Tropical Aquatic and Soil Pollution

Review
Volume 3(2), 2023, 120-130
https://doi.org/10.53623/tasp.v3i2.262

Microplastics in and Near Landlocked Countries of Central and East Asia: A Review of Occurrence and Characteristics

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SUBMITTED: 18 May 2023; REVISED: 15 June 2023; ACCEPTED: 20 June 2023

ABSTRACT: The detection of microplastics in the water and sediment samples of the landlocked countries in central and eastern Asia means the relatively less populous countries are not spared from microplastic pollution. It is crucial to understand the severity of microplastic pollution in and near those countries since there are significantly fewer regional studies on microplastic pollution conducted for those countries. This review aims to systematically present the occurrence and characteristics of microplastics in and near the landlocked countries to shed light on the severity of microplastic pollution therein. It analyzed the contents of more than 38 papers to achieve its aim. Of all the landlocked countries, Mongolia has the most studies on microplastic pollution, while there are none for Turkmenistan, Afghanistan, Uzbekistan, Kyrgyzstan, and Tajikistan. For dried sediment samples, the microplastic contents ranged from 862 items/kg in the Tuul River of Mongolia to 15–46 items/kg on the Iranian side of the Caspian Sea near Turkmenistan. Lake Hovsgol in Mongolia recorded a microplastic density of 20,264 items/km^2, whereas the Selenga River system had a mean microplastic density of 120.14 items/km^2. Microplastics concentrations in the Caspian Sea varied, with areas near the southwest of Turkmenistan having microplastics concentrations ranging from 0.000246 items/l to 0.710 items/l. The microplastics levels in the countries are comparable to those of other regions in the world, indicating the impacts of human activities on microplastic pollution. Some microplastics might also have entered the countries through long-range transport by air and water from areas of higher human activity.

KEYWORDS: Abundance; characteristics; landlocked; microplastics; sediment; water

1. Introduction

Microplastic(s) (MP) have received much attention globally because of their environmental prevalence. They have been detected in all environmental media and in the most remote regions of the world [1]. Allen et al. found MP in the supposedly pristine French Pyrenees, where the abundances of MP fragments, films, and fibers were reported to be 249, 73, and 44 per m^2, respectively [2]. The MP had most likely reached the catchment through air streams capable of carrying MP as far as 95 km [2]. Besides, MP were discovered in the snow samples taken from the Arctic at concentrations ranging from 0 to 14.4 x 10^3 items per liter, in comparison to 0.19 x 10^3 – 154 x 10^3 items per liter in Europe, including the Swiss Alps [3]. This points to the presence of MP in some of the most remote places at low but significant concentrations [4]. The MP comprised rubber, polyamide (PA), polyethylene (PE), and varnish and were predominantly of the smaller size fractions. Similarly, atmospheric transport played a crucial role in the transport of MP to those places [3].

MP have contaminated the Arctic Sea ice. A study revealed the presence of MP in the Arctic Sea ice did not follow a particular pattern, and the patterns were affected by the development and movement of sea ice, thus demonstrating uniqueness [5]. MP up to 1.2 x 10^7 items per m^3 of ice core were retrieved from the Fram Strait in the Arctic. MP abundances in the ice core samples varied by an order of magnitude, with small MP of 11 µm making up the bulk of the MP recovered [5]. Consistent with the study of Bergmann et al., with the exception of rubber, PA, PE, and varnish were the most abundant MP [3, 5]. Variability in MP types was observed in the ice core samples. The MP characteristics in the ice core seemed to correlate with the drift trajectories of the sea ice [5]. MP were detected in remote ecosystems, for instance, those of the Antarctic. 83% of the microbenthic samples taken from the Ross Sea of Antarctica were reported to contain MP ranging from 0.01 – 3.29 items/mg, and those sized 50 to 100 µm were the most abundant [6]. In this instance, the predominant MP were polyoxymethylene, polytetrafluoroethylene, and phenolic resin. Higher abundances of MP were detected in bivalves and gastropods, indicating their correlation with feeding mechanisms [6]. Besides, another study conducted in the sub-Antarctic Atlantic Ocean revealed the presence of MP, but with an abundance of 0.013 ± 0.005 items/m^3, significantly lower than the global mean [7]. These MP were likely to be consumed by amphipods, and they might have originated from fishing vessels or long-distance transport [7]. Though having the lowest concentrations of MP in the world (188 ± 589 particles per km^2), the Southern Ocean is not spared from MP. The low abundance of MP in the Southern Ocean was probably attributed to the Subtropical Front impeding the southward drift of marine litter [8].

With mounting interest in the distribution and abundances of MP in different parts of the world, including the remote regions, it is of interest to examine their abundances in the landlocked countries in central and eastern Asia. The universal use of plastics has resulted in the detection of MP in the least populated or unpopulated parts of the world through long-range atmospheric transport of MP or the drifting of MP with ocean currents [1, 8]. In populated places, the abundance of MP is often related to population density, hence the intensity of human activities. MP have entered the environment through primary sources such as microbeads in personal care products, microfibers from synthetic textiles, and synthetic rubber microparticles from the abrasion of tires, as well as through secondary sources from the degradation of larger plastic items in the environment [9, 10]. It is likely that the landlocked countries in central and eastern Asia face MP pollution since these places are populated and there are apparent human activities. Though the population densities of those countries are lower than those of other Asian countries, particularly China, India, and Indonesia, it is reasonable to deem that there are sufficient human activities to render MP pollution a major environmental problem [11, 12]. However, in comparison to other regions, the studies on MP in these regions are comparatively few, let alone the reviews on MP occurrence and characteristics.

Reviews have been conducted on the occurrence of MP in remote regions and ecosystems, for instance, the polar regions, places with low population density, as well as habitats deep in the oceans and mountains [13–15]. Currently, there is a lack of review of the

MP in the landlocked countries in central and eastern Asia with relatively low population densities. It is crucial to gain insight into the occurrence and characteristics of MP in those countries to enable a better understanding of the magnitude of MP pollution in those countries and a comparison of the distribution of MP in those countries with countries having coastlines. This review, therefore, aims to systematically present the MP occurrence and characteristics in the landlocked countries in central and eastern Asia to fill in the review gap and contribute to the characterization of MP pollution in those countries.

2. Method

To achieve the aim of this review, relevant peer-reviewed scholarly articles were retrieved from major journal databases comprising the Web of Science, Scopus, and ScienceDirect [16]. The search was conducted with keywords such as microplastics, occurrence, abundance, distribution, characteristics, central Asia, and Mongolia, and a combination of the keywords such as ‘abundance microplastics in central Asia’ and ‘occurrence microplastics in Mongolia’ to refine the search. The articles retrieved were screened with the following criteria:

- The articles must be published in the past 10 years.
- The articles must be peer-reviewed.
- The articles must be related to the occurrence and characteristics of MP in the landlocked countries in central and east Asia. The landlocked countries in central Asia are Kazakhstan, Uzbekistan, Turkmenistan, Afghanistan, Kyrgyzstan, and Tajikistan (Figure 1). Mongolia is the only landlocked country in the east Asia. If studies specific to the countries are not available, those conducted near the countries (<200 km) would be sourced.

Content analysis was performed on the screened articles by examining their abstracts first to extract the relevant information and the texts subsequently to extract further information required for the review.

Figure 1. Map showing the countries in the central Asia and the location of Mongolia.

3. Results and Discussion

3.1. Abundance of MP.

Studies on the occurrence and characteristics of MP are limited in the landlocked countries of interest. Mongolia has the most studies, and even so, the studies are significantly fewer than those of the neighboring countries, especially China and Russia. Only one study on this domain is available in Kazakhstan, and it was conducted on the Kazakh side of the Caspian Sea basin [11]. Another study was conducted for lakes in the southern part of Russia, near the northeastern border of Kazakhstan [17]. No studies on the occurrence and characteristics of MP have been conducted for Turkmenistan, Afghanistan, Uzbekistan, Kyrgyzstan, or Tajikistan. However, with Iran sharing the southern perimeter of the Caspian Sea, few studies on the southern Caspian Sea were conducted near the southwestern border of Turkmenistan [18, 19]. Similarly, for Afghanistan, a study was conducted for the Mahodand Lake of Pakistan, near its northeastern border [20].

The MP abundances in the studies varied considerably. For sediments, dried samples from the Caspian Sea basin of Kazakhstan recorded the highest content of MP (862 items/kg), followed by those from the Tuul River in Ulaanbaatar, Mongolia (603 ± 251 items/kg) [11, 21]. On the Iranian side of the Caspian Sea near Turkmenistan, dried sediment samples contained an average of 15–46 MP/kg (Table 1). The higher abundance of MP on the Kazakh side of the Caspian Sea basin than on its southern shoreline, which has a denser population, is probably due to the inflow of the Volga River, which brought pollutants from multiple sources to the Caspian Sea. The large Volga River basin might receive pollutants from a significantly larger population than that along the Caspian Sea shoreline [11]. The river meanders across densely populated areas as well as industrial and agricultural zones before draining into the Caspian Sea. The sediment of the Tuul River in Mongolia had relatively high MP, probably because the study area was located in Ulaanbaatar, the capital city of Mongolia, which is more densely populated than other cities therein. There were substantial human activities along the section of the Tuul River in the study area, including a large organic farm [21]. While the levels of MP in sediments are related to human activities, the long-range transboundary transport of MP through river flows in the landlocked nations might lead to an uneven distribution of MP, with less densely populated areas sometimes recording higher MP levels than the more populated areas [17].

Despite lower population density, MP in the sediment samples of the landlocked nations are comparable to those in other regions of the world. For instance, sediments sampled from the Thames in the UK were found to contain a mean of 165 MP/kg dry weight (dw), whereas those from the Antua River in Portugal contained 18 to 629 MP/kg dw [22, 23]. The MP in the Brisbane River of Australia ranged from 10 to 520 MP/kg dw [23], and those in the less populated Tibet Plateau of China ranged from 50 to 195 MP/kg dw [24]. In Malaysian Borneo, where population density is low, 400–1000 MP were retrieved from 1-kg dried sediment samples taken from the Baram River and 283–457 MP from 1-kg dried sediment samples taken from the Miri River [25, 26]. Industrial activities along the rivers were deemed to contribute to the high MP reported.

As with sediment samples, sampling of rivers and lakes in and near the landlocked nations revealed variable MP levels, with MP densities as high as 20,264 items/km^2 recovered from water samples of Lake Hovsgol, northern Mongolia, while the Selenga River system had a mean MP density of 120.14 ± 121.49 items/km^2 [27, 28]. In terms of MP concentration, the inshore and offshore waters of the Caspian Sea near the southwestern border of Turkmenistan contained 0.000246 MP/l in comparison to 0.710 MP/l reported for the coastal waters of the Caspian Sea also in the southwest vicinity of Turkmenistan [18, 29]. This implies the significant variability of MP even for samples taken from locations in proximity, probably due to factors such as human activities and water flow, which demonstrate significant spatial and temporal variations. The lakes near the northeastern border of Kazakhstan and the northwest of Mongolia recorded a mean MP concentration of 11 ± 7 items/l [17], while Mahodand Lake in the northeast vicinity of Afghanistan contained a mean of 2.3 ± 1.52 MP/l [20]. The latter, though located remotely, is, in fact, a tourist spot. This may implicate other sources of MP, such as airborne MP and the surrounding land use contributing to the slightly elevated MP of the former. In fact, a few of the lakes near Kazakhstan and Mongolia were observed to be affected by significant human and transport activities [17]. In addition, considerable MP (68–199 items/l) had been detected in the snow samples from Arongqi, Inner Mongolia, located near the eastern border of Mongolia, and the MP levels seemed to be associated with the land uses around the sampling sites. Snow samples near thermal power plants recorded the highest levels of MP [30]. The presence of MP in snow could also be due to atmospheric transport and deposition of MP.

MP concentrations in the waters in and near landlocked countries are comparable to those in other regions of the world. The glacial lakes in the Sierra Nevada of Southern Spain contained 21.3 MP/l, which is close to the MP concentration of the lakes near Kazakhstan and Mongolia as well as that of the Mahodand Lake (Table 1) [31]. Some of the lakes, though remotely located, are not spared from human activities and pollution. The MP levels of the lakes are also similar to those of the Greater Bay Area of China with 4–25.5 MP/l [32], the Pearl River of China (2.2–8.9 MP/l) [33], and Lake Ontario of Canada (15.4 MP/l), which are exposed to substantial human activities. However, their MP levels are lower in comparison to more polluted terrestrial aquatic systems such as the Saigon River of Vietnam (17–519 MP/l) [34] and Lake Erie of the USA (105.5 MP/l) [27]. With MP concentrations ranging from 0.000246 items/l to 0.719 items/l, the MP concentrations at the southern part of the Caspian Sea near the southwestern border of Turkmenistan are considered relatively low (Table 1).

Table 1. Microplastics concentrations in soil samples.

Location	Abundance of MP	Size of MP	Type of MP	Shape, color and other features of MP	Reference
Mongolia					
Shore of the Tuul River	Not specified	Not specified	Polystyrene (PS);	The biofilms contained nitrogenous organic substances from bacteria and fungi; the PS MP experienced varying degrees of surface oxidation; the biofilms trapped plant residues and mineral, evidenced by lignocellulose and silicate on the surfaces of PS-MP.	[35]
Sediments from the Tuul River, Ulaanbaatar	603 ± 251 items/kg	28.4 – 3409.1 µm (70% 100 – 200 µm)	Polyester (PES) and PA	Shape - Fiber (35%), fragment, foam and film Color – White, colored, translucent, black	[21]
Lake Hovsgol, northern Mongolia	Mean 20,264 particles/km^2 (997 – 44,435 particles/km^2)	0.999 mm - >4.75 mm	Not specified	Shape – Fragment (40%), film (38%), line/fiber (20%), foam (1%), pellet (1%)	[27]

Location	Abundance of MP	Size of MP	Type of MP	Shape, color and other features of MP	Reference
Selenga River system	Mean 120.14 ± 121.49 items/km^2	Not specified	PS	Shape – Foam (99%)	[28]
Arongqi of Inner Mongolia Plateau, near the eastern border of Mongolia	68 – 199 items/l (snow samples)	Not specified	Polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC)	Shape – Fiber (63%), foam (18%), fragment (11.6%)	[30]
Kazakhstan					
Caspian Sea basin (area of Kazakhstan)	862 items/kg dried sediment	<35 µm	Not specified	Shape – Fiber (96.7%), irregular (2.1%), elongated (0.6%), angular (0.5%) Color – Red, blue, green, black, yellow	[11]
Lakes near the northeastern border of Kazakhstan and northwestern border of Mongolia	Mean 11 ± 7 items/l surface water (4 – 26 items/l)	31 – 60 nm (most common)	Not specified	Shape – Fragment (37%), film (21%), pellets (19%), foam (14%), fiber (9%) Color not specified	[17]
Turkmenistan					
Caspian Sea near the southwestern border of Turkmenistan	Mean 15 items /kg (dried sediment samples) Mean 710 items /m^3 or 0.710 items/l (water samples)	350 – 500 µm (36%) (sediment samples); >1000 µm (42%) (water samples)	PET-nylon PET-PS PET PS Nylon	Shape (sediment samples) – Fiber (97%), fragment (2%), pellet (1%) Shape (water samples) – Fiber (95%), fragment (5%) Color (sediment samples) – Black/ grey (40%), blue/ green (26%), yellow/ orange (20%) Color (water samples) – Black/ grey (49%), blue/ green (17%), yellow/ orange (16%)	[18]
Estuary of Gorgan River near the southwestern border of Turkmenistan	46 items/kg dried sediment	0.3 – 1 mm (100%)	PE, PET, PS, PP	Shape – Fiber mainly Color not specified	[19]
Inshore and offshore waters of Caspian Sea near the southwestern border of Turkmenistan	0.246 items/m^3 or 0.000246 items/l)	500 – 1000 µm, 1000 – 3000 µm	PE, PET, PP	Shape – film, fiber, fragment Color – White. transparent, blue	[29]
Afghanistan					
Mahodand Lake near the northeastern border of Afghanistan	Mean 2.3 ± 1.52 items/l (0 – 5 items/l)	300 – 500 µm (most abundant)	Low-density polyethylene (LDPE) (44.4%), PP (19.4%), PVC (30.5%), high-density polyethylene (HDPE) (5.5%)	Shape – Fiber (50%), sheet (28%), fragment (22%) Color not specified	[20]

3.2. Characteristics of MP

The MP in and near the landlocked countries were dominated by those of the smaller fractions. The most common fraction is >500 µm [18, 20, 21]. Within this fraction, Malygina et al. reported that MP sized 31–60 nm were most common [17], while D'Hont et al. found those < 35 µm were most abundant [11]. Some of the regional studies did not specify the most abundant MP sizes or adopted a typical size range to define MP without further categorizing them into more detailed size fractions [19, 27]. Nonetheless, Manbohi et al. found larger MP of 500–3000 – 3000 µm more predominant in their water samples from the Caspian Sea [29]. The prevailing particle sizes of MP reported for the region are in line with other studies showing that the smaller MP were often more abundant as compared to the larger ones [12, 36]. The predominating MP sizes in different samples obtained from the same area, particularly the part of the Caspian Sea southwest of Turkmenistan (Table 1), are different, attributed mainly to the variation of human activities across different sampling locations as well as the different sampling and sample treatment methods used.

The most common types of MP reported are PS, PES, PA, PP, PET, PVC, PE, LDPE, and HDPE (Table 1). This agrees generally with the studies on MP indicating the frequent detection of PE, PP, PVC, and PS, probably because these polymers are used in a wide range of products due to their versatility and because they are among the most highly manufactured polymers [22, 37]. For instance, PE is a major material used in the manufacturing of plastic bags and plastic films, and these items are heavily used globally, leading to their prevalence in all environmental compartments [38]. Similarly, PP is a constituent of items such as fishing gear, packaging materials, and furniture widely used in our daily lives [27]. Upon entering the environment, MP can serve as surfaces for microbial growth and interact with other pollutants or natural substances [39]. A study on PS MP retrieved from the shore of the Tuul River, Mongolia, revealed the presence of bacterial and fungal nitrogenous organic substances in the biofilms associated with the MP in addition to plant residues and minerals entrapped (Table 1). The MP underwent various degrees of aging in the environment, as evidenced by surface oxidation [35]. Mixed-type MP such as PET-nylon and PET-PS were also reported [18].

Fiber is the most common shape of MP in and near landlocked nations, as reported in six studies, with the percentage of fibrous MP ranging from 35% to 97% (Table 1). In two studies, fragmented MP were observed to be the most abundant (40% and 37%, respectively) [17, 27], whereas Battulga et al. found foam-shaped MP to make up 99% of the MP in the water samples obtained from the Selenga River system, Mongolia [28]. Other commonly reported MP shapes are film, sheet, and pellet (Table 1). A reason for the prevalence of fibrous MP in the environment could be the release of fibers from synthetic textiles during laundry and the fishing activities in the Caspian Sea involving fishing nets and lines [18, 36].

The predominant colors of MP in the environmental samples of the landlocked nations varied between white, black, grey, and red, with white-colored MP observed to be most abundant in two studies [21, 29]. White plastic materials are, in fact, commonly encountered, particularly as parts or the entirety of packaging, utensils, tools, and clothing. Other typical colors of MP are translucent, blue, green, yellow, or orange (Table 1). Transparent/ translucent MP which have been frequently revealed to be predominant in other studies are less prevailing in and near the landlocked nations [12]. Only two studies reported translucent MP, and they are often associated with agricultural activities such as plastic mulching and fishing gear [21, 29]. Many common packaging items are also translucent.

4. Conclusions

This review shows that MP have permeated the landlocked countries in central and eastern Asia, and the abundances of MP in the environmental samples are comparable to those of other regions despite the lower population densities of the nations. It confirms that MP are present as long as there are human activities. It shows the variability of MP in the landlocked nations, and in some instances, MP abundances are not linked to population density, most likely because of the long-range transport of MP through air and water, particularly when the inflowing water receives runoff from areas of intensive land use. This review is the first to present the abundances of MP in and near the landlocked countries in central and eastern Asia whose MP pollution has not been subjected to extensive study. It is instrumental in providing insight into the severity of MP problems in those nations, particularly the environmental prevalence of MP therein in relation to other regions of the world. It reveals that country-specific studies on MP occurrence are not available for Turkmenistan, Afghanistan, Uzbekistan, Kyrgyzstan, and Tajikistan currently. It demonstrates that MP pollution in the landlocked countries is not more severe than that in other countries, and some remote aquatic systems in the countries actually have lower MP concentrations than more polluted river systems in other places, such as the Saigon River in Vietnam. The risks of MP pollution in the landlocked nations are deemed to not significantly differ from those in other places, but the lack of studies on MP occurrences and abundances constrains the understanding of the ecological and health risks associated with MP in the nations. The current studies on MP in the regions are also limited by their coverage of information, particularly in terms of the characteristics of MP. Therefore, studies on MP pollution could be included in their national agendas. There is much room for studies on the occurrence, distribution, fate, and transport of MP in those nations, which can escalate into studies on the exposure and risk assessments of MP. In addition, a more detailed examination of the MP characteristics can be included, particularly in terms of the size fractions, colors, and types of MP, to permit a better characterization of the risk. As MP have permeated various environmental matrices of the nations, it is crucial to examine if MP have entered the food chains by detecting and quantifying MP in organisms at various trophic levels and in food items to shed light on the extent of MP exposure. Knowing the magnitude and severity of the MP problem will enable the landlocked nations to better formulate mitigations targeted at removing MP from and reducing plastics entry into the environment.

Acknowledgments

The author wishes to acknowledge the University of Arizona for the support given.

Competing Interest

The authors declare that there is no competing interest.

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