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Microplastics in Russian Freshwater Systems: a Review

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Abstract: The global production of polymers and accumulation of waste has resulted in the worldwide problem of environment contamination by plastic debris. Microplastic (MP) particles (<5 mm) have been found almost everywhere. Despite the significant number of publications devoted to the microplastic contamination in freshwater and marine environments, Russia is a major gap in the review articles about worldwide freshwater systems. The article provides the summary of studies focused on MPs in both water samples and bottom sediments from Russian rivers and lakes. Information on microplastic concentration, methods, investigated particle size, morphological characteristics and polymer type are collected in tabular format. The map of the MP distribution in Russian freshwater systems are presented. The concentration of microplastics in freshwater system is highly variable in both water and bottom sediments. For the most studied particle size 0.3–5 mm in aquatic environments, the minimum content was obtained in the N. Dvina River (0.004–0.01 items/m^3), while the maximum was in the Ob River (26.5–114 items/m^3). The highest MP concentration (4000–26,000 items/m^3) in water samples was estimated in the Altai lakes (Western Siberia) for particle size 10–960 nm. The minimum MP abundance (14 items/kg dry weight (DW) for 0.06–5 mm size particles) was estimated in Ladoga bottom sediments, the maximum content (52,107 items/kg DW for 0.174–5 mm size particles) was found in Kondopoga Bay in Lake Onego.

Keywords: Microplastics, contamination, plastic production, plastic waste, microfiber, river, lake, Russia.

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Research Article

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Introduction

The strength, lightness, toughness, chemical resistance and low cost of polymers have made plastics a widely used material in various sectors of the market as well as in everyday human life. Some plastic products are exploited for decades, while others are designed for a single use.

The rise in plastic production, which is only a slight pause due to Covid-19, creates a significant amount of waste, most of it being disposed in landfills or discarded into the environment. The global growth of plastic waste accumulation and poor management increases plastic contamination on Earth [*Geyer et al.*, 2017; *Ritchie et al.*, 2023]. According to the UN Environment Programme, if current trends persist, our oceans could have more plastic than fish by 2050.

The full mineralization of most polymers takes decades or centuries, but their mechanical degradation is orders of magnitude faster and produces many debris particles smaller than 5 mm, termed microplastics [*Barnes et al.*, 2009; *Thompson et al.*, 2004]. Microplastic (MP) particles have been found in a wide variety of environments: water [*Li et al.*, 2020], air [*O'Brien et al.*, 2023], soil [*Qi et al.*, 2020], snow [*Bergmann et al.*, 2019], living organisms [*Guzzetti et al.*, 2018], bottled water [*Welle and Franz*, 2018]. Plastic contamination of the natural environment has already become a global problem, and the scientific community is paying a lot of attention to it.

There are numerous reports on microplastic contamination in the marine environment, including both individual studies [*Chubarenko et al.*, 2022; *Russell and Webster*, 2021] and reviews [*Auta et al.*, 2017; *Bagaev et al.*, 2021; *Cole et al.*, 2011; *Derraik*, 2002], while MP contamination of freshwater systems has been less studied [*Cera et al.*, 2020; *Horton et al.*, 2017; *Li et al.*, 2020]. Despite limited research, MP in freshwater have been found around the world: both in the urban areas and in the protected zones [*Dusaucy et al.*, 2021; *Mani and Burkhardt-Holm*, 2020; *Wang et al.*, 2017]. River waters transport the microplastic particles, whereas the sediments of rivers, lakes and oceans accumulate MPs, forming a global storage of polymers. The 80% of plastic debris in the marine environment brings from the land, and rivers are the main pathways for the MP transport [*Cera et al.*, 2020; *Horton et al.*, 2017; *Li et al.*, 2020]. Near-stream pumping wells are often supplied by induced stream infiltration [*Filimonova and Baldenkov*, 2015], so pore scale MPs from river water or bottom sediments can transport into pumping wells. Therefore, there may be a potential risk for drinking water supplies; estimating MP contamination in the catchment zone is crucial.

In recent years, several investigations have been conducted on microplastic contamination in rivers and lakes in European and Siberian parts of Russia. Microplastic particles were detected in the Volga River [*Lisina et al.*, 2021; *Yasinskii et al.*, 2021], the Northern Dvina River [*Zhdanov et al.*, 2022], the Yenisei River [*Frank et al.*, 2021], the Ob River [*Frank et al.*, 2020], the Malaya Neva River and the Smolenka River [*Pozdnyakov and Ivanova*, 2018], six small rivers of the Kaliningrad region [*Krivopuskova and Shibaev*, 2022], Lake Ladoga [*Pozdnyakov and Ivanova*, 2018], Lake Onego [*Zobkov et al.*, 2020, 2023], six Siberian lakes [*Malygina et al.*, 2021] and even Lake Baikal [*Il'ina et al.*, 2021; *Meyer et al.*, 2021; *Moore et al.*, 2021].

However, in foreign reviews on the MP distribution in freshwater systems, relatively little attention is paid to Russian investigations, and Russia is shown as a white spot on the world map.

This article aims to fill in knowledge gaps and provide an overview of studies on MP contamination in Russian freshwater bodies.

Plastic: Production, Use and Waste

Plastics, due to their properties, are widely used in building construction, automotive, shipbuilding, aircraft construction, mechanical engineering, textile industry, agriculture, medicine and in everyday life (Figure 1). Most of the plastic is being used in packaging and building construction, accounting for 40.5% and 20.4% respectively [*Plastics Europe and EPRO*, 2021].

All plastics are divided into two large groups: thermoplastic and thermosetting. While thermoplastics are recyclable polymers which easily melt when the temperature is raised, take a given shape, solidify, and then can be melted again, thermosets are not capable of changing from one phase state to another several times. When the temperature of thermosets rises, an irreversible chemical reaction occurs, resulting in the formation of a non-molten and insoluble material [*Kazmiruk*, 2020].The first synthetic polymer was developed by Leo Baekeland in 1907 (USA), called Bakelite. It is a thermosetting phenol formaldehyde resin, formed from a condensation reaction of phenol with formaldehyde. The development of plastics based on phenol and formaldehyde in Russia was taking place at the same time. A group of chemists synthesized carbolite in 1914, a Russian analogue of bakelite.

Thermoplastic polymers include such widespread materials as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET), then thermosets are now less commonly known. However, that in the mid-20th century thermosetting polymers were more widely used than thermoplastic plastics, even in the 1980s and 1990s more attention was paid to compositions based on hardenable resins, their modifications and obtaining products from them. Basic thermoplastics were produced quite a long time ago, however, types with strength properties were not invented for a long time.

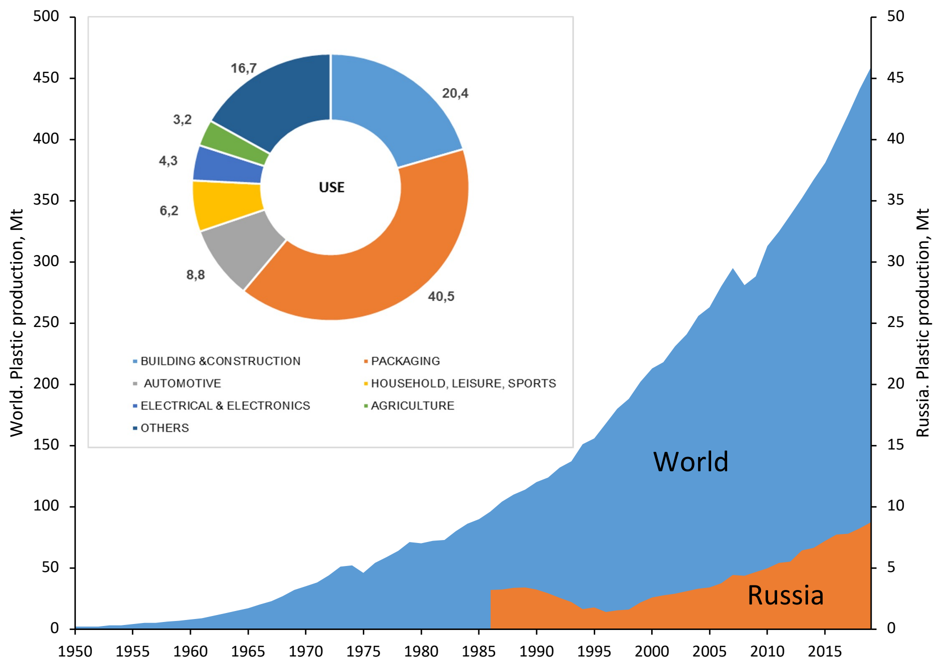

Figure 1. Global and Russian plastic production and percentage application in the market sectors. Figure is based on the data [*Geyer et al.*, 2017; *Ritchie et al.*, 2023; *Speranskaya et al.*, 2021].

The intensive use of plastic began after World War II, in 1950 amounted ~ 2 million tons (Mt). Further, there has been a rapid growth in the production of polymers (Figure 1). Cumulative global production of plastics, including both polymer resin and fibers, by 2019 had reached 9.5 billion tons, more than one ton of plastic for every person alive today [*Ritchie et al.*, 2023].

Bioplastics is not included in this amount. Currently, biodegradable plastics represent less than one percent of global production [*European Bioplastics*, 2018]. According to the latest market data compiled by European Bioplastics global production of biodegradable plastics should increase from 2.42 Mt in 2021 to approximately 7.59 Mt in 2026, raising its contribution to 2% of total polymer production. Bioplastics are used in the same market segments as plastics: packaging, catering products, consumer electronics, automotive, agriculture, toys and textiles. Packaging is the largest market segment for plastics and bioplastics with 40.5% and 48%, respectively [*European Bioplastics*, 2018].

The largest amount of plastic is produced in China (35% of the total volume), North America (19%), Europe (15%); currently, Russia's contribution to the global production of plastics is not very large and amounts to about 3% [*Plastics Europe and EPRO*, 2021]. The production of plastic was 10.2 Mt in 2020, accounting for 15% of the total industrial production in Russia [*Federal State Statistics Service*, 1999]. The main types of plastic production are: polyethylene (PE, 36%), polypropylene (PP, 21%), polyvinylchloride (PVC, 12%). They are followed by groups of plastics based on polystyrene (PS), polyethylene terephthalate (PET) and polyurethane (PU) (<10% each) [*Geyer et al.*, 2017]. Six groups of varieties of these plastics account for more than 90% of the global production of all polymers.

In recent years in Russia, as elsewhere in the world, there has been a significant growth in the production of various types of plastics. Thus, in 2014–2019 the growth was 64.2%, PE production increased on average by 7.3%, PP – by 7.1%, PVC – by 8.5%, PS – by 0.9%, and PET – by 2.2% [*Speranskaya et al.*, 2021]. The distribution of polymer types in global and Russian primary production is shown in Figure 2.

Geyer et al. [2017] analyzed in detail global primary plastic production, use and waste, authors obtained, that 6300 Mt of primary and secondary plastic waste have been generated before 2015. Authors suggested, that approximately 12,000 Mt of plastic waste will be

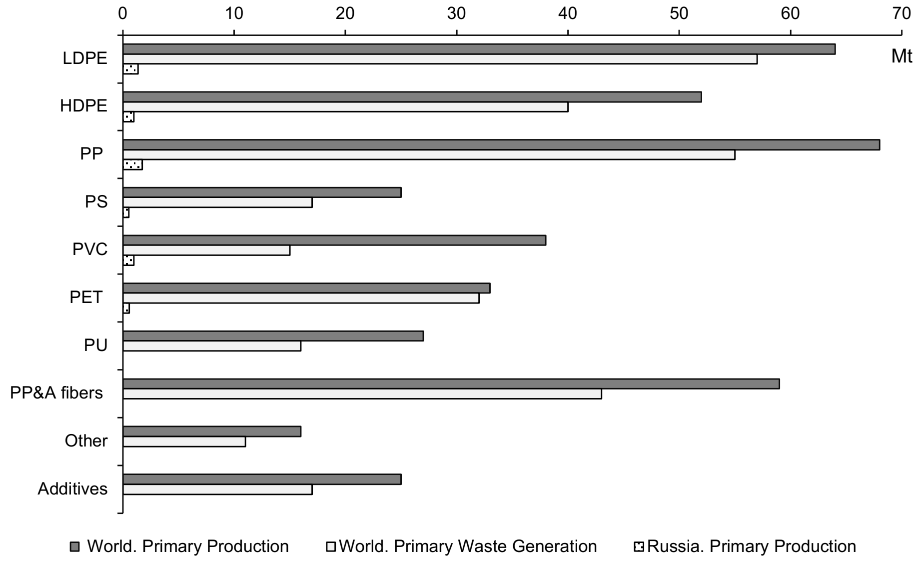

Figure 2. Polymer type in global primary production and waste generation. Figure is based on the data [*Geyer et al.*, 2017; *Ritchie et al.*, 2023; *Speranskaya et al.*, 2021].

in landfills or in the natural environment by 2050 due to current production and waste management trends. Top 10 countries produced the most total plastic waste in 2016 is shown in Figure 3. 5800 Mt of global primary plastics is single-used, 600 Mt (9%) was recycled since 1950, only 10% of which have been recycled more than once [*Geyer et al.*, 2017]. Non-recyclable plastics are incinerated or discarded. Approximately 800 Mt (12% of primary and secondary plastics) have been incinerated. Most waste has accumulated in landfills or in natural environment. Before 1980, plastic recycling and incineration were negligible. Global recycling and incineration rates have slowly increased, currently, 13–32% of plastics waste is recycled in Europe, and up to 76% is incinerated, in China 25% is recycled and 30% is incinerated [*National Bureau of Statics of China*, 1999; *Unnisa and Hassanpour*, 2017]. The leader in plastic waste management is Switzerland, where 24% of waste is recycled, 76% is incinerated and nothing is discarded in landfills. In the Russian Federation the recycling of plastic is 7–12.5% [*Federal State Statistics Service*, 1999], while various experts estimate this rate in the range of 5–25% [*Volkova*, 2020]. The rest of the plastic waste is discarded in landfills or incinerated. Approximately 20% of PET bottles are

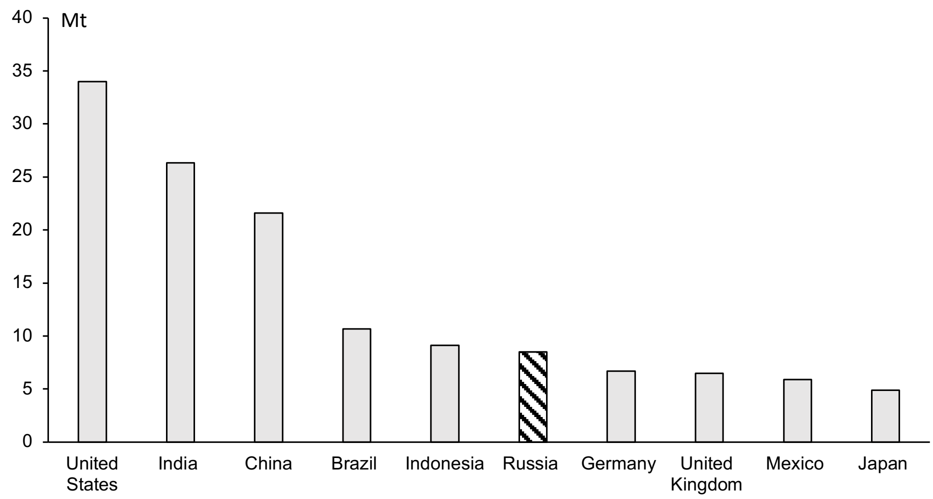

Figure 3. Countries, produced the most total plastic waste in 2016 [*World Population Review*, 2023].

recycled, 10% of total PVC products, 12% – of PS, 17% – of PP, 12% – of other thermoplastic [*Speranskaya et al.*, 2021]. According to the Ministry of Trade of the Russian Federation, there are about 500 companies in the country, which can recycle 350–450 thousand tons of plastic waste.

Types of Microplastics

Microplastics include a quite wide group of polymers that differ not only in composition and physical properties, but also in shape due to different origin. There can be distinguished primary and secondary microplastics. The primary microplastics are specially manufactured as microgranules for use in cosmetics, medicines and cleaning, personal care products, in blasting, in drilling fluids for oil and gas exploration or pellets (pre-production plastics) to produce larger products [*Cole et al.*, 2011; *Duis and Coors*, 2016; *Kazmiruk*, 2020]. This category comprises of pellets, grains, and spheres, beads, i.e. a number of shapes that are close to spherical, such as ovoid or cylindrical particles [*Lusher et al.*, 2020]. Microplastics from personal care products represent granules with a less regular particle surface due to use as exfoliants.

Secondary microplastics is produced by the disintegration of large polymer products: abrasion of car tires, destruction of road surfaces, losses and defragmentation of plastic materials; degradation of plastic debris on land and in the oceans, domestic and industrial washing or production of synthetic textiles [*Duis and Coors*, 2016; *Kazak et al.*, 2023]. Fibers and fragments relate to the group of secondary microplastics. Fibers are elongated particles whose length is significantly greater than their width; fibers may also be present in bundles. Synthetic textiles are the main source of synthetic fibers. Some researchers classify MPs produced during the washing processes or synthetic clothes production as primary plastics. Fragments are a highly diverse category of particles, including such specific subcategories as foams and films [*Lusher et al.*, 2020]. Fragments are characterized by their relative angularity. Films are particles with two dimensions are significantly greater than the third. Foams is fragments from expanded plastics. The majority of fragments are formed during macroplastic degradation (physical, chemical, biological).

Materials and Methods

Data collection was performed by bibliographical search in several databases such as Scopus, Web of Science, and Russian Science Citation Index (without a lower time limit, until August 2023). The keywords given in Russian and English were “microplastic(s)”, “plastic pollution”, “lakes”, “rivers”, and “Russia”.

16 articles dedicated to microplastic particles in freshwater bodies of Russia were selected for analysis. Identical results published in different publications were rejected (e.g., if a brief report was published first, followed by a more detailed paper about the same site). The following information has been collected from all articles: 1) the investigated object: bottom sediments, river water or lake water; 2) methodology: sampling method, MP extraction process, identification techniques; 3) abundance and characteristics of MPs: size, shape, polymer type. The obtained information is systematized in Table 1 and graphical formats (Figure 4).

Techniques: Sampling, Extraction and Identification

Investigations of environmental contamination by MPs can be conducted for water, bottom sediments or coastal deposits. Determination of MP abundance in freshwater systems include three steps: 1) sampling MPs from nature water or sediments; 2) extraction MPs from organic and inorganic matter; 3) identification size, shape, color, chemical type and other properties of polymers.

The sampling methods used for capturing microplastics divided into three groups: selective, bulk and volume-reduced [*Hidalgo-Ruz et al.*, 2012]. Selective method is used for analysis MPs from coastal sediments, whereas bulk method is applicable for bottom sediments. The volume-reduced method is the most commonly implemented for water sampling and sometimes for bottom sediments [*Zobkov and Esiukova*, 2018]. Water sampling equipment is MANTA trawls, Neuston net, pelagic/bottom trawls, Niskin bathometers, self-made filtration units, and pumping devices [*Bagaev et al.*, 2021].

Trawling with MANTA net or Neuston net is the main method for sampling surface water for the estimation of microplastic concentration used in Russia (Table 1). The mesh size traditionally is 330 μm [*Frank et al.*, 2020; *Il'ina et al.*, 2021; *Lisina et al.*, 2021], in this case particles of size 0.33–5 mm are analyzed. Net with 67-μm mesh was involved in study [*Krivopuskova and Shibaev*, 2022], that allows to catch smaller MP particles. Researches also used filtration device with mesh size of 100 or 132 μm [*Pozdnyakov et al.*, 2020; *Yasinskii et al.*, 2021]. The listed methods only collect plastics from the surface and near-surface water layer, and hence light polymers are analyzed. Pumping systems are applied to sample MP particles from the water column, this technique is often practiced for studies in the marine environment [*Bagaev et al.*, 2021; *Zobkov and Esiukova*, 2018], for freshwater systems it is used less frequently [*Ivanova and Tikhonova*, 2022; *Moore et al.*, 2021]. Vertical net with 174-μm mesh was involved in study [*Zobkov et al.*, 2023], this sampling technique allows to research MPs in the water column. In one study [*Meyer et al.*, 2021], bulk method was used, water samples were taken into bottles and the filtration process was performed into the laboratory.

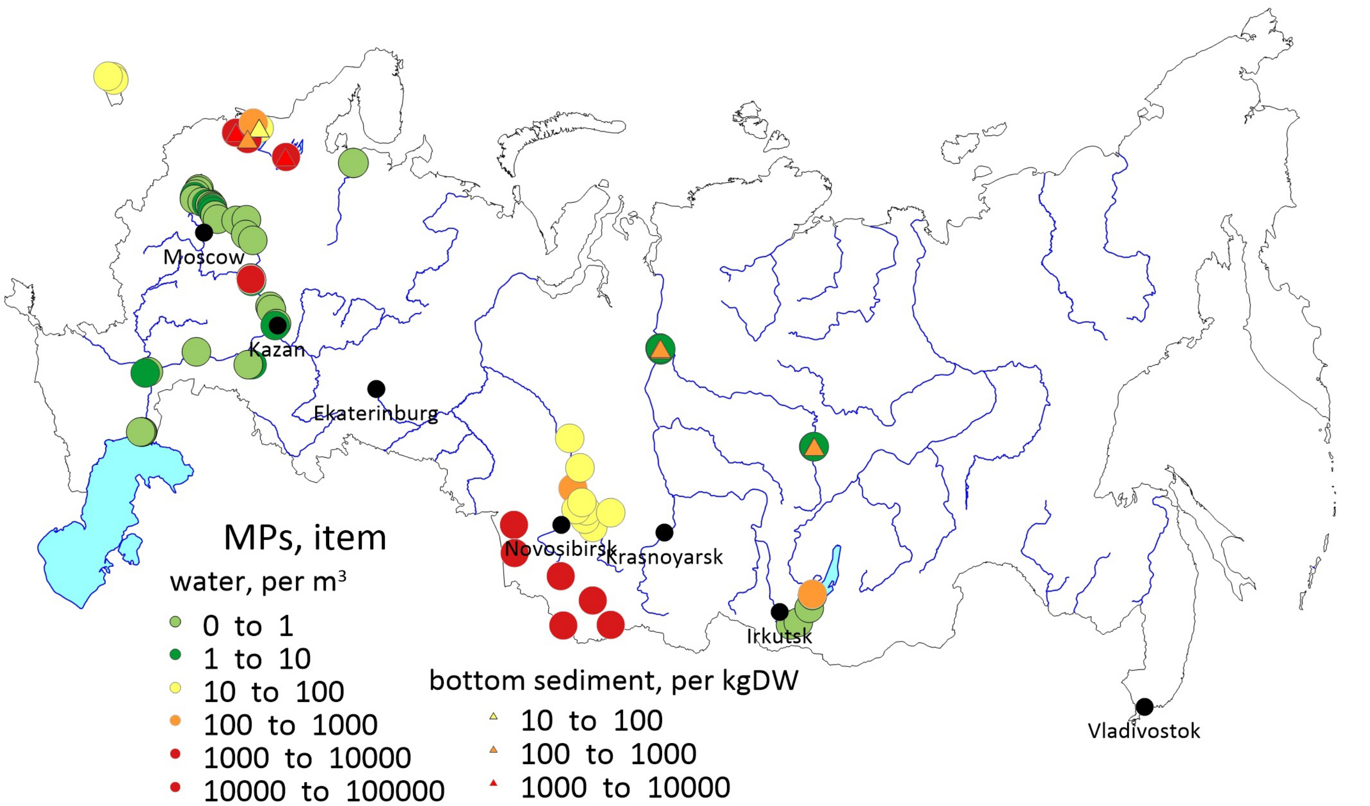

Figure 4. Map of microplastic sampling locations and its abundance from investigations in Russian freshwater bodies in 2018–2023.

Table 1. Description of microplastic particles found in Russian freshwater systems

Object	Sampling methods	Extraction methods	Metod density separation	Detection methods	Concentration, for water samples items/m^3 for bottom sediments – items/kg DW; *Cm* – mean concentration	Size	Shape	Polymer type	Reference
Ob and Tom Rivers (surface waters)	Manta-trawls with a 0.33 mm mesh net	Sieving, oxidation with Fenton, density separation	NaCl 1.19 g/ml	Stereo-microscope	26.5–114; *Cm* = 44.2–51.2	0.00045–0.15 mm – 19.4%, 0.15–0.3 mm – 28.6% 0.31 mm – 45.5% 1–5 mm – 6.5%	fragments 47.4%; fibers 22.1%; films 20.8%; spheres 9.74%	not detected	[*Frank et al.*, 2020]
Volga River (surface water)	Manta-trawls with a 0.3 mm mesh net	Sieving, oxidation with 30% NaOH and with 30% H_2O_2, filtration, density separation	saturated solution NaCl	Stereo-microscope, DSC	0.156–4.1; *Cm* = 0.9	0.3–5 mm	fragments 41%; films 37%; fibers 22%	PE, PP, PS, PVC	[*Lisina et al.*, 2021]
N. Dvina River (surface water)	Trawls with a 0.33 mm mesh Neuston net	Visual analysis, density separation and sieving	no data	FTIR	0.004–0.010; *Cm* = 0.007	0.333–0.5 mm	fragments 82%, films, fibers, spheres, foams	PE 52.6%, PP 36.8% , EEA 10.5%	[*Zhdanov et al.*, 2022]

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Object		Sampling methods	Extraction methods	Metod density separation	Detection methods	Concentration, for water samples items/m^3, for bottom sediments – items/kg DW; Cm – mean concentration	Size	Shape	Polymer type	Reference
Nizhnyaya Tunguska River and Yenisei River	Surface water	Manta-trawls with a 0.3 mm mesh net	Sieving, oxidation with Fenton, density	NaCl 1.20 g/ml	Stereomicroscope	1.2 ± 0.7 to 4.53 ± 2.04	0.30–1.00 mm	fragments of irregular shape, fibers, films, spheres	not detected	[Frank et al., 2021]
	Bottom sediments	Stainless steel spoon, then samples were stored in aluminum foil bags				235 ± 83.0 to 543 ± 94.1				
Siberian lakes (surface water)		5-liter glass jars	Filtration with a vacuum filter pump Filtration through glass microfiber filters. Drying in Petri dishes	Not used	SEM/EDS	(4–26)×10^3; $Cm = 11 \times 10^3$	10–960 nm	films 21%, fragments 37%, fibers 9%, foam 14%, pellets 19%	not detected	[Malygina et al., 2021]
Talmen Lake						8000				
Dzhulukul Lake						5000				
Teletskoye Lake						12,000				
Zludyri Lake						4000				
Degtyarka Lake						26,000				
Kuchuk Lake						8000				

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Object		Sampling methods	Extraction methods	Metod density separation	Detection methods	Concentration, for water samples items/m^3, for bottom sediments – items/kg DW; Cm – mean concentration	Size	Shape	Polymer type	Reference
Lake Ladoga	Surface water	Self-made filtration unit mesh size of 100 µm	Oxidation with H_2O_2, sieving and density separation	Saturated solution NaCl	Stereo-microscope	20–2400	0.1–1.5 mm (more common) 1.5–5 mm	—	not detected	[Pozdnyakov and Ivanova, 2018]
	Bottom sediments	no data				60–200 items/kg				
Lake Baikal (surface water)		Trawls with a 0.33 mm mesh net	Sieving and density separation	Saturated solution NaCl	Binocular micro-scope, IR spectrom-etry	0.095–0.48; Cm = 0.27	0.33–1.6 mm – 55.7% 1.6–3.2 mm – 27.7% 3.2–5.0 mm – 8.2% 5.0–32.8 mm – 8.4%	films (59.6%), fragments (23.5%), fibers (16.8%), foam (2%)	PE – 50%, PP – 40%, PS – 10%	[Il'ina et al., 2021]
Lake Onego (bottom sediments)		Peterson grab (2018), Box Corer Grab (Hydrobios) (2019).	Oxidation with H_2O_2 sieving and dense-liquid separation	HCOOK 1.5 g/ml	Stereomicro-scope with Raman spectro-metry	Cm = 2188.7 Central part of lake 2290–4679	0.174–5 mm	fibers (54.6%), beads (19.6%), fragments (12.9%), films (12.9%)	PC, PE, cello-phane and polyacry-lonitrile (together forming 57%)	[Zobkov et al., 2020]

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Object	Sampling methods	Extraction methods	Metod density separation	Detection methods	Concentration, for water samples items/m^3, for bottom sediments – items/kg DW; Cm – mean concentration	Size	Shape	Polymer type	Reference
Smolenka river (surface water)	Self-made filtration unit; mesh size of 100 μm	—	—	Optical microscope; Raman spectrometry, FTIR	$Cm = 1.1 \times 10^3$	3–5 mm (2%) 1.5–3 mm (9%) 0.1–1.5 mm (89%)	fibers (96%), beads (1%), fragments (3%)	PET	[Pozdnyakov et al., 2020]
M. Neva river (surface water)					$Cm = 3.0 \times 10^3$				
Smolenka river (bottom sediments)	no data	2 times density separation; oxidation with H_2O_2 sieving and dense-liquid separation	$ZnCl_2$ 1.7 g/ml	Optical microscope; Raman spectrometry, FTIR	Cm = 60 items/kg	3–5 mm (2%) 1.5–3 mm (9%) 0.1–1.5 mm (89%)	fibers (95%), beads (4%), fragments (1%)	PET	
M. Neva river (bottom sediments)					Cm = 30 items/kg				
Tributaries of the Volga River (surface water)	10 liters	Oxidation with Fenton; filtration	—	Optical microscope with hot needle test	$(0.5–1.3) \times 10^3$	90–2000 μm	fibers	not detected	[Yasinskii et al., 2021]

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Object	Sampling methods	Extraction methods	Metod density separation	Detection methods	Concentration, for water samples items/m^3, for bottom sediments – items/kg DW; Cm – mean concentration	Size	Shape	Polymer type	Reference
Lake Baikal (surface water)	Pumping 300 L and filtration through a nylon plankton net (20-μm mesh)	Filtration; oxidation with H_2O_2	NaI	Optical microscope; FTIR	291	15–2946 μm	Fibers (31%), fragments (69%)	PP 65%, PET 16%, PE 4%, PVC 4%, alkyd resin 4%, other 7%	[Moore et al., 2021]
South part of lake Baikal (surface water)	Sampling in 1.5 L plastic bottles	Filtration with net 47 μm	—	Stereo-microscope	no data	0.3–5 mm	Fibers, fragments, beads	not detected	[Meyer et al., 2021]
Six small rivers of the Kaliningrad region (surface water)	Planktonic network with a mesh size of 67 μm	Filtration through the membrane filter	—	Stereo-microscope	20–120	1–5 mm	Fibers, fragments	not detected	[Krivopuskova and Shibaev, 2022]
Lake Ladoga (surface water)	Pumping through a net (60-μm mesh)	Oxidation with Fenton; filtration	—	Optical microscope; Raman spectrometry	18–353	60–5000 μm	Fibers (98%), Fragments (1%), Films (1%)	PET (46%), Polyacrylate (31%), PP (15%), PE (8%)	[Ivanova and Tikhonova, 2022]
Lake Ladoga (bottom sediments)	Ekman Berge grab	2 times density separation, filtration, oxidation with Fenton; filtration	$ZnCl_2$ 1.7 g/ml		14–90		Fibers (99%), Fragments (1%)		

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Object	Sampling methods	Extraction methods	Metod density separation	Detection methods	Concentration, for water samples items/m^3, for bottom sediments – items/kg DW; Cm – mean concentration	Size	Shape	Polymer type	Reference
Lake Onego (surface water)	Vertical net with 174 μm-mesh	Oxidation 30% H_2O_2; density separation	HCOOK (1.5 g/ml)	Raman spectrometry	78–3680	174–5000 μm	Fibers (99%)	Synthetic additives (30%), PP (12%), PET (12%), PA, PE, AC, modified cellulose etc.	[Zobkov et al., 2023]
Lake Onego (bottom sediments)	Peterson grab and Hydrobios box grab	Oxidation 30% H_2O_2; filtration, density separation			234.8–52,107.0; Cm = 6667.1±4326.8		Fibers (50–60%), beads, films, fragments	PE (17%), PC (15%), AC (15%), PA, PET, PS, PU modified cellulose etc.	

Bottom samples is mostly collected using different grabs (Van Veen, Peterson, Ekman), box Corer and rockhopper ground gear. In the works under consideration, Peterson grab and Box Corer (Hydrobios) [*Zobkov et al.*, 2020, 2023] and Ekman Berge grab [*Ivanova and Tikhonova*, 2022] were used. In study [*Frank et al.*, 2021] sediments were collected bystainless steel spoon. Two papers do not mention the sampling technique [*Pozdnyakov and Ivanova*, 2018; *Pozdnyakov et al.*, 2020].

Sampling and identification methods are varied, but methods of separating plastics are standardized and modified are based on NOAA protocol [*Masura et al.*, 2015] or modified NOAA protocol [*Zobkov et al.*, 2020], and consists of the following steps: drying, oxidation, flotation, filtration. The most commonly used flotation reagent is NaCl (1.2 g/mL) (Table 1), other salts were also used: HCOOK [*Zobkov et al.*, 2020, 2023], $ZnCl_2$ [*Ivanova and Tikhonova*, 2022; *Pozdnyakov et al.*, 2020], NaI [*Moore et al.*, 2021]. In study [*Zobkov et al.*, 2023], it is noted that the use of HCOOK and $ZnCl_2$ as a separation reagent shows identical results and allows to compare the MP concentrations of different investigations.

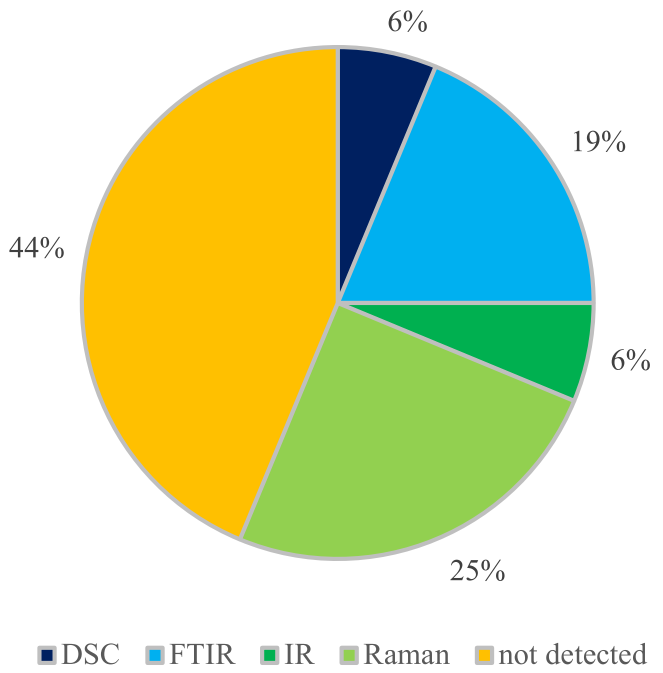

Figure 5. Techniques for identifying the polymers used for microplastics in Russian studies.

Identification techniques for determination polymer type divided into 2 groups: visual and analytical. Visual characterization of microplastics includes three descriptive categories al descriptions: morphology (size, shape, and texture), optical properties (color, reflectivity, and birefringence) and behavior (flexibility, density, etc.) [*Lusher et al.*, 2020]. Electron microscopy plus energy-dispersive X-ray spectroscopy (SEM/EDS) determines surface morphology and elemental composition to identify whether each particle was potentially a plastic [*Malygina et al.*, 2021]. Researches showed that false identification of plastic-like particles by microscopy can be 20%, and for transparent ones – 70%, which was confirmed by subsequent spectroscopic analysis [*Hidalgo-Ruz et al.*, 2012].

Polymer types were identified in 8 studies. The most commonly used analytical methods for determining the presence and type of polymers are IR spectroscopic techniques such as Fourier Transform Infrared Spectroscopy (FTIR) and Raman spectroscopy, which were applied in 7 researches (Figure 5). Besides FTIR [*Moore et al.*, 2021; *Zhdanov et al.*, 2022; *Zobkov et al.*, 2023] and Raman spectroscopy [*Pozdnyakov et al.*, 2020; *Zobkov et al.*, 2020, 2023], thermal methods have been used to identify the composition of microplastics, among them pyrolysis-gas chromatography and differential scanning calorimetry. Unlike the spectroscopic approach, this technique is destructive. DSC was used to identify particles in Volga water [*Lisina et al.*, 2021].

The detailed description, advantages and limitations of each method are not presented here, as there are a sufficient number of articles on this subject [*Kazak et al.*, 2023; *Kazmiruk*, 2020; *Zobkov and Esiukova*, 2018].

Distribution of Microplastics in Freshwater Bodies

The researches of microplastic particles in freshwater environments are widely performed all over the world. In Russia, the first investigation of microplastics in surface water began in 2018 with the study of surface water and bottom sediments of Lake Ladoga [*Pozdnyakov and Ivanova*, 2018]. Later MP contamination determined also in Lake Onego [*Zobkov et al.*, 2020], Lake Baikal [*Il'ina et al.*, 2021; *Meyer et al.*, 2021; *Moore et al.*, 2021], lakes in the southern part of Western Siberia [*Malygina et al.*, 2021]. MP research in Russian river systems are at the at the early stages of development, several water samples from the Volga River have been investigated [*Lisina et al.*, 2021; *Yasinskii et al.*, 2021], in the river mouths of the Neva Bay [*Pozdnyakov et al.*, 2020], and samples have been taken in the Northern Dvina [*Zhdanov et al.*, 2022], the Yenisei and the Ob [*Frank et al.*, 2020, 2021].

The following information is summarized and presented in Table 1: sampling methods, extraction processes, identification techniques, and MP characteristics such as concentration, size, shape and chemical composition of polymers.

Microplactics in Lake and River Waters

Fourteen investigations were made to analyze MP contamination in Russian lakes and rivers. Water samples were collected using 300-μm mesh size trawl net in the Volga [*Lisina et al.*, 2021], the Yenisey [*Frank et al.*, 2021], the Northern Dvina [*Zhdanov et al.*, 2022], the Ob and the Tom [*Frank et al.*, 2020]. NaCl (1.2 g/mL) is used as flotation reagent in these investigations, except the Northern Dvina River, where the separation method is not mentioned. Single sampling method and NaCl salt for density separation allows reliable comparison of study data.

A study was conducted along the entire Volga River in 2020. Thirty-four samples of surface water were taken from upstream to downstream along river. Microplastics were found at all the locations, but their concentrations varied significantly from 0.16 to 4.1 items/m^3 [*Lisina et al.*, 2021]. Maximum MP concentrations (1.9–4.1 items/m^3) were detected near large cities: Kazan, Nizhny Novgorod, Volgograd, and Tver (Figure 4). Similar concentrations were obtained in the middlestream of the Yenisey River of 1.2–4.5 items/m^3 [*Frank et al.*, 2021]. MP concentration in the upper Ob River and its tributary Tom River was ranged from 29.2 to 114 items/m^3, and the maximum abundance was detected near Novosibirsk [*Frank et al.*, 2020]. In the delta of the Northern Dvina River were collected 9 samples during 9 months' ice-free period. The amount of microplastics ranged in the limits 0.004–0.010 items/m^3, no clear trend of seasonal variability can be detected [*Zhdanov et al.*, 2022].

A comparison of MP content in rivers around the world using a similar sampling method (0.3 mm mesh trawls) shows the same significant range of values. For example, in the Rhine, the MP concentration is 0.04–9.97 items/m^3 higher MP concentrations in the downstream German Rhine River versus the Rhine in Basel and upstream Swiss tributaries are associated with greater anthropogenic pressure and mismanaged waste [*Mani and Burkhardt-Holm*, 2020]. Higher concentrations were observed in three urban Chinese estuaries (100–4100 items/m^3) [*Zhao, Sh. et al.*, 2015] and at five locations near major cities on the Ganga Rive (3.8–6.8 × 10^5 items/m^3) [*Singh et al.*, 2021].

Estimation MP abundance in small rivers in Kaliningrad region, using planktonic net with 67-μm mesh for sampling, shows 20–120 items/m^3 [*Krivopuskova and Shibaev*, 2022]. The use of the same water sampling method – trawling, but with different mesh sizes, already at the first stage of research (sampling stage) creates uncertainty for comparison of polymer particle concentrations.

For tributaries of the Volga [*Yasinskii et al.*, 2021], the M. Neva and Smolenka rivers [*Pozdnyakov et al.*, 2020] filtration through 132 and 100 μm mesh was used, respectively. The obtained concentrations of microplastic particles are similar. For the Volga tributaries the MP abundance is (0.5–1.3) × 10^3 items/m^3, for the mouth parts of the Neva Bay rivers (1.1–3) × 10^3 items/m^3 (Table 1).

The morphological characteristics of microplastics were made for each study, but the percentage of different forms was not determined in all cases (Figure 6). In the Volga water, the mean ratio of shapes was: fragments 41%, films 37%, and fibers 22%, but their ratio was not constant in different locations. It was found that as increase the total abundance of all types of particles, the proportion of fragments also increases, indicating the emergence of new sources of contamination [*Lisina et al.*, 2021]. Particles of various shapes (fragments, films, fibers, spheres, foams) were found in the surface waters of the Northern Dvina River, the majority of particles were fragments 82% [*Zhdanov et al.*, 2022]. Irregularly shaped fragments were the most abundant among the Ob and Tom samples (47.4%) and exceeded fibers (22.1%), films (20.8%), and spheres (9.74%) on average [*Frank et al.*, 2020]. Microfragments were the most abundant in the all samples, except for the sampling site near Kemerovo in the Tom River. The highest concentration (56.8%) of microbeads was observed at this site due to the fact that plastics plants are located in this area. Fibers, film and fragments were detected in water samples from the Yenisei River [*Frank et al.*, 2021]. Microspheres and pellets were not detected. The percentage ratio of MP particle shapes obtained in the river water of the Neva and Smolenka rivers is as follows: fibers – 96%, fragments – 3%, beads – 1% [*Pozdnyakov et al.*, 2020].

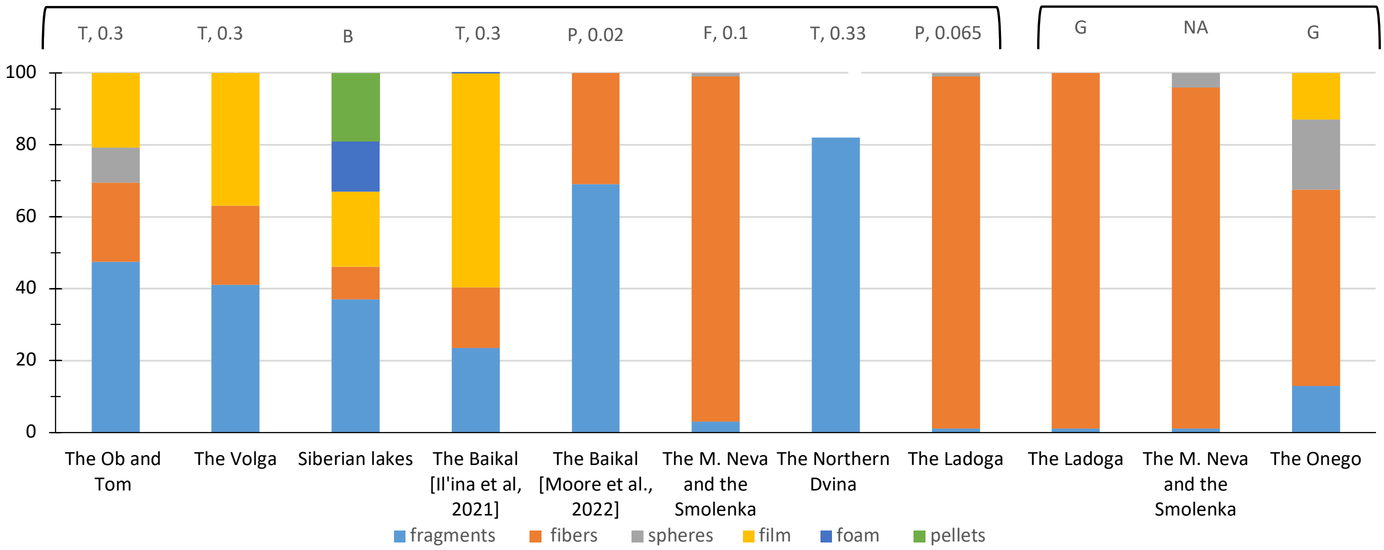

Figure 6. Shapes of microplastic particles in freshwater bodies and sampling method: T – trawling, B – bulk method, P – pumping, F – filtration, VN – vertical net, G – grab; number –mesh size of net or filter in mm.

The morphological characteristics of microplastics help to suggest MP sources and degradation degree of particles, for this reason, it is recommended to describe the shape of the particles in as much detail as possible [*Lusher et al.*, 2020]. Significant concentration of virgin plastic pellets indicates the nearby plastics plants or highways where pellets are lost during transportation, contamination of polyester fibers located near textile factories; high values of both fibers and microbeads from personal care products show wastewater discharge; beads are also used in airblasting technology; fragments reveal the impact of runoff on the crushing of large pieces of plastic [*Auta et al.*, 2017; *Ziajahromi, Sh. et al.*, 2016]. Most of the MPs that entered the seas from rivers were synthetic polymers from WWTP (42%) and plastic-based textiles from laundries (29%), while smaller sources of fibers came from household dust (19%) and personal care microbeads (10%) [*Siegfried et al.*, 2017]. A global assessment of the percentage of MP shape found in freshwater showed the following results: fibers were 59%, fragments counted 20%, beads, films and foams were also observed in a proportion of less than 10%; the analysis includes all studies addressing the MP investigations in freshwater bodies without taking into account sampling, extraction and identification methods [*Li et al.*, 2020].

Identification of the polymer type in the considered works was carried out by different methods (Table 1). Types of polymers found in Volga are determined by differential scanning calorimetry. The DSC results showed that PE and PP prevailed in all samples and represent items of various shape and color, single samples of PVC and PS have been identified out [*Lisina et al.*, 2021]. Chemical composition of the found plastic items in the delta of the Northern Dvina River was made by FTIR. The majority of the microplastics were identified as polyethylene (PE) 52.6%, followed by polypropylene (PP) 36.8% and Ethylene Ethyl Acrylate Copolymer (EEA) 10.5%. Among types of mesoplastics were found particles PU and PS [*Zhdanov et al.*, 2022]. The majority of fibers were identified as PET in the Smolenka and the M. Neva by methods of Raman and IR-spectrometry [*Pozdnyakov et al.*, 2020]. Polymer types in other investigations were not detected.

A global estimation of MP composition shows, that PP and PE represent 24% each in the composition of the microplastics found in freshwater samples, together with PS and PET contribute almost 3/4 of the contamination in freshwater systems [*Li et al.*, 2020]. Cera and co-authors note PP and PE are the main contaminants for sediment and water, while PE and PET are mostly found in biota [*Cera et al.*, 2020].

Microplastic concentration was studied in 9 Russian lakes (Lake Onego, Lake Ladoga, Lake Baikal and the Altai lakes). Microplastic particles in Lake Baikal water were investigated in three studies, using different sampling methods: MANTA trawling with 330-μm mesh size [*Il'ina et al.*, 2021], pumping 300 L and filtration through a nylon plankton net (20-μm mesh) [*Moore et al.*, 2021] and collecting water samples in plastic bottles [*Meyer et al.*, 2021]. The study [*Meyer et al.*, 2021] has no detailed description of sampling methods and plastic particles extraction methods, but indicates the size range of detected MPs > 330 μm. MP concentrations in water samples were 0.27 items/m^3 for 0.33–32.8 mm size particles [*Il'ina et al.*, 2021], 1.79 items/m^3 for 0.33–5 mm [*Meyer et al.*, 2021], and 291 items/m^3 for 15–2946 μm size particles [*Moore et al.*, 2021]. Since MPs < 330μm particles are 88% of the total MPs, content of MPs > 330 μm is 34.92 items/m^3 in [*Moore et al.*, 2021]. According to results of [*Il'ina et al.*, 2021], the microplastic size range represents 91.6% of the total content, thus, MP abundance in Lake Baikal varies from 0.25 to 34.92 items/m^3, using different sampling techniques. The research [*Barrows et al.*, 2017] showed that the microplastic concentration was three times lower by sampling with a mesh size of 335 μm than similar volume of 1 L surface grab water sampling. [*Uurasjärvi et al.*, 2019] reported, that MP abundance in the surface water of Kallavesi Lake (Finland) was 0.27 ± 0.18 items/m^3, sampled with a 0.333 mm Manta net, and 1.80 ± 2.30 items/m^3, sampled with a 0.3 mm filter pump.

Microplastic particles were detected in all water samples taken from Lake Ladoga during 2018–2021 [*Ivanova and Tikhonova*, 2022; *Pozdnyakov and Ivanova*, 2018]. The minimum MP concentration was 0.02 items/L and maximum was 2.4 items/L at a sampling point located in several kilometers from the household waste dump [*Pozdnyakov and Ivanova*, 2018]. Converting the concentration to m^3, the MP content is 20–2400 items/m^3 for 0.1–5 mm size particles. In study [*Ivanova and Tikhonova*, 2022] the summary of the results of MP investigations in Ladoga water for the period 2018–2021 is given and the concentration of microplastics is presented as 18–353 items/m^3 for particles 60–5000 μm size. Self-made filtration unit with mesh size of 0.1 mm was used initially, later pumping device with filter of 60-μm mesh size was involved, i.e. the minimum size in previous studies was 100 μm, in subsequent studies it was reduced to 60 μm. A saturated NaCl solution was used for floatation [*Pozdnyakov and Ivanova*, 2018], later $ZnCl_2$ was applied as a separation reagent [*Ivanova and Tikhonova*, 2022]. The location with the maximum concentration was not included in the analysis 2022 year.

Water samples from Lake Onego were taken using vertical net with 174-μm mesh size during 2019–2021 period. MP abundance from water column based on the results of 17 samples was 78–3680 items/m^3 [*Zobkov et al.*, 2023].

Microplastic contamination were investigated in the surface waters from six lakes in the Western Siberia. The studied lakes are located both in the Altai mountains and the West Siberian plain, they differ in size, origin, and climate and human activities [*Malygina et al.*, 2021]. Samples were collected into 5-liter glass jars. Particles of size 1–350 nm were investigated in this research. When smaller particle sizes are studied, due to all other factors being equal, a higher particle content will be detected. Therefore high concentrations of microplastics (4–26) × 10^3 items/m^3 were detected for all lakes, despite the fact that the three lakes are situated in a protected area Katunsky and Altaisky Nature Reserves. Authors suggested tourist litter, motorboat traffic and atmospheric transboundary transport as potential MP sources. Shoreline population changes have less effect on MP concentration in lakes than tributary presence in the lakes, confirming the important role of rivers in particle transport.

Compared with the other lakes worldwide, there is a significant variation in concentrations: from 0.12 items/m^3 in Lake Hovsgol (Mongolia) to 1.9×10^6 items/m^3 in Lake Winnipeg (Canada) for particles of size 0.3–5 mm [*Li et al.*, 2020]. MP abundance, detected in water samples from 20 urban Chinese lakes, is 1660–8925 items/m^3 [*Wang et al.*, 2017] for particles 60 to 5000 µm. The mean concentration is 2562 items/m^3, obtained from analysis of 62 water bodies all over the world for particles <5 mm [*Cera et al.*, 2020]. Another study [*Dusaucy et al.*, 2021] reported MP content from 0.27 to 34,000 items/m^3 with a median value around 1442 items/m^3, summarized from 98 worldwide lakes with a variety of particle sizes, contrasting sampling techniques and analyses.

Fibers and fragments are the main shapes detected in the water of lakes (Figure 6). Fibers are the dominant in water samples from Lakes Ladoga and Onego, accounting for up to 98–99% of the total amount [*Ivanova and Tikhonova*, 2022; *Zobkov et al.*, 2023]. According to [*Il'ina et al.*, 2021] in water samples from Lake Baikal the predominant shape was film (59.6%), fragments (23.5%) and fibers (16.8%) were found; but according to [*Moore et al.*, 2021] the fragments accounted for 69%, fibers – 31% of total, the primary plastic was not detected in both study. The obtained concentrations of plastic particles in Baikal water correlate with population density and the location of tourist centers. It should be noted that films and fragments predominate in samples taken near areas with anthropogenic load, while fibers are prevalent in samples taken at a distance from the main sources of polymers. The greatest diversity of particle forms was detected in the waters of Siberian lakes: fragments (37%), fibers (9%), films (21%), foam (14%), pellets (19%) [*Malygina et al.*, 2021].

Identification of the plastic composition in water samples from lakes has been carried out only in 5 works using spectrometry (Table 1). The chemical composition of MPs from Lake Baikal was carried out only for ten particles using IR spectroscopy, the following results were obtained: PE was 50%, PP 40%, PS 10% [*Il'ina et al.*, 2021]. PET and PVC were not detected in the analysis. The absence of these polymers is possibly due to their density, which is higher compared to water, and therefore they are more probably found in bottom sediments rather than in the surface water layer. In [*Moore et al.*, 2021], a diverse contrary ratio of polymer types Lake Baikal was obtained: PP 65%, PET 16%, PE 4%, PVC 4% and others due to the use of pumping method and hence collection of polymers from the water column. Only 20% of particles from Lake Ladoga were detected in [*Ivanova and Tikhonova*, 2022], the dominant types were PET (46%) and polyacrylate (31%). The small percentage of PE (8%) is probably due to the large number of narrow fibers that were burned during identification. In water samples from Lake Onego, 81% of particles were identified, among which both synthetic and natural polymers were found. Synthetic additives (30%), PP (12%), PET (12%), PA, PE, AC, modified cellulose and others were detected [*Zobkov et al.*, 2023].

Notably, 79% of the polymers from the identified samples had a higher specific density than fresh water. Scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM/EDS) was performed for samples from Siberian lakes. EDS analysis determined the elemental composition and showed Cl peaks that allows us to classify such particles as PVC [*Malygina et al.*, 2021].

According to review studies, the most common shapes in lake water were fibers and polymer types were PE and PP [*Dusaucy et al.*, 2021; *Li et al.*, 2020; *Wang et al.*, 2017]. To reveal patterns in chemical types of polymers from water bodies of the Russian Federation at this stage is not possible due to the small number of works and contrasting sampling and identification techniques.

Microplactics in Bottom Sediments

MP contamination in bottom sediments of freshwater bodies (Lake Onego, Lake Ladoga, the Yenisei River, the Smolenka River, the M. Neva River) was investigated in 6 studies (Table 1).

A detailed study of the bottom sediments of Lake Onego was performed in different seasons 2018–2021 [*Zobkov et al.*, 2020, 2023]. Sediment samples were collected using Peterson grab and Box Corer. MP extraction was performed using a modified NOAA protocol [*Zobkov et al.*, 2020]. The research results showed that the mean concentration of MPs was 6667.1 ± 4326.8 items/kg DW (0.174–5 mm size particles). The MPs abundance in Onego bottom sediments varied significantly depending on the site location [*Zobkov et al.*, 2020]. The highest MP abundance in bottom sediments was 52,107 items/kg DW, located near the Kondopoga pulp and paper mill and the town of Medvezh'egorsk [*Zobkov et al.*, 2020, 2023].

Investigation of MP particles in Ladoga sediments also began in 2018 [*Pozdnyakov and Ivanova*, 2018], unfortunately the sampling technique is not mentioned. MP particle content in bottom sediments was 60–200 items/kg DW for 0.1–5 mm size particles. Ekman Berge grab were used to collect sediments in further research [*Ivanova and Tikhonova*, 2022]. MP abundance was estimated as 14–90 items/kg DW for 0.06–5 mm size particles.

MP particles were also studied in river bottom sediments. The amount of MPs in the Yenisei bottom sediments were 235–543 items/kg DW (0.15–5 mm particle size) with no tendency of downstream increasing [*Frank et al.*, 2021]. Sediment samples were collected with a stainless steel spoon and stored in aluminum foil bags. The concentration of MP particles in the bottom sediments of the M. Neva and The Smolenka Rivers was 30–60 items/kg DW (0.1–5 mm particle size) [*Pozdnyakov et al.*, 2020].

For particles between 500–5000 μm, the MP concentration was low (<1 items/kg DW) in samples taken from the Roter Main River sediments (Germany), while for pore scale particles (20–50 μm) the high content was measured (~ 30,000 items/kg DW) [*Frei et al.*, 2019]. *Dusaucy et al.* [2021] reported that MP abundance in bottom sediments from 98 lakes worldwide ranged from 0.7 items/kg DW to 7707 items/kg DW with a median value around 385 items/kg DW, the authors summarized the results of all studies without considering particle size range.

In bottom sediments MP was mainly was mainly represented by fibers (Fig. 5). In two samples from the Yenisei River percentage of fibers reached 100% [*Frank et al.*, 2021], from Lake Ladoga – 99% [*Ivanova and Tikhonova*, 2022], from the M. Neva and the Smolenka – 95% [*Pozdnyakov et al.*, 2020]. In Onego sediments fibers accounted for 50–60% of the total, fragments, films and bears have been also found [*Zobkov et al.*, 2023]. The percentage of MP morphological forms is caused by the sampling location and the nearness of the contamination sources.

In total, 16 polymer types have been identified in bottom sediments in the Lake Onego [*Zobkov et al.*, 2023]. PC, PE, cellophane, and polyacrylonitrile were the most dominant polymers in bottom sediments in the Lake Onego, together accounting for over 57% of the identified samples, using Raman spectroscopy [*Zobkov et al.*, 2020]. The MP composition of Ladoga bottom sediments is similar to that of the water samples: PET and polyacrylate [*Ivanova and Tikhonova*, 2022]. The majority of polymers from the examined samples from the M. Neva and the Smolenka sediments were identified as PET [*Pozdnyakov et al.*, 2020].

Similar to lake water, fibers are the most frequently found in lake sediments, and the dominant types of polymers are PE and PP [*Dusaucy et al.*, 2021; *Wang et al.*, 2017].

Conclusion

The growth of plastic production in Russia, and consequently the accumulation of plastic waste in landfills leads to increased environmental contamination by microplastics. The investigation of microplastic contamination in Russian freshwater systems is at the initial stage; studies are scattered and fragmentary, although researching on plastics in freshwater is increasing.

The analysis of 16 articles dedicated to MPs in Russian freshwater bodies resulted in a summary of the results in tabular and graphical formats. The studies of MPs in freshwater bodies have focused on both water samples and bottom sediments. The microplastic particles in the Volga water, the main water artery of the European part of Russia, were studied in quite detail; MP concentration in the water of the Northern Dvina River delta was estimated at the single location, but within a time range; water samples were collected at several points of the Ob, the Tom, and the Yenisei (Siberian rivers), also six small rivers of the Kaliningrad region and two small rivers near Neva Bay (Leningrad region) were investigated. Microplastic contamination was studied in water samples from 9 lakes in European and Siberian parts of Russia. 6 studies reported MP contamination in bottom sediments of Russian lakes and rivers: Lake Onego, Lake Ladoga, the Yenisei River, the Smolenka River and the M. Neva River.

Currently, there is no standardized methodology for the MPs analysis (sampling, extraction, identification). The Russian studies reported the following water sampling methods: trawling, pump filteration, and bottle collection. Some researchers collect plastics from surface and near-surface water, while others study MPs in the water column. Using different salts as a separation reagent also results in different particle counts, NaCl, $ZnCl_2$, HCOOK, NaI were used as flotation reagent. Application of different methods of MP identification (microscopy, DSC, FTIR, Raman spectroscopy) also creates uncertainties in estimation of polymeric particles concentrations.

It is challenging and impossible to compare MP concentrations obtained from different techniques and particle size ranges. In 4 studies of river systems, MP particles were caught by MANTA or Neuston nets trawling with the same mesh size (0.330 mm); and NOAA protocol [*Masura et al.*, 2015] or modified NOAA protocol [*Zobkov et al.*, 2020] were used as the extraction method. Due to the use of similar techniques, it is possible to compare the concentrations obtained. The results showed that the MP concentration varies by three orders of magnitude: from parts of items/kg in the Volga River and the Northern Dvina River to hundreds of items/kg in the Upper Ob for particles 0.3–5 mm size.

Microplastic particles in Lake Baikal were investigated in three studies. Water samples were collected using MANTA net, pumping device and plastic bottles. MP abundance in Lake Baikal varies from 0.25 to 34.92 items/m^3 for particles 0.3–5 mm size. $(4–26) \times 10^3$ items/m^3 is the highest MP concentration in water samples, estimated in the Altai lakes (Western Siberia), which is related to the studied particle size (10–960 nm).

MP contamination of water and bottom sediments in Onego and Ladoga lakes has been studied in sufficient detail, both spatially and temporally. The highest MP abundance in bottom sediments was 52,107 items/kg DW for 0.174–5 mm size particles, sampled in Kondopoga Bay (Lake Onego), while the concentration of MP particles in Lake Ladoga does not exceed 200 items/kg DW for 0.1–5 mm size particles. MP content in Onego water reached 3680 items/kg (0.174–5 mm size), in Ladoga water – 2400 items/kg (0.1–5 mm size).

MP studies conducted in Russian freshwater systems reveal that MP concentration is highly variable in both water and bottom sediments. The MP content in water bodies can be distinguished, first, by various sources of contamination in urbanized, agricultural and natural areas; second, by different natural factors (wind regime, hydrological and hydrodynamic conditions of water bodies); third, by contrasting sampling techniques and different size ranges of the investigated particles.

Chemical composition, physical properties and morphological characteristics of microplastic particles help suggest possible sources of polymer contamination, so it is necessary to examine the caught MPs in as much detail as possible. Identification of the source of contamination will help to make decisions on environmental protection and to assess the risk of water contamination.

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