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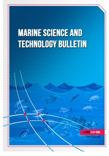

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REVIEW ARTICLE

Microplastic distribution and composition in various ecosystems of the Marmara Region: Current gaps and research needs

Ceyhun Akarsu[1*] • Vildan Zülal Sönmez[2] • Aminat İsrapilova[1] • Nüket Sivri[1]

[1] *Istanbul University-Cerrahpasa, Faculty of Engineering, Department of Environmental Engineering, 34320, Istanbul, Türkiye*
[2] *Düzce University, Faculty of Engineering, Department of Environmental Engineering, Düzce, Türkiye*

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ABSTRACT

Microplastics are ubiquitous worldwide and are increasingly recognized as a significant environmental problem. In Türkiye, research on microplastics has expanded over the years, providing valuable insights into the issue. However, studies focusing on different ecosystems are still limited and critical knowledge gaps have not been filled. The aim of this study, therefore, is to compare the composition of microplastics in five different ecosystems—marine water, freshwater, marine sediment, freshwater sediment and soil—across Istanbul and the Marmara region, while also identifying similarities and potential sources of pollution. Furthermore, the study emphasizes the need for more comprehensive research on microplastic pollution and its prevention within the different ecosystems of the region. For this purpose, a total of 26 studies were reviewed, in which 312 samples were collected from 304 stations, 222 of which were located in Istanbul. These stations were categorized by ecosystem type and the predominant composition of microplastics. Results revealed that there is a lack of studies on microplastics in surface waters and soil samples at various locations in Istanbul. While studies in the Marmara region have primarily focused on surface water samples from different locations in the Sea of Marmara, research on lentic and lotic systems, sediments and soils is still insufficient. The results also show that various environmental and anthropogenic factors, including water currents and direction, meteorological conditions, maritime traffic, human and industrial activities, proximity to residential areas and wastewater treatment plants, and atmospheric transport influence the concentration and composition of microplastics. In addition, seasonal and annual variations and the effect of station depth on the accumulation of microplastics were observed. Given that, the analyzed stations represent only a small fraction of the region's ecosystems, this study underlines the urgent need for further research to address existing

* Corresponding author
E-mail address: ceyhunakarsu@iuc.edu.tr (C. Akarsu)

knowledge gaps. The lack of comprehensive studies hinders the effective management of plastic and microplastic litter in the Marmara region. To enable meaningful comparisons at both local and international scales, adapting standardized methodologies in microplastic research is essential.

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Introduction

The increasing production of plastics and the inadequate disposal of plastic waste have led to the widespread distribution of microplastics in the environment (Mortula et al., 2021). These new pollutants persist in both aquatic and terrestrial ecosystems and pose a significant threat to global biodiversity (Horton et al., 2017; Zhang et al., 2023). Given their potential negative impacts on biota, addressing microplastic pollution is essential from both environmental and human health perspectives.

Microplastics, typically defined as particles with a size of 5 mm to 1 µm, can enter ecosystems via different pathways (Bhatt & Chauhan, 2023). Plastics can break down into smaller fragments and microplastics (<5 mm) through physical, chemical and biological processes in the environment, which, in conjunction with the slow degradation process of plastics, leads to an accumulation of plastic fragments of different sizes (Devereux et al., 2023). Due to their physical properties, such as size and specific gravity, they can be transported horizontally and vertically through air, soil and water. In surface waters, low-density microplastics can easily enter coastal areas through surface currents (Ivar do Sul & Costa, 2014). Polymers such as polyethylene (PE), polypropylene (PP), expanded polystyrene (EPS) and ethylene vinyl acetate (EVA), which have a lower density than seawater, tend to float in marine environments and are more likely to be found in surface waters (Woodall et al., 2013). In contrast, denser polymers such as polyamide (PA), polyethylene terephthalate (PET), polystyrene (PS), polyvinyl chloride (PVC), polycarbonates (PC), acrylonitrile butadiene styrene (ABS), polyurethane (PU) and acrylic more likely to sink and accumulate in sediments (Engler, 2012; Uddin et al., 2020).

The physical properties of microplastics, including shape, color, and polymer structure, provide valuable insights into their origins within ecosystems (Kroon et al., 2018; Schwarz et al., 2019; Zhu et al., 2021). Studies have identified laundry washing as a major source of microplastic fibers, with wastewater treatment plants serving as potential entry points for these pollutants into surface waters (Napper & Thompson, 2016; Wentworth & Stafford, 2016). In addition to wastewater discharge, microplastics can be transported over long distances through atmospheric deposition, allowing them to reach terrestrial ecosystems far from water bodies and densely populated areas (Zhang et al., 2020; Surendran et al., 2023).

The first study on the distribution and composition of microplastics in the surface waters of the Sea of Marmara was conducted in 2018 and provided initial data on microplastic distributions (Tunçer et al., 2018). However, pollution in the region has continued to increase and poses an urgent ecological challenge. Addressing this problem requires a comprehensive study of the composition and sources of microplastics. The current lack of comprehensive data limits the development of a solid framework for understanding the distribution and impacts of microplastic pollution. Without accurate identification of the sources of pollution, formulating effective waste prevention and reduction strategies remains difficult (Zhou et al., 2024). Therefore, an expansion of research on microplastics in both aquatic (marine, brackish and freshwater) and terrestrial ecosystems in the Marmara region is essential.

The aim of this study, therefore, is to compare the composition of microplastics in five different ecosystems — seawater, freshwater, marine sediment, freshwater sediment and soil — in the entire Marmara region and to identify commonalities and potential sources of pollution. By analyzing the relationships between the sampling stations, this study attempts to determine the possible sources of the detected microplastics. In addition, areas where microplastic pollution has not yet been sufficiently investigated will be identified to support future research and contribute to the development of a comprehensive map of microplastic pollution in the Marmara region.

Material and Methods

Study Area

The Marmara region (40°63'N, 28°12'E), covering around 67,000 square kilometers and accounting for 8 % of Türkiye's total land area, is home to 26,650,405 people as of the 2022 census (Aydın et al., 2023). Istanbul, the most populous city in Türkiye with 15,907,951 inhabitants, is located in this region, which also includes Bursa, the fourth most populous city with 3,194,720 inhabitants (TÜİK, 2022). Istanbul (41.013611°N, 28.955°E) covers an area of 5,421 square kilometers, connects the Sea of Marmara with the Black Sea via the Bosporus. The city of Istanbul has four natural lakes, five reservoirs and a total of 106 rivers, 67 of which are on the European side and 39 on the Asian side (Dinç & Bölen, 2014). In the Marmara region, 40 Organized Industrial Zones operate wastewater treatment plants with a total treatment capacity of 942,515 m^3/day, while the amount of wastewater actually treated is around 545,000 m^3/day (Ersoy & Özbay, 2023). Similarly, according to the report published by the Marmara Municipalities Union (2021), the total amount of wastewater discharged from wastewater treatment plants in seven provinces of the region amounted to 4,658,098 m^3, of which Istanbul accounted for 3,564,835 m^3. Given the significant pollution that these discharges, along with other anthropogenic factors, introduce into the Sea of Marmara, a detailed assessment of their environmental impact is essential.

Review Protocol and Data Analysis

In this study, research papers on microplastics conducted in the Marmara region and Istanbul province were searched in the "Scopus" and "Science Direct" databases, regardless of the year of publication. The keywords used for the search were "microplastics" AND "Marmara" and "microplastics" AND "Istanbul". The studies were analyzed using data that included at least one of the following: frequency of microplastics, color, shape and polymer structures of the samples collected from the stations identified within the study areas. These data were categorized into five main groups: Seawater, Freshwater, Sediment and Soil, corresponding to each type of aquatic and terrestrial ecosystem. The abundance of microplastics at surface water stations was expressed as MP/m^3, while the abundance of microplastics in sediment and soil stations was expressed as MP/kg. The stations from the study areas identified in the articles obtained from the literature review were mapped using Google Earth based, and the data was visualized using JPM 18.0 and Flourish.

Results and Discussion

Distribution of Microplastic Studies in Marmara Region

This study, which complies data on the abundance and characterization of microplastics in different ecosystems in the Marmara region, examines a total of 26 research articles. These studies were conducted at a total of 304 stations, 222 of which were in Istanbul. A total of 312 samples were collected from these stations. Most of the samples were sediment samples, including 104 from seawater sediments and 40 from freshwater sediment. Data were collected for the surface water of the Sea of Marmara (87 seawater), the rivers flowing into the Sea of Marmara (17 freshwater) and the wastewater discharged from wastewater treatment plants into the Sea of Marmara (4 wastewater treatment plant effluents) (Figure 1).

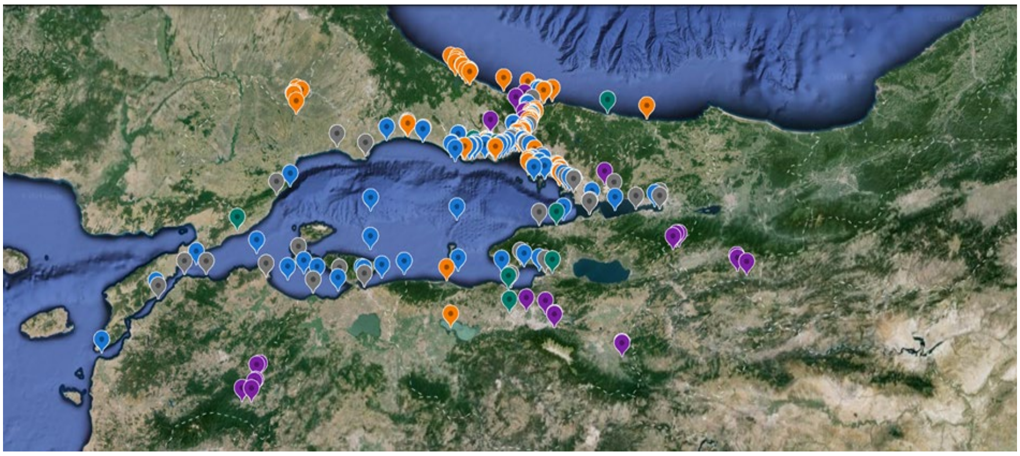

Figure 1. Sampling points in the Marmara Region within the scope of relevant studies (Each color on the markers represents a different sample type taken from the stations. Seawater and freshwater samples are given in blue, seawater and freshwater sediment samples in orange, soil samples in purple, other samples (e.g., organisms) in grey, and wastewater treatment plants in green)

A review of the studies revealed that the number of stations where studies on microplastics were conducted in the Marmara Region was not sufficient to make the data fully representative. While surface water studies have been conducted in the Bosporus and southern coastal waters of Istanbul, research in the northern coastal waters is limited. In addition, there are few studies on the abundance and characterization of microplastics in rivers and lakes (Mülayim et al., 2022; Akdogan et al., 2023). It is also noteworthy that sediment studies were mainly conducted at stations where water samples were also collected (Çullu et al., 2021; Sari Erkan, 2021a; 2021b). Soil studies are limited to two research studies in which samples were taken from urban and industrial areas at eight stations on the European side of Istanbul (Tunali et al., 2022).

General Distribution and Characterization of Microplastics in Marmara Region

Distribution and characterization of microplastics in seawater and sediments

An analysis of the Marmara region shows that the densest stations are to be found in Istanbul. A study in Istanbul found that the stations on the piers near the coast had the highest microplastic frequency, while the stations on the open sea had the lowest values (Sari Erkan et al., 2021a). Microplastic levels were significantly higher at stations with heavy shipping traffic, near sewage treatment plants and industrial activities. Similarly, in a study conducted by Sönmez et al. (2023), it was found that microplastic concentration increased with increasing spatial proximity to wastewater treatment plants. Stations where wastewater treatment plant discharges reached the Sea of Marmara via the rivers showed high microplastic concentration across all sampling periods, highlighting wastewater treatment plants as a major source of microplastics. In another study by Tunçer et al. (2018), it was found that the regional differences in microplastic abundance in the Sea of Marmara could be due to the different treatment capacities of wastewater treatment plants. In a study conducted by Gürkan & Yüksek (2022), surface water and water column samples from various stations in the Sea of Marmara were analyzed and found that microplastic abundance in surface water was significantly lower than in the water column at the same stations. It is hypothesized that this difference is due to the tendency of polymers to sink or float depending on their density and shape, as well as water currents. On the other hand, Terzi et al. (2022) found the highest microplastic abundance on the northern coasts of the Marmara region, and it was stated that this situation is because the region is one of the most populated and industrialized areas of Türkiye. In addition, various studies show that microplastic concentration is higher in the Marmara region compared to similar studies in other parts of the world (Çullu et al., 2021; Sari Erkan et al., 2021a; Gürkan & Yüksek, 2022; Sönmez et al., 2023). This situation is directly related to the dense population, land and sea transport, industrial activities and inadequate waste management.

Various studies show that the composition of microplastic changes over time (seasonally and monthly) (Çullu et al., 2021; Sönmez et al., 2023). The main reasons for this variability include seasonal weather events, current direction and speed, human activities and shipping traffic. It has been observed that the abundance of microplastic increases especially during rainy periods. This increase can result from the transport of road litter to receiving areas and sewage systems due to the effect of rain and the sedimentation of microplastic in the atmosphere at the surface. The most common types of microplastic in the surface waters of the Marmara region are white, blue and black and consist of PE, PP, PET and EVA in the form of particles and fibers. When examining the distribution of microplastic concentrations (MP/m^3) in surface waters according to color, shape and polymer types (Figure 2), it was found that blue and black EVA fibers dominated.

The highest microplastic concentration in sediment samples was found at the coastal and shallow water stations (Baysal et al., 2020; Sari Erkan et al., 2021b; Mülayim et al., 2022). The predominant polymers in the sediments of the Marmara region were PP, PE, PS, polyphenylene sulphide (PPS) and ABS polymers, which are commonly found in blue and black colors in the form of fragments and fibers. Çullu et al. (2021) detected blue PE particles in the surface water of the Küçükçekmece Lagoon. Similarly, in the study conducted by Baysal et al. (2020) in the southeast of the Sea of Marmara (Pendik-Tuzla region), PE was found to be the dominant polymer. Sediment studies conducted at 15 sites in Istanbul revealed that MP concentration was higher during the rainy season, similar to surface water (İşlek et al., 2023). These seasonal variations were associated with the increased human activities, traffic and changes in current speed and direction. Olguner et al. (2023) investigated the influence of shipping traffic, tourism, and fishing and population concentration on microplastic pollution in the Bosporus, where about 45,000 ships pass annually. High concentrations of microplastics were found in relatively less urbanized areas such as Anadolu Hisarı and Rumeli Feneri, while the lowest microplastic concentrations were found in Karaköy, despite the intense maritime and tourism activities. These results show that the regional flow systems play a crucial role in the accumulation of microplastics. Overall, while seasonal variations affected MP concentration, polymer type and shape distribution remained relatively stable, with blue fibers predominating in most seasons.

In a sediment study conducted at 43 stations in Istanbul, Sari Erkan et al. (2023) revealed an increased occurrence of microplastics in the summer months, with the highest concentrations observed in the Golden Horn. This increased microplastic concentration is likely due to shipping traffic and hydrodynamic conditions. While microplastic particles were more abundant in summer, fibers were detected more frequently in the other seasons. The presence of microplastics particles indicates secondary pollution from the degradation of plastic waste at high temperatures, while the large amount of fibers could indicate pollution from the textile industry and inefficient wastewater treatment.

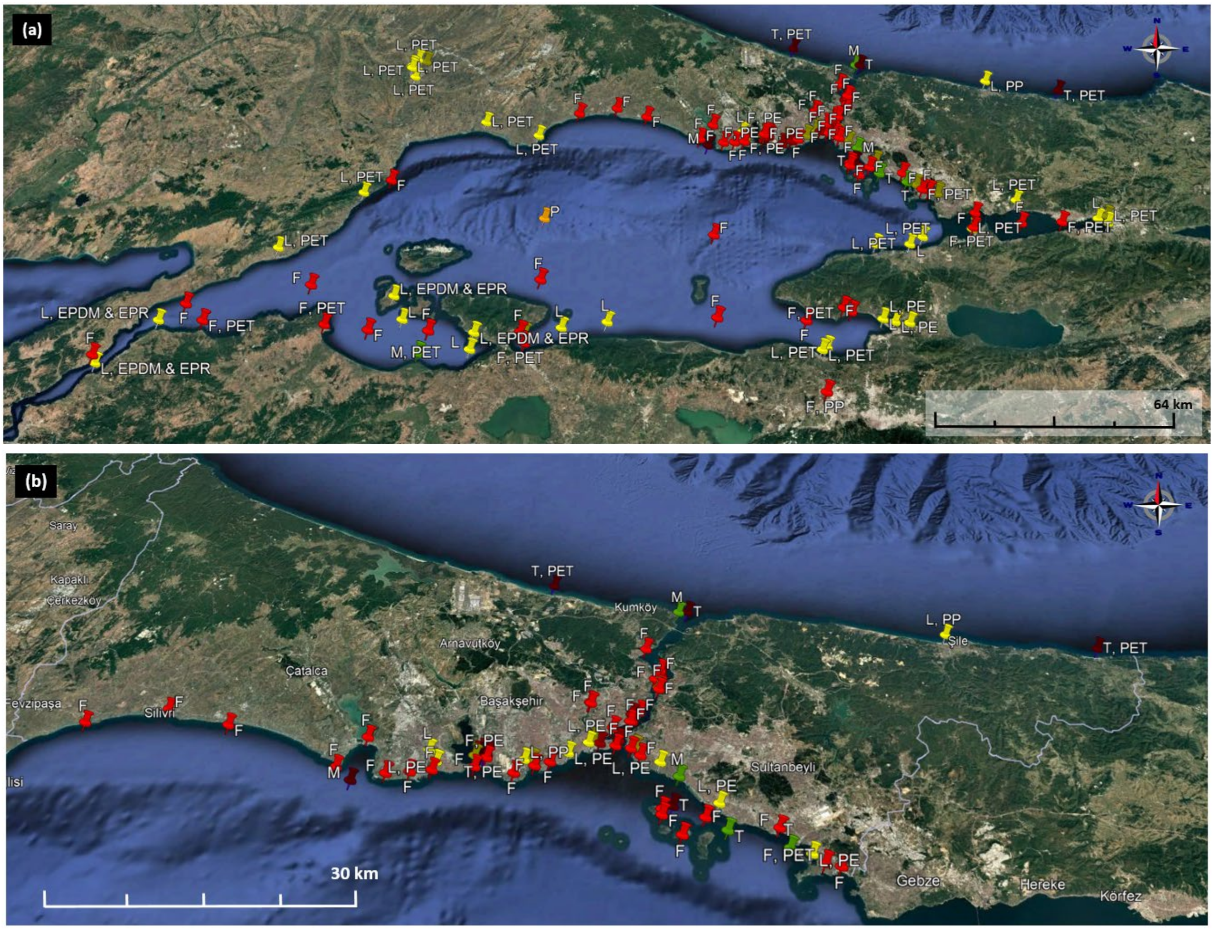

Figure 2. Dominant physical and chemical characteristics of microplastics detected in surface waters a) Marmara Region and b) Istanbul (Fragment = F (Red Pin), Fiber = L (Yellow Pin), Film = M (Green Pin), Filament = T (Purple Pin), Pellet = P (Orange Pin))

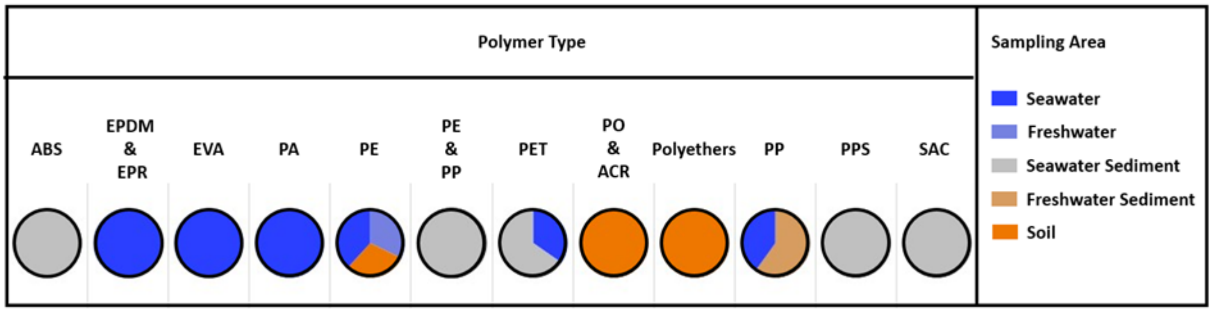

Figure 3. Proportional distribution of identified polymer types in seawater, freshwater, sediment, and soil samples

Distribution and characterization of microplastics in freshwater and sediments

Akdogan et al. (2023) conducted fresh water and sediment investigations at six stations in the Ergene Basin. While black PET fibers were the predominant type of microplastic in the surface waters, black PS particles predominated in the sediments. The study revealed significant temporal variations in the amount of microplastics in the sediments and a correlation between the microplastic concentrations in the river morphology. These findings highlight the possible influence of upstream industrial areas and wastewater treatment plants on the amount of microplastics at the sampled river stations. Similarly, in a study conducted by Mülayim et al. (2022) in Lake Durusu in Istanbul, transparent PP particles were identified as the predominant microplastic type. This was attributed to the degradation of improperly disposed plastic waste used in packaging and other commercial applications. In another study, Almas et al. (2022) investigated the Susurluk Basin and found that fibers were the predominant microplastic type in sediment samples. Despite these findings, research on microplastic pollution in freshwater environments within the Marmara region remains limited. Given the critical role of rivers and lakes as transport pathways for microplastics into marine ecosystems, further studies are needed to comprehensively assess sources, distribution patterns and seasonal variations in these areas. Expanding research efforts in freshwater systems will enable a more comprehensive understanding of regional microplastic pollution and its wider environmental impacts.

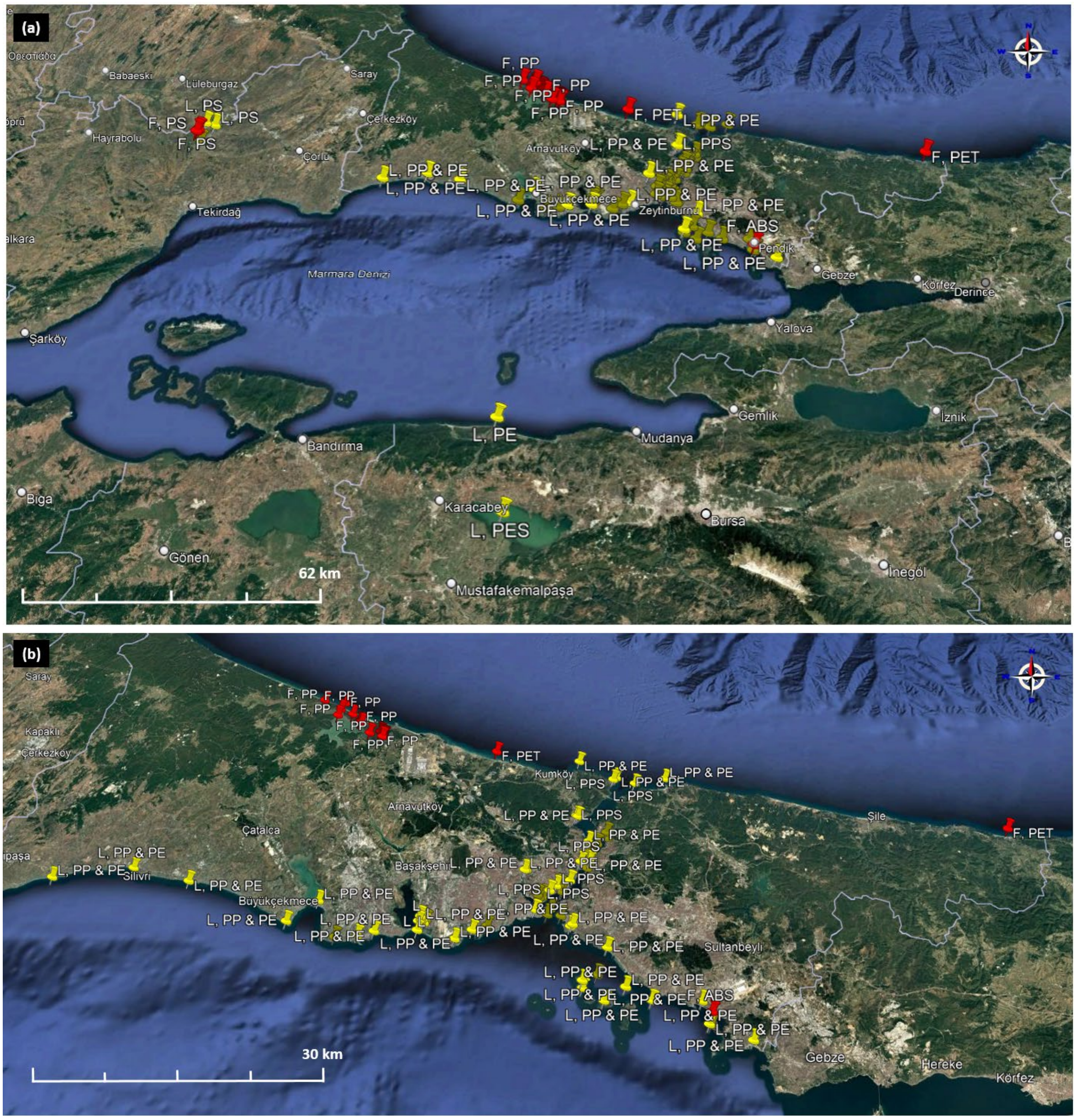

Figure 4. Dominant physical and chemical characteristics of microplastics detected in sediments a) Marmara Region and b) Istanbul (Fragment = F (Red Pin), Fiber = L (Yellow Pin), Film = M (Green Pin), Filament = T (Purple Pin), Pellet = P (Orange Pin))

Figure 5. Dominant physical and chemical characteristics of microplastics detected in soils **a)** Marmara Region and **b)** Istanbul (Fragment = F (Red Pin), Fiber = L (Yellow Pin), Film = M (Green Pin), Filament = T (Purple Pin), Pellet = P (Orange Pin))

Distribution and characterization of in soils

Studies on soil microplastic pollution in the Marmara region remain limited, with research to date focusing primarily on microplastic concentrations in recreational, agricultural and industrial soils. In a study conducted in Sakarya, Bursa and Çanakkale, five agricultural and one urban soil samples were analyzed. The results showed that microplastic concentration was higher in agricultural soils than in urban soils (Akca et al., 2024). In particular, blue PE fibers were the predominant microplastic type in urban soils (parks, roadsides and green areas), reflecting the composition observed in the agricultural soils of the same cities, although they are geographically separated. This pattern suggests that inefficiently treated irrigation water or atmospheric transport may play a role in the accumulation of microplastics. Tunali et al. (2022) also investigated the distribution and morphology of microplastics in soil samples from three recreational, three urban and three industrial areas. The highest microplastic concentration was found in a soil sample from the Belgrade Forest, while urban soil samples from a park and a college campus also showed higher concentrations than industrial areas. These results confirm the hypothesis that microplastics tend to accumulate in soils over time. The predominant MP types varied depending on land use: recreational areas showed red PO and acrylate fibers, urban areas were dominated by red POM and polyether pellets, while industrial soils were dominated by yellow PE pellets. Despite these findings, soil microplastic pollution in the Marmara region is still poorly understood. Given the critical role of soil as both a sink and a potential source of microplastics, further research is needed to assess the long-term environmental behavior, transport mechanisms and potential risks to terrestrial ecosystems. As plastics can be transported, they can accumulate both in the water column and in sediments, e.g., in the river bed, which can serve as temporary sinks depending on the specific characteristics of the river or river section (Horton et al., 2017).

Table 1. Current studies on microplastic pollution in various environmental compartments in Marmara Region

Sampling Area	**Number of Stations**	**Predominant Microplastic**					**Reference**
		Concentration	***Size (μm)***	***Shape***	***Color***	***Type***	
Seawater	5	37.37 particles/L	>50	fragment	blue	-	Çullu et al. (2021)
Seawater	13	0.071 particles/L	300 - 2000	fiber	black	-	Gürkan & Yüksek (2022)
Seawater	43	1284.74 particles/km^2	>1000	fragment	white	-	Sari Erkan et al. (2021b)
Seawater	9	146.63 particles/L	100 – 249	fiber	transparent	EVA	Sönmez et al. (2023)
Seawater	16	0.019 particles/ L	2070	fiber	-	PET	Terzi et al. (2022)
Seawater	14	1.263 particles/m^2	-	fragment	white	-	Tunçer et al. (2018)
Seawater Sediment	14	0.3 – 85.6 g/kg	-	fragment	black	ABS	Baysal et al. (2020)
Seawater Sediment	1	1960 particles/kg	20–200	fragment	-	-	Belivermiş et al. (2021)
Seawater Sediment	3	3332 particles/kg	<100	fiber	black	-	İşlek et al. (2023)
Seawater Sediment	15	326.62 particles/kg	<1000	fiber	black	PPS	Olguner et al. (2023)
Seawater Sediment	43	1957.37 particles/kg	>300	filaments	blue	-	Sari Erkan et al. (2021a)
Seawater Sediment	43	4337.5 particles/kg	>1000	fiber	blue	PE	Sari Erkan et al. (2023)
Freshwater	1	6.90 particles/L	1000 - 2000	fiber	black	PET	Akdogan et al. (2023)
Freshwater	5	28.78 particles/L	>50	fragment	blue	-	Çullu et al. (2021)
Freshwater Sediment	1	277.76 particles/kg	45 - 1000	fiber	black	PS	Akdogan et al. (2023)
Freshwater Sediment	1	-	1380	fiber	transparent	PE	Almas et al. (2022)
Freshwater Sediment	1	-	1700	fiber	black	PE	Almas et al. (2022)
Freshwater Sediment	2	2648.3 particles/kg	<100	fiber	black	-	İşlek et al. (2023)
Freshwater Sediment	11	134.76 particles/kg	-	fragment	blue	PP	Mülayim et al. (2022)
Soil	55	160 particles/kg	<1000	fiber	blue	-	Akca et al. (2024)
Soil	27	3556.4 particles/kg	<1000	fiber	red	Acrylate	Tunali et al. (2022)

General Evaluation and Future Perspectives

Table 1 contains a comprehensive dataset on microplastic pollution in different environmental compartments in the Marmara region, showing the differences in the number of stations, concentration values and relevant references. Several important observations can be derived from these data, which take into account both the spatial distribution and the methodological consistency of the studies. Studies on marine waters have the largest spatial coverage, with the number of stations ranging from 5 to 43. In particular, the study conducted by Sari Erkan et al. (2021b) at 43 stations provides a large-scale assessment of microplastic pollution in the marine environment and highlights the importance of extensive sampling for understanding spatial variability. Marine sediments show a similar pattern, with the number of stations reaching 43 in some cases (Sari Erkan et al., 2023). This parallel trend between water and sediment studies indicates that research is strongly focused on the deposition of microplastics from the water column to the seafloor. However, the variations in concentration values, ranging from 0.019 to 146.63 particles/L in seawater (Figure 6a) and from 326.62 to 4337.5 particles/kg in sediment (Figure 7a), indicate significant differences in pollution levels, possibly influenced by hydrodynamic conditions, sedimentation rates and proximity to pollution sources. The high accumulation in sediments is consistent with global findings that sediments serve as a long-term reservoir for microplastics.

Freshwater environments appear to be less extensively studied, with the number of stations ranging from 1 to 5 (Çullu et al., 2021; Akdogan et al., 2023). This limited research coverage raises concerns about data gaps, especially when considering the role of rivers in the transport of microplastics from the terrestrial to the marine environment. Reported concentrations vary considerably, with the highest value being 28.78 particles/L (Çullu et al., 2021). Considering that freshwater systems act as transition pathways for microplastics before they reach the marine environment, the relatively small number of stations highlights the need for further research to capture the dynamics of microplastic transport and retention in freshwater ecosystems. Studies of freshwater sediments show even greater variability, with concentrations ranging from 0.3 to 2648.3 particles/kg (İşlek et al., 2023) (Figure 7a). The highest concentration found in sediments indicates that depositional environments in freshwater systems can act as sinks for microplastics. However, due to the limited number of sampling stations, it is difficult to generalize trends, especially in relation to land-based pollution sources and hydrological processes that influence sedimentation rates. Figure 6b shows a chord diagram illustrating the relationships between the composition of microplastics in different ecosystems based on polymer types, colors and physical forms. The identified polymers include common plastic types such as PE, PP, PET and EVA. Notably, PE and PP are more prevalent in seawater, while freshwater ecosystems have a greater diversity of microplastic types. In terms of color distribution, blue, black and opaque microplastics are predominant.

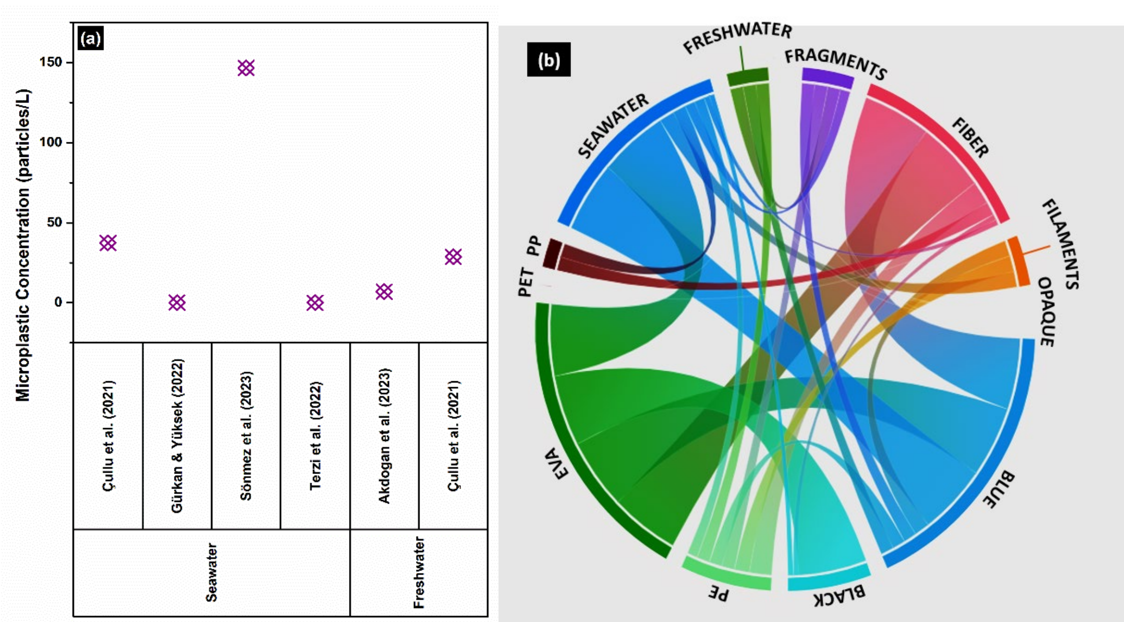

Figure 6. Current reports on (a) microplastic abundance across surface water stations in the Marmara Region and (b) dominant compositions of microplastics

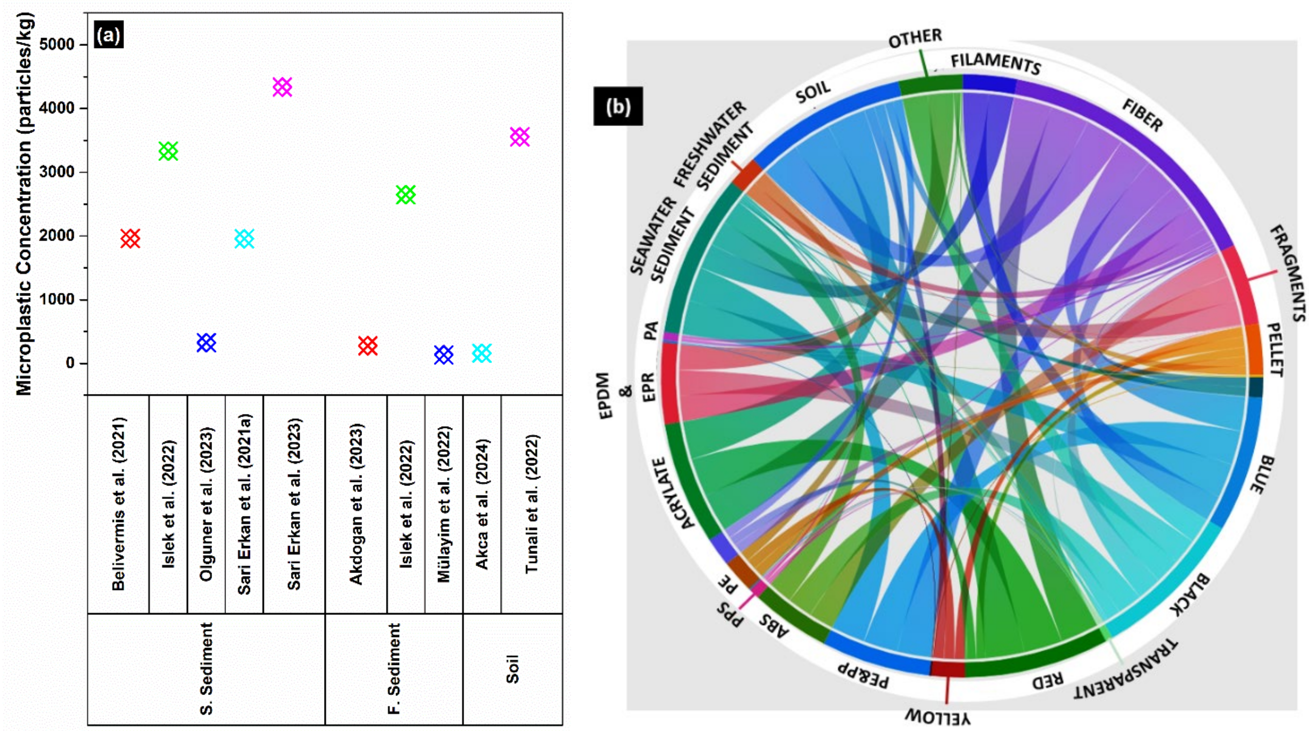

Figure 7. Current reports on (a) microplastic abundance across sediments and soils in the Marmara Region and (b) dominant compositions of microplastics

Figure 8. Hotspot stations for microplastic studies (Blue markers indicate stations with microplastic studies, while red markers represent key stations)

Soil studies demonstrate a wider geographical range, with the number of stations reaching 55 (Akca et al., 2024) and 27 (Tunali et al., 2022). These studies show some of the highest measured microplastic concentrations with values of 3556.4 particles/kg (Tunali et al., 2022) (Figure 7a). The significant accumulation of microplastics in soils highlights the potential role of agricultural activities, urban runoff and atmospheric deposition in shaping contamination patterns. As soils can act as both sources and sinks for microplastics, the high variability of reported concentrations suggests that local land use patterns and anthropogenic activities strongly influence contamination levels. As given in Figure 7b, the soil samples contain predominantly fiber-based microplastics, with acrylate and PP which is consistent with the use of plastics in agriculture, geotextiles and the degradation of plastic mulch films. The presence of red-colored acrylate fibers also indicates that synthetic textiles and coatings contribute significantly to microplastic contamination in the terrestrial environment. The results suggest that soil serves as a long-term sink for microplastics, with retention mechanisms differing from those in aquatic environments.

A comprehensive review of all data shows that the shape, color, and polymer type of microplastics found predominantly in an ecosystem can provide valuable insights to its origin. However, it has been shown that the natural conditions of the ecosystem and human activities play a crucial role in the distribution of microplastics. In short-term studies conducted in closely located environments, a varying microplastic distribution pattern was detected. These differences underline the dynamic nature of microplastic communities over different time periods. It was found that the concentration and composition of microplastics can change seasonally and even monthly. It was also found that factors such as water depth and proximity to the coast influence the distribution of microplastics in water and sediment samples.

The lack of standardization of reporting units and the disproportionate focus on the marine environment make it difficult to compare different environmental areas. These inconsistencies in reporting not only make it difficult to combine results, but also limit our ability to draw reliable conclusions about the distribution of microplastics in different ecosystems. A more standardized research approach is needed to better assess the extent of microplastic pollution in different environments. There are significant gaps in microplastics research in several areas, including Istanbul, particularly in surface water and soil sampling (Figure 8). These gaps highlight the need for more comprehensive monitoring of microplastic pollution beyond the marine environment. Surface waters, sediments and soils, which can contain large amounts of microplastics, have not been adequately studied.

Conclusion

The Marmara region, with its dense population, industrial activity, transportation networks and tourism, is facing an increasing threat from microplastics. However, the lack of adequate data on this important pollutant prevents effective action from being taken. This study aims to provide a valuable reference for future research on microplastics and its sources in the Marmara region, especially in Istanbul.

To the best of the author's knowledge, this is the first baseline study on the abundance of microplastics in the Marmara region, providing valuable insights for policy makers and efforts to reduce plastic pollution. The findings can serve as a reference for future monitoring of microplastics in the Sea of Marmara, particularly in assessing the effectiveness of measures aimed at reducing land-based microplastic inputs into surface waters.

Given the complex industrial and urban development of the region, it is crucial to extend monitoring measures to different environmental areas. While most studies have focused on the marine environment, which is an important aspect of the problem, pollution of freshwater ecosystems, soils and air deposition is equally important. Since freshwater bodies eventually flow into the sea, pollution from non-marine sources has a direct impact on marine ecosystems. Therefore, research should also focus on key areas such as river basins, wetlands and urban soils to track the movement of microplastics from land and freshwater to the sea. Expanding research in these areas is essential to fully understand the extent of microplastic pollution and develop effective solutions. A more balanced approach to research will improve our understanding of the behavior of microplastics and their long-term impact on human health and biodiversity.

Compliance With Ethical Standards

Authors' Contributions

CA: Conceptualization, Writing – original draft, Formal analysis, Writing – review & editing
VZS: Writing – original draft, Formal analysis
AI: Formal analysis
NS: Conceptualization, Writing – original draft,
All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Funding

Not applicable.

Data Availability

All data generated or analyzed during this study are included in this published article.

AI Disclosure

The authors confirm that no generative AI was used in writing this manuscript or creating images, tables, or graphics.

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