RESEARCH PAPER

MICROPLASTIC ABUNDANCE IN VOLGA RIVER: RESULTS OF A PILOT STUDY IN SUMMER 2020

Anastasia A. Lisina[1*], Maxim M. Platonov[2], Oleg I. Lomakov[2], Alexey A. Sazonov[1], Tatiana V. Shishova[2], Anna K. Berkovich[3], Natalia L. Frolova[1]

[1]Lomonosov Moscow State University, Faculty of Geography, Department of Land Hydrology, Russia
[2]Non-Profit Foundation "Clean Hands, Clean Rivers", Moscow, Russia
[3]Lomonosov Moscow State University, Faculty of Chemistry, Polymer Department, Russia
*Corresponding author: lisanastya99@mail.ru
Received: April 10th, 2020 / Accepted: August 2nd, 2021 / Published: October 1st, 2021
https://DOI-10.24057/2071-9388-2021-041

ABSTRACT. In order to analyze the problem of microplastics pollution a comprehensive environmental survey was conducted along the entire Volga river in summer of 2020. The analysis of 34 water samples allowed us to determine the average concentration of microplastic (MP) in the surface water layer of the Volga river which accounted for 0.90 items/m^3 (0.21 mg/m^3). MP particles were found in all samples taken. The concentrations ranged from 0.16 to 4.10 items/m^3 (from 0.04 mg/m^3 to 1.29 mg/m^3). The maximum MP concentrations were recorded in large cities downstream of the sewage treatment plants. For Tver, Nizhny Novgorod, Kazan and Volgograd they reached 3.77, 1.91, 4.10 and 1.34 items/m^3 respectively. The key role of large settlements as sources of MP in the Volga water was revealed. The minimum MP concentrations were recorded upstream of the large cities showing relatively stable levels of 0.25 items/m^3 (0.05 mg/m^3). The lowest MP content (0.16 items/m^3) was revealed in the downstream area of the Cheboksary reservoir near Cheboksary. The results of weighing MP particles showed that their average concentration in the Volga water is 0.21 mg/m^3. In each of the investigated samples particles of three determined fractions – fragments, fibers and films – were found, however, their ratio was not constant. On average, the proportion of fragments and films in the Volga water was 41% and 37% respectively and share of fibers accounted for 22%.

KEYWORDS: Microplastics, river runoff, freshwater pollution, Volga river

CITATION: Anastasia A. Lisina, Maxim M. Platonov, Oleg I. Lomakov, Alexey A. Sazonov, Tatiana V. Shishova, Anna K. Berkovich, Natalia L. Frolova (2021). Microplastic Abundance In Volga River: Results Of A Pilot Study In Summer 2020. Geography, Environment, Sustainability, Vol. 14, No 3, p. 82-93 https://DOI-10.24057/2071-9388-2021-041

Conflict of interests: The authors reported no potential conflict of interest.

INTRODUCTION

Rivers are the main source of microplastics input into the oceans. The distinctive features of polymers, particularly their low density and resistance, make them a commonly used material, which, however, is becoming a dangerous pollutant nowadays. By themselves, polymer particles with a diameter of less than 5 mm (Cole et al. 2011; Hidalgo-Ruz 2012; Wright 2013) do not pose a threat to humans but their surface can adsorb toxic substances and bacteria, including pathogenic ones (McCormick et al. 2016).

In previous years, a lot of attention in the literature was given to the problem of pollution of the ocean by plastic waste, and a relatively small number of works considered the problem of river pollution, although 65-90% of plastics are carried into the ocean with river runoff (Hurley et al. 2018; He et al. 2019). Lebreton et al. (2017) and Schmidt et al. (2017) estimated that the input of plastics from rivers into the ocean ranges from 0.50 to 2.75 million tons per year. In recent years, studies are more often focusing on rivers as the main source of microplastics input to the ocean (Wijnen et al. 2019). Some of the first publications considering microplastics abundance in river waters (Moore et al. 2011; Klein et al. 2015; Dris et al. 2018; Horton et al. 2017; Liedermann et al. 2018) presented the data from rivers in California (2011) as well as the Rhine (2015), Seine (2015), Thames (2017) and Danube (2018) rivers. Depending on the shape, the following types of microplastic particles are distinguished: fragments, fibers, films, pellets, granules, foams (Dris et al. 2018). According to the origin, there are two types of microplastics – primary and secondary (Xu et al. 2019; Kapp et al. 2018; Horton et al. 2016).

The problem of microplastic pollution of freshwater bodies in Russia has not received sufficient attention. A comprehensive overview written by V.D. Kazmiruk (2020) contains more than 1000 references which include only 6 references to the studies performed in Russia. The research (Frank et al. 2021) is of importance. It contains the first results on the concentrations in the Surface Water of the Ob and Tom Rivers in Siberia.

The present field sampling provided the first estimation of microplastic abundance in the Volga river and can be considered as one of the first studies concerning this problem in Russia. The aim of the present research was to analyze data on microplastics in the water of the largest river draining the European part of Russia, the Volga river, from its source to the mouth.

The Volga river, the longest European river (3531 km), is of exceptional importance to Russia (Butorin et al. 1978). The Volga basin contains approximately 40% of the Russian population (about 60 million) and relates to 45% of the country's industrial and agricultural produce. The northern part of the Volga basin is in the taiga and mixed forest landscape zones, and the southern part is in forest–steppe zone, steppe zone, and the semidesert zone. The mean annual discharge at Volgograd (catchment = 1350000 km^2) is 8364 m/s. (Schletterer et al. 2019).

The objectives of the study included determination of the abundance, distribution and composition of microplastics in the Volga water. Water sampling, laboratory analysis and further processing of the obtained data were carried out by employees of the non-profit foundation "Clean Hands, Clean Rivers" and the scientists from the Faculty of Geography of Lomonosov Moscow State University.

RESEARCH METHODOLOGY

The main method of collecting surface water samples for the analysis of microplastic concentration involves sampling with a trawl net that allows to catch microplastic particles (Liedermann et al. 2018; Bruge et al. 2020; Collignon et al. 2012; Desforges et al. 2014). In general, either plankton nets (Campanale et al. 2019; McCormick et al. 2014; Eo et al. 2019) or MANTA nets designed for microplastic sampling are used (Yonkos et al. 2014, Mani et al. 2018). During sampling, a 2-meter-long net (Campanale et al. 2019) is towed behind a boat for a certain period of time. It is recommended to attach the net to the side of the towing boat in order to minimize the influence of waves generated by the movement of the vessel (Mani et al. 2018), as well as to avoid jets from the boat engine. The inlet of the net is half-submerged in order to reduce the force acting on the net from the flow and to take a sample only in the thin layer closest to the water surface. A spinner is installed in MANTA to calculate the volume of filtered water (Kapp et al. 2018). At the end of sampling, all unfiltered particles are transferred to a container for further laboratory analysis.

In the present study, we used LEI-MANTA300 set manufactured by EkoInstrument LLC with 300 μm bags for filtration (fig. 1). This device includes a net with a mesh size of 300 μm attached to the boat, which allowed to sample particles larger than 300 microns from the surface water. The inlet of the net with cross-section 30 x 15 cm is supplied with a current meter for determining the total volume of filtered water. During sampling, the LEI-MANTA300 net was towed behind the boat at a speed of about 5 km/h. Within this pilot study one sample was collected at each point. The towing duration was determined based on the expected microplastic abundance and ranged between 45 and 60 minutes. In case of a microplastic concentration of 0.1 particles/m^3, to detect only one particle it is necessary to filter at least 10 m^3 of water. For obtaining reproducible data, this volume must be increased. In the present study, the actual filtered volume ranged from 25 to 130 m^3.

After each sampling, the net was flushed so that the entire filtered sample was in the lower detachable beaker. The contents of the beaker were transferred to pass through a series of 5 mm (top) and 0.3 mm (bottom) sieves made of stainless steel. Coarse debris stopped by the upper sieve was removed after the adsorbed particles of microplastics had been washed off and collected. The particles stopped by the lower sieve, which included a mixture of microplastics and biological residues 0.3 – 0.5 mm in size, were transferred into a glass container and preserved in a 70% alcohol solution for subsequent laboratory analysis. The samples contained a significant amount of organic material that had to be removed prior to the analysis for microplastics. To do this, they were transferred into a 2-liter glass beaker mounted on a magnetic stirrer with a heating element, a 30% sodium hydroxide solution was added and heated to a temperature of 75-80°C. A 30% solution of hydrogen peroxide was added to the heated sample in small portions under constant stirring until its complete discoloration. The decomposition of a sample took from one to several hours, depending on the number of organic residues.

Unlike natural organic compounds, the majority of synthetic polymers are resistant to peroxide and little affected during the described process of organic material decomposition. The particles, which did not react with peroxide, were filtered off on a sieve with a mesh size of 100 μm. The mineral particles in the sample were separated

Fig. 1. Sampling for microplastics using the MANTA300 net (photo by M. Platonov)

from less dense polymer particles using a saturated saline solution and a funnel. The particles stopped on the sieve were examined using a stereo microscope with maximal 80x magnification for visual identification and counting of microplastic particles, which were then assigned to one of the six types: fragments, fibers, films, foams, pellets, granules. Visual identification avoids counting undecomposed organic or mineral particles. The counting of such nonpolymer particles is probably the reason for the tenfold difference with the microplastic concentration in the Ob River (Frank et al. 2021). This technique allows to quantify the distribution of different types of microplastic particles in different layers of river water and determine the total export of microplastics to the seas.

In most studies, types of polymers are determined using Fourier-transform infrared spectroscopy (Leslie et al. 2017; Mani et al. 2018; Kapp et al. 2018). The method of differential scanning calorimetry was applied by Castaceda et al. (2014). In the present study differential scanning calorimetry (DSC), which allows to record the phase transitions in polymeric materials, was used. Sample A combined the samples collected along the river section from Selizharovo to Tver (the Upper Volga), sample B –from the Ivankovskoye reservoir to Kostroma (the Upper Volga), sample C and sample D – the Middle Volga and the Lower Volga, respectively. The samples were dried at 60 °C, the images of the dried samples are presented in Table 2. Red marks identify the items that were selected for the analysis. When choosing individual particles for the analysis, two circumstances were taken into account: particles should be as diverse as possible and large enough to ensure accurate identification

The measurements were carried out on DSC 402 F1 Phoenix (Netzsch, Germany) at the Chemistry Department of Moscow State University. A weighed plastic item was placed in an aluminum crucible and heated in a range of temperatures from 25 to 200°C, with a rate of 10°C/min in an argon flow of 50 ml/min. As a reference sample, an empty aluminum crucible was used. Fig. 3 gives an example of the DSC thermograms obtained for the items in sample A. The peaks on the curves represent melting points, the inflections correspond to glass transition, the temperature of both was compared to literature data. The measurement results for all selected items are presented in Table 2.

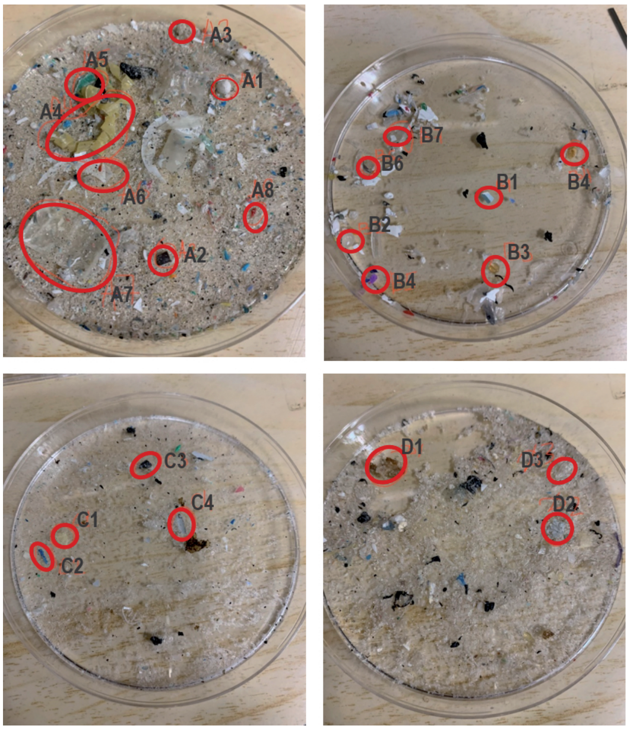

Fig. 2. Samples selected for the chemical analysis

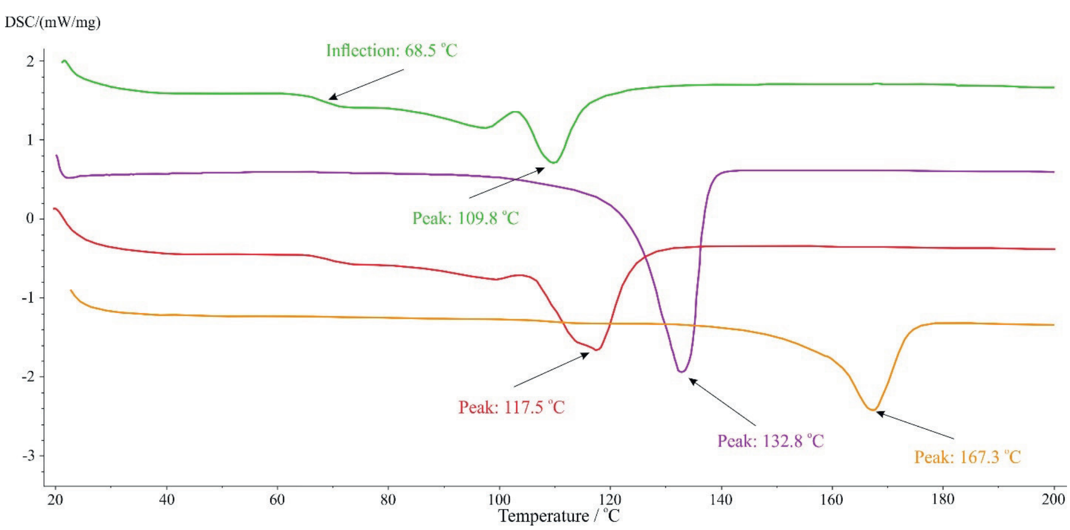

Fig. 3. DSC thermograms for plastic fragments in the sample A. The curves in the figure correspond to the fragments A2 (blue), A3 (olive), A5 (black), A7 (dark blue)

RESULTS

During the expedition, which took place in the summer and autumn of 2020, the sampling for microplastics was carried out at different locations along the entire course of the Volga river upstream and downstream of large cities (Table 1). The Upper Volga section, about 400 km long, was sampled from 12 to 18 July 2020 during the rain flood period (Fig. 4). During this period the sampling covered the area from the village Selizharovo to the village Gorodnya (both are located in Tver region) (Fig. 5).

Table 1. Microplastic abundance and distribution of particle types in water samples collected along the Volga river

No	Coordinates*	Site name	Number of item types	Volume, $м^3$**	Concentration	
	Latitude/ Longitude		Total [Fibers/Films/ Fragments]		items/m³	mg/m³
		The Upper Volga (fig. 5)				
1	56.842/35.478	Selizharovo	17 [1/1/5]	50.4	0.337	0.029
2	56.750/33.688	Yeltsy	10 [6/1/3]	58.5	0.171	0.036
3	56.654/33.775	Downstream of Yeltsy	22 [2/8/12]	57.0	0.386	0.161
4	56.465/33.953	Upstream Rzhev (Sihka river, Dunka river, flooded sand quarry)	47 [13/5/29]	65.2	0.720	0.189
5	56.306/34.086	Rzhev	85 [17/15/53]	40.1	2.121	0.654
6	56.253/34.345	Staritsa	23 [15/3/5]	47.7	0.482	0.105
7	56.527/34.918	Downstrean of Staritsa (Ulyust river, Rzhavtsa river)	4 [1/2/1]	23.4	0.171	0.079
8	56.685/35.317	Bolshie Borki town	42 [6/0/36]	23.5	1.787	0.408
9	56.81/35.592	Upstream of Tver	17 [13/1/3]	24.3	0.700	0.115
10	56.85/35.793	Tver	13 [8/0/5]	26.4	0.493	0.078
11	56.857/35.935	Tver, city center	29 [15/1/13]	71.5	0.406	0.077
12	56.811/36.013	Tver, downstream of the wastewater treatment facilities	200 [30/20/150]	53.1	3.769	1.046
13	56.786/36.313	Tver, downstream	120 [30/15/75]	53.7	2.235	0.615
14	56.761/36.736	Upper Ivankovskoe reservoir	36 [15/11/10]	132.5	0.272	0.055
15	56.764/37.200	Dubna, downstream	49 [22/7/20]	65.2	0.751	0.106
16	57.556/38.302	Uglich, downstream	13 [8/3/2]	60.6	0.215	0.032
17	58.048/38.878	Rybinsk, downstream	42 [17/5/20]	107.6	0.390	0.054
18	57.556/40.079	Yaroslavl, downstream	26 [15/5/6]	95.0	0.274	0.039
19	57.678/40.996	Kostroma, downstream	43 [22/9/12]	65.2	0.660	0.103
		The Middle Volga (fig. 6)				
20	56.357/43.907	Nizhny Novgorod, Sormovsky backwater	56 [27/20/9]	87.0	0.644	0.137
21	56.337/44.048	Nizhny Novgorod, city center	46 [15/18/13]	66.2	0.695	0.170
22	56.272/44.165	Nizhny Novgorod, downstream of the wastewater treatment facilities	118 [30/32/56]	61.9	1.907	0.404
23	56.166/47.243	Cheboksary, city center	10 [3/5/2]	64.3	0.156	0.044
24	56.119/47.563	Novocheboksarsk, downstream	17 [4/9/4]	25.9	0.655	0.200
25	55.791/48.932	Kazan, city center	15 [0/8/7]	77.6	0.193	0.065
26	55.682/49.005	Kazan, downstream of the wastewater treatment facilities	221 [7/106/108]	53.9	4.100	1.286

The Lower Volga (fig. 7)						
27	53.297/50.185	Samara, downstream Ptichi i.	102 [63/20/19]	81.1	1.258	0.174
28	53.161/49.969	Samara, downstream pr. Suhaya Samara	82 [35/15/32]	89.0	0.921	0.146
29	51.495/45.982	Saratov, Alekseevsky gully	49 [22/10/17]	69.0	0.710	0.116
30	48.780/44.652	Volgograd, downstream Volga HPP dam	12 [7/2/3]	65.2	0.184	0.024
31	48.604/44.626	Volgograd, downstream of the wastewater treatment facilities	94 [50/25/19]	70.0	1.344	0.234
32	46.390/48.060	Upstream of Astrakhan	47 [25/8/14]	98.7	0.476	0.067
33	46.360/48.033	Astrakhan, downstream of the wastewater treatment facilities	62 [35/10/17]	86.3	0.719	0.096
34	46.274/47.949	Astrakhan, downstream (Zolotoy backwater)	24 [11/6/7]	72.8	0.330	0.059

*the coordinates indicate the central point of the sampled river section, the length of which usually varied from 3 to 8 km. The boat moved predominantly downstream and followed the middle part of the river course

** the built-in current meter makes 3 readings per 1 m, the size of the MANTA inlet is 30x15cm, which, when half-submerged, provides a cross section of $0.3x0.075 = 0.0225$ m^2

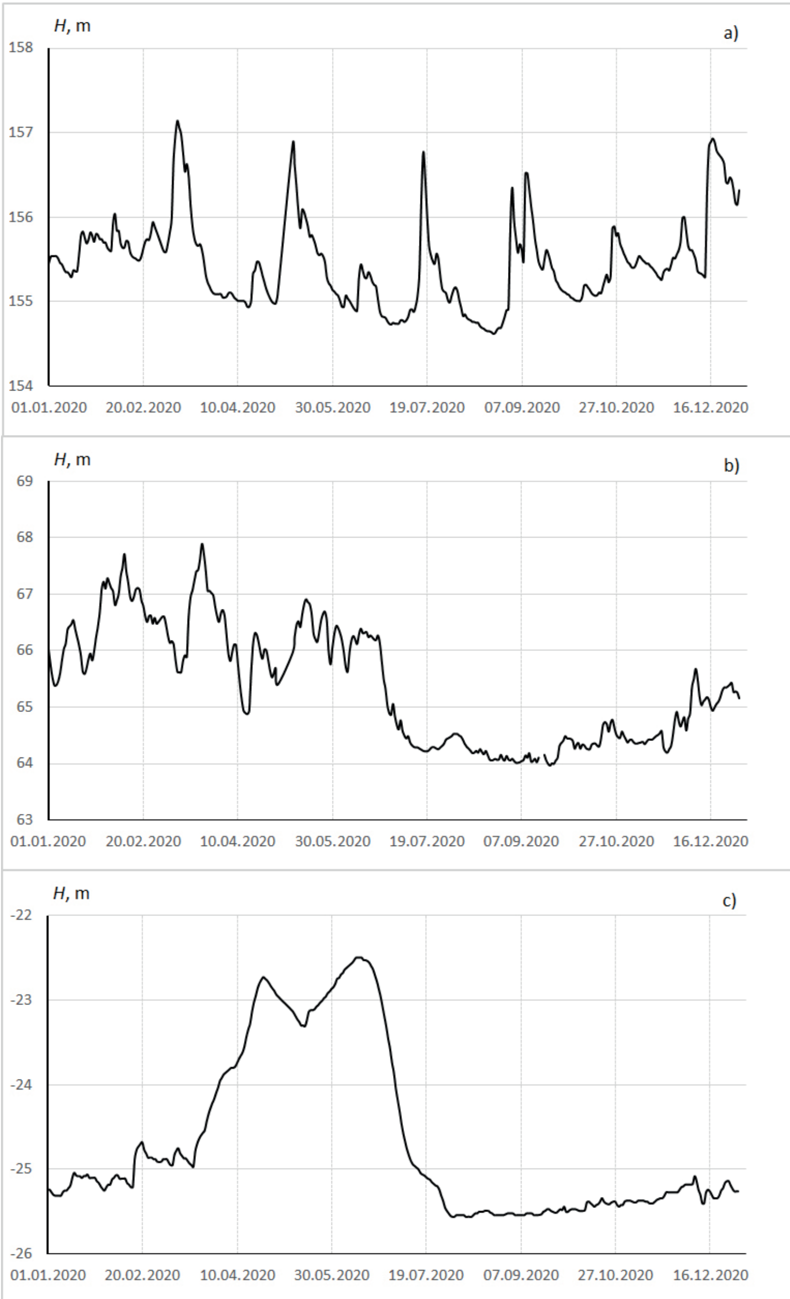

Fig. 4. Changes in the water level of the Volga river near Rzhev (a), Nizhny Novgorod (b) and Astrakhan (c) in 2020 (according to vodinfo.ru (2021))

According to the weather station in Staritsa (rp5.ru (2021)), the amount of precipitation in the period from 12 to 17 July was 123 mm. Due to heavy rainfall, the water levels in the considered section of the Volga river were increasing during the entire period of the expedition according to http://gis.vodinfo.ru/ (Fig. 4a). Such untypical hydrograph (fig. 4a) with the missing spring flood is likely related to the fact, that there was a "warm" winter with no ice on the river in 2019/20 – thus a lot of rain was falling in winter. Also, during the rest of the year there were heavy rainfalls, when the water levels reached the levels of the spring flood. Over that period (from 12 to 17 July), a total of 13 samples for microplastics were taken (Fig. 5). In the area of Selizharovo, the observed concentration was only 0.17 to 3.77 items/m^3 (from 0.036 mg/m^3 to 1.046 mg/m3), while near Rzhev these values increased to 2 items/m3, reaching about 4 items/m^3 at Tver. Largely due to heavy precipitation and the formed flood, the obtained values of the microplastics concentration turned out to be significantly higher than expected, characterizing the pollution of the Upper Volga as above average and, in some locations, as alarming. While in the upper section of the route the pollution consisted mostly of synthetic fibers, samples collected near Rzhev contained particles of different types of microplastics. The expected large amount of microplastics was found in the samples taken downstream of the wastewater treatment plant in Tver (up to 4 items/m^3 or up to 1 mg/m^3). At the same time, 10 km downstream of the wastewater treatment facilities of Tver the concentration almost halved, dropping down to 2.235 items/m3 (0.615 mg/m^3),. The high concentrations of about 2 items/m^3 (0.65 mg/m^3), were also obtained in areas outside large settlements, which was probably related to the washing off of the accumulated waste from the riverbanks that took place during the expedition. The average abundance of microplastics at the Selizharovo-Gorodnya section was about 1 items/m3 or 0.3 mg/m^3.

The section of the Upper Volga between the Ivankovskoye reservoir and Kostroma was surveyed later, from 28 to 31 October 2020, with the collection of 6 more samples. The average microplastics abundance within this section was less than 0.5 items/m^3 (0.07 mg/m^3), with a maximum of 0.75 items/m^3 (0.016 mg/m^3) (Dubna). The proportion of fibers in these samples reached 50%, while the share of fragments rose with the increase in the number of particles. Downstream of Dubna, the concentration increased several times – from 0.27 to 0.75 items/m3 (from 0.039 mg/m^3 to 0.106 mg/m^3), 40% of which was represented by fragments. The minimum concentration of microplastics was recorded at Uglich – 0.215 items/m^3 (0.032 mg/m^3), among which fragments accounted for only 15%.

Sampling along the second section was carried out from August 31 to September 3, which corresponds to the period of summer-autumn low water (Fig. 4b, Fig. 6). The samples were taken in Nizhny Novgorod, upstream, in the center and downstream of the city (at the wastewater treatment plant), in Cheboksary, upstream and downstream of the Cheboksary HPP dam, as well as upstream and downstream of Kazan (7 samples in total). All the samples contained a significant volume of organic substances that hindered the identification of microplastic particles, which required their additional preparation for the analysis. Microplastics were found at all the locations, while their amount and composition varied significantly. The analysis of the samples showed that the concentration of microplastics upstream of large cities was in the range from 0.156 to 0.695 items/m^3 (from 0.044 mg/m^3 to

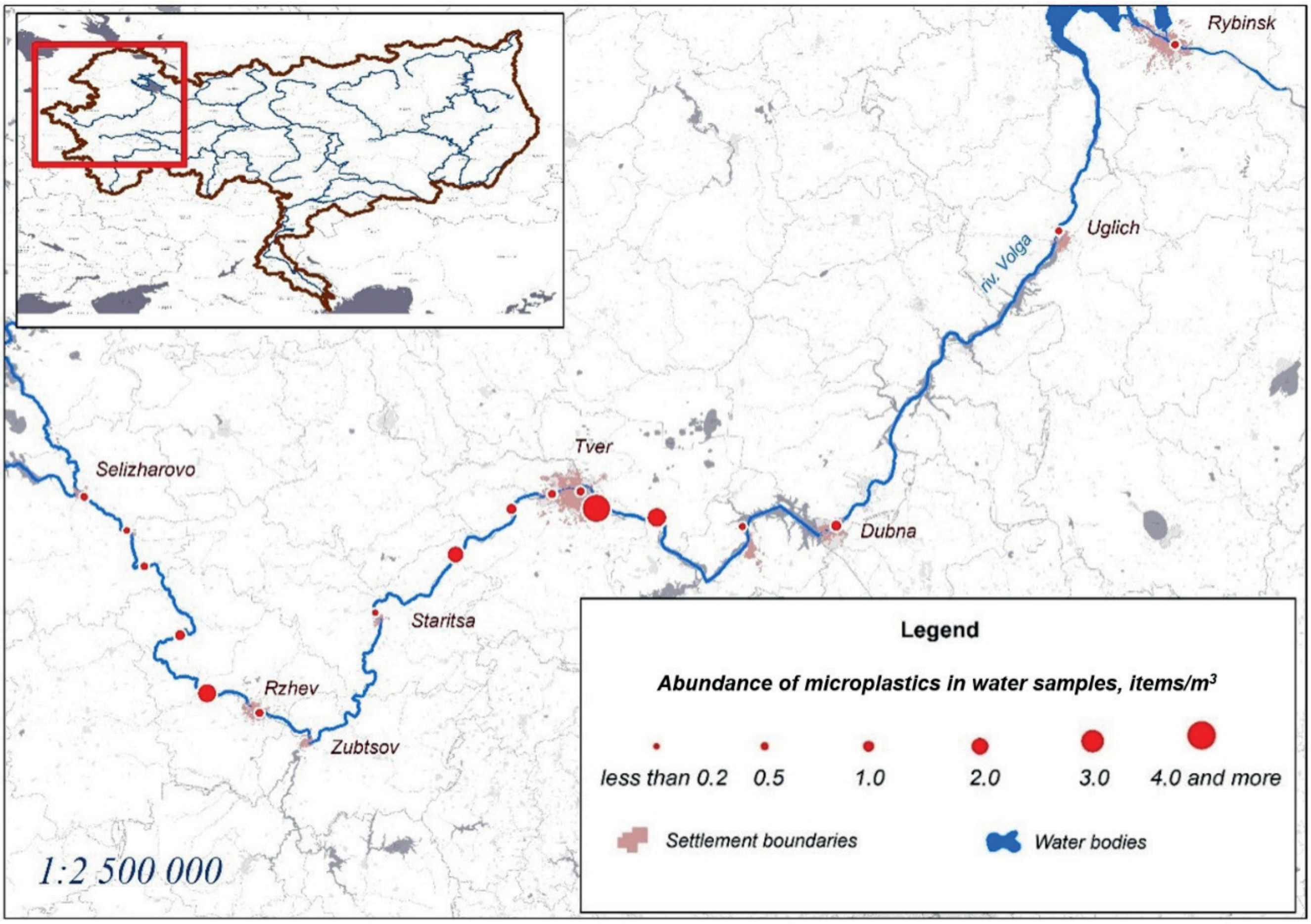

Fig. 5. Map of microplastics sampling locations and its abundance in the water samples (items/m^3) in the first section, from Selizharovo to Gorodnya

0.170 mg/m^3). The sample taken downstream of Nizhny Novgorod contained about 2 items/m^3 (0.4 mg/m^3), while downstream of Kazan the concentration reached 4 items/m3. The average microplastic concentration in this section was about 1.2 part/m^3 or 0.35 mg/m^3, which is 20% higher compared to the Upper Volga. This study once again confirm the significant contribution of wastewater treatment plants in large cities to the pollution of rivers with microplastics, which can be clearly seen in the example of Nizhny Novgorod and Kazan. At the same time, the negative effect of the Novocheboksarsk WWTP with approximately the same capacity was much lower. This can be related not only to their submerged water outlet but mainly to the technology of treated wastewater filtration, which was recently introduced at these treatment facilities and is applied before discharging water into the river. The worst conditions in terms of microplastics abundance were observed downstream of Kazan as the identified value of 4 items/m^3 is comparable to the level of pollution downstream of Tver.

The third part of the expedition was carried out in the lower reaches of the Volga river and took place from 12 to 19 October 2020 during the summer-autumn low water period (Fig. 4c). Eight samples were taken upstream and downstream of Samara, Volgograd and Astrakhan, all of which contained a significant amount of organic matter, making it difficult to identify microplastic particles. However, microplastics were still found in all the samples and their concentration averaged at 0.75 items/m^3 (0.12 mg/m^3) (Fig. 7), which was less than the average value for the Volga in general. The previously noted relationship between the microplastic abundance and the presence of large settlements was not found for this section of the river as the concentrations downstream of Samara and Astrakhan even slightly decreased. A significant rise in the number of microplastic particles (from 0.184 to 1.34 items/m^3) (from 0.024 mg/m^3 to 0.234 mg/m^3), was registered for Volgograd. This could be explained by a direct discharge of water from urban wastewater treatment plants into the main channel of the Volga, which occurs in Volgograd but not in Samara or Astrakhan. Volgograd is one of the most problematic cities in terms of adverse impact on the Volga and urgently requires modernization of existing wastewater and stormwater treatment facilities or installation of new ones. The situation in Astrakhan in terms of microplastics turned out to be better than in other cities. In the main channel of the Volga, the abundance of microplastics was about 0.5 items/m^3, but the situation in other branches might be much worse. In recent years, biologists have found microplastics in many dead organisms living in the Volga floodplain (Litvinov 2020), which indicates the need for a more detailed study of its abundance in the waters of this natural reserve.

An important aspect of this study was the analysis of the microplastics distribution between its different types (Fig. 8). The ratio of these types was different. It was found that with an increase in the total abundance of particles of all types, the share of fragments also increased. Thus, for samples with microplastics concentration exceeding 1 items/m^3, fragments on average accounted for 53% of all particles, while for concentrations of less than 1 items/m3 their share was around 32%. An increase in the proportion of fragments indicates the emergence of new pollution sources.

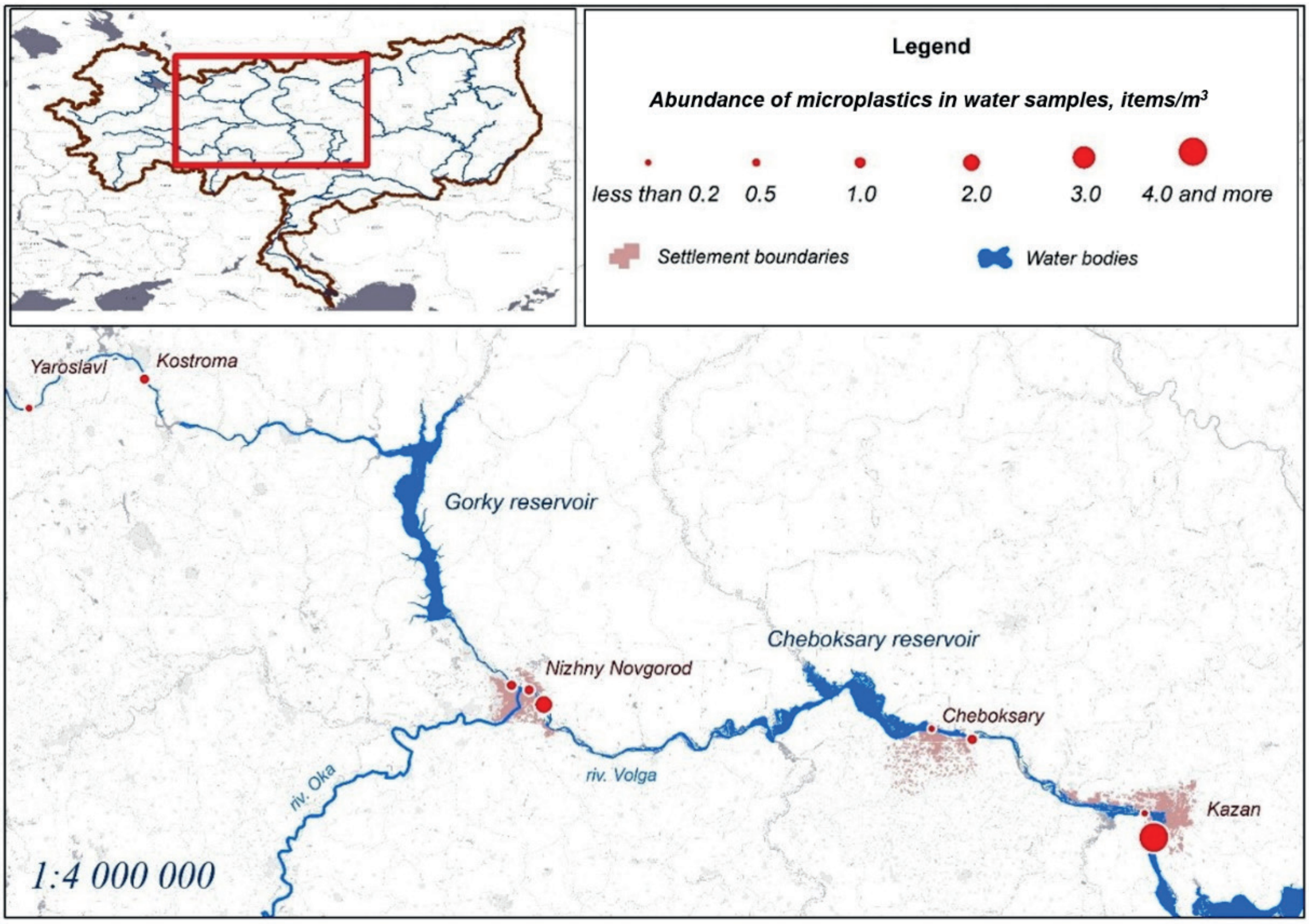

Fig. 6. Map of microplastics sampling locations and its abundance in the water samples (items/m^3) in the second section from Nizhny Novgorod to Kazan

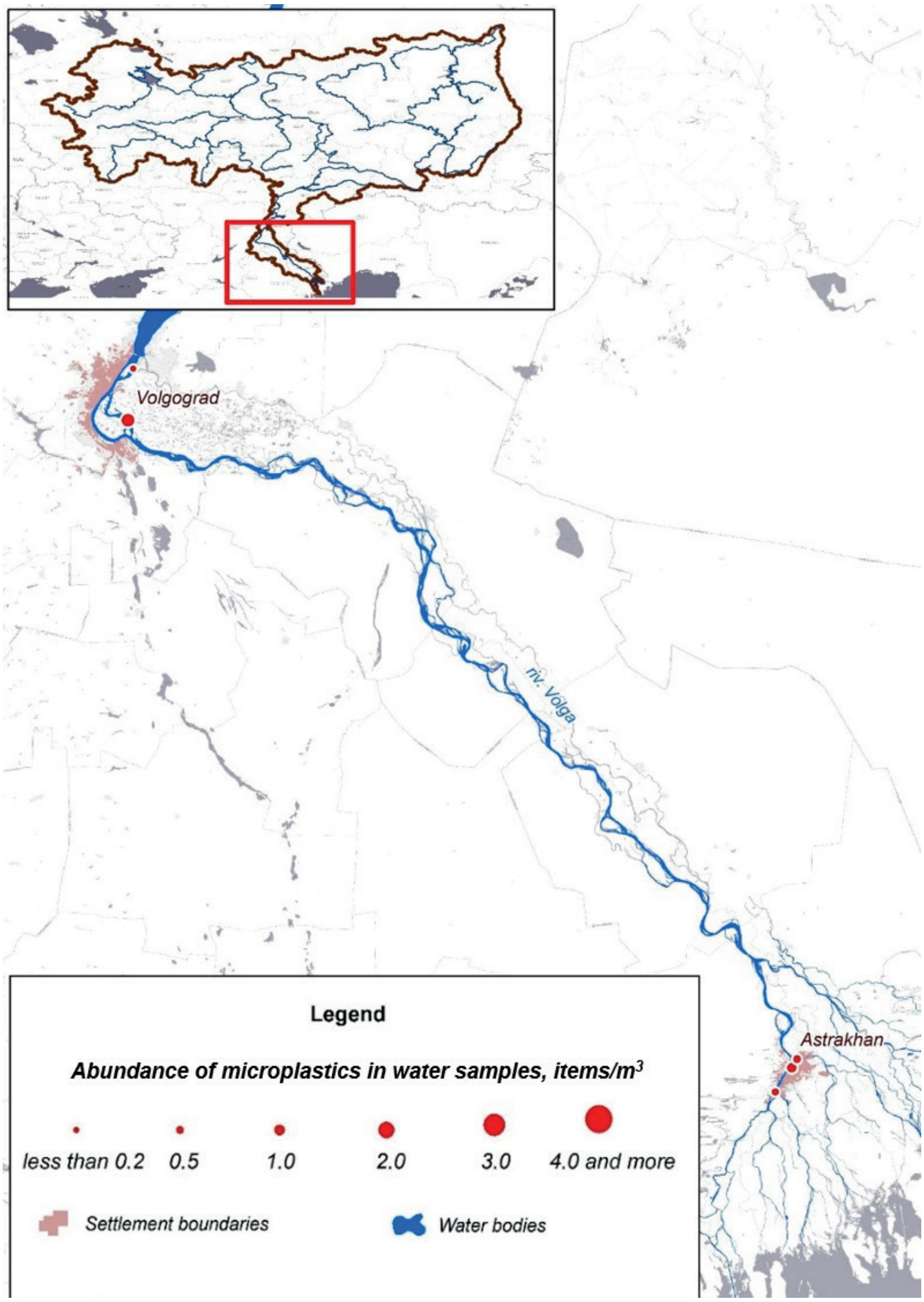

Fig. 7. Map of microplastics sampling locations and its abundance in the water samples (items/m^3) in the third section from Volgograd to Astrakhan

The DSC results (table 2) showed that polyethylene and polypropylene prevailed in all samples and represent items of various morphology and color, which indicates their different origin and confirms that household plastic waste is the main source of microplastics in the river. The samples also contained items that remained unchanged within the studied temperature range. These materials, which are likely characterized by transition temperatures outside this range, can include rubbers (whose transition temperature is below room temperature) or, on the contrary, more thermally stable polymers. Also, visible transitions may not occur in the case of so-called thermosetting polymers, which are three-dimensional crosslinked materials that do not change until the decomposition temperature is reached, for example, some polyurethanes, phenol-formaldehyde and epoxy resins. In addition, it should be noted that all samples were collected from a river and therefore predominantly contain fragments of materials with a density equal to or lower than that of water. These materials are mainly represented by polyethylene, polypropylene and polystyrene, while the likelihood of finding polyethylene terephthalate (PET) in a sample is quite small.

DISCUSSION

Microplastic particles were found in all the collected water samples (Fig. 2 – Fig. 7). Analysis of 34 water samples allowed us to determine the average concentration of microplastics in the Volga river, which was equal to 0.901 items/m^3 (0.212 mg/m^3) with the median value of 0.649 items/m^3 (0.106 mg/m^3) and a range of 0.156 to 4.100 items/m^3 (0.065 mg/m^3 to 1.286 mg/m^3).

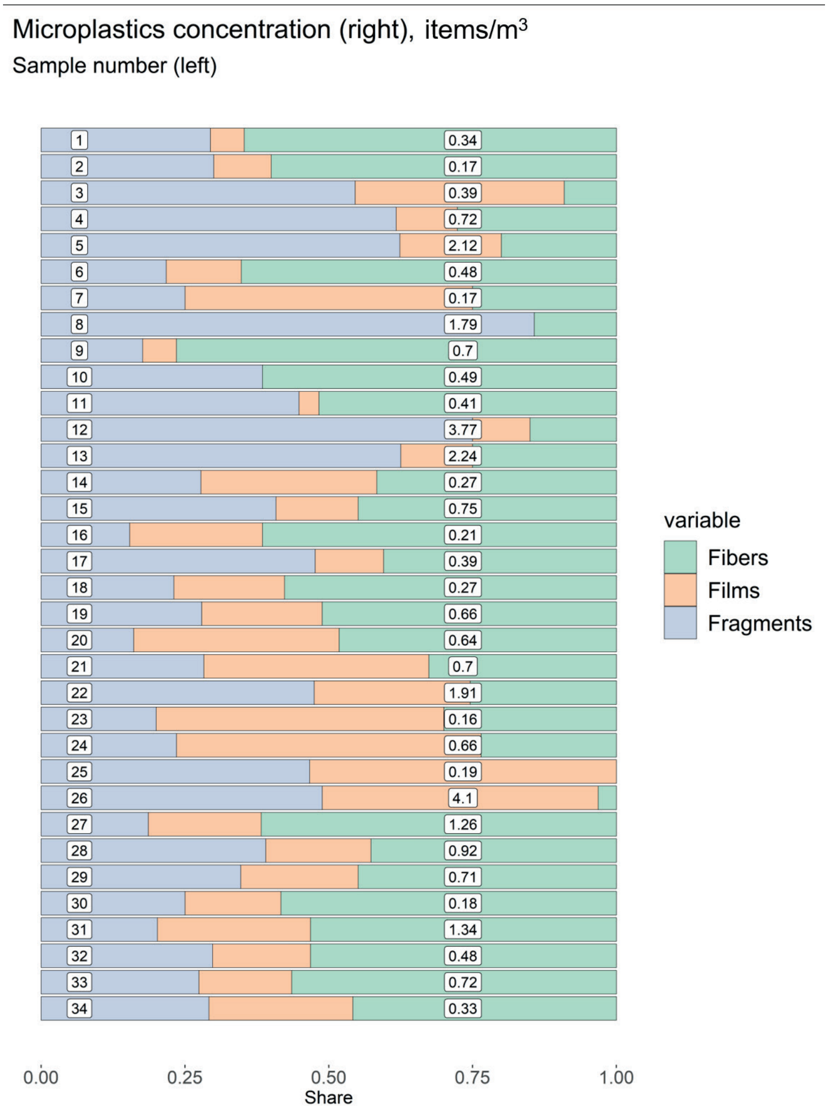

Fig. 7. Distribution of microplastics in samples by type

Table 2. The results of the differential scanning calorimetry analysis

Sample ID **	Temperature of phase transition*	The supposed nature of polymeric material
A1	T_g=107.7oC	Polystyrene
A2	T_g= 68 oC;T_m=109.8oC	Polyvinyl chloride
A3	T_m=117.5°C	Polyethylene
A4	T_m=131.7°C	Polyethylene
A5	T_m=167.3°C	Polypropylene
A6	T_m=125.7°C	Polyethylene
A7	T_m=107°C	Polyethylene
A8	T_m=132.8°C	Polyethylene
B1	T_m=165°C	Polypropylene
B2	T_m=159°C	Polypropylene
B3	T_m=110°C	Polyethylene
B4	T_m=108.1°C	Polyethylene
B5	T_m=167.2°C	Polypropylene
B6	T_m=130.7°C	Polyethylene

B7	T_m=164.6°C	Polypropylene
C2	T_m=107.8°C	Polyethylene
C4	T_m=124.6°C	Polyethylene
D2	T_m=124°C	Polyethylene
D3	T_m=112.2°C	Polyethylene

To assess the role of urban areas in the pollution of the Volga river by microplastics, their concentrations were measured upstream and downstream of several cities. Microplastics concentration downstream of Kazan compared to the upstream location increased more than 21 times, from 0.193 items/m^3 (sample 25) to 4.100 items/m^3 (sample 26) (from 0.024 mg/m^3 to 0.234 mg/m^3), the increase of more than 7 times (from 0.184 items/m^3 (sample 30) to 1.344 items/m^3 (sample 31) or from 0.044 mg/m^3 to 1.286 mg/m^3) was observed in Volgograd.

The maximum concentrations of microplastics were recorded downstream of the wastewater treatment facilities of large cities, particularly in Volgograd 1.344 items/m3 or 0.234 mg/m^3), Nizhny Novgorod (1.907 items/m^3 or 0.404 mg/m^3), Tver (3.769 items/m^3 or 1.046 mg/m^3) and Kazan (4.100 items/m^3 or 1.286 mg/m^3). The minimum concentrations were observed upstream of large cities and, in general, were around 0.25 items/m^3 (0. 054 mg/m^3). The lowest concentration of 0.156 items/m3 (0.044 mg/m^3) was observed downstream of the Cheboksary reservoir near Cheboksary. Unfortunately, water samples were taken in different phases of the Volga river hydrological regime: during a flood in the Upper Volga and in low-water conditions in the Middle and Lower Volga. Thus, the obtained results imply that urban wastewater treatment plants are one of the main sources of microplastics in the Volga river.

Our results provide a first indication of the microplastic pollution in the Volga river. The obtained values are significantly lower compared to the available data on the microplastics abundance in the water of other rivers worldwide. The most complete understanding of the microplastics runoff currently is available for the rivers of Northern and Western Europe and the USA. For example, in the Rhine, the microplastics concentration can reach 8.85 and 11.1 items/m^3 at Duisburg and Ries, respectively (Mani et al. 2018). Similar concentrations were observed in the Elbe where they varied from 0.88 to 13.2 items/m^3 (Scherer et al. 2020). For the Danube river, the analysis of the microplastics samples from the near-surface layer has shown an average concentration of 0.317 items/m^3 with a maximum of 14.2 items/m^3 (Dris et al. 2018), in Budapest, concentrations reached 50 items/m^3 (hu.wessling-group.com (2019)). A relatively high microplastics abundance was recorded in the Thames – within the area of the city it reached 24.8 items/m^3 (Rowley et al. 2020).

CONCLUSIONS

The results obtained in the present study provide a first indication of the microplastic contamination of the Volga river and can be used for comparison to other water bodies worldwide. The microplastic abundance in the Volga river turned out to be significantly lower than that in other large rivers. The obtained results, however, strongly depend on the sampling methods as well as on the location of the sampling site relative to large settlements, different systems of wastewater treatment facilities, phase of the hydrological regime, presence of reservoirs and other factors. Further estimation will require more detailed monitoring with multiple measurements. But in this study, we aimed to obtain the first results along the Volga river. In our pilot study we could only collect one sample per point, due to the fact that sampling takes from 45 minutes to an hour. Based on this, a more detailed monitoring with multiple measurements (parallel samples) is recommended. In order to draw more sound conclusions, data for the same hydrological conditions and phases of the water regime are required along with information on microplastics distribution over the water column and detailed consideration of urban impact, influence of reservoirs and other factors. An important aspect of future research would be addressing a number of methodological issues related to the collection and processing of water samples.

REFERENCES

Bruge A., Dhamelincourt M., Lanceleur L., Monperrus M., Gasperi J. and Tassin B. (2020). A first estimation of uncertainties related to microplastic sampling in rivers. Science of the Total Environment, 718, 37319, DOI: 10.1016/j.scitotenv.2020.137319.

Campanale C., Stock F., Massarelli C., Kochleus C., Bagnuolo G., Reifferscheid G. and Uricchio V.F. (2020). Microplastics and their possible sources: The example of Ofanto river in Southeast Italy. Environmental Pollution, 258, 113284, DOI: 0.1016/j.envpol.2019.113284.

Castaneda R., Avlijas S., Simard A. and Ricciardi A. (2014). Microplastic pollution in St. Lawrence River sediments. Canadian Journal of Fisheries and Aquatic Sciences, 71(12), 1-5, DOI: 10.1139/cjfas-2014-0281.

Cole M., Lindeque P., Halsband C. and Galloway T. S. (2011). Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin, 62(12), 2588-2597, DOI: 10.1016/j.marpolbul.2011.09.025.

Collignon A., Hecq J.-H., Glagani F., Voisin P., Collard F., and Goffart A. (2012). Neustonicmicroplastic and zooplankton in the North Western Mediterranean Sea. Marine Pollution Bulletin, 64(4), 861-864, DOI: 10.1016/j.marpolbul.2012.01.011.

Desforges J.P., Galbraith M., Dangerfield N., and Ross P. (2014). Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean. Marine pollution bulletin, 79, 94-99, DOI: 10.1016/j.marpolbul.2013.12.035.

Dris R., Gasperi J. and Tassin B. (2018). Sources and fate of microplastics in urban areas: a focus on Paris Megacity. Freshwater Microplastics The Handbook of Environmental Chemistry, 58. Springer Nature. Cham, 308, DOI: 10.1007/978-3-319-61615-5_4.

Eo S., Hong S.H., Song Y.K., Han G.M. and Shim W.J. (2019). Spatiotemporal distribution and annual load of microplastics in the Nakdong River, South Korea. Water Research, 160, 228-237, DOI: 10.1016/j.watres.2019.05.053.

Frank Y.A., Vorobiev E.D., Vorobiev D.S., Trifonov A.A., Antsiferov D.V., Soliman Hunter T., Wilson S.P., Strezov V. (2021). Preliminary Screening for Microplastic Concentrations in the Surface Water of the Ob and Tom Rivers in Siberia, Russia. Sustainability, 13(1), 80, DOI: 10.3390/su13010080.

He B., Goonetilleke A., Ayoko G.A., and L. Rintoul. (2019). Abundance, distribution patterns, and identification of microplastics in Brisbane River sediments, Australia. Science of the Total Environment, 700, 134467, DOI: 10.1016/j.scitotenv.2019.134467.

Hidalgo-Ruz V., Gutow L., Thompson R.C. and Thiel M. (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ. Sci. Technol, 46, 3060-3075, DOI: 10.1021/es2031505.

Horton A.A., Svendsen C., Spurgeon D.J. and Williams R.J. (2017). Large microplastic particles in sediments of tributaries of the River Thames, UK – Abundance, sources and methods for effective quantification. Marine Pollution Bulletin, 114(1), 218-226, DOI: 10.1016/j.marpolbul.2016.09.004

hu.wessling-group.com (2019). WESSLING Group [online]. Available at: https://hu.wessling-group.com/en/news/50-microplastic-particles-per-cubic-meter-in-the-river-danube

Hurley R., Woodward J. and Rothwell J.J. (2018). Microplastic contamination of river beds significantly reduced by catchment-wide flooding. Nature Geosci, 11(4), 251-257, DOI: 10.1038/s41561-018-0080-1.

Kapp K.J. and Yeatman E. (2018). Microplastic hotspots in the Snake and Lower Columbia rivers: A journey from the greater Yellowstone ecosystem to the Pacific Ocean. Environmental Pollution, 241, 1082-1090, DOI: 10.1016/j.envpol.2018.06.033.

Kazmiruk V.D. (2020). Microplastics in the environment. The growing problem of a global scale Moscow: LENAND, 432. [In Russian]

Lebreton L., van der Zwet J., Damsteeg J. W., Slat B., Andrady A. and Reisser J. (2017). River plastic emissions to the world's oceans. Nature Communications, 8, 15611, DOI: 10.1038/ncomms15611.

Leslie H.A., Brandsma S., Velzen M.J.M. and Vethaak A. (2017). Microplastics en route: Field measurements in the Dutch river delta and Amsterdam canals, wastewater treatment plants. North Sea sediments and biota Environment International, 101, 133-142, DOI: 10.1016/j.envint.2017.01.018.

Liedermann M., Gmeiner P., Pessenlehner S., Haimann M. Hohenblum P., and Habersack H. (2018). A Methodology for Measuring Microplastic Transport in Large or Medium Rivers. Water, 10, 414-423, DOI: 10.3390/w10040414.

Litvinov K.V., Kalmykov A.P. and Biryukova M.G. (2020). Microplastics as a new component in the ecosystem of the lower zone of the Volga delta. Astrakhan bulletin of ecological education, 6(60), 147-152, DOI: 10.36698/2304-5957-2020-19-6-147-152.

Mani T. and Burkhardt-Holm P. (2018). Seasonal microplastics variation in nival and pluvial stretches of the Rhine River – From the Swiss catchment towards the North Sea. Science of the Total Environment, DOI: 10.1016/j.scitotenv.2019.135579.

McCormick A., Hoellein T.J., London M.G., Hittie J., Scott J.W., and Kelly J.J. (2016). Microplastic in surface waters of urban rivers: concentration, sources, and associated bacterial assemblages. Ecosphere, 7(11), DOI: 10.1002/ecs2.1556.

Moore C.J., Lattin G.L. and Zellers A.F. (2011). Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California. J. Integr. Coast. Zone Manag, 11(1), 65-73, DOI: 10.5894/rgci194.

Rowley K.H., Cucknell A.C., Smith B.D., Clark P.F., and Morritt D. (2020). London's river of plastic High levels of microplastics in the Thames water column. Science of the Total Environment, 740, 140018, DOI: 10.1016/j.scitotenv.2020.140018.

rp5.ru (2021). Reliable Prognosis rp5 [online]. Available at: https://rp5.ru/Погода_в_Старице,_Тверская_область [Accessed 1 Mar. 2021].

Scherer C., Weber A., Stock F., Vurusic S., Egerci H., Kochleus C., Arendt N., Foeldi C., Dierkes G., Wagner M., Brennholt N. and Reifferscheid G. (2020). Comparative assessment of microplastics in water and sediment of a large European river. Science of the Total Environment. 738. p. 139866. DOI: 10.1016/j.scitotenv.2020.139866

Schletterer M., Shaporenko S. I., Kuzovlev V. V., Minin A. E., Van Geest G. J., Middelkoop H., and Górski K. (2019). The Volga: Management issues in the largest river basin in Europe. River Research and Applications, 35(5), 510-519, DOI: 10.1002/rra.3268.

Schmidt C., Krauth T., and Wagner S. (2017). Export of Plastic Debris by Rivers into the Sea. Environ. Sci. Technol, 51, 12246-12253, DOI: 10.1021/acs.est.7b02368.

van Wijnen J., Ragas Ad M.J. and Kroeze C. (2019). Modelling global river export of microplastics to the marine environment: Sources and future trends. Science of The Total Environment, 679, 392-401, DOI: 10.1016/j.scitotenv.2019.04.078.

vodinfo.ru (2021). Center for registration and cadastre [online]. Available at: http://gis.vodinfo.ru/hydrographs/post/75003/lev/18.05.2020-17.06.2021/001101.0000.00.0.f4dff6f8de7d4070297cdfd6340d7367 [Accessed 1 Mar. 2021].

Butorin N.V., Mordukhai-Boltovsky F.D., Fortunatov M.A. (1978). Volga i ee zhizn'. Leningrad: Nauka

Wright S.L., Thompson R.C. and Galloway T.S. (2013). The physical impacts of microplastics on marine organisms: A review. Environ. Pollut, 178, 483-492, DOI: 10.1016/j.envpol.2013.02.031.

Xu X., Jian Y., Xue Y., Hou Q. and Wang L.P. (2019). Microplastics in the Wastewater Treatment Plants (WWTPs): Occurrence and Removal. Chemosphere, 235, 1089-1096, DOI: 10.1016/j.chemosphere.2019.06.197.

Yonkos L.T., Friedel E.A., Perez-Reyes A.C., Ghosal S. and Arthur C.D. (2014). Microplastics in four estuarine rivers in the Chesapeake Bay, U.S.A. Environmental Science & Technology. 48(24), DOI: 10.1021/es5036317.