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Microplastics characterization, abundance and distribution on the coast of Ordu province (Türkiye)

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Abstract

Plastics, one of the most common materials polluting our seas, are now a serious global problem. These plastics persist in our environment for a long time and gradually turn into much smaller particles that we call microplastics (MPs). In this study, the MPs profile of sand and seawater samples taken from 6 different stations from the coasts of Ordu Province was analysed in detail. As a result of MPs and µ FTIR spectroscopic analyses, the presence of MPs in sand and seawater samples was determined and their characterisation, abundance and distribution characteristics were revealed. In this study, 291.11 items kg-1 MPs was found in sediment samples and 0.263 items L-1 MPs in water samples. A total of 420 MP fragments were detected from seawater and sand samples on the coasts of Ordu Province and analysed for colour, shape, size and species. Fibre and film type MPs fragments were found the most and it was determined that these fragments were generally blue and transparent in colour. It was observed that MPs were commonly in the size range of 0-50µm (50.71%) and the detected MPs were not larger than 800 µm. Most of the MPs observed were polyethylene (56%), followed by polypropylene (19%), polystyrene (15%), polyvinyl acetate (7%) and polytylene tereftelate (3%). In conclusion, MPs pose serious threats to human health and the environment, and it is recommended that waste generation should be reduced, necessary precautions should be taken, monitoring studies should be carried out and necessary removal methods should be applied in order to reduce the risk caused by wastes released into the seas.

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INTRODUCTION

Coastal and marine areas are vital for people living in a region to lead a healthy life. In addition to contributing economically to the region, these areas are also characterized by their natural functions, thereby raising living standards. They are also the areas where we feel the effects of climate change and play a critical role in stabilizing ecosystems. In addition, coastal and marine areas are also crucial for the protection and rehabilitation of endangered species (Uslu and Sesli, 2011). Anthropogenic activities such as climate change, pollution from shipping, uncontrolled terrestrial fishing, marine accidents, oil exploration, overfishing, and deep-sea mining are causing serious damage to marine and coastal areas (Wright et al., 2018). The continuous increase in production and consumption is the main source of marine plastic pollution, which is one of the biggest global issues today (Thompson et al., 2009). Plastics are long-chain polymeric structures composed of carbon, oxygen, hydrogen, silicon and chloride elements. Today, plastics have replaced traditional materials such as glass and metal thanks to their lightweight, processable, durable, flexible, low-cost, heat and electrical insulating, corrosion-resistant and waterproof properties. Such properties of plastics are used in a wide range of applications, from the packaging sector to automotive and aquaculture.

Despite the high production of plastics, only 14% of plastic waste is recycled and the rest is either incinerated for energy recovery or disposed of through landfill and landfill (Liu et al., 2023). Most of the plastic in the ocean (80%) comes from terrestrial sources. Macro- and micro-plastics from terrestrial sources are transported by wind or surface runoff (Jambeck et al., 2015). Rivers and canals are the main sources of plastic waste entering the ocean. However, estuaries, which serve as a transition zone between marine and freshwater environments, are also important sources of MPs (Rakib et al., 2022). Large pieces of plastic that enter the marine environment degrade over time under physical, chemical, mechanical and biological influences and break down into more harmful MPs called MPs smaller than 5mm (Plastics Europe, 2019; Lestari et al., 2020). These are widely dispersed on a global scale by processes such as currents, eddies and wind (Auta et al., 2017; Aydemir Çil et al., 2023; Akkan et al., 2023). Since these plastics are very small in size, continuously produced, non-biodegradable and long-lasting in the environment, their accumulation in the environment is of global concern (Chamas et al., 2020). In marine ecosystems, polypropylene (PP), polyamide (PA), polystyrene (PS), polyethylene (PE), polyvinyl chloride (PVC), and polyethylene terephthalate (PET) are the most common polymer types (Llorca et al., 2020).

MPs have a large surface area to volume ratio. This increases their capacity to adsorb harmful pollutants in marine waters (Rodrigues et al., 2019). They are carriers of harmful compounds such as polybrominated diphenyl ethers and dichlorodiphenyltrichloroethane (DDT) (Zhang et al., 2022; Wang et al., 2020). MPs enter the bodies of aquatic organisms through direct ingestion, predation or respiration (Barboza et al., 2018). MPs ingested by organisms can cause blockage of the digestive tract and bioaccumulation in soft tissues and chemicals/additives leached from them can affect normal cellular functioning (Browne et al., 2007). The accumulation of all kinds of wastes deposited in aquatic ecosystems and all the systems with which they are in contact directly or indirectly causes an increase in water pollution rates (Mutlu et al., 2023).

Due to the ingestion of small particles, biotransformation and associated biomagnification, filter-feeding organisms such as mussels are particularly susceptible to MPs and waterborne chemical contaminants while feeding (Avio et al., 2015). In marine environments, MPs can persist for hundreds of years, thus creating a suitable habitat for the colonization of many harmful microorganisms (Curren et al., 2019). High levels of MPs in seawater can be transferred to the consumer through human consumption of fish and shellfish, marine mollusks, clams, shrimps, mussels, etc. The worldwide abundance of MPs in lakes, rivers, estuaries, oceans and beaches has been documented in highly populated areas or areas with intense anthropogenic activities (He et al., 2020). Up to 60% of fish from 198 species in 24 countries have ingested MPs, and humans have been shown to ingest a total of 55,000 MPs per year (Danopoulos et al., 2020; Bayhan and Aydin Uncumusaoglu, 2024).

In spite of the wealth of recent knowledge, especially ecotoxicology studies, fate, prevalence and the many studies to deal with the threat of MP pollution, there is still a huge gap. This study was carried out to investigate MP pollution in designated beaches within the borders of Ordu province. The rate of MPs in one-time samples (sand and seawater samples) taken from six stations on the coasts of Ordu province was determined, MPs were characterized in terms of size, color and type, and the structure of MPs was analyzed to reveal the ecological risk.

MATERIAL and METHOD

Characteristics of Sampling Stations

In this study, the presence of MPs was investigated by taking seawater and sand samples from 6 stations determined from Gülyalı, Altınordu, Perşembe, Fatsa, Ünye districts along the Black Sea coast of Ordu province on August 4, 2023, and the characterization, abundance and distribution of the MPs found were examined (Figure 1).

Figure 1. Map of the study area and stations (S)

The study area covers the area along the Black Sea coast of Ordu Province. Seawater and sediment samples were taken once from each station by scanning the area. A total of 36 samples were analyzed in triplicate during the study. In the analyzed samples, the proportion of MPs in the size range of 1µm-5mm was determined and the polymer structures were examined and the color, size and type analysis of the detected MPs were analyzed.

Sampling of Water and Sediment Samples

Seawater and sand samples were taken from six stations along the Eastern Black Sea coastline extending from Gülyalı district of Ordu province bordering Giresun province to Ünye district of Ordu province bordering Samsun province in August 2023. The characteristics of these stations are given in Table 1. Some values of the stations at the sampling in situ. Some values (temperature, pH, electrical conductivity, salinity, and dissolved oxygen values) of water samples of the stations were measured in situ by YSI 556 MPS field-type multiprobe instrument (Table 2).

Table 1. Characteristics of stations

Stations	Characteristics of stations	Sampling Coordinates
S1 (Blue World Beach)	It is 7.6 km away from the District Center. It is in an area with a low population. It has a sandy surface and is one of the famous beaches of the region.	40°58'22.45"N 38° 1'47.65"E
S2 (Cumhuriyet Mahallesi Public Beach)	It has a sandy beach, 4 km away from the District Center. There is an industrial area, a river and a WWTP nearby.	40°58'59.50"N 37°56'40.72"E
S3 (Kumbaşı Municipality Beach)	It has a sandy beach, 7 km away from the District Center. There are WWTP, Port and stream near the region.	41° 1'6.88"N 37°50'23.64"E
S4 (Çaka Beach)	It is 12.7 km away from the District Center. There are camping areas in the region. The stream reaches the sea nearby.	41° 6'48.13"N 37°42'45.81"E
S5 (Bolaman Beach)	It is 9 km away from the District Center. There is a port near the area. Also, The stream reaches the sea nearby.	41° 2'12.58"N 37°35'33.50"E
S6 (Kırkevler Beach)	It is 10 km away from the District Center. There is a WWTP nearby. It is located close to the town centre. The stream reaches the sea nearby.	41° 7'2.95"N 37°18'34.39"E

Table 2. Some values of the stations at the sampling in situ.

Satation	Water Temperature (°C)	pH	Conductivite (µs/cm)	Dissolved Oxygen(mg/L)
S1	28.51	6.94	56.25	5.37
S2	27.95	6.89	45.03	5.80
S3	29.14	6.61	46.88	5.35
S4	29.17	6.58	46.87	5.34
S5	27.98	6.90	58.14	5.50
S6	28.59	6.89	49.55	5.48

Beach Sand samples were taken using a metal shovel, one from each station, 5 cm from the surface of a 1 x 1 m square area, immediately behind the shoreline and from the middle part of the shore (witness sample) (Zhou et al., 2021). Sand samples were bagged and brought to the laboratory. Seawater samples were taken by filtering a total of 100 liters of seawater through a plankton net with a 35 µm mesh opening with the help of a 5 L bucket, one from each station, and stored in a glass jar and brought to the laboratory (Masura et al., 2015).

MPs Analysis

They were isolated from samples using wet peroxidation (WPO) and density separation techniques (Masura et al., 2015). The wet sediment samples brought to the laboratory were placed in separate containers and dried in an oven at 70 °C to a constant weight and then passed through a steel sieve with a pore opening of 5 mm to remove particles larger than 5 mm. The dried sediment samples (50 g) were weighed and mixed with 200 mL of saturated sodium chloride (140 g/L NaCI) solution in a 250 mL glass bottle for 15 minutes. The whole procedure was repeated at least three times for each sample to ensure good particle separation and each sample was placed in an immersion funnel, covered with aluminum foil to avoid contamination and allowed to settle for 24 hours. The solution at the top of the sedimented samples containing MPs was transferred to a clean beaker using a glass pipette. A solution of ferrous sulfate ($FeSO_4$-$7H_2O$) (20 mL) as a wet peroxidation (WPO) catalyst and 30% hydrogen peroxide (H_2O_2) solution (20 mL), known as fenton reagent, were used to remove organic matter. The sample was placed on a hotplate and oxidized at 60-70 °C at 80 rpm for 6 hours (Masura et al., 2015). The MPs in the resulting mixture were filtered using a glass filter paper (GF/F pore size: 0.45 µm, 100 mm Ø) and a vacuum pump. The filter papers were dried reliably in a glass petri dish at room temperature in the laboratory and then the MPs were observed with a stereomicroscope.

The wet peroxidation (WPO) method was also used for seawater samples brought to the laboratory. The solutions were added to beakers containing the extracted particles and allowed to stand for 10 minutes. The beakers were then placed on a hotplate and oxidized at 60-70 °C at 80 rpm for 6 hours (Masura et al., 2015). For quality assurance, dissection and transfer of samples were performed as quickly as possible to avoid possible airborne MPs contamination and the work area was disinfected with alcohol before starting the procedures. Nitrile gloves, cotton lab coats, glass and metalware were used throughout the study. Blind sampling was performed for possible MP contamination from the laboratory. For this purpose, three blank filter papers were filtered with distilled water and kept uncovered in the laboratory for 24 hours and then observed under stereomicroscope and no MPs were detected in these filter papers (Zhao et al., 2023).

FT-IR Spectroscopy Analysis

For this study, FT-IR spectra were acquired in Attenuated Total Reflectance (ATR) mode utilizing a single element MCT detector, which is considered to be the most compatible setup for the type and morphology of the plastic samples. A Particle Attenuated Total Reflectance-Fourier Transform Infrared spectrometer (VERTEX 70 Series, Bruker, Germany) was used for the analysis. The spectral range was 4000-400 cm^{-1} and 128 repeated scans were performed at a resolution of 2.0 cm^{-1} to determine the polymer type. The spectral data obtained from the samples were linearly corrected based on "0" and normalization transformations were performed according to the highest absorbance value. "Speaktragryph© version 1.2.14" program was used in the transformations. The absorbance spectra obtained were mirrored with the data stored in the device library and analyzed according to the similarity between them by matching with the spectra of the proposed polymer species (Gedik and Gözler, 2022; Çebi and Aydın Uncumusaoğlu, 2024; Aydin Uncumusaoglu, 2024).

Potential ecological risk assessment for MPs

The polymer risk index (H) was used to determine the ecological risk of MPs in all samples. The potential ecological risk of MPs was carried out using the polymer hazard index (PHI) method used in previous studies (Lithner et al. 2011; Xu et al., 2018; Ranjani et al. 2021). The potential risks of plastic polymers to the environment and human health can be assessed according to the chemical toxicity of the monomers (Lithner et al. 2011). The expression of hazard status, score and risk categories when evaluating the polymer type is given in Table 3. The polymer hazard index (PHI) from MPs can be calculated using the following formula:

$$\text{PHI} = \sum PnxSn$$

Here, Pn represents the percentage of each type of MPs polymer detected in each sample, and Sn is the hazard score of the polymers in MPs provided in the study by Lithner et al. (2011). Additionally, the hazard categories and values were evaluated by following the study carried out by Ranjani et al. (2021).

Data analysis

One-way analysis of variance (ANOVA) was used to compare whether there was a significant difference between the stations according to the MPs abundance of the stations. Multivariate Hierarchical Cluster Analysis (HCA) technique was used to classify the clusters that may form between the mean MPs abundances of the stations using Ward's method as a similarity measure. The significance level was set at $P < 0.05$ and mean values were expressed as mean ± standard deviation (SD). Statistical analyses were performed using SPSS Statistics for Windows, version 25.0 (IBM, USA). Results were expressed as graphs or tables.

RESULTS AND DISCUSSION

Descriptive Statistics on the MPs

In this study, MPs in the size range of 1µm -5 mm were analyzed from sediment and water samples. Samples from each station were analyzed in detail in terms of color, size and type of MPs. In this research, 291.11 items kg^{-1} MPs was found in sediment samples and 0.263 items L^{-1} MPs in water samples. A total of 420 MP fragments were detected from seawater and sand samples on the coasts of Ordu Province and analysed. The distribution of MPs according to stations is detailed in Figure 2.

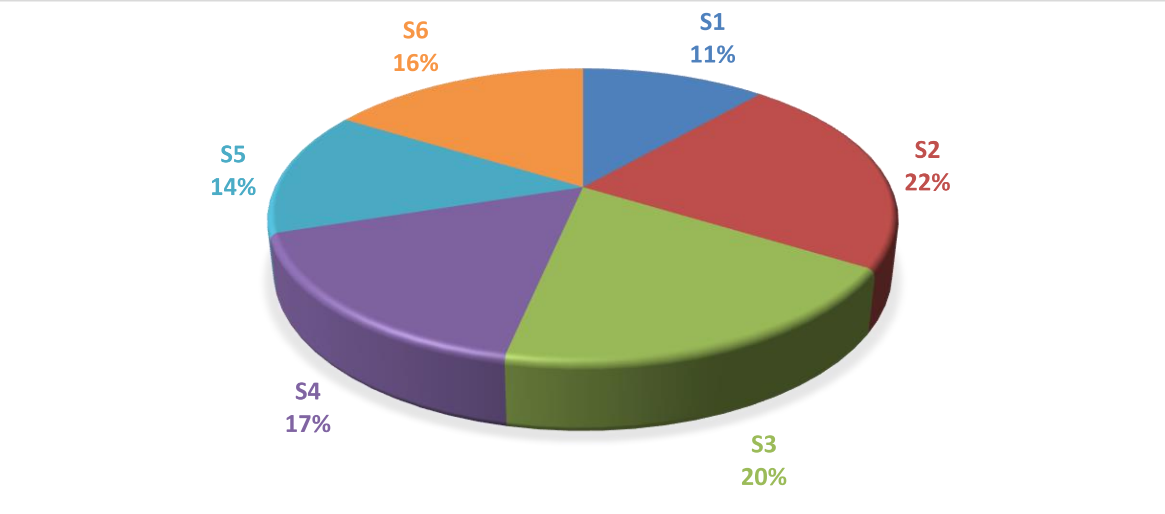


Figure 2. The abundance ratios (%) and items MPs values by the stations (S W: Station Water, S S : Station Sand)

There was no significant difference in the size of MPs between all stations (one-way ANOVA; $P > 0.05$). However, a significant difference was observed between stations for the colors white (one-way ANOVA; $P = 0.219$) and black (one-way ANOVA; $P = 0.035$), while no statistically significant difference was found for the other colors. Regarding the shape of MPs structures, statistically significant differences were found for all varieties except Pellet (one-way ANOVA; P=0,068). No statistically significant difference was observed between polymer types for all MPs varieties except PE (one-way ANOVA; P=0.000) (one-way ANOVA; $P > 0.05$) (Akbulut, 2022). There were statistically significant differences among the MPs colors detected in the water samples for red (one-way ANOVA; $P = 0.013$), blue (one-way ANOVA; $P = 0.001$) and transparent (one-way ANOVA; $P = 0.001$), while no significant differences were detected for the other colors. There was a statistically significant difference (one-way ANOVA; $P < 0.05$) between the shapes of MPs structures in water for all types except Foam (one-way ANOVA; $P = 0.562$). No statistically significant difference was observed between the polymer types in seawater (one-way ANOVA; $P > 0.05$) for all MPs types except PVAc (one-way ANOVA; $P = 0.05$).

Among the MPs colors detected in the sand samples, red (one-way ANOVA; P=0.039), and transparent (one-way ANOVA; P=0.001) were statistically significant, while no significant difference was detected in the other colors. Among the shapes of MPs structures in sand, significant differences were found for film (one-way ANOVA; P=0.002), fiber (one-way ANOVA; P=0.000) and foam (one-way ANOVA; P=0.000) types, but not for others. No statistically significant differences were observed for MPs types (one-way ANOVA; $P > 0.05$) except for PE (one-way ANOVA; $P = 0.01$) and PS (one-way ANOVA; $P = 0.021$).

According to the results of the color analysis of the MPs detected in the samples taken during the research, a total of 6 different colors were determined as red, green, blue, black and transparent. The most common color was recorded as blue with 32%. These were followed by 29% transparent, 23% black, 11% red, 4% green and 1% white. The distribution of MPs according to the stations is given in detail in Figure 3. Young et al. (2016) in Kamilo Beach and Kahuku Beach, Zhu et al. (2018) in the North Yellow Sea, Liu et al. (2023) in the South China Sea and Sönmez et al. (2023) in the Marmara Sea in Turkey, the predominant color was transparent, which is mostly similar to the beach sand results. This is mostly due to the widespread use of transparent plastics, especially in packaging materials and beverage bottles. Transparent plastics are less noticeable in water and can therefore be overlooked during cleaning efforts. This can lead to their accumulation in the seas. In addition, some types of transparent plastics (e.g. PET) degrade more slowly in nature. This causes them to remain in the seas for longer. Again, some types of transparent plastics may be less in demand for recycling than other colored plastics, which may result in more waste. Blue color was found more dominant in water samples, blue plastics are widely used in a variety of consumer products, especially water bottles, detergent containers, toys and fishing gear. This widespread use can lead to a high number of blue plastics entering the environment. The color blue is often preferred in products associated with water. In particular, the color blue is common in products related to maritime, fishing and water sports. This increases the likelihood of blue plastics ending up in the sea, and the color blue can be more resistant to sunlight and other environmental influences. This can result in blue plastics remaining intact in nature for longer. Fishing nets, ropes and other fishing gear can often be blue in color. Over time, these materials can erode into the sea and turn into MPs.

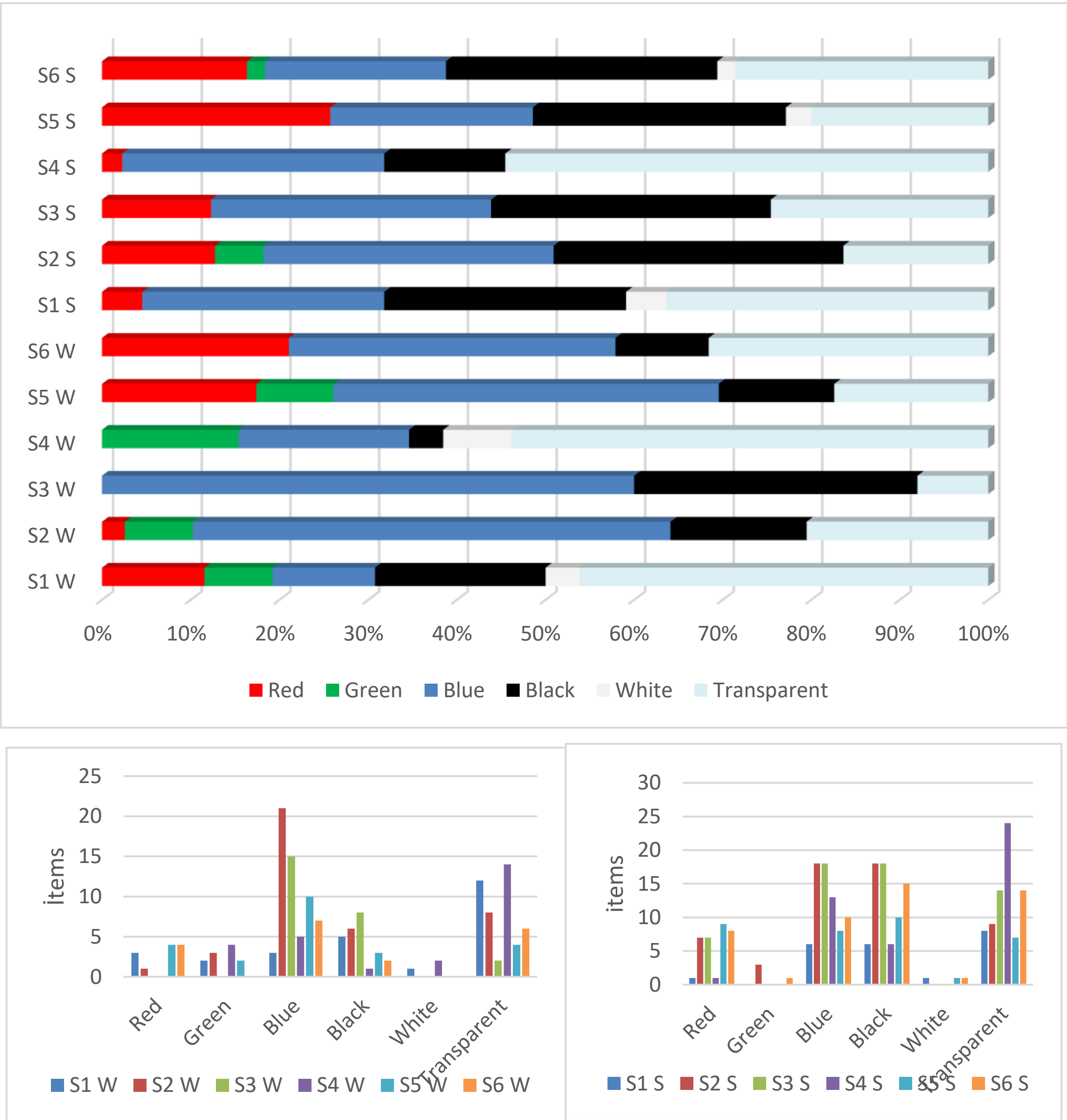


Figure 3. Distribution of MPs by colour in all stations (%) (S W: Station Water, S S : Station Sand)

Within the scope of the study, MPs were grouped by performing size analysis on samples taken from 6 different stations. The analysis was divided into eight groups in the range of 1 µm -800 µm. According to the size analysis, it was determined that 50.71% of the most common MPs were in the 0-50µm size range. This was followed by 22.61% 50-100 µm, 18.09% 100-200 µm, 4.04% 200-300 µm, 2.14% 300-400 µm, 1.19% 400-500 µm, 0.95% 500-600 µm and 0.23% 600-800 µm, respectively. The MP distributions according to size are shown in detail in Figure 4. The dominant size results obtained in this study are similar to those of Zhu et al. (2018) with more than 70% of the total number of MPs in the North Yellow Sea, Jiang et al. (2020) with 78% of the total MPs in the South Yellow Sea and Dutta et al. (2022) found similar results in the coastal areas of Mumbai, India with mostly MPs smaller than 500 µm. Liu B. et al. (2023) found 47.7% of the MPs in the South China Sea in the size range of 100-500 µm and no MPs smaller than 30 µm.

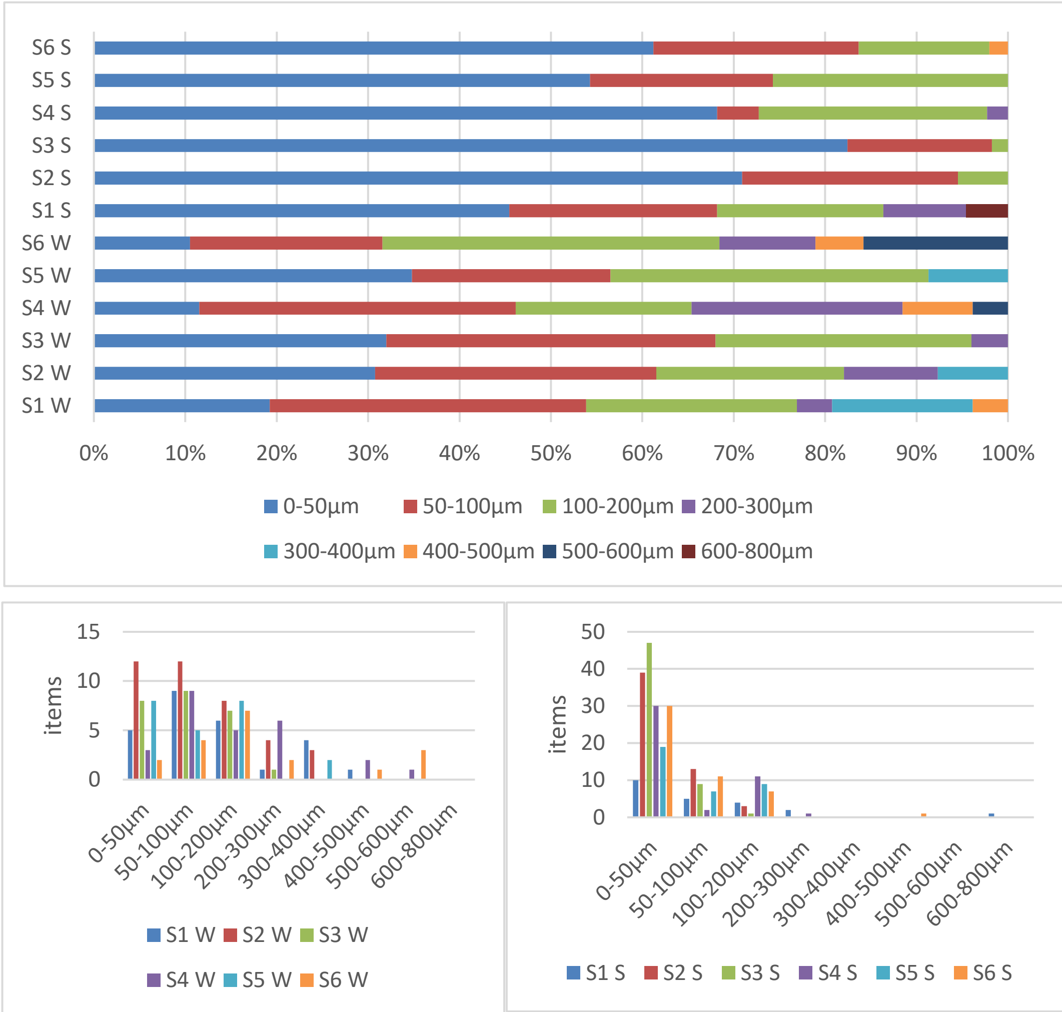


Figure 4. Sizes of MPs in all stations (%) (S W: Station Water, S S : Station Sand)

MPs fragments detected from samples taken from water and beach sand on the beaches of Ordu province were grouped into five different categories as film, fragment, fiber, foam, and pellet. According to the data obtained, fibers were detected at the most common rate of 58.33% in total. According to these findings, the most common MPs after fibers are 21.43% film, 9.76% fragments, 8.80% plastic pieces and 1.66% pellets, respectively. The detailed distribution of the detected MPs according to type is given in Figure 5. Photographs of the Mps shapes detected in this study are given in Figure 6. The predominant MP type results were similar to those of Zhao et al. (2014) in the East China Sea, Castillo et al. (2016) in Qatar marine waters, Zhu et al. (2018) in the North Yellow Sea, Terzi et al. (2022) in the South Black Sea, Şener and Yabanlı (2023) in the South Aegean Sea, Sönmez et al. (2023) in the Marmara Sea. MPs, mostly in the form of fibers, accumulate in the seas and beaches because synthetic fabrics (e.g. polyester, nylon, acrylic) are one of the largest sources of MP fibers and these fibers are mixed with water during the washing of clothes and reach the seas through sewage systems. Furthermore, wastewater treatment plants cannot filter out all MPs. In particular, small and fibrous MPs can pass through the water in treatment processes and reach the sea, and fishing nets, ropes, ship rigging and other marine equipment can erode over time into MP fibers and enter the sea. These fibers can be transported in the atmosphere and reach the sea through rain or wind. MP fibers can accumulate, especially near coasts, and these fibers can remain intact in the marine environment for long periods of time, causing them to accumulate over time. MP fibers can be dispersed over large areas by ocean currents and winds. This can lead to their more widespread presence in seas and on beaches.

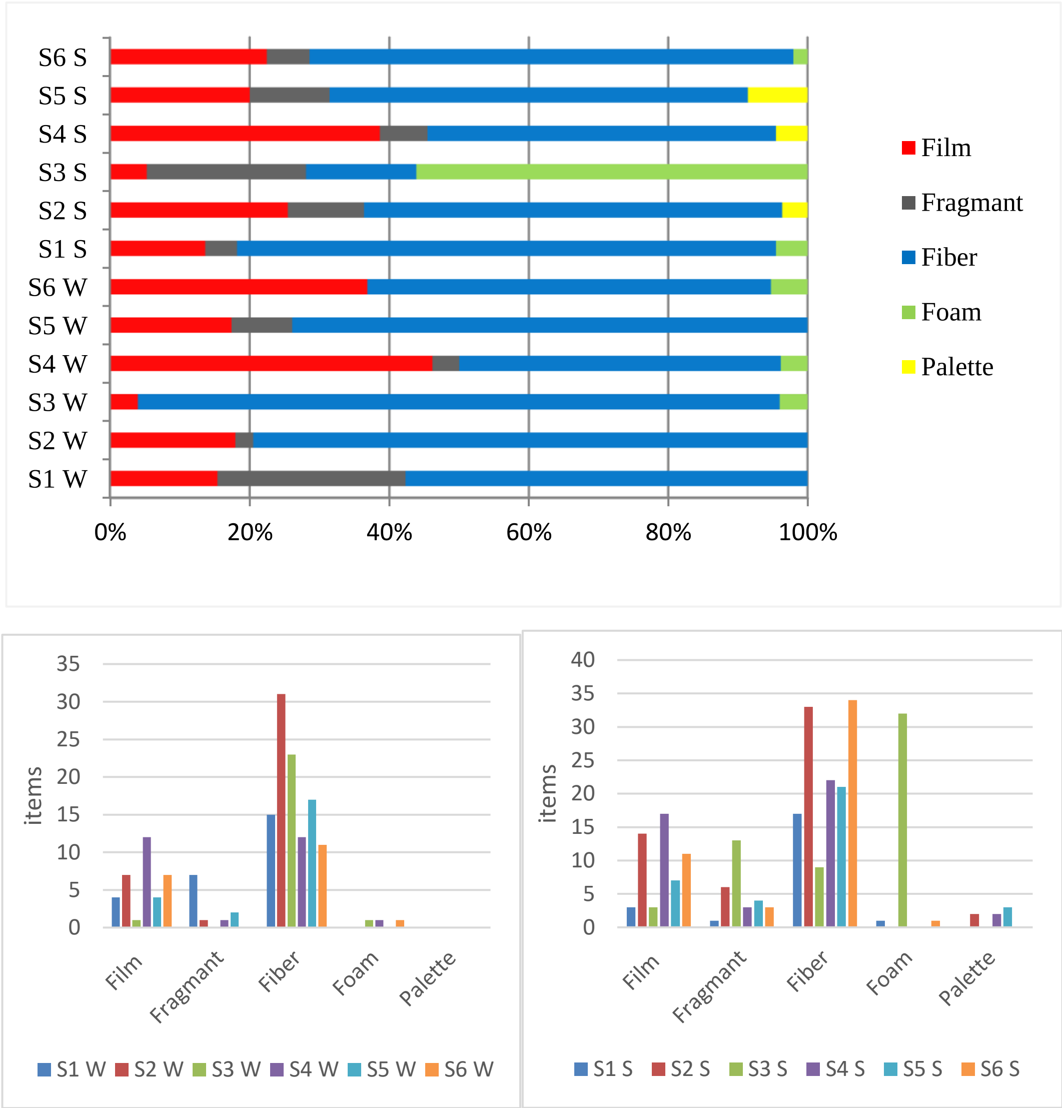


Figure 5. Distribution according to MPs shape in all stations (%) (S W: Station Water, S S : Station Sand)

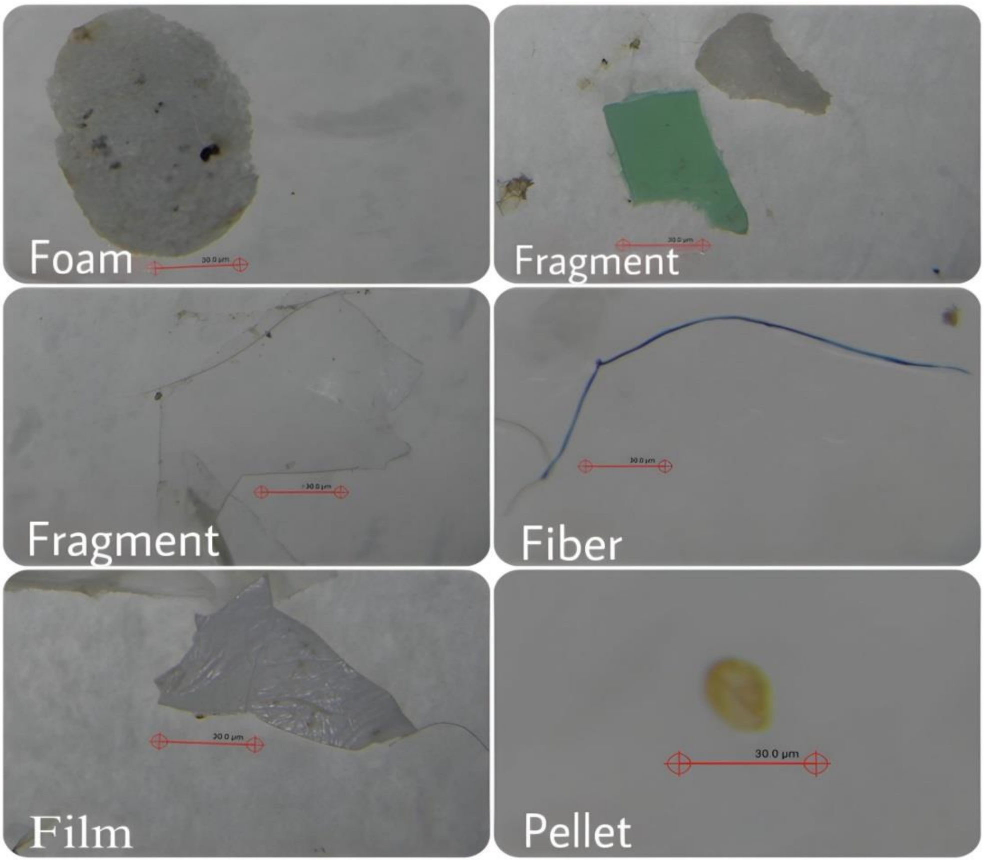
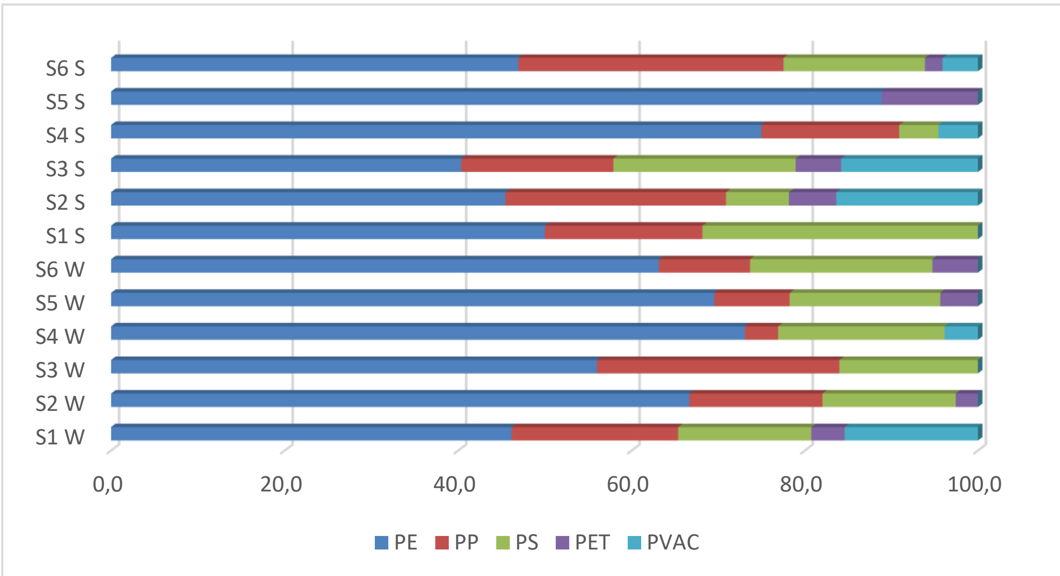


Figure 6. Microscope images of MP shape types

According to the FT-IR analysis results, when the MPs were analyzed by type, polyethylene was found to be the most common MP type with 56%. It was followed by Polypropylene with 19%, Polystyrene with 15%, Polyvinyl Acetate with 7% and Polyethylene Terephthalate with 3%. The detailed distribution of MPs by type is given in Figure 7. FTIR spectra of MPs detected in seawater and beach sand samples taken from the beaches of Ordu Province are given in Figure 8. Similar to this study, Young et al. (2016) in Kamilo Beach and Kahuku Beach, Şener and Yabanlı (2023) in South Aegean Sea (Turkey), Sönmez et al. (2023) in Marmara Sea Coasts, Gedik et al. (2022) in Northeastern Mediterranean coasts found PE as the predominant species. PE is highly resistant to environmental conditions and degrades slowly in nature, which causes them to remain and accumulate in seas and coasts for a long time. PE is also one of the most widely used types of plastic, found in packaging materials, plastic bags, bottles, toys and many other everyday items. This widespread use can lead to a high amount of PE entering the environment. The recycling rate of PE products is often low and these plastics can enter the environment when waste management systems are inadequate. PE materials are lightweight and can be easily transported by wind and water currents, causing them to spread over large areas and reach the sea.



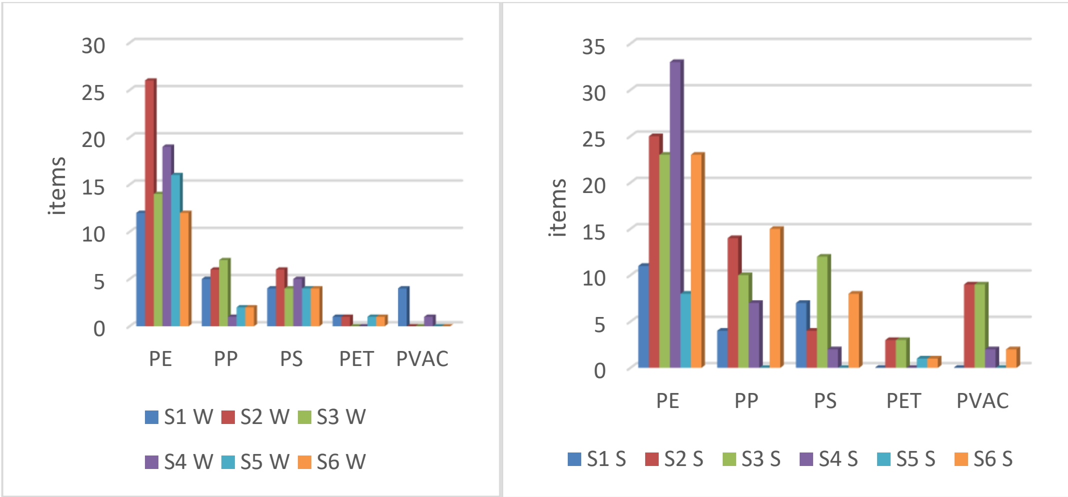


Figure 7. MPs polymer type abundances for water and sediment samples

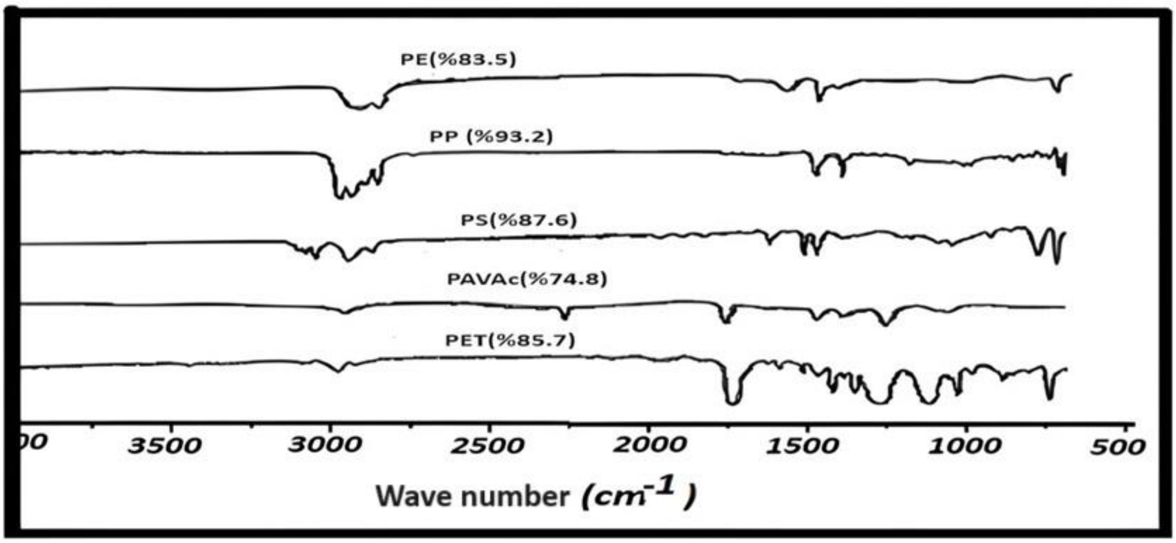


Figure 8. The FTIR spectra of MPs found on the beaches of Ordu Province (Values in parentheses indicate the average matching ratio with the standard spectrum for each polymer: PE (polyethylene), PP (polypropylene), PS (polystyrene), PVAc (polyvinyl acetate) and PET (polyethylene terephthalate))

Potential ecological risk assessment of MPs

Based on the PHI (Potential Health Index) studies of Lithner et al. (2011) and Ranjani et al. (2021), it was concluded that the PHI (Potential Health Index) calculated in this study falls into the III (High) and IV (Danger) damage and risk categories (Table 3). Detailed potential ecological risk results of MPs for seawater and beach sand are given in Table 4 and Table 5.

Table 3. Potential Health Impact of MPs on the beaches of Ordu province (Total sampling)

Polymers	Proportion (%)	Hazard score *	PHI**	Hazard category**	Risk Category**
PE	60.10	11	661	Tehlike	IV
PP	16.12	1	16	Yüksek	III
PS	15.45	30	463	Tehlike	IV
PET	3.32	4	13	Yüksek	III
PVAC	5.00	10.551	52	Yüksek	III

* Lithner et al. (2011), **Ranjani et al. (2021).

Table 4. Potential Health Effects of MPs on the beaches of Ordu province (Seawater)

Polymers (Water)	**Proportion (%)**	**Hazard score ***	**PHI****	**Hazard category****	**Risk Category****
PE	62.44	11	687	Tehlike	IV
PP	14.28	1	14	Yüksek	III
PS	17.41	30	522	Tehlike	IV
PET	2.67	4	11	Yüksek	III
PVAC	3.21	10.551	34	Yüksek	III

* Lithner et al. (2011), **Ranjani et al. (2021).

Table 5. Potential Health Effects of MPs on the beaches of Ordu province (Sand)

Polymers (Sediment)	**Proportion (%)**	**Hazard score ***	**PHI****	**Hazard category****	**Risk Category****
PE	58	11	635	Tehlike	IV
PP	18	1	18	Yüksek	III
PS	14	30	405	Tehlike	IV
PET	4	4	16	Yüksek	III
PVAC	7	10.551	72	Tehlike	IV

Hiyerarşik Kümeleme Analizi (HCA)

The HCA test was applied to the data of this study to clearly determine the similarities or differences between the MPs densities of the stations. At the end of the analysis based on the MP amounts obtained from the stations where the coastal sea waters of Ordu province were taken, two groups were basically formed in the stations (Figure 9). Station 2, which constitutes Cluster B, was identified separately from the other stations due to the fact that there is an industrial zone nearby, the river outlet is close to this coast and although it is close to the treatment plant, the MPs load is higher than the other stations. Cluster A consists of stations other than Station 2 (Stations 6,5,4,3 and 1). Station 6 is different from the others because it has a treatment plant nearby, it is close to the district center and the stream reaches the sea very close to it.

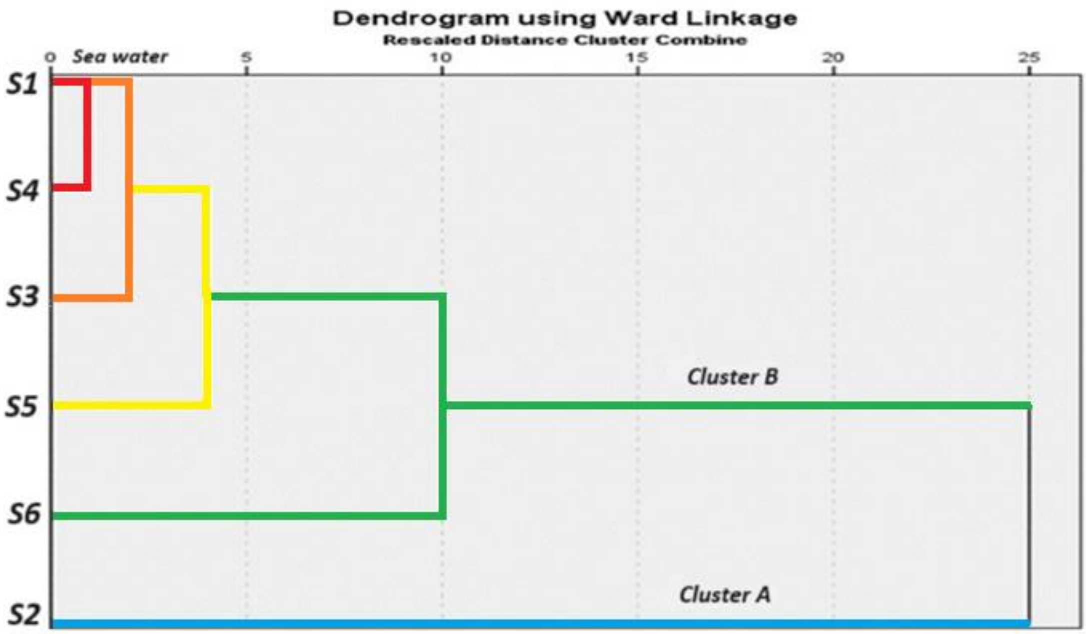


Figure 9. HCA Analysis according to the abundance of MPs in seawater.

As a result of the analysis based on the MP quantities obtained at the stations where Ordu coastal sea sand was taken, two groups were formed at the stations (Figure 10). Cluster A was found to be more similar than Cluster B. Cluster A consists of stations 1 and

5. The similarity in terms of MPs loads due to the distance of this Cluster from the settlement and the fact that they are located in a region that is not very dense in terms of human population is the source of their loads. Since the other members of Cluster B have similar MPs load sources (streams, etc.), the similarities between the members of this Cluster were found to be high.

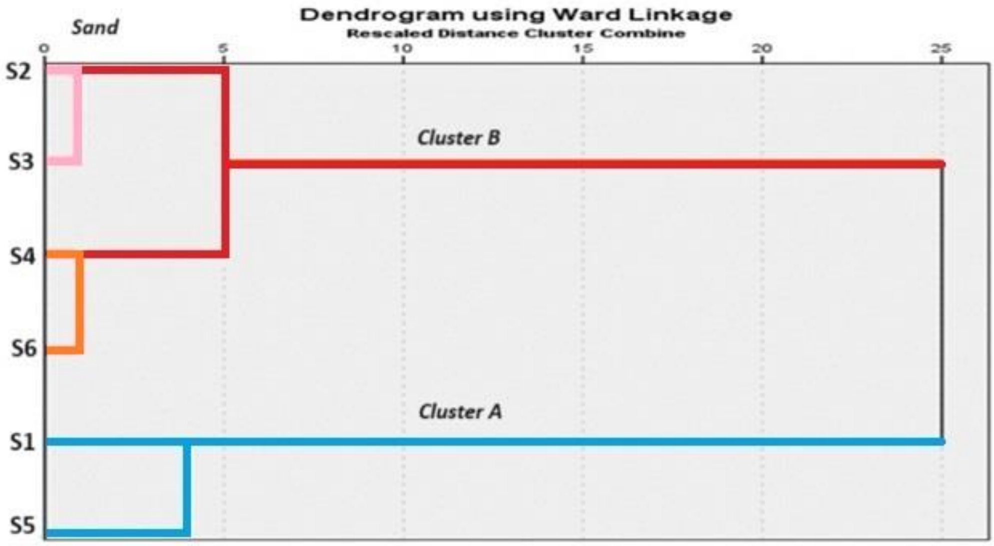


Figure 10. HCA Analysis according to the abundance of MPs in sand.

CONCLUSION

In this research, the MP profile of sand and seawater samples taken along the Black Sea coast of Ordu province on August 4, 2023 was examined in detail and the color, shape, size characterizations of the MPs found were determined and the polymer types were examined. It is aimed that the data obtained from this study will contribute to other studies on MP pollution in the region. When the size analysis of MPs in the research process was performed, it was found that when we look at the MPs in the water, the most common MP size is 50-100 µm and when we look at the MPs in the beach sand, the most common MP size is in the size range of 0-50µm. Comparing MPs in water and sand, MPs of smaller size are more common in sand than in water. Within the scope of this study, when the color analysis of the MPs obtained, the colors of the MPs in the water were mostly 38% blue. When the colors of MPs found in sand samples were evaluated, transparent color was found with 29%. In water, it was concluded that mostly blue color was dominant.

The types of MPs found in water were examined and MPs were found mostly in the form of fibers, films, fragments and foam. When the MPs found in sand were examined, mostly fiber, and film, foam, fragment and pellet were detected respectively.

As a result of the polymer type analysis of the MPs identified in this study, PE was found to be the most common polymer type in seawater. This was followed by PS, PP, PET, and PVAc. The most common polymer type found in beach sand and beach seawater was PE.

The number of MPs detected in the sand samples taken from the beach was higher than in the seawater samples. In this study, stations were selected based on proximity to urban wastewater treatment plants, proximity to stream discharge points, areas with the highest population density, and areas near ports and industrial facilities. In addition, the sampling day was selected from the hottest days of the summer months and the day when air movements and waves were low.

In the seawater and sediment of the coast of Ordu province, the fiber type of MPs fragments is the most common and blue and transparent colors are more intense. Although all fragments are below 800µm, MPs in the size range of 0-50µm are predominant. In the study, polyethylene type MPs were dominant in water and sand samples. PE are used in packaging, kitchen products, toys, textiles and are released into nature mostly as a result of human activities (Yurtsever, 2015). Textile products such as blankets, quilts and clothes cleaned in the washing machine reach the wastewater system together with the MP fibers they contain. Therefore, MPs can accumulate in the tissues or organs of organisms such as zooplankton, macroinvertebrates, fish, etc. at important steps in the food chain. Since the density of PE is lower than water, no matter how much the coagulant dose is increased in fast mixing, slow mixing and settling processes in classical WWTPs, very little removal can be achieved by remaining on the surface, and the majority of them are discharged to the receiving environment (Berber and Yurtsever, 2016).

The PHI (Potential Health Index) calculated in this study was found to fall into the III (High) and IV (Danger) damage and risk categories. In studies on food safety, as a result of human exposure to MPs through the consumption of marine and food products, additives used in the production of MPs and pollutants deposited on the environment where plastics are present can cause chemical toxicity, MPs can cause microbial contamination and cause diseases, and cumulative harmful effects will occur if they accumulate in tissues and cause chemical toxicity (Li et al., 2018).

To protect the environment and human health, systems that filter MPs can be installed in wastewater treatment plants. Using ultrafiltration (UF) membrane in wastewater treatment plants, the retention rate of MPs in the surface area was found to be over 98% (Yang et al. (2023). Since (UF) membrane bioreactors provide MP treatment with very high efficiency, local governments can be recommended to install UF membrane bioreactors in their treatment plants.

In addition, the following recommendations can be considered for the prevention and reduction of MPs in beach water and sand:

- Provide education about MP pollution in schools and community centers,

- Awareness campaigns can be organized through social media, brochures and public meetings,

- Recycling of plastic waste should be encouraged,

- Regular beach cleaning events can be organized,

-An adequate number of garbage bins and recycling bins should be provided on the beaches,

- Reusable alternatives to single-use plastic products should be promoted,

- The use of certain plastic products may be banned or restricted,

- Legal regulations and sanctions should be implemented to reduce MP pollution,

- Strict environmental protection laws could be introduced on the production and use of MPs,

-Systems that filter MPs can be installed in wastewater treatment plants

- More scientific work needs to be done to investigate the impacts of MPs and methods to reduce them,

- Voluntary groups and non-governmental organizations fighting MP pollution should be supported,

- Local people should be involved in decision-making processes and joint solutions should be developed for the protection of the coast,

- International cooperation and projects can be developed against MP pollution,

- Regional and global strategies can be developed for marine and coastal management.

When these recommendations can be implemented to prevent and reduce MP pollution on the world's coasts, everyone will fulfill their duty in terms of human and environmental health in the future.

COMPLIANCE WITH ETHICAL STANDARDS

a) Author Contributions

1. TK: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, writing—original draft preparation, writing—review and editing,

2 AAU: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision. All authors have read and agreed to the published version of the manuscript

b) Conflict of Interests

The authors declare that there is no conflict of interest

c) Statement on the Welfare of Animals

Not applicable

d) Statement of Human Rights

This study does not include human participants.

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