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JOURNAL OF AGRICULTURAL PRODUCTION
ISSN: 2757-6620
PRENSIP
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RESEARCH ARTICLE

Microplastic Levels in Water and Sediment of Karaçomak Dam Lake (Kastamonu, Türkiye)

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ARTICLE INFO

Article History
Received: 30.11.2024
Accepted: 25.12.2024
First Published: 31.12.2024

Keywords
Karaçomak Dam Lake
Plastic
Pollution
Sediment
Water

ABSTRACT

This paper investigates the microplastic (MP) abundance and morphology in Karaçomak Dam Lake, a freshwater source used for irrigation and drinking water, located in Kastamonu, Türkiye. Water and sediment samples were collected during January, April, July and October 2023 from two stations determined on the lake. MPs obtained from the samples were counted and classified according to their sizes, shapes (fiber, fragment, film, microbead) and colors. Results showed that the mean MP abundance in the water samples was 3206 particle/m^3, while it was 180 particle/kg dry weight in the sediment samples. The most frequent MP type was fiber in surface water samples and fragment in sediment samples. Predominant colors were blue and black for surface water and sediment, respectively. Majority of the MPs found were small-sized MPs (<1 mm). MP abundance was the highest in winter season, followed by autumn, spring and summer, respectively. The seasonal differences were probably driven by rainfall and the anthropogenic activities around the lake. We concluded that the values obtained in this study are moderate in comparison with the literature data. Although it was inferred that sources of MP are domestic waste, agriculture and recreational activities, it is recommended to conduct more comprehensive studies to better understand the sources of MP pollution in Karaçomak Dam Lake.

Please cite this paper as follows:

Taştan, Y., & Sönmez, A. Y. (2024). Microplastic levels in water and sediment of Karaçomak Dam Lake (Kastamonu, Türkiye). *Journal of Agricultural Production*, *5*(4), 283-294. https://doi.org/10.56430/japro.1593885

1. Introduction

Plastics are widely used worldwide due to their lightness, durability, corrosion resistance and low electrical and thermal conductivity (Wagner et al., 2014). This use has led to intensive production and has become one of the biggest threats to the environment in recent years. These plastics, which are discarded into nature from various sources or have limited recycling possibility, undergo a series of degradation processes and turn into microplastics (MPs), defined as those with a diameter of less than 5 mm (Andrady, 2011). MPs can spread widely to all surrounding environments (i.e., soil, water and atmosphere) through various ways (Peeken et al., 2018; Sun et al., 2021).

MPs can be dispersed into the aquatic ecosystem through natural means such as wind, water currents, turbulence and oceanographic effects (e.g., physical properties of water and wave movements) (Ballent et al., 2012; Turra et al., 2014). In addition to being transported naturally, they can also enter the aquatic ecosystem as a result of human activities. MPs directly or indirectly mix into the aquatic ecosystems as a result of

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unfiltered discharge of domestic or industrial wastewater (Ryan et al., 2009). The circulation in aquatic ecosystems can cause critical pollution problems. A significant portion of these ecosystems consists of freshwater ecosystems used for drinking water, irrigation, fishing and energy production (Şahin & Zeybek, 2019). While most researchers focus on the presence of microplastic pollution in the seas, the reality of microplastics in freshwater systems has received less attention (Wong et al., 2020). However, studies show that microplastics also constitute a significant pollution burden in freshwater ecosystems (Egessa et al., 2020).

The examination of freshwater resources in Türkiye in terms of MP pollution has gained momentum in recent years (Atamanalp et al., 2022a, 2022b, 2023; Böyükalan & Yerli, 2023; Çullu et al., 2021, Erdoğan, 2020; Gedik & Atasaral, 2022; Gündoğdu et al, 2023; Kankılıç et al., 2023; Mutlu et al., 2024; Tavşanoğlu et al., 2020; Turhan, 2022). However, more data are required and more freshwater sources need to be monitored to better understand the nature of MP pollution and determine the current status. Furthermore, seasonal investigations are limited to only a few studies. Seasonal determination will help evaluate the trends in MP pollution.

Therefore, this study aims to fill the data gaps regarding MP pollution in Türkiye's freshwater ecosystems and to contribute to the creation of an infrastructure for future monitoring studies by qualitatively and quantitatively determining the microplastic load of the Karaçomak Dam Lake, which is used as a source of drinking and irrigation water for Kastamonu and is also an important recreational fishing area, and examining its seasonal changes.

2. Materials and Methods

2.1. Study Area and Field Sampling

Karaçomak is a dam lake, which was built for irrigation, flood control and drinking water supply purposes, located on the Karaçomak Creek within the borders of Kastamonu province in the Western Black Sea region, at the coordinates of 41°19′08″N, 33°44′41″E (Figure 1). Its height from the river bed is 49.00 m, the lake's volume at normal water level is 23.10 hm^3, and the lake's area at normal water level is 1.43 km^2. It provides irrigation service to an area of 2,596 hectares and 3 hm^3 of drinking water per year (DSİ, 2016).

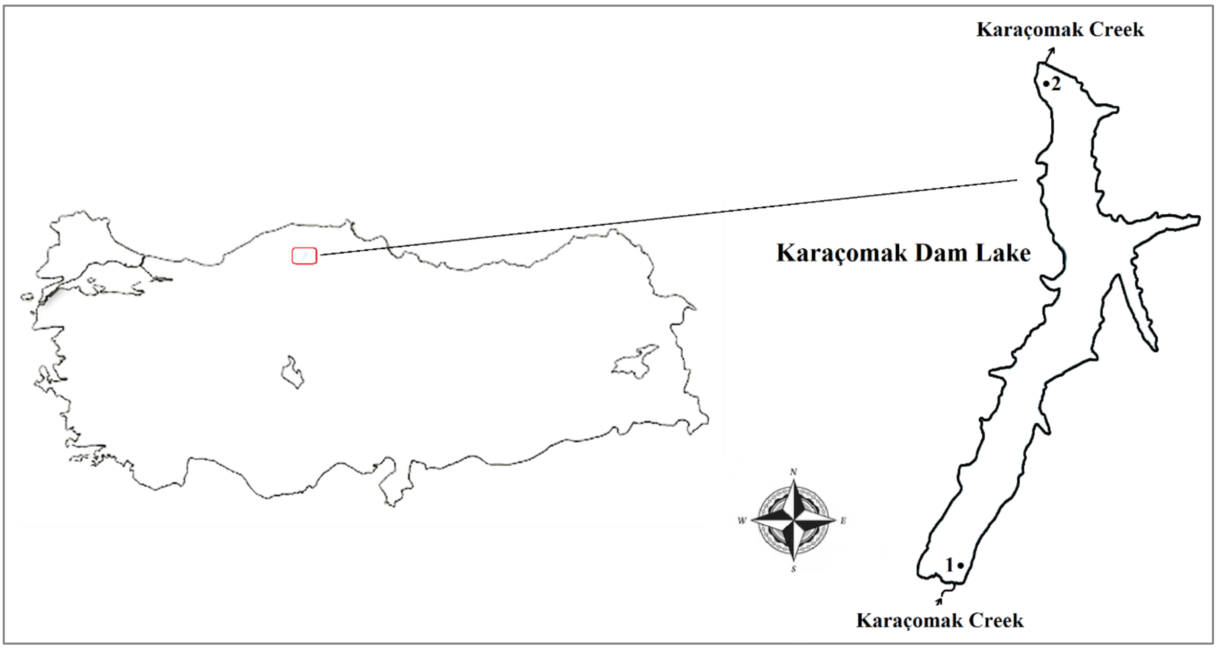

Figure 1. Location of the investigated lake and the sampling stations.

Surface water and sediment samplings were carried out on January, April, July and October 2023. Two stations were determined on the dam lake and samplings were carried out from these stations. The 1st station was the Karaçomak Creek's entrance to the dam and the 2nd station was the dam's outlet (Figure 1).

Surface water and sediment sampling was carried out according to Baldwin et al. (2016), Bergmann et al. (2017) and Gray et al. (2018) with some modifications. For surface water sampling, forty liters of surface water sample (0-30 cm depth) was collected from each station with a large pre-cleaned stainless-steel bucket. The collected water was passed through a stainless-steel sieve (45 µm mesh size). All particles remaining on the sieve were carefully taken into a 1-L glass bottle containing deionized water. At each sampling interval, the sampling bucket was carefully cleaned with pre-filtered deionized water to prevent cross-contamination. At each sampling, a new sieve was used.

Sediment samples (at least 1 kg) were collected from each station using a stainless-steel Van Veen Grab sediment sampler. The samples were put into pre-cleaned glass bottles and transported to the laboratory along with the water samples immediately.

2.2. Laboratory Analysis

Wet peroxide oxidation was used to detect the presence of microplastics in surface water samples (Masura et al., 2015). Water samples were transferred to a conical flask and 30 ml of H_2O_2 was added to the samples. Then, organic substances were removed with hydrogen peroxide in an incubator at 50°C for 72 hours (Nuelle et al., 2014). Afterward, this mixture was passed through a 0.45 µm mesh-sized filter (47 mm ⌀) and left to dry for 24 h at room temperature (Tavşanoğlu et al., 2020).

Sediment samples were transferred to 1-L glass beakers covered with aluminum foil and placed in an oven at 50°C for 48 h to dry (Yuan et al., 2019). After drying, 500 g of the sediment samples were weighed on a precision scale and placed in 1-L beakers, and 1 L of 1.2 ppm NaCl solution was added to the samples and then mixed for 5 min (Di & Wang, 2018). The samples were left to settle for 24 h. Afterwards, the upper part was transferred to a separate beaker, taking care not to suspend the sediment samples that settled to the bottom. This process was repeated three times. Then, 100 mL of 30% H_2O_2 was added to this beaker. The beakers were covered with aluminum foil and kept in an oven at 50 °C for 72 h. After this period, the liquid in the beaker was removed from the oven and filtered through a 0.45 µm mesh-sized filter (47 mm ⌀) and left to dry for 24 h at room temperature.

2.3. Identification of Microplastics

MPs were counted and classified under a stereomicroscope (ZEISS Stemi 508) at up to 250x magnification, and the number of MPs determined was calculated as particles per m^3 water (p/m^3) in water samples and as particles per kg dry weight (p/kg) in sediment samples. Unfortunately, we were unable to further characterize MPs with an instrument, such as FT-IR or µ-Raman spectroscopy. For this reason, while identifying MPs, a set of rules were followed. The items, which lack cellular structures, have uniform width and display artificial color (Barrows et al., 2018; Hidalgo-Ruz et al., 2012; Weideman et al., 2019), were recorded as MPs. Although it has been recommended to use spectroscopy to confirm MP type when available, it has been proposed that visual inspection with a microscope is a sufficient tool for quantification of MPs bigger than 50 µm (Kotar et al., 2022).

2.4. Quality Assurance and Quality Control

Utmost attention was paid to prevent contamination of samples and filters. Nitril gloves and cotton lab coats were worn throughout all procedures. All reagents used were pre-filtered through 0.45 µm mesh-sized filters. Three blank filters were arbitrarily left in different places in the lab throughout the laboratory work to detect airborne contamination. Also, three blank samples were prepared following the same procedure for water samples with the pre-filtered distilled water to identify the efficacy of the filtration and cleanliness of the equipment. None of the materials used were plastic. All equipment were rinsed with pre-filtered distilled water three times before use and in between samples. Equipment and samples were covered with aluminum foil when not in use.

2.5. Statistical Analysis

MP numbers between stations and seasons were compared with Kruskal-Wallis test. Mann-Whitney U test was employed to determine different groups. All analyses were carried out using SPSS (IBM) version 23.0. Five percent confidence interval was preferred.

3. Results

3.1. Microplastic Abundance

MP values detected in water and sediment samples taken from two stations in the Karaçomak Dam for different seasons are given in Table 1. No MP was detected in blank samples throughout the study.

Table 1. MP abundance in water and sediment samples.

Sample	Season	Station	Mean	Range
Water (p/m^3)	Winter	1st	3925 ± 1082	3025-5125
		2nd	3733 ± 401	3350-4150
	Spring	1st	3458 ± 472	3050-3975
		2nd	2592 ± 101	2500-2700
	Summer	1st	2850 ± 250	2600-3100
		2nd	2825 ± 139	2700-2975
	Autumn	1st	3367 ± 76	3300-3450
		2nd	2900 ± 246	2700-3175
Sediment (p/kg)	Winter	1st	236 ± 22	216-260
		2nd	257 ± 28	230-286
	Spring	1st	152 ± 17	136-170
		2nd	159 ± 16	144-176
	Summer	1st	133 ± 11	122-144
		2nd	125 ± 12	114-138
	Autumn	1st	210 ± 11	200-222
		2nd	169 ± 23	146-192

3.2. Morphological Features of Microplastics

The classification graphs of MPs detected in water and sediment samples collected from different seasons in terms of their size, color and shape are presented in Figures 2, 3 and 4, respectively.

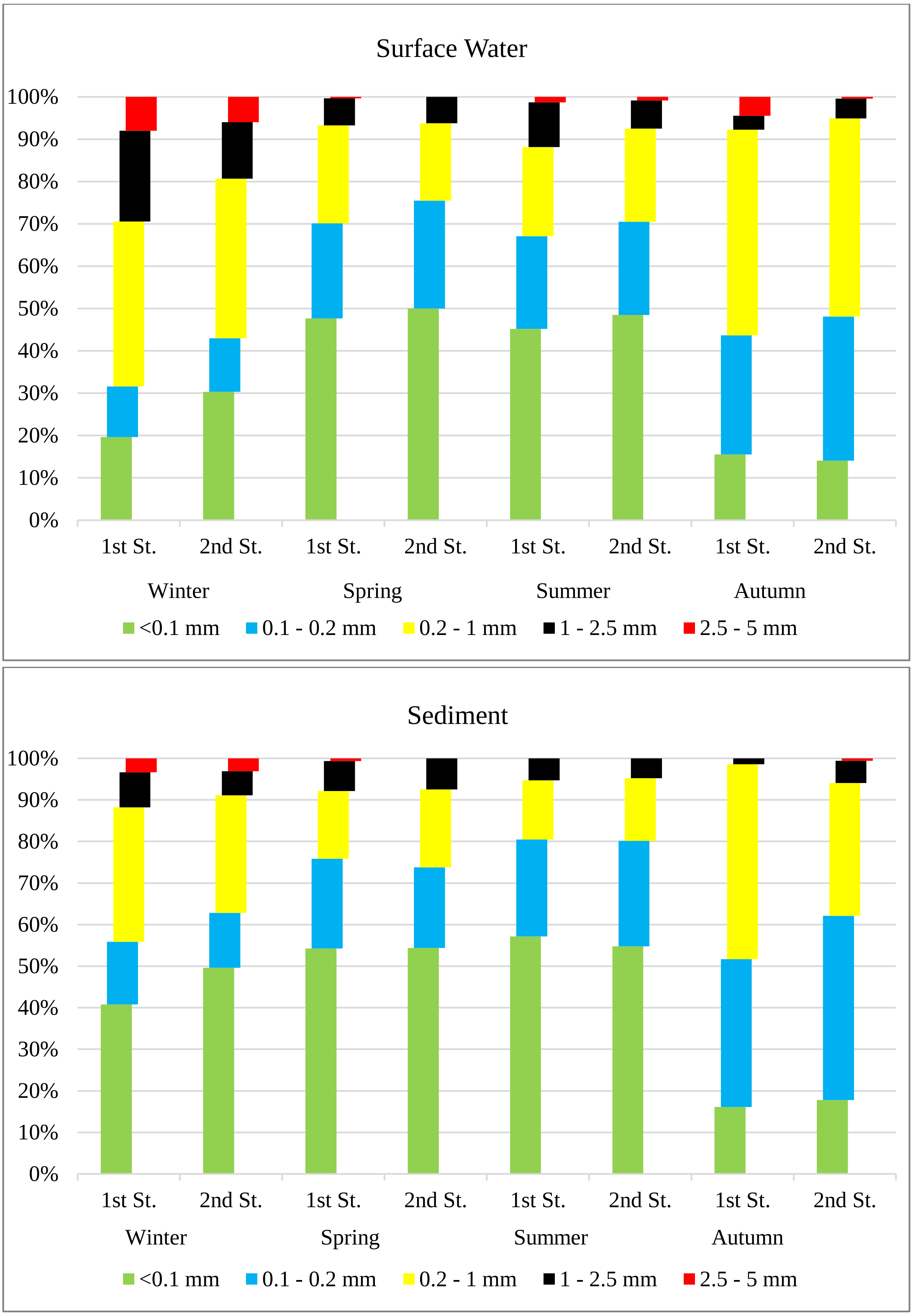

Figure 2. Percentages of MPs detected in surface water and sediment samples in different seasons according to their size ranges.

When the distributions according to sizes were examined, the predominantly detected MP groups in surface water in autumn and winter seasons were microplastics between 0.2-1 mm, while microplastics with sizes <0.1 mm were more frequent in other seasons. There was a statistical difference between all seasons in terms of microplastic sizes ($p<0.05$). In sediment samples, microplastic sizes measured in autumn and winter seasons were statistically higher than in other seasons ($p<0.05$).

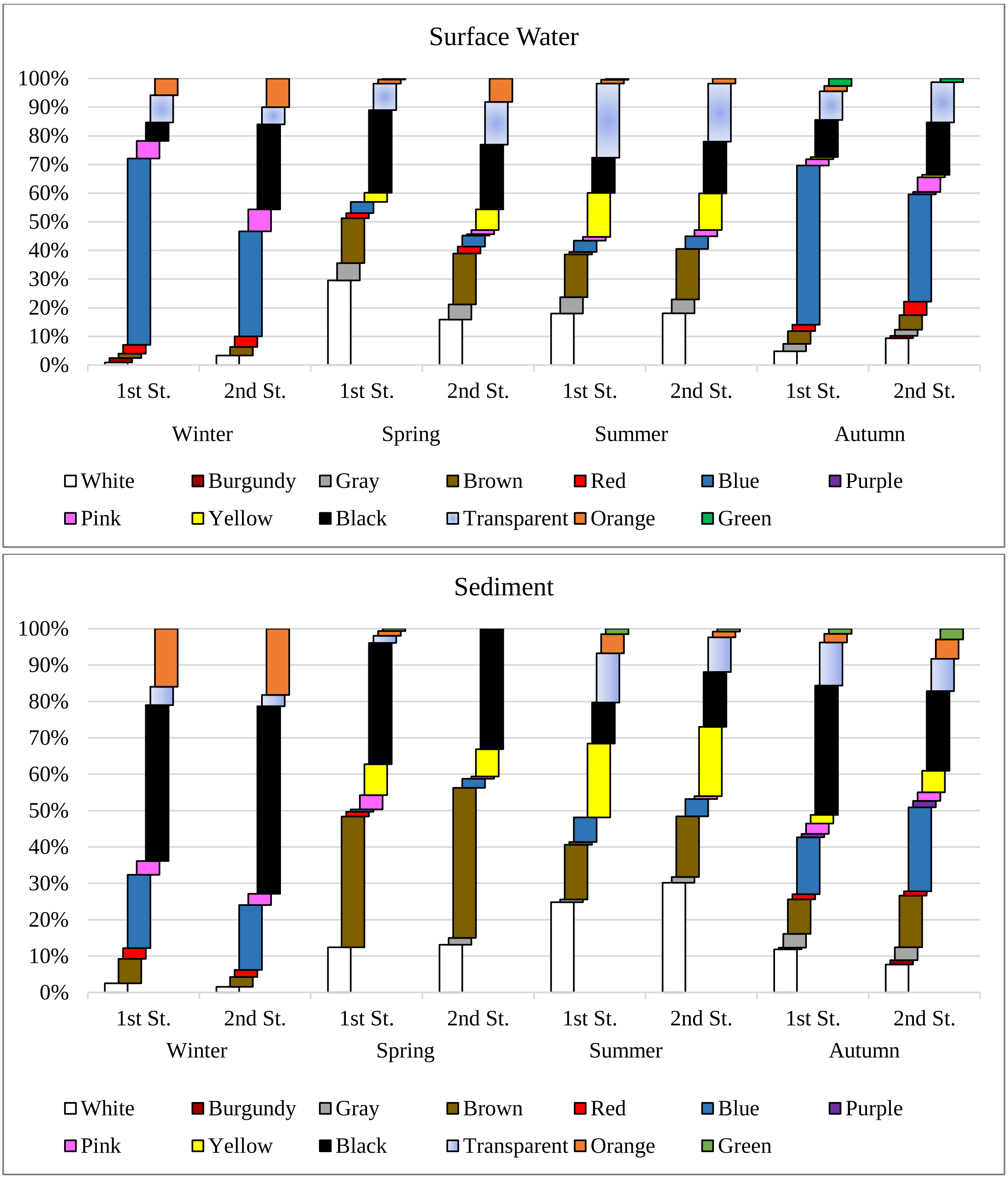

Figure 3. Percentages of MPs detected in water and sediment samples according to their colors.

The classification of microplastics in surface water and sediment samples based on their colors is given in Figure 3. According to the findings, blue colored microplastics were dominant in the water samples in the autumn and winter seasons, while white, brown, black and transparent colored microplastics were distributed proportionally close in the spring and summer seasons. In the sediment, black was dominant in the winter, while white, brown, black and partly yellow colors were distributed in the stations in other seasons.

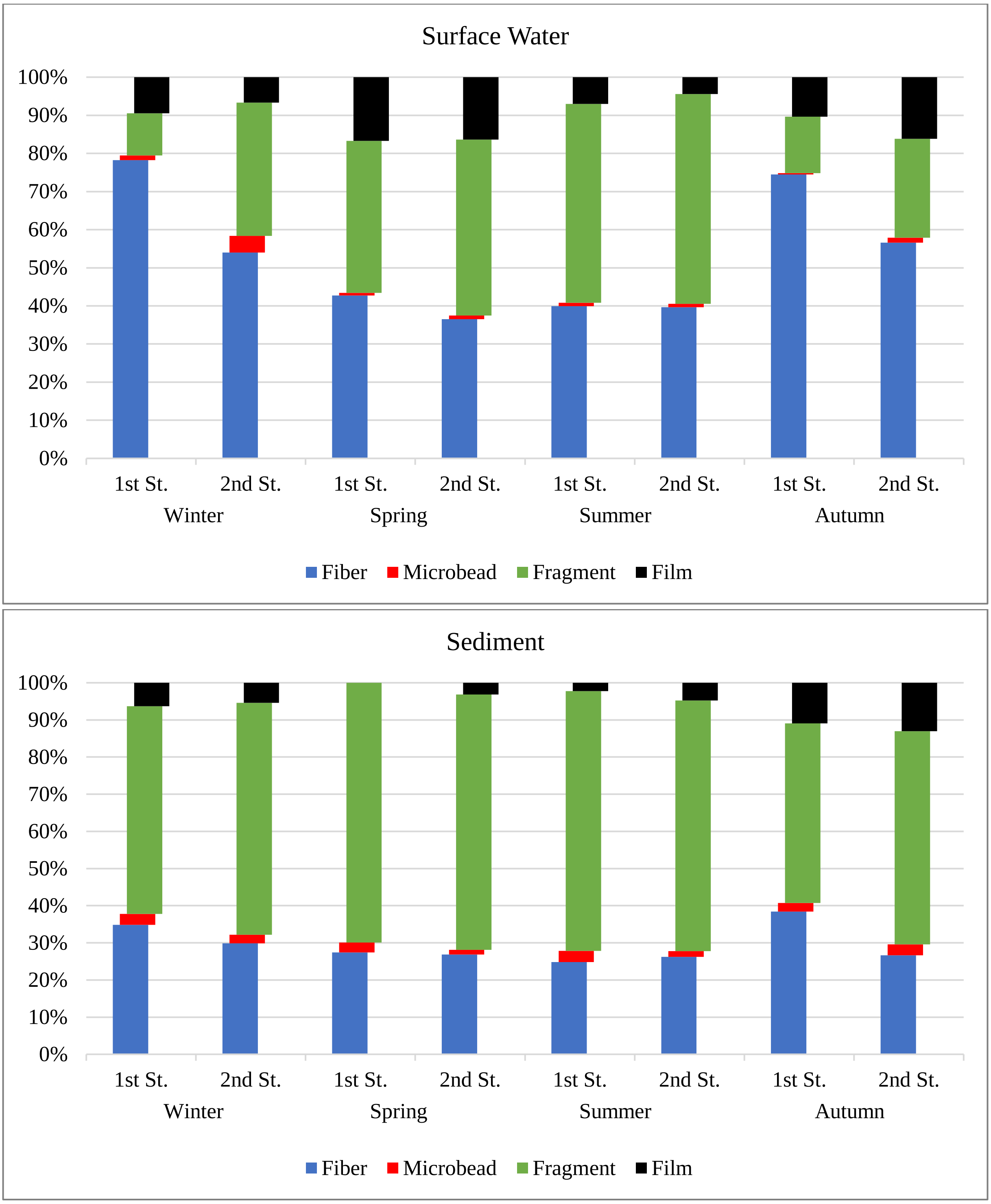

Figure 4. Percentages of MPs detected in water and sediment samples according to their types.

When the distribution of microplastics detected in water and sediment samples was examined according to their shapes, it was observed that fibers were usually predominant in water samples, whereas the most common MP type in sediment samples were fragments.

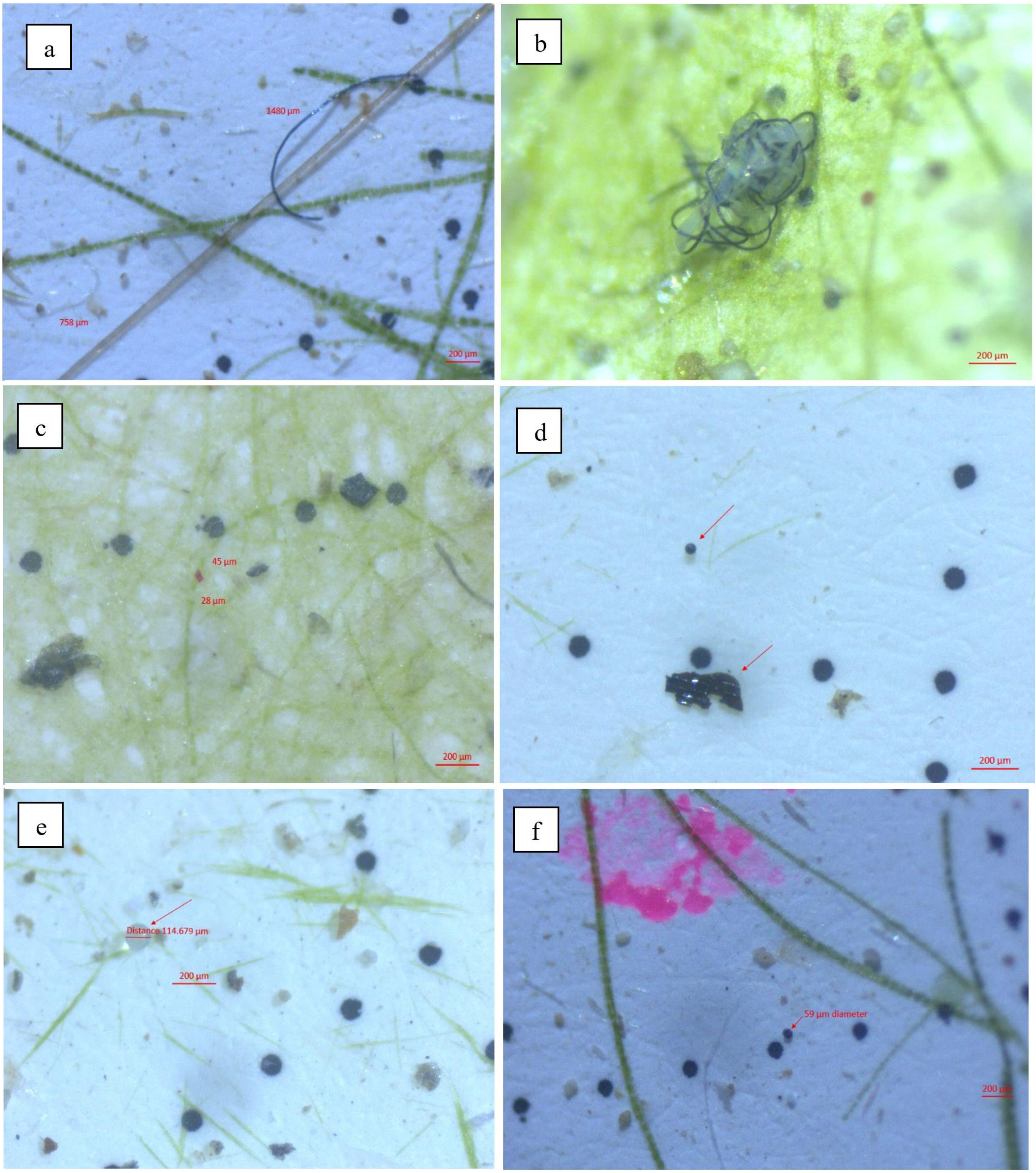

Figure 5. Photographs of MP types detected in surface water and sediment samples. (a): Two fibers; (b): An entangled fiber; (c): A fragment; (d): A microbead and a film; (e): A microbead; (f): A fragment.

4. Discussion

MPs are defined as plastic particles smaller than 5 mm. Some of these MPs are produced as small on purpose, while others are formed as a result of the breakdown of large plastics under the influence of sun, temperature, wind and waves, and can be transported to water resources either by direct disposal or by factors such as rain, wind, stormwater, etc. (NOAA, 2024). MPs have been detected in many water sources and MP pollution has become a major problem on a global scale today because MPs pose a health risk to both aquatic life and other wild animals and humans who use the respective water resource (Zolotova et al., 2022). Therefore, it is utmost importance to monitor water sources and determine MP pollution levels. Based on this, this study aimed to determine the amounts and types of MPs in Karaçomak Dam and a total of 3523 MPs were counted in the water and sediment samples obtained. It was observed that the average number of MPs in water was 3829 p/m^3 in winter, 3133 p/m^3 in autumn, 3025 p/m^3 in spring and 2837.5 p/m^3 in summer. Similarly, an average of 247 p/kg of MPs were detected in the sediment in winter, 189 p/kg in autumn, 156 p/kg in spring and 129 p/kg in summer. Other studies on lakes and dams have yielded varying results. For example, it was determined that the surface water of the Three Gorges Dam in China contained an average of 4703 p/m^3 and its sediment contained an average of 82 p/kg MPs (Di & Wang, 2018). Another similar research found that the surface water of Lake Taihu contained between 3400 and 25800 p/m^3 MPs (Su et al., 2016). It has been reported that the surface water of Sürgü Dam contains an average of 157 p/m^3 MPs (Turhan, 2022). Significantly less than these results, MPs detected in the waters of Chiusi and Bolsena lakes were in the range of 2.68-3.36 p/m^3 and 0.82-4.42 p/m^3, respectively (Fischer et al., 2016). As can be inferred from these data, the MP numbers in different water sources can significantly vary. Although the sampling method could influence this difference, it is primarily attributed to the level of anthropogenic pressure that the relevant water source is under (Ma et al., 2024; Quesadas-Rojas et al., 2021). Furthermore, one should note that we were unable to use spectrometry to characterize the MPs. For this reason, the numbers reported in this paper may be slightly overestimated.

It was determined that the majority of MPs in Karaçomak Dam water were fibers (54%). Likewise, fibers were reported as the dominant MP type in many different freshwater sources, including Sürgü Dam (Turhan, 2022), a treatment plant in Scotland (Blair et al., 2019), Süreyyabey Dam (Tavşanoğlu et al., 2020), Pearl River (Lin et al., 2018) and Manas River Basin (G. Wang et al., 2020). Plastic fibers mixed into water bodies can originate from many products. The main sources of these are fishing gear, textile products, industrial activities and domestic waste (Dris et al., 2015; Horton et al., 2017; Hu et al., 2020). On the other hand, in this study, it was determined that the most common MP type in sediment samples was particles (61%). Similar to these results, it has been reported that particle-type MPs are predominant in Lakes Erie and Ontario (Mason et al., 2020), a wastewater treatment plant in China (Lv et al., 2019) and the Nakdong River (Eo et al., 2019). Particle MPs found in water resources can originate from various plastic products such as widely used plastic bottles, toys, decorative products, building products, etc. (Lv et al., 2019). In this study, it was determined that the film and microbead-type MPs were the least abundant. While 11% of MPs in water were films and 1% were microbeads, it was observed that 6% of MPs in sediment were films and 2% were microbeads. Films are generally formed as a result of the breakdown of plastic bags and packaging wastes (Nor & Obbard, 2014). The main source of microbeads is personal care products (Cheung & Fok, 2016). These results show that Karaçomak Dam is under the pressure of MP pollution from many different products and that these are predominantly composed of secondary MPs.

It was determined that most of the MPs in the water samples obtained from Karaçomak Dam Lake were blue (29%) and were followed by black MPs (19%). In sediment samples, it was observed that the majority consisted of black (33%) and brown (16%) MPs. Color is an important parameter in MPs because MPs can be perceived as food by aquatic creatures or water birds due to their colors and can be ingested (Hidalgo-Ruz et al., 2012). Furthermore, due to the variety of pollutants affecting water resources, MPs with different colors can be detected in different water bodies. For example, there are studies reporting that MP samples are predominantly transparent (Tavşanoğlu et al., 2020), white (Li et al., 2018), black (Lam et al., 2020) or blue (Weideman et al., 2019). Color can also give an idea about for how long MP pollution has been persistent because MPs that have been in water for a long time tend to fade (yellowing) due to oxidation (Hidalgo-Ruz et al., 2012). However, in this study, white-yellow MPs were detected in very small amounts and the observed MPs typically had bright and vivid colors. This indicates that the MP pollution in Karaçomak Dam may be relatively recent.

When classified based on their sizes, MPs sized 0.2-1 mm and smaller than 0.1 mm were detected in the water samples at the same rate (33%). These were followed by MPs sized 0.1-0.2 mm with 22%. In the sediment samples, the predominant MP size was MPs smaller than 0.1 mm with 42%, while MPs sized 0.2-1 mm (27%) came second, and MPs size 0.1-0.2 mm (24%) came third. On the other hand, MPs sized 1-2.5 mm (10% in water, 6% in sediment) and 2.5-5 mm (3% in water, 1% in sediment) were found in much smaller amounts. According to these results, it is possible to say that the majority of MPs in Karaçomak Dam Lake are small-sized. Consistent with these findings, it has been reported that most MPs in both water and sediment in Three Gorges Dam are small in size (Di & Wang, 2018). MPs perceived as food and ingested by aquatic organisms may cause internal abrasions, physical obstruction or damage to the endocrine system through the release of toxic components (Wright et al., 2013; Wright & Kelly, 2017). MPs can be taken into the body of fish not only by being swallowed but also via water passing through the gills and skin. The small sizes of the MPs detected in this study may facilitate this intake. Therefore, considering the high MP concentrations and small sizes, it is possible to infer that MP pollution may pose a risk for the populations in the Karaçomak Dam Lake. Karaçomak Dam is also the drinking water source of Kastamonu. With this feature, it has the potential to threaten human health.

The abundance of MP levels in Karaçomak Dam was determined in winter, autumn, spring and summer seasons, respectively. It was determined that the amount of MP increased in autumn, peaked in winter, and started to decrease in spring and reached the lowest amount in summer. This situation can be attributed to the amount of rainfall during the year, the area where the dam is located, the surrounding agricultural and animal husbandry activities, and the fact that the dam lake is also a good fishing and recreational area. Indeed, many studies have shown that MP concentrations in water can vary seasonally, and heavy rainfall, stormwater and melting snow can transport MPs from land to water (Ross et al., 2023; J. Wang et al., 2022). Moreover, it is an unequivocal fact that human activities such as urban life, agriculture, fishing and tourism can also affect the amounts of MPs in water resources (Zhao et al., 2024).

5. Conclusion

Ultimately, the microplastic data obtained from the study conducted in the Karaçomak Dam Lake are similar to other studies conducted in Türkiye and the world lakes in terms of quantity and quality, and are at average levels. However, this is insufficient to draw a conclusion on whether the dam lake is rich or poor in plastic, under a risk/pressure or not since there is no reference regarding how much MPs cause pollution in the waters and to what extent yet. On the other hand, it is not possible to clearly demonstrate how much of it is ingested by inhabitant wildlife in the lake or how much of it poses a risk to the end consumers. Therefore, more studies and comprehensive research are needed. Based on this, studies should be carried out to determine the source of MP pollution in the Karaçomak Dam, reduce and prevent it. Furthermore, the MP levels in tap waters should be investigated in future studies as the dam provides drinking water to Kastamonu.

Conflict of Interest

The authors declare that they have no conflict of interest.

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