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Determination of microplastics and large plastics in the sediments of the Golden Horn Estuary (Halic), Istanbul, Turkey

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ABSTRACT

The aim of this study was to assess the microplastic (1–5 mm) and large plastic (>5 mm) contamination levels in the sediments of the Golden Horn Estuary (Halic), Istanbul, Turkey. The seasonal sediment samples were collected from seven stations in the estuary from May 2017 to February 2018. The size class and abundance by the number and weight of the plastics (microplastics and large plastics) within the sediment samples were examined. The total plastic abundance by number was recorded as 566 particles/kg wet sediment and determined to be 115 (20.3%) in spring, 105 (18.6%) in summer, 103 (18.2%) in autumn, and 243 (42.9%) in winter. The most common size was >5 mm plastics (198 particles), followed by microplastics in the range of 1–2 mm (118 particles). The plastic abundance by weight in total was identified as 11.1258 g/kg wet sediment. The results of this preliminary study showed that the Golden Horn Estuary (Halic) was contaminated by plastic debris.

Keywords: Golden Horn; Marine pollution; Microplastic; Plastic debris; Sediment

1. Introduction

The notion of microplastic has gained importance with increasing plastic pollution in the seas and oceans in recent years. It is estimated that 70,000 to 130 tons of microplastics are left to the seas every year in Europe [1]. Microplastics are particles smaller than 5 mm resulting from the degradation of large plastic pieces due to wind, current, temperature and ultraviolet rays [2–7]. Determining the microplastics in aquatic environments in comparison to the other large wastes is quite difficult due to their small size. Microplastics constitute a threat to the marine environment since they have properties like toxicity, adsorption of organic substances, transporting pollutants [8–10], floating, hydrophobic surface, biological and thermal fragmentation [11].

The microplastics are divided into two groups: primary and secondary microplastics. Primary microplastics are the products that are used by people in their daily life such as toothpaste, cosmetics, cleaning materials, fly-repellent spray, synthetic attires, and materials that are produced in various industries [8,12,13]. Besides, the microplastics which are considered as raw materials in the production of plastic products and defined as ‘‘pellet’’ having cylindrical or spherical shapes and sizes of less than 5 mm are among the primary microplastics [6,14]. Secondary microplastics are small pieces occurred with the degradation of large plastic pieces. This disintegration is influenced by environmental factors such as flow, temperature, sunlight, as well as the structural properties such as size, elasticity, and density of the plastics [14,15].

Researches showed that the microplastics accumulate in beaches, surface waters, and seafloor sediments [13,16,17]. Especially, sea floors and submarine canyons host high amounts of plastic. These pollutants accumulated in the sediment can begin to move along the water column again due to the turbulence generated by the currents [18,19]. Moreover, it

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was revealed that they were found in a wide range of marine creatures such as sea birds, fish, poultry, mammals, and crustaceans [7,20–22]. These microplastics are absorbed in phytoplankton and zooplankton, which are the first two rings of the food chain, and create a serious threat for the health of human and marine species [8,23,24].

In this preliminary study, plastic contamination levels within sediments from the Golden Horn Estuary (Halic), Istanbul, Turkey were investigated. The seasonal sediment samples were collected from seven locations in the Golden Horn Estuary. The plastics ((microplastics (1–5 mm) and large plastics (>5 mm)) were examined and assessed in terms of number and weight abundance.

2. Materials and methods

2.1. Study area and sampling

Within the scope of this study, seasonal sediment samples were collected from seven locations in the Golden Horn Estuary (Halic) between May 2017 and February 2018 (Fig. 1). The Golden Horn is one of the most efficient areas which ensure that marine and sediment pollution has gained importance in our country [25,26]. The Golden Horn has approximated 7.5 km length and an average of 400 m width. The widest zone is between Sarayburnu and Tophane with a width of 1,000 m. While the deepest place is Galata Bridge with approximately 40 m, the depth decrease down to 2–3 m around Halicioglu and Eyup [27–29]. The Golden Horn, which connects Alibeyköy and Kağıthane streams with Bosphorus, is an important area for the Sea of Marmara. This area, which was wealthy in terms of biodiversity, had a private and efficient marine ecosystem in the past. This ecosystem has been destroyed as a result of overpopulation, industrialization and unplanned settlement. The unrestrained discharge of domestic and industrial wastes has caused the formation of sludge deposits at the bottom of the Golden Horn. Therefore, the Golden Horn has been transformed into a serious environmental problem for Istanbul. The improvement works for the Golden Horn, which started in the 1980s with increasing green areas and reduction of industries, are still in progress [28,30]. Nowadays, the Golden Horn is one of the places that has the highest human population in Istanbul, which is the most crowded city in Turkey, due to its location on the historical peninsula with recreational and touristic places.

Sediment samples were collected along the Golden Horn using Van Veen Grab sampler. Samples, which were obtained from the surface layer of the sediments (0–5 cm), were put into glass sample jars and then transported to the laboratory under suitable conditions. The map showing the sampling stations is presented in Fig. 1.

2.2. Sample analysis

In the laboratory, the sediment samples(1 kg)were introduced into a glass beaker with a high concentration solution of sodium chloride (NaCl) (140 g/L), then stirred for 5 min. It has waited for 1 h for the floating plastic particles to be recovered and for the sediment to sink to the bottom of the glass beaker. The beakers were covered with aluminum foil to avoid any contamination during the waiting process. The resulting supernatant, with floating particles extracted from the sediment was filtered on a range of 5, 4, 3, 2, and 1 mm sieves [2]. Therefore, 5 size classes were detalied as

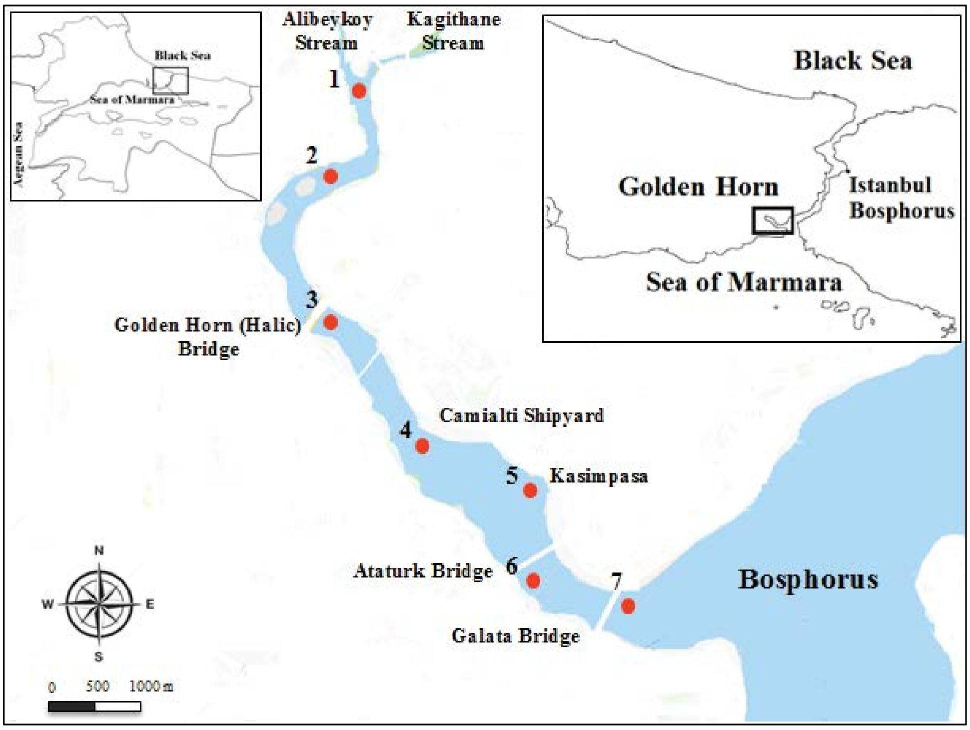

Fig. 1. Geo graphic locations of the sampling stations along the Golden Horn Estuary (Halic).

class 1 (1–2 mm), class 2 (2–3 mm), class 3 (3–4 mm), class 4 (4–5 mm), and class 5 (>5 mm). Sieve apertures were determined according to the size classification accepted by Martins and Sobral [31]. This procedure was repeated three times consecutively. Plastics (microplastics and large plastics) retained on the sieves were placed in glass petri dishes with the help of forceps, and characterized according to their dimensions and weights. The views of the plastic sizes determined in this study are shown in Fig. 2.

The abundance by number and weight of microplastics and large plastics were expressed as the number of microplastics or large plastics per kg of wet sediment (particles/kg wet sediment), and the weight of microplastics or large plastics per kg of wet sediment (g/kg wet sediment), respectively.

3. Results and discussion

3.1. Distribution of plastic abundance

The seasonal distribution of plastics (%) is shown in Fig. 3. The highest plastic abundance by number (42.9%) was observed in winter, followed by spring (20.3%), summer (18.6%), and autumn (18.2%), respectively.

The plastic abundance by number in total was determined as 566 particles/kg wet sediment. While similar values were obtained in spring, summer and autumn, the highest values were obtained in winter, which is thought to be as a result of the increased fishing activities during winter in the region. However, it was also estimated that the values were affected by the periodic increase in the precipitation in the winter season. Similarly, higher microplastic abundance by number after the rainy season was obtained in a study performed in Goiana Estuary on the North Eastern Coast of Brazil by Lima et al. [32]. In the studies performed in Ontario Lake in Canada by Corcoran et al. [33], and in Bolsena and Chiusi Lakes in Italy by Fischer et al. [34], it was reported that higher microplastic abundance by number after the rainy season were found, which were consistent with the results of our study.

As can be seen from Fig. 4, Kasımpasa and Sunnet Bridge have the highest plastic abundance by number in total, respectively. The lowest plastic abundance by number in total were found in the Halic Islands and Galata Bridge. The Sunnet Bridge is influenced from wastes carried by Alibeyköy and Kağıthane streams. The current direction of the Golden Horn can cause accumulation of wastes around Kasimpasa station, which is like a small bay. Halic Islands are the most untouched area in the Golden Horn. These islands have hosted sea birds like seagull, cormorant, and rabbits for many years. This area is not affected by sea traffic

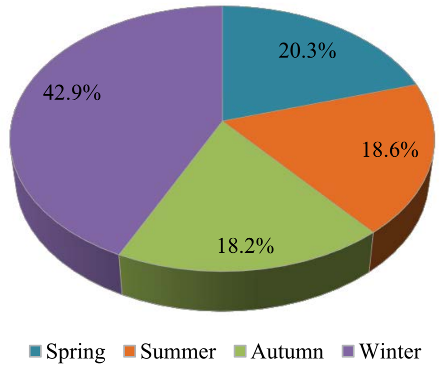

Fig. 3. Seasonal distribution of plastic (microplastic and large plastic) abundance by number.

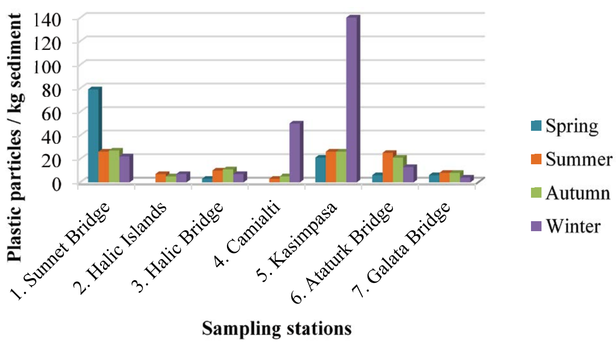

Fig. 4. Seasonal variation of the plastic (microplastic and large plastic) abundance by number.

Fig. 2. Views of plastic sizes defined in this study.

and human related pollutants. The Galata Bridge station is located at the commissure of the Golden Horn and the Bosphorus. The Bosphorus currents are double-layered in most of the year. The surface currents are generally towards the south, and the sublayer currents are towards the north. However, undertow currents are formed in the entrance of the Golden Horn with the influence of the Sarayburnu peninsula, and the surface currents are observed in the opposite direction (north) along the coast [35]. Due to this mobility, the accumulation of plastic debris is thought to be less in the sediments of this region.

3.2. Number and weight of plastic abundance by size range

In this study, the plastics larger than 5 mm have the maximum abundance by number in total, followed by the size ranges of 1–2, 3–4, 2–3, and 4–5 mm, respectively (Fig. 5a). When the plastic abundance by weight was evaluated, it was seen that the plastics larger than 5 mm had the maximum abundance by weight in total (Fig. 5b). The microplastic abundance by weight according to the size range in total were seen to vary in the following order: 3–4, 4–5, 2–3, and 1–2 mm, respectively.

The high abundance by number of microplastics in the Sunnet Bridge station is estimated to be due to the wastewater discharges that the area has been exposed to for many years. Researches support that the microplastics, which cannot be purified by classical treatment methods due to their very small sizes and floating nature, joined the marine environment [36–39].

During the autumn and winter seasons, plastics higher than 5 mm were determined to have the highest abundance by number in total, respectively. While the number of microplastics in the size range of 3–4 mm had the highest value in the spring, the number of microplastics in the size range of 1–2 mm had the highest value in the summer season (Fig. 6a). It was determined that, in total, the abundance by weight of plastics larger than 5 mm were much more compared to the plastics in the size range of 1–5 mm. The microplastic abundance by weight was obtained to be the highest in spring (Fig. 6b).

It was seen that the abundance by weights of plastics larger than 5 mm was higher in all the season than the other size range of plastics (1–5 mm). In general, the abundance by weights of plastics is proportional to their size ranges. The reason why the microplastics in the range of 3–4 mm was

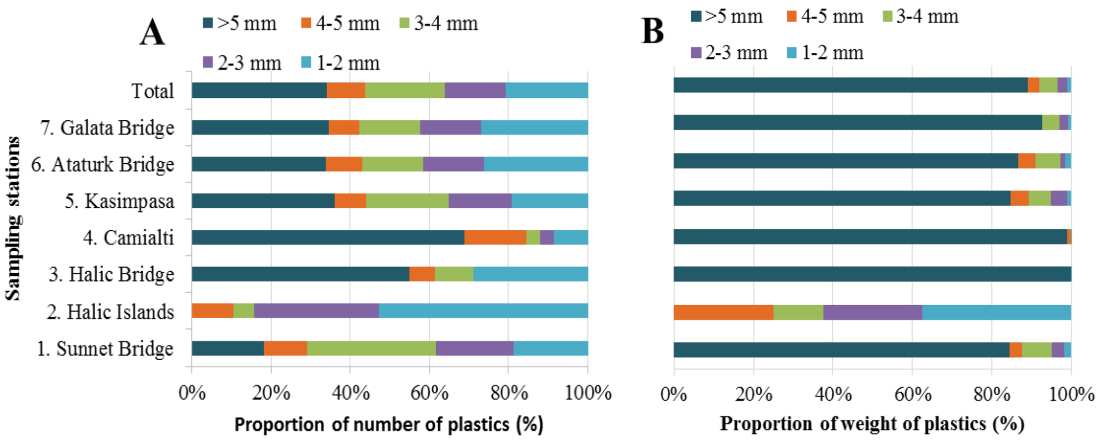

Fig. 5. Spatial distribution (in % of the total number of particles collected) of plastic (microplastic and large plastic) abundance within size (Fig. 5a) and weight (Fig. 5b) categories.

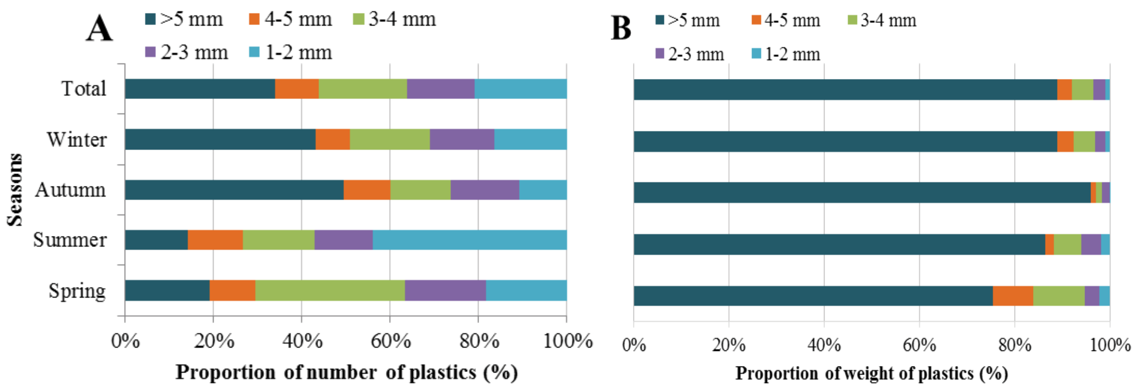

Fig. 6. Seasonal distribution (in % of the total number of particles collected) of plastic (microplastic and large plastic) abundance within size (Fig. 6a) and weight (Fig. 6b) categories.

more than the microplastics in the range of 4–5 mm in terms of weight was that their amounts were more than the others. In their study on the Tuscan coasts, Baini et al. [40] identified 69,161.2 particles and 41.1 g of particles in the size range of <0.5–5 mm/km². Munari et al. [41] reported a total of 1,661 particles in all sediment samples (31 samples) ranged from 0.3 to 22 mm in length, and the plastic abundance by weight was 3.14 g in total.

When spatial distribution (in % of the total number of particles collected) of plastic abundance within size category (Fig. 5a) is examined, except for Halic Islands, it can be seen that large plastics (>5 mm) in % of the total number of particles collected have higher percentage than those of the other size categories. This result is important because the large plastics eventually degrades into micro- and nanoplastics. Although an abundance of large plastics of >5 mm in Halic Islands was clearly less than those of the other stations, an abundance of microplastics of 1–2 mm in Halic Islands were higher than those of the other stations. This is also an interesting result related to the microplastic pollution in the Golden Horn. As also stated above, Halic Islands are the most virgin points of the estuary, and less affected by anthropogenic activities than the other stations. Hence, this trend is attributed to the movement of microplastics by means of currents, wave action and wind conditions [12,42].

Considering these results, it can be said that the microplastic pollution in the Golden Horn is of importance. It can also be said that the abundance of the microplastics and large plastics in the Golden Horn Bay may pose a risk for marine organisms and human health. It is well known that nowadays, plastic pollution in the marine environment is accepted as a real threat due to its global scale distribution and negative effects containing molecular level, physiological performance, and organism's health. Plastics on marine ecosystems have a long-life. Therefore, even if their production and disposal are now stopped, the adverse effects on marine life will continue for many decades [43].

3.3. Comparison of the results for microplastics in the Golden Horn Estuary (Halic) and those of other studies in the literature

In this study, the results for microplastics in the Golden Horn and those of the other studies in the literature are compared in Table 1. As can be seen from Table 1, the mean values of microplastics in the Golden Horn sediments (16.6 particles/kg dry sediment) were lower than those observed in the sediments of Dikili, Turkey [15], Sicily, Italy [15], Normandy, France [15], Tromsø, Norway [15], Pelion, Greece [15], North Tunisian Coast, Tunisian [44], Sishili Bay, China [45], Andratx, Mallorca Island [16], Es Port and Santa Maria, Cabrera Island [16], Derwent Estuary, Tasmania, Australia [46], Guanabara Bay, Brazil [47], Lamongan, Indonesia [48], and Belgian Coast [49]. On the other hand, the mean values of microplastics in the Golden Horn sediments were higher than those observed in the sediments offence-Belgian-Dutch coastline (6.0 particles/kg dry sediment) [50], North Sea Island of Norderney, Germany (1.3–2.3 particles/kg dry sediment) [51]. However, it should be considered that the used methods and the reported size classes in the studies reported in the literature and our study are more or less different from each other.

4. Conclusion

The results of the present study indicated that microplastic and large plastic particles were present in the

Table 1
Abundance by number of the microplastics in sediment samples reported from the different marine environment of the world

Country	Location	Mean abundance (particle/kg dry sediment)	Size class	Literatures
Turkey	Golden Horn Estuary	16.6	1–5 mm	This study
Turkey	Dikili	248	>0.45 µm	[15]
Italy	Sicily	160	>0.45 µm	[15]
France	Normandy	143–156	>0.45 µm	[15]
Norway	Tromsø	72	>0.45 µm	[15]
Greece	Pelion	232	>0.45 µm	[15]
Mallorca Island	Andratx	80–700	1–2 mm	[16]
Cabrera Island	Es Port	230–340	1–2 mm	[16]
Cabrera Island	Santa Maria	160–920	1–2 mm	[16]
Tunisian	North Tunisian Coast	141.2–461.2	>1 µm	[44]
China	Sishili Bay	499.8	<500–5,000 µm	[45]
Tasmania, Australia	Derwent Estuary	6,630	63 µm–4 mm	[46]
Brazil	Guanabara Bay	528	115.5 µm–4.9 mm	[47]
Indonesia	Lamongan	206	0.3–5 mm	[48]
Belgian	Belgian Coast	52.8–213.4	>38 µm	[49]
Frenche, Belgian, Dutch	Frenche-Belgian-Dutch Coastline	6.0	30–1,175 µm	[50]
Germany	North Sea Island of Norderney	1.3–2.3	<1 mm	[51]

*Microplastic concentration in this study was presented as a number of particles/kg dry sediment to make comparison with other studies.

sediments of the Golden Horn Estuary (Halic). Based on the results of this preliminary study, it can be said that plastic contamination may cause environmental problems in the estuary (Halic) in the future. Therefore, the local authorities should cooperate with non-governmental organizations to take necessary measures relating to tithe plastic pollution. Public awareness should also be created on plastic pollution.

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