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First Evaluation of Microplastic Pollution in the Surface Waters of the Lake Kovada (Isparta, Türkiye)

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Abstract: Microplastics (MPs) are emerging contaminants of global concern due to their persistence, ubiquity, and ecological risks. Although freshwater ecosystems have received increasing attention, data from protected non-urban lakes remain limited. This study provides the first comprehensive assessment of MP pollution in Lake Kovada, a protected freshwater body in the Western Mediterranean Basin of Türkiye. Surface water samples were collected from three stations during the summer and autumn of 2024 using standardized procedures to minimize contamination. MPs were morphologically characterized under a stereomicroscope and chemically identified using ATR-FTIR spectroscopy. MP abundance was 442 particles/m², with the highest at the Kovada Canal–Lake junction (K1: 167 particles/m²) and the lowest at K3 (29 particles/m²). Filaments and fragments were the most frequent morphotypes, predominantly black and red in color. Among the identified polymers, polyethylene (PE) and polyethylene terephthalate (PET) exhibited the highest occurrence. Compared to other freshwater systems, MP levels were relatively low, likely due to the lake's National Park status, rural location, and limited industrial/agricultural activity. However, nearby agriculture, recreation, and the hydrological connection to Lake Eğirdir likely contribute to filament-rich MP inputs via atmospheric fallout and runoff. Seasonal variations in MP abundance and composition indicate combined impacts of human activity and natural processes such as precipitation and temperature shifts. The study highlights the importance of monitoring MP pollution even in relatively undisturbed ecosystems and offers valuable baseline data for environmental protection strategies in the region.

Keywords: Microplastic, Water pollution, Lake Kovada, Türkiye

Kovada Gölü (Isparta, Türkiye) Yüzey Sularında Mikroplastik Kirliliğinin İlk Değerlendirmesi

Özet: Mikroplastikler (MP'ler), kalıcılıkları, her yerde bulunabilirlikleri ve ekolojik riskleri nedeniyle küresel ölçekte endişe yaratan yeni ortaya çıkan kirleticilerdir. Tatlı su ekosistemleri son yıllarda artan bir ilgi görmesine rağmen, koruma altındaki kentsel olmayan göllerle ilgili veriler hâlâ sınırlıdır. Bu çalışma, Türkiye'nin Batı Akdeniz Havzası'nda yer alan koruma altındaki bir tatlı su kütlesi olan Kovada Gölü'ndeki MP kirliliğinin ilk kapsamlı değerlendirmesini sunmaktadır. Yüzey suyu örnekleri, 2024 yılı yaz ve sonbahar dönemlerinde üç istasyondan alınmış ve kontaminasyonu en aza indirmek için standartlaştırılmış yöntemler kullanılmıştır. MPler, stereo mikroskop altında morfolojik olarak karakterize edilmiş ve ATR-FTIR spektroskopisi kullanılarak kimyasal olarak tanımlanmıştır. Ortalama MP bolluğu 442 parçacık/m² olarak belirlenmiş; en yüksek yoğunluk Kovada Kanalı–Göl birleşiminde (K1: 167 parçacık/m²), en düşük ise K3 istasyonunda (29 parçacık/m²) tespit edilmiştir. Filament ve parçacık (fragment) tipleri en yaygın morfotipler olup, ağırlıklı olarak siyah ve kırmızı renklidir. Belirlenen polimerler arasında polietilen (PE) ve polietilen tereftalat (PET) en yüksek oranda görülmüştür. Diğer tatlı su sistemleriyle karşılaştırıldığında MP seviyeleri nispeten düşük bulunmuştur; bu durum gölün Milli Park statüsü, kırsal konumu ve sınırlı endüstriyel/tarımsal faaliyetleriyle ilişkilendirilmektedir. Bununla birlikte, yakın çevredeki tarımsal faaliyetler, rekreasyonel kullanımlar ve Kovada Gölü'nün Eğirdir Gölü ile olan hidrolik bağlantısı, atmosferik taşınım ve yüzey akışı yoluyla özellikle filament tipi MP girişine katkı sağlamaktadır. MP bolluğu ve bileşimindeki mevsimsel değişimler, insan faaliyetleri ile yağış ve sıcaklık değişimleri gibi doğal süreçlerin ortak etkisini yansıtmaktadır. Bu çalışma, nispeten bozulmamış ekosistemlerde bile mikroplastik kirliliğinin izlenmesinin önemini vurgulamakta ve bölgedeki çevresel koruma stratejileri için değerli bir başlangıç verisi sunmaktadır.

Anahtar Kelimeler: Mikroplastik, Su Kirliliği, Kovada Gölü, Türkiye

Research Article

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1. Introduction

Plastic is a synthetic material that has become indispensable in modern life. Due to its affordability, excellent barrier properties against oxygen and moisture, biological inertness, and light weight, plastic has become one of the most versatile and widely adopted materials in the packaging sector (Ertaş, 2021; Shaikh et al., 2021; Rakib et al., 2022). While the widespread use of plastic significantly enhances quality of life, the mismanagement and improper disposal of plastic waste have caused serious ecological degradation (Dusaucy et al., 2021; Riberio et al., 2021; Ertaş et al., 2022a). The issue is further aggravated by inadequate solid waste management systems and intensified anthropogenic activities. Plastic materials are highly persistent in the environment, often remaining intact for several centuries (Kibria et al., 2023). Plastic debris enters aquatic ecosystems through multiple pathways, including surface runoff, wastewater effluents, and atmospheric deposition, ultimately accumulated in freshwater and marine environments (Schwarz et al., 2019). Once introduced, these materials undergo progressive fragmentation driven by a combination of environmental stressors, such as mechanical abrasion (e.g., wave-induced turbulence), ultraviolet (UV) photodegradation, and microbial activity, leading to the formation of increasingly smaller plastic particles (Ramakrishnan et al., 2025).

Microplastics (MPs), referring to plastic debris with dimensions from 0 to 5 mm, represent a growing environmental threat due to their pervasive occurrence across diverse habitats and their potential to exert toxicological impacts. Various human activities including plastic production and usage, domestic and industrial emissions, agricultural practices, marine aquaculture, shipping, and tourism contribute significantly to the increase in microplastic pollution in aquatic systems (Chen et al., 2024; Ding et al., 2024; Pinjia et al., 2025). The rising prevalence of MP contamination is closely linked to the rapid growth in global plastic production, which is projected to exceed 1.8 billion tons annually by 2050 (Conowall et al., 2023).

Transported by surface runoff, wind, and precipitation, MPs ultimately enter water bodies, effectively transforming these ecosystems into repositories of microplastic pollution. Most studies on MP contamination in freshwater environments have concentrated on rivers and lakes located near urban areas (Shi et al., 2023). In contrast, relatively little research has been conducted on aquatic systems situated in remote regions, far from human settlements and industrial zones. Lakes and reservoirs within or near cities are typically in proximity to residential and industrial sources, making them more vulnerable to MP inputs from sewage, runoff, and atmospheric deposition. Consequently, these sites often show higher MP concentrations due to the presence of both industrial and municipal wastewater, rendering them less suitable for distinguishing the influence of agricultural microplastic pollution in sparsely populated rural areas (Davis and Selvaraju, 2023; Pastorino et al., 2023).

Due to their large surface area-to-volume ratio and hydrophobic properties, MPs can act as vectors for the accumulation and transport of pesticides, organic pollutants, heavy metals, and pathogens. This makes them potential threats to human health (Immanuvel et al., 2023). Agricultural regions, particularly those with intensive pesticide use, are recognized as important sources of such contaminants. MPs generated from the degradation of agricultural plastic films may bind with these pollutants, posing serious risks to the environment, aquatic organisms, and public health (Colleen et al., 2022). Therefore, conducting comprehensive and systematic assessments of MP contamination in non-urban or peri-urban areas including rivers, lakes, sediments, and aquatic organisms such as fish is vital for safeguarding aquatic ecosystem health and ensuring long-term water security (Li et al., 2023).

Studies carried out in the Western Mediterranean Basin of Türkiye, known for its rich freshwater systems, have revealed that these ecosystems are increasingly exposed to diverse sources of pollution (Ertaş et al., 2021; Sukatar et al., 2021; Yorulmaz and Ertaş, 2021; Ertaş et al., 2022b, c; Ertaş and Yorulmaz, 2022; Ertaş et al., 2023, 2024; Yorulmaz et al., 2024). Although microplastic (MP) contamination in freshwater ecosystems of the Mediterranean region has been the focus of some research efforts globally, significant knowledge gaps persist, especially in geographically underrepresented areas such as the Mediterranean Basin of Türkiye. In response to this deficiency, the present study provides an assessment of MP pollution in Lake Kovada, a protected freshwater body with high ecological value. By systematically characterizing the abundance, morphology, and polymer composition of microplastics, as well as identifying their potential sources, this research contributes valuable baseline data essential for understanding the extent of pollution, informing management strategies, and guiding future monitoring and mitigation efforts in the region.

2. Materials and Methods

2.1. Study area and stations

This study was conducted in Lake Kovada, located within the Western Mediterranean Basin of Türkiye (Figure 1). The coordinates and site-specific characteristics of the sampling stations are summarized in Table 1. Sampling locations were selected based on proximity to potential pollution sources, accessibility, and the intensity of anthropogenic activities in the surrounding areas. The most frequently utilized areas throughout the year were prioritized for sampling. Lake Kovada, a critical surface water resource for the Isparta Province, is ecologically significant due to its surrounding forests and natural landscape. In recognition of its environmental value, the lake was designated as a National Park in 1970 and subsequently classified as a 'First-Degree Natural Protected Area' in 1992

(Kesici and Kesici, 2006). Situated at an elevation of 900 meters above sea level, Lake Kovada covers an area of approximately 900 hectares, with its primary inflow originating from the Kovada Canal, which connects the lake-to-Lake Eğirdir.

Figure 1. Study area and stations

Table 1 Coordinates and characteristics of sampling stations

Stations	Coordinates	Characteristics
K1	N37°38'53.86160 E30°52'15.65190	The Kovada Canal serves as the connection point between tl canal and the lake. The surrounding region is predominant characterized by agricultural land use and farming activitie Additionally, several villages are in the vicinity of the lake.
K2	N37°37'43.64920 E30°52'19.39020	The area encompasses recreational zones and a nature par while agricultural lands and farming activities represent tl
K3	N37°36'37.29310 E30°53'16.93070	dominant land use. In addition, several villages are located the vicinity of the lake.

The northern section of Lake Kovada was selected as the primary study site due to its environmental relevance and susceptibility to anthropogenic influences. This area includes the Kovada Canal, which transfers water unidirectionally from Lake Eğirdir into Lake Kovada, serving as a major pathway for potential pollutant input into the lake. Previous assessments indicate that the Kovada Canal carries a substantial pollutant load, increasing the vulnerability of this part of the lake to external contamination. Furthermore, the presence of recreational areas such as picnic sites, a nature park, and a beach leads to intense human activity throughout the year, further amplifying the anthropogenic pressure on this region. Consequently, this area was chosen to assess existing pollution levels and to establish baseline data that may guide future comprehensive monitoring and management efforts.

2.2. Microplastics isolation from lake water

The study was conducted in the summer and autumn seasons of 2024 across three sampling stations in Lake Kovada. Surface-water samples from the designated stations were collected using 2.5-liter bottles. During the sampling process, only clean and sterilized bottles were used to minimize external contamination; all bottles were carefully rinsed with distilled water before each sampling. These measures aimed to increase the reliability of the analyses by preventing potential contamination that might occur during sampling. The procedures for separating microplastics in the collected water samples were carried out following the method protocol developed by Coppock et al. (2017). The obtained samples were filtered through membranes with appropriate pore sizes. The filters were then examined in detail under a stereomicroscope, and microplastics were detected. During the identification and classification stages, the focus was on the morphological properties of microplastic particles such as shape, structure, and color—and the identification criteria proposed by Hidalgo-Ruz et al. (2012) and Viršek et al. (2016) were taken as the basis for this process. Microplastic particles detected on the filters were divided into six main categories according to their morphological structures: fragment, film, filament, granule, foam, and pellet.

2.3. Microscopic Examination and ATR-FTIR Spectroscopy

Following the isolation procedures, the samples, along with pre-cleaned and microscopically inspected empty glass petri dishes, were examined under the microscope. The number of plastic particles previously detected in the petri dishes was deducted from the total particle count to account for potential background contamination. Throughout the sampling process, all samples and glassware were covered with aluminum foil to minimize airborne contamination. Immediately after filtration, the filter papers were carefully transferred into petri dishes to further reduce the risk of external contamination. All filters were subsequently analyzed under a stereo microscope (Leica S8) at 40× magnification. During microscopic examination, all plastic particles were measured, and their size, color, and morphological types were systematically recorded.

After drying the plastic particles in an oven and conditioning them at room temperature for 2 days, polymer identification was conducted using ATR-FTIR spectroscopy. The analyses were performed in double reflection mode, with each spectrum collected at a scan rate of 16 scans per measurement, a spectral resolution of 2 cm^{-1}, and within the mid-infrared range of 400 to 4000 cm^{-1}. The polymer composition of the particles was determined by comparing the obtained spectra with reference data from the FDM polymer spectral library.

3. Results and Discussion

The present study provides original data on plastic pollution in freshwater ecosystems by revealing the presence, seasonal distribution, and morphological characteristics of microplastic (MP) contamination in the northern part of Lake Kovada—one of Türkiye's important protected freshwater resources. The findings enable an evaluation of both the seasonal variability in the physicochemical water quality of the lake and the distribution characteristics of MP particles.

As a result of this study, the total abundance of MP particles in Lake Kovada was determined to be 442 particles/m². The highest MP density was observed at station K1 (167 particles/m²), while the lowest was recorded at station K3 (29 particles/m²). Among the detected morphotypes during the summer and autumn sampling periods, filaments were the most frequently observed MP type, with the highest concentration also occurring at station K1 (227 particles/m²). When MP particles were classified according to color for both sampling seasons, black particles (221 particles/m²) were the most abundant, followed by red particles (92 particles/m²).

The overall abundance of microplastics (MPs) in the study basin was found to be comparatively low relative to reports from other freshwater ecosystems (Table 2). This observation may largely reflect the basin's geographical position, being partially distant from densely inhabited urban zones and subject to relatively limited anthropogenic pressures. Furthermore, spatial heterogeneity in MP concentrations across different freshwater environments is likely governed by a complex interplay of factors, including the proximity and nature of pollution sources, hydrodynamic conditions, prevailing wind regimes, population density, and the diversity of plastic polymer types present in the environment (Mani et al., 2015; Xiong et al., 2018; Luo et al., 2019)

One of the most important reasons for the low MP rates in Lake Kovada is probably the low density of human activities in the settlements around the lake. Lake Kovada is protected as a National Park and the factors that can increase the sources of microplastics such as industry, agriculture or dense settlement are quite limited in its surroundings.

Table 2. Microplastic pollution in freshwater resources

Study area	Country	Mesh size (μm)	MP abundance (m²)
Tuna River (Lechner et al., 2014)	Austria	500	141.65
Seine and Marne River (Dris et al.,2015)	France	80	1.08×10^{-1}
Siling Co Lake (Zhang et al., 2017)	China	500	563 ± 1219
Ofanto River (Campanale et al., 2020)	Italy	333	$1.3\times10^{-2} \pm 5\times10^{-3}$

Victoria Lake (Egessa et al., 2020)	Tanzania	300	120,588
Cevdet Dündar Pond (Erdoğan, 2020)	Türkiye	61	233
Sassolo Lake (Velasco et al., 2020)	Switzerland	500	33
Han River (Park et al., 2020)	South Korea	100	$4.29x10^{-2}$
Veeranam Lake (Bharath et al., 2021)	South India	-	92 ± 604
Ems River (Eibes and Gabel, 2022)	Germany	250	5.28×10^{-3}
Anchar Lake (Neelavannan et al., 2022)	India	50	233 ± 1533
Maracanã River (Drabinski et al., 2023)	Brazil	300	3651.5
Balaban Lake (Ertaş et al., 2024)	Türkiye	50	477
Kovada Lake (Present study)	Türkiye	50	442

Filament- and fragment-type microplastics (MPs) were identified as the predominant categories across all sampling stations. Fragment MPs, which typically represent larger plastic debris, are primarily derived from the breakdown of consumer products such as beverage bottles, discarded containers, market packaging, food-related materials, and office waste (McCormick et al., 2014; Hartmann et al., 2019). In contrast, filament-type MPs may originate from both primary and secondary plastic sources (Peters and Bratton, 2016). Global production of filament-based textile materials exceeded 90 million tons in 2016 (Gasperi et al., 2018), and domestic wastewater effluents, particularly those generated from washing machine discharges, are recognized as major contributors of synthetic filaments to aquatic environments (Salvador et al., 2017). Although Lake Kovada is geographically distant from major urban centers and its surrounding settlements are characterized by low population density, the higher prevalence of filament-type MPs relative to fragments suggests the potential influence of atmospheric deposition (wind transport) and hydrological events (flooding) in mobilizing and introducing these particles into the basin. Gasperi et al. (2015) determined 29–280 particles/m²/g filament-type MPs in atmospheric fallout in their study. Macroplastic products discarded along the shores of Lake Kovada may be another source of filament-type MPs.

MP particles of different colors were observed in the samples, and the most frequently observed colors were black and red. Similar studies in the literature support these findings. Özkor (2022) drew attention to the density of filament-type microplastics in black, blue, and white colors in his study conducted in the Kızılırmak River and stated that these particles mostly derived from domestic waste. Similarly, in the study conducted by Şahutoğlu (2022) in the Asi River, it was reported that the abundance of microplastics increased significantly, especially in areas close to city centers and in areas where drainage channels were located. In this study, it was stated that a large part of the microplastics detected were in film form and generally blue in color. Although white is a prevalent color in numerous plastic consumer products, multiple studies have demonstrated that blue can often dominate in microplastic (MP) contamination profiles, particularly in aquatic environments (Devriese et al., 2015; Young and Elliott, 2016; Güven et al., 2017; Karlsson et al., 2017; Zhang et al., 2017; Kosuth et al., 2018; Li et al., 2019; Erdoğan, 2020; Ren et al., 2020). In contrast, the present findings from Lake Kovada revealed a clear dominance of black-colored MPs. This pattern is likely linked to the long-term environmental degradation and weathering of black-colored waste materials, which may fragment more extensively under UV exposure and oxidative processes, resulting in higher MP generation. Similar observations of black MP predominance have been reported in other freshwater and marine systems, underscoring its common occurrence in aquatic ecosystems subjected to prolonged waste accumulation (Ren et al., 2020; Young and Elliott, 2016). Red and white particles were the second and third most abundant color categories, respectively. The significant presence of white MPs can be largely attributed to the frequent use of white-colored disposable bags in recreational activities around the lake. The considerable proportion of red MPs may reflect the accumulation of beverage bottles, many of which are manufactured with distinctive red caps. Importantly, previous research has highlighted that certain aquatic organism exhibit color-selective feeding behaviors, with a particular tendency to ingest red-colored microplastics (Devriese et al., 2015; Güven et al., 2017; Karlsson et al., 2017). Such selective ingestion raises ecological concerns, as it may exacerbate the bioavailability and trophic transfer potential of red-colored MPs within aquatic food webs. These observations emphasize not only the significance of color profiles in microplastic pollution assessments but also their potential biological implications for aquatic ecosystems.

The results of ATR-FTIR analysis performed to determine the polymer types of microplastics are isolated from the sampling points are shown in Figure 2 and Figure 3.

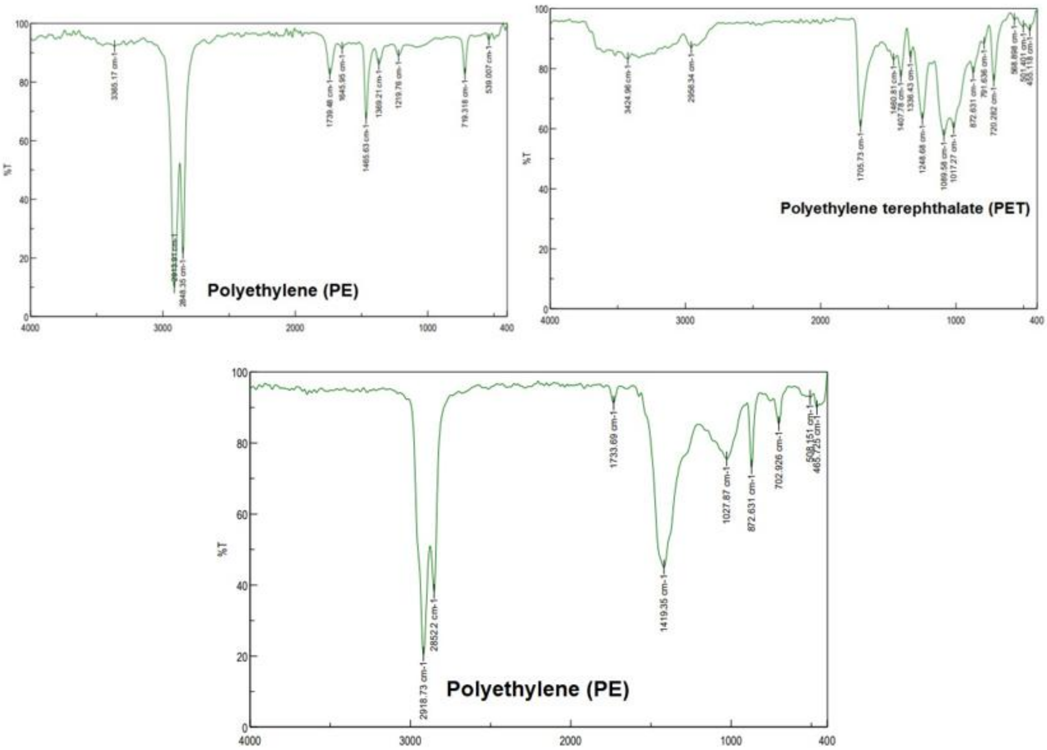

Figure 2. FTIR spectra of MP particles from summer season

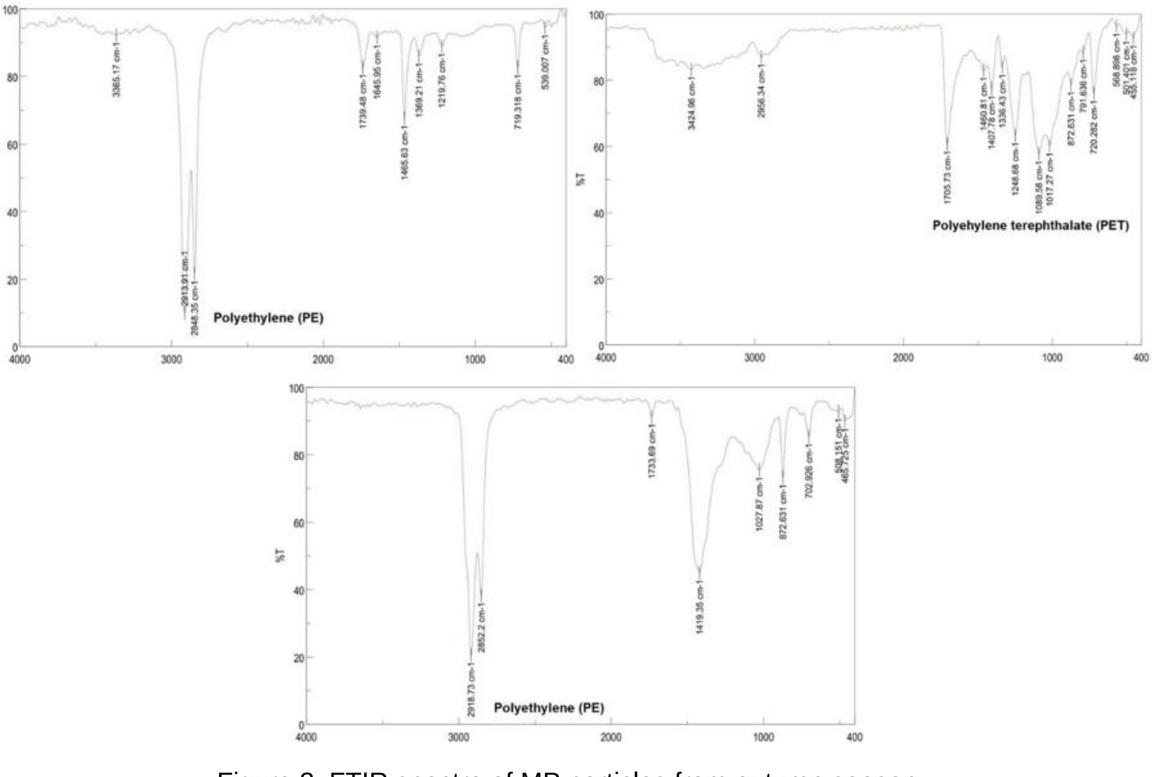

Figure 3. FTIR spectra of MP particles from autumn season

ATR-FTIR spectroscopy is a widely applied and effective method for identifying the polymer composition of microplastics (Rochman et al., 2014; Desforges et al., 2014; Miranda and de Carvalho-Souza, 2016; Gündoğdu and Çevik, 2017; Blettler et al., 2017; Cincinelli et al., 2017; Tsang et al., 2017; Primpke et al., 2018; Wen et al., 2018; Prata et al., 2019; Corami et al., 2020; Erdoğan, 2020). In many earlier studies, microplastic identification was performed solely through visual inspection (Rochman et al., 2014; Miranda and de Carvalho-Souza, 2016; Erdoğan, 2020).

However, more recent research increasingly incorporates spectroscopic techniques such as µ-Raman or FTIR alongside microscopic examination to enhance the reliability of polymer classification (Gündoğdu and Çevik, 2017; Tsang et al., 2017; Primpke et al., 2018; Wen et al., 2018). Nevertheless, the high cost and time-consuming nature of these techniques often limit the number of particles that can be analyzed. In alignment with previous studies, polyethylene (PE) and polyethylene terephthalate (PET) were identified as the dominant polymer types in Lake Kovada. PET is commonly encountered in aquatic ecosystems due to its extensive use in products such as beverage bottles, plastic bags, and containers (Desforges et al., 2014). According to Blettler et al. (2017), PET originating from beverage bottles constitutes a major source of microplastic contamination in aquatic systems; however, knowledge regarding the effects of PET in freshwater environments remains limited.

In general, the amount of microplastic detected in Lake Kovada indicates that the lake tends to accumulate contaminants due to its closed-basin structure. In addition, the high proportion of filament-type particles supports the inference that pollution sources in the region are mainly textile- and domestic-waste-based. Seasonal variations clearly demonstrate that human activities and natural processes (e.g., precipitation, temperature change) play important roles in microplastic dynamics.

In the case of Lake Kovada, the high microplastic density observed particularly near the channel connection point clearly reveals the impact of human activities in the region, including agriculture, animal husbandry, and waste discharge from residential areas. Microplastics transported into the lake together with terrestrial pollution inputs especially during rainy periods—constitute a mechanism supporting the seasonal increase in pollution. In a study conducted by Kalyoncu et al. (2009) on the Isparta Stream, it was similarly emphasized that the organic pollution increasing with rainfall is of terrestrial origin. Furthermore, studies carried out by Zeybek et al. (2014) on the Değirmendere Stream near the Kargı Stream, and Zeybek (2017), revealed that water quality is highly sensitive to external pollution pressures.

4. Conclusion

In conclusion, this study conducted in Lake Kovada has provided important data on the presence and distribution of microplastic pollution in freshwater ecosystems; it has also drawn attention to the effects of this pollution on ecosystem health. The findings strongly suggest that sustainable environmental policies should be established, effective monitoring programs should be developed, and advanced research should be supported to protect freshwater systems. Such studies provide a scientific basis for determining the sources of microplastic pollution and developing strategies to reduce this pollution. For example, measures such as replacing plastic materials used in agriculture and animal husbandry activities with more sustainable alternatives or improving waste management systems can be taken. In addition, better management of the connection between Lake Eğirdir and Lake Kovada can reduce microplastic transport.

The ecosystem of Lake Kovada stands out as an area worth protecting due to its rich biodiversity and natural beauty. Therefore, preventing environmental threats such as microplastic pollution will not only support the ecological health of the lake, but also the economic and social sustainability of the region.

This study underscores the need for targeted environmental monitoring in protected freshwater ecosystems and highlights the importance of controlling diffuse MP sources. The findings contribute valuable baseline data for future pollution assessments and emphasize the necessity of developing region-specific mitigation strategies, particularly in ecologically sensitive areas like Lake Kovada.

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6. Compliance with Ethical Standard

a) Author Contributions

1. MZY: Methodology-formal analysis and investigation, Writing-original draft, Writing-review & editing, Conceptualization, Funding acquisition,
2. İ.Ş: Formal analysis- investigation, Writing-original draft, Visualization, Funding acquisition;
3. A.E: Investigation, Visualization, Data curation, Writing-original draft, Writing-review & editing, Supervision; 4. Ö.E: Investigation, Visualization, Supervision

b) Conflict of Interests

There is no conflict of interest, according to the authors.

c) Statement on the Welfare of Animals

Not relevant,

d) Statement of Human Rights

There are no human subjects in this study.

e) Declaration of Not Using AI

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

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