established guidance values. Additional challenges include high analytical costs, limited availability of equipment, limited laboratory capacity for analysis of samples and insufficient trained personnel. The lack of regulatory requirements for microplastic monitoring further limits implementation. These factors affect overall preparedness and highlight the need for harmonised approaches that support comparability while allowing flexibility across the Danube River Basin.

The Knowledge Base also enables comparative analysis across EU and non-EU countries, supports transparency in methodological approaches, and provides the foundation for implementing microplastics monitoring, upon which the harmonised MP approach was developed. Furthermore, the MicroDrink Knowledge Base enables users to input their own data, contributing additional information and ensuring usability and applicability even beyond project lifetime.

The knowledge base serves several key functions:

- It documents the current legal and regulatory landscape across the Danube region, including gaps and emerging EU-level developments.

- It compiles information on sampling and analytical practices, highlighting methodological diversity and areas requiring alignment. It maps laboratory capacities and instrumentation availability, identifying structural disparities in technical preparedness.
- It provides a shared reference point to support comparability, cross-border cooperation, and informed decision-making.

Through this structured compilation of information, the knowledge base creates transparency regarding existing heterogeneity and supports evidence-based discussion on feasible harmonisation pathways. It represents a foundational element for the development of Output 1.1.

These findings are directly reflected in the structure and content of the MicroDrink Knowledge Base, which compiles and organises information on sampling procedures, analytical methods, laboratory capacities, and regulatory context across the Danube River Basin, providing a practical reference to support improved understanding, transparency, and comparability of monitoring approaches.

The knowledge base is accessible at: https://microdrink.wordpress.com/.

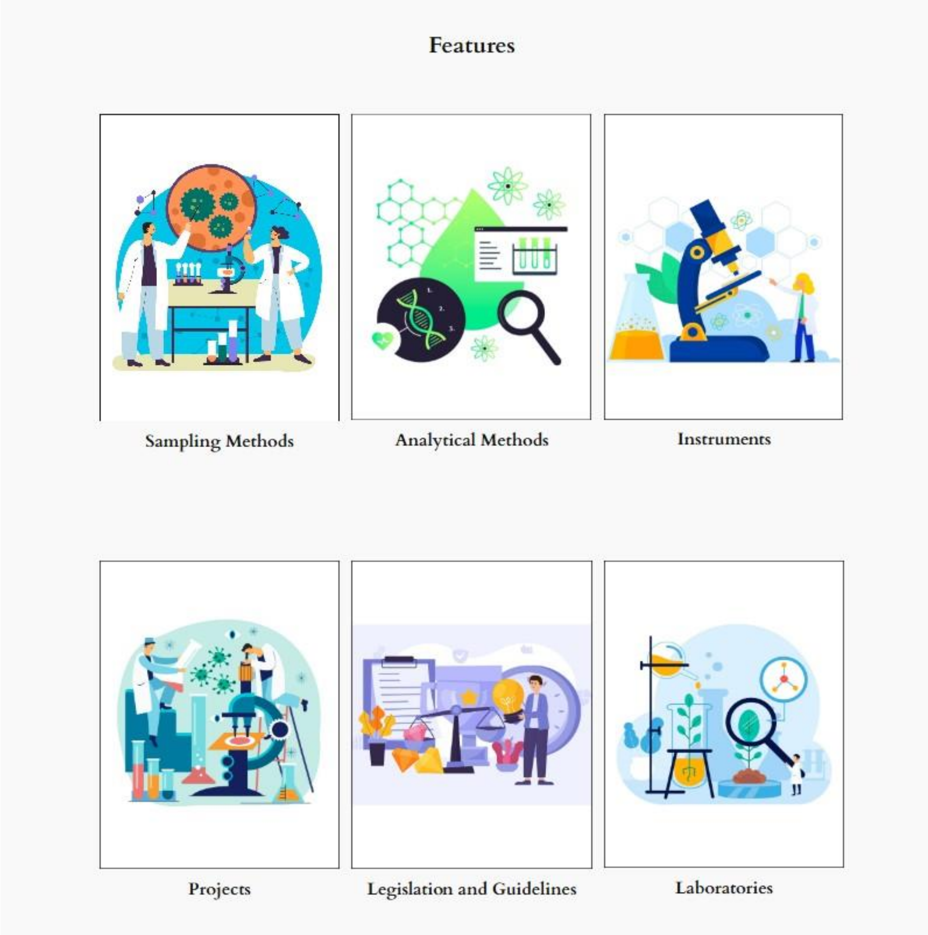


Figure 12. Screenshot of the MicroDrink Knowledge Base interface and structure.

5. Harmonised Approach Applied in the Project

Within the project, a harmonised MP approach was implemented based on a set of shared technical principles and minimum criteria applied consistently across pilot activities. The approach is aligned with Commission Delegated Decision (EU) 2024/1441 and reflects current methodological developments at EU level. This approach was applied across participating sites with the aim of generating comparable, interpretable datasets across the Danube River Basin (DRB), while allowing necessary adaptations for local differences in technical capacity, laboratory infrastructure, and operational conditions.

Its application across pilot activities also enabled practical evaluation of feasibility, identification of technical challenges, and structured exchange of experience between participating laboratories and water utilities.

5.1. Harmonised sampling and analytical approach applied in the project

5.1.1. Sampling Framework

A harmonised sampling framework was applied across case-study sites based on minimum technical criteria aligned with Commission Delegated Decision (EU) 2024/1441, which lays down the methodology for measuring microplastics in water intended for human consumption under Directive (EU) 2020/2184. These criteria included the use of closed filtration systems, contamination-prevention measures, a minimum sampling volume of 1,000 L, and cascade filtration with filter pore sizes of 20 µm. The project tested this harmonised approach at transnational level as preparation for potential future mandatory monitoring of microplastics at drinking water facilities, with a focus on assessing feasibility and building monitoring capacity across the Danube River Basin.

Sampling procedures were applied across different drinking water resource types, including – karst systems, intergranular aquifers and surface water, and riverbank filtration systems. The detailed minimum sampling criteria is provided in Annex 1. Site-specific conditions, including infrastructure constraints and operational feasibility, were taken into account during implementation. All sampling activities were documented using a common reporting structure (see Annex 3 - Sampling report template) including information on sampled volumes, sampling duration, filter characteristics, and any deviations from the agreed framework. Recording of contextual information supports interpretation of results and future comparability of datasets generated under different environmental and operational conditions.

Experience gained during pilot implementation was systematically documented and informed refinement of the harmonised MP approach, particularly regarding practical feasibility of large-volume sampling and handling of low-concentration samples.

Figure 13 to Figure 17 illustrate the full sampling system, from design to field application. Figure 13 presents the conceptual layout of the sampling equipment and the internal configuration of the filter cartridges, showing how water is directed through a controlled filtration unit. The cross-section highlights the vertical flow path and the placement of filtration elements, ensuring that particles are retained while minimizing contamination risks. Figure 14 focuses on the inlet spout of the cartridge, where water enters the system through a secure and tightly sealed connection, allowing direct transfer into the filtration chamber without exposure to external conditions.

The filtration process itself is supported by the stainless-steel sieves shown in Figure 15 and Figure 16, which act as the primary particle retention medium within the cartridges. Their robust and reusable design ensures consistent separation of particles based on size. Finally, Figure 17 shows the complete system deployed in the field, where all components are assembled into a functional setup. Water is conveyed from the source through hoses and flow control elements into the filter cartridges, demonstrating how the individual parts work together as an integrated system for on-site sampling and filtration.

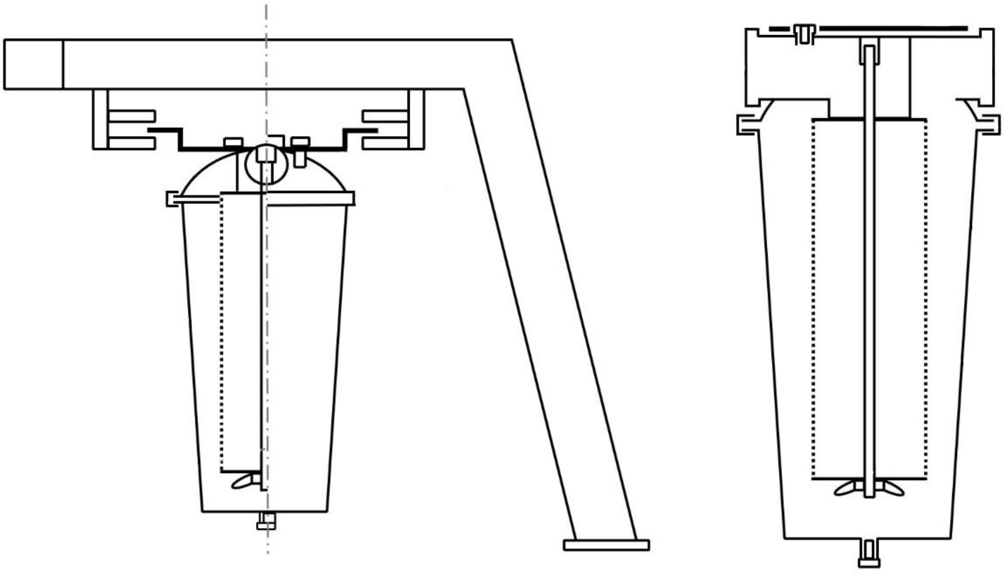


Figure 13. Sampling equipment design and cross-section of filter cartridges.

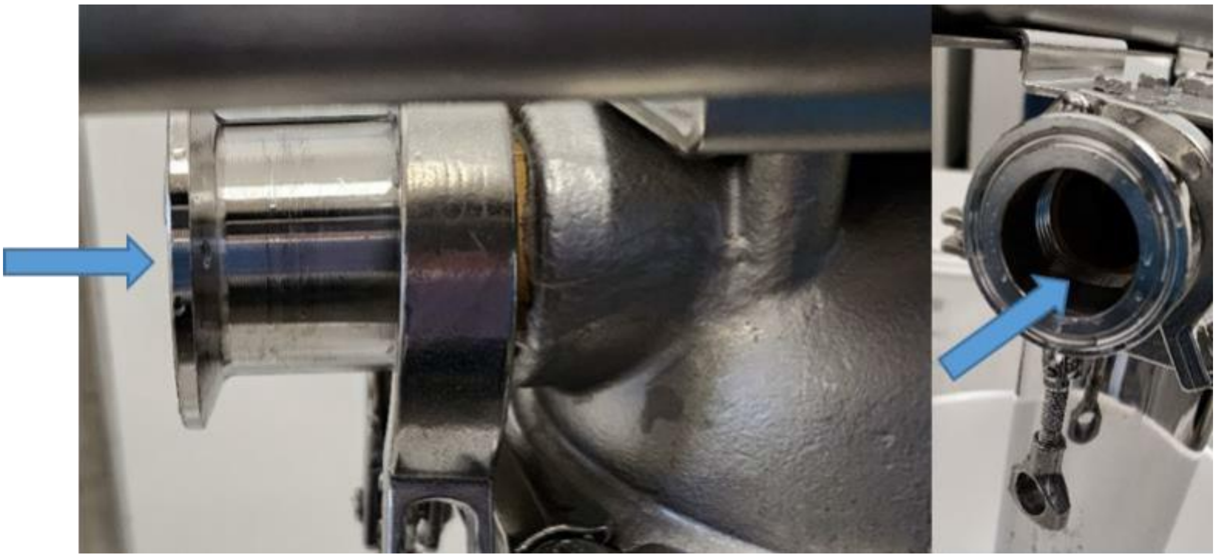


Figure 14. Inlet spout of the filter cartridge (photo: Environment Agency Austria).

Figure 15. Stainless steel sieves (photo: Environment Agency Austria).

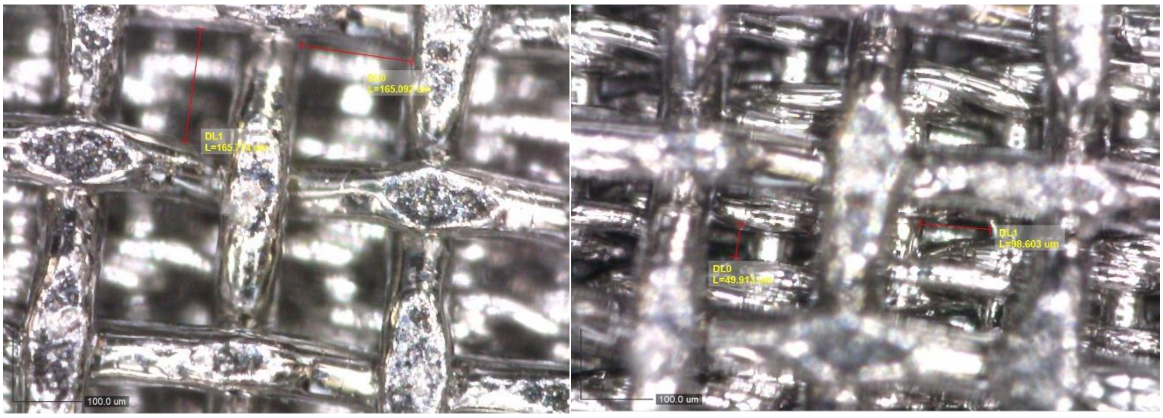


Figure 16. Close-up of the steel filter mesh, first and second layer (photo: Environment Agency Austria).

Figure 17. Complete sampling system setup in the field (photo: Public Utility Service Company "Drugi oktobar" Vršac).

To ensure consistent implementation of the harmonised approach across partner countries, a joint sampling training session was organised within the project. This public event allowed project partners to apply the agreed methodology under the guidance of experienced experts and ensured a common understanding of sampling procedures, contamination prevention measures, and handling of filtration systems. Participation of laboratory professionals and water practitioners enabled the sharing of knowledge on this novel approach and enhanced preparation status for the monitoring of microplastics within the Danube River Basin.

Following the training, national sampling campaigns were conducted across the Danube River Basin, where project partners applied the harmonised approach under different hydrogeological and operational conditions. Sampling was carried out across multiple drinking water resource types, including karst systems, intergranular aquifers, surface water, and riverbank filtration systems, covering both raw and treated water. The applied sampling systems followed the minimum technical criteria, including the use of closed cascade filtration systems. In practice, large water volumes were processed to support detection of low microplastic concentrations, with operational parameters adapted to site-specific conditions such as water quality, infrastructure, and accessibility.

Examples of sampling systems and field implementation are presented in Figure 18, illustrating typical configurations, filtration setups, and deployment conditions across national sampling campaigns.

Figure 18. Field sampling across eight partner countries, illustrating sampling systems and field conditions.

5.1.2. Laboratory Analysis

Within the harmonised MP approach, laboratory analysis focused on the application of vibrational spectroscopy techniques suitable for identification of polymer types in drinking water matrices. FTIR and Raman spectroscopy represent currently established methods capable of supporting polymer identification within the size range defined by EU methodological developments. The detailed minimum analytical requirements applied in the project are provided in Annex 2.

Particular emphasis was placed on:

- transparent documentation of analytical procedures;

- traceable reporting of particle size classes and polymer identification results;
- reporting of analytical uncertainties and detection limits;
- documentation of quality assurance procedures applied within participating laboratories.

Implementation experience across pilot laboratories confirmed that differences in available analytical infrastructure, instrument configuration, and laboratory workflows influence achievable analytical resolution and throughput. To support quality control and ensure consistency of results, samples were collected in duplicate at each pilot site. One set of samples was analysed by the respective national laboratories, while the second set was sent to a central project laboratory in Hungary, enabling cross-checking of analytical results and methodological consistency.

While differences in laboratory capacity may influence processing time and analytical detail, consistency is maintained through shared minimum analytical requirements, standardised reporting formats, and quality assurance procedures, including use of procedural controls and documentation of background contamination levels, recognising that blank results may influence interpretation of low concentration datasets.

Figure 19 shows the extraction of samples from the filter cartridges prior to laboratory analysis. The procedure begins with opening the cartridge in a controlled laboratory environment to access the filtration elements. The retained material on the sieves is then recovered by disassembling the unit and preparing it for further processing. This step ensures that all particles collected during sampling are made available for analysis.

Following this, the filtration components and internal surfaces are rinsed using clean, filtered water, allowing the retained particles to be transferred into glass collection vessels. The rinsing process is carried out systematically to achieve efficient recovery of the sample while avoiding losses. The extracted material is then collected in suitable containers for subsequent analytical procedures.

Figure 19. Extraction of samples prior to analysis (photo: University of Ljubljana)

5.1.3. Pilot Actions Context

The harmonised MP approach was applied across 9 pilot actions in partner countries (Austria, Bosnia and Herzegovina, Croatia, Czech Republic, Germany, Hungary, Slovenia and two pilots in Serbia) representing different drinking water resource types within the Danube River Basin, including karst groundwater, intergranular aquifers, and surface water and riverbank filtration systems. The diversity of pilot conditions enabled testing of the harmonised approach under varying hydrogeological and operational contexts typically encountered in DRB drinking water supply systems.

Further technical description of the pilot sites and hydrogeological settings is provided in the public project outputs:

- Output 2.1 – Karst systems;
- Output 2.2 – Intergranular aquifers;
- Output 2.3 – Surface water and riverbank filtration systems.

These documents are published on the official project website[1] and provide detailed context regarding site selection, environmental pressures, and monitoring relevance within each resource type. Application of the harmonised approach across pilot sites provided practical insights regarding feasibility of sampling procedures, analytical constraints, and interpretation of results in low-concentration environments.

The pilot actions confirmed the importance of clear documentation of sampling conditions and procedural steps and careful interpretation of results where particle concentrations approach detection limits.

Overall, the practical experience gained through project monitoring contributes to improved understanding of current technical limitations and supports the gradual development of more comparable microplastic monitoring approaches across the Danube River Basin.

5.2. Monitoring Capacity Mapping Across the DRB

Implementation of the harmonised MP approach highlighted differences in existing technical capacity for MP monitoring across participating countries.

The project assessed the availability of key enabling factors for MP monitoring, including:

- availability of sampling equipment suitable for large-volume filtration;
- access to vibrational spectroscopy techniques (FTIR or Raman);
- laboratory experience with microplastic analysis;
- availability of trained personnel;

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[1] https://interreg-danube.eu/projects/microdrink

- institutional capacity to conduct research-based monitoring activities.

The assessment confirmed heterogeneous capacity across the DRB. Advanced analytical infrastructure is primarily available within specialised research institutions, while routine monitoring capacity within water utilities remains limited. In several participating countries, MP analysis is currently conducted primarily within research projects rather than as part of regular monitoring programmes.

Key limiting factors identified during implementation include:

- high analytical costs per sample;
- limited availability of specialised instrumentation;
- absence of accredited routine methods for drinking water;
- limited access to reference materials;
- limited laboratory personnel experienced in MP analysis.
- no legal obligation for MP monitoring and the lack of assessment criteria/regulatory thresholds.

Overall, the current capacity for large-scale, routine monitoring of microplastics in drinking water across the DRB is not yet sufficient. While technical capabilities exist in selected laboratories, their distribution remains uneven, and integration into routine monitoring frameworks is still limited.

Addressing these gaps requires targeted capacity-building efforts, including expansion of analytical infrastructure, training of laboratory personnel, development of standardised and accredited analytical procedures, and strengthening collaboration between research institutions and water utilities. The experience gained through MicroDrink pilot actions provides a practical basis for identifying these gaps and supports the gradual development of monitoring capacity across the region.

To address these gaps, project MicroDrink has developed several supporting documents and sampling guidelines, as well as the Decision-making support tool (DMST) to equip water practitioners and decision makers with the necessary tools to aid in future microplastic monitoring implementation efforts. All the above will be publicly available on the project website.

5.3. Lessons Learned from Implementation and Best Practices

The following best practices are derived from the implementation of the harmonised approach across pilot activities and reflect practical experience gained during the project. Based on implementation experience across pilot sites, several practices were identified as supporting comparability and transparency of MP monitoring results:

- implementation of contamination-prevention measures throughout sampling and laboratory workflows; including the use of plastic-free equipment where feasible, pre-cleaning of sampling devices, application of field and procedural blanks, and minimisation of sample exposure to air during handling;

- use of established vibrational spectroscopy techniques suitable for MP identification in drinking water matrices (FTIR, Raman);
- transparent reporting of analytical procedures and associated uncertainties;
- documentation of deviations from agreed minimum technical criteria;
- consistent recording of sampling metadata enabling contextual interpretation of results. including documentation of sampling volume, filtration duration, sample coding (e.g. raw water, treated water, sample, or blank);
- avoidance of materials that may interfere with sampling and analysis (e.g. SBR rubber hoses), and careful selection of system components to reduce risk of contamination or clogging;
- control of operational parameters during sampling, particularly maintaining appropriate pressure and flow rates to prevent damage to filter meshes and ensure stable filtration performance.

These elements support improved alignment of monitoring practices while maintaining flexibility necessary for implementation under varying institutional and technical conditions.

6. Stakeholder Feedback

Continuous stakeholder engagement formed an important component of the MicroDrink project, supporting knowledge exchange, alignment of methodological approaches, and identification of practical challenges related to microplastics monitoring in drinking water. Engagement activities enabled dialogue between research institutions, laboratories, water utilities, and policy actors working on microplastics in aquatic environments.

Through workshops, technical discussions, exchange visits, and joint communication activities, the consortium contributed to improved understanding of current monitoring practices and promoted consistency in interpretation of emerging methodological developments. Stakeholder feedback provided valuable practical perspectives regarding feasibility of sampling approaches, analytical constraints, and future monitoring needs.

The following subchapters summarise selected stakeholder exchange activities and their contribution to refinement of the harmonised MP approach.

6.1. Roundtable Discussion and Knowledge Exchange Activities

As part of the validation and refinement process of the harmonised MP approach, two online round-table discussions were organised throughout May and June 2025 as knowledge-exchange events. The meetings facilitated dialogue between ongoing European initiatives addressing microplastics monitoring in aquatic environments and drinking water systems. Participants attended the event, representing research initiatives, European institutions, and organisations involved in microplastics monitoring and environmental assessment.

The roundtable discussion enabled exchange of technical experience related to sampling implementation, contamination prevention, analytical capacity, and interpretation of monitoring results. Participants shared insights from ongoing research activities addressing microplastics occurrence in freshwater systems, wastewater, and drinking water resources.

Representatives of the Joint Research Centre (JRC) presented the scientific work which supported the development of the harmonised methodology for measuring microplastics in drinking water, formalised through Commission Delegated Decision (EU) 2024/1441 supplementing Directive (EU) 2020/2184 (Belz et al.2024). The methodology describes a structured monitoring workflow covering sampling, sample preparation, analytical identification, and reporting of results. For the sampling stage, the JRC tested a cascade filtration system composed of filters with decreasing pore sizes, designed to capture microplastic particles across different size ranges while reducing the risk of contamination. The JRC emphasised that analytical technologies continue to evolve and that flexibility remains necessary while monitoring approaches mature (Figure 20**Error! Reference source not found.**).

Participants highlighted several practical considerations related to implementation of microplastic monitoring. Sampling equipment applied in research contexts is often specifically designed and may not yet be widely available as standardised commercial systems. Prevention of contamination during sampling and laboratory processing was identified as a critical issue requiring careful procedural design. Limited availability of laboratories equipped with spectroscopic instrumentation also remains a challenge for scaling up monitoring activities.

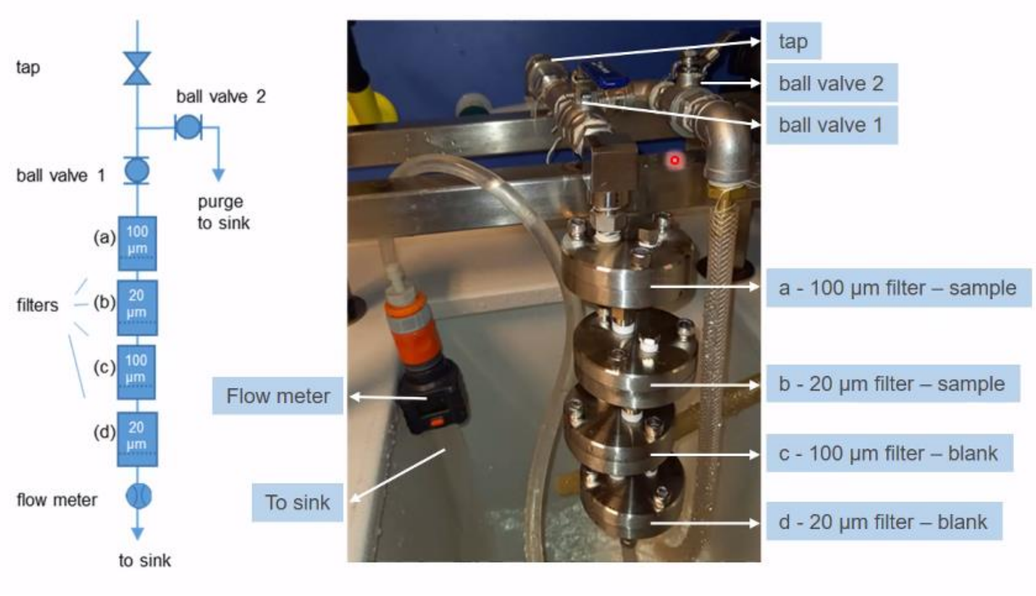

Figure 20. Overview of sampling system used by the JRC when developing the methodology prescribed in Commission Delegated Decision 2024/1441 supplementing EU DWD 2020/2184.

Participants also noted that scientific understanding of potential health implications of microplastics in drinking water is still developing. As a result, regulatory thresholds have not yet been established, and current efforts primarily focus on improving methodological consistency and strengthening the scientific evidence base.

In addition to the roundtable discussion, knowledge exchange was supported through exchange visits between project partners and preparation of a joint project newsletter. These activities contributed to sharing of practical experience related to sampling procedures, analytical workflows, and interpretation of results under different institutional conditions.

Stakeholder exchange activities provided useful feedback supporting refinement of the harmonised MP approach, particularly regarding feasibility of sampling procedures, variability in laboratory capacity, and importance of transparent documentation of analytical parameters.

Key observations emerging from stakeholder discussions include:

- microplastic analysis in drinking water remains technically demanding and resource-intensive;
- laboratory capacity and access to specialised analytical instruments vary across countries;
- consistent documentation of sampling procedures supports comparability of monitoring result;
- methodological flexibility remains necessary while analytical techniques continue to develop;
- continued exchange between research institutions, laboratories, and water utilities supports gradual alignment of monitoring practices.

These insights contributed to refinement of the harmonised MP approach applied within the MicroDrink project and support development of comparable monitoring practices under current technical conditions.

6.2. National Stakeholder Feedback

National stakeholder workshops were organised across partner countries to collect feedback on the application of the harmonised approach and to facilitate exchange between water supply operators, laboratories, researchers, and competent authorities. The workshops provided a structured platform to discuss implementation experience and to better understand practical considerations influencing monitoring activities for microplastics in drinking water (Figure 21).

Feedback from stakeholders indicated that experience with microplastics monitoring varies across participating countries. While some laboratories already perform analytical identification of microplastics, others are still in the process of developing the necessary technical capacities. Differences were observed regarding access to analytical equipment, trained personnel, and financial resources required to perform analyses.

Participants highlighted operational aspects that may influence implementation feasibility, including coordination between water suppliers and laboratories, planning of sampling activities, and the effort required for analytical processing. Stakeholders noted that microplastics analysis requires specialised expertise and may involve relatively high resource requirements compared to routine water quality parameters. In several cases, participants emphasised the relevance of technical guidance and exchange of experience to support consistent application of analytical procedures.

Figure 21. National stakeholder workshops organised within the project across 8 partner countries of the Danube River Basin.

Discussions also reflected that methodological development in the field of microplastics monitoring is ongoing and that interpretation of analytical results continues to develop as scientific knowledge progresses. Stakeholders indicated that continued communication between laboratories and research institutions can support comparability of results and improve understanding of analytical limitations under different operational conditions. Participants further noted that differences in institutional readiness may influence the pace at which monitoring activities can be introduced.

A key point was that monitoring of drinking water for the occurrence of microplastics is not yet mandatory, and should it become mandatory, it is likely that each Member State will define how monitoring will be implemented nationally. However, without clearly defined threshold values and readily available sampling equipment, monitoring implementation in the near future is highly challenging and therefore may be unlikely.

Overall, the workshops highlighted the value of continued technical dialogue between implementation actors and research institutions in order to support knowledge exchange and facilitate gradual alignment of monitoring practices across participating countries.

7. Conclusions

The presented harmonised MP approach results from the synthesis of several complementary sources of evidence generated within the MicroDrink project. These include MicroDrink Knowledge Base on microplastics in drinking water resources across the Danube River Basin, the technical implementation of harmonised sampling and analytical procedures during project pilot activities, the structured mapping of monitoring capacities across participating countries, and stakeholder input gathered through surveys, workshops, and expert discussions.

Together, these sources provide a comprehensive overview of the current state of microplastic monitoring in drinking water across the region and highlight the main technical, institutional, and regulatory factors influencing monitoring practices. The evidence confirms that monitoring activities remain largely exploratory and research-oriented, while significant differences persist in laboratory infrastructure, technical expertise, analytical capacity, and financial resources across countries of the Danube River Basin.

The synthesis of these findings enabled project partners to identify several key considerations for the development of a harmonised approach:

- which technical elements can reasonably be aligned across countries under current monitoring conditions;
- which aspects require flexibility due to differences in laboratory infrastructure, technical expertise, and resource availability;
- where targeted capacity-building and methodological support are most needed to improve comparability;
- how monitoring results should be interpreted cautiously given the evolving nature of analytical methods and the absence of regulatory threshold values.

Based on this synthesis process, the harmonised MP approach is presented as a supportive and non-binding reference framework designed to facilitate methodological alignment without imposing rigid standardisation. The framework provides a set of minimum technical principles and documentation practices that can be voluntarily adopted by national authorities, water utilities, and laboratories. At the same time, it allows proportional implementation reflecting differences in monitoring capacity, laboratory infrastructure, and national regulatory contexts across the Danube River Basin.

From a practical perspective, the harmonised MP approach can support stakeholders across the region in several ways:

- comparing existing national sampling and analytical practices with the harmonised criteria defined in this approach;
- identifying monitoring capacity gaps and potential priorities for laboratory or methodological development;
- strengthening documentation, metadata reporting, and transparency of analytical procedures.

Output 1.1 therefore represents a coordinated transnational effort to improve methodological transparency and preparedness regarding microplastics in drinking water. By consolidating knowledge from project activities, stakeholder consultations, and evolving EU methodological developments, the harmonised MP approach provides a practical reference that supports comparability of monitoring practices across EU and non-EU countries in the Danube River Basin, while remaining consistent with the preparatory and capacity-building mandate of the MicroDrink project and the Interreg Danube Region Programme.

Reference

Baini, M., Fossi, M. C., Galli, M., Caliani, I., Campani, T., Finoia, M. G., & Panti, C. (2018). Abundance and characterization of microplastics in the coastal waters of Tuscany (Italy). Marine Pollution Bulletin, 133, 543-552. https://doi.org/10.1016/j.marpolbul.2018.06.016

Barboza, L. G. A., & Gimenez, B. C. G. (2015). Microplastics in the marine environment: Current trends and future perspectives. Marine Pollution Bulletin, 97(1-2), 5-12. https://doi.org/10.1016/j.marpolbul.2015.06.008

Barboza, L. G. A., Dick Vethaak, A., Lavorante, B. R. B. O., Lundebye, A. K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. Marine Pollution Bulletin, 133, 336-348. https://doi.org/10.1016/j.marpolbul.2018.05.047

Belz, S., Cella, C., Geiss, O., Gilliland, D., La Spina, R., & Sokull-Kluettgen, B. (2024). Analytical methods to measure microplastics in drinking water (JRC136859). European Commission, Joint Research Centre. Publications Office of the European Union. https://doi.org/10.2760/109944

Carbery, M., O'Connor, W., & Palanisami, T. (2018). Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health. Environment International, 115, 400-409. https://doi.org/10.1016/j.envint.2018.03.007

Chakraborty, I., Banik, S., Biswas, R., Yamamoto, T., Noothalapati, H., & Mazumder, N. (2023). Raman spectroscopy for microplastic detection in water sources: A systematic review. International Journal of Environmental Science and Technology, 20(9), 10435-10448. https://doi.org/10.1007/s13762-022-04505-0

Cincinelli, A., Scopetani, C., Chelazzi, D., Lombardini, E., Martellini, T., Katsoyiannis, A., Fossi, M. C., & Corsolini, S. (2017). Microplastic in the surface waters of the Ross Sea (Antarctica): Occurrence, distribution and characterization by FTIR. Chemosphere, 175, 391-400. https://doi.org/10.1016/j.chemosphere.2017.02.024

Council of the European Union. (1998). *Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. Official Journal of the European Communities, L 330*, 32-54.

Danopoulos, E., Twiddy, M., & Rotchell, J. M. (2020). Microplastic contamination of drinking water: A systematic review. PLOS ONE, 15(7), e0236838. https://doi.org/10.1371/journal.pone.0236838

European Commission. (2023). *Commission Regulation (EU) 2023/2055. Official Journal of the European Union, L 238.*

European Commission. (2023). Commission Regulation (EU) 2023/2055 of 25 September 2023 amending Annex XVII to Regulation (EC) No 1907/2006 concerning synthetic polymer microparticles. Official Journal of the European Union, L 238, 67–100

European Commission. (2024). *Commission Delegated Decision (EU) 2024/1441. Official Journal of the European Union.*

European Parliament and Council of the European Union. (2019). *Directive (EU) 2019/904. Official Journal of the European Union, L 155.*

European Parliament and Council of the European Union. (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 (recast). Official Journal of the European Union, L 435*, 1-62.

European Union. (2020). Finding the right methods for measuring microplastics in water. https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/methods-measuring-microplastics-water-2020-02-28_en

Ferraz, M., Bauer, A. L., Valiati, V. H., & Schulz, U. H. (2020). Microplastic concentrations in raw and drinking water in the Sinos River, Southern Brazil. Water, 12(11), 3115. https://doi.org/10.3390/w12113115

Huang, J., Chen, H., Zheng, Y., Yang, Y., Zhang, Y., & Gao, B. (2021). Microplastic pollution in soils and groundwater: Characteristics, analytical methods and impacts. Chemical Engineering Journal, 425, 131870. https://doi.org/10.1016/j.cej.2021.131870

Karlsson, T. M., Karrman, A., Rotander, A., & Hassellov, M. (2020). Comparison between manta trawl and in situ pump filtration methods. Environmental Science and Pollution Research, 27(5), 5559-5571. https://doi.org/10.1007/s11356-019-07274-5

Kirstein, I. V., Gomiero, A., & Vollertsen, J. (2021). Microplastic pollution in drinking water. Current Opinion in Toxicology, 28, 70-75. https://doi.org/10.1016/j.cotox.2021.09.003

Koelmans, A. A., Mohamed Nor, N. H., Hermsen, E., Kooi, M., Mintenig, S. M., & De France, J. (2019). Microplastics in freshwaters and drinking water. Water Research, 155, 410-422. https://doi.org/10.1016/j.watres.2019.02.054

Kosuth, M., Mason, S. A., & Wattenberg, E. V. (2018). Anthropogenic contamination of tap water, beer, and sea salt. PLOS ONE, 13(4), e0194970. https://doi.org/10.1371/journal.pone.0194970

Kumar, P., Sharma, Y., Singh, S., & Sharma, S. (2023). Microplastics in drinking water: Assessing occurrence and potential risks. Journal for Research in Applied Sciences and Biotechnology, 2(3), 189-197. https://doi.org/10.55544/jrasb.2.3.25

Kye, H., Kim, J., Ju, S., Lee, J., Lim, C., & Yoon, Y. (2023). Microplastics in water systems: A review of their impacts on the environment and their potential hazards. *Heliyon*, *9*(3). https://doi.org/10.1016/j.heliyon.2023.e14359

Mai, L., Bao, L.-J., Shi, L., Wong, C. S., & Zeng, E. Y. (2018). A review of methods for measuring microplastics in aquatic environments. Environmental Science and Pollution Research, 25(12), 11319-11332. https://doi.org/10.1007/s11356-018-1692-0

Miller, E., Sedlak, M., Lin, D., Box, C., Holleman, C., Rochman, C. M., & Sutton, R. (2021). Recommended best practices for microplastics. Journal of Hazardous Materials, 409, 124770. https://doi.org/10.1016/j.jhazmat.2020.124770

Mintenig, S. M., Loder, M. G. J., Primpke, S., & Gerdts, G. (2019). Low numbers of microplastics in drinking water. Science of The Total Environment, 648, 631-635. https://doi.org/10.1016/j.scitotenv.2018.08.178

Mintenig, S. M., Kooi, M., Erich, M. W., Primpke, S., Redondo-Hasselerharm, P. E., Dekker, S. C., Koelmans, A. A., & van Wezel, A. P. (2020). A systems approach to understand microplastic occurrence and implications in drinking water sources. Water Research, 176, 115723. https://doi.org/10.1016/j.watres.2020.115723

Mukotaka, A., Kataoka, T., & Nihei, Y. (2021). Rapid analytical method for microplastics in drinking water using a continuous flow-through sampling technique. Science of The Total Environment, 790, 148231. https://doi.org/10.1016/j.scitotenv.2021.148231

Nava, V., Frezzotti, M. L., & Leoni, B. (2021). Raman spectroscopy for the analysis of microplastics in aquatic systems. Applied Spectroscopy, 75(11), 1341-1357. https://doi.org/10.1177/00037028211043119

Negrete Velasco, A., Ramseier Gentile, S., Zimmermann, S., Le Coustumer, P., & Stoll, S. (2023). Contamination and removal efficiency of microplastics and synthetic fibres in a conventional drinking water treatment plant. Science of the Total Environment, 880, 163270. https://doi.org/10.1016/j.scitotenv.2023.163270

Obbard, R. W., Sadri, S., Wong, Y. Q., Khitun, A. A., Baker, I., & Thompson, R. C. (2014). Global warming releases microplastic legacy frozen in Arctic sea ice. Earth's Future, 2(6), 315-320. https://doi.org/10.1002/2014ef000240

Panno, S. V., Kelly, W. R., Scott, J., Zheng, W., McNeish, R. E., Holm, N., Hoellein, T. J., & Baranski, E. L. (2019). Microplastic contamination in karst groundwater systems. Groundwater, 57(2), 189-196. https://doi.org/10.1111/gwat.12862

Pittroff, M., Muller, Y. K., Witzig, C. S., Scheurer, M., Storck, F. R., & Zumbulte, N. (2021). Microplastic analysis in drinking water based on fractionated filtration and Raman microspectroscopy. Environmental Science and Pollution Research, 28(42), 59439-59451. https://doi.org/10.1007/s11356-021-12467-y

Pivokonsky, M., Cermakova, L., Novotna, K., Peer, P., Cajthaml, T., & Janda, V. (2018). Occurrence of microplastics in raw and treated drinking water. Science of The Total Environment, 643, 1644-1651. https://doi.org/10.1016/j.scitotenv.2018.08.102

Prata, J. C., da Costa, J. P., Lopes, I., Andrady, A. L., Duarte, A. C., & Rocha-Santos, T. (2021). A One Health perspective of the impacts of microplastics on animal, human and environmental health. Science of The Total Environment, 777, 146094. https://doi.org/10.1016/j.scitotenv.2021.146094

Primpke, S., Fischer, M., Lorenz, C., Gerdts, G., & Scholz-Bottcher, B. M. (2020). Comparison of pyrolysis GC/MS with other spectroscopic techniques for the analysis of microplastics. Analytical and Bioanalytical Chemistry, 412(30), 8283-8298. https://doi.org/10.1007/s00216-020-02979-w

Rodrigues, M. O., Abrantes, N., Goncalves, F. J. M., Nogueira, H., Marques, J. C., & Goncalves, A. M. M. (2018). Spatial and temporal distribution of microplastics in water and sediments of a freshwater system. Science of the Total Environment, 633, 1549-1559. https://doi.org/10.1016/j.scitotenv.2018.03.233

Schreiber, M. P., Komppa, V., Wahlstrom, M., & Laine-Ylijoki, J. (2006). Chemical and environmental sampling: Complementary aspects. Accreditation and Quality Assurance, 10(9), 510-514. https://doi.org/10.1007/s00769-005-0045-0

Schwaferts, C., Niessner, R., Elsner, M., & Ivleva, N. P. (2019). Methods for the analysis of submicrometer- and nanoplastic particles in the environment. TrAC Trends in Analytical Chemistry, 112, 52-65. https://doi.org/10.1016/j.trac.2018.12.014

Schymanski, D., Goldbeck, C., Humpf, H. U., & Furst, P. (2018). Analysis of microplastics in water by micro-Raman spectroscopy: Release of plastic particles from different packaging types. Water Research, 129, 154-162. https://doi.org/10.1016/j.watres.2017.11.011

Selvam, S., Jesuraja, K., Venkatramanan, S., Chung, S. Y., Roy, P. D., Muthukumar, P., Kumar, M., & Singaraja, C. (2021). Hazardous microplastic characteristics and its role as a vector of heavy metal in groundwater and surface water of coastal south India. Journal of Hazardous Materials, 402, 123786. https://doi.org/10.1016/j.jhazmat.2020.123786

Senathirajah, K., & Palanisami, T. (2023). Strategies to Reduce Risk and Mitigate Impacts of Disaster: Increasing Water Quality Resilience from Microplastics in the Water Supply System. ACS ES&T Water, 3(9), 2816-2834. https://doi.org/10.1021/ACSESTWATER.3C00206

Shan, W., Li, B., Zhang, H., Zhang, Z., Wang, Y., Gao, Z., & Li, J. (2021). Distribution, characteristics and daily fluctuations of microplastics throughout wastewater treatment plants with mixed domestic-industrial influents in Wuxi City, China. Frontiers of Environmental Science & Engineering, 16(1), 6. https://doi.org/10.1007/s11783-021-1440-4

Van Cauwenberghe, L., Vanreusel, A., Mees, J., & Janssen, C. R. (2013). Microplastic pollution in deep-sea sediments. Environmental Pollution, 182, 495-499. https://doi.org/10.1016/j.envpol.2013.08.013

Xu, Z., Sui, Q., Li, A., Sun, M., Zhang, L., Lyu, S., & Zhao, W. (2020). How to detect small microplastics (20-100 um) in freshwater, municipal wastewaters and landfill leachates? A trial from sampling to identification. Science of The Total Environment, 733, 139218. https://doi.org/10.1016/J.SCITOTENV.2020.139218

Yuan, C., Almuhtaram, H., McKie, M. J., & Andrews, R. C. (2022). Assessment of microplastic sampling and extraction methods for drinking waters. Chemosphere, 286, 131881. https://doi.org/10.1016/J.CHEMOSPHERE.2021.131881

Zhang, G. S., & Liu, Y. F. (2018). The distribution of microplastics in soil aggregate fractions in southwestern China. Science of the Total Environment, 642, 12-20. https://doi.org/10.1016/j.scitotenv.2018.06.004

Zhang, Q., Xu, E. G., Li, J., Chen, Q., Ma, L., Zeng, E. Y., & Shi, H. (2020). A Review of Microplastics in Table Salt, Drinking Water, and Air: Direct Human Exposure. Environmental Science and Technology, 54(7), 3740-3751. https://doi.org/10.1021/ACS.EST.9B04535

Zheng, Y., Li, J., Sun, C., Cao, W., Wang, M., Jiang, F., & Ju, P. (2021). Comparative study of three sampling methods for microplastics analysis in seawater. Science of the Total Environment, 765, 144495. https://doi.org/10.1016/j.scitotenv.2020.144495

Annex

Annex 1 – Minimum Technical Criteria for Sampling

Documents for reference:

- a. C(2024) 1459 COMMISSION DELEGATED DECISION supplementing Directive (EU) 2020/2184 of the European Parliament and of the Council by laying down a methodology to measure microplastics in water intended for human consumption + annex;
- b. ISO/DIS 5667-27: Water quality – Sampling – Part 27: Guidance on sampling for microplastics in water.

1. Equipment
    - a. Plastic free sampling equipment should be applied (stainless steel, glass, rubber);
    - b. Materials and equipment should be carefully cleaned before use with MP free water and reagents. To produce MP free water, deionised water should be filtered through <1 µm mesh size inorganic filters.
2. Procedure
    - a. Minimum 1000 L should be sampled;
    - b. Smallest mesh size during sampling should be 20 µm;
    - c. The sampled volume should be piped directly to the filter cascade without the use of intermediate collection;
    - d. Register all data required on the sampling sheet;
    - e. Blanks are generated with two subsequent filters with the same mesh size, first filter is considered the sample, second filter considered the field blank.
3. General
    - a. Avoid atmospheric contamination by covering equipment when not in use;
    - b. Avoid wearing clothes made out of synthetic polymers.

Annex 2 – Minimum analytical criteria for microplastic analysis

Documents for reference:

c. C(2024) 1459 COMMISSION DELEGATED DECISION supplementing Directive (EU) 2020/2184 of the European Parliament and of the Council by laying down a methodology to measure microplastics in water intended for human consumption + annex;

d. ISO/DIS 16094-:2 Water quality – Analysis of microplastic in water – Part 2: Vibrational spectroscopy methods for waters with low content of suspended solids including drinking water.

1. Equipment
    a. Avoid general plastic laboratory consumables;
    b. All items should be cleaned before use: washing with detergent, rinse with MP free water and if needed with 96% ethanol. To produce MP free water, deionised water should be filtered through <1 µm mesh size inorganic filters;
    c. Reagents used need to be filtered on <1 µm mesh size inorganic filter;
    d. Whenever possible, sample manipulation steps need to be conducted under a laminar flow hood that applies HEPA filters.
2. Procedure
    a. Whole water sample needs to be processed;
    b. If this is not possible by any case, it has to be recorded and min. 10% subsample needs to be analysed after thorough homogenisation of the full sample;
    c. Samples need to be analysed with FTIR, Raman or QCL-IR techniques;
    d. In general, the whole sample needs to be analysed on the full filter or sample support;
    e. If it is not possible to analyse the full filter or sample support in a practical time, the operator may limit analysis to one or more smaller sub-areas of the filter: the selection of the area shall follow appropriate sub-sampling strategies which maintain a representative sample that shall cover at least 20% of total area of all particles;
    f. If subsampling is applied, this should be reported, including the total filter area/analysed filter area or total particle number/analysed particle number.
3. Reporting

   a. The following priority polymer types need to be analysed: Polyethylene (PE); Polypropylene (PP); Polyethylene Terephthalate (PET); Polystyrene (PS); Polyvinylchloride (PVC); Polyamide (PA); Polyurethane (PU); Polymethylmethacrylate (PMMA); Polytetrafluoroethylene (PTFE); Polycarbonate (PC);
   b. Identified microplastics should be classified in 2 size categories: 20 – 100 µm and >100 µm;
   c. Identified microplastics should be classified in 2 shape categories (for both size fractions): particles (length to width ratio is less than 3) and fibres (length to width ratio is equal to or greater than 3).

4. Quality control
   a. Avoid atmospheric contamination by covering equipment when not in use;
   b. Avoid wearing clothes made out of synthetic polymers;
   c. To quantify the typical levels of background contamination occurring during the performance of the analytical procedures, it is recommended that a minimum of 10 procedural blanks are processed and analysed according to the procedures used for the samples. These values shall be used to calculate the mean and standard deviation of the background microplastic contamination;
   d. Limit of quantification (LOQ) of the method for all microplastic and per polymer type should be reported based on the results of 10 procedural blanks as mean value + 10x standard deviation;
   e. Experimental verifications shall be performed to assess the recovery of the procedure. Spike particles with sizes in the range 120 to 200 µm and 30 µm to 70 µm should be used to assess the recovery. The polymers used should include at least one with higher density than water (e.g. PET) and at least one with lower density (e.g. PE). In each case, the number of spiked particles should be in the range 50-150. The analysis procedure is considered to be acceptable if the recovery rate is within the range 100% +/- 40%.

5. Users of this methodology shall ensure that the following additional information is recorded in relation to each sample collected and measured:
   a. Total volume of water sampled; and
   b. Sample treatment details; and
   c. Spectroscopic method and instrument applied; and
   d. Details of any sub-sampling during analysis or sample preparation
   e. Chemical nature of any plastic component(s) in sampling device or in equipment used during sample preparation.

Annex 3 - Sampling report template

Sample type: ☐ raw water ☐ treated water

Sample code:

Description of sampling location (e.g. well, collector, location in technology, sampling tap identifier applied by the plant, etc.):

Filter pore size (µm): ☐ 20 ☐ 100

Subsequent blank filter applied (20 µm): ☐ yes ☐ no

Sample code of blank filter (if applied):

Water meter before sampling: **after sampling:**

Sampled water volume (L):

Sampling date: **Sampling start time:** **end time:**

Sampling organisation:

Name of sampling personnel:

Signature: