Illustrated Joint Protocol for Plastic Waste Monitoring in and along rivers

Tid(y)Up

F(ol)low the Plastic from source to the sea: Tisza-Danube integrated action plan to eliminate plastic pollution of rivers

Deliverable T1.3.1 Elaboration of micro and macro plastic database

O.T1.3 Illustrated Joint Protocol for Waste Monitoring

Tid(y)Up project is focusing on the improvement of water quality and reduction of plastic pollution in one of Europe's most heavily contaminated rivers, the Tisza, and investigates plastic pollution and its effect on the Danube and the Black Sea. Currently there are no standard methods and consistent data available on plastic pollution of rivers in the Danube Basin that would help harmonized actions of water management authorities and allow cooperation with other sectors.

With this illustrated Joint Protocol for waste monitoring (E-book) which was developed within Work Package T1 practical possibilities for evaluation and monitoring of macro and microplastics in rivers are provided. Given information helps to combat plastic pollution and is relevant to volunteers conducting clean-up activities as well as to decision makers

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1. Foreword

Despite the advanced waste management and ambitious recycling objectives of the EU, studies indicate the presence of plastic and microplastic pollution in rivers of CE. For this reason, within the Tid(y)Up project financed by the Interreg Danube Transnational programme seven partners from five riparian states of the Danube were focusing on the improvement of water quality and reduction of plastic pollution of the Danube and the Tisza river from its source to the Black Sea. This Joint protocol is one major output of these activities to help to implement harmonized actions of water management authorities and allow cooperation with other sectors necessary to stop the pollution in the Danube river basin. Within the project partners develop and launch a set of integrated actions, consult and provide tools for relevant stakeholders and initiate long term transboundary and intersectoral cooperation with the aim of eliminating the plastic pollution of rivers (see project site: https://tisztatiszaterkep.hu/#/en/ and pollution map: https://tisztatiszaterkep.hu/#/en/).

The presented guideline shall support water authorities to monitor the amount of plastic waste in rivers and their influence on the environment in order to adopt proper mitigation solutions. The first chapters present common procedures regarding measurement of micro- and macroplastic waste (accumulation) focussing on Tisza-Danube water bodies, banks and shores and includes the proposal on a 1) microplastic measurement methodology to facilitate comparable microplastic assessment results in the Danube basin and 2) a macroplastic waste flow assessment strategy

Recommendations for sampling, comparison rates and analytical methods under certain boundary conditions considering cost-benefit ratio are given. As a baseline the results from measurements in the years 2020 and 2021 are presented in the 2nd part. This helps to identify the most important sources and pathways of micro and macro-plastic pollution in the downstream area of the Danube Basin.

2. Microplastic - Sampling method

2.1. Microplastic sampling methods in rivers – status quo

Currently, there is no standard method used to sample microplastics from riverine systems. Most microplastic research focuses on quantity, in particular on particle numbers, and composition of microplastics. The complexity of microplastics and the lack of harmonization in sampling methodology make it difficult to compare different studies (Dris et al., 2015; Koelmans et al., 2019; Kooi & Koelmans, 2019) cited in (van Emmerik and Schwarz, 2020).

However, assessing possible threats attributed to microplastic (MP) requires fast, reliable and at least representative sampling, sample preparation and detection methods that will eventually be harmonized. Only then, a comparison of findings will be possible and avoidance strategies or regulative measures to decrease the unintended entry of plastics into the environment can be discussed (Bannick et al., 2019).

Sampling MPs in a riverine system is different from collecting particles in the marine environment. Several factors, including hydrological conditions of the water body (e.g. water density, wind, currents, waves and tides), temporal and geographical factors determined by the shape of the river, the morphology, and the meteorological situation will influence the pathway of microplastics in the catchment area. These natural elements should be considered when developing a sampling strategy and monitoring of MPs (González-Fernández cited in (Campanale et al., 2020). A major factor is the high proportion of suspended solids and organic matter, which makes sampling of microplastic in rivers more complex than in the ocean. Nevertheless, to make data about microplastics pollution comparable we need to harmonise sampling, preparation and analysis of microplastics from riverine systems.

In particular, the following steps have to be considered: firstly sampling from the aquatic compartment. Based on the goal of the research, specific devices can be used to collect particles from different matrices. It follows their quantification after extraction from the environmental matrix, adopting different protocols to isolate microplastics from a large amount of organic matter present in a riverine system. In the end, additional qualitative analyses (e.g., RAMAN and FTIR spectroscopy, GC-MS) are required to identify the chemical composition of particles for a better information regarding polymer types, their origin or other relevant information.

Especially riverine samples are very heterogenous, which makes sample preparation and isolation of microplastics a challenge. Samples from different sampling techniques have different compositions, suggesting that they are complementary rather than substituting methods. But even within the same method, the composition varies greatly depending on the sampling point.

Within Tid(y)Up project three existing and already applied sampling methods were tested under varying boundary conditions:

- Multiple depths net-method: Simultaneously net sampling with mesh sizes of 500 µm and 250 µm in three different depths of water column (≈ 3,000 m^3 of water per net and 15,000 m^3 per sampling point within approx. 45 min).
- Pump-method: sampling with a 1 mm pre-filter with subsequent cascade filtration down to 300 µm, 100 µm and 50 µm; applicable in varying depths of water column, sample volume 0.001-0.002 m^3 depending on suspended solids.
- Sedimentation-box: sampling close to water surface for approximately 2 weeks; it was also used within the Joint-Danube-Survey.

A detailed description is given in the next chapters followed by a description of the sampling sites, the sampling approach.

2.2. Multiple-depth net-method

Due to turbulent mixing, the different densities of the polymers, aggregation, and the growth of biofilms, plastic transport cannot be limited to the surface layer of a river, and must be examined within the whole water column as for suspended sediments. These results imply that multipoint measurements are required for obtaining the spatial distribution of plastic concentration and are therefore a prerequisite for calculating the passing transport. Therefore Liedermann et al. (2018) developed a new methodology for measuring microplastic transport at various depths applicable to medium and large rivers. Compared to established net-measuring methods like the manta trawl, this method offers the possibility of measuring microplastic transport at different depths of verticals that are distributed within a profile. The net-based device is robust and can be used at high flow velocities and discharges. Nets with different sizes (250 µm and 500 µm) are exposed in three different depths of the water column (at the surface, in the middle of the water column, and at the bottom of the river). The analysis of filtration efficiency and side-by-side measurements with different mesh sizes showed that 500 µm nets led to optimal results (Liedermann et al. 2018).

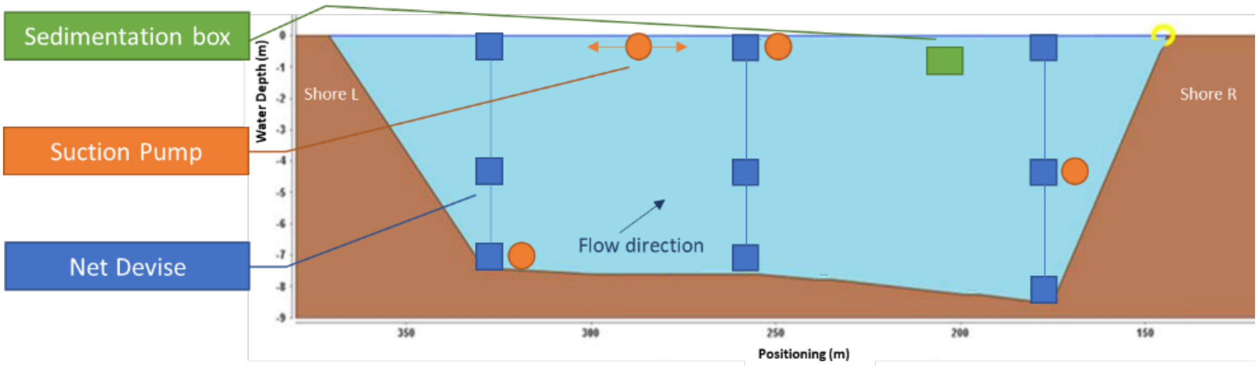


Figure 1: Sketch of microplastic sampling approach including depth variance and spatial distribution of microplastics

The nets, which are attached to a steel rope, are lowered into the water by crane either by truck from a bridge or by ship. The average measuring time per sampling point (e.g. 3 points over cross profile according to Figure 1; depends on the flow rate and turbidity (clogging occurs at some point) and should be between 20 and 45 minutes. After removing the nets from river, the sample will be washed with a high-pressure sprayer into a labeled sampling container. The catch can than easily be emptied within comparatively short operational times (30–40 min for all nets).

The discharge (m³/s) is measured via mechanical flow meter fixed in the middle of the net frame. Additionally, the flow velocity can be determined by an acoustic Doppler current profiler (ADCP) - a hydroacoustic current meter – to get more accurate results. In the end, the plastic transport (e.g. kg/d or t/a) can be estimated.

Setup Net-Devise

- **Size:** 2 frames à 60x60cm
  (max. width ~140cm with buoyant body)
- **Length/height:** Depends on the water level; the nets can be adjusted accordingly on the rope (middle and top);
- **Weight:** Depends on the flow velocity; tests in AT (relatively high velocity compared to eastern Danube region; and positioning of the crane/nets at 90° angles to the flow direction) have shown a compressive force/load capacity of 2 tons; can be seen as a maximum!
- **Anchorage:** crane hook is needed
- **Measurement options:**

  a) per truck on bridge

  b) with ship

Figure 2: Net device developed by Liedermann et al. (2018).

Figure 3: Details net device: a) Metal frame à 60x60cm, b)Steel rope and shackles, c) Buoyant body (surface skimming), d) Long fin and inclination rack, e) Centred single net, f) Upright position when inside the water, g) sampling container, h) Cleaning per high-pressure sprayer, i) Mechanical flow meter (Liedermann et al., 2018)

Measurement by truck

The truck must have an extendable/ telescopic lifting crane. The height of the crane should be at least the depth of the river section to be sampled plus 1-2 meters (this is the depth to which the nets are set on the rope, for example, if the river depth is 6m, a height of 7-8m would be desirable). The maximum lifting capacity depends on the flow velocity.

Measurement by boat or ship

Basically, the ship must be able to hold the position on the water. Regarding the height of the crane, it should also be considered that an additional 2 meters to the sampled water depth would be desirable to lift the net device onto the boat. If this height were not possible, the first (lowest) net would have to be lowered into the water, and only then can the middle net be attached to the rope. The same applies to the upper net. However, this method would take more time. In addition, it must be considered that the vessel has enough space to handle the net device (cleaning the nets, etc.). The lifting capacity of the crane would have to be at least 2 tons, because unlike the bridge measurement, where the net hangs in the water in the flow direction, the net would have to be positioned sideways (90° angle) from the ship. The forces acting on the crane increase accordingly.

Compared to measurement by truck, sampling by boat/vessel is much more flexible on the water, but the method is probably also correspondingly more expensive, as the ship has to have a corresponding size.

The **permissions/approvals** to be obtained can vary greatly from country to country. The approval requirements listed are intended to help partners provide possible indications.

Following requirements concern **measurement by truck at bridge**:

- During the measurement, at least one lane is blocked for a short distance and would have to be closed off or secured accordingly (traffic signs for speed reduction, etc.)
- Depending on the type of road (responsibility), approval would have to be obtained from the traffic authority (in AT district administration/magistrate or municipal office).
- If the measurement should take place e.g. at the bicycle path on the bridge, an additional permission would have to be obtained from the authority (department of statics)
- A bridge is often a border between two districts, which means that both authorities in the adjacent districts may have to be informed!
- The bridge should essentially not run too high above the river. This could have a negative effect on the requirements of the crane.
- Likewise, priority should be given to bridges with moderate or low traffic volumes.
- The bridge should not have “side walls”.

Figure 4: The bridge should not have “side walls” (pictures: Wikipedia)

Following requirements refer to both measuring by truck at bridge or ship:

- Since the measurement could affect shipping traffic (steel rope not visible), notifications often have to be made to the national shipping inspectorate / regulatory authority.
- Normally, 2 persons (upstream and downstream) are required to supervise shipping traffic; depending on the authority's licensing requirements, these persons may also be provided directly by the authority, which may result in additional costs.
- When measuring from ship, the vessel can be directly radioed and informed about the measurement.

2.3.Pump-method and associated sample preparation and analytics

The vast majority of microplastic studies in the aquatic environment apply different nets (e.g. manta net), but the application of different (fractionated) filtration systems operated by pumps are getting more common (Prata et al., 2019; Stock et al., 2019).

A fractionated filtration system has been developed at WESSLING Hungary Ltd. The size of the complete apparatus enables sampling from a smaller boat or from the shore as well. A jet pump is operated by a generator and surface water is transported from a foot-valve (with 1 mm prefilter) through rubber hoses to the stainless-steel filters. Water is filtered through 10" filter cartridges with a mesh size of 300; 100 and 50 µm. Sample volume is measured by a flowmeter. To obtain good representativeness, 1000-2000 L water is pumped through the series of connected filters, that were analysed later jointly, so results refer to microplastics between 1 mm and 50 µm. The system is presented in Figure 5 The effectiveness of the sampling apparatus has been tested in controlled environment by (Bordós et al., 2021).

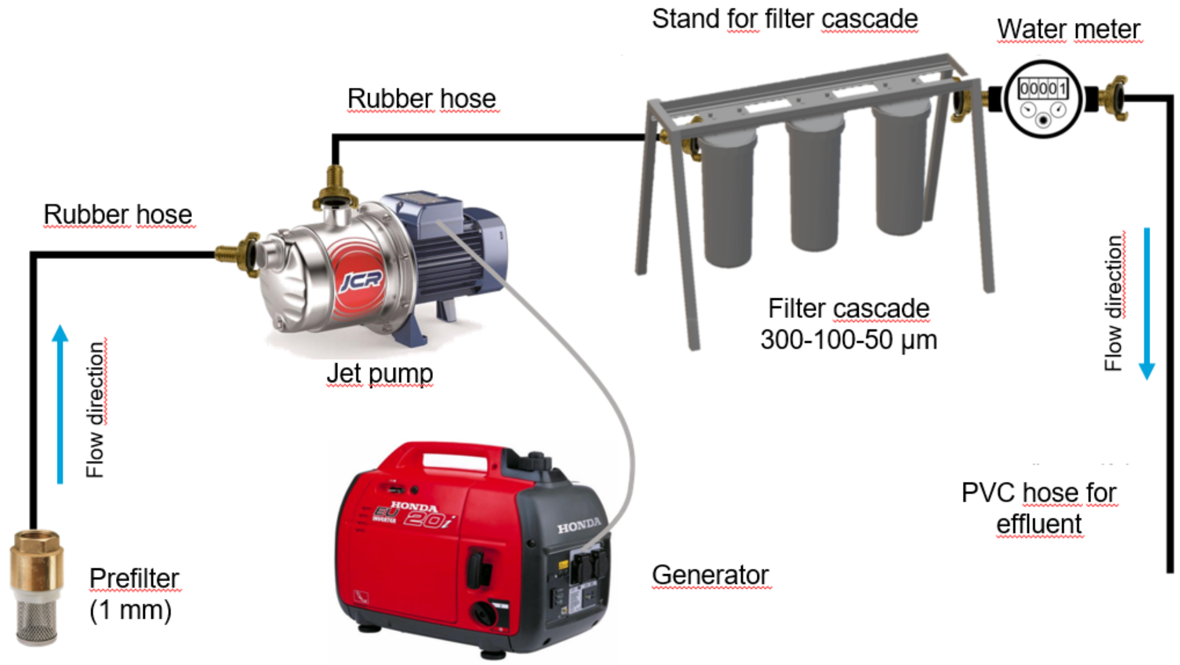


Figure 5: Fractionated filtration device developed by WESSLING Hungary Ltd.

Figure 6: Filter cascade for fractionated filtration

Figure 7: Fractionated filtration device in use.

2.4.Sampling with sedimentation box

The sedimentation box is based on the principle that incoming (river) water enriched with suspended particulate matter (SPM) is slowed down by the chamber-shaped structure, causing the particles to settle down (Figure 8). This passive sampler is placed in around 60 cm below the water surface for 2 weeks There are six 1 cm inlet holes on the front side. The water flows through a total of six chambers before leaving the stainless-steel box at the rear 4 holes. When the box is removed, the holes are closed with silicone stoppers to prevent loss of sample contents. The sample is transferred by ladle into suitable sample containers for transport. Deposits on the bottom are removed from the box by adding water and also emptied into the sample container.

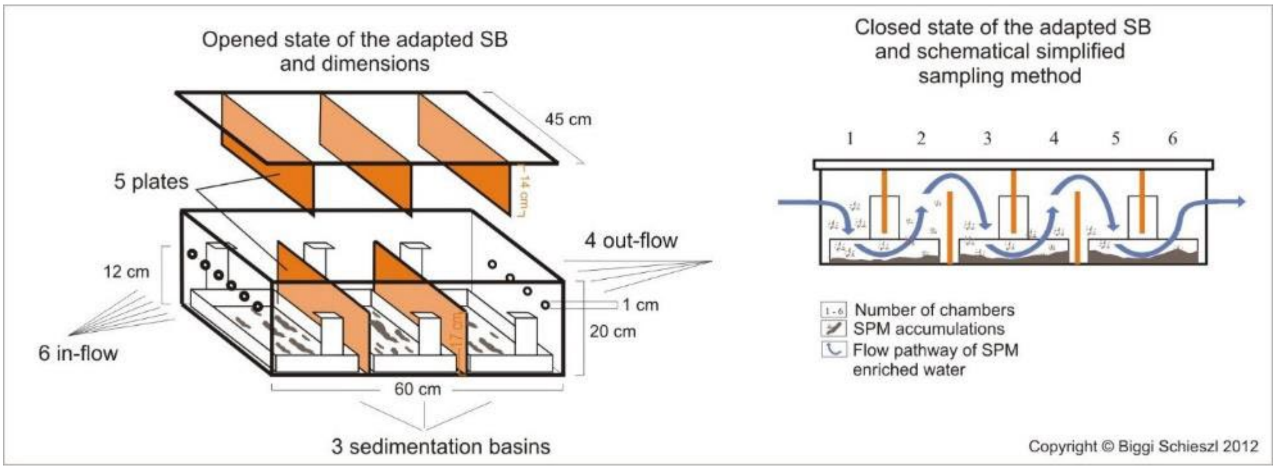


Figure 8: Sedimentation box

The operation of the sedimentation box was described in the Guideline for Sampling and preparation of Suspended Particulate Matter - Standard Operation Procedure (SOP) which was provided by German Environmental Agency during the JDS4 of the Danube river. During this survey, suspended particulate matter samples were taken by means of sedimentation boxes (see chapter 1.2.)

The sampling has to be performed by trained personal. The sedimentation box is deployed directly in the water body according to the main current by means of stainless-steel ropes, stainless steel chains or in necessary by a fixed stainless-steel construction (Figure 8) The 3-chamber sedimentation box has more wholes for the incoming water masses (six), easy to recognize. The sedimentation box has to be deployed on a dynamic fixing point (e.g. a buoy, a pontoon) for a constant exposition depth of 50 cm below the water surface.

Close to a weir, lock or dam with a regulated water level the deployment can be realized by a fixed system, keeping in mind the minimal water level throughout the year.

At flow velocities above 1.5 m/s a disturbance or failure of sampling is possible. The sampling efficiency of particles is decreased. In that case, the number of incoming wholes has to be reduced by means of silicon stoppers. A flow velocity between 0.5 – 1.0 m/s is highly recommended to obtain comparable results. Only in an absolute emergency can a sampling location be selected at which s the flow velocity is above 1 m/s. The sampling location must be selected in order to obtain comparable results. In any case, at increased flow velocities, these must be measured before, during and after exposure and noted in the protocol. Only in these absolutely exceptional cases can inlet openings be closed with silicone plugs. At a flow velocity between 1.0 – 1.5 m/s lock two holes and above 1.5 m/s lock three holes in the inflow section.

2.5.**Main Findings on Microplastic Sampling Methodology**

Little comparable information about microplastic in rivers is available. A variety of methods for sampling, sample preparation and analysis were tested previously. In order to develop a practicable, affordable monitoring tool three sampling methods, and two analytical methods were evaluated within this study. The evaluations revealed that there is no “best option” for sampling and analysis. Depending on the boundary conditions of the river, the prerequisite of the labour, and the respective research questions methods for sampling and sample treatment and analysis should be chosen. Also, a combination of sampling methods may be recommended in some cases (E.g. sampling with net and with pump to cover a wider particle size range).

In the following chapters sampling methods, sample pre-treatment and analysis steps as well as “quality” of results gathered with different methods are compared and summarized. A comparison of sampling and analytical methods under certain boundary conditions is given. Details considering cost-benefit ratio can be found in Deliverable T1.1.1 (Lenz et al., 2022)

2.5.1. **Sampling methods**

The tested sampling methods vary in terms of practicability, duration, costs, necessary skills and special requirements. Also, the representativity of the drawn samples varies with the methods. The comparison of the evaluated sampling methods is summarized in Deliverable T1.1.1 (Lenz et al., 2022). Important aspects are there discussed in detail.

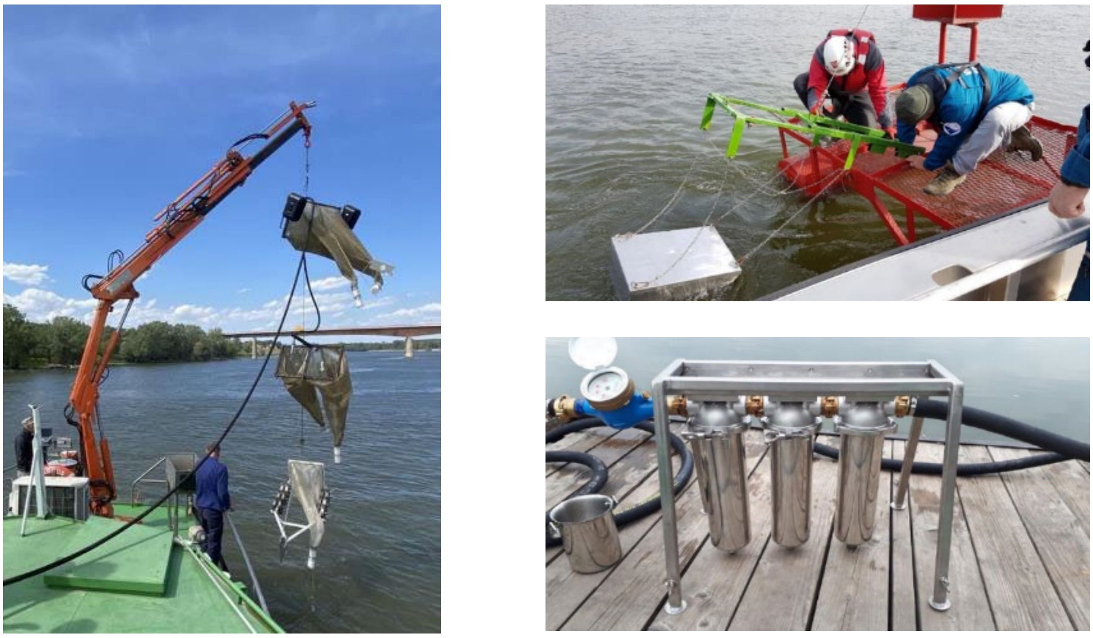


Figure 9: Microplastic sampling methods (left: net, right above: sedimentation box, right bottom: pump-method)

Table 1: Comparison of microplastic sampling methods

	Net-sampling	Pump-method	Sedimentation box
Practicability/ handling	🙁	😐	😐
Duration of preparation Duration of measurement	🙂	🙂	🙁
Costs	😐	🙂	🙂
Necessary skills	🙁	😐	🙂
Official approvals (e.g. bridge sampling necessary)	🙁	😐	😐
Representative sampling over water column	🙂	🙂 😐	🙁
Representative sampling over the river cross section	🙂	🙂	🙁

Comparing the tested sampling methods by considering the aspects listed in Table 1, the following conclusion is reached:

Sampling of microplastics with **multi-depth-net device** turned out to be the most complex procedure, primarily in terms of providing the necessary conditions (a vessel of larger dimensions equipped with a crane, official approvals etc.), as well as a long-term procedure of cleaning the nets after sampling. The applied method with net enables simultaneous sampling at different depths, as well as sampling with two different net diameters at the same depth.

The **sedimentation box** is a very practical, passive, economically viable monitoring tool that is easy to install in a water body and does not require any special prior knowledge. A prerequisite for the measurement is a load-bearing, floating object to which the box can be attached during the sampling period. However, this is also the sampling methodology is the most inaccurate and many parameters cannot be recorded due to the simple setup. The temporal aspect is probably the biggest advantage of this method (measurement period over 2 weeks), but derivations on the degree of pollution cannot be made due to the low coverage of the river.

Compared to the other two methods, the **pumping method** is moderately complex. Except of a power source and a vessel, there are no other essential requirements for conducting the sampling. No special prior knowledge is required, and measurements at all heights in the water column and at all points across the river cross section allow representative sampling. Pump sampling is the only method that allows composite sampling across the river cross section (movement of the pump from one bank to the other, during the measurement).

With the current setting of the net sampling apparatus, **pump sampling is clearly recommended.**

2.5.2. Sample preparation and analysis

The chosen sampling has great influence on the composition and volume of the samples and thus also on the effort of sample preparation and quality of the results. It turned out, that the effort of sample preparation prior to analysis can be equal or even greater than the effort of the measurement of the microplastic particles itself.

Figure 10: Net samples during exemplarily pre-treatment steps, prior to measurement of the microplastic particles

For all methods, suitable protocols for sample preparation and subsequent analysis were developed and provided in Deliverable T1.1.1.

Table 2: Comparison of sample preparation and analysis steps along with the tested sampling methods

	Net-sampling + Lab-method A	Net-sampling + Lab-method B	Pump-method + FTIR-microscope	Sedimentation box + FTIR-microscope
Captured particle size range	(250) 500-5000 µm	250) 500-5000 µm	50 µm -1000 µm	< 1cm
Sample composition	Heterogenic sample composition (size, material), mainly organic impurities	Heterogenic sample composition (size, material), mainly organic impurities	Homogenic size distribution, little bycatch	Homogenic size distribution, mainly inorganic impurities
Time for sample preparation	😐 ☹️	☹️	🙂	🙂
Time for measurement of microplastic particles	😐	☹️	😐	😐
Estimated costs of sample preparation and analysis per sample	☹️ 😐	☹️ 😐	☹️ 😐	☹️ 😐

When comparing the methods, the **net method (in the current setting)** performs worst due to the extensive sample preparation steps and the associated costs. Due to the large sample volumes and the large amount of unwanted bycatch, numerous treatment steps are necessary, resulting in high costs. However, a great advantage of the method is the large volume of water that is examined. **Method A** does not require each single MP to be isolated by hand, as measurement is performed automatically. Investment costs of this method are high compared to Method B. **Method B** requires all particles to be picked out individually under the microscope and applied manually, one at a time, to the measuring cell of the FTIR-ATR spectrometer.

Hand collection and individual identification (lower investment costs) is a more cost-effective option for larger particles (in combination with net sampling).

Many treatment steps carry the risk of reducing or crushing particles as well as a higher risk of secondary contamination. Although recovery rates for plastics were very high in the tests performed, these were carried out with "new" plastic particles. The recovery rate of the added particles that went through the above sample preparation steps with the sample was 81.96%. The recovery rate of PE was 84.59%, that of PP 76.77% (Berghammer, 2022). It should be noted that the tests were performed with new plastics. Tests with plastic films that have already been exposed to environmental influences such as solar radiation or abrasion (as was the case, for example, with many macro-plastic films found in the Danube in a previous project) are recommended.

The preparation of **sedimentation box** samples represents a moderate effort and thus only causes lower costs. However, the detected plastic particles cannot be compared to any volume flow and are therefore not suitable for the determination of loads. A comparison between sampling locations or sampling times as well as the analysis of the composition plastic types is nevertheless possible and useful.

For **pump-method samples**, due to the pre-filter, no leaf debris or other macro particles are sampled and needs to be removed prior to analyses. As the diameter becomes smaller, the number of micro plastic particles in the water increases. Due to a not too large sample quantity and a rather homogeneous sample composition, preparation and measurement efforts are kept within limits. Therefore, apart from the investment costs, the measurement costs are also not too high. On the other hand, particles > 1000 µm are excluded from the analysis and particles that adhere to leaves, for example, are also not taken into as they are excluded by the pre-filter.

With regard to sample preparation and analysis, the pump method is recommended as the more practicable method for long term monitoring especially with more sampling sites in different countries with different framework conditions. The pumping method also offers the possibility to detect particles smaller than 250 µm. This is all the more important as this fraction accounts for up to 2/3 of the detected particles. However, this method is only useful if appropriate laboratory equipment is available for the automated detection of such small particles. If this is not available and manual selection with tweezers is increasingly required, the advantages of the net method can be seen.

2.5.3. Usability of Results

Within project numerous samples gathered with three different sampling methods and analyzed in different ways were analyzed. Detailed results are reported in Deliverable T1.1.1 (Lenz et al., 2022). Assessment according chosen evaluation criteria are summarized in Table 3 for all methods.

Table 3: Comparison of results of different sampling and preparation methods

	Net-sampling + method A	**Net-sampling + method B**	**Pump-method +FTIR-microscope**	**Sedimentation box + FTIR-microscope**
Detectable MP size range	(250) 500-5000 µm 😐 *	(250) 500-5000 µm 😐 *	50 µm -1000 µm 🙂 *	50-5000 µm 🙂 *
Determination of MP number	🙂	🙂	🙂	🙂
Particle number /m³ sampled water volume (MP concentration)	🙂	🙂	🙂	☹️
Particle shape /size	🙂	🙂	🙂	🙂
Particle Weight	☹️	😐 **	☹️	☹️
Detection of plastic type	😐 🙂	😐 ***	😐 🙂	😐 🙂

* the evaluation of the particle size ranges assumes that the lower size range is more significant due to the higher number of particles (in most publications results are given in MP numbers /m³). If the focus lies on MP masses, the net method performs better.

** at least for the particles of the fraction 1000-5000 µm the determination of the mass by means of analytical balance is possible, for smaller particles only sum values can be recorded

*** subjectivity of examiner may result in underestimation of MPs – it is recommended to pick out all potential particles as generously as possible, if non-plastics are isolated, they will be rejected again after the FTIR measurement

Detectable particle size ranges depend on sampling method. While net-sampling only allows determination of concentrations for MPs > mesh size (500 µm) pump method also covers small particle size ranges. Determination of plastic types is possible also for very small particles with the

FTIR-microscope. Measurements of fibers with ATR-FTIR-spectrometer mostly do not yield spectra of the required quality for determination of plastic types.

The pumping method also offers the possibility to detect particles smaller than 250 µm. This is all the more important as this fraction accounts for up to 2/3 of the detected particles. Analyses down to a lower particle size of 50 µm are possible.

Net samples also catch particles smaller than the mesh size, but they cannot be related to a sampled water volume as it is not known when the net starts clogging. The box captures all particle sizes downward - but again, the particles cannot be juxtaposed to a volume stream.

MP numbers, sizes and shapes can be determined for all samples, concentrations for all except the box-samples. MP weight can only be estimated for all variants which used FTIR-microscope for analyses. Only lab-method B, where each particle is picked manually allows, to determine masses at least for fractions > 1000 µm.

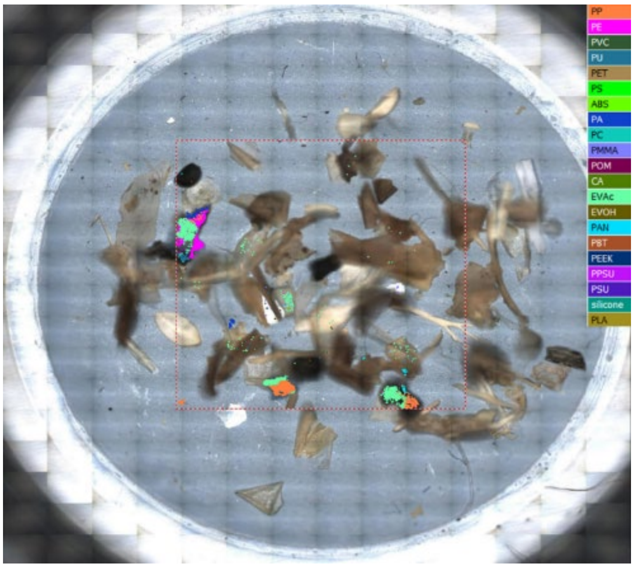


Figure 11: Microplastics detected with FTIR-microscope

Detection of MPs types was performed using databases /software's descried in the Annex. Softwares like PURENCY offers advantage like high reliability and traceability and robust analysis results for a wide range of matrices, including very polluted environmental samples, whereas database of BRUKER ATR-FTIR-microscope and own reference spectra do not contain spectra of weathered plastics, which is a disadvantage. Also, the subjectivity of the examiner may result in underestimation of MPs with this method. Standardized databases for microplastics, which guarantee comparability of results of different studies should be aimed. Databases should also contain spectra of weathered plastics. Also, it may be helpful to have reference spectra of common non-plastic natural polymers (in this study e.g. beetles, seed shells etc.) to avoid false positive assignments. Since only plastic types, which are already contained within databases, can be determined it is recommended to have visual looks (microscope) at the potential particles from time to time.

Determination of plastic types is considered as an important aspect, since only the number of MPs alone provides little possibility to find the origin/cause of the pollution which is a prerequisite to derive prevention measures.

Considering all aspects, results from pump-method + FTIR-microscope seems to be best option due to the possibility to detect small MPs. For research questions were only plastic type is requested (e.g. comparison of locations or for comparison of different measurement times, sedimentation box is the method of choice.

2.5.4. Summary and conclusions on microplastics

The optimal sampling method depends on the respective boundary conditions. But only the net method and the pump method allow calculations of microplastic concentration and load. Each of the methods studied has certain advantages and disadvantages. Weighing the advantages and disadvantages should be done in the context of the particular problem as well as framework conditions. Advantages of a large sampled water volume (net method), for example, go hand in hand with higher sample processing costs.

The composition of the sample, particle sizes as well as examined water quantity, the time expenditure of the sample preparation and measurement depend on the kind of the respective sampling. Thus, the sample preparation effort also depends on the sampling method.

Sample preparation must not be ignored and is usually more complicated and time-consuming than the measurement of the particles themselves. The major challenge here is to isolate all plastic particles from all other unwanted organic and inorganic contaminants in the sample and thus make them detectable without altering or even destroying the microplastic particles in any way. In river samples, there are comparatively few microplastic particles in a heterogeneous and complex matrix of organic and inorganic bycatch, so the processing is very challenging compared to other environmental samples

Pre-treatment steps performed can influence results (lost and undetected particles, secondary contamination, etc.) Porous plastics can be crushed by the preparation process, leading to an overestimation of the number of particles. Thus, different preparation steps and analytical methods lead to results of different quality and significance and thus prevent comparability of MP studies in rivers.

Therefore, for the respective sampling methods, the sample preparation and measurement procedure for different sampling methods were optimized within the Tid(y)Up project and recorded in protocols for future standardization. However, harmonized protocols or standardized approaches for quality assurance and quality control in sampling and evaluation of microplastics need to be (further) developed.

Comparing the three-sampling methods together with sample preparation and analysis procedure it turns out that each method has own advantages and disadvantages which can compensate each other. For a comprehensive scientific monitoring, a combination of net and pump sampling would be recommended as in combination of both methods' MP concentrations can be detected over a range of 50-5000 µm.

Sampling of microplastics with **multi-depth-net device (in current design)** turned out to be the most complex procedure, primarily in terms of providing the necessary conditions (a vessel of larger dimensions equipped with a crane, official approvals etc.), as well as a long-term procedure of cleaning the nets after sampling. The applied method with net enables simultaneous sampling at different depths, as well as sampling with two different net diameters at the same depth. Also, sample preparation of net samples is challenging. Due to the large sample volumes and the large amount of unwanted bycatch, numerous treatment steps are necessary, resulting in high costs. However, a great advantage of the method is the large volume of water that is examined. Lab Method A (analysis with FTIR-microscope) does not require each single MP to be isolated by hand, as measurement is performed automatically. Investment costs of this method are high compared to Method B. Method B (analysis with ATR-FTIR-spectrometer) requires all particles to be picked out individually under the microscope and applied manually, one at a time, to the measuring cell of the FTIR-ATR spectrometer.

The **sedimentation box** is a very practical, passive, economically viable monitoring tool that is easy to install in a water body and does not require any special prior knowledge. A prerequisite for the measurement is a load-bearing, floating object to which the box can be attached during the sampling period. However, this is also the sampling methodology is the most inaccurate and many parameters cannot be recorded due to the simple setup. The temporal aspect is probably the biggest advantage of this method (measurement period over 2 weeks), but derivations on the degree of pollution cannot be made due to the low coverage of the river. The preparation of sedimentation box samples, prior to analysis, represents a moderate effort and thus only causes lower costs. However, the detected plastic particles cannot be compared to any volume flow and are therefore not suitable for the determination of loads. A comparison between sampling locations or sampling times as well as the analysis of the composition plastic types is nevertheless possible and useful.

Compared to the other two methods, sampling with **pumping method** is moderately complex. Except of a power source and a vessel, there are no other essential requirements for conducting the sampling. No special prior knowledge is required, and measurements at all heights in the water column and at all points across the river cross section allow representative sampling. Pump sampling is the only method that allows composite sampling across the river cross section (movement of the pump from one bank to the other, during the measurement). For pump-method samples, due to the pre-filter, no leaf debris or other macro particles are sampled and needs to be removed prior to analyses. As the diameter becomes smaller, the number of micro plastic particles in the water increases. Due to a not too large sample quantity and a rather homogeneous sample composition, preparation and measurement efforts are kept within limits. Therefore, apart from the investment costs, the measurement costs are also not too high. On the other hand, particles > 1000 µm are excluded from the analysis and particles that adhere to leaves, for example, are also not taken into as they are excluded by the pre-filter.

With regard to sample preparation and analysis, the **pump method is recommended** as the more practicable method for long term monitoring especially with more sampling sites in different countries with different framework conditions. The pumping method also offers the possibility to detect particles smaller than 250 µm. This is all the more important as this fraction accounts for up to 2/3 of the detected particles. However, this method is only useful if appropriate laboratory equipment is available for the automated detection of such small particles. If this is not available and manual selection with tweezers is increasingly required, the advantages of the net method can be seen.

Hand collection and individual identification (lower investment costs) is a more cost-effective option for larger particles (in combination with net sampling).

Figure 12: Isolation of microplastics under the microscope (left) and measurement (right)

3. Macroplastic waste flow assessment strategy

3.1.Macro-plastic ashore

The developed sampling protocol is an important tool to determine locations along rivers a) where plastic waste is preferably discharged and b) where a particular number of plastics accumulates. Beside general information about the collection, sampling area, group size and others, the protocol contains a detailed questionnaire regarding the chosen river section (bank structure, vegetation, surrounding area). It also provides the opportunity of graphically recording noteworthy circumstances that were observed in the course of the collection.

3.1.1. The right sampling sites

First of all, it must be decided what the focus of the planned activity against plastic pollution should be. Depending on this, the right place for the collection of plastic waste and sampling have to be chosen. If the focus of the activity is mainly to collect as much plastic waste as possible ("applied access"), you will have to visit regions which on the one hand are easily accessible, and where, of course, enough waste has been accumulated to collect. The motivation for such events is usually environmental and ethnic and can be seen as an essential tool for awareness-raising. However, if you want to get representative information about the plastic pollution in and along a certain distance of a river ("scientific access"), a much broader view is needed. Thus, for monitoring purposes, an expanded area must be considered.

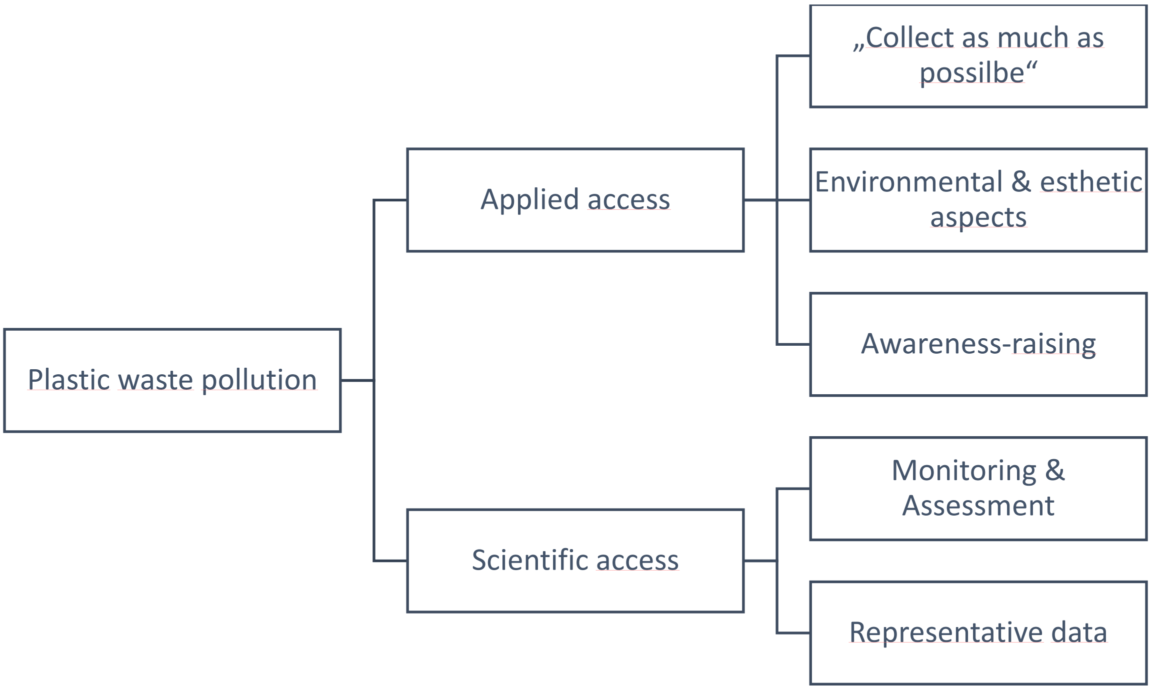


Figure 13:Different accesses to counteract the problem of plastic waste pollution

3.1.1.1. Applied access: cleaning intention

The following section gives information how to - for the sake of the environment - get out as much waste from the river system as possible. The focal point of this collection are aesthetic aspects and environmental thoughts. Assertions regarding the quantification of plastic pollution in the river section under consideration are difficult to derive. A representativity of the data is not guaranteed, because especially for pollution hotspots an extrapolation would lead to an overestimation of the plastic discharge. The results of a subsequent sorting analysis can only be used as an overview of the plastic waste composition.

But how can these sampling places be found?

- **Own observations** e.g. during a walk along rivers, bicycle ride, visit of a "natural" bathing area: Identification of a river section or area close to a river with "own eyes", which urgently needs to be cleaned of (plastic) pollution.
- **Experiences of other actors** e.g. national park rangers, NGOs, environmental organisations, fisheries associations, community representatives, etc.:
  Obtain reliable information from another party about a plastic pollution zone that is to be cleaned from litter and has a good accessibility.
- **Typical accumulation zones:** In some areas of a river, plastic accumulation is more frequently observed. If no other information is available, these can be targeted and waste can be collected there. One example of a typical zone is the riparian zone or the zone of the shoreline. In the areas with changing water shoreline, plastic can be washed ashore, and if the area then dries out, a deposit will occur. Other examples would be the bushes (undergrowth) in outflow areas or in side arms systems. A third type of target zones would be eddy zones in running waters in which plastic waste circulates and is more likely to leave the system.

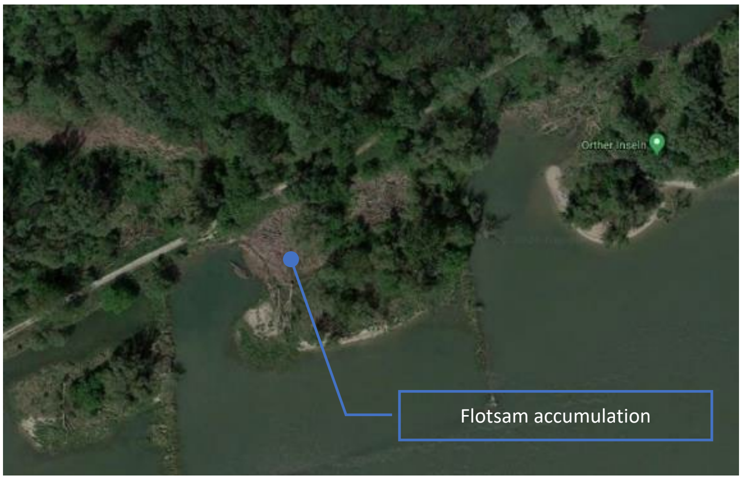


Figure 14: Identification of large-scale pollutions per web mapping

- **Large-scale pollutions** after flood events or other environmental disasters:
  In specific cases aerial photographs, satellite images, web mapping, etc. can also be used for detecting of polluted river sections. The actuality and a correspondingly good resolution of the images ("free" detection of pollution) is an important prerequisite for this. This method is also suitable for locating natural flotsam accumulations (not per se caused by a flood), which are often heavily contaminated with plastic litter (Figure 14).

3.1.1.2. Scientific access: monitoring and assessment

In order to estimate and quantify the actual plastic discharge or the degree of pollution of a river, it is necessary to apply standardized sampling and sample analysis. Various conditions directly or indirectly influence the input or discharge of plastic litter in a fluvial ecosystem. On the one hand, land use or population density of the surrounding area directly affects the plastic entry into the watercourse, but only indirectly determine the discharge. On the other hand, river morphology (e.g. type of running water, river width, flow velocity), bank structure and protection or riparian vegetation directly influence the plastic discharge. Taking all these different conditions of the river system into account, general statements can be made.

According first findings of "PlasticFreeDanube" (Liedermann et al., 2020) no clear relation between accumulation data and hydraulic parameters like water depth, flow velocities and specific discharge can be drawn. Accumulation processes, however, were found to have a clear correlation to vegetation and woody debris leading to high macro plastic concentrations. Maximum concentrations of 1130 g/m² in the inundation area of the Donau-Auen National Park (AT) compared with bank-near maximum concentration of 20 g/m² along the Danube stretch indicate, that the floodplain area works as a filter due to its vegetation.

The use of numeric and hydrodynamic models to predict plastic accumulation zones turned out to be a helpful tool (Liedermann et al., 2020). For example, these models could be employed to identify zones of higher or lower pollution potential, which in turn would allow on-site sampling of selected zones in each category (low-medium-high pollution potential). The other possibility is to choose sampling zones randomly in advance without considering the river and bank morphology.

Single sampling field

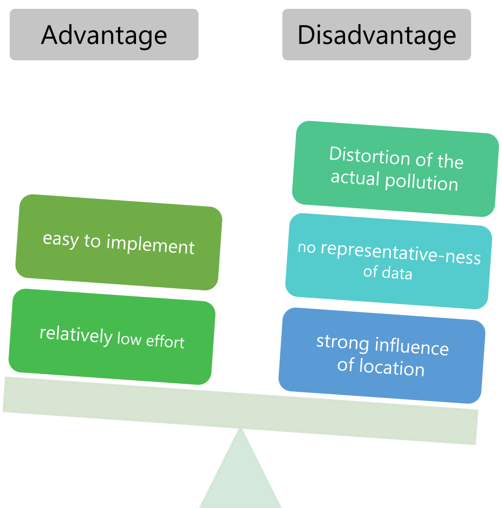


Figure 15: Pros and cons of single sampling fields

The simplest approach to monitor the riverine plastic pollution over a longer period of time would be to select a single measuring area for field test. This should be located near the water body and should also be "flooded" on a regular basis. Depending on the degree of plastic pollution, a minimum size of around 100m^2 (10x10m) would be recommended. If the area is too small, it could happen that no plastic items "land" in the test area. Natural conditions, e.g. prominent larger trees or stones, can be used as boundaries or markers. However, it is important to note that these markers must be able to withstand flooding and remain in place, otherwise the test area may not be able to be located or accurately determined. A calibration with GPS is recommended. Markers proved to be not fit for purpose.

A major disadvantage of this approach is that the assessment of plastic accumulation has no claim to for generally valid statements about the degree of pollution of the river. Depending on the positioning of the test area, the generated data can deviate very strongly from the actual pollution situation (strong under- or overestimation).

Multiple sampling sites

In this approach, multiple sampling sites in a selected area are examined over an extended period of time. The individual test fields are either to be predefined on the basis of expected plastic pollution (by hydrodynamic modelling) or to be randomly selected. The statements about the actual “degree of contamination” are far more meaningful in this respect.

In principle, a distinction can be made between bank-near test fields and those located in the hinterland. While the areas close to the riverbanks can provide findings about the "daily" or continuous accumulation potential, sampling in the inundation area gives information about the discharge behaviour at higher flows/water levels or floods. To arrange the test fields along the shore, a simple method would be to divide the investigated river section by the chosen number of sampling sites (e.g. 5km river length and 10 sampling sites → 500m). In this context, it should be noted that – from the statistical point of view - it makes more sense to have smaller test areas, but several. Experience in the PFD project has shown that, for example, a width of 5-10m is well feasible with two people. Collections were made side by side from the towpath (at the dam as a natural barrier) to the waterline.

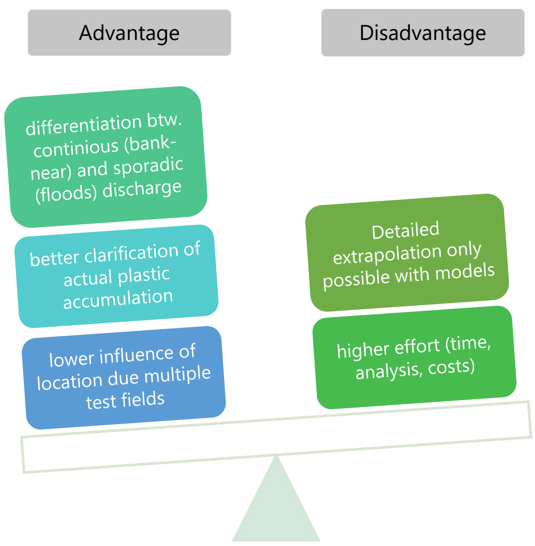


Figure 16: Pros and cons of multiple sampling sites

The **test areas in the hinterland** can be selected with the help of flood maps (e.g. HQ1-5). The map should ensure that the areas will be flooded in the foreseeable future or during the monitoring period (e.g. annual flood = HQ1). One option to randomly define the test areas is to place a grid over the floodplain to be studied. Each cell is numbered and represents a fixed size unit (e.g. 100m²). By means of randomization, a certain number of areas is determined. Finally, the coordination of the test fields can be assigned using a (online) map service or common GIS (geographic information system) software.

Depending on the research question as well as local conditions a focus of the sampling at **bank-near test fields** might be preferable. Sample areas can be selected by defining test areas at specific intervals along the bank. The distances are determined by the length of the examined river section. A selection of a minimum of 15 test fields is recommended (Figure 17).

Furthermore, it should be ensured that sampling along the riverbanks can be carried out within one day, since fluctuating water levels can considerably influence the sample of the respective test area. Test fields in the hinterland are excluded in this respect because they are flooded only during occasional floods anyway, but are also usually associated with a greater volume of pollution. In this respect, there is more time to clean the respective testing zones, because flood events do not usually occur in immediate succession.

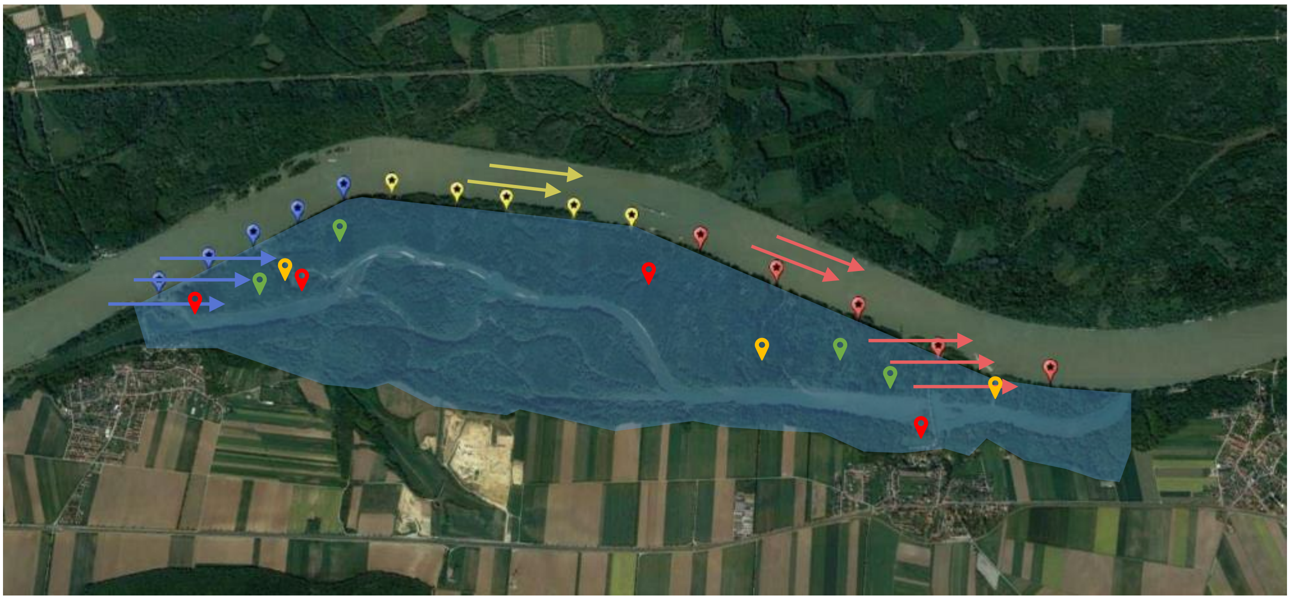
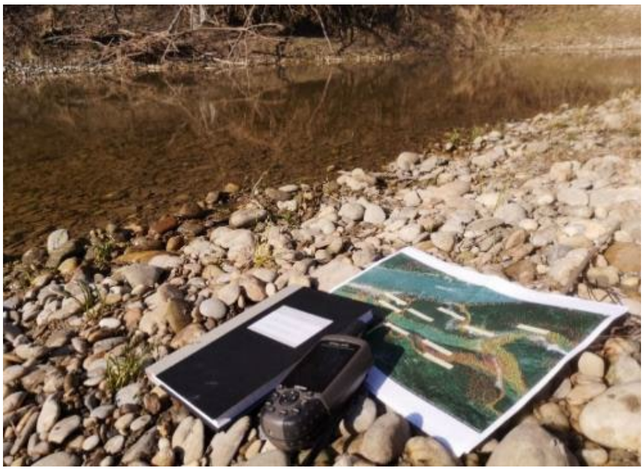


Figure 17: Possible multiple sampling design for bank-near and hinterland test fields

3.1.2. Planning a sampling activity

For many people, the collection of carelessly discarded waste in nature or in public spaces (= littering) is primarily related to aesthetic aspects. At the same time, it is accompanied by the removal of potential environmental hazards (e.g. formation of micro-plastic caused by breakdown of larger plastic objects → adhesion of pollutants to these tiny particles → absorption via the food chain = bioaccumulation). However, the collected waste can be used to carry out further investigations, which are decisive for the development of measures to reduce environmental pollution. Besides chemical analyses, which can provide data on the environmental hazard potential of a substance, sorting analyses are a simple method of generating information on the composition and thus the origin and source of the waste. To get representative results, a correspondingly careful planning of the collection/sampling activity precedes this.



Check out these issues before sampling…

What is the purpose and the objective of the collection / sampling initiative?

- ↳ Is the focus of the activity solely on cleaning a river section of plastic litter (awareness raising) or to generate scientific data on plastic pollution in the study area?
- ↳ For whom could the resulting data & information also be of interest?

Who is the initiator and/or coordinator? Who takes over the organisation of a sampling activity?

- ↳ Division of tasks; for larger events an organising team is recommended
- ↳ Who bears the responsibility?
- ↳ Do I first determine the location that should be cleaned and then the number of collectors or vice versa?

Who should collect or take samples at all?

- ↳ Whom do I want to reach, whom do I want to invite? (organisations, associations, clubs, schools, colleagues, researcher, private people, etc.)
- ↳ Is it a private or public event?
- ↳ Ideally, the collection is done by volunteers, but of course it can also be done by researchers themselves; the advantage of a volunteer collection is the saving of time (for scientists) and the aspect of raising awareness; on the other hand, researchers usually obtain a more precise knowledge of the plastic pollution location

How can potential participants be reached? ↳ Where can I advertise the "event"? Special advertising necessary? ↳ Which channels can be used for communication and information (social media, newspaper, radio, word of mouth, etc.)?
Find a date and place for the collection: ↳ Where exactly is it to be collected? Are "permits" to be obtained (e.g. national parks)? Who would be the contact person for this? ↳ Find and fix a date for your campaign - you don't want to go collecting alone! ↳ Online calendar for coordinating meetings (e.g. doodle) could be a handy tool to narrow down or set a suitable date
How many people will participate approximately? ↳ compile a list of participants ↳ ask again if necessary
Clarify the route in advance: ↳ Parking lots available, if you arrive by private car? ↳ What is the public connection (bus, train) to the location?
Determine an exact meeting point ↳ Choose a prominent location that is easy to find (possibly also visible in web mapping services like Google Maps, Apple Maps, etc.) ↳ Locate GPS coordinates if necessary
Check list of equipment ↳ Organize the purchase of cut-resistant gloves, garbage bags, writing materials, etc. ↳ Who is responsible for food and drinks of the volunteers? ↳ Printing Sampling Protocols
Organise in advance who will transport the collected waste. Where will they be stored? ↳ Suitable vehicle for transport ↳ Clarify access to collection areas ↳ Where can waste be stored temporarily until it is sorted ↳ Clarify who is responsible for the subsequent disposal (after sorting) and who will pay for any costs ↳ Where can the waste be finally disposed of?
Who is responsible for the collection team? Who is the person responsible on site?
Send an invitation to the participants with the most important information (date, time, meeting point, expected duration, personal goods, etc.).

On site, you should consider…

Give a short introduction

- ↳ Wherefore is the collection? Touch briefly upon the plastics problem.
  Why is it important to take the waste out of the river system?
  What happens to the waste (leading to the topic sorting analysis)?
- ↳ The introduction should motivate the volunteers to collect as accurately as possible, while making clear to them why it is important to collect accurately (to get adequate data)

Distribute cut-resistant gloves and garbage bags (or other collection containers like buckets)

Distribution of the sampling protocols and pencils

- ↳ Brief explanation of the information to be collected
- ↳ Point out that the introduction of the protocol should be read thoroughly
- ↳ Designate someone in the group for the entry in the log (the others should help!)

Clarify who walks which route approximately

- ↳ Division into groups (if several people are present)
- ↳ Limit the "frame" (e.g. up to max. 50m away from the river)
- ↳ Avoid that the individual groups of the same section go off twice (cleaning)

Determine meeting point and time for break or end of collection

- ↳ Get a mobile phone number to contact each group
- ↳ Please note that it can happen that there is no reception outside to make a call.
  Agree already before the beginning, where you will meet again and when!

If possible, already collect plastic waste separately

- ↳ When you collect litter along the water body, then you will not only pick up plastic waste.
  For later specific analyses, it makes sense to separate the plastics from other waste in advance.
- ↳ in differently coloured bags for instance
- ↳ or mark the "plastic waste" bags

Define parking of full bags/containers along the route

At the end of collection assign the bags to the respective group or cleaned section by labelling or clearly marking them accordingly (e.g. date, name of group / river section, specific code that is also noted at the sampling protocol)

Collection done, but then…

Question round to the participants

- ↳ How have they been doing with the collection?
- ↳ Which (plastic) waste was discovered particularly frequently?
- ↳ Were there places along the route where a lot of waste was discharged?

Gather the sampling protocols

- ↳ Brief check whether the most important points have been filled in

Gather and control the collected bags whether they are clearly labelled or marked

Take away the full garbage bags to the storage location

An additional helpful application… The TrashOut App

Registration

- ↳ Guide video with subtitles: https://www.youtube.com/watch?v=yd9IBX5LDqk

Capture the pollution on your mobile phone

- ↳ For large deposits that run more hundreds meter along the river mark the two ends

Recorded locations are on the map: https://www.trashout.ngo/hu#TrashMAp

Photos in the TrashOut records

Many smaller deposits found including two large hotspots

Map about hotspots for exact locations and directions:

https://www.google.com/maps/d/edit?mid=19KBpjjydQWI5Pw3L2D4Z1geZDO kwVl&usp=sharing

3.1.3. The Use of Sampling Protocols

Preparation and Procedure

The developed sampling protocol (see Annex) helps to obtain data which are useful for monitoring and scientific assessment of riverine plastics ashore. The following points of the protocol have to be taken into account! They contain precise instructions on how to use the protocol under the respective conditions (several groups, rapidly changing bank structures). It also contains a query which should be filled out to record the boundary conditions like morphology, banc structures, vegetation and the surrounding area. With the help of gathered information, collected plastic waste assessment can be done in context with boundary conditions and makes results more meaningful. High amounts of plastic waste in zones where plastics are easily accumulated (dense vegetation etc.) for example lead to different conclusions about plastic waste transport in rivers than high amounts in areas where discharge can hardly take place (e.g. behind embankment stabilisation).

The collection of all data of the protocol is desirable but in practice often not accepted by the collectors. Here, the TrashOUT app (https://www.trashout.ngo/), which is connected with the pollution map (https://tisztatiszaterkep.hu/#/en/) has established itself as a helpful tool, where some important info about location and amounts of waste in the environment can be entered easily.

General Information

Most of this information can be entered before the sampling begins, some during and other at the end of the collection. It is therefore advisable to take a brief look at the entire protocol in advance!

The estimation of the cleaned area needs special attention. This is necessary in order to be able to make statements about the degree of contamination of concerning area (e.g. plastic items per unit area). In this context, it is important to record the cleaned area by means of GPS coordinates or river kilometres. In addition, the width/depth of the cleaned area should be determined by yourself (e.g. pace off the distance). A specification of the used equipment (mobile phone, GPS device) and further details, like the projection, coordinate system or used web/online-application facilitates the evaluation of the data. Experiences have shown that it makes sense to record the start (point) immediately, on the one hand in order not to forget it and on the other hand in order not to have to go back the entire route if the collection ends at another point (end point) and you leave the area from there.

Besides the number of participants (per group) and number of (full) garbage bags they have collected, an estimate of the most frequently found or picked up waste is also asked.

Description of the sampling area

Here you can choose between three options, depending on your distance to the river ("where exactly does the collection take place"). Essentially, a distinction is made between sampling at the riverbanks or collection in the hinterland (e.g. inundation area). Depending on your selection, you have further questions to answer. There is of course also the possibility to collect on the riverbank and in the hinterland (e.g. a regulated brook with a correspondingly small bank area and directly adjoining farmland or other area), in this case, all points in the protocol would have to be filled in. If the riverbanks to be cleaned and the collection area in the hinterland are correspondingly far away from each other and are nevertheless sampled together (by the same group), it is recommended to fill in two protocols.

Characterisation of river morphology & bankside area

In principle, deposited plastic litter along rivers originate from a) on-site littering at the riverbanks as well as the immediate environment or b) discharge as flotsam from the river. Depending on the general conditions, one or the other "pollution type" will prevail or can be excluded. Thus, it is especially important to note down a precise description of the present river section (river width, type of bank, where is the collection area located). This includes a guide for the approximate calculation of the flow velocity.

Bank structures and bank protection influence the plastic discharge of the river very differently. While sealed and smooth structures (e.g. concrete dams) hardly allow adhesion and thus the waste remains in the water stream, some natural conditions in combination with the riparian vegetation favour an increased plastic accumulation. The vegetation acts as a natural ridge, depending on the type, size, area spread and much more, has a great potential to retain (plastic) waste already at the edge of the bank, and thus prevents it from spreading further into the rear zones.

Structural elements such as guiding walls or groynes can also influence the plastic discharge. Turbulences or prolonged retention times of the water in these fields increase the likelihood of a landing of contaminants.

Furthermore, popular recreation and bathing areas or other regular or highly frequented areas in the immediate littoral zone can implicate an increased littering. In some cases, it is really difficult to distinguish between the on-site littering waste and the plastic discharge by the river. "Natural soiling" by sand, mud, algae, or water residues may be a possible indication that the present plastic item concerns to discharged litter. New or clean plastic debris (e.g. clean flexible packaging) tends to indicate local littering waste.

Characterisation of the surrounding area

Try to depict the predominant type of land use in the immediate surroundings at this point. A range of examples is given in the table in the protocol, but other forms of land use can also be specified. Further, estimate the proportion of the selected areas (e.g. 50% green area with lower vegetation, 40% rural settlement area, 10% cycle paths and roads), the sum should be 100% obviously. Land use may provide some indication why one type of plastic has been detected particularly common (e.g. increased occurrence of littered waste at riverside promenade in urban areas; or mulch / horticultural film used in surrounding agriculture).

Other characteristics such as accumulation points are also queried. If places where a lot of waste are found, have been located along the sampling route, a short description should be given (e.g. accumulation of floating debris including pollution, punctual accumulation area of only a few square metres nearby a tributary, increased combing of foliage through riparian vegetation like willows or reeds).

Graphic Description

Some people may find it easier to record their observations graphically or to draw in any noteworthy circumstances, special structures or others that have caused increased discharge/accumulation of plastic.

3.2. Macro-plastics in fluvial systems

Transport behaviour of macro- and microplastics are rather unknown till know. Main impact factors are particle properties (e.g. density, shape, size, biofilms) and flow conditions. Whereby, especially flow condition of water is very complex and difficult to describe. Thus, the quantities and types of plastics that drift through the Danube and the exact path they take can only be estimated approximately. Methods for their assessment are depicted in Figure 19 and described in detail below.

Figure 19: Methods for plastic flow assessment within fluvial systems

In principle, each approach has its advantages and disadvantages. In order to determine the most accurate estimate of plastic pollution in the river under investigation, it would be necessary to use different macroplastic measurement methods so that the disadvantages of one method are balanced by the advantages of the other. The figure on the right side gives an assessment between accuracy and effort of individual selected measurement methods.

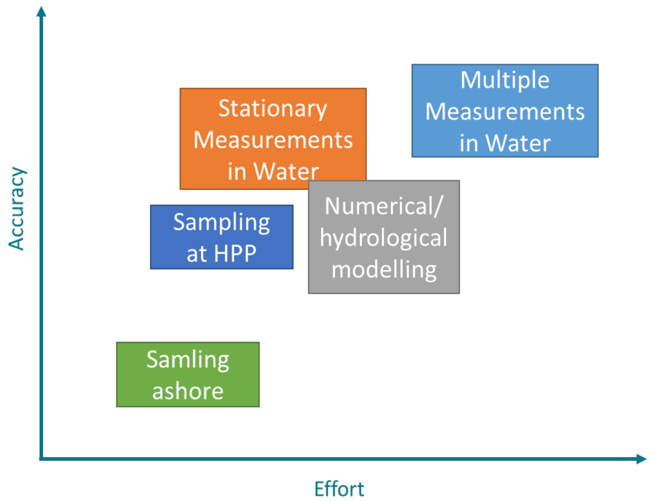


Figure 18: Evaluation of accuracy and effort of selected macroplastic measurement methods in rivers

3.2.1. Measurements in water

Currently little information about plastic pollution in fluvial systems is available as sampling directly in the flowing water proves to be very difficult and complex. Nevertheless, a few measurement methods suitable for the determination of macro-plastics in rivers have existed for several years: visual observations of floating plastics, net measurements echo-sounding etc. but hardly any for spatial distribution of macro plastic waste in the water column – especially in (large) rivers (Liedermann et al., 2020). But as plastics are not only floating at the surface measurements consider the entire water column is very important. Within the study "Plastics in the Danube" a methodology which enables measurements of plastic transport at different depth was developed.

At University of Natural Resources and Life Sciences, Vienna a special net sampling device for sampling of macro plastics in medium and large sized rivers has been developed for parallel measurements in several depths of the water column of medium and large sized rivers was developed (Liedermann et al., 2021a).

By means of a specifically developed equipment carrier, the nets are lowered into the water. Equipment carrier and nets are specifically developed to keep stable even in high flow velocities and turbulences. Special requirements were also set for the mesh size of the net. To gain also information about microplastics, mesh sizes from 250 µm to 8 mm were tested within the PlasticFreeDanube project. If only macro plastics are addressed mesh sizes of 5mm would be appropriate.

The only problem of this method is, that only a comparatively small cross-section of the entire river cross-section can be sampled. It might happen, that in river sections with low macro-plastic pollutions, no plastics are captured during sampling. Macro-plastic sampling is performed with nets from boats or bridges.

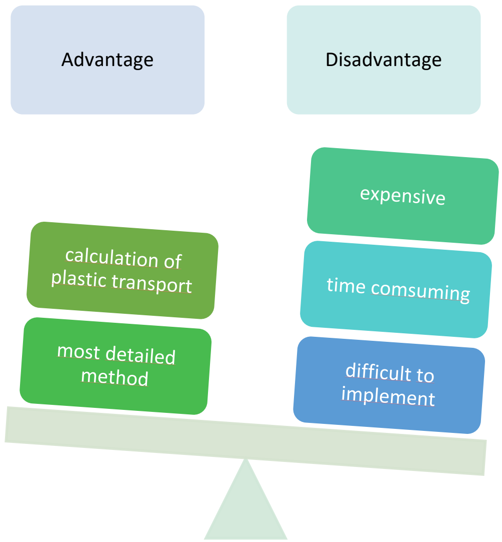


Figure 20: Pros and cons of measurement in water

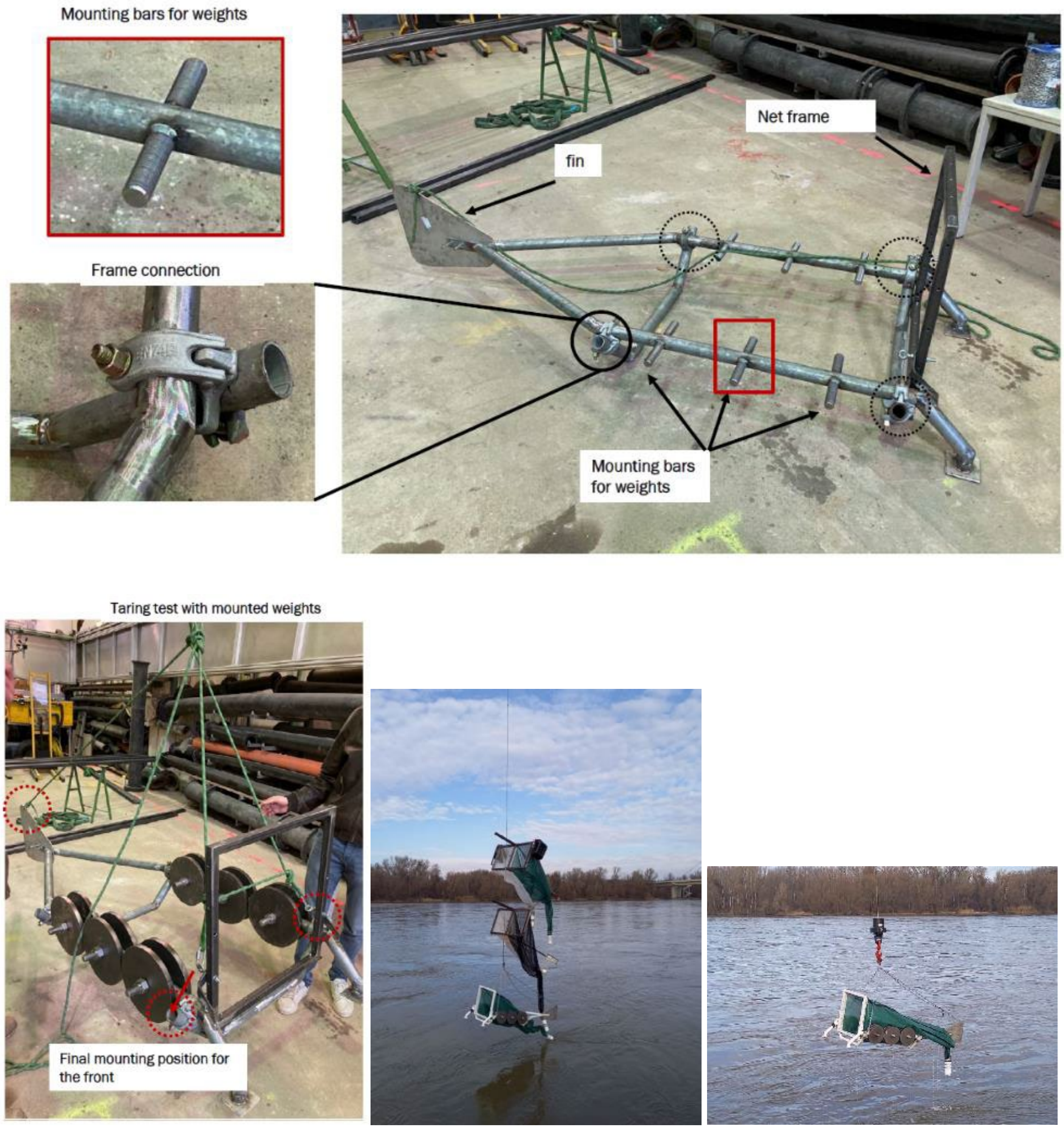


Figure 21: Net-sampling device

Within “PlasticFreeDanube” macroplastic pollution in Austrian stretch of Danube river was investigated. In order to describe hydraulic and morphological parameters of typical accumulation zones for plastics such as secondary flows, backwater, groyne shapes an angels, bank slopes etc. particle tracing tool was developed and applied. It aimed to describe fluvial process related to plastic waste in river systems by the means of numerical simulations and particle tracing in particular. Therefore, 3D and 2 D models were developed (Liedermann et al., 2021).

3.2.2. Particle tracing

Particle tracing plays a significant role in gaining knowledge about transport and fate of macro-plastics in streams and can be considered as a supporting or enhancing method. It can either be performed with GPS tagged items, or with coloured particles that are observed by boat. Especially GPS-tagged floating items offer a good opportunity to gain new insights into the transport processes of macroplastics or to validate transport simulation models as well.

Currently, such a GPS tracking field study is in process in the Danube and Tisza rivers to gather and evaluate data on transport and aggradation behaviour of different plastic items.

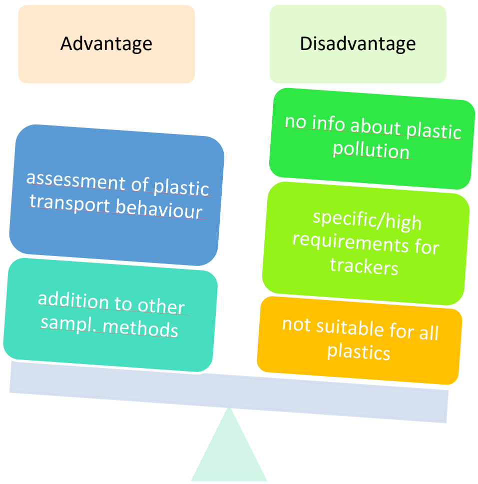


Figure 22: Pros and cons of particle tracing

Criteria on GPS-tracker

Tracking of macro plastic in rivers can be seen as an upcoming methodology. There are a variety of GPS devices available, however, only a few are suitable for such experiments due to their specific requirements. Beside robustness and water resistance of the tracker, they should guarantee a long battery life. Individual configurations like setting of tracking intervals can favour the lifetime of devices. Size and weight of the tracker should be as small as possible in order to not influence plastic item transport, also alarms when entering or leaving a predefined zone can ease the tracking. Sufficient network coverage ensures that the trackers can send their positions in real time to e.g. an online platform. Finally, the prize of the used GPS tracker is also crucial, as a larger number of trackers is also accompanied by more reliable result.

Criteria on tracked items

As GPS based navigation systems physically fail under water, this methodology can only be used for floating items. Another criterion is the size and the weight of the tracker, limiting the minimum size of used particles to track. Furthermore, it is clearly of great interest, to track those items that contribute most to pollution in the target area. This is preceded by an investigation about the composition of riverine waste, equally whether by samplings, literature research or information from experts in the research area. In this case, sampling activities showed, that PET bottles, foamed plastics from

Figure 23: Used macro plastic items filled with different GPS transmitters GPS in the ongoing TidyUp field trial

constructions sites (e.g. EPS panels), household, clothing and leisure waste as well as sport articles are frequently found in waste accumulation zones. Subsequently, items like empty and filled plastic bottles, part of XPS panel and household waste were fitted with GPS transmitters for the ongoing tests in the Danube and Tisza river.

3.2.3. Measurements in fluvial sediments

As no standardized method which is suitable for macro plastics sampling in fluvial sediment was available when starting the project, it was necessary to build sampling tool that can be used for the investigation of macro plastics from the floodplain sediment and the bottom of the river bed.

Development of a sampling drill prototype

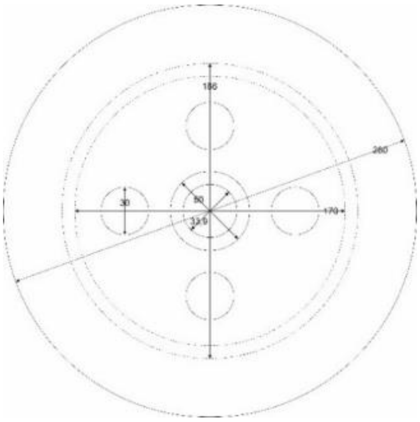
Commercially available tools or drill, had the disadvantage that thy crushed the sample. Also, multi stage sludge and sediment set with a very low cross -section, manual pipe that cannot cut the plastic, was just pushed aside. The Ekman Dredge, cannot be used at stones or plants overgrown with sampling points and can only be sampled from the surface layer. It was therefore also not suitable.

Figure 24: commercial tool (left), multi stage sludge and sediment set (middle), Ekman Dregde (right)

Following consultations between partners, we started to develop a prototype that had to meet the following criteria:

- can be prepared from a budget of less than € 2000 based on the published planning documentation
- is easy to use
- it is possible to take samples under water (max. 2 m deep), riverside mud and floodplain sediments
- is suitable for different soil types

According to the figure below, a prototype was prepared with minor modifications, but eventually proved to be appropriate. The device can be used to take a 160 mm diameter and 500 mm depth sample.



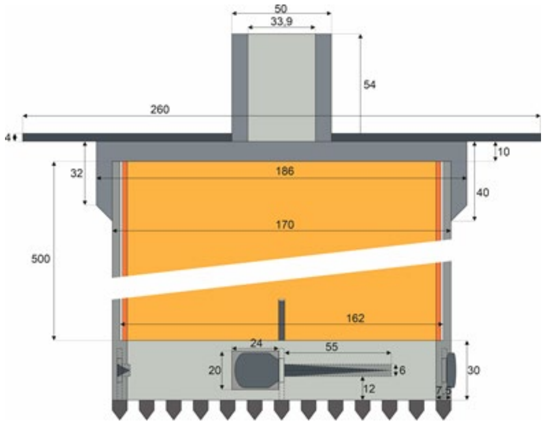


Figure 25: Prototype of sampling device for macro-plastics in fluviatile sediments within Tid(y)Up project

Its operation can be viewed on the following short film: https://youtu.be/ZiSF91GmKqI and is also depicted in Figure 26.

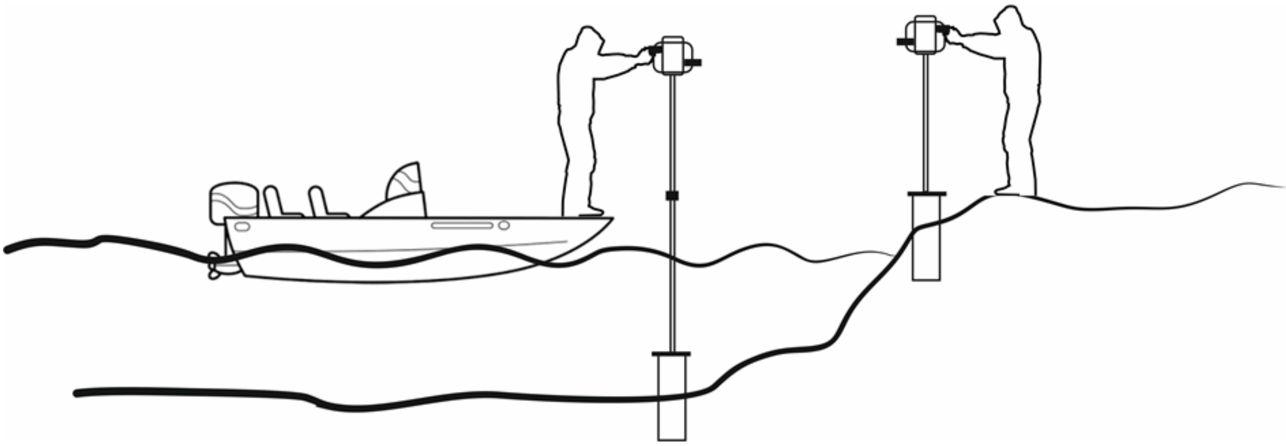


Figure 26: Schematic diagram of the use of the sampling drill device

Advantages:

- it does not destroy the sample, stratification remains recognizable and plastics are identifiable
- no diver required for underwater sampling
- can also be used from small boats

Disadvantages:

- for operating a tall and strong person is needed
- can't keep very thin sludge (we're working on a solution)
- not suitable for stony soils (but there is no plastic dump in such soil)

The device was tested in a real environment on the Szamos and Tisza rivers. It proved to be functional. Further improvements would still be needed to reduce the weight of the device and to solve dilute samples, but the framework for this project is already beyond this

3.2.4. Sampling at hydropower plants

According to previous studies (MicBin, PlasticFreeDanube, etc.), hydropower plants (HPPs) can contribute significantly to the removal of plastic waste from running waters. Sampling at HPPs can give a rough overview of the composition and extent of plastic pollution, provided that the floating debris are captured by the HPPs trash rack system. This assessment approach scores mainly because of its manageable effort, as sampling is often easy to arrange compared to the other methods. The cleaning of the trash racks is usually (fully) automatic, the collected waste is then temporarily stored in containers or transported away. These containers could then be used for example as sample units and subsequently evaluated within a sorting analysis.

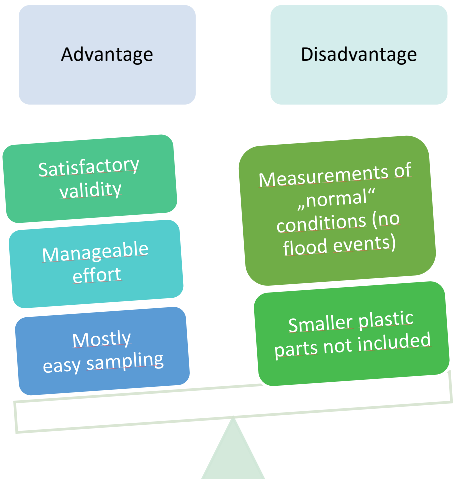


Figure 27: Pros and cons sampling at HPPs

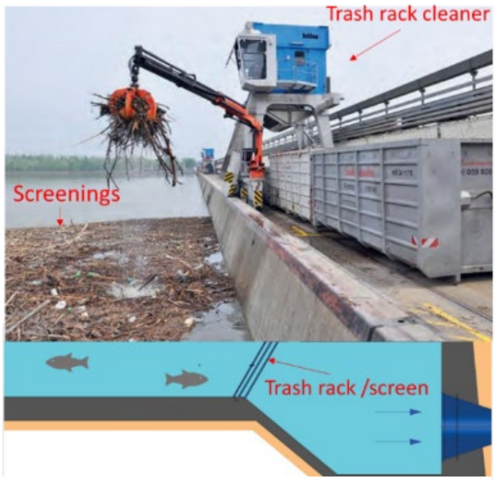


Figure 28: Description of terms regarding HPPs trash rack cleaning system

Additionally, with the appropriate sampling design it is possible to assess the retention potential of trash rack cleaning systems more precisely and to examine which types of plastic waste in particular are retained by the grate.

Nevertheless, the investigations of screenings at HPPs only include normal conditions because usually only a small part of the flotsam is captured during flooding, as the majority passes the power plant unimpeded due to open weirs. Another disadvantage of this evaluation approach is that smaller and flexible plastics (e.g. small foil parts) are usually not considered, since these particles - depending on the clear spacing (width between bars) - can usually pass through the HPP unhindered.

3.3. **Sorting Catalogue**

A number of waste classifications already exist for the monitoring of anthropogenic marine pollution (Cheshire et al. 2009; OSPAR 2010; van der Wal et al. 2015). These served as a starting point for a comparison of existing catalogues – also called masterlists - and the plastic fractions defined therein. In order to determine the entry pathways of plastics and to develop and evaluate prevention measures, it is necessary to classify plastic waste.

Similar (product) groups or categories of reviewed protocols were combined, simplified and standardised to establish a preliminary categorisation of plastic waste in running waters. To address prospective prevention measures for plastic pollution, a functional classification was chosen in order to be able to assign the respective fractions to the emitting sector or source in the best possible way.

This classification for plastic litter tries to guarantee a good balance between operational efficiency and resolution. The system comprises a four-level hierarchy (**Fehler! Verweisquelle konnte nicht gefunden werden.**) that identifies plastic items firstly by main use "packaging" and "non-packaging" (with the exception of the difficultly assignable foamed plastics, which constitute an overlap) and then by utilisation sector (e.g. household, building sites, etc.). A further subdivision in categories primarily based on functionality as well as form and type of plastic. The classification system contains a list of four different main groups, 9 sub-groups and a total of 24 discrete categories of plastic litter. To ensure long-term monitoring, the selected categories can also be determined by laypersons without special knowledge.

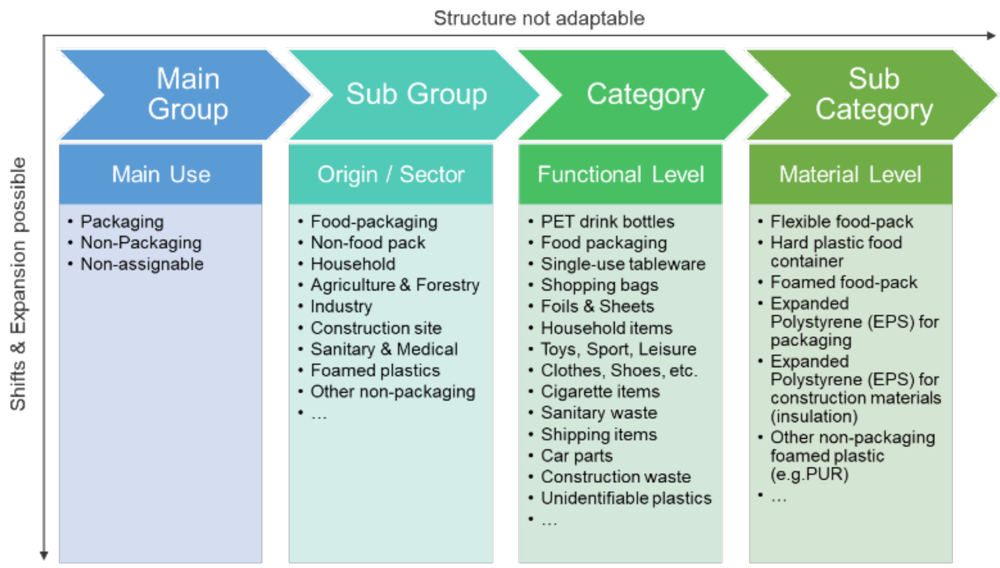


Figure 29: Applied systematics of plastic litter classification

3.4. **Material Flow Analysis**

Litter entering running waters moves with the flowing wave from the point of entry to the estuary, into adjacent streams or lakes and ultimately into the seas and oceans where they are distributed with the global ocean currents. The associated potential ecological and economic impacts of floating debris are not limited to a local area, but are much more part of the global water cycle of all surface waters (Breitbarth, 2017).

Global estimations on plastics entering the oceans via rivers vary strongly in literature, the quantities range from 0.4 to 12.7 million tons annually (Jambeck et al., 2015; Lebreton et al., 2017; Schmidt et al., 2017). Nevertheless, it is widely used that up to 80% of marine debris originates from land and in this context, rivers are recognized as the main pathways of pollution (IMO et al., 1990; Jambeck et al., 2015).

Reliable estimates of the occurrence and composition of macroplastics (>5mm) are essential to develop targeted prevention measures to reduce plastic pollution and to make the success of the measures taken measurable. A material flow analysis (MFA) offers a possibility to show and display the main sources, inputs, transport and disposal pathways of plastic waste of the Danube and its riverbanks. A simplified material flow model was created for the area between Vienna and Bratislava (Mayerhofer et al. 2022).

Based on a literature review, potential pollution sectors in the project area were first classified. In order to verify which sources or pathways are actually responsible for the plastic input into the system, a qualitative assessment of potential input sources was performed based on defined indicators (e.g. distance to the water body, existing retention barriers, municipal cleaning measures, etc.). After the definition of the system boundaries and the development of an MFA model, the evaluation of available data on the amount, type and sources of macroplastics input was carried out. In addition, standardized sampling in and along the Danube (bank collections, power plant sampling, measurements in the Danube, GPS tracing experiments) and numerical transport modelling were used to generate additional data on plastic waste in the investigated area.

The MFA model starts with the end-of-life phase of plastic products for the balance year 2020. Waste generation can be divided into properly collected and recovered plastic waste that is sent for recovery (e.g. recycling or thermal recovery) and plastic waste that enters and remains in the environment through littering, illegal waste disposal or improper waste treatment. In some cases, it is possible to assign plastic waste to a specific source sector, while other quantities are grouped as "general waste" as it is often not possible to determine the origin. With regard to the input of plastic waste into the system, a distinction is made between direct input into water bodies (Danube) and indirect input (riparian area).

Different processes (wind, flood, etc.) influence the input and output of plastic waste into the system or the exchange between the considered balance areas (river & riparian area). Based on the "pollution inventory", the individual plastic flows are assigned to the land-based and river-based input and output sources, respectively. The MFA model was created with the software STAN (subSTance flow ANalysis).

In order to counteract the problem of river pollution and to develop suitable, application-oriented and pragmatic measures, the sources (e.g. industry, agriculture, packaging, household waste, ships, ports, illegal landfills) and possible entry paths of plastic emissions must be classified. The comparability with other studies should be considered as well as the practicability of the implementation (sorting catalogue). Categorizations of marine pollution already exist (GESAMP, 2016; UNEP, 2016), for riverine plastic pollution a classification was developed in the course of the project PlasticFreeDanube (Mayerhofer et al, 2020). The applied classification is based on the following three pillars: i) the sources by sector and input pathways mentioned in the literature, ii) the classification of EU plastic waste generation, and iii) the identification of those emitting sectors and input pathways in the study area that are expected to have a potential impact on the river system or that could be identified by sorting analyses.

To verify which sources or pathways are actually responsible for plastic input into the system, a listing of all possible pollution sources and locations of release into the environment was compiled for the project area. Based on defined indicators (availability of individual sources in the project area, general pollution potential due to increased plastic waste generation or missing activities/measures, established cleaning measures or retention barriers, etc.), a pollution potential, visualized in the form of a traffic light system, could be determined for the project region.

Over a period of two years, a more detailed picture of the occurrence and composition of fluvial plastic pollution in the study area was obtained using various survey methods. In addition to the evaluation of 17 plastic samples from volunteer collections (CleanUp events) in the Danube Floodplain National Park, standardized sampling in the riparian area (n=11) and in the floodplain of the Danube east of Vienna (n=4), data from power plant sampling (screenings, n=7) as well as two net measurements in the Danube were obtained. In addition, GPS tracing experiments and numerical transport modeling (Liedermann et al. 2021) were used for validation purposes.

The MFA (Figure 30) for the Area between Vienna and Bratislava shows that about 96,000 t per year are accounted for by separate plastic collection and recycling in the project area between Vienna and the AT-SK country border, with packaging waste representing the largest waste stream at about 30,860 t. The majority of plastic waste is thermally recycled (62,327 t), 32,602 t are sent to a recycling process and about 960 t are landfilled. The macro plastic input by littering can be estimated with about 1,260 t ("expected scenario"), of which about 31 t are directly discharged into the Danube, the major part of the KSA with 1,230 t ends up in the adjacent environment.

About 10 t of KSA in the flotsam interact between the riverbank and the water body, they accumulate on the riverbank until they are mobilized and carried further. The main sources of discharge are municipal or public cleaning measures, which account for 892 t, and voluntary collection activities (e.g. spring cleaning campaigns), which account for around 198 t. Approximately one ton of plastic waste is collected annually from riparian areas by the Danube Floodplains National Park (NPDA) in the course of clean-up events. Thus, about 140 t of macroplastic per year remain in the adjacent terrestrial environment.

About 2 t of plastic waste are removed from the water body by the screenings collection at the Freudenau power plant in Vienna. Measurements carried out in the Danube suggest that about 29 t of macroplastic are transported further in the flowing water and thus leave the balance area.

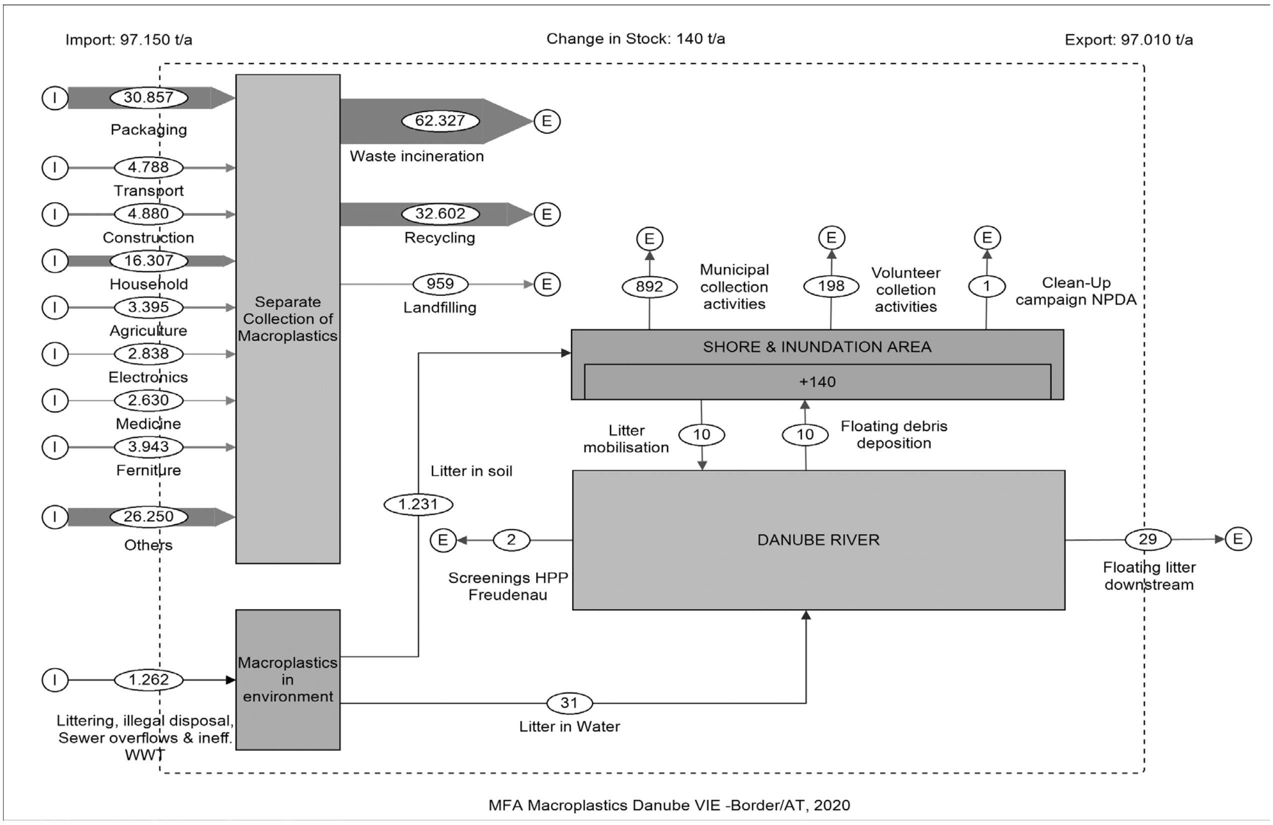


Figure 30: Material flow analysis of plastic waste in and along the Danube between Vienna and the state border AT-SK

With regard to the quality of the MFA data, the disposal and recycling quantities as well as the quantities of plastic waste removed by screenings, public cleaning measures and voluntary collections in the NPDA are considered to be well-founded. The quantities of other voluntary land cleaning activities, the KSA circulating in the riparian area and the KSA remaining in the water body are of moderate quality. The assessment of macroplastics introduced into the system (through littering, illegal dumping, etc.) and their distribution into the fluvial and terrestrial environment is still subject to the greatest uncertainties.

3.4.1. Main origin and sectors of plastic waste

The main pollution sectors of fluvial plastic pollution according to Mayerhofer et al (2022) are shown in the following pie chart (Figure 31). Over 60% by weight of the collected and analysed plastic waste can be directly attributed to households due to "intentional" littering (beverage bottles, food packaging and other disposable packaging, cigarette articles, etc.). Other plastics, in turn, could enter the Danube due to flooding, drifting, or careless situations (e.g., bathroom shoes caught by a wave on the shore).

In terms of weight, shipping has the second highest share of plastic pollution with about 16 wt%, as items such as fenders, buoys or ropes are very large and heavy compared to other KS items. However, in terms of the number of items, marine litter plays a rather minor role. Plastic construction materials (incl. packaging) and, above all, foamed insulation boards (EPS or XPS) can be assigned to the construction sector with 12% by weight. The latter are very light and are quickly transported via drift. Larger foam pieces quickly break down into microplastics (EPS beads) due to their high porosity and pose an additional environmental problem.

A very small amount of macroplastic is condemned by inefficient wastewater treatment (<1 wt%). This waste is mainly hygiene products such as wet wipes, feminine hygiene products, and cotton swabs, which are very likely to end up directly in streams during heavy rain events due to overflowing of retention ponds (Lenz et al., 2021). Just under 8% by weight of fluvial plastic waste cannot be attributed to a specific origin or source. This is the category of unidentifiable or unassignable plastic parts, which are mostly highly fragmented and include a variety of plastic types (e.g. PE, PP, PVC, etc.).

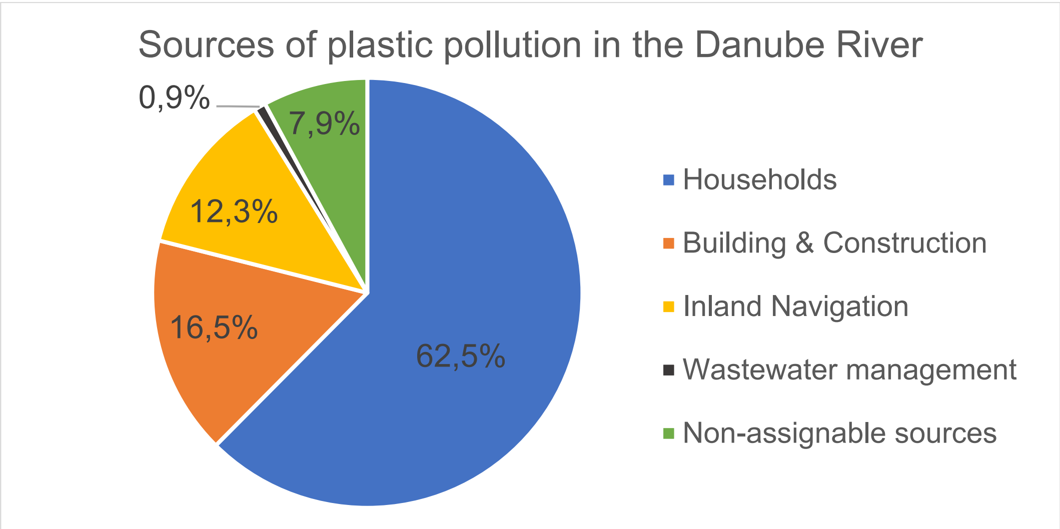


Figure 31: Origin and sources of plastic pollution in the Danube River.

3.5. Summary and conclusions on macro plastic

Macro plastic pollution in the Danube and the Tisza sometimes assumes immense proportions (Figure 32). Cleaning and prevention measures are absolutely necessary.

Figure 32: plastic waste accumulation after a flood in downstream Hungary, at the Kisköre hydropower plant. The temporary structure can be 3 meters thick and reach more than a hectare in overall size.

As riverine systems are very complex and also macro plastics are different in terms of transportation behaviour, density, shape, degradability etc. data about amounts transported, accumulated, mobilised, etc. are very challenging to gain.

Transport behavior of macro- and microplastics are still rather unknown. Main impact factors are particle properties (e.g. density, shape, size, biofilms) and flow conditions. Whereby, especially flow condition of water is very complex and difficult to describe. Thus, the quantities and types of plastics that drift through the Danube and the exact path they take can only be estimated approximately.

To get an insight into macro plastics in rivers the collection of data is essential. Macro plastics in the river itself is more difficult to survey than in the surrounding area (banks). It is recommended to use a mix of the described methods (Figure 19) as far as possible.

In principle, each approach has its advantages and disadvantages. In order to determine the most accurate estimate of plastic pollution in the river under investigation, it would be necessary to use different macro plastic measurement methods so that the disadvantages of one method are balanced by the advantages of the other.

Most common method of macroplastic assessment is plastic waste collection ashore. In the collection of macro plastics distinguish two different ulterior motives: i) the cleaning of the environment which has also a great effect on waste prevention because participating volunteers get aware of the plastic pollution problem and ii) the scientific aspect, where representative data is generated by waste collection measures at carefully considered sampling locations with subsequent sorting of the collected waste according to research question (e.g. gain information about sources of plastic waste and its transport behaviour in riverine system) Sampling fields for scientific purposes are chosen randomly and are polluted to randomly degree, whereas cleaning activities are performed mainly at so called “hot spots” – locations where large amounts of plastic waste are accumulated. . An example of how the localization and cleaning of a hotspot can be done can be seen in the following Youtube video: https://www.youtube.com/watch?v=fM278ywODEM

Large quantities of plastics are also taken out by the removal of screenings upstream hydro power plants (HPPs). HPPs thus represent an important barrier for the retention of plastic waste in rivers and additionally provide important data on transported plastics. Sampling in fluvial system provide additional information about plastics that have been probably accumulated a long time ago and whose re-mobilization can be expected only in cases of major high-water events.

Sampling in water, tracing experiments and hydrological modelling are scientific methods to gain insight on amounts and transportation behaviour of plastic waste in rivers.

4. Recommendations

Plastic waste pollution is a transboundary problem which should be solved not on a national level but rather requires transnational cooperation. Insights in plastic waste composition, sources, and transport behaviour have to be shared between countries to learn from each other and enable optimised solutions. Also, methods for sampling and analysis of collected macro and microplastics needs to be harmonized between riparian states in order to obtain comparable data as well as to evaluate and monitor the success of implemented mitigation measures. Detailed knowledge of the extent and cause of pollution enables the derivation of mitigation measures. Measures should also always be developed in cooperation with countries that also border the river. For example, it is more effective to prevent pollution already in country A, than to eliminate macro and micro plastic pollution in country B, which is located downstream.

Sampling and sorting/analysis of macro and micro plastic waste always needs to be adapted to respective boundary conditions, existing financial possibilities and infrastructure structure (e.g. measuring devices) and research questions.

4.1. Sampling of microplastics

For routine monitoring of MP in rivers sampling with pump-method and subsequent cascade filtration is recommended if appropriate analytical equipment is available. Otherwise, the net method can be preferred because a larger volume of water is sampled. Also in case of very scientific questions, where large investigated water volumes are necessary for representativity, net-sampling is recommended. To avoid large volume, heterogenic samples taken with net it is recommended to develop scaled down net sampling device

Hand picking and individual identification (lower investment costs) is a more cost-effective option for larger particles (in combination with net sampling). If only the MP composition is required or sites or different sampling time frames are to be compared, the use of sedimentation boxes are recommended.

During the Tid(y)Up project protocols for sampling, sample pre-treatment and analysis were developed an provided within **DT1.1.1. Study on the assessment of microplastic measurements under different conditions in fluvial systems** (Lenz et al., 2022).

4.2. Sampling of macro-plastic waste

Clean up activities are a great measure to reduce plastic waste pollution and also to raise awareness about plastic waste pollution problem among citizens.

In order to gain data while environment is cleaned, it is recommended to use sampling protocols which allow to generate comparable data about collected amounts and boundary conditions which allow to generate important scientific data. These data can be used to estimate pollution situations and help to monitor pollution prevention measures etc.

In order to increase the willingness of the participants to collect data, it is important to make as simple as possible (e.g. TrashOUT app (https://tisztatiszaterkep.hu/#/en/) or very simple protocols, which are only questioning few main important info’s).

For scientific monitoring purposes, the focus should be on selecting sampling points that are as representative or at least random as possible.

During the Tid(y)Up project for the assessment of macro-plastic waste were provided:

- ***DT1.2.1. Handbook on the introduction of standardised procedures for the assessment of macro plastic ashore***
- ***DT1.2.2 Handbook on the introduction of standard procedures for the assessment of macro plastic in fluvial systems, including the retention capacity of hydropower plants and other barriers***
- ***DT 2.1 transnational river cleanup handguide***

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6. Annex

TID(Y)UP SAMPLING PROTOCOL

to assess riverine macro plastics ashore

How the sampling of riverine plastic litter succeeds...

- The present protocol helps us to determine where plastic waste related to rivers is mainly transported and where a particularly large number of plastics accumulates.
- Please **read this protocol at the beginning**. Some points can be filled in immediately, other questions can only be answered at the end of the collection.
- If you are collecting with a group and you split up, please use a **separate protocol for each subgroup.**
- If you are moving along a river with rapidly changing bank structures within short distances, it is easier to fill in an additional **protocol for each section**.
- In some cases (e.g. large rivers with wide river banks), it is advisable to divide the collection area in sub areas and agree which subgroup will "clean" which terrain strip in advance (e.g. one group will march along the gravel bank near the water, another group within the overgrown zone).

GENERAL INFORMATION

Information about collection

Name of river/creek, you collect:			
Name of the "cleaned" area:			
Date (d/m/y):			
Time:	Start:	End:	Duration (h):
Nearest town / city			

Choose one of the following 3 options to indicate the start and end of the collection area:

1) GPS-coordinates: (e.g. via Google Maps; at least 3 coordinates)		
2) River kilometer:	Start:	End:
3) Other recording		

Further information about GPS recording (coordinate system, projection, device, etc.):

Sampled width of the area (e.g. 10m to water; 20m wide strip in floodplain forest / wetland):

Collection point/area is located orographically (in flow direction):	☐ left ☐ right
Date of the last cleaning / collection activity (d/m/y):	

Name of organisation / association that collects:

Number of persons of your (sub)group:

How many garbage bags* were filled with plastic waste in your (sub)group?

Number	Volume of bags in litre	Filling level in percent (e.g. half full)

*IMPORTANT for more than one group: try to make your garbage bags assignable to your collection protocol, e.g. by labelling, colour marking, etc.

Which plastic wastes were mainly (number of pieces) collected (*e.g. beverage bottles, food packaging, films, bags, wet wipes, cotton swabs, cigarettes, etc.*)?

What other waste did you find (*e.g. metal cans, glass bottles etc.*)?

How was the weather during the collection?

☐ fair weather ☐ rain ☐ snow ☐ wind ☐ fog

Information about the sampling area

Where did you mainly collect? Choose one of the three following options:

(1) ☐ riverbank* For collection on the riverbank, please answer points 2.1 to 2.6 below. *to the water	**(2)** ☐ hinterland vegetation at the place of collection in the surrounding hinterland (tick): O grassland, pasture O bush O (alluvial)forest O agricultural land O other: ________________________________ If known, continue with point 2, otherwise point 3	**(3)** ☐ riverbank and hinterland For collection on riverbank **and** hinterland, please answer all the following points

Does the vegetation impede the collection? ☐ no ☐ yes If yes, how far?	*For instance: due high vegetation (densely overgrown area, high grass) plastic waste is hardly visible; inaccessible places, because under water; etc.*

CHARACTERISATION OF RIVER MORPHOLOGY

River width

☐ trickle, rivulet, brook (width 1-3 m)

☐ creek (width 3-10 m)

☐ river (width >10 m, flows into stream)

☐ stream (width >10 m, flows into sea)

Flow velocity

Estimation of the flow velocity by

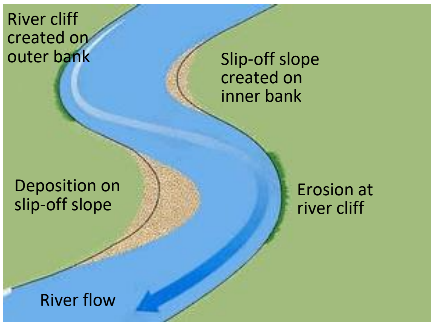
(1) walking a distance of 10m along the shore and marking start (S) and end (E),
(2) a stick (or similar floating natural material) is thrown into the river at (S)
(3) the time from start to end point is recorded,
(4) the procedure is repeated three times and
(5) is then inserted into the following formula to calculate the average flow velocity:

$$Average\ Time = \frac{measure\ 1: \qquad [sec] + measure\ 2: \qquad [sec] + mesure\ 3: \qquad [sec]}{3} = \qquad sec$$

$$Flow\ velocity = \frac{10\ m}{sec} = \boxed{}\ m/s$$

☐ Flow velocity could not be determined because:

Description of collection area at the river

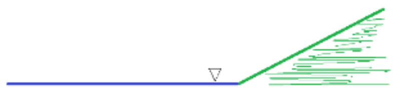


Location:

☐ straight river section
☐ outer bank /cut bank
☐ inner bank / slip off slope

Type of shore:

☐ rather steep bank (A)
☐ rather shallow bank (B)



(A)

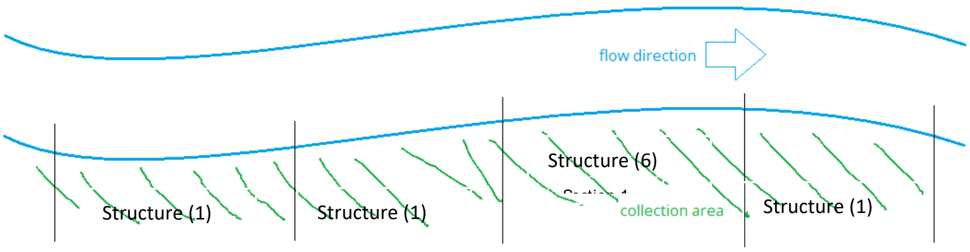
(B)

BANK STRUCTURE & PROTECTION

Please tick the main structure (natural or obstructed) along the collection route. If the structure changes, you can also select several shapes and enter them graphically below (*see example*).

Description	Picture	Description	Picture
(1) ☐ natural bank (e.g. gravel and sandbank)		**(2)** ☐ natural rock, "no bank protection"	
(3) ☐ Concrete dams, sheet piling, etc. (smooth bank reinforcement)		**(4)** ☐ rip-rap revetment (rather smooth)	
(5) ☐ ecological bank protection (e.g. using wooden stakes)		**(6)** ☐ rough array of stones (larger blocks)	

Example:



Sketch

DESCRIPTION OF RIPARIAN VEGETATION

Please tick the mainly occurring riparian vegetation along the collected route. In case of changing vegetation, choose several and enter them graphically below (*see example above*).

Vegetation	Picture	Vegetation	Picture
(1) ☐ "green" slope, embankment		**(2)** ☐ perennials, bushes, herb corridor, grassy / weedy vegetation	
(3) ☐ reed bank		**(4)** ☐ (alluvial) forest (also with undergrowth)	
(5) ☐ gallery forest		**(6)** ☐ none (due to erosion)	
(7) ☐ none (due to bank protection)		**(8)** ☐ other	

Sketch

OTHER HYDRO-ENGINEERING STRUCTURES

Which of the following hydraulic engineering structures did you notice along the collection route? You can then record these elements graphically.

Description	Existing?	Picture
transverse structures like groynes or flow-directing longitudinal structure like guiding wall; other flow-affecting structures?	☐ yes ☐ no	
damming transverse structures like weirs, ramps etc.	☐ yes ☐ no	 
hydraulic channel narrowing	☐ yes ☐ no	
woody debris	☐ yes ☐ no	
diversion (e.g. hydro power plant) /tributary	☐ yes ☐ no	Which one?
Sketch		

CHARACTERISATION OF THE SURROUNDING AREA

Description of land use

What is the predominant type of land use in the immediate surroundings of the sampling area? Describe only the cleaned bank side and indicate how the areas of use listed below are proportionally present *(e.g. 80% natural landscape + 10% hiking trails + 10% cycle path = 100%).*

☐	natural landscape or nature reserve		____%
☐	agricultural land	O *farm-, cropland*	____%
		O *grassland, pastures, meadow*	____%
		O *(alluvial) forest, flood plain*	____%
		O *vineyards*	____%
☐	settlement area	O *urban settlement area*	____%
		O *rural settlement area*	____%
		O *Industrial area (brief description if known):* ______________________________	____%
		O *Municipal facilities* *o waste collection center, recycling yard* *o sewage treatment plant* *o landfill* *o other:*	____%
		O *sport-, leisure and recreation area (e.g. bathing area, picnic, dog area, playgrounds; brief description if known):* ________________________________	____%
☐	traffic area	O *roads*	____%
		O *rails*	____%
		O *cycle paths*	____%
		O *hiking trails*	____%

		O *parking lots*	____%
☐	other	O *Flood protection (dam)*	____%
		O *Flooding area*	____%

OTHER CHARACTERISTICS

Did you find any accumulation points (increased quantities of plastic waste at specific points) along your collection route? ☐ yes ☐ no

If yes, how many have you seen? [ ]

COMMENTS

If you noticed any noteworthy circumstances, you can note it here:

GRAPHIC DESCRIPTION

You can also draw the observed noteworthy circumstances (like pollution hotspots) along you

Sketch