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Anthropogenic Waste Pollution of the Danube Shoreline between Komárom and Neszmély, with Special Emphasis on Mesoplastics

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Research into microplastics is increasingly important, as these particles are widespread and their long-term effects remain unclear. Plastic waste enters rivers and breaks down into smaller fragments, prompting our focus on mesoplastics in rivers—an under-researched area. Based on litter collection efforts along the Danube, we selected sampling sites near Komárom, Almásfüzitő, Dunaalmás, and Neszmély. Data from these “clean-up” actions were used to assess anthropogenic inputs and to conduct both quantitative and qualitative analyses.
During the river sampling methods, where the goal was to develop a method suitable for domestic conditions, custom-made nets were applied based on descriptions found in the literature. The size, quantity, and polymer type of the particles were determined through visual inspection and FTIR spectroscopy. According to our test results so far, most of the particles were identified as originating from packaging waste, mainly polyethylene and polypropylene. The highest contamination was measured 20 m from the shore of Almásfüzitő, close to the drift line, concentrated in the upper 20–50 cm layer of the river water, which correlates with the results found in the literature regarding water depth. Based on these findings, it can be concluded that our measurement method, which is still under development, is progressing in the right direction, but further measurements will be required to confirm this with greater certainty.

1. Introduction

Mesoplastics represent a growing category of environmental contaminants with the potential to harm ecosystems. Investigating them is essential, as they serve as an intermediate stage between macroplastics and microplastics, offering insight into plastic degradation processes, transport mechanisms, and associated ecological consequences. Mesoplastics have the potential to interfere with ecosystem stability by contributing to biodiversity loss, polluting terrestrial and aquatic environments, and altering trophic dynamics. They may also act as carriers for chemical additives and harmful microorganisms, raising concerns about their ecological impact. Their distribution and abundance are shaped by a combination of human-induced and natural processes (Ellos et al., 2025). Plastics can be categorized as macroplastics (> 2.5 cm), mesoplastics (0.5 cm to 2.5 cm), microplastics (1 µm to 5 mm), and nanoplastics (<1 µm) (MSFD Technical Subgroup on Marine Litter, 2013). Microplastics can be either primary, meaning they are made to be tiny from the start, or secondary, meaning they form when bigger plastics break apart (Shashoua et al., 2024). Based on their morphology, they may be classified as fragments, beads, fibers, pellets, filaments, or films.
Macro- and mesoplastics have already been linked to visible harm in a variety of animal species. For instance, Connors and Smith (1982) found that red phalaropes with plastic particles in their stomachs tended to have reduced fat reserves, suggesting a negative impact on their ability to migrate and reproduce (Connors and Smith, 1982). According to Jeong et al. (2024), microplastics can enter animal bodies through ingestion or inhalation, leading to inflammation, tissue damage, and in some cases, long-term health effects (Jeong et al., 2024). Mahapatra et al. (2023) also reported two incidents in which monocled cobras died after ingesting plastic waste, highlighting the deadly consequences of improper plastic disposal in terrestrial environments (Mahapatra et al., 2023). When plastics break down into smaller pieces, animals eat them, and these particles move up the food chain, eventually putting all the species that consume them at risk (Ragusa et al., 2021).

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The Danube has been heavily influenced by anthropogenic pollutants, as it flows through densely populated and industrialised areas. Despite Hungary's constantly evolving recycling system, it is inevitable that plastic waste will end up in the (Bándy and Élő, 2023). In Austria, researchers examined how much plastic was present in the Danube at three different water depths. It was determined that 88 % of plastic waste is transported to the upper 0.5 m (Van Emmerik et al., 2019). Mesoplastic concentration has also been linked with river hydrology, just like microplastic concentration. It was previously found that when water levels were lower, there was less plastic in the river, likely because particles sank to the bottom more easily, depending on their shape and density (Balla et al., 2024). Baranya et. al. (2022) established a correlation between the discharge points of wastewater treatment facilities and increased microplastic concentrations in the Danube. On average, 44 % of the detected pollutants consisted of polystyrene (PS), while 25 % were polyethylene (PE). During "clean-up" campaigns along the Danube, waste was sorted by sight, and over half of it turned out to be packaging, mostly made of polyethylene terephthalate (PET). The mesoplastic particles found in the samples were mostly linked to the same types of plastics used in packaging waste. The installation of Floating Plastic Waste Detectors on the main sections of the River Danube—following the example of the River Tisza—should be considered as a means to enhance the efficiency of water cleaning operations (Élő and Peller, 2023).

Based on data from Ellos et al. (2025), studies on this type of mesoplastic are not particularly common in Europe, but rather in East Asia. Our goal during the research was to conduct studies on mesoplastics on the Danube River using specific sampling procedures for mesoplastics in order to make the data comparable with that of other rivers. In addition, we also examined the limiting parameters affecting the sampling procedures (e.g., sampling net size, sampling duration, etc.). In line with the findings of Emmerik et. al. (2019) and Balla et al. (2024), the aim was to examine the sample distribution for the vertical spectrum of the selected river section and to explore the possible relationship between sample distribution and changing hydrological conditions. To complement the research, we looked for a correlation between plastic pollution resulting from anthropogenic activities along the coast and the pollution of coastal water bodies by plastic particles, taking into account the typical plastic load in the coastal zone.

2. Materials and methods

2.1 Sampling

In order to select the appropriate sampling method, numerous publications were studied, and Ellos et al. (2025) summarized the relatively few studies available worldwide on the examination of mesoplastics. Since the given environment (marine or freshwater) and the associated hydrological conditions can vary greatly, there is no uniform measurement method. In our study, a measurement method for freshwater was chosen, which is intended to be adapted to domestic conditions, so sampling on the Danube is considered a method development that can be applied under domestic conditions.

For long-term and cost-effective monitoring of macroplastics in river systems, the Mekong River Commission (MRC) has developed a standardized protocol (Mekong River Commission, 2023). Although the protocol includes several sampling methods, net sampling from research vessels proved to be the most suitable for this study. Sampling took place on two separate dates (October 24, 2024, and March 4, 2025). The first sampling took place on the Danube between Komárom and Almásfüzitő, while the second sampling covered the entire test section. We took more than 40 samples during the testing of the methods (Figure 1).

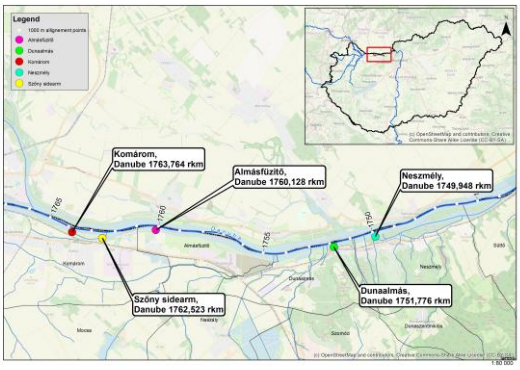

Figure 1: Sampling sites along the Danube between Komárom and Neszmély (Source: own creation based on ÉDUVIZIG data*)*

To reduce the risk of plastic contamination during sampling, most of the tools were made from metal, with all materials standardized except for the first custom-built net (Figure 2a), which was made from plastic-coated mosquito mesh. Before use, this net was mechanically rubbed and checked with FTIR spectroscopy and visual inspection, and no changes or damage were detected in the material. However, because the net's mesh sometimes lets samples wash out, it was later replaced with a sturdier, box-shaped metal device (Figure 2b). No traces of the plastic coating were found in any of the samples, confirming that the original net did not degrade during sampling and that no cross-contamination occurred.

Standard field tools were also used, including a built-in sonar system to measure water depth, a stopwatch, small plastic jugs, and other basic measuring equipment. Filtration was carried out with 1 mm pore-sized metal filters, in 20 cm and 23 cm diameters, one of which was custom-made and stretched for stability. A 1.5 m plastic rod and a 50 m measuring tape were used to keep sampling depth and positions consistent. After rinsing with about 200 mL of distilled water, samples were handled using metal spatulas and stored in resealable plastic bags. Additional tools, including metal buckets and insulating tape, supported the fieldwork.

The standard MRC procedure was slightly modified by splitting the recommended 20 min sampling period into two 10 min intervals. This change was necessary because of the two-layer sampling method. The first layer focused on the top 20 cm of the water column, using a 1 mm pore-sized, 20 cm diameter metal filter (Figure 3). The second layer was collected at a depth of about 80 cm with the custom-built metal box device (Figure 2).

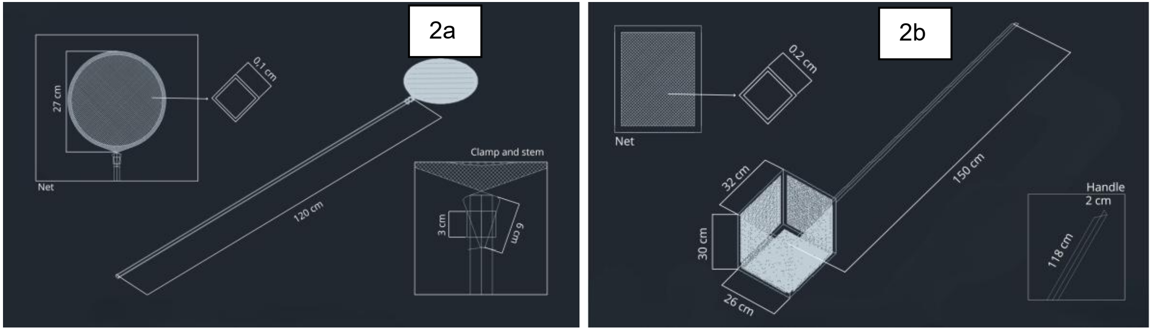

Figure 2: Drawing of deeper sampling devices (Source: own creation). (a) Stretched net for first sampling; (b) Box-shaped net for second sampling

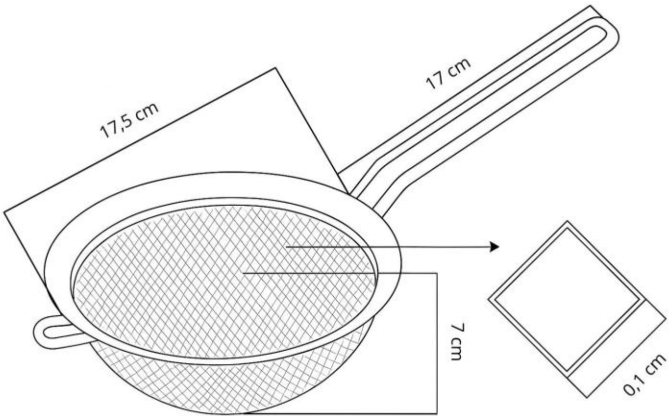

Figure 3: Drawing of water surface sampling device (Source: own creation).

Samples were taken at three distances from the riverbank: 1–1.5 m, about 10 m, and about 20 m (Figure 4). A 5 m margin of error was allowed at each site because of the shallow riverbank and local flow variations. After the rinsing process, the remaining suspension was placed in resealable plastic bags and transported to the laboratory.

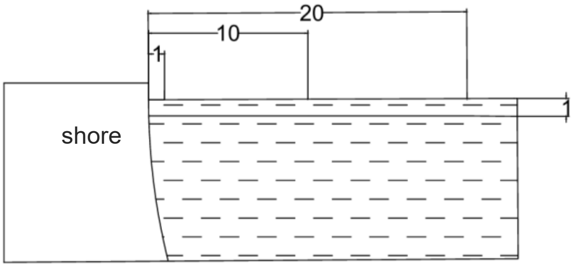

Figure 4: Location of sampling points from the shore, in meters (Source: own creation)

On the first sampling occasion, the Komárom gauging station recorded a water level of 200 cm and a surface flow rate of 2,500 m³/s. Sampling sites included the Szőny discharge point, the confluence of the Szőny side branch, and the area near the Almásfüzitő boathouse. The Szőnyi island and sidearm confluence was identified as a site of special significance, as confirmed by the research of Balla et al. (2024), which demonstrated that the small watercourse transports plastics along with sediment, which tend to accumulate in side branches.

During the second sampling session, the methodology was essentially the same. The only modification involved further development of the custom sampling device, as samples could not be reliably collected from the riverbed. This observation is also supported by existing literature. More focus was placed on adapting internationally validated sampling procedures (MRC protocol). Water levels were noticeably lower during the second sampling, measured at 74 cm, with a flow rate of 1,178 m³/s. In certain locations, due to the absence of significant current — typical of low-flow conditions — the filters had to be towed manually by boat to ensure effective sampling.

2.2 Sample preparation

During sample preparation, the presence of mesoplastics was determined through visual inspection. The suspension from the sample storage bag was first poured onto a 2.5 mm pore size metal filter. The storage bags were then rinsed twice with 200 mL of distilled water to recover any remaining particles, and the rinse water was also poured onto the filter. The filtrate that passed through into a 500 mL beaker was subsequently poured through the next finer metal filter with a 1 mm pore size. The same rinsing process with distilled water was repeated. This sequential filtering and rinsing method was continued until the finest filter with a 0.5 mm pore size was used. The samples were placed onto Petri dishes using tweezers, allowed to air-dry, and visually inspected to determine the number of particles. Each particle presumed to be a plastic fragment based on visual inspection was subsequently analyzed by FTIR spectroscopy.

2.3 FTIR Measurements

FTIR spectra were used at room temperature using a PerkinElmer Spectrum 3 FTIR spectrometer equipped with an ATR accessory featuring a single-reflection diamond crystal top plate and a pressure arm designed to press the sample against the crystal surface. Measurements were conducted around 50-70 N compressive force. Between each measurement, the sample holder was thoroughly cleaned with 96 % ethanol to prevent cross-contamination. Spectral data were analyzed using PerkinElmer's Spectrum IR software, which enabled comparison with the reference library. A match was considered valid if the spectral similarity exceeded 95 %, indicating the identification of a reference compound.

3. Results and Discussions

3.1 Quantitative analysis

The first sampling found 45 suspected plastic elements, while the next sampling found 21; these samples contain all particles suspected to be plastic. In the first survey, 28 items were retrieved from the upper 20 cm of the water column, whereas 17 were collected at a depth of approximately 80 cm. No particles were detected 10 m from the Szőny confluence, a result attributed to nearly stagnant conditions that allowed debris to settle on the riverbed. The greatest local abundance (9 items) was recorded at Szőny, 10 m from the shore, within the top 20 cm.

The lower count observed in the second campaign is thought to have been driven by two changes: the deployment of a newly designed sampling device and markedly reduced water levels, which reduced the water flow velocity and limited the transport of debris, while allowing larger pieces to settle. Even under low-flow conditions, the examination of the upper 20 cm again proved most effective. Debris was most frequently recovered 20 m from the shoreline, a distribution pattern likely promoted by the higher current speed at that distance. With respect to settlement, samples were obtained at every transect near Dunaalmás, whereas

several other transects yielded none, a disparity that may reflect inputs carried by the Által-ér tributary. The highest item count during the second survey (6 pieces) was recorded at Almásfüzitő, 20 m offshore. In terms of the efficiency of all measurements, there was much more waste in the top 20 cm than in the deeper units.
The size distribution of the samples ranges over a wide range, and not only mesomaterials were found. There were 9 mesoplastics in the first measurement and 3 in the second measurement.

3.2 Qualitative analysis

All samples presumed to be synthetic in origin were analyzed using FTIR spectroscopy. Materials visually identified as being of natural origin were excluded from the analysis. The identified peaks were assigned (Veerasingam et al., 2021). The assignment of the characteristic absorption bands in the PE sample is as follows (Figure 5) 2,915 cm⁻¹ (*C–H* stretching vibration), 2,848 cm⁻¹ (*C–H* stretching vibration), 1,472 cm⁻¹ (CH_2 bending vibration), 1,462 cm⁻¹ (CH_2 bending vibration), 730 cm⁻¹ (CH_2 rocking vibration), and 719 cm⁻¹ (CH_2 rocking vibration).

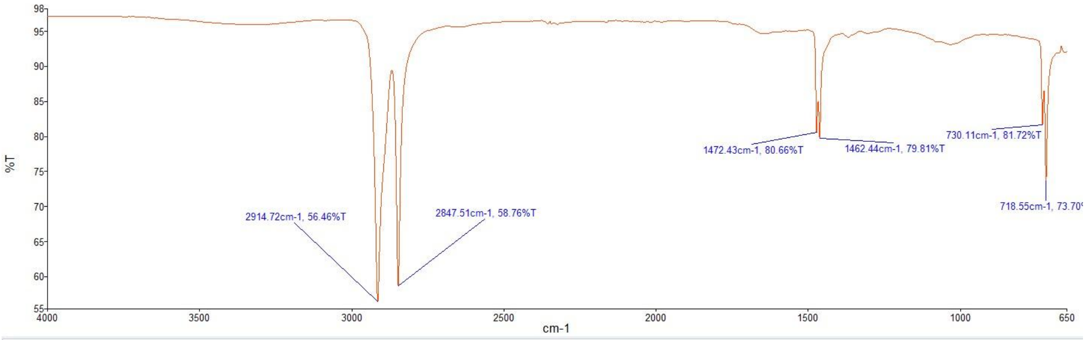

Figure 5: FTIR spectrum showing characteristic peaks of a PE sample from the Danube River (Source: own measurement)

In the PP sample, the main absorption bands are observed at 2,950 cm⁻¹ (*C–H* stretching vibration), 2,915 cm⁻¹ (*C–H* stretching vibration), 2,838 cm⁻¹ (*C–H* stretching vibration), 1,455 cm⁻¹ (CH_2 bending vibration), 1,377 cm⁻¹ (CH_3 bending vibration), 1,166 cm⁻¹ (*C–H* stretching vibration; CH_3 rocking vibration), 997 cm⁻¹ (*C–C* stretching vibration), 972 cm⁻¹ (CH_3 rocking vibration; CH_3 bending vibration), 840 cm⁻¹ (*C–H* bending vibration), and 800 cm⁻¹ (CH_3 rocking vibration; *C–C* stretching vibration; CH_2 rocking vibration; $C–CH_3$ stretching vibration; *C–CH* stretching vibration). In some cases, the samples were physically damaged or fractured under pressure during the measurement process, yet successful identification was still achieved. The most frequently detected polymer was high-density polyethylene (HDPE), observed in five samples, followed by polypropylene (PP), found in four instances. Other plastic types, such as polystyrene acrylate, were also detected.

3.6 Comparison of the results with those from litter collection campaigns

Waste collection activities along the Danube consistently show that PET bottles and other household-related plastic packaging materials dominate the litter. Analysis of water samples from the same area confirmed the presence of polyethylene (PE) and polypropylene (PP), the most widely produced commodity plastics. The low PET content in water samples, despite its dominance in shoreline waste, may be explained by differing sources and transport pathways between land and river environments.

4. Conclusions

As described in the study by Ellos et al. (2025), there are several methods for collecting mesoplastics. In surface freshwater, the net method is most commonly used (stow net vessel 25 %, collection of water sample 25 %), but within this, the plankton net (plankton net 50 %) is used most frequently. This study expands our knowledge of mesoplastic pollution with field data collected from the Danube River between Komárom and Neszmély. FTIR analysis of the particles filtered from the water confirmed the presence of synthetic particles (mainly polyethylene and polypropylene), whose depth distribution is primarily determined by hydrological conditions (primarily water level and water flow at the time of sampling), the composition and size of the materials, and indirectly by human activity. Based on our results so far, it can be said that at low water levels, the upper 20 cm layer of the water column proved to be the most effective for sampling, which supports the findings of Balla et. al. (2024) based on their studies on the Tisza River. The proximity of wastewater discharge points correlated with higher particle concentrations. During our investigations, we focused primarily on developing the method, so further studies are needed on the observed spatial variability and its actual effect on mesoplastic transport dynamics. Taking into account the parameters of nets used in international research on freshwater, we tested the net solutions available in Hungary, as well as a prototype based on the type of net used on the Mekong River. The results highlight the need to refine standardized protocols to enable consistent monitoring across studies and ensure efficient and representative collection of mesoplastics.

The present research will continue in the future. Through planned sampling (in the thalweg and at the river cross-section), a more comprehensive data set is expected to be available to refine our partial results and perform statistical analyses. Our study aims primarily to contribute to the development of a sampling method for mesoplastic materials that is adapted to domestic conditions. Long-term, coordinated studies are needed to monitor trends and evaluate interventions in freshwater systems, which can serve as a basis for planning and implementing further effective interventions affecting freshwater systems.

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