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Microplastic Pollution Profile of Pazarsuyu Stream (Giresun, Türkiye)

Dilek Güngör[1*], Cengiz Mutlu[2], Arzu Aydın Uncumusaoğlu[2]

Abstract: In this study, microplastic (MP) profiles in water, sediment and fish samples from three stations along the Pazarsuyu Stream, one of the important water resources in the Bulancak district of the Black Sea Region, were investigated. Water, sediment and fish samples were collected seasonally and the presence, type and amount of microplastics were determined. Both microscopic and ATR-FTIR spectroscopy techniques were used to analyze and identify the MPs. In the analysis made for all stations, it was found that there were 480 units/kg in sediment samples, 0.75 units/L in water samples, and 5.3 units/g in the stomach contents of 7 fish of freshwater chub (*Squalius orientalis Heckel, 1847*). The dominant color of MPs in water and sediment samples observed in the study is black, while the dominant color in stomach contents of fish is blue and black. In the analysis is of polymer shapes from the collected water and sediment microplastics in this study, fibers were the dominant group. Conversely, fragments were predominantly found in stomach contents. Based on the FT-IR analysis results PP (Polypropylene) and PE (Polyethylene) were identified as the most abundant MP polymer types. Microplastics were also found in the digestive systems of fish, indicating a potential risk of passage into the food chain. This study reveals the extent of microplastic pollution in the Pazarsuyu Stream ecosystem and emphasizes the need for further research in terms of its potential effects on aquatic life and human health in the region. It also provides important data to local governments and stakeholders for pollution reduction strategies.

Keywords: Fish, Freshwater, Microplastic, Sediment, Pazarsuyu Stream

Pazarsuyu Deresi’nin (Giresun, Türkiye) Mikroplastik Kirlilik Profili

Öz: Bu çalışmada, Karadeniz Bölgesi'nde yer alan Bulancak ilçesindeki önemli su kaynaklarından biri olan Pazarsuyu Deresi boyunca üç istasyondan su, sediment ve balık örneklerindeki mikroplastik (MP) profili araştırılmıştır. Su, sediment ve balık örnekleri mevsimsel olarak toplanmış ve mikroplastiklerin varlığı, türü ve miktarı belirlenmiştir. Mikroplastikleri analiz etmek ve tanımlamak için hem mikroskobik hem de ATR-FTIR spektroskopisi teknikleri kullanılmıştır. Tüm istasyonlar için yapılan analizde, sediment örneklerinde 480 adet/kg olduğu ortaya çıkarken, su örneklerinde 0,75 adet/L olduğu, 7 adet tatlı su kefali (*Squalius orientalis* Heckel, 1847) balığının mide içeriklerinde ise 5,3 adet/g rastlanmıştır. Çalışmada gözlenen su, sediment örneklerindeki MP’lerin baskın rengi siyah, balıkların mide içeriklerinde ise baskın renk mavi ve siyahtır. Araştırmada toplanan su ve sediment MP’lerinin polimer şekli analizinde baskın grup lif, mide içeriğinde ise fragment bulunmuştur. FT-IR analiz sonuçlarına göre, PP ve PE tespit edilen en bol MP polimer türleri olmuştur. Balıkların sindirim sistemlerinde de mikroplastiklere rastlanmış olup, bu durum besin zincirine potansiyel geçiş riskini işaret etmektedir. Bu çalışma, Pazarsuyu Deresi ekosistemindeki mikroplastik kirliliğinin boyutlarını ortaya koymakta ve bölgedeki sucul yaşam ve insan sağlığı üzerindeki potansiyel etkileri açısından daha fazla araştırmanın gerekliliğini vurgulamaktadır. Ayrıca, yerel yönetim ve paydaşlara kirliliği azaltma stratejileri için önemli veriler sunmaktadır.

Anahtar kelimeler: Balık, Mikroplastik, Sediment, Tatlı Su, Pazarsuyu Deresi

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1. Introduction

The breakdown of plastics through biological, chemical, or mechanical processes, or their direct industrial production, results in the formation of particles ranging in size from 0.1 to 5000 micrometers (μm). These particles are known as microplastics (MPs) (Öncü and Aydemir, 2024). While plastics provide convenience in our daily lives, they persist in our environment. The increased production and widespread use of plastic materials contribute to environmental pollution and the increase in plastic waste. This plastic pollution stems from excessive plastic consumption and deficiencies in waste management (Ciner et al., 2023). In addition to environmental pollution, the excessive use of plastics negatively impacts other living organisms in these environments, including humans.

The most widely used and therefore most frequently encountered polymer types in the environment include polyethylene terephthalate (PET) and polyethylene (PE), which are widely used in packaging materials; polypropylene (PP), which is found in food containers and textiles; polystyrene (PS), which is frequently found in disposable products; and polyvinyl chloride (PVC), which is used in piping systems (Jambeck et al., 2015; Geyer et al., 2017). The distribution of MPs in the marine ecosystem has led to the frequent presence of these particles in the digestive systems of various marine organisms such as mussels, fish, and shrimp (Cole et al., 2011; Jabeen et al., 2017). Surface waters and sediments of seven different lakes in Türkiye were examined, and PE was found to be prevalent in the water and PP in the sediments (Mutlu et al., 2025). In recent years, the rapid increase in plastic production and use has led to the accumulation of hard-to-decompose plastic waste, and MPs, which are released during the breakdown of these wastes, have become a significant global environmental problem. Freshwater ecosystems, in particular, are notable for their intense transport and accumulation, resulting in adverse effects on the physiological, biochemical, and reproductive processes of living organisms in these systems (Bozma et al., 2023). MPs are not only physical pollutants but also serve as carriers for toxic chemicals. They mediate the transport of persistent organic pollutants such as polychlorinated biphenyls (PCBs) in aquatic environments and their entry into the food chain by adsorbing them to their surfaces. This creates indirect risks extending to human health through fish and poses a critical threat to ecosystems and food security (Güler, 2022).

It has been reported that MP pollution in freshwater resources is particularly exacerbated by wastewater, and that transport and accumulation processes in river systems can be understood through hydrodynamic modeling. Sediment transport models can be used to determine the spatial distribution of MPs at local and global scales, enabling the analysis of pollution dynamics, risk assessments, and the development of strategies to protect water resources (Uysal, 2021). Furthermore, it has been demonstrated that MPs accumulate not only on the surface but also in sediment, creating a long-term source of pollution. MPs detected in the gastrointestinal tracts of fish can reach humans through the food chain. This poses serious risks to ecosystem health, food safety, and public health, emphasizing the need for stronger measures regarding plastic use (Şimşek, 2021). Finally, MPs are widely found in water resources and aquatic organisms, posing a threat to both ecosystem and human health due to their toxic chemical transport properties. Therefore, sustainable strategies must be developed to prevent pollution. Reducing single-use plastics, implementing circular economy practices and promoting environmentally friendly materials are seen as critical solutions for long-term sustainability (Gençağ, 2025).

After being consumed by aquatic life, these MPs enter the human diet through the food chain (Bulat & Kılınç., 2020). One reason for the increase in plastic waste in our environment is the increase in plastic use over the last fifty years due to industrial growth. Although most plastic waste is recyclable, an estimated 5–12 million tons of plastic enters aquatic environments each year (Baalkhuyur et al., 2018). MP pollution has been identified as posing a risk of reaching marine life and potentially the human food chain (Mutlu et al., 2025; Eryaşar et al., 2021).

Wastewater treatment plants (WTPs), and especially streams discharging into the Black Sea, have been found to carry large amounts of MPs into the marine environment (Akdemir and Gedik, 2023; Terzi et al., 2025). The annual MPs discharge load of 29 rivers flowing into the Black Sea has been calculated as billions of particles (Terzi et al., 2025). The presence of MPs reaches significant levels not only in aquatic environments but also in sediments. Furthermore, the accumulation of various wastes on the seabed hinders gas exchange and poses another threat to the survival of benthic organisms (Akkan et al., 2023; Bayhan and Aydın Uncumusaoğlu, 2024).

One of the most striking consequences of MP pollution is its detection in both marine and freshwater fish. Fish can ingest these pollutants by filtering contaminated water or by consuming foods contaminated with MPs (Lusher et al., 2013). MPs accumulation in fish tissues raises concerns about various adverse effects, including physiological stress, inflammation, nutritional deficiencies, and even reproductive problems (Wright and Kelly, 2017). The smallest particles of plastics are nanoplastics (NPs), ranging in size from 1 nanometer (nm) to 1 micrometer (μm), and MPs, ranging from 1 μm to 5 millimeters (mm). These NPs and MPs can enter the human body not only through the respiratory and digestive systems but also through skin contact with cosmetics and clothing. The accumulation of these plastics in the human body can lead to a number of health problems, including asthma, lung cancer, respiratory disorders, fatigue, dizziness, intestinal diseases and various disorders in the intestinal microbiota (Winiarska et al., 2024).

The widespread presence of humans worldwide inevitably exposes them to the harmful effects of plastics. Plastic waste in the form of MPs can cross cell membranes and accumulate in human tissues, particularly through the digestive and respiratory tracts and damaged skin (Dzierżyński et al., 2024). The potential impact on human health is a key focus of MPs research. It has been suggested that MPs, which can enter the human body through air, water, and food, can lead to health problems such as tissue accumulation, inflammation, and toxic effects (Cox et al., 2019). However, research in this area is still in its early stages, and comprehensive studies are needed to better understand the long-term effects.

The objective of this study is to comprehensively examine the current status, sources, distribution, and potential ecological impacts of MPs pollution in water, sediment, and fish. Furthermore, it will shed light on the long-term consequences of MPs pollution on aquatic ecosystems and discuss potential strategies to address this important environmental problem.

2. Materials and Methods

Pazarsuyu Stream originates in the high mountains of Giresun and follows a undulating course. Estimated to be approximately 64 to 80 kilometers long, it flows west of the Bulancak district center and flows into the Black Sea. Its wider basin, compared to some other streams in Bulancak, increases its water collection capacity. However, the stream, which exhibits the characteristics of a typical Black Sea river, can fluctuate significantly depending on rainfall patterns. While there is a significant decrease in water flow, particularly during summer months, sudden increases can occur during periods of heavy rainfall, posing a risk of flooding.

The first sampling in Pazarsuyu Stream took place on December 16, 2021. Samples were collected from the river bank due to easy access to the shoreline (Figure 1). At this stage, three stations (S) were initially determined. Station 1 (S1) was set up at a point away from the town, Station 2 (S2) was set up closer to residential areas, and Station 3 (S3) was selected as the point where the stream approaches the sea (Figure 2). The coordinates of S1 were determined as 40°48´10¨N 38°09´14¨E, S2 as 40°52´15¨N 38°09´25¨E, and S3 as 40°56´38¨N 38°10´27¨E.

Station	Latitude	Longitude
S1	38°09'14"E	40°48'10"N
S2	38°09'25"E	40°52'15"N
S3	38°10'27"E	40°56'38"N

Figure 1. Map of the study area and stations (S1 First station, S2 Second station, S3 Third station).

Figure 2. Photographs from Sample Stations (S1, S2, S3)

Sampling points were strategically selected along the stream to represent a variety of land use types, including residential areas, agricultural areas, and natural habitats. Sample collection began in December 2021 and continued seasonally throughout 2023. Sediment and water samples were collected at three designated stations along the Pazarsuyu Stream. In this study, seven specimens of freshwater chub (*Squalius orientalis* Heckel, 1847) were obtained from a commercial fisherman operating in this Stream. The efficacy and application of this method have been detailed by Bayley and Herendeen (2000). After species identification, captured fish were placed into separate sterile polyethylene bags and transported to the laboratory in a cooler containing ice packs. In the laboratory, the total length and weight of each fish were measured. Their digestive tracts were then carefully extracted using sterile dissection tools for microplastic analysis. Fish samples were stored at -20°C until the digestive tracts were removed.

For sediment samples, 1 m² areas were scraped from the surface to a depth of 5 cm with a metal shovel (Zhou et al., 2021). Wet sediment samples were transported to the laboratory in labeled glass jars.

To ensure that the water samples were fully representative, water samples were collected from three designated points in the stream: two near the shore and one in the center. Additionally, water samples were collected from each station using a 5-liter metal bucket at three designated points. These samples were then filtered through a 35-μm-pore plankton net, yielding a total of 100 liters of stream water, which was then transferred to glass jars for transport to the laboratory (Masura et al., 2015). The collected glass jars, labeled with the sampling point code, date, and time, were transported to the laboratory. On-site measurements of field parameters such as pH, water temperature (°C) (WT), dissolved oxygen (ppm) (DO), and electrical conductivity (μs/cm) (EC) were made using a portable water quality meter (Table 1).

Table 1. Water taken from Pazarsuyu Stream stations seasonal water parameters values in samples

	Season	WT(°C)	pH	DO (ppm)	EC (μs/cm)
S1	Spring	9	6.2	70	140
S2		9	6.6	70	150
S3		12	6.3	110	230
S1	Summer	16	7	40	70
S2		17	7.3	60	150
S3		18	7.1	50	80
S1	Autumn	12	7	20	40
S2		12	8.3	60	120
S3		11	7.3	40	90
S1	Winter	5	7.4	20	40
S2		6	8.2	60	120
S3		7	7.7	40	80

2.1. Microplastic Analysis

The separation of MP particles from the samples was accomplished by first applying wet peroxidation (WPO) and then density separation techniques. For water samples transferred to the laboratory, WPO (wet peroxidation) was applied as a critical pre-digestion step. In this step, a 30% hydrogen peroxide (H_2O_2) solution was used together with ferrous sulfate heptahydrate ($FeSO_4$-$7H_2O$) solution as a catalyst. The oxidation reaction was carried out over a period of 6 h on a hot plate stirred at 80 revolutions per minute (rpm) at a temperature range of 60 to 70 °C (Masura et al., 2015). Sample preparation and MP identification protocols were adapted from the National Oceanic and Atmospheric Administration (NOAA) protocol (Masura et al., 2015). After digestion of organic matter, microplastics were removed by density separation. For this purpose, a sufficient amount of sodium chloride (NaCl) was added to the solution (to achieve a density of 1.2 g cm^{-3}) to effectively separate MPs from other components in the water. The solution was allowed to settle overnight in an Imhoff funnel, allowing MPs to collect on the surface. In the final step, MPs were filtered using 1.2 μm pore-sized glass filter paper (e.g., Whatman, GE Healthcare, United Kingdom) and a vacuum pump. The collected glass filter papers were dried at room temperature in the laboratory before analysis and made ready for processing.

For the MP isolation procedure, all wet sediment samples delivered to the laboratory were first dried in an oven at 70°C until a constant mass was reached. After drying, the samples were passed through a 5 mm mesh steel sieve to remove large stones and coarse debris. Following this sieving step, 50 g of dried sediment subsamples were weighed and mixed with 100 mL of saturated sodium chloride (NaCl) solution at a concentration of 140 g L^{-1}. This suspension was stirred for 15 min and then allowed to settle for 24 h to allow MPs to rise to the upper phase. The upper phase containing MPs was then separated and transferred to a beaker in at least three replicates. Following this step, the WPO process was initiated. To oxidize the organic components, ferrous sulfate heptahydrate ($FeSO_4$-$7H_2O$) solution and 30% hydrogen peroxide (H_2O_2) solution were used as catalytic reagents. The mixtures in the beakers were oxidized on a hot plate at 60 to 70 °C with a stirring speed of 80 revolutions per minute (rpm) for a total of 6 hours. After the oxidation process was completed, sodium chloride (NaCl) was added to the mixture in an amount to provide a density of 1.2 g/cm³ to separate MPs from the remaining components. The solution was left to settle again overnight in an Imhoff funnel. The microplastics in the resulting supernatant were filtered using glass fiber filter paper with a 1.2 µm pore size (e.g., Whatman, GE Healthcare, United Kingdom) and a vacuum pump. Finally, the glass filter papers used were dried at room temperature in the laboratory to prepare for analysis.

The isolated MPs were examined in detail under a stereo microscope (Nikon, Tokyo, Japan) (Hermsen et al., 2017). During this visual analysis, the sizes and shapes of each particle were determined. The largest dimension was accurately measured using a high-resolution digital camera integrated into the microscope. The hot needle test was applied to confirm the plastic-like materials (Bellas et al., 2016). This test observed the melting or deformation behavior of the plastics. MPs were then separated into six colors (red, green, blue, black, white, and transparent) and visually identified as particles, fibers, films, foam, or pellets. All these characterized particles were stored for Fourier Transform Infrared (FT-IR) spectroscopy analysis to further identify the polymer type.

Strict procedures were implemented to minimize the risk of airborne contamination from MP samples. Samples were dissected, transferred, and processed as quickly as possible, and work surfaces were disinfected with alcohol before each use. Nitrile gloves, cotton laboratory coats, and glassware were used as contamination barriers throughout the analysis process. All equipment not in use was meticulously covered with aluminum foil to prevent external particulate contamination. Additionally, blank sample tests were conducted to check the cleanliness of the laboratory environment and the reliability of the procedure. For these tests, three pieces of filter paper were placed in distilled water for 24 hours in the laboratory. These filters were then examined under a stereomicroscope to detect any possible MP contamination. As a result of the examinations, no MP particles were detected in any of these control filter papers (Zhao et al., 2023; Bayhan and Aydin Uncumusaoglu, 2024).

2.2. Statistical Analysis

Data analysis was performed using SPSS version 25.0 (IBM, USA). One-way ANOVA followed by Tukey's HSD post-hoc test was used to determine significant differences between data sets (Kleinbaum et al., 1998). A significance level of $P < 0.05$ was used for all comparisons. Multivariate Hierarchical Cluster Analysis (HCA) was used to classify potential clusters among the mean microplastic abundance across stations, and Ward's method was used as a measure of similarity (Mutlu and Aydın Uncumusaoglu, 2024; Mutlu and Aydın Uncumusaoğlu, 2025).

3. Results And Discussion

In this study, MPs of various sizes were investigated. The water properties at the sampling stations during sample collection are presented in Table 1. These values were obtained seasonally. MPs in water, sediment, and fish stomach samples collected seasonally from designated stations along the stream were analyzed based on their size, color, and morphology. Analyses at all stations revealed a total of 480 MPs per kilogram in sediment samples, 0.75 MPs per liter in water samples, and 5.3 MPs per gram in fish stomach contents (Figure 4). Considering all the data in this study, MPs showed significant differences, particularly in blue, black, and white colors (one-way ANOVA; $P<0.05$). Regarding MP types, significant differences were observed for particles, fibers, and foams, while no significant differences were detected in the sizes of microplastics (one-way ANOVA; $P>0.05$).

Statistical analysis of the study stations revealed a significant difference only in blue microplastics (one-way ANOVA; $P<0.05$). A significant difference in particle size was found between microplastic types. No significant differences in size were found between stations (one-way ANOVA; $P>0.05$).

Statistical evaluation of microplastic data obtained from the gastrointestinal tracts of fish collected from the study area revealed no significant differences except for blue and black colors (one-way ANOVA; $P<0.05$). Similarly, fish MPs showed no significant differences except for fragments and fibers (one-way ANOVA; $P<0.05$). There was no significant difference in MP sizes (one-way ANOVA; P>0.05).

When microplastics (MPs) in water samples from the stations were statistically analyzed, a significant difference was observed between blue and black colors (one-way ANOVA; P<0.05). However, there was no significant difference in MP types or sizes (one-way ANOVA; P>0.05).

A significant difference between microplastics in sediment samples was observed only for blue color (one-way ANOVA; P<0.05). Among MP types, fragments and fibers showed significant differences (one-way ANOVA; P<0.05). No significant difference was found in size (one-way ANOVA; P>0.05).

Statistical analysis of MP type diversity data obtained from all microplastics in the study area revealed no statistically significant difference among the various microplastic types (one-way ANOVA; P > 0.05). Statistical analysis revealed no significant difference among the MP types detected in water samples except PAN (one-way ANOVA; P < 0.05). Similarly, no significant difference was detected among the MP types in sediment samples except PE (one-way ANOVA; P < 0.05). No significant difference was found in the diversity of microplastic types found in samples obtained from fish (one-way ANOVA; P > 0.05).

Analysis of MP density in water and sediment content at all stations revealed that the highest MP density was observed at S3, followed by S1, and the lowest MP density was observed at S2 (Figure 3).

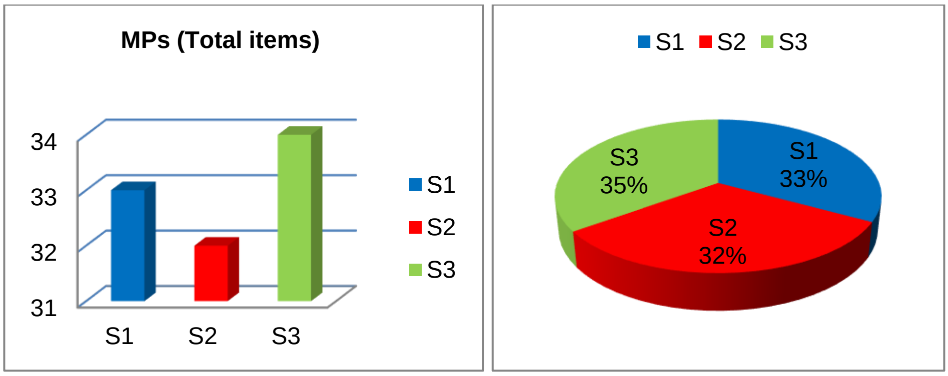


Figure 3. Abundance rates (%) and substance MP values (S) by stations

Among the water samples, the highest MP abundance was found in S2 (37%), followed by S3 (35%) and S1 (28%). In the sediment samples, MP abundance was highest in S1 (50%), followed by S3 (33%) and S2 (17%). Among the captured fish, the highest MP concentration in stomach content was detected in M4 (27%), followed by M5 (22%), M2 (20%), M6 (9%), M7 (9%), M1 (8%) and the lowest MP concentration was detected in M3 (5%) (Figure 4). Pazarsuyu Stream appears to be exposed to lower MP concentrations compared to Aksu Stream. This difference may be attributed to the higher concentration of settlements, human population and industrial plastic waste along the Aksu Stream (Aydın Uncumusaoğlu, 2024).

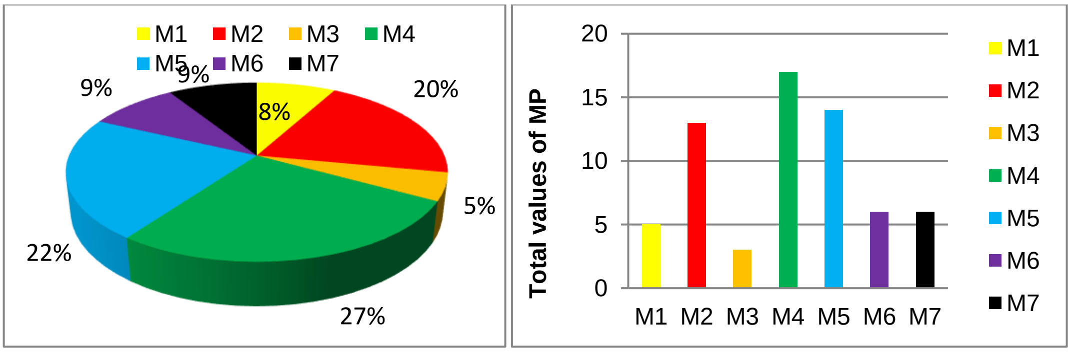


Figure 4. MP abundance rates (%) and values in stomach content of fish.
M1 Fish-1 stomach content, M2 Fish-2 stomach content, M3 Fish-3 stomach content,
M4 Fish-4 stomach content, M5 Fish-5 stomach content, M6 Fish-6 stomach content,
M7 Fish-7 stomach content.

Color analysis of MPs found in samples collected during the study identified a total of six different colors: red, green, blue, black, white, and yellow. The most dominant color among MPs in all water and sediment samples was black (41%), followed by blue (33%), red (13%), green (8%), yellow (3%), and white (2%) (Figure 5). Similar findings were reported in a study on the Ergene River, where black and blue were the most frequently observed colors in water and sediment samples (Akdogan et al., 2023). When the colors of MPs in the stomach contents were examined, blue and black were found to be the most dominant colors (Figure 6). A similar result was observed in MPs in the digestive systems of commercial fish from marine farms in the East China Sea, China (Wu et al., 2020).

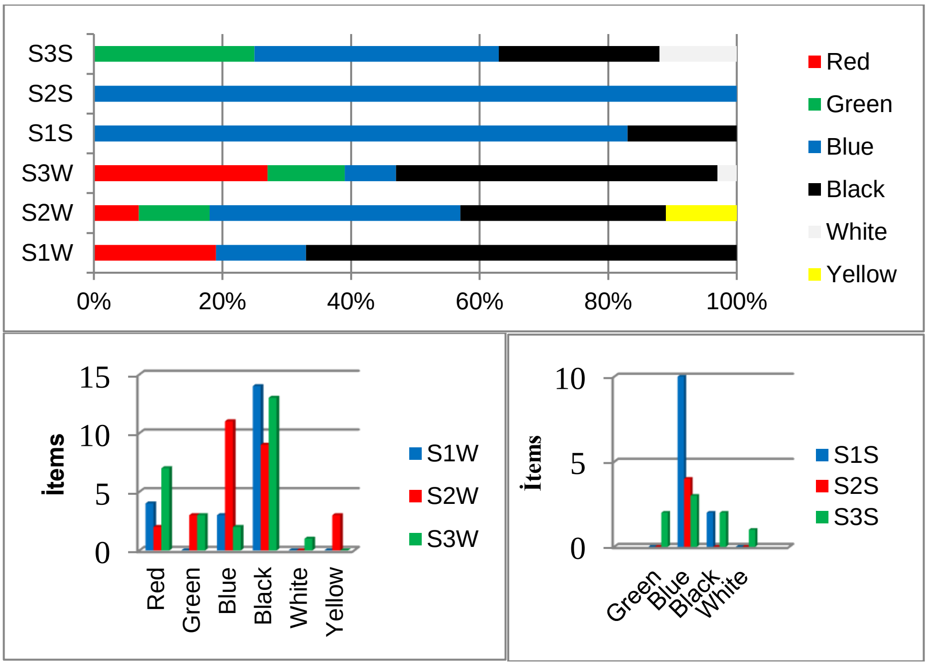


Figure 5. Percentage distribution of MPs at stations according to color
S1W First station water, S2W Second station water, S3W Third station water
S1S First station sediment, S2S Second station sediment, S3S Third station sediment

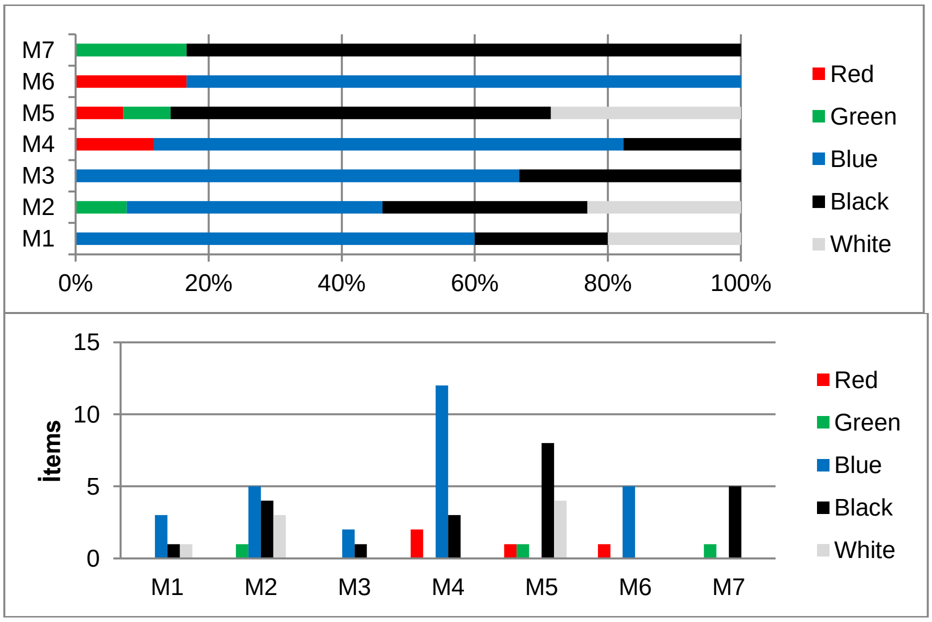
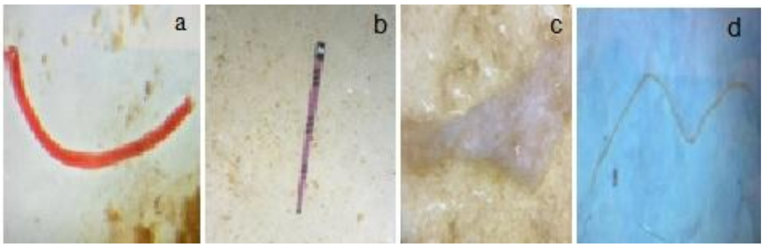


Figure 6. Percentage distribution and values of MPs in stomach contents of fish according to color

Microscopic examination revealed the morphologies of MPs, as shown in Figure 7. MP polymer shapes detected in water and sediment samples collected from Pazarsuyu Stream predominantly consisted of fibers (79%), fragments (19%), and pellets (2%) (Figure 8). Specifically, fragments were the most prevalent MP shape in the sediment samples, accounting for 71%. Our study found that 29% of the MP content consisted of fibers. This contrasts with sediment samples from Laizhou Bay, China, where a higher proportion of fibers was observed (Teng et al., 2020), while our study revealed a greater abundance of fragments. Further comparisons with MP pollution in Turkish ponds highlight regional differences. Studies conducted in Bursa, Erzincan, Şanlıurfa, and Antalya (Tatlı et al., 2023) detected MP particles in sediment samples, with fibers being the dominant morphology, accounting for 75% of the MPs.



Şekil 7. MPs shape types a- Fragment b- Pelette, c- Foam, d- Fiber

In our study, we detected fibers (95%), fragment (3%), and pellets (2%) in water samples (Figure 8). The results of our study indicate that fiber-shaped particles are overwhelmingly dominant in microplastic morphology. This finding is consistent with an international study examining microplastic discharge in rivers flowing into the Black Sea (Terzi et al., 2025). Therefore, the fiber-dominant data obtained from our study demonstrate that pollution in the Black Sea Region is a source-based and acute environmental problem, and that its solution will be possible through regional and national water management policies.

Fiber particles were found to be more abundant (65%) in water samples from the Ciwalengke River in Indonesia, while fiber forms were more prevalent (91%) in sediment samples (Alam et al., 2019). Our research, consistent with these findings, yielded similar results.

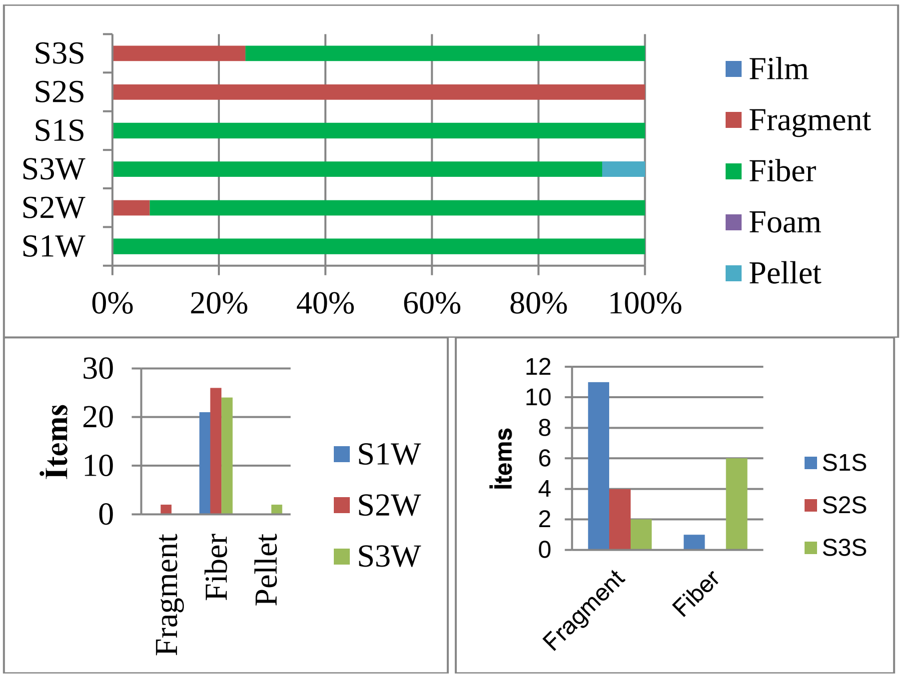


Figure 8. Percentage distribution and values of MPs at stations according to their shapes

Analysis of fish stomach contents in our study revealed a higher prevalence of fibrous MP structures (47%) (Figure 9). Two other studies on fish species (*Squalius spp*.) from Turkish inland waters are strongly consistent with our findings. Both studies have shown that fibers are the predominant form of MPs in the digestive tracts of freshwater fish (Gedik and Atasaral, 2022; Gedik et al., 2024). This supports the view that the primary source of microplastic pollution in freshwater ecosystems is likely the release of synthetic textiles into the environment through washing. Consequently, the high fiber content is an important indicator that confirms the regional impact of this widespread pollution source in Türkiye's inland water systems.

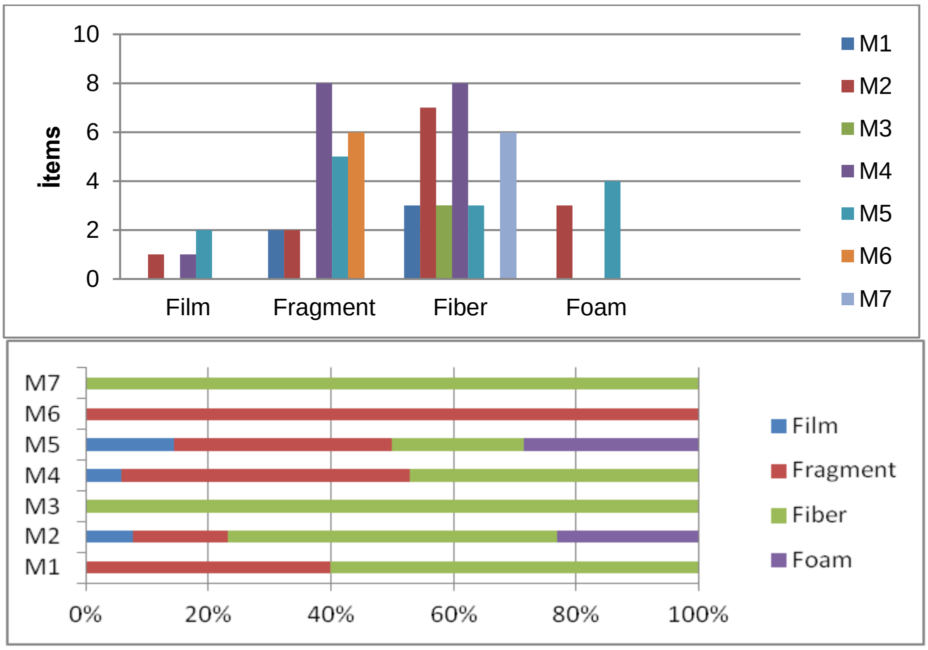


Figure 9. Percentage distribution and values of MPs in stomach contents of fish according to shapes

This finding contrasts significantly with studies on horse mackerel caught off the Turkish Black Sea coast, where fibers were identified as the predominant form of microplastics, accounting for 66% (Mutlu et al., 2022). The varying results between our study and other studies highlight an important point: Regional activities such as industrial activities, fishing practices, and various livelihood activities significantly influence the types of microplastics found in different environmental zones. This includes the impact on ecological elements such as water, sediment, fauna, and flora, leading to different microplastic morphologies in different regions. Detailed studies of commercial fish in the Gulf of Izmir indicate that almost half (49.4%) of the microplastics detected were in the form of fibers (Eryaşar et al., 2024). This high fiber content is primary evidence of the transport of synthetic textile waste from urban areas into the aquatic environment via domestic wastewater. Furthermore, studies indicate that fibers are the most common morphotype in various aquatic environments, including mussels in the Marmara and Black Seas (Gedik and Atasaral, 2022). Therefore, the results of our study confirm the problem of inadequate filtration of WWTPs and widespread textile pollution, supporting a global concern for aquatic ecosystems in Türkiye. This situation highlights the risk of microplastic transmission to humans through the food chain, not only for fish health but also at the national level.

The most dominant MP size fractions observed in the water samples were 0-50 μm (47%), followed by 50-100 μm (25%), 100-200 μm (23%), 200-300 μm (3%), 300-400 μm (1%) and 700-800 μm (1%) (Figure 10). A similar prevalence was also detected in the 0-50 μm size range off the coast of Ordu province, which is consistent with the findings of our current study (Kılıç and Uncumusaoğlu, 2024). In the Black Sea, microplastics (MP) ranging from 500-1000 μm constitute 33% of the total found in horse mackerel caught off the coast of Turkey (Mutlu et al., 2022).

When examining the microplastic density in the sediment, 0-50 μm particles are the most common at 71%, followed by 50-100 μm at 29% (Figure 10). Our findings are consistent with the results of a study conducted in Batlama Stream, which showed similar results (Aydın Uncumusaoğlu, 2024).

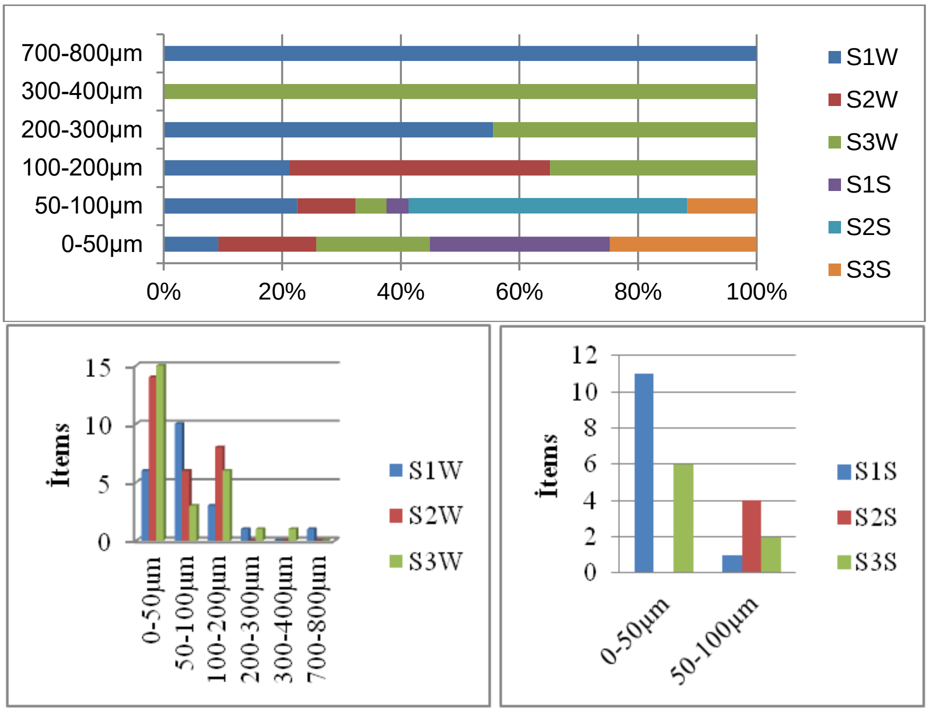


Figure 10. Percentage distribution of MP sizes at stations

Samples with sizes of 0-50 µm (72%), 50-100 µm (25%), and 100-200 µm (3%) were detected in the stomach contents of fish (Figure 11). Generally, the sizes are between 0-50 µm. While the dominant size range (0-50 µm) observed in this study is not consistent with the findings of studies conducted on the Maozhou River, Batlama Stream, and the urban river network in eastern China (Wang et al., 2020; Çebi and Aydın Uncumusaoğlu, 2024; Fan et al., 2022).

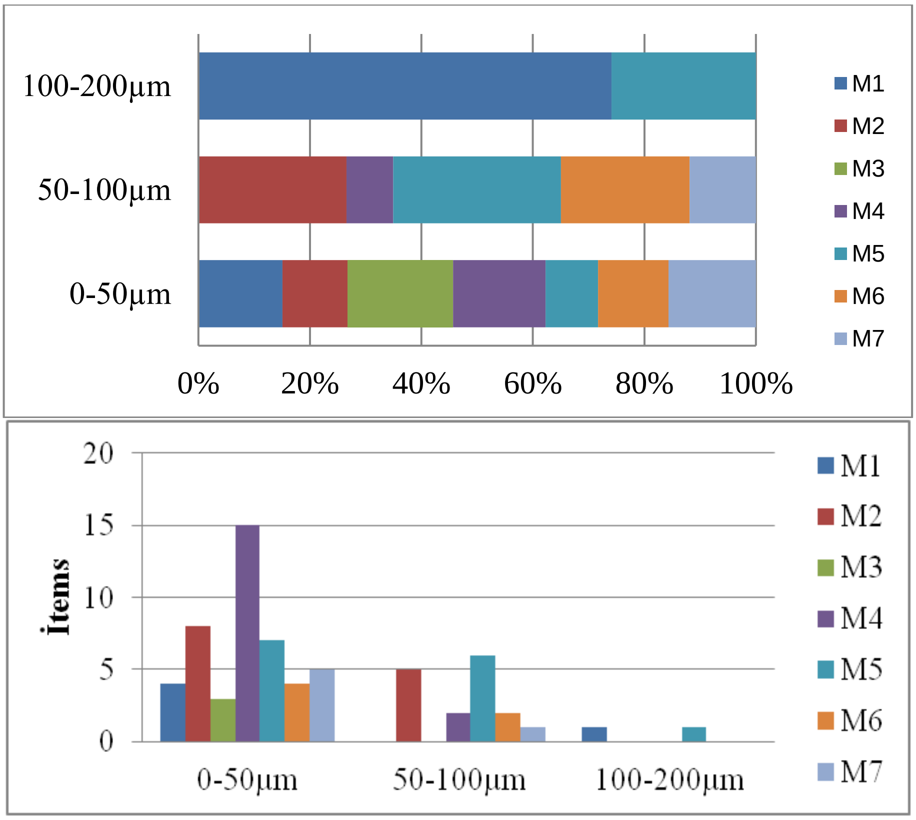


Figure 11. Percentage distribution of MPs in stomach contents of fish according to shapes.

When the research results were evaluated seasonally, it was determined that MP concentrations were generally higher in winter (47%), spring (25%), summer (23%) and autumn (5%) at all stations. MP concentrations were generally highest in winter, accounting for 47% of the total. This is followed by spring with 25%, summer with 23% and autumn with the lowest detection rate of 5% (Figure 12). However, completely different results were obtained in similar studies. For example, the MP load in the Nakdong River in South Korea constitutes 71% of the total annual load between July and September (Eo et al., 2019). This shows how the local environment is affected by unique biotic and abiotic factors. In our study, it was observed that the MP concentration in water samples was highest in winter at all three stations. MP concentration in sediment was evident at the first station in spring and summer, and at the second and third stations in summer. Considering both water and sediment, MPs were predominantly detected as follows: The highest concentration in spring was at S3W; In summer, 43% were observed in S2S; in autumn, 50% were observed in S1W and S3W; and in winter, 42% were identified in S2W (Figure 12).

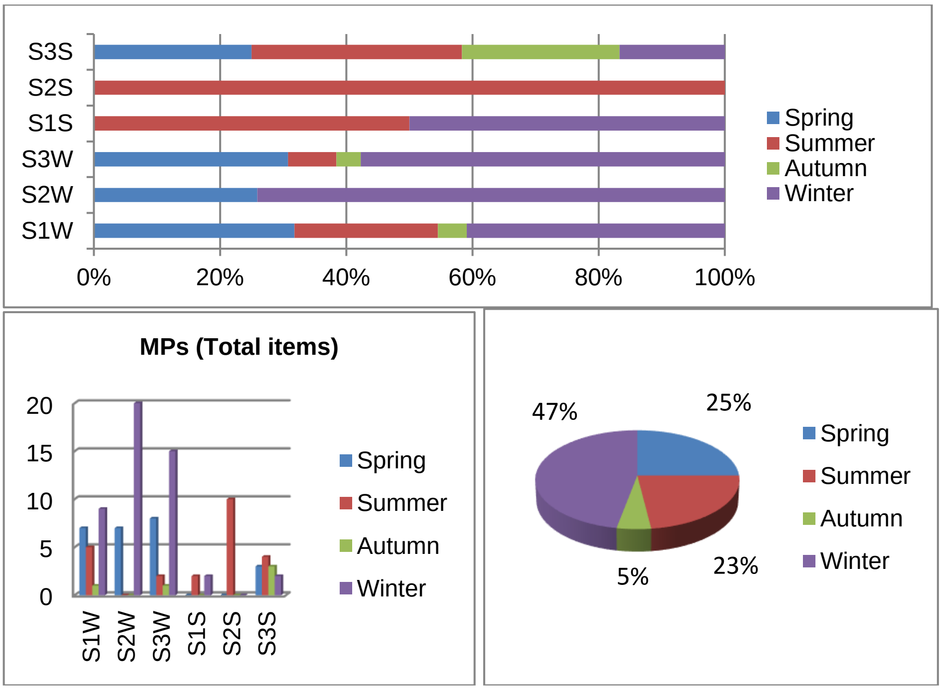


Figure 12. MP density ratios (%) and values (S) at seasonal stations

Considering the seasonal variation of microplastics in fish stomach contents, the highest MP concentration was observed in autumn (58%), followed by summer (25%), spring (9%), and winter (8%) (Figure 13). Seasonal variation in MP concentration in freshwater fish can show contrasting results depending on geographic location and hydrological conditions; for example, in Chaohu Lake, China, microplastic abundance per fish increased during the dry season, which was attributed to amplification of pollution by lowering water levels (Wu et al., 2022).

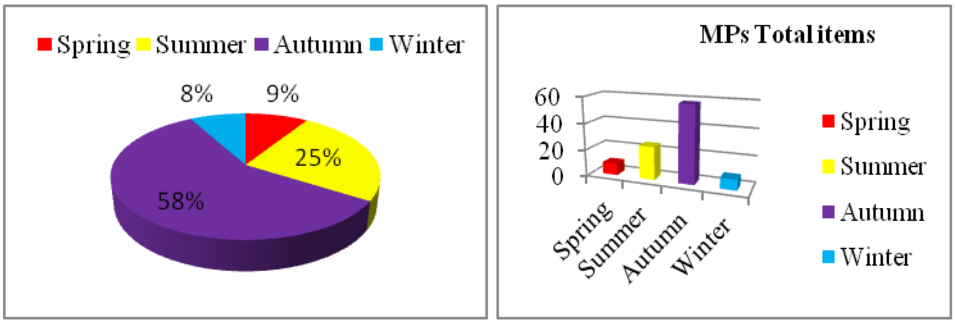


Figure 13. MP density ratios (%) and values at seasonal fish stomach contents

FT-IR analysis was performed to determine the polymer types of the microplastic samples. Polypropylene (PP) was the highest at 30%, followed by Polyethylene (PE) at 24%, Polystyrene (PS) at 18%, Polyethylene Terephthalate (PET) at 16%, and Polyacrylonitrile (PAN) at 12%. The microplastic types detected in the water samples were 33% PP, 27% PE, 22% PET, 9% PS, and 9% PAN. In terms of MPs in the sediment samples, PE, PP, and PAN were the most abundant, accounting for 25% each, followed by PS at 17% and PET at 8% (Figure 14).

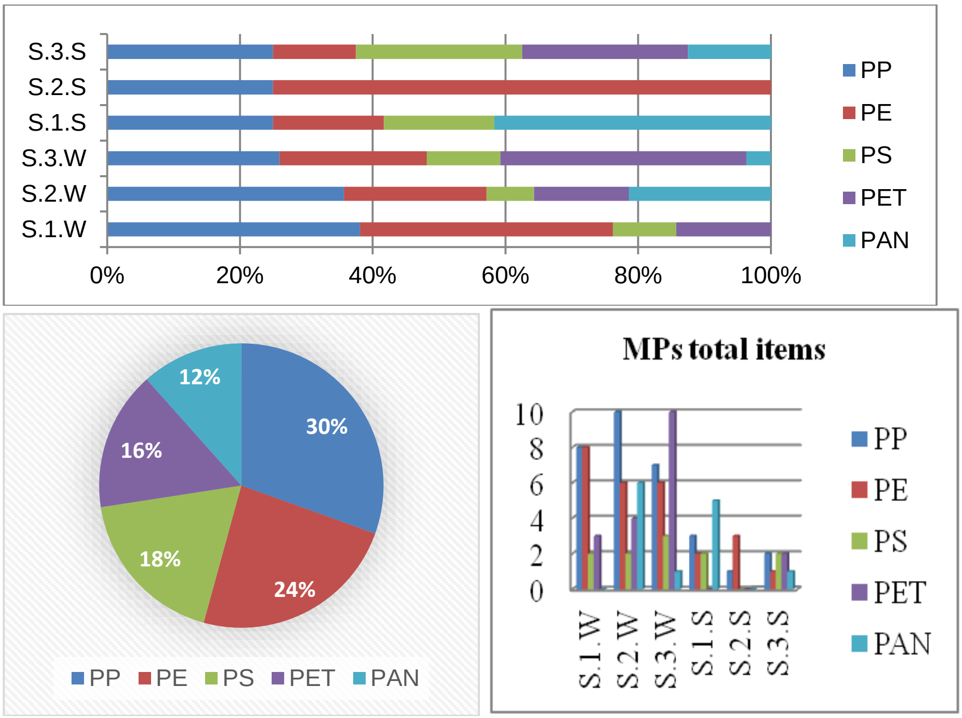


Figure 14. MP density ratios (%) and values by polymer types (PP: Polypropylene, PE: Polyethylene, PS: Polystyrene, PET: Polyethylene Terephthalate,PAN: Polyacrylonitrile)

Analysis of microplastic polymer forms in the stomach contents of fish revealed the following abundances: PP 28% (M4), PE 42% (M4), PS 58% (M5), PET 38% (M4) and PAN 50% (M4) (Figure 15).

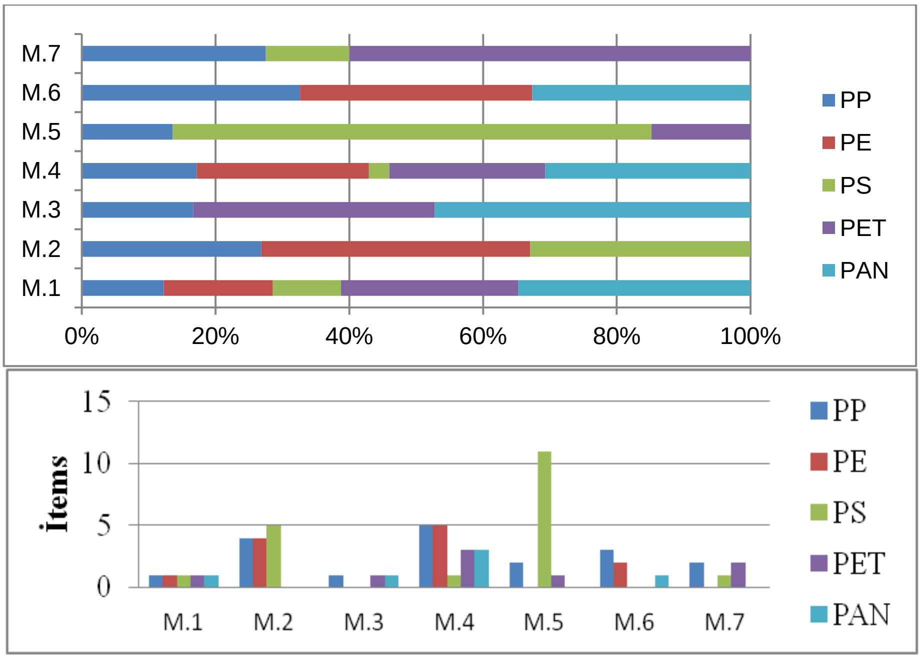


Figure 15. MP polymer type in fish stomach content

The predominance of polyethylene (PE) as a polymer type in microplastic research conducted in aquaculture waters and sediments aligns with the findings of our study (Miserli et al., 2023). The FT-IR spectra of microplastics from the Pazarsuyu stream are presented in Figure 16.

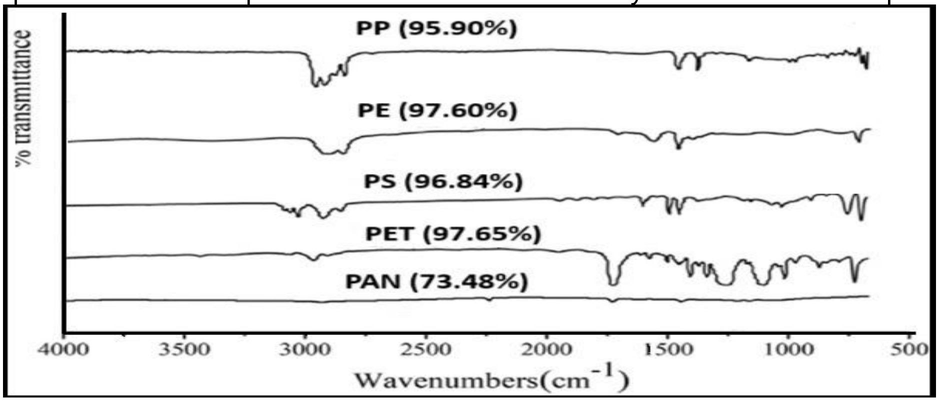


Figure 16. FT-IR spectra of Pazarsuyu stream microplastics. Values in parentheses indicate the average match rate with the standard spectrum for each polymer: PP, PE, PS, PET and PAN.

According to seasonal water parameter values in water samples taken from Pazarsuyu Stream stations, pH and water temperature show normal seasonal fluctuations; as water temperature increases, dissolved oxygen levels decrease. This demonstrates that temperature is one of the most critical factors for aquatic life. While stations S1 and S2 are similar across stations, station S3 stands out with its high electrical conductivity (230 µs/cm), especially in spring, and higher dissolved oxygen (110 ppm) values than other stations across seasons. This could indicate input to S3 from external sources (e.g., fertilizers or industrial waste from agricultural activities) or a different geological structure in the area where the station is located. This anomaly requires further investigation. The low dissolved oxygen values of 20 ppm recorded at station S1 during the autumn and winter months suggest a significant organic pollution load or slowing of water flow at this station. This situation could pose a risk to aquatic life and potentially lead to the formation of a hypoxic zone.

3.1. Hierarchical Cluster Analysis (HCA)

Hierarchical Cluster Analysis (HCA) was applied to the data in this study to clearly identify similarities and differences in MP concentrations. Analysis based on MP abundances obtained from water samples collected from Pazarsuyu Stream revealed two distinct clusters among the sampling stations (Figure 3). Cluster A includes Station S1. This station exhibited a distinct similarity pattern compared to the others due to its proximity to the river's source and its greater distance from industrial zones and residential areas. Cluster B includes Stations S2 and S3. These stations differ from the others due to the presence of an industrial zone near the stream, its proximity to the river's outlet, and its proximity to the district center.

Analysis of MP abundance in sediment samples collected from Pazarsuyu Stream yielded results similar to those obtained from water samples in terms of both proportion and clustering patterns (Figure 17). Consequently, the reasons for the observed differences also remain consistent between the two matrices.

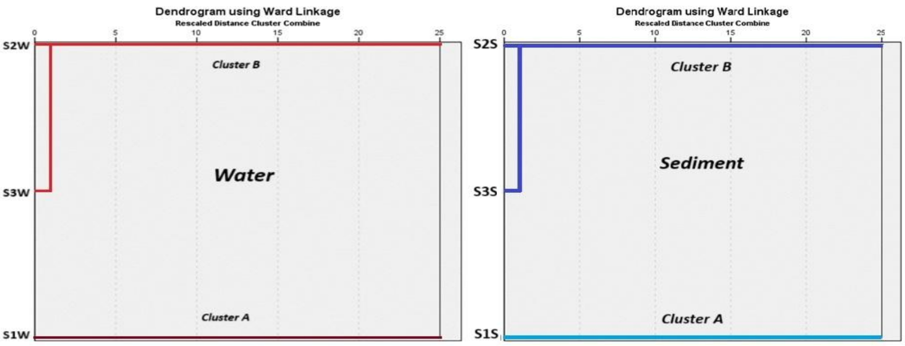


Figure 17. HCA analysis based on MP abundance in water and sediment (Cluster A: S1 and Cluster B: S2, S3).

4. Conclusion

In conclusion, this study comprehensively describes the prevalence and distribution of microplastic pollution in water, sediment, and fish stomach contents of the Pazarsuyu Stream. The findings indicate that the stream ecosystem is under significant microplastic pressure, posing serious risks to both aquatic life and potentially human health.

The accumulation of microplastics, particularly observed in fish, highlights the potential for these pollutants to be transmitted throughout the food chain. High microplastic concentrations in sediment samples suggest that streams act as a microplastic sink. Their analyses confirmed the presence of plastic polymers such as polypropylene, polyethylene, and polyacrylonitrile. Given this finding, it is crucial to be careful in the selection and use of various products in our daily lives. Plastic polymers, particularly PP, PE, PS, and PAN, are fundamental building blocks of modern life due to their unique properties. Their extensive applications across various industries make them critically important in a variety of areas, from engineering to everyday use. The potential impacts of products containing PP, PE, and PAN should be considered, particularly in areas such as food contact containers, packaging materials, children's toys, and personal care products. Consumers who make informed choices play a critical role in both their personal health and environmental sustainability. Carefully examining product labels and opting for alternatives made from safer materials are important steps in this regard. The results of our study clearly demonstrate the urgent need for action plans specific to Pazarsuyu Stream. These plans should encompass approaches such as identifying and controlling microplastic sources, improving waste management systems, and raising public awareness of this critical issue. Furthermore, implementing continuous monitoring programs is vital for maintaining the ecological balance and sustaining biodiversity within the stream. Future research is recommended to further investigate microplastic pollution studies and their potential impacts on human health. Reducing microplastic pollution in Pazarsuyu Stream is a critical step not only for the local ecosystem but also for the health of all living organisms in the region.

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6. Compliance with Ethical Standard

a) Author Contributions

Author C.M.: Conceived the study
D.G.: Wrote the first draft of the article
A.A.U.: Performed and supervised the statistical analyses.
All authors read and approved the final article.

b) Conflict of Interests

The authors declared that there are no conflicts of interest regarding the publication of this article. Views and opinions expressed are however those of the authors only.

c) Statement on the Welfare of Animals

Ethical approval: Necessary permissions have been obtained for my study.

d) Statement of Human Rights

This study does not involve human participants..

e) Declaration of Not Using AI

The authors declare that they did not use any type of generative artificial intelligence in the writing of this article or in the creation of images, graphs, tables or corresponding titles.

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This research is part of the doctoral dissertation conducted by Dilek Güngör at Giresun University, Institute of Science, Department of Biology in Turkey. All expenses incurred during the execution of this study (including equipment, consumables, field research, and publication fees) were personally covered by the author. Therefore, no direct or indirect financial support was received from any institution or organization.

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