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Research Article

Microplastic pollution in a small fishing port in Zonguldak/Türkiye

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ABSTRACT

In this study, the occurrence and morphology of microplastics in a small fishing port in the Black Sea were determined by bulk sampling and visually analyzed by a stereo microscope. Three sampling campaigns were carried out, two of which were after the opening of the legal fishing season. The average abundance of the microplastics was found to be 3417+1401 items/m^3. The determined microplastic concentration was 1.43 times higher on the day of the most intense fishing activities. No statistically significant differences were observed for the different sampling locations (coast, middle, and seaside). The most frequent microplastic colors observed were blue, followed by black, green, red, white and grey, while fibers represented the dominant shape. The prevalent size of microplastics was <50 µm which makes it easy to ingest by even the smaller fishes and introduce into the food chain as well. However the NP value which shows the bioavailability of microplastic was calculated as 0.72 indicating a low bioavailability (≤2).

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INTRODUCTION

Plastic debris is described as "any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes" in UNEP Regional Seas Reports and Studies [1]. Plastics are exposed to the action of biological organisms and exogenous agents like solar radiation, wind, and waves after they are spread in the environment, which speeds up degradation through thermal, photo-oxidative, and mechanical stimuli. The breakdown of these plastic items creates microplastics (plastics< 5 mm; MPs). Microplastics (MPs) have now been discovered in almost every component of the aquatic environment, including seawater, lake water and beach and bottom sediments. Additionally, MPs have been found in a variety of aquatic animals, including mussels and fish, and it has been shown that they can transfer within the planktonic food web [2].

The diversity and composition of microplastics match consumption trends for plastic goods quite well. Primary microplastics are produced in tiny sizes and can be employed either directly, as the microbeads in toothpaste, soap, and facial cleansers, or as precursors in industrial production [3]. Anthropogenic activities, the hydrodynamic regime, and regional characteristics are linked to the spatial distribution and composition profile of microplastics. Areas with a lot of anthropogenic activity, such as those with industry, tourism, aquaculture, and residential processes, are high in

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microplastic concentration [4]. Aquacultural and fishing activities are one of the important anthropogenic sources in ponds, lakes and surface waters. Plastic ropes, nets, fences, boats, floats, cages, impermeable membranes, feeders, oxygenators, and packaging materials used during these activities are linked to the high abundance of microplastics in the marine environment [5]. Microplastics may be transported and deposited differently in coastal and marine environments due to hydrodynamic characteristics such as current velocity, turbidity, turbulence, and residual circulation [6]. The study of Liu et al. [4] reported that microplastic abundance was significantly influenced by the human population density, waste management efficiency, maritime activity and hydrodynamic conditions. In particular, the ratio of tidal range to average water depth showed a significantly negative correlation with microplastic abundance ($P<0.01$), whereas river plastic emissions and aquaculture production were significantly positively correlated with microplastic abundance ($P<0.01$). The methodological decisions, such as the pore size of filter paper (PSFP), density separation (DS), drying temperature (DT), sample depth (SD), identification method (IM), and digesting method (DM), had a significant impact on microplastic abundance as well ($P<0.05$). The mesh size of the filter is an important parameter when performing in situ monitoring because only particles larger than the mesh size are retained, the smallest microplastics are therefore missed and not counted. These small particles make up a significant portion of the total mass and the total number of microplastic particles expressed per volumetric unit [7]. It was discovered that the mean concentrations were two orders of magnitude higher when using a mesh size of 50 µm than when using a sample net of 330 µm. [8]. Microplastic transport is also influenced by the materials' own characteristics, such as particle size and surface modification, as well as other environmental factors (e.g., pH, light and dissolved organic matter) [4]. MPs consist of heterogeneous polymer mixtures of various shapes and sizes, and they can be unevenly distributed in the aquatic environment. Overall, plastics with a higher density than water, like polyesters (PES, 1.2–2.3 g/cm^3) or polyvinylchloride (PVC, 1.2–1.6 g/cm^3), are more prone to sink to the bottom [9]. In turn, the most produced polymers, such as polypropylene (PP), polyethylene (PE), and polystyrene (PS), have a density lower than or similar to that of water (0.9–1.1 g/cm^3), and they are more likely to disperse from their sources [2].

Large efforts have been undertaken to gather data on the prevalence of plastic in shorelines and the open sea, but few studies have concentrated on peculiar maritime habitats, such as ports. The port areas are constantly subjected to intense anthropogenic pressures that significantly degrade their quality. They serve as a source for spreading contaminants (including plastics) originating from land by connecting to the open sea [9]. Indeed, plastics entering the port region may be carried by water currents outside the basin but may also be impacted by sinking processes, just as in any other marine ecosystem [10]. Due to the regular dredging operations that result in silt resuspension from the bottom, ports are a peculiar example of a marine environment [11]. In addition to land inputs, ports are characterized by the high presence of boats and vessels, which can work as sources of plastics and microplastics (MPs) [12].

In the present study, MP contamination in a fishing port was investigated by in situ bulk sampling. Three sampling campaign was carried out, two of which is after the start of the fishing season. The abundance of microplastics was calculated and classified according to their size, shape and color. Microplastic bioavailability was calculated by the Nemerow Pollution Index (NPI).

MATERIALS AND METHODS

Study Area

The sampling was carried out in a small fishing port, shown in Figure 1, used mainly by small boats for fishing activities. The port is in the city of Zonguldak/Türkiye located in the western Anatolian part of the Black Sea. It is 390 m in wide and 170 m in length with a varying depth of 7–10 m. It is not used for commercial sea transportation and there are approximately 110–120 boats of different sizes registered. The sampling area was divided into 3 regions; the coast, middle and seaside. Four samples were collected at each region and a total of 12 samples were collected in each sampling campaign. Sampling was carried out on three different days in 2020 as; August 28, September 3 and September 21. A notable point in the sampling dates is that September 1 is the beginning of the legal fishing season in Türkiye.

Sampling and Analysis

Bulk surface water samples were collected from 0–60 cm depth with a metal bucket suspended from a fishing boat. The sampling method was adopted from literature studies with a modification of sample size [13, 14] Before sampling, all the materials were rinsed with first tap water then distilled water and then seawater (for each sampling point). A fisherman's boat was used to reach sampling points. At each sampling point, a metal bucket was immersed in water and 15 L sample was collected. Then it was passed through a 5 mm and 0.045 mm stainless steel sieve respectively. Bigger particles remaining on the 5 mm sieve were removed and the materials remaining on the 0.045 mm sieve were washed into glass jars with distilled water and stored at +4°C until analysis.

Pre analysis methods were carried out based on previous studies [15–17] At the laboratory, organic material was removed from the samples by acid ingestion. For this purpose, 10–25 ml of 30% Hydrogen Peroxide (H_2O_2) was added to the samples and were shaken at 80 rpm for 2 days. Mixing was

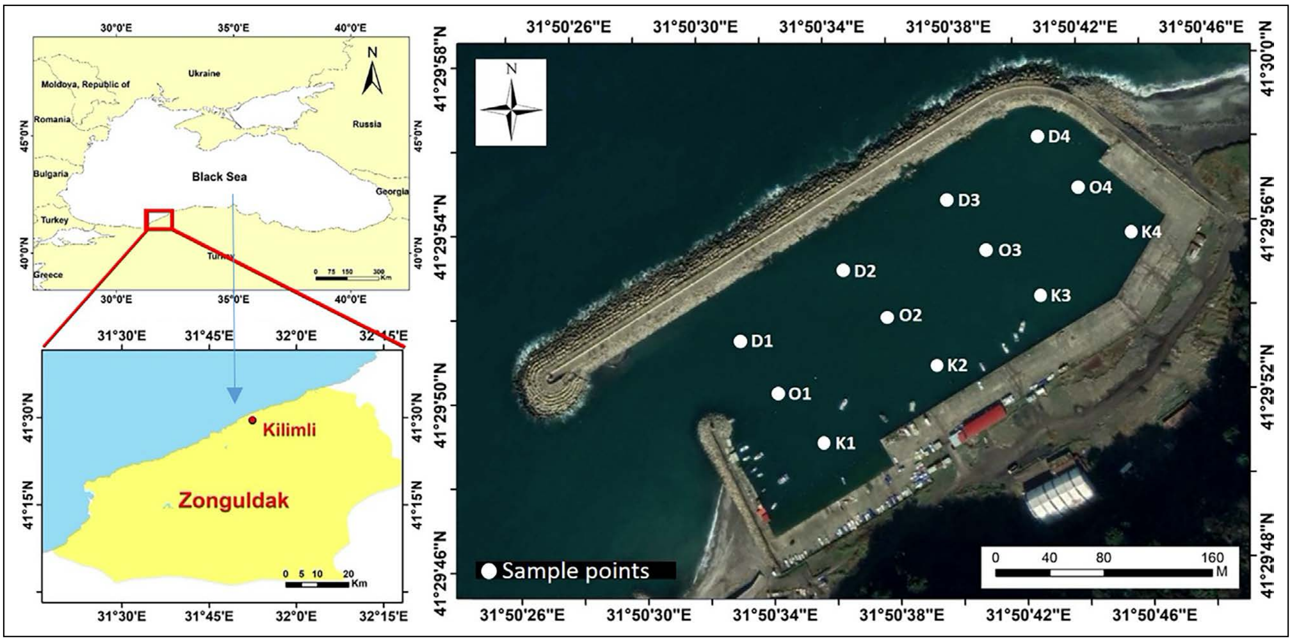

Figure 1. Sampling area and sampling points.

carried out at 40 °C to accelerate the reaction if necessary. The density separation was provided by adding saturated sodium chloride solution to the sample and by keeping it overnight. After filtering through a Whatman GF/C filter the samples were ready for visual analysis. Visual analyses were performed by Euromex NZ.1903-P stereo microscope equipped with ImageFocus Alpha software and a camera attached to it. The number, color (red, blue, green, black, yellow, white, transparent and others), shape (fiber, fragment, pellet, foam), and size of all detected microplastics were recorded.

Microplastic Bioavailability

Currently, no standardized procedure has been developed to assess the potential environmental risk of MPs exposure. However, the bioavailability of the microplastics in the port was calculated as in the study of Liu et al. [4] (2022) using Nemerow Pollution Index (NPI) by Equation 1.

$$NPI = \sqrt{\frac{\left(\frac{Ci}{Si}\right)max^2+\left(\frac{Ci}{Si}\right)ave^2}{2}} \qquad (1)$$

where Ci represents the measured MP abundance and Si refers to the maximal regulatory abundance for regulatory standard [4] Si value was taken as 6650 particles /m^3 seawater [18]. When the NPI value is ≤2 the bioavailability level is low and if it is >2 then the bioavailability is high.

Statistical Analyzes

SPSS 15.0 was used to summarize the basic statistics and analyze the differences between the groups. The statistical significance of the difference between the sampling campaigns was evaluated by non-parametric statistical tests. Although parametric tests are more powerful tools to explain the differences between the groups, in cases where parametric test assumptions are not met, non-parametric tests can be used to examine these differences.

Table 1. Basic statistical results of microplastic abundance

Date	Statistical parameter (items/m^3)			
	Mean	Min.	Max.	Std. Dev.
Augu 28	2800	1200	5600	1393
Sept 3	3425	1400	5300	1404
Sept 21	4017	2500	5900	1239
Total	3417	1200	5900	1401

RESULTS AND DISCUSSION

Abundance of Microplastics

Microplastics were detected in all water samples collected from the Kilimli port and basic statistics are given in Table 1. A total of 1847 MP were determined at the end of three sampling campaigns (505 MP in August, 619 MP in September 3 and 723 MP in September 21) with an average of 3400±1400 items/m^3 and a range of 1200 to 5860 items/m^3. The average abundance of microplastics in the first and second sampling were 2800±1400 and 3400±1400 items/m^3 while it was determined slightly higher in the third sampling campaign as 4000±1230 items/m^3.

In this study, since the number of samples is small (<30) and the data is not normally distributed for each group

Table 2. Normality test and differences between the groups

Sampling date	Shapiro-Wilk			Friedman test	
	Statistic	df	Sig.	Mean rank	
Augu 28	0.810	12	0.012	1.50	Chi-Square: 6.00
Sept 3	0.908	12	0.199	2.00	Df :2
Sept 21	0.910	12	0.213	2.50	Asymp.Sig.: 0.05

Figure 2. Boats in the port on a routine day (top photos) and on September 21 (photo below).

(Shapiro-Wilk test), the Friedman test, which is the non-parametric equivalent of the one-way analysis of variance, was used to explain the differences between the groups (Table 2). In Table 2, it can be seen that the data of the second (Sept 3) and third (Sept 21) sampling campaigns shows a normal distribution ($p>0.05$), while the August sampling campaign did not ($p<0.05$). The difference between the groups was evaluated from the result of the Friedman test which indicates a significant difference between the three sampling dates ($p=0.05$). The mean rank column shows the order of the mean values where the MP abundance is the highest on the 3rd date, followed by the 2nd and the first date. The evidence about the impact of human activities on the presence of microplastics can be observed in the data. As mentioned before the first of September is the opening of the legal fishing season in Türkiye. After that day fishermen start heavy fishing activities using larger fishing nets instead of angling. Furthermore, even larger boats from other cities of the Black Sea participate in fishing activities in the port from time to time which was also encountered in the third sampling campaign of our study (Fig. 2).

The main sources of plastic pollution in the port are varying solid wastes arriving from owners of the boats and locals as a result of human activities. An unusual increase in human activities can also be associated with an increase in the amount of MP. Here, a prediction can be made about this relationship, but the effect of fishing activities on MP concentration can be proved by a more detailed sampling study. The big boats anchored in the port at the

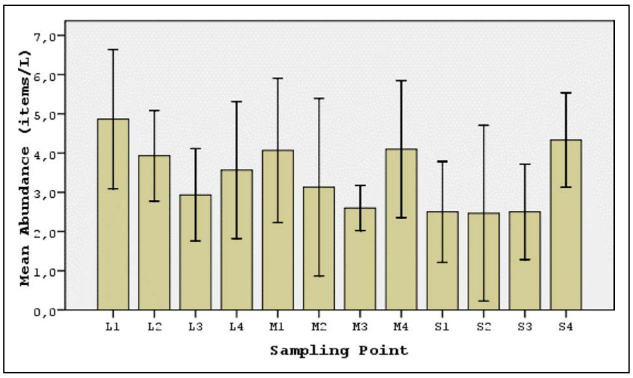

Figure 3. Microplastic distribution at sampling points along the port.

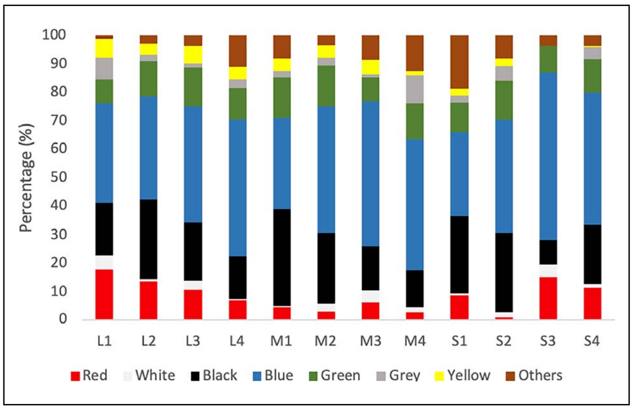

Figure 4. Color distribution of microplastics.

third sampling date were stuffing the fish into the crates and transporting them to trucks over a belt. This activity can be considered one of the unusual activities that may increase MP concentrations. In the field observations, plastic bottles, packaging wastes and styrofoam particles were recorded in addition to polypropylene grass carpets and piles of tools used in the fishing activities. All these wastes can act as microplastic sources degrading by sunlight, waves, and wind.

The distribution of MP along the sampling points given in Figure 3 shows that microplastic abundances were higher in land sampling points but the difference between the land, middle and seaside sampling points was not statistically significant ($p>0.05$). The maximum abundance of MP was 5900 items/m^3 at sampling point L1 and an average of 3800±1320 items/m^3. Because the boats are tied to the coast and launched to the sea from this region, there are lots of plastic sources like ropes, spherical plastic pontoons, and various plastic junk. The average number of microplastics in the middle and seaside samples were 3500±1430 and 3000±1400 items/m^3. It is difficult to compare the results of different microplastic studies because there is no uniform standard for recording microplastic data. Sampling methodologies, concerning particle size, time and date of sampling, and even quantification units differ for various studies [19]. The first study on MP pollution on the Anatolian coast of the Blacksea was conducted by Aytan et al. [20] (2016) on the southeastern coast of the region. Average microplastic abundance was $1.2\pm1.1 \times 10^3$ items/m^3 in November and $0.6\pm0.55 \times 10^3$ items/m^3 in February. The primary shapes were fibers (49.4%) followed by plastic films (30.6%) and fragments (20%), and no microbeads were found. In the study of Terzi et al. [21] (2022) MP concentration along the whole Anotalian part ot the blacksea was investigated. They reported a mean abundance of 18.68±3.01 items/m^3 and furthermore they concluded that the highest MP abundances were gathered from some of the sampling points at the western and Marmara region. The study of Sönmez and Sivri has reported a 0 to over 1 items/m^3 MP in İstanbul with a dominant size of 249–100 μm and color of transparent [22]. As can be seen microplastic concentrations fluctuate over a wide range of studies all over the world. The heterogeneity in the reported MP concentrations could be related to several factors as mentioned before. First of all, every sampling area/region is unique in terms of meteorological, hydrological, and hydrodynamic parameters in addition to the presence and diversity of natural and anthropogenic sources. Secondly, the lack of a standardized protocol for sampling and analysis is still a handicap in the field of microplastic research. While Egessa et al. reported 0.73 items/m^3 in Lake Victoria, a range of 21000–49000 items/m^3 were addressed in Manas River Basin, China [17, 23]. Filtering or digestion of organic materials could also affect the identified MPs. When considering the sampling location; the distance from the coast and the influence of hydrodynamic properties such as currents, up and downwelling, gyres and fronts could also be responsible for the heterogeneity in MPs concentrations [24]. Desforges et al. [25] reported 4–27 times greater microplastic concentrations at the nearshore sampling sites than the offshore in the ME Pacific Ocean. They also reported increased plastic sizes from coast to the offshore. A study by Garces-Ordonez et al. [26] 2022 investigates the effect of sampling depth, distance from river mouth and distance from population centers to microplastic concentrations. Although no relationship was reported for water depth, the microplastic concentration significantly decreases by distance to the river mouth and population center.

In our study, a small mesh size of 45 μm has resulted in relatively higher concentrations when compared to most of the studies. Schönlaua and friends investigated the microplastic concentration in open surface waters by using a manta trawl and in-situ filtering pump. They reported a higher concentration of microplastic particles in pump samples compared to trawl sampling. Moreover using a smaller mesh size of 0.05 mm has also resulted in higher concentrations [27].

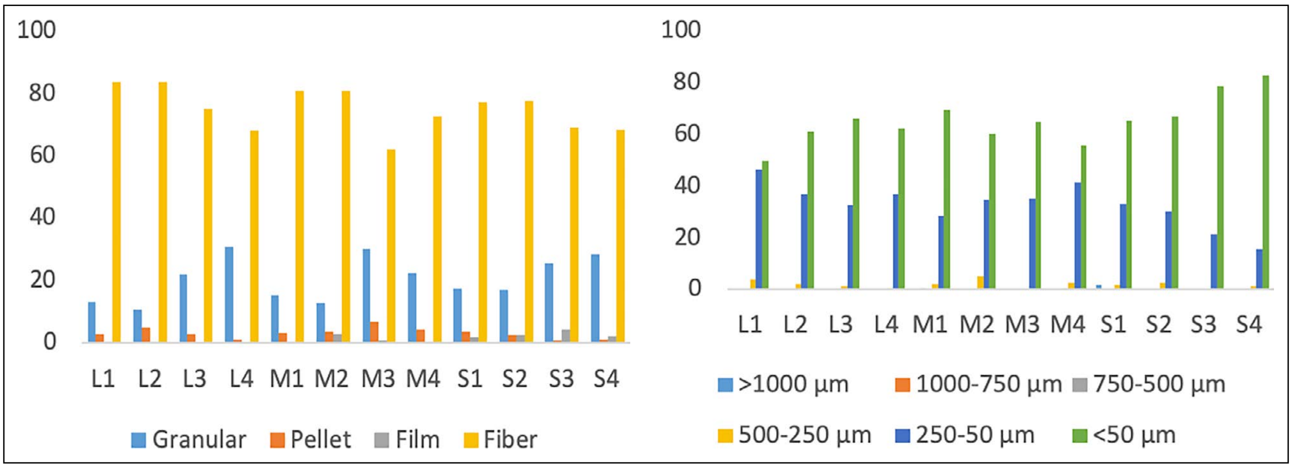

Figure 5. Shape and size distribution of microplastics.

Morphological Properties of Microplastics

Eleven different microplastic colors were observed under the microscope as; black, white, red, blue, green, grey, yellow, orange, purple, transparent and brown as shown in Figure 4. The dominant color was blue, followed by black, green, red, white and grey. The remaining colors were determined in a small number of samples so they were classified as others.

The shape and size distribution of the microplastics are presented in Figure 5. The most common forms of microplastics were fibers which are mostly blue in color and are over 60% in all sampling points. These fibers are thought to arrive from intense fishing activities by abrasion of fishing nets and lines. These results are consistent with field observations where blue fishing nets were recorded. The abundance of granular microplastics is between 12–31% followed by pellets 0.8–7% and films 0.46–4.42%.

The prevalent size of microplastics is <50 µm, followed by 50–250 µm and 250–500 µm. Microplastic with a size of >1000 µm, 750–1000 and 500–750 were detected in only one sample during the all sampling campaigns. The smaller size of determined microplastics can be suspected to be ingested by smaller fishes.

Bioavailability

The interacting of organisms with microplastics increases as a result of increasing environmental concentrations. It is well known that microplastics are available for ingestion by marine biota due to their small sizes. Microplastics can collect in the gut, the digestive gland, the gills, or the liver of some organisms after consumption or they can be moved along the digestive system until elimination [28]. Microplastics can have negative impacts on aquatic species when they are ingested or adsorbed to them. It can affect the number of species or their biomass at the population level and can have an impact on survival, reproduction, growth, feeding, emergence, embryonic development and photosynthetic effectiveness at the individual level. The severity of the effects varies depending on the properties of the microplastics, their concentrations and the exposure time [29]. Microplastic ingestion mainly depends on bioaccessibility. The NP value which shows the bioavailability of microplastic was calculated as 0.72 in our study which indicates a low bioavailability (≤2). High levels of bioavailability were reported for Beibu Golf and Sanggou Golf with NPI values being 8.48 and 4.42 respectively.

Energy and nutrient flow via both individual species and ecological networks may be affected by plastics. For that reason, it is crucial to understand the entry and transfer pathways of plastics through food webs. Jams and his friends have researched the relationship between the body length of an animal and ingested plastic size from published literature. They reported that animal body length alone explains 42% of the variation in the length of plastic an animal may ingest, resulting in a size ratio of about 20:1 between animal body length and the largest plastic the animal may ingest [30]. Their study has reported the relationship between ingested plastics and a minimum plastic size of 0.2 mm and a maximum of approx. 800 mm. Plastic sizes between 0.2 mm and 1 mm can be ingested by animals with a body length of 6–200 mm. Black Sea meets 76% of Türkiye's fish production. Of the fish caught from the Black Sea, 61.5% is anchovy, 26% is sprat, 4.3% is Black Sea horse mackerel and 2% is bonito. Their average body length is approx. 120, 130, 250 and 350 mm so these are susceptible to MP exposure. The study of Aytan et al. [20] proves the presence of MP in these species where they investigated the occurrence of MP in seven commercial fish species of the Black sea. They reported a 0.81±1.42 mean number of plastic particles per fish. Plastics were detected in 190 of the 650 fish analyzed of which 93.2% were micro (<5 mm), 6.5% meso (5–25 mm) and 0.3% were macroplastics (>25 mm). Fibers were the most frequent type of plastic (68.5%), followed by films (19%), fragments (11.9%), foams (0.3%), and microbeads

(0.3%). Black (39.3%) and blue (19.5%) were the most popular plastic colors, followed by transparent (18.1%). The length of plastics ranged from 0.05 to 26.5 mm with an average of 1.84±2.80 mm. The plastic occurrence was highest in bonita (plastic in 70% of the analyzed individuals [31].

Conclusion and prospects

This study was conducted to investigate microplastic pollution in a small fishing port, which can be considered as a closed marine environment. Our study has reported preliminary evidence about the effect of increasing fishing activities on microplastic abundance. The Black Sea has twice as much floating macro litter, mostly plastic, than the Mediterranean, according to a study on the environment funded by the European Union and the United Nations Development Programme (UNDP) [32]. The average abundance of MP was 3417+1401 items/m^3. A slight increase observed after the fishing season and between the two different fishing days shows the influence of fishing activities.

Further study is required that includes identification of the polymer types, the prevalence in the biota and indeed sediment samples. It is also necessary to evaluate the daily habits of the fisherman and test their awareness regarding the factors.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] G. Macfadyen, T. Huntington, and R. Cappell, "Abandoned, lost or otherwise discarded fishing gear," United Nations Environment Programme Food and Agriculture Organization of The United Nations, 2009.

[2] M. Viitala, Z. Steinmetz, M. Sillanpää, M. Mänttäri, and M. Sillanpää, "Historical and current occurrence of microplastics in water and sediment of a Finnish lake affected by WWTP effluents," Environmental Pollution, Vol. 314, Article 120298, 2022. [CrossRef]

[3] D. Zhang, Y. Cui, H. Zhou, C. Jin, X. Yu, Y. Xu, Y. Li, and C. Zhang, "Microplastic pollution in water, sediment, and fish from artificial reefs around the Ma'an Archipelago, Shengsi, China," Science of The Total Environment, Vol. 703, Article 134768, 2020. [CrossRef]

[4] D. Liu, Z. F. Guo, Y. Y. Xu, F. K. S. Chan, Y. Y. Xu, M. Johnson, and Y. G. Zhu, "Widespread occurrence of microplastics in marine bays with diverse drivers and environmental risk," Environment International, Vol. 168, Article 107483, 2022. [CrossRef]

[5] X. Xiong, S. Xie, K. Feng, and Q. Wang, "Occurrence of microplastics in a pond-river-lake connection water system: How does the aquaculture process affect microplastics in natural water bodies," Journal of Cleaner Production, Vol. 352, Article 131632, 2022. [CrossRef]

[6] L. Zhang, S. Zhang, J. Guo, K. Yu, Y. Wang, and R. Li, "Dynamic distribution of microplastics in mangrove sediments in Beibu Gulf, South China: Implications of tidal current velocity and tidal range," Journal of Hazardous Materials, Vol. 399, Article 122849, 2020. [CrossRef]

[7] K. Enders, R. Lenz, C. A. Stedmon, and T. G. Nielsen, "Abundance, size and polymer composition of marine microplastics ≥10 μm in the Atlantic Ocean and their modelled vertical distribution," Marine Pollution Bulletin, Vol. 100(1), pp. 70–81, 2015. [CrossRef]

[8] J. H. Kang, O. Y. Kwon, K. W. Lee, Y. K. Song, and W. J. Shim, "Marine neustonic microplastics around the southeastern coast of Korea," Marine Pollution Bulletin, Vol. 96(1-2), pp. 304–312, 2015. [CrossRef]

[9] A. Reboa, L. Cutroneo, S. Consani, I. Geneselli, M. Petrillo, G. Besio, and M. Capello, "Mugilidae fish as bioindicator for monitoring plastic pollution: Comparison between a commercial port and a fishpond (north-western Mediterranean Sea)," Marine Pollution Bulletin, Vol. 177, Article 113531, 2022. [CrossRef]

[10] M. Mali, D. Malcangio, M.M. Dell' Anna, L. Damiani, and P. Mastrorilli, "Influence of hydrodynamic features in the transport and fate of hazard contaminants within touristic ports. Case study: Torre a Mare (Italy)," Heliyon, Vol. 4(1), Article e00494, 2018. [CrossRef]

[11] F. Preston-Whyte, B. Silburn, B. Meakins, A. Bakir, K. Pillay, M. Worship, S. Paruk, Y. Mdazuka, G. Mooi, R. Harmer, D. Doran, F. Tooley, T. Maes, "Meso- and microplastics monitoring in harbour environments: A case study for the Port of Durban, South Africa," Marine Pollution Bulletin, Vol. 163, Article 111948, 2021. [CrossRef]

[12] H. A. Nel, J. W. Hean, X. S. Noundou, and P. W. Froneman, "Do microplastic loads reflect the population demographics along the southern African coastline?," Marine Pollution Bulletin, Vol. 115, pp. 115–119, 2017. [CrossRef]
[13] F. Dubaish, and G. Liebezeit, "Suspended Microplastics and Black Carbon Particles in the Jade System," Southern North Sea, Water, Air, & Soil Pollution," Vol. 224, Article 1352, 2013. [CrossRef]
[14] L. Lahens, E. Strady, T. C. Kieu-Le, R. Dris, K. Boukerma, E. Rinnert, J. Gasperi, and B. Tassin, "Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity," Environmental Pollution, Vol. 236, pp. 661–671, 2018. [CrossRef]
[15] J. Zhang, H. Chen, H. He, X. Cheng, T. Ma, J. Hu, S. Yang, S. Li, and L. Zhang, "Adsorption behavior and mechanism of 9-Nitroanthracene on typical microplastics in aqueous solutions," Chemosphere, Vol. 245, Article 125628, 2020. [CrossRef]
[16] P. Wu, Y. Tang, M. Dang, S. Wang, H. Jin, Y. Liu, H. Jing, C. Zheng, S. Yi, and Z. Cai, "Spatial-temporal distribution of microplastics in surface water and sediments of Maozhou River within Guangdong-Hong Kong-Macao Greater Bay Area," Science of The Total Environment, Vol. 717, Article 135187, 2020. [CrossRef]
[17] G. Wang, J. Lu, Y. Tong, Z. Liu, H. Zhou, and N. Xiayihazi, "Occurrence and pollution characteristics of microplastics in surface water of the Manas River Basin, China," Science of The Total Environment, Vol. 710, Article 136099, 2020. [CrossRef]
[18] G. Everaert, L. Van Cauwenberghe, M. De Rijcke, A. A. Koelmans, J. Mees, M. Vandegehuchte, and C. R. Janssen, "Risk assessment of microplastics in the ocean: Modelling approach and first conclusions, Environmental Pollution," Vol. 242, pp. 1930–1938, 2018. [CrossRef]
[19] E. D. Osorio, M. A. N. Tanchuling, and M. B. L. D. Diola, "Microplastics Occurrence in Surface Waters and Sediments in Five River Mouths of Manila Bay," Frontiers in Environmental Science, 9, pp. 1–14, 2021. [CrossRef]
[20] U. Aytan, A. Valente, Y. Senturk, R. Usta, F.B. Esensoy Sahin, R.E. Mazlum, and E. Agirbas, "First evaluation of neustonic microplastics in Black Sea waters," Marine Environmental Research, Vol. 119, pp. 22–30, 2016. [CrossRef]
[21] Y. Terzi, K. Gedik, A. R. Eryasar, R. C. Ozturk, A. Sahin, and F. Yilmaz, "Microplastic contamination and characteristics spatially vary in the southern Black Sea beach sediment and sea surface water," Marine Pollution Bulletin, Vol. 174, Article 113228, 2022. [CrossRef]
[22] V. Z. Sonmez, C. Akarsu, and N. Sivri, "Impact of coastal wastewater treatment plants on microplastic pollution in surface seawater and ecological risk assessment," Environmental Pollution, Vol. 318, Article 120922, 2023. [CrossRef]
[23] R. Egessa, A. Nankabirwa, H. Ocaya, and W. G. Pabire, "Microplastic pollution in surface water of Lake Victoria," Science of The Total Environment, Vol. 741, Article 140201, 2020. [CrossRef]
[24] M. Kazour, S. Jemaa, C. Issa, G. Khalaf, and R. Amara, "Microplastics pollution along the Lebanese coast (Eastern Mediterranean Basin): Occurrence in surface water, sediments and biota samples," Science of The Total Environment, Vol. 696, Article 133933, 2019. [CrossRef]
[25] J. P. W. Desforges, M. Galbraith, N. Dangerfield, and P. S. Ross, "Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean," Marine Pollution Bulletin, Vol. 79(1-2), pp. 94–99, 2014. [CrossRef]
[26] O. Garcés-Ordóñez, J.F. Saldarriaga-Vélez, L. F. Espinosa-Díaz, A. D. Patiño, J. Cusba, M. Canals, K. Mejía-Esquivia, L. Fragozo-Velásquez, S. Sáenz-Arias, T. Córdoba-Meza, and M. Thiel, "Microplastic pollution in water, sediments and commercial fish species from Ciénaga Grande de Santa Marta lagoon complex," Colombian Caribbean, Science of The Total Environment, Vol. 829, Article 154643, 2022. [CrossRef]
[27] C. Schönlau, T. M. Karlsson, A. Rotander, H. Nilsson, M. Engwall, B. van Bavel, and A. Kärrman, "Microplastics in sea-surface waters surrounding Sweden sampled by manta trawl and in-situ pump," Marine Pollution Bulletin, Vol. 153, Article 111019, 2020. [CrossRef]
[28] K. L. Kaposi, B. Mos, B. P. Kelaher, and S. A. Dworjanyn, "Ingestion of microplastic has limited impact on a Marine Larva," Environmental Science & Technology, Vol. 48(3), pp. 1638–1645, 2014. [CrossRef]
[29] A. A. Koelmans, P. E. Redondo-Hasselerharm, N. H. M. Nor, V. N. de Ruijter, S. M. Mintenig, and M. Kooi, "Risk assessment of microplastic particles," Nature Reviews Materials, Vol. 7, pp. 138–152, 2022. [CrossRef]
[30] I. B. Jâms, F. M. Windsor, T. Poudevigne-Durance, S. J. Ormerod, and I. Durance, "Estimating the size distribution of plastics ingested by animals," Nature Communications, Vol. 11, Article 1594, 2020. [CrossRef]
[31] U. Aytan, F. B. Esensoy, Y. Senturk, E. Arifoglu, K. Karaoglu, Y. Ceylan, and A. Valente, "Plastic occurrence in commercial fish species of the Black Sea," Turkish Journal of Fisheries and Aquatic Sciences, Vol. 22(12), 2021. [CrossRef]
[32] United Nations Development Programme, "Black Sea twice as polluted by marine litter as Mediterranean Sea – EU project's survey," 2019. https://www.undp.org/ukraine/press-releases/black-sea-twice-polluted-marine-litter-mediterranean-sea-%E2%80%93-eu-project%E2%80%99s-survey Accessed on Feb 6, 2023.