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# Evaluation of microplastic pollution in the Vilnelė River

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**Abstract.**The aim of the work was to carry out experimental research and numerical simulation of microplastic pollution in the Vilnelė River. Six locations were selected for the experimental studies: 3 measurement points and 3 releasers. It was determined that the average concentration of microplastics at the selected measurement points was in the range between 0.10 and 0.42 particles/L. The concentration of microplastics at the selected releasers ranged from 3 to 31.6 particles/L. A morphological analysis of the microplastics was also carried out. Synthetic polymer microplastics were found to be the dominant type among all detected microplastics. The ANSYS software was used for numerical modelling. The Euler–Lagrange method was selected to model the movement of microplastics in river water. It was found that microplastic pollution in the Vilnelė River was mainly lower than in other selected rivers and lakes around the world. The numerical simulation of microplastic pollution in the Vilnelė River provided models that, by depicting the pollution sources, show how far microplastic particles are transported within one hour. These models help identify the most suitable locations for further microplastic research, enable the prediction of pollution levels, and allows other researchers to repeat the research.

## Introduction

Microplastic pollution has emerged as a pervasive issue in freshwater environments, with microplastics (MPs), typically defined as plastic particles <5 mm (and nanoplastics <1 μm), now detected in rivers and lakes worldwide (Gao et al. 2024). Urban areas are significant sources of MPs, as municipal wastewater treatment plant (WWTP) effluents and urban stormwater runoff can discharge large quantities of MPs into surface waters (Obermaier and Pistocchi 2022). Even advanced WWTPs, which can remove 80–99% of influent microplastics via settling and filtration, still release residual particles due to the high volumes of water processed (Murphy et al. 2016). For example, a modern WWTP in Scotland was found to emit only ~0.25 MP per liter in its effluent (≈250 particles/m$^3$), yet this translated to ~65 million microplastic particles discharged per day into the receiving river (Murphy et al. 2016). Stormwater and combined sewer overflows can bypass treatment entirely, flushing accumulated street litter, fibers, and tire wear particles directly into waterways during rain events (Obermaier and Pistocchi 2022). As a result, urban rivers often exhibit higher MP contamination than rural watercourses, especially downstream of city centers, WWTP outlets, and storm outfalls (Büngener et al. 2024).

Although our current study focuses on microplastics (particles >25 μm), nanoplastics represent a critical research frontier due to their smaller size and higher mobility, greater potential for biological uptake, and the challenges associated with their detection in environmental matrices. Wastewater treatment plants (WWTPs) are a major pathway for both micro- and nanoplastics entering aquatic systems. Several studies have confirmed that even advanced tertiary treatment stages cannot fully remove plastic particles in the nanoscale range, which are then discharged into receiving rivers (Koelmans et al., 2019; Enfrin et al., 2020). While nanoplastics were not explicitly measured in our current study, we acknowledge their importance and potential presence in urban runoff and WWTP effluents as part of the broader context of plastic pollution. Microplastics in river water originate from various sources, primarily influenced by human activities and environmental factors. Urban rivers receive microplastics from drainage ditches, atmospheric deposition, wastewater treatment plants (WWTPs), industrial activities, agricultural land and the breakdown of larger plastic debris. In the Vilnelė River, the main source of MPs are surface water releasers (Liu et al. 2024, Park et al. 2020, Kay et al. 2018, Akdogan et al. 2023).

Microplastic pollution in rivers is a significant environmental problem and has been extensively investigated by researchers (Bruge et al. 2020, Buwono et al., 2021, Chanez et al., 2024, He et al., 2021, Haque et al., 2024, Liu et al. 2021, Pham et al. 2024, Sekudewicz et al., 2021, Siregar et al. 2025, Stanton et al. 2020). In order to solve this problem, it is necessary to evaluate the amount of microplastic particles in the water and identify possible sources of microplastic pollution. In Lithuania, no scientific publications have yet been released on the topic of microplastic pollution, and local water bodies have not been studied; therefore, the extent of pollution is still unclear. Unlike open marine environments, freshwater systems are relatively closed. Due to slower flow, poor diffusion, and close proximity to human activities, freshwater environments tend to receive and accumulate large amounts of microplastics (Wang et al., 2022).

Microplastic transport in water is influenced by various factors such as particle size, shape, density, and surrounding environmental conditions. Numerical modelling tools such as ANSYS, PHOENICS, or COMSOL Multiphysics can be used for simulating microplastic movement in surface waters. In this study, ANSYS was selected to model and predict the behavior of microplastics in aquatic environments. Computational Fluid Dynamics (CFD) coupled with Discrete Element Methods (CFD-DEM) can be used for simulating the vertical movement of microplastics in quiescent water (Ostadhosseyni, et al. 2025). The migration behavior of microplastics is influenced by hydraulic parameters such as flow rate and turbulence. Higher flow rates enhance the vertical exchange of microplastics between water and sediment, significantly affecting their transport (Yang and Foroutan 2023, Fatahi et al. 2023). The type, size, and shape of microplastics play important roles in their movement. Larger and denser particles tend to settle on the riverbed, while smaller and lighter particles remain suspended or float near the surface (Fatahi et al. 2023, Kabir et al. 2025). For example, polypropylene (PP) particles migrate

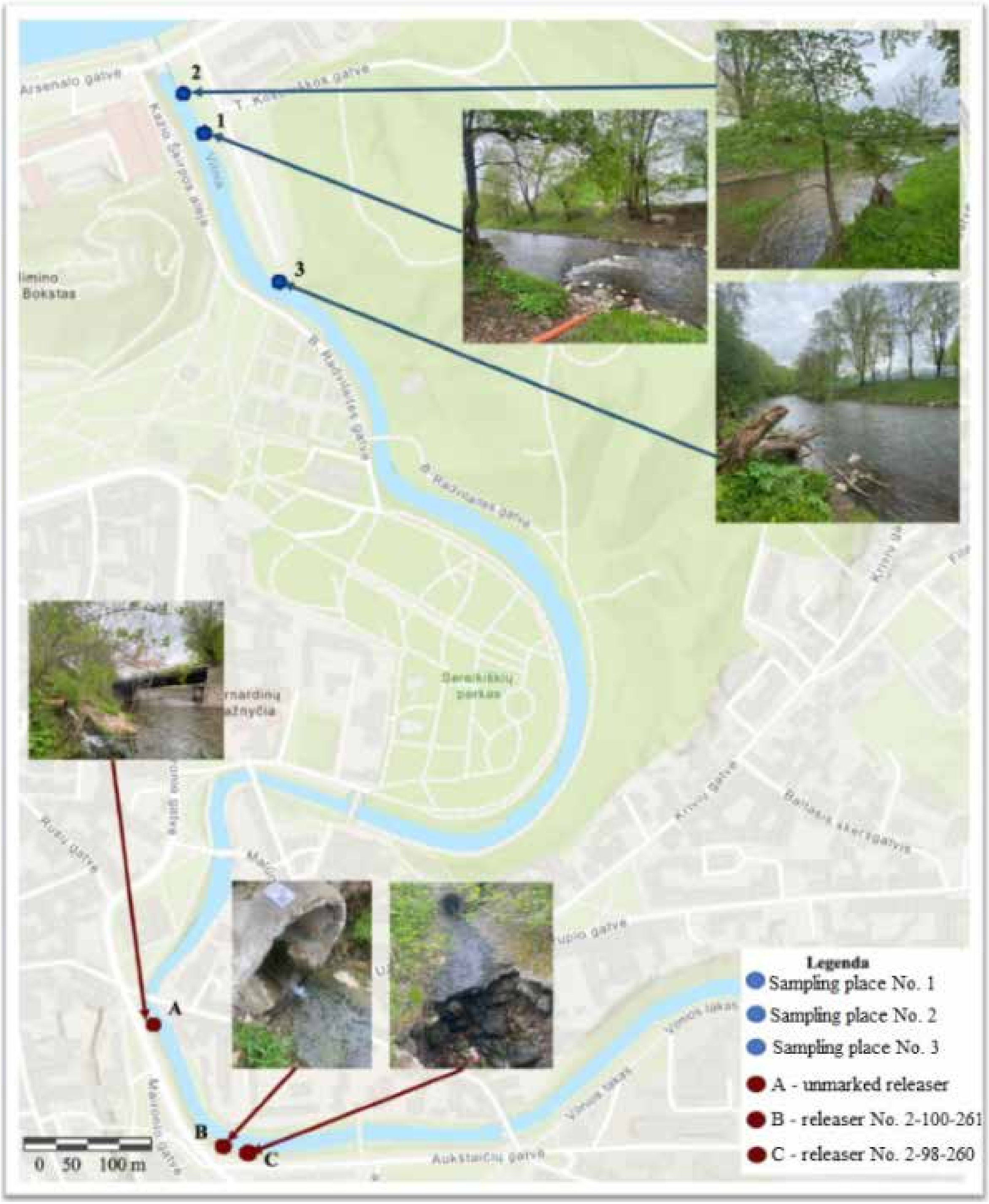


**Fig. 1**. Research object and sampling locations

**Table 1**. Sampling information

| Title | Coordinates | Amount of water, L |
|---|---|---|
| Sampling location No. 1 | 5 54.68796, 25.29339 | 420 |
| Sampling location No. 2 | 54.68832, 25.29299 | 420 |
| Unmarked releaser | 54.680069, 25.292699 | 6 |
| Releaser No. 2-100-261 | 54.670109, 25.293829 | 3 |
| Releaser No. 2-98-260 | 54.670367, 25.293965 | 3 |
| Sampling location No. 3 | 54.68666, 25.29449 | 420 |

as floating debris, while polystyrene (PS) and polyamide (PA) particles smaller than 0.5 mm migrate as suspended loads (Li et al. 2025). In our study, horizontal transport of microplastics in the Vilnelė River was simulated using ANSYS software. The Euler–Lagrange method was selected to model microplastic movement in the river water. The aim of this work is to carry out both experimental research and numerical simulations to assess microplastic pollution in the Vilnelė River.

## Methodological part

### *Research object and location*

The Vilnelė River, which flows through the capital of Lithuania, Vilnius, was chosen as the research object (Fig. 1). The length of the Vilnelė River is 81.6 km, and the total basin area is 623.5 km$^2$.

### *Sampling*

In order to assess microplastic pollution in the Vilnelė River, 6 sampling points were chosen (Table 1). Filtration was conducted using mesh sizes of 2000, 841, 400 and 250 µm. These mesh sizes were selected to capture a broad spectrum of plastic particles, ranging from larger macroplastics to smaller microplastics, aligning with established methodologies in freshwater microplastic research (Hidalgo-Ruz et al., 2012). The **2000 µm mesh** served primarily as a **pre-filter** to remove larger organic matter and prevent clogging of finer filters, as recommended in field-based microplastic sampling protocols (Hidalgo-Ruz et al., 2012). The finer meshes (841, 400, and 250 µm) were selected based on commonly reported mesh sizes in microplastic studies in riverine and urban runoff environments (Klein et al., 2015; Liu et al., 2019), ensuring comparability with existing datasets and capturing a representative range of particle sizes. This filtering sequence enabled the isolation of microplastics across a wide particle size spectrum, while also facilitating size-based classification during analysis.

The selection of sampling locations along the Vilnelė River within city of Vilnius was guided by hydrodynamic and morphological criteria:

- Sites with relatively uniform flow, free from obstructions such as vegetation, debris, or artificial structures, were prioritized, in order to ensure representative sampling.
- Locations were selected based on the river's cross-sectional geometry and bed topography, avoiding areas with high turbulence or dead zones that could bias particle concentration.
- Selected sites provided access to water depths of 2–4 meters, enabling effective immersion of the sampling apparatus and improving particle recovery from the water column.

This site selection approach is consistent with recommendations for minimizing sampling bias in heterogeneous fluvial environments (Dris et al., 2016).

### *Preparation for sampling*

All means and instruments were washed with tap water and deionized water.

### *Sampling process*

Sampling was conducted by wading into the river at 1.5-2.0 m from the shoreline. A visual analysis was performed. A straighter part of the riverbed was chosen. Samples were collected by immersing the sampling device to a depth of 15-20 cm below the water surface.

The microplastic sampling campaign, including repeated measurements, was conducted between November and April, covering late autumn, winter, and early spring conditions. This period was intentionally chosen to capture the seasonal variability of the river's hydrological regime, which plays a significant role in the transport and distribution of microplastics. From November to December, the river typically experiences autumn flood events caused by increased rainfall. These events elevate water levels and flow velocities, enhancing the mobility of suspended particles, including microplastics. In January and February), the river may experience ice cover or partial freezing. While overall discharge tends to be lower, occasional thaws can lead to short-term water level fluctuations. Sampling was timed to avoid full ice cover. In March and April, the Vilnelė undergoes spring flooding, primarily driven by snowmelt and ice thawing. This period is characterized by peak discharge and increased flow energy in the river, leading to greater mobilization of microplastics from riverbanks and point sources such as stormwater outfalls. Based on flow measurements and regional hydrological data, river discharge during sampling period ranged from approximately 3.0 to 6.0 m$^3$/s, with local increases linked to runoff peaks. These conditions represent active hydrodynamic phases, relevant for understanding microplastic dispersion patterns in the urban river environment (Darnu group, 2021, Lithuanian Hydrometeorological Service, Visuotinė lietuvių enciklopedija, Van Emmerik and Schwarz 2020). The sampling scheme and filters used for sampling are presented in Fig. 2.

Based on standardized methods, a total of 420 L of river water was filtered. This volume was selected according to study of Mahlangu et al. (2011). Water samples from potential pollution sources (i.e., point=source releasers) were collected directly into 3-L glass containers (Order No. DI-313 2006). The surface flow velocity of the Vilnelė River flow was measured using a surface float method.

### *Treatment with 30% hydrogen peroxide ($H_2O_2$)*

Precipitated material from filters of different diameters was collected in glass bottles containing deionized water. The remaining parts of the filter columns were covered with aluminum foil. Each sample was placed in a separate glass bottle. Approximately 200 mL of 30% $H_2O_2$ was added to oxidize organic matter while leaving microplastics intact (Hossain et al., 2020). The glass bottles were then covered with aluminum foil and placed in a bath for heating. In the bath, the samples were heated for 8 h at 80 °C and then stored at room temperature for 24–48 h, depending on the effect of oxidation of soft tissues (Hossain et al., 2020). Heating of microplastics up to 80 °C is generally not sufficient to induce significant changes in their physical properties, particularly in terms of polymer integrity or morphology. At this temperature, some minor surface softening or deformation may occur, particularly in low-melting-point polymers such as polyethylene (PE) or polystyrene (PS). However, since no mechanical stress was applied, the overall morphology, particle size, and structural identity of the microplastics remained largely unchanged (Ivleva et al., 2017).

The aim of moderate heating in sample preparation is often to remove organic content. Studies have shown that thermal treatments below 100 °C are considered safe for preserving microplastic characteristics in visual and morphological analyses (Löder et al., 2017; Munno et al., 2020). In our study, heating was not intended for chemical modification or degradation, but rather as part of standard sample preparation, during which no observable deformations or fusion of microplastic particles occurred. Therefore, we conclude that heating to 80 °C did not significantly alter the physical properties of the microplastics.

### *Laboratory filtration method*

Before visually counting microplastics and examining them under a microscope, the samples were pre-treated with an $H_2O_2$ solution (Hossain et al. 2020). Microplastics were collected on a glass fiber filter through filtration, with each sample filtered separately. After filtration, the glass fiber filter was placed in a glass container for analysis. The container was then closed and heated at 30°C.

### *Morphological identification of microplastics*

The morphological assessment of the Vilnelė River, including the riverbed topography and water level variations, was conducted to enhance the accuracy of microplastic distribution modeling, particularly considering stormwater outfalls as primary sources. The river's cross-sectional geometry was reconstructed using data from the Lithuanian Geoportal, which provided detailed information on riverbed elevations ranging from 0.4 to 0.8 meters within the study area. These morphological characteristics influence flow patterns and sediment transport, which are critical factors in microplastic

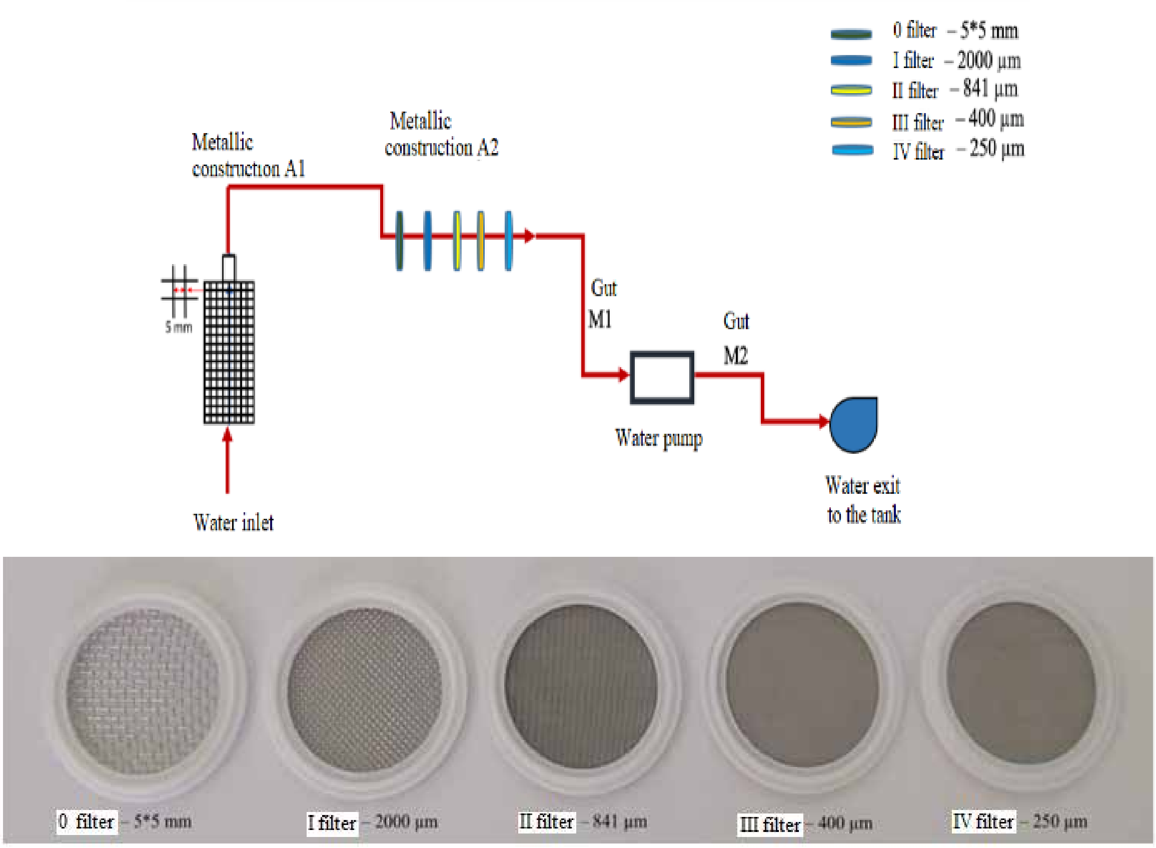


**Fig. 2**. Sampling scheme and filters used for sampling

dispersion. Boundary conditions for the hydrodynamic model were established based on flow data from the Lithuanian Hydrometeorological Service. The average flow velocity in the selected river section was measured at approximately 3.2 $m^3/s$ using the float method. However, the river's longitudinal slope, which can reach up to 0.4% in the lower reaches, was not explicitly included in the model. Incorporating this parameter in future studies could further refine the understanding of microplastic transport dynamics. By integrating morphological data into the modeling framework, we aimed to simulate realistic flow conditions and identify potential accumulation zones for microplastics, thereby providing a more comprehensive assessment of pollution patterns in the Vilnelė River. The microplastics collected on the filter were compared with the examples presented in the literature (Pervez et al., 2020). Sample filters were visually inspected, and microplastic particles were classified according to their physical properties, following the sample analysis protocol (Viršek et al., 2016). Microplastics were classified by type, color, and size to provide data on environmental concentrations. Detectable microplastic particles were quantified and categorized into fragments, granules, threads, films, and foam. Sources of microplastics, such as fragments of consumer goods (e.g., fishing nets), raw materials, industrial pellets, or microplastics from household effluents, were also considered.

The shape of the fragments is rounded, thick, and stiff, irregular in shape with sharp and curved edges. Granules - cylindrical, disk-shaped, flat, oval, or spheroid. Threads - short or long, varying thickness and color. Films - irregular in shape, thin, flexible, and usually transparent, unlike fragments. Foam - irregular shapes. Microplastics may also show signs of erosion, ranging from fresh and intact to incipient changes such as cracks, irregular surfaces, jagged fragments, linear fractures, and subparallel ridges.

A Zeiss Axiocam ERc 5s microscope was used for the visual identification of microplastics, while an Olympus BX51 optical-fluorescence microscope was additionally used for the evaluation of sample morphology. Detectable microplastic particles were quantified and categorized. During visual inspection, samples were stored in sealed Petri dishes to prevent contamination, and all visible microplastics were recorded. The size of each microplastic particle was determined. Dry filters are examined under a microscope at 4.5x magnification. Covered filters were dried for 24 hours at room temperature.

### *Particle and texture lifting*

Most microplastic particles are somewhat flexible and do not break when pushed. Tweezers allow researchers to separate them into separate sides. Microplastic particles will often bounce or wobble when pushed. If an object breaks when touched, it is not considered microplastic. A study was conducted on filters loaded with a large number of debris. Detritus and salts can cover pieces of microplastics or make them difficult to see. Debris is carefully picked off and removed to assess each microplastic particle.

Quality control for sampling and counting microplastics (MPs) in river water ensures accurate and reliable data collection. It involves several key steps:

- Standardized sampling protocols: Using consistent methods, such as net-based or pump filtration, to minimize variability.
- Contamination prevention: Avoiding plastic equipment and ensuring clean handling procedures to prevent sample contamination.
- Replicates and blanks: Collecting duplicate samples and blank controls to identify potential errors.
- Calibration and validation: Regularly calibrating instruments and validating analytical techniques like FTIR or Raman spectroscopy.
- Data consistency checks: Comparing results across different sampling events to ensure reproducibility.

In this study, the first and second steps were used for quality control.

### *Simulation of microplastic movement in water flow with the ANSYS program*

In the selected Euler–Lagrange method, the fluid is treated as a continuum in which the Navier–Stokes equations are solved, while the discrete phase is handled by tracking particles, droplets, or bubbles. The Eulerian model was selected because it has several advantages when simulating microplastic movement in surface water using ANSYS. The Eulerian model treats the dispersed phase (microplastics) as a continuous field, rather than tracking individual particles. Unlike Lagrangian methods, which require calculating the trajectory of each particle, the Eulerian approach solves transport equations for concentrations. This makes it more efficient, especially for modeling microplastic dispersion across large domains. In scenarios where microplastic concentrations are relatively high, the Eulerian method also avoids particle clustering issues that can occur with Lagrangian methods. Additionally, because the Eulerian model aligns with fluid dynamics simulations, it integrates well with models of river flow, turbulence, and sediment transport, enabling more accurate predictions of how microplastics interact with the water column.

### *Scalability for Environmental Studies*

For large-scale environmental modeling, Eulerian models offer a practical approach to simulate pollution dispersion over extended time periods without incurring excessive computational costs (Babajamaaty et al. 2023, Akdogan et al. 2023, Travaš et al. 2021, Kim et al. 2023).

The Eulerian multiphase model is well suited for simulating microplastic transport in aquatic environments, especially when implemented in ANSYS Fluent. Its effectiveness is supported by both its theoretical advantages and practical applications demonstrated in recent scientific literature.

#### *1. Appropriate for High Particle Concentrations*

The Eulerian model treats each phase (fluid and particles) as interpenetrating continua. This approach is particularly useful for simulating microplastic pollution in urban rivers, where particle concentrations can be high. Unlike Lagrangian approaches, which track individual particles and become computationally intensive at large scales, the Eulerian model allows for efficient and stable simulation of bulk particle-phase behavior (Quyen et al., 2024).

#### *2. Integration with ANSYS Fluent*

ANSYS Fluent offers robust support for Eulerian-Eulerian multiphase flow modeling, enabling the simulation of momentum exchange, drag forces, and the settling behavior of

**Table 2.** The input data

| Outfall | Particles/ hour | Particle count (normalized) | Total mass (kg) |
|---|---|---|---|
| 1 | 37.525 | $5.45 \times 10^{-10}$ | $1.32 \times 10^{-17}$ |
| 2 | 4.200 | $1.31 \times 10^{-7}$ | $2.78 \times 10^{-18}$ |
| 3 | 4.198 | $6.50 \times 10^{-8}$ | $1.10 \times 10^{-17}$ |

microplastics. The modeling approach is particularly effective when combined with tools such as the Rosin-Rammler particle size distribution, which allows for a realistic representation of polydisperse microplastic flows (Madsen & Khawaja, 2018).

*3. Proven Use in Similar Contexts*

Recent research has applied the Eulerian model to simulate microplastic behavior in estuarine and riverine systems, capturing processes such as particle accumulation, resuspension, and vertical transport. These studies demonstrate the model's versatility under complex hydrodynamic conditions and its suitability for urban freshwater systems like the Vilnelė River (Kaimathuruthy et al., 2025).

In conclusion, the Eulerian model is a technically and scientifically justified choice for modeling microplastic transport in flowing water. Its integration with ANSYS Fluent, along with support from current modeling practices, reinforces its effectiveness for environmental applications.

Microplastic size was selected using the Rosin-Rammler distribution, which provides a realistic approximation of particle size variation within a continuous distribution. This approach is commonly applied in multiphase flow simulations, where particle heterogeneity significantly influences transport dynamics. To define the discrete phase, the following Rosin-Rammler parameters were applied:

- Spread parameter (n): Increased from the default value of 6.9 to 9.6, as recommended in the modeling software guidelines, to improve particle size resolution based on observed experimental results.
- Diameter parameters (m):
- Minimum Diameter (m): $3.5 \times 10^{-5}$ to $7.0 \times 10^{-5}$;
- Maximum Diameter (m): 0.000748 to 0.0014;
- Mean Diameter (m): 0.000404 to 0.000748.

This distribution spans particle sizes from 35 µm to 1.4 mm, encompassing both small microplastics and larger particles typically observed in stormwater runoff (Liu et al., 2019; Kay et al., 2018). Three stormwater outfalls were included as discrete microplastic input sources. For each outfall, input data were defined by total mass, particle count, and emission rate per hour ( le 2).

The selected particle size distribution and emission parameters were incorporated into the hydrodynamic model as a discrete phase to simulate microplastic transport under flow conditions representative of the Vilnelė River in Vilnius. While particle density and shape effects were simplified by assuming spherical particles, the application of Rosin-Rammler model introduced realistic size variability, enhancing the model's predictive capability (Ghadiri et al., 2011). This modeling approach enabled the identification of potential accumulation zones and downstream dispersion patterns, contributing to the detection of pollution hotspots and supporting mitigation strategies in urban river systems.

The hydrodynamic regime plays a critical role in microplastic transport and distribution, especially in small, seasonally variable urban rivers such as the Vilnelė.

In our model, flow velocity measurements were conducted using the floating object (float) method, which yielded an average discharge rate of approximately 3.2 m³/s in the study section. This value served as an input for flow boundary conditions in the hydrodynamic simulation.

However, we acknowledge that certain hydrological features were not explicitly included in the model:

- The longitudinal slope of the river, which can reach up to 0.4% in the lower reaches (Darnu Group, 2021), was not incorporated.
- Aquatic vegetation, which significantly alters the river's roughness and flow resistance during growth periods (Sand-Jensen, 1998), was also excluded at this stage of modeling.

These omissions may affect the accuracy of flow dynamics and particle transport, especially during spring and summer, when vegetation density increases and flow pathways are altered. In future modeling stages, we plan to incorporate these factors by including dynamic vegetation cover and spatially variable bed slope data.

Nonetheless, the simulation aimed to assess first-order microplastic dispersion patterns under representative steady flow conditions. The main hydrodynamic input—average discharge—was derived from in situ measurements. The model outputs reflect potential transport and accumulation areas during typical high-flow scenarios, such as those observed in autumn rainfall or spring snowmelt (Van Emmerik and Schwarz 2020). Additional hydrological regime data of the Vilnelė River are presented in Table 3.

**Table 3.** The hydrological regime data of the Vilnelė River

| Season | Average Discharge (m³/s) | Water Level Fluctuations | Factors affecting the hydrological regime |
|---|---|---|---|
| Spring | 6.0–8.0 | High (up to +1.3 m) | Snow and ice melt; increased surface runoff |
| Summer | 2.5–4.0 | Low (up to –0.9 m) | Lowest discharge; aquatic vegetation may affect flow |
| Autumn | 5.0–6.5 | Rising | Autumn rainfall; elevated runoff levels. |
| Winter | 3.0–5.0 | Variable | Ice cover formation; possible ice drift. |

The following data were used to describe the discrete phase. To define the discrete phase, the following Rosin-Rammler parameters were applied:

- Spread parameter (n): Increased from the default value of 6.9 to 9.6, as recommended in the modeling software guidelines, to improve particle size resolution based on observed experimental results.
- Diameter parameters (m):
  - Minimum Diameter (m): $3.5 \times 10^{-5}$ to $7.0 \times 10^{-5}$,
  - Maximum Diameter (m): 0.000748 to 0.0014,
  - Mean Diameter (m): 0.000404 to 0.000748.

Mass and energy are exchanged between the continuum and discrete phases. Depending on the modeling approach, particle–particle interactions may or may not be included in the simulation. Neglecting these interactions simplifies the method and reduces computational time. This method assumes that the discrete phase has a low volume fraction, although the mass loading can still be high. Since each particle is tracked individually, the model allows for post-processing, including visualization of the trajectory t of specific particles over space and time. Particle trajectory prediction is made possible by integrating the force balance on each particle within a Lagrangian frame of reference (ANSYS Fluent Tutorial Guide, 2017). The force balance can be expressed as:

$$\frac{d\,\overrightarrow{u_\rho}}{dt} = \frac{\vec{u}-\overrightarrow{u_\rho}}{\tau_\gamma} + \frac{\vec{g}(\rho_\rho-\rho)}{\rho_\rho} + \vec{F} \qquad (1)$$

Where:

$\vec{u}$ – local velocity of the liquid phase,
$\overrightarrow{u_\rho}$ – velocity of particles,
$\rho_\rho$ – density of particles,
$\rho$ – density of the continuum phase,
$\vec{F}$ – additional force term,
$\frac{\vec{u}-\overrightarrow{u_\rho}}{\tau_\gamma}$ – Drag force per unit mass of particles.

### *Model selection*

The Eulerian model was selected to evaluate the movement of solid particles in the water. The inlet and outlet of the water flow, along with simulation grid, are presented in Fig. 3.

The arrows in the figure on the right indicate outlets, while the arrows on the front indicate water flow. Red arrows indicate flow exiting the module. Inlets A, B, and C are used for supplying microplastics, while separate inlet and outlet boundaries are defined for water flow. All other surfaces are assigned wall boundary conditions.

The boundary conditions are as follows:
X-axis – 131.04 m, Y-axis – 294.57 m and Z-axis – 1.05 m. Total cells (elements) - 34265, and nodes - 71397.

The multiphase Eulerian model, which is suitable for modelling continuous-continuous flow, was selected for the calculation. The model's main parameters are entered by selecting water and microplastic fluids with water acting as the carrier fluid. A discrete phase was created, labeled solid, and the Granular option was enabled to incorporate solid phase interactions. The calculation characteristics of the model were changed by selecting granulation parameters. The Gidaspow model was selected to represent solid density, as it is appropriate for fluidized bed applications. This model was combined with the Syamlal-O'Brien resistance model. The laminar nature of the flow is selected. This selection allows for obtaining reliable modelling results due to the convergence of the problem. The modelling area under consideration covers 131 meters in length and 294 meters in width. The discrete phase was determined by selecting the parameters of the input flow. The input flow of microplastics is determined by specifying its location in the calculated space. Also, the speed of microplastics in the water flow was indicated, which was set at 1 m/s. The time selected for calculating the flow parameters was set at 1 hour, which is sufficient to observe the transport and accumulation of microplastics in the entire model area.

The Rosin-Rammler model was selected for the distribution of microplastic particles in the inflow. This approach allows the flow of microplastic particles to be introduced into the model, considering the size distribution of plastic particles. The decomposition parameter increased from 6.9 to 9.6, in accordance with the user guide recommendations. A constant plastic density was selected for the simulation of the distribution of microplastic flow, which corresponds to polyethylene (PE) since this plastic was predominant in experimental study data. The water flow boundary conditions were derived from data provided by the Lithuanian Hydrometeorological Service. Although the river's slope, which can reach 0.4% downstream, was not considered during the simulation, the riverbed geometry was reconstructed using Geoportal data, reflecting elevation variations between 0.4 and 0.8 m.

In the calculations, the average velocity of the river flow in the selected section was 3.2 $m^3/s$, based on field measurements using the float method. At the outflow boundary, the pressure was set to 0 Pa, allowing for free outflow but does not estimate the velocity changes, which are calculated based on the initial

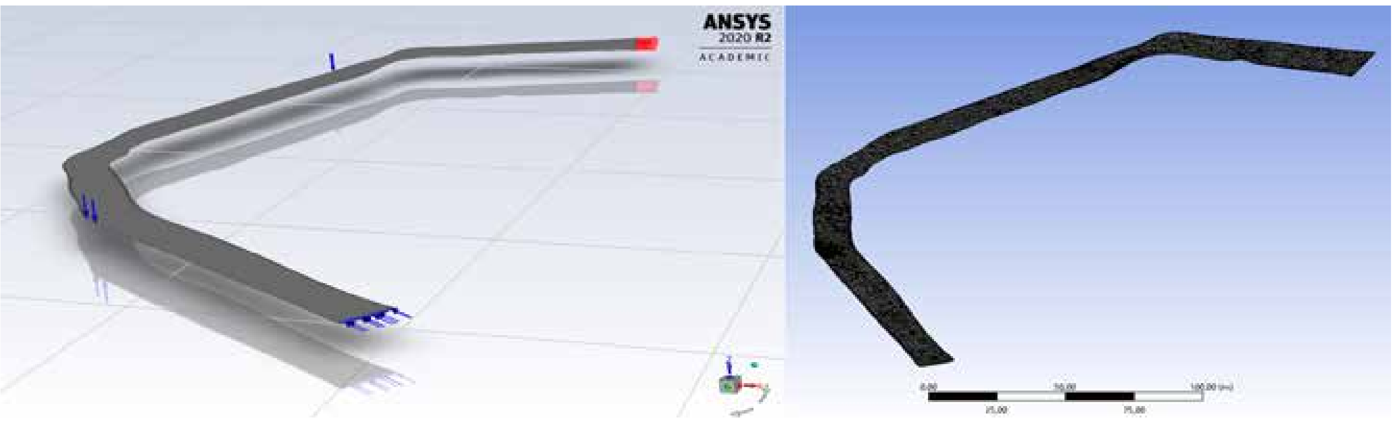


**Fig. 3**. The Inlet, the outlet of water flows and the simulation grid

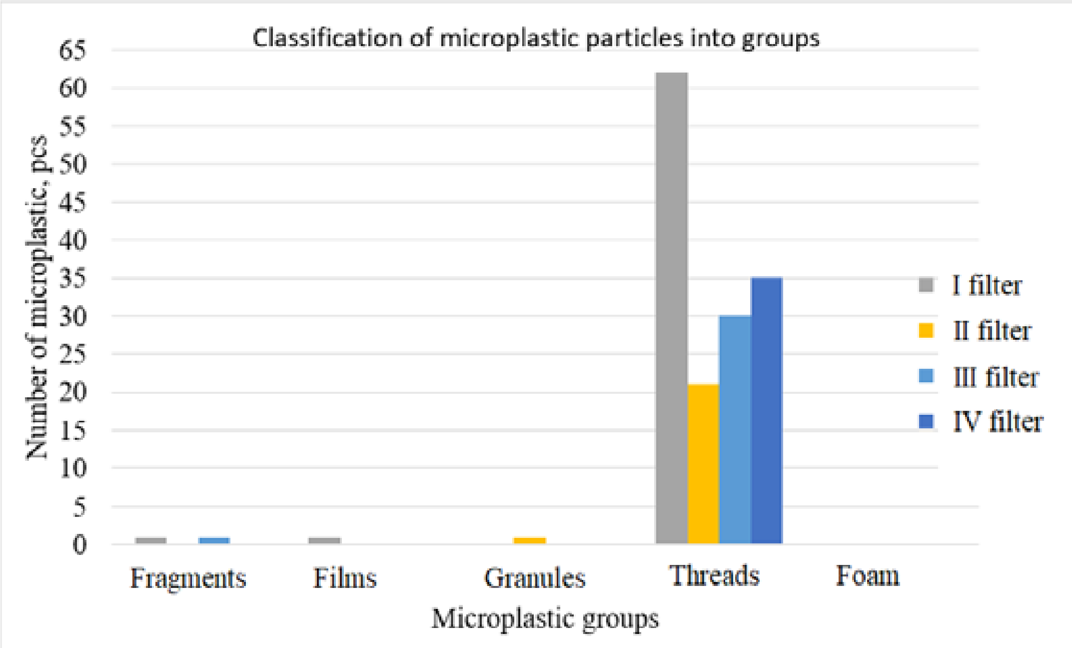


**Fig. 4.** Grouping of microplastic particles

boundary conditions of the water flow. In the calculation parameters window, the parameters that control the calculation process were selected. In the calculation settings, a time step of 0.01 seconds was selected, with up to 10 repeated calculations performed (the specified number is equal to 10). Before calculation, all fields are subjected to an initialization-checking process, which can introduce errors and cause the model to produce inaccurate results. The progress of the calculation and the process of convergence of the problem result are monitored in the results window.

If the problem does not converge sufficiently, it is concluded that the obtained data is not sufficiently accurate. In such cases, it is necessary to increase the number of iterations, reduce the calculation step, and perform the simulation again.

### *Identification of the microplastic group*

The determination of the microplastic group is presented in Fig. 4.

The dominant group of microplastics identified in all filters was threads. In filter I, 62 threads were found along with 1 fragment and 1 film. Filter II contained 21 threads werand 1 granule type of microplastic. Filter III had 30 threads and 1 fragment, while filter IV contained 35 threads (Fig. 4).

The study performed descriptive statisticsand presented the data in graphs, showing the predominant types and sizes of particles in the sample. Due to the potentially high spatial variability of microplastics, the evaluation of plastic concentrations in the environment is very important. In this study, water samples from the Vilnelė River were collected in a relatively small area, so their representativeness for a larger area should be interpreted with caution.

However, the presence of microplastics at all sampling sites indicates that the Vilnelė River in the study area may be highly contaminated with microplastics. During the studies of the Vilnelė River, using a filtering system and a visual identification method, relatively small microplastics, ranging from 0 to3 mm in diameter, were found to predominate.

The research results obtained from the samples in the Vilnelė River and nearby pollution sources (dischargers) were compared globally with the data obtained by other scientists. For example, a study conducted by Indian scientists on the Netravathi River in tropical India, which flows into the Arabian Sea, found microplastics in all samples, with an average numerical abundance of 288 particles/m$^3$. At each sampling site, ~125 L of water were collected from the upper 50 cm water column along the river banks.

Fibres, films, and fragments were the main groups of microplastics recovered from the river basin. Polyethylene (PE) and polyethylene terephthalate (PET) polymers were found to be the most abundant.

However, the statement regarding the dominance of PE and PET was not based on direct spectroscopic measurements (e.g., FTIR or Raman spectroscopy) and should therefore not be interpreted as a confirmed analytical result. In this study, we did **not conduct polymer-specific identification** of microplastic particles. The assumption regarding the presence of PE and PET was based on two key factors:

1. Literature evidence, which consistently reports PE and PET as the most commonly occurring polymers in urban freshwater environments and stormwater runoff, due to their widespread use in packaging and synthetic textiles (Ziajahromi et al., 2017; Dris et al., 2016).
2. Textile-related origin of fibers, which are typically composed of PET or PE-based synthetic materials, especially in urban runoff and domestic sources (Napper & Thompson, 2016). Without chemical confirmation, such statements remain speculative. The original claim must therefore be revised to clarify that it represents a hypothesis based on literature and contextual knowledge, not on direct material analysis. Future research will include polymer identification techniques such as µ-FTIR to confirm the particle composition and improve the accuracy of polymer classification.

The breakdown of larger plastics from mismanaged solid waste and the washing of clothes are the main sources of

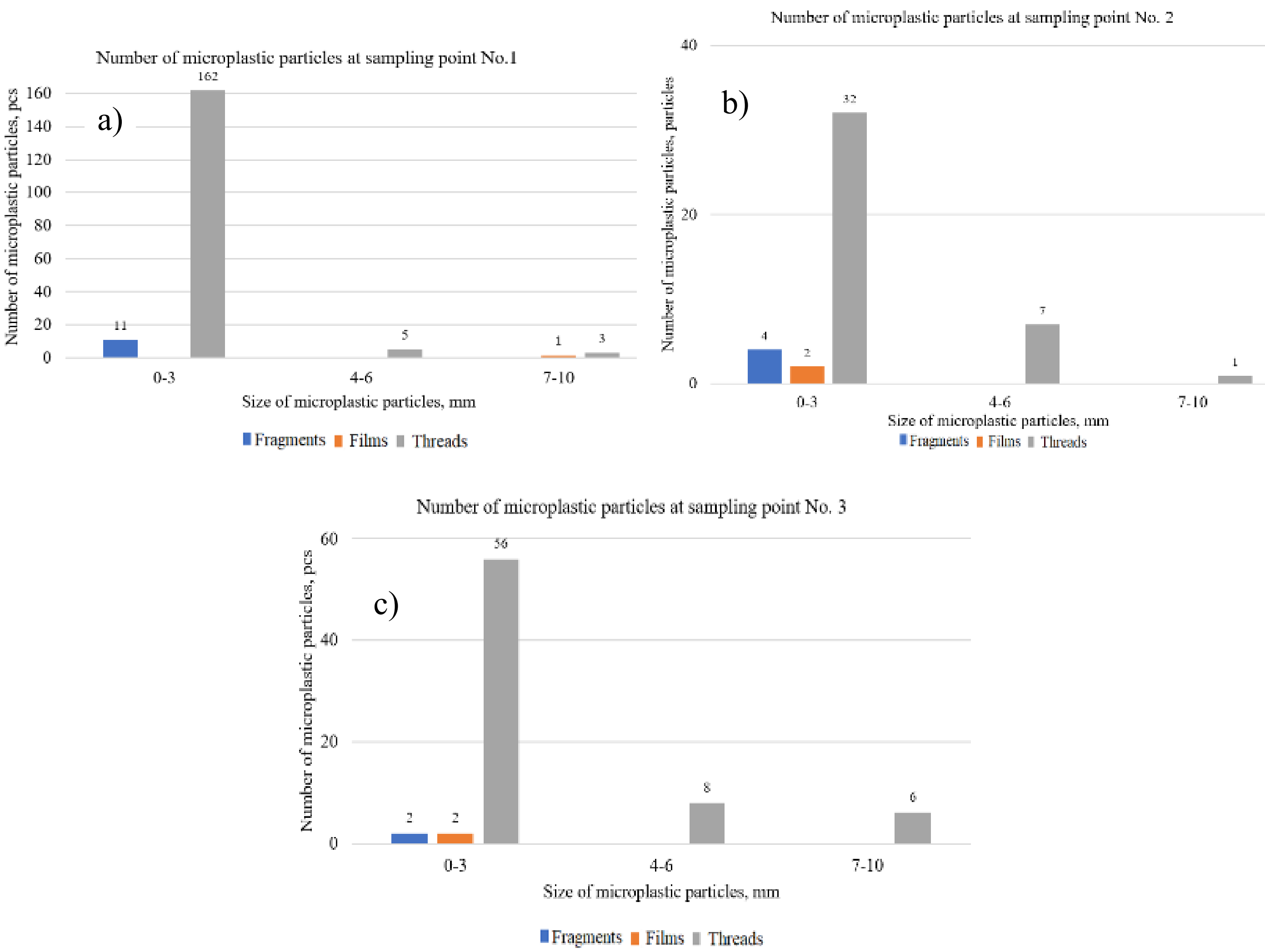


**Fig. 5.** Test results: a – first sampling site, b – second sampling site, c – third sampling site

these materials in the river basin. Sampling sites near major pilgrimage centres, such as Dharmasthala and Subrahmanya, recorded higher concentrations of fibres released from laundry activities (Amrutha and Warrier, 2020).

Another study was conducted on the Sina River in southern Brazil, where the river water contained an average of 330.2 plastic particles/L. Fibres were the most abundant form of microplastic particles in the samples. The predominance of fibres suggests that untreated washing machine runoff may be a major source of pollution in the Sina River, especially in the upper reaches. In comparison, 123 particles/L were found in Lake Taihu, China. In the French river Seine, 3 particles/m$^3$ were found (Ferraz et al., 2020). One American lake in Ontario recorded 0.8 particles/L, while Red Hills Lake in India showed 5.9 particles/L (Wang et al., 2022). Test results from the current sampling sites are presented in Fig. 5. (Fig. 5a – first sampling site, Fig. 5b – second sampling site, Fig. 5c – third sampling site).

Threads were the predominant type of microplastic, accounting for 95.51% (170 particles) of the first sample, compared to irregular fragments and films in the sample. Fragments comprised 3.93% (7 particles), while films made up only 0.56% (1 particle) (Fig. 5a). Based on the particle size distribution, the majority of microplastics were small particles, measuring between 0-3 mm. These relatively small particles from 420 L of filtered water, represent 94.94% (169 particles) of the total. In contrast, largest particles measuring 7-10 mm accounted for only 2.25% (4 particles), and those in the 4-6 mm range made up 2.81% (5 particles).

The first filter, with a mesh size of 2000 µm, retained microplastic particles ranging from 0.50 to 10.00 mm, which accounted for 45.51% (81 particles) of the total captured across all filters. The second filter, with a mesh size of 841 µm, retained microplastic particles between 0.50 and 7.0 mm, which accounted for 12.36% (22 particles). The third filter, with a mesh size of 400 µm, captured 0.20-3.0 mm particles, which accounted for 26.40% (47 particles).

The smallest diameter filter, with a mesh size of 250 µm, retained particles of 0.20-10.0 mm, which accounted for 15.73% (28 particles). A film measuring 10 mm in length and 4 mm in width was retained by the first filter and did not enter the further filters due to its morphological characteristics (width). It can be assumed that threads, due to their small width, can pass through filters of different mesh sizes regardless of their length.

The microplastic concentration at the first test point was $1.70\times10^{-6}$ ng/L or 0.42 particles/L. Comparing the obtained research results with data from various rivers and lakes worldwide, it was determined that microplastic pollution in the first Vilnelė

River is lower than in many other aquatic systems. Threads next to fragments were the most common types of microplastic particles (Viršek et al., 2016). The microplastics detected in this study are comparable to those reported in literature. It was observed that the dimensions of individual microplastics ranged from the smallest particle of 0.20 mm to the largest of 10 mm, with the longest edge measured for threads, films, and fragments. The average particle size in the sample was 1.42 mm.

The correlation between the first and second sampling results shows a similar predominance of threads. In the second sample, threads accounted for 86.96% (40 particles) of the total microplastic particles (Fig. 5b). Compared to the first sample, a significant change in the composition of other microplastics was observed, with fragments accounting for 8.70% (4 particles) and granules making up 4.35% (2 particles).

The obtained results showed that the majority of microplastics consisted of small particles measuring 0-3 mm. Specifically, 82.61% (38 particles) of relatively small particles were found in 420 L of filtered water. Particles sized 4-6 mm accounted for 15.22% (7 particles), while only 2.17% (1 particle) fell within 7-10 mm range.

The first filter, with a mesh size of 2000 µm, retained microplastic particles ranging from 1.0 to 6.0 mm, which accounted for 21.74% (10 particles) of the total number of microplastic particles in the sample. The second filter, with a mesh size of 841 µm, retained microplastic particles from 0.40 to 6.0 mm, representing the same proportion - 21.74% (10 particles) - as the first filter.

The third filter, with a mesh size of 400 µm, retained particles ranging from 0.04 to7.00 mm, which accounted for 39.13% (18 particles) of the total. The smallest diameter filter, with a mesh size of 250 µm, retained particles between 0.05 and2.0 mm, which accounted for 17.39% (8 particles). As the sample contained mostly threads, which are characterized by their thinness and variable lengths, the largest microplastic particle was found in the third filter (400 µm). Fragments and granules were detected in both the third filter (2 fragments) and the fourth filter (2 fragments and 2 granules). The smallest particle size recorded was 0.14 mm, and the largest one was 0.72 mm.

The concentration of microplastic particles at the second sampling site was $6.10x10^{-6}$ ng/l or 0.10 particles/L. After comparing the obtained research results with data from several rivers and lakes around the world, it was determined that microplastic pollution in the second sample of the Vilnelė River was lower compared to other rivers and lakes globally. The largest microplastic particle (a thread) was found in the third sample filter and measured 7.00 mm in size. The average particle size in the second sample was 1.93 mm. Filaments were the predominant type of microplastic, accounting for 94.59% (70 particles) of the third sample, compared to irregular fragments and films in the sample (Fig. 5c). Fragments and films each comprise 2.70% (2 particles) of the sample. Based on the particle size distribution results, it can be concluded that most of microplastics were small particles between 0 and 3 mm in size. These relatively small microplastics, from 420 L of filtered water, accounted for 81.08% (60 particles). Meanwhile, larger particles from 7-10 mm in size accounted for 8.11% (6 particles), and particles between 4-6 mm accounted for 10.81% (8 particles).

Based on the optical analysis of filters with different diameters, the first filter, with a mesh size of 2000 µm, retained microplastic particles ranging from 1.00 to 9.00 mm, accounting for 9.47% (7 particles) of the total distribution across all filters. The second filter, with a mesh size of 841 µm, retained particles ranging from 0.10 to 3.0 mm, representing 29.73% (22 particles). The third filter, with a mesh size of 400 µm, retained particles from 0.10 to8.0 mm, which accounted for 36.49% (27 particles). Finally, the smallest filter, with a mesh size of 250 µm, retained particles from 0.10 to8.0 mm, which accounted for 25.68% (19 particles).

The first filter retained a fragment that did not pass through the subsequent filters due to its morphological characteristics (the width of 3 mm).

The concentration of microplastics at the third sampling site was $9.28x10^{-7}$ ng/L, or 0.18 particles/L. After a comparing the results with data from several rivers and lakes worldwide, it was determined that microplastic pollution in the third sample from the Vilnelė River is lower than that observed in other rivers and lakes of the world.

According to literature and analysis of potential sources, threads, also known as microfibers and classified as secondary microplastics, are formed due to the wear of textiles and tires. Morphological analysis revealed that the smallest particle in the third sample measured 0.10 mm, while the largest was 9.00 mm, with an average particle size of 1.87 mm. Fig. 6 presents the results of sampling from 3 sources: (Fig. 6a – No. 2-100-261; Fig. 6b – No. 2-98-260; Fig. 6c – unmarked).

Threads were the predominant type of microplastic, accounting for 96.88% (62 particles) of the samples from releaser No. 2-100-261. The remaining portion consisted of fragments, comprising 3.13% (2 particles) (Fig. 6a). Based on the particle size analysis, the most microplastics were small particles between 0 and 200 µm. These relatively small microplastic particles, collected from 6 L of water, accounted for 76.56% (49 particles), while microplastics with a size of 201-800 µm accounted for 23.44% (15 particles).

The first filter, with a mesh size of 2000 µm, retained microplastic particles ranging from 7.00 to 534.64 µm, accounting for 28.13% (18 particles) of the total in all filters. The second filter, with a mesh size of 841 µm, captured particles ranging from 5.0 to 349.75 µm, which accounted for 18.75% (12 particles). The third filter, with a mesh size of 400 µm, retained particles between 69.59 and615.00 µm, which accounted for 21.88% (14 particles). The smallest filter, with a mesh size of 250 µm, captured between 33.43 and492.10 µm particles, which accounted for 31.25% (20 particles).

The concentration of microplastics from releaser No. 2-100-261 was $6.62x10^{-8}$ ng/L or 31.6 particles/L. When compared to microplastic pollution levels in several rivers and lakes worldwide, the concentration from releaser No. 2-100-261, discharging into the Vilnelė River, was significantly higher. For reference, the Netravathi River in India reported 288 particles/$m^3$, the Sina River in Brazil reported 330.2 particles/L, the Seine River in Francehad 3 particles/$m^3$, Lake Ontario in the United States had 0.8 particles/L, Red Hills Lake in India had 5.9 particles/L.

Strands were the most common type of microplastic particles, next to fragments. The fragments and threads observed in this study were compared with examples reported

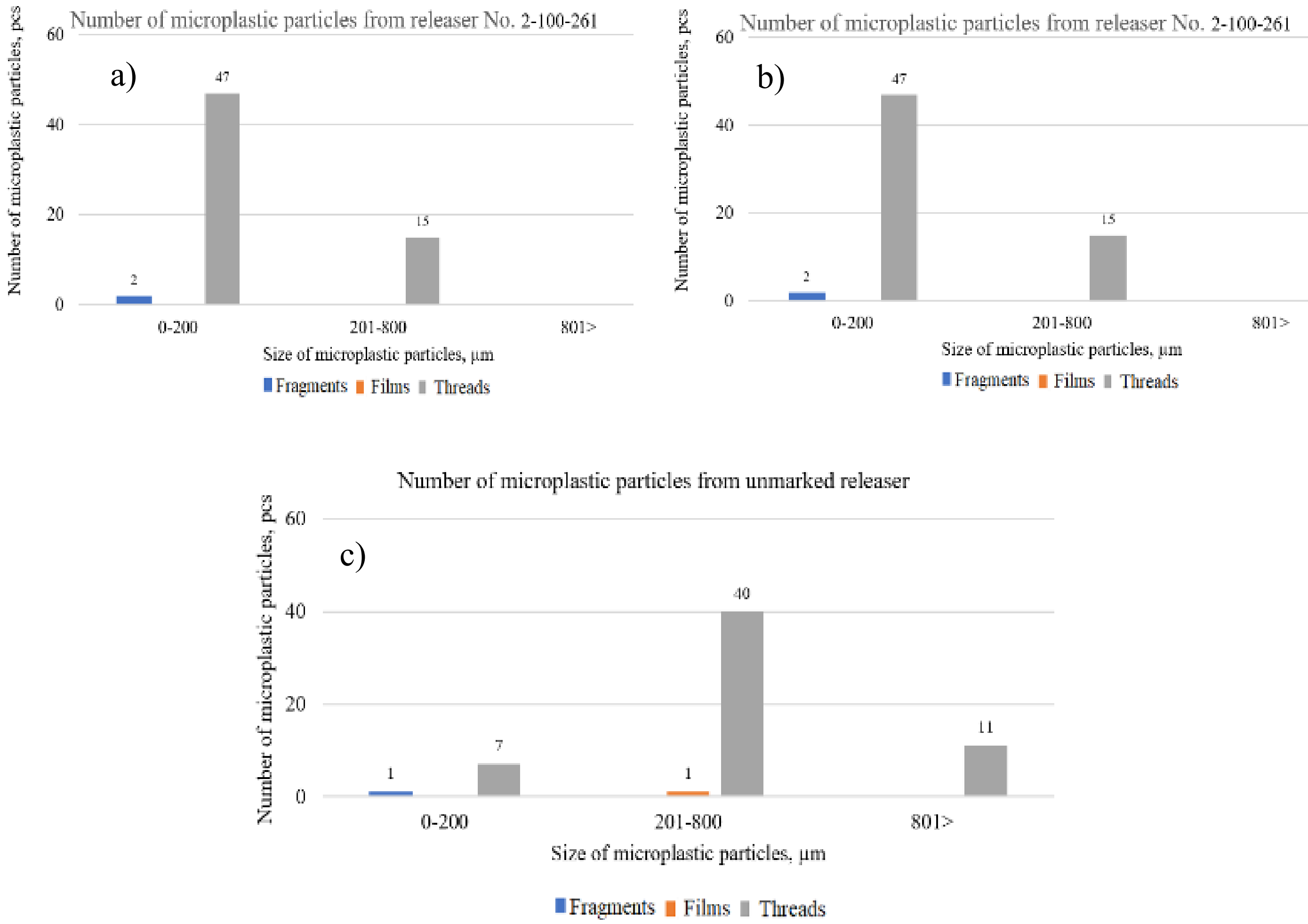


**Fig. 6.** Research results from releases: a) No. 2-100-261; b) No. 2-98-260; c) unmarked

in the literature. Analysis of the morphological characteristics from releaser No. 2-100-261 revealed that the smallest fragments measured 5 µm and 7 µm. The average particle size in the sample was 146.51 µm.

Threads were the predominant type of microplastic, which accounted for 93.68% (89 particles) of the releaser No. 2-98-260 sample (Fig. 6b). The remaining particles consisted of fragments (5.26%, 5 particles) and 1 pellet (1.05%).

Based on the particle size analysis, it was determined that the majority of microplastics ranged from 201 to800 µm, which accounted for 62.11% (59 particles) of microplastic particles found in 3 L of water. Particles between 0 and200 µm accounted for 31.58% (30 particles), while particles larger than 801 µm made up only 6.32% (6 particles).

Optical analysis using filters of different mesh sizes showed that the first filter with a mesh size of 2000 µm retained microplastic particles ranging from 50.00-1400.00 µm, which accounted for 28.13% (18 particles) of all filtered particles. The second filter (841 µm) retained microplastic particles from 35.00 to 1391.30 µm, which accounted for 18.75% (12 particles). The third filter (400 µm) captured particles between 45.20 and832.50 µm, which accounted for 21.88% (14 particles). The smallest mesh filter (250 µm) retained particles sized 40.00-621.10 µm, which accounted for 31.25% (20 particles).

The concentration of microplastics from releaser No. 2-98-260 was $2.63 \times 10^{-7}$ ng/l, or 21.3 particles/L. When compared with data obtained from several rivers and lakes worldwide, the level of microplastic pollution from releaser No. 2-98-260, discharging into the Vilnelė River, was found to be higher. For reference, the Netravathi River in India reported 288 particles/$m^3$, the Sina River in Brazil reported 330.2 particles/L, the Seine River in France reported 3 particles/$m^3$, Lake Ontario in the United States had 0.8 particles/L, and Red Hills Lake in India had 5.9 particles/L.

The smallest microplastic particle was 35.0 µm, and the largest measured 1400.00 µm. The average particle size in the sample was 399.31 µm.

As presented in Fig. 6c, filaments were the predominant type of microplastic, which accounted for 96.76% (58 particles) of the unmarked releaser sample. The remaining microplastics consisted of fragments (1.67%,1 particle) and films (1.67%, 1 particle).

Most microplastics were between 201 and 800 µm in size, making up 68.33% (41 particles) of the particles found in 6 L of water. Microplastics with a size from 0-200 µm accounted for 13.33% (8 particles), while particles larger than 801 µm accounted for as much as 18.33% (11 particles).

It can be seen that the first filter, with a mesh size of 2000 µm, retained microplastic particles ranging from 70.00 to643.53 µm, which accounted for 11.6% (7 particles) of the total across all filters. The second filter (841 µm) retained microplastic particles ranging from 200.00 to992.56 µm, which accounted for 13.33% (8 particles). The third filter (400 µm) retained particles from 100.00 to13768.00 µm, which accounted for 16.67% (10 particles). The smallest mesh filter (250 µm) retained particles ranging from 118.60 to1561.40 µm, which accounted for 58.33% (35 particles). The concentration of microplastics in the Vilnelė River from an unmarked releaser was 3.15x10$^{-7}$ ng/l or 10 particles/L.

When compared with results from other rivers and lakes around the world, it was determined that microplastic pollution from an unmarked releaser, discharging into the Vilnelė River, was higher than that reported in the Netravathi River in India (288 particles/m3), the Seine River in France (3 particles/m$^3$), lake Ontario in the United States (0.8 particles/L), and Red Hills lake in India (5.9 particles/L), but lower than that found in the Sina River in Brazil (330.2 particles/L).

Strands were the most common type of microplastic particles, followed by fragments. The fragments and threads observed in this study were compared with examples described in the scientific literature. Analysis of the morphological characteristics in the sample from the unmarked releaser revealed that the smallest microplastic particle measured 70.00 µm ( with the longest edge measured in the case of fragments), the largest measured 13768.00 µm, and the average particle size in the sample was about 748.09 µm.

### *Modelling of Vilnelė River microplastic pollution*

The distribution of microplastic particles in the flow by speed (m/s) and concentration of microplastic particles in the flow (kg/m$^3$) is presented in Fig. 7**.**

The following are the masses of microplastics released from 3 releasers over the course of 1 hour:

Releaser No. 2-101-261:
- Total microplastic particles released per hour: 37,525,
- Total units of microplastic particles: 5.449768x e$^{-10}$,
- Total microplastic mass: 1.319733x e$^{-17}$ (kg).

Releaser No. 2-101-262:
- Total microplastic particles released per hour: 4,200,
- Total units of microplastic particles: 1.309222xe$^{-07}$,
- Total microplastic mass : 2.780400xe$^{-18}$ (kg).

Unmarked releaser:
- Total microplastic particles released per hour: 4,198,
- Total units of microplastic particles: 6.498518xe$^{-08}$,
- Total microplastic mass in kg: 1.104074e$^{-17}$ (kg).

Fig. 7a shows that the velocity of microplastic particles released from the first releaser (No. 2-100-261) in the straight section near releaser No. 2-98-260 ranged from 1.8 to 2.5 m/s (at a distance of ~139.1 m). These particles primarily moved within the central flow of the river. For comparison, the total flow rate of the river was 3.2 m/s. Near terrain irregularities, where the riverbed narrows (~ 45 m distance), the flow velocity increased from 2.51 to 6.28 m/s. Considering the river profile and increased velocity near the shoreline, microplastics in this area were transported at speed ranging from 1.26 to 6.28 m/s.

At the third, unmarked releaser, the water stream with microplastics exhibited a high velocity of 6.28 m/s, which then dropped to 2.15 m/s at a distance of a few meters. A reverse flow was also observed, caused by the terrain, which temporarily reduced the river velocity before it increased again. This backflow is caused by the terrain and affects the speed of the river. Microplastics were distributed within ~2 m from the shoreline. The concentration of microplastic particles in the flow (kg/m$^3$) is presented in Fig. 7b).

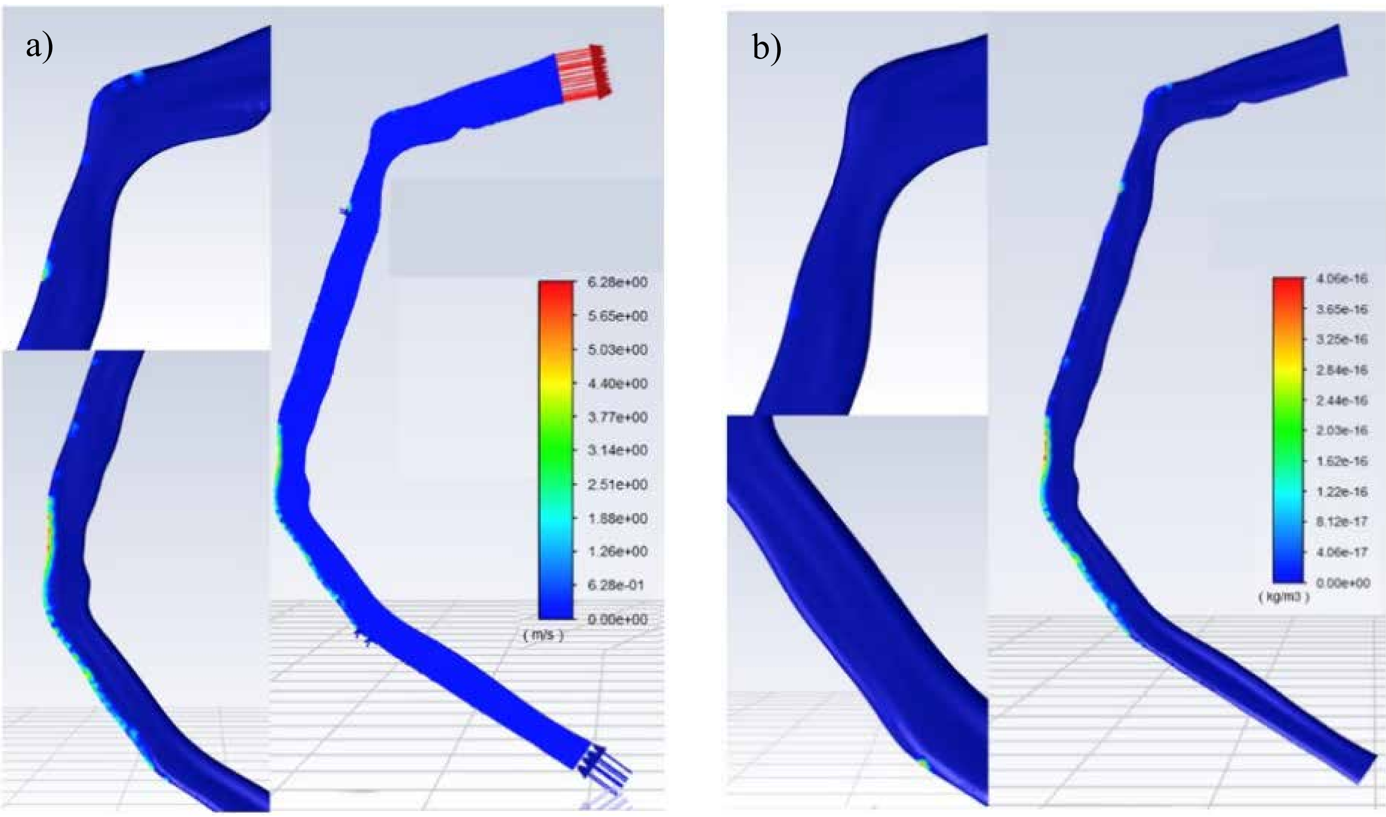


**Fig. 7.** Modelling results: a) distribution of microplastic particles in the flow by speed (m/s); b) concentration of microplastic particles in the flow (kg/m$^3$)

This exposure is indicative of microplastic concentrations in surface water. The masses of microplastics emitted from the releasers were determined to be 1.319733e$^{-17}$ (kg), 2.780400e$^{-18}$ (kg), 1.104074e$^{-17}$ (kg), respectively. It can be seen that the concentrations from releasers No. 2-100-261 and No. 2-98-260 dissipate at ~ 264.4 m, while the concentration from the unmarked outfall dissipates at ~ 132.2 m per hour. Parameters of microplastic are presented in Fig. 8: a) distribution of microplastic particles in the flow by size (m); b) flow time (s) of microplastic particles; c) distribution of microplastic particles in the stream by mass (kg).

Fig. 8a shows that in 1 hour, microplastics released from the releaser travelled a distance of ~ 418.8 m. Large microplastic particles from releasers No. 2-100-261 and No. 2-98-260 started to accumulate at a distance of ~ 48.7 m from the pollution sources and continued over the next ~ 76.6 m. In contrast, particles from the unmarked releaser travelled only ~113.8 m. For accurate research, sampling locations should be chosen as close as possible to the pollution source. Larger microplastic particles tend to move more slowly and therefore take longer to travel compared to finer particles.

**Fig. 8.** Parameters of microplastic: a) distribution of microplastic particles in the flow by size (m); b) flow time (s) of microplastic particles; c) distribution of microplastic particles in the stream by mass (kg)

From Fig. 8b**,** it is possible to estimate how long microplastics take to travel a certain distance. Small microplastics move very quickly, for instance, particles with small diameter from releasers No. 2-100-261 and No. 2-98-260 covered ~255.8 m in 3.7 s. Microplastic particles from an unmarked releaser travelled 100.5 m in 1.26 s. Near the releasers No. 2-100-261 and No. 2-98-260, the concentration of microplastics is the highest for a very short time, then the highest concentration is observed at a distance of 132.9 m from these pollution sources (Fig. 8c). The concentration of smaller particles from pollution sources extends for another 89.7 m beyond this point. For the unmarked releaser, the highest concentration of microplastics from is observed near the source of pollution at a distance of ~ 3.8 m. Further, a clear dispersion of microplastics is observed, and due to changes in terrain, particles can be detected at a distance of ~32.1 m.

Despite ANSYS's capabilities, certain challenges remain:

- Data acquisition: Accurate River flow parameters and microplastic properties are necessary for producing realistic simulations.
- Computational complexity: Large-scale simulations, particularly those involving long-term environmental modeling, require significant computational resources.
- Validation: Experimental validation is essential to ensure model reliability.

Currently, there no enough comparative data available to validate simulations of microplastic movement in river water using ANSYS program against results from other researchers.

Particle Tracking Models (PTMs) are effective tools for predicting the distribution and behavior of microplastics in water bodies. Several modeling approaches have been employed to simulate microplastic transport in river systems. GoldSim software has been used to model microplastic transport in river systems by employing mass-balance and hydrodynamic equations. OpenFOAM, a computational fluid dynamics (CFD) software, has been applied to simulate the fate and transport of microplastics in riverine systems. The WASP (Water Quality Analysis Simulation Program) model has been evaluated for its applicability in simulating microplastic concentrations in river environments. Markov Models, including continuous-time random walk and spatial models, have been used to investigate microplastic transport in open-channel flows, offering high-efficiency and effective predictions. The hydrological regime of a river plays a crucial role in the transport of microplastics. Several factors influence how microplastics move through waterways:

- **Flow velocity**: Higher flow velocities can transport microplastics over long distances, while slower flows may lead to their accumulation in sediments.
- **Seasonal variations**: Wet and dry seasons impact microplastic transport, with higher discharge rates during rainy periods increasing their movement.
- **Sediment interaction**: Depending on hydrodynamic conditions, microplastics may settle into riverbeds or become resuspended.

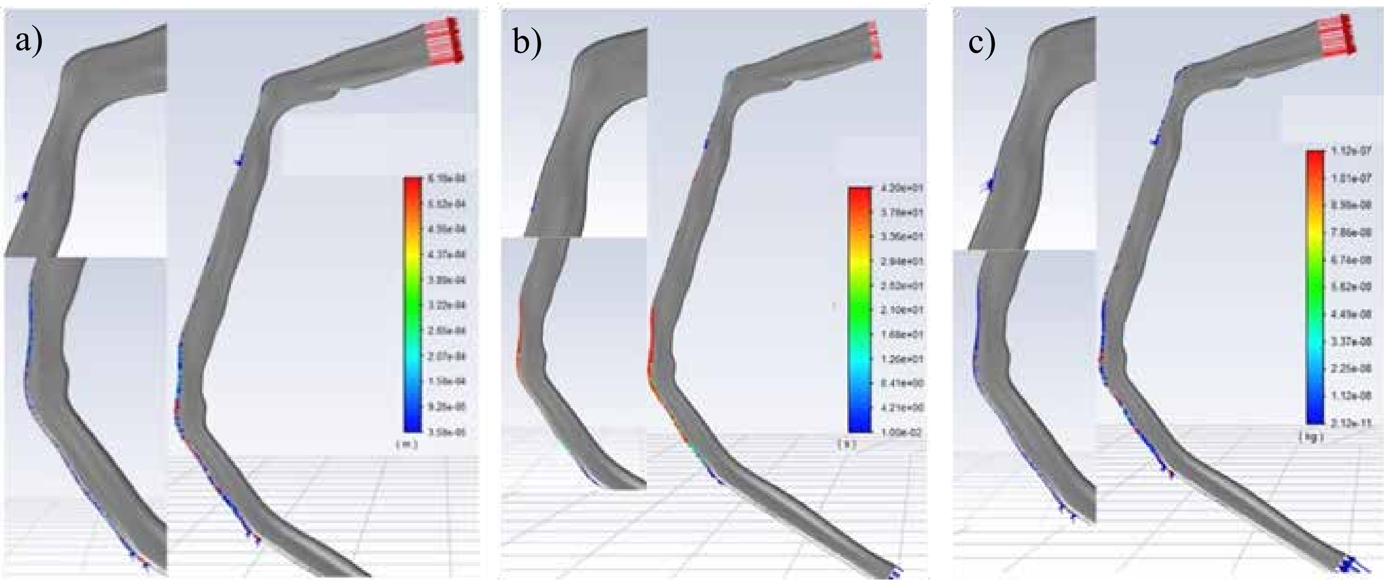


**Fig. 8.** Parameters of microplastic: a) distribution of microplastic particles in the flow by size (m); b) flow time (s) of microplastic particles; c) distribution of microplastic particles in the stream by mass (kg)

- **Tidal forces**: In estuarine environments, tidal fluctuations affect microplastic retention and export flux.
- **Pollution sources**: Inputs from surface runoff, wastewater discharge, and industrial activities contribute to the presence and distribution of microplastics in river systems.
  - Model validation using ANSYS for simulating microplastic dispersion in river water could involve comparing simulated results with experimental data to ensure accuracy. The validation process would assessi hydrodynamic behavior, particle transport, and accumulation zones, refining model parameters for better predictions.
  - The permissible error between modeling and experimental results may range from 20% to 50%, based on verbal assessments by environmental protection specialists. This variation depends on factors such as pollutant concentrations, model complexity, and the nature of the enviromental processes being assessed. It is important to note that riverine flow is turbulent, making exact correspondence between modeling and experimental data challenging. While the model effectively visualizes general trends in the microplastic dispersion in river water, it is not suitable for precise assessment. Aa such, this model has not been validated, and the error margin between modeling results and experimental data has not been assessed.

## Discussion

Recent European studies have documented the extent of micro- and nanoplastic pollution in rivers receiving treated and untreated wastewaters. Typical microplastic concentrations in European rivers are on the order of tens of particles per cubic meter (Gao et al. 2024). A 2025 survey of major rivers (Thames, Rhine, Danube, etc.) found MPs present in all cases, with a mean concentration of only ~3 particles/m³ (‚Alarming' microplastic...2025). However, this value reflects only larger microplastics (>500 µm) and likely underestimates the abundance of smaller particles. In more urbanized stretches, concentrations tend to be higher. For instance, the River Thames in London contained about 19.5 microplastics per cubic meter of water, exceeding levels in many other European rivers (Microbeads and glitter...2020). Moreover, extreme localized values reaching thousands of particles per cubic meter have been reported near certain pollution sources (e.g., up to ~2072 p/m³ in a tributary of the Elbe, Germany) (Gao et al. 2024). In Lithuania and neighboring Baltic countries, where research on freshwater microplastics is emerging, recent measurements have likewise revealed substantial MP loads. Surface water samples collected near municipal outfalls in Klaipėda and Šiauliai (Lithuania) contained, on average, 16.6 ± 20.3 particles/L (≈16,630 particles/m³) of microplastics (Pashaei et al. 2023).

These levels are comparable to those found in Latvia (e.g., Daugavpils, Liepāja) under similar conditions (Pashaei et al. 2023). Notably, seasonal differences have been observed in some regions. For example, an urban tributary in Athens (the Kifissos River) showed MP concentrations rising from ~8 p/m³ during dry summer conditions to ~28 p/m³ during winter high-flow (wet weather) events (Zeri, et al. 2021). This suggests that rainfall-driven runoff and combined sewer discharges can significantly elevate microplastic loads in rivers (Zeri, et al. 2021).

Microplastic characteristics in urban waters provide clues to their origins. Studies consistently find that fibers and fragments are the dominant shapes, whereas microbeads (from cosmetics) are comparatively rare (Pashaei et al. 2023). For example, over90% of MPs in the Thames were identified as fibrous or film fragments derived from the breakdown of consumer plastics (Microbeads and glitter...2020). Likewise, surface waters in Lithuania were overwhelmingly contaminated by fibers (~95% of particles) rather than fragments (Pashaei et al. 2023). Fibers primarily originate from synthetic textiles (released via laundry and WWTP effluent) and from fishing or industrial sources, whereas fragments and films often come from degraded packaging, bags, and other plastic litter (Gao et al. 2024). The polymer composition of microplastics in rivers tends to reflect these sources. Polyolefins such as polyethylene (PE) and polypropylene (PP) – common in packaging – are frequently reported as major components of MP assemblages in European rivers (Gao et al. 2024). For instance, MP fragments in the Thames were largely composed of PE/PP (Gao et al. 2024) and a Lithuanian study found significant fractions of PET (polyester) and PVC alongside nylons in its samples (Pashaei et al. 2023).

Nanoplastics are even more challenging to measure, but advances in spectroscopy have indicated that sub-micron plastics vastly outnumber larger particles both in mass and count (‚Alarming' microplastic...2025). Overall, the literature shows that municipal effluents and runoff are key pathways bringing diverse plastics (from clothing fibers to packaging films) into urban rivers (*Zeri, et al. 2021).* Given that even small water bodies can accumulate high MP concentrations (sometimes higher than those in large rivers due to less dilution, Büngener et al. 2024), monitoring and mitigating these point sources is critical. Table 4 below summarizes recent findings on micro- and nanoplastic pollution in European urban rivers – with an emphasis on the Baltic region (Lithuania) – including concentrations, source flows, and plastic characteristics reported.

## Conclusions

Following a visual assessment of microplastic samples and based on statistical evaluation, it was found that the microplastic concentration at the first test point of the Vilnelė River was 0.42 particles/l, at the second point - 0.10 particles/l, and at the third test point - 0.18 particles/L. From an unmarked releaser, the microplastic concentration was 10 particles/L. In releaser No. 2-100-261, 21, the concentration was 3.0 particles/L, while in releaser No. 2-98-260, it reached 31.6 particles/L.

After comparing the obtained results with those from several rivers and lakes worldwide, it was found that microplastic pollution in the Vilnelė River is generally lower than in other rivers and lakes selected for comparison. Synthetic polymer microplastics were the dominant type detected; however, this conclusion was not sufficiently supported by analytical data. Upon further review, we acknowledge that this claim is unsubstantiated and will be removed to avoid misleading conclusions.

In this study, microplastic particles retained on filters were examined visually under a Zeiss Axiocam ERc 5s microscope.

**Table 4.** Recent findings on micro/nanoplastic pollution in European urban rivers

| *City (River)* | MP Concentration | Seasonal Variation | River Discharge | Effluent Discharge | Morphology of MP | Polymer Types (% share) | Reference (APA) |
|---|---|---|---|---|---|---|---|
| *Klaipėda, LT (Curonian Lagoon outlet) – urban WWTP effluent into lagoon* | ~16.6 ± 20.3 particles/L (surface water and effluent, July & Dec 2021) ≈ 16,630 particles/m³ | Summer vs. winter (2021) – two sampling campaigns (July, Dec) showed no significant overall difference in MP abundance. | Not reported (lagoon estuary; mixing zone) | Not reported (Klaipėda WWTP, serves ~150k population) | Fibers ~95%, Fragments ~5% of particles. Fibers mostly blue/black in color. | PET ~33%, PVC ~33%; also Nylon ~12%, Polyester (PS) ~11%, HDPE ~11%. (Composition via μ-Raman analysis) | Pashaei et al. (2023) – Toxics, 11(4), 292. |
| *Athens, GR (Kifissos River) – urban stream with combined sewer inputs* | 27.7 particles/m³ (high-flow winter rain) vs 8.11 particles/m³ (low-flow summer); values for >100 μm MPs. | Marked seasonal/ flow effect: higher MP concentrations in wet winter (runoff event) ~3.4× the summer low-flow level. Winter sampling (Dec) had flood conditions; summer (July) much lower flow. | Ephemeral. High-flow event in winter; low base flow in dry season (not quantified). | N/A (two municipal WWTPs upstream; combined sewer overflows during rain) | Films dominated in winter (~90% of MPs); films ~56–59% in summer, with remainder filaments (20–30%) and fragments (3–17%). Very few foams or pellets. | Polyethylene (PE) ~94% and polypropylene (PP) ~6% in winter high-flow sample. In summer and in a less urban river nearby, more varied polymers (PE ~56%, plus polyvinyl acetate 18%, PP 11%, etc.). | Zeri et al. (2021) – Sustainability, 13(10), 5328. |
| *London, UK (Thames River) – large urban river with multiple WWTP inputs* | 19.5 particles/m³ in surface water (tidal Thames at Greenwich); ~94,000 microplastic particles/second flowing downstream (estimated flux). (MP >~50 μm; fibers excluded in this count) | No pronounced seasonal analysis in study (sampling covered various tides). Consistently polluted year-round; comparisons show Thames MP density exceeds other major EU rivers. | ~70 m³/s (tidal freshwater flow at sampling site) – moderate river flow, but tidal influence present. | Numerous WWTP effluents along Greater London; also storm drain outfalls (intermittent). Individual effluent flows not detailed (combined impact reflected in river). | Fragments & films >90% of observed MPs (from breakdown of bottles, wrappers, bags). Fibers were abundant in watershed but largely not counted in the 19.5 p/m³ figure. Wet wipes and sanitary fibers accumulate on riverbanks (local hotspots). | Polyolefins dominate: mainly PE and PP in fragments/films, consistent with packaging litter. (Microfibers, mostly polyester/ PA, accounted for ~79% of MPs in a separate study of the Thames Estuary but were excluded from the count above). | Rowley et al. (2020) – Sci. Total Environ., 740, 140018. |
| *Braunschweig, DE (Oker River) – small river (pop. ~250k catchment) with 2 WWTPs and storm outfalls* | 28–134 particles/m³ (range along river; mean ~63 particles/m³) in water column (0.3–5 mm size fraction). Higher concentrations observed downstream of urban areas and discharge points. | Some temporal variability (multiple surveys) but spatial variation dominates: urban sections and downstream of point sources show elevated MP levels compared to rural upstream. Seasonal effect not highlighted (study suggests constant inputs from WWTPs/runoff). | ~5–10 m³/s (small lowland river; flow not given, but much lower dilution capacity than large rivers). | WWTP I: serves ~90k PE; WWTP II: ~130k PE (approx.). Both secondary treatment (no tertiary filtration). One urban stormwater sewer (“Rain”) outfall also studied. Effluent flow rates: WWTP I ~0.15 m³/s; WWTP II ~0.20 m³/s (estimates). | Mixed fibers and fragments – no clear longitudinal trend in type proportion. Point-source influence: at one WWTP outfall, fibers were predominant; at another, fragments dominated, reflecting differences in source inputs. Overall river samples contained both, with site-specific variability. | Varied; polyethylene and PP were common (as in other Central European rivers). One study in a German river (Elbe) found ~50% PP and ~17% acrylate plastics in water, indicating a high share of packaging and synthetic fibers – similar plastics likely present in Oker. (Detailed polymer data for Oker not reported apart from indicating similarity to other rivers.) | Büngener et al. (2024) – J. Contam. Hydrol., 264, 104366. |

When available, morphological characteristics were further evaluated using an Olympus BX51 optical-fluorescent microscope. Particles were visually compared to reference images found in the literature (Pervez et al., 2020), and classified by physical characteristics such as color, shape, and texture, in accordance with established microplastic analysis protocols (Viršek et al., 2016). However, no spectroscopic or chemical analyses (e.g., FTIR or Raman spectroscopy) were performed to verify the polymer composition of the particles. Therefore, any statements regarding the dominance of synthetic polymer microplastics are not scientifically justified in this context. We will revise the manuscript and remove this statement in the final version. This correction aligns with good scientific practice, especially in studies relying on visual identification, where uncertainties in polymer composition remain significant without spectroscopic confirmation (Hidalgo-Ruz et al., 2012).

Microscopic studies helped to assess the nature of microplastic pollution in the Vilnelė River. Microfiber contamination was observed on all filters used in the study. Notably, microfiber particles tend to bypass filters due to their small diameter and low surface area. The majority of microfibers were retained by the first filter, which had a mesh size of 250 micrometers. The retention efficiency of microfibers in subsequent filters was lower than 50%, but gradually increased as the filter mesh size decreased from 2000 to 400 micrometers.

Following the numerical modelling of microplastic pollution in Vilnelė River water, the resulting models, featuring identified pollution sources, show how far microplastic particles can be transported within 1 hour. These models help identify suitable locations for future microplastic sampling, enable predictions of pollution levels, and provide a reproducible framework for other researchers to repeat the experimental procedures.

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