Microplastics Contamination of the Yenisei River

Subjects: Area Studies

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This study is a pioneering attempt to count microplastics (MPs) in the Yenisei River system to clarify the role of Siberian Rivers in the transport of MPs to the Arctic Ocean. The average MPs content in the surface water of the Yenisei large tributary, the Nizhnyaya Tunguska River, varied from 1.20 ± 0.70 to 4.53 ± 2.04 items/m3, tending to increase along the watercourse ($p < 0.05$). Concentrations of MPs in bottom sediments of the two rivers were 235 ± 83.0 to 543 ± 94.1 with no tendency of downstream increasing. Linear association ($r = 0.952$) between average organic matter content and average counts of MPs in bottom sediments occurred. Presumably MPs originated from the daily activities of the in-situ population. Further spatial-temporal studies are needed to estimate the riverine MPs fluxes into the Eurasian Arctic seas.

Keywords: microplastics abundance ; microfibers ; Siberian rivers ; surface water ; bottom sediments

1. Introduction

Global research is increasingly focusing on microplastics (MPs) (plastic particles < 5 mm in diameter), both their presence as well as the source of this pollution. Environmental and health concerns regarding water pollution from MPs include the ecotoxicological effect on aquatic organisms, as well as its potential accumulation in food chains up to humans [1][2]. Such concerns arise as a result of the hazardous chemicals present in the plastics, which arise both as a result of additives during the manufacturing process to improve polymer properties, and the adsorption of toxic chemicals by MP, enabling MP to become carriers of these chemicals into ecosystems [3][4].

MPs enter into oceans and continental water bodies primarily via rivers [5][6], which deliver up to 80% of plastic detritus into these water bodies [7]. Lebreton et al. [5] estimates that 1.15–2.41 million tons of plastic flow into oceans from riverine systems across the globe every year. The north-flowing rivers of Eurasia can carry MPs to the Arctic Ocean, and these Arctic waters are susceptible to contamination. A recent study found MPs, with particle average concentration 1.14 items per cubic meter, in 7 out of 13 sites in the White Sea basin, [8]. The results of quantitative analyses of MP abundance in the surface and subsurface waters of the East Siberian, Laptev, Barents and Kara seas have been published [9]. The highest mass concentration of MPs was observed in surface waters of Atlantic origin, whilst Siberian Rivers were identified as the second most important source of pollution in the Eurasian Arctic [9]. However, the contribution of rivers of Siberia to MPs flows in the Arctic region remains uncertain.

The load and transport of MPs in the Arctic-emptying great Siberian Rivers remain grossly understudied. In this preliminary study, we quantified MPs in the surface of the Ob River in its upper and middle course [10], thereby demonstrating the capacity for MPs to flow to arctic waters via the discharge of the Ob River to the Kara Sea. The Yenisei River system has not been previously investigated for the presence and abundance of MP particles in water and bottom sediments. This study is a pioneering attempt to count MPs in the Yenisei River system. Obtaining quantitative data on the presence of plastic microparticles in the components of the aquatic environment of the remote Yenisei tributary, the Nizhnyaya Tunguska (Lower Tunguska) River, will supplement current aggregate knowledge about the distribution of pollution of global aquatic ecosystems.

2. Current Insights

2.1. Levels of the Microplastic Pollution in Rivers

MPs are abundant in freshwater environments, but regional variations in intensity and distribution of MP pollution occur due to population density, industrial sources, accepted wastewater treatment technologies, and waterbody characteristics [6][11][12]. Moreover, a reliable comparison of particles counts for different rivers to date has been very difficult because variable and non-standardized methods are currently used for sample collection and processing in riverine MPs quantification studies [13][14]. This study attempts to compare the total counts of MPs in the N. Tunguska and the Yenisei

Rivers with published data on the world's rivers; data on the particle content of surface water and bottom sediments of the world's rivers, obtained using the similar methodology, mainly visual counting and sorting, were selected.

Data from 37 global freshwater locations demonstrate that continent with the highest level of freshwater MP is Asia, followed by North America, Africa, Oceania, South America, and Europe. Of all Asian countries, China has the highest level of MP pollution [12]. Comparative analysis of the particle counts in rivers shows that the content of MPs in river water can vary from <1 item/m^3 [15][16][17] to >1000 items/m^3 [18][19][20]. So, the N. Tunguska and the surveyed section of the Yenisei River cannot be classified as rivers heavily polluted with MPs. This is expected, given there are no large industrial centers or large settlements in the study area, and therefore no strong sources of pollution. Compared with the previously survey of sections of the Ob River system utilizing the same methodology [10], which are much more populated and with a developed industry, the average concentrations of MPs in the surface water of the N. Tunguska and the Yenisei River are 10–40 times lower.

Concomitantly, bottom sediments are considered as a long-term sink for MPs [21][22] and could serve as a more reliable criterion of plastic pollution level, although to date few studies have focused on MPs in freshwater bodies [17][23]. However, oscillations in the spread of MPs in bottom sediments along the river course arises since complete mixing and redistribution of the pollutant can occur at a considerable distance from the source, with currents, turbulence, and wind forces contributing to the accumulation of MP particles [24]. MPs distribution may depend on the morphology and sedimentation rates in the of the waterbody sections. Association of the MP counts with the total organic matter content in bottom sediments revealed in our study may also reflect higher rates of sedimentation processes in different parts of the river.

To date, there have been occasional reports of low concentrations of MPs in freshwater bottom sediments [17][25][26]. More often, the values are expressed in hundreds or thousands of particles per kg of dry sediments. The highest average MPs count revealed in the bottom sediments of the Wen-Rui Tang River, China, 32,947 ± 15,342 items kg^{-1} dry sediment [27]. However, this number were dominated by small particles (0.02–0.30 mm), which are rarely quantified in other studies.

It is documented that MPs pollution reaches remote areas of the planet such as remote mountain regions in Europe, and National Parks in the USA [28][29][30], with air transport reported as the main transport route for MPs. However, the patterns of the pollution in the Nizhnyaya Tunguska indicates the ingress of plastics from the shore and from fishing activities (Section 4.2). The N. Tunguska is a remote tributary of the Yenisei River, flowing through sparsely populated territory, but even minimum anthropogenic load is enough to pollute rivers with MPs. Similarly, previous studies demonstrate that MPs can contaminate waterbodies in remote areas like rivers in the Tibet Plateau, China, and Lake Hovsgol in Mongolia [31][32].

2.2. Potential Sources and Distribution of Microplastics in the Surveyed Area

MPs in freshwater environments arise from multiple sources, including synthetic fabrics and fibers, health and hygiene products, plastic waste, and raw materials from industry [22]. According to some estimates [33], the majority of MPs entering the sea from rivers occurs from particles of synthetic polymers remaining after incomplete wastewater treatment (42%), microfibers of synthetic fabrics (29%), fragments and fibers formed during the decay of plastic waste (19%), and microspheres from personal hygiene products and industrial sources (10%).

MPs sources may be characterized by specific "profiles" that reflect the origin of the pollution. For instance, levels of microspheres used in personal care and cosmetic products, along with microfibers from synthetic fabrics and fibers, are highest close to wastewater discharge points [34][35]; high concentrations of polyester fibers located near textile factories [36]; microbeads typically occur in areas located near the production of plastic goods [37]; fragments of composite thermoplastics containing reflective glass spheres may be associated with the ingress of road marking components into surface waters along with storm runoff [13]. Of course, remote locations have fewer sources of pollution, and some of them can be excluded from the list for Siberian Rivers.

Polymer composition analysis may help for the identification of MP sources. This study is a fast screening of the MP presence and abundance in the Yenisei River system and does not include analysis of the particles polymer composition due its pilot nature. Rather, this study focuses on the morphology of the MPs based on the possible pollution source given that MP shapes, sizes and colors are determined (but not limited to) by the original plastic features [38][39].

In our study, the most abundant particles in the water and sediments were those ranging in size from 0.30 to 1.00 mm. MPs in this size range are typical for the riverine MP studies, including Russian rivers [10][16]. This may be explained by using of 0.30–0.33 mm mesh nets for sampling in most of cases, which cut off the quantification of the smallest particles.

In general, MPs with a particle size of less than 1.00 mm are more abundant in freshwater sediments and as particle size increased, the MP abundances show a trend of decrease [27][40].

Generally, fibers are the dominant shape for MPs in freshwater sediment worldwide [20]. MPs recovered from the surface of the N. Tunguska and the Yenisei Rivers include fibers, fragments and films. MP particles from the bottom sediments were also dominated by transparent fibers, indicating that MPS in this study might be derived from the fishing activity of the local population [41], such as that identified in the relatively clean Dalälven River that flows through a basin in Sweden with a population of less than 250,000 [42]. Since we also observed colored fibers in the water and sediments samples (Figure S2), the second possible source of fiber-shaped MPs is the direct clothing of residents and other synthetic fabrics. Intentional or accidental discarding of garbage by local residents is identified as another source of plastic waste, with plastic wastes observed on the bank of the N. Tunguska River, as well as direct plastic contamination of the small watercourses in the settlements during sampling fieldwork in this study (Figure S1(7–9)).

Therefore, potential sources of MPs in the N. Tunguska and the Yenisei Rivers may be associated with the human activities, including mismanaging of the plastic waste, use of synthetic fabrics, and intensive fishing. Previously, MPs have been identified in remote rivers, confirmed by MP in both surface water and bottom sediments on the Tibet Plateau [32] with resident and tourist activities likely the source of the MPs.

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