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Research Article

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Microplastic Accumulation in Lake VAN Sediment

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Abstract

The impact of microplastics on ecosystems and living organisms is an issue of increasing concern. In this study, sediment samples collected from 3 different stations in 4 settlements on the shore of Lake Van in October 2021 were analyzed for the presence of 4 different types of microplastics, namely LDPE, PP, PS, and PET. Methods such as sieve filtration, organic matter removal and density separation were used to isolate microplastics in the collected samples. After isolating microplastics from the samples, visible microplastics were detected and photographed in the relevant samples, bacterial density was measured with microbiological analysis, microplastic particles were measured with a sensitive balance, the color and shape of microplastics were examined with a stereomicroscope, and microplastic particles were identified with FTIR spectroscopy. The spectra obtained from the sediment samples were compared with reference peaks in KnowIt All and the Spectroscopy Online virtual library and PS was identified as the predominant polymer type. When microplastic was analyzed, it was determined that the predominant microplastic form was white/transparent and the microplastic size was between 3 and 5 mm. As a result of microbiological analyses, the presence of Escherichia coli (6/2 100 cfu/ml) was detected in the water samples of Van1 and Erciş1 lakes, and the highest total coliform bacteria count was found in Erciş2 lake. In this study, information about the presence of microplastics in sediment, which is one of the elements of Lake Van aquatic ecosystem, was obtained.

Keywords: Aquatic Ecosystems, Food Safety, FTIR, Human Health, Lake Van, Microplastic, Sediment

1. Introduction

Plastics are synthetic polymers originating from petroleum and its derivatives, serving as ubiquitous raw materials in our daily lives [1]. Their widespread use is attributed to their ease of processing, chemical resistance, cost-effectiveness compared to alternative materials, and simplicity of production [2, 3]. Plastics finds applications across diverse sectors, ranging from the automotive industry, construction, and medical fields to packaging, sports equipment, and household and kitchen appliances [4]. The prevalence of plastics in nearly every facet of modern life has led some scientists to characterize the present era as the 'plastic age' [5, 6].

Due to the biodegradable nature of plastics and improper waste management, there has been an intense accumulation of plastic almost everywhere in nature [7]. Several studies have revealed the presence of plastic particles in various environments, including the air [8], glaciers [9], soil [10], table salt [11], nearly all surface waters [12], and even in the Mariana Trench, recognized as the deepest point in the world at 10,994 meters [13].

Over time, plastic particles discarded into nature undergo decomposition into smaller fragments influenced by external factors. These plastic particles, measuring less than 5 mm, are termed microplastics. The degradation rate of plastics varies based on the size of the original plastic and the type of polymer [14]. The process of plastics breaking down into microplastics involves five main types: biodegradation (decomposition by microorganisms), photodegradation (through exposure to UV light), thermal

degradation (due to high temperature), thermo-oxidative degradation (slow oxidative degradation), and hydrolysis (through reaction with water). Microplastics can be categorized into five shapes: fibers, foams, films, fragments, and microbeads [15].

Microplastics can infiltrate aquatic ecosystems through various pathways, with a significant portion originating from terrestrial sources. The transportation of plastics is notably facilitated by rivers and winds [16, 17]. Plastics accumulating in the sediments of aquatic ecosystems gradually transform into microplastics and find their way into the water. Microplastics have been identified in sediment samples from several lakes, including Lake Onego (the second largest lake in Europe), Lake Anchar in the Northwest Himalaya, Lake Ziway in Africa, and Lake Ontario in Canada [18-21].

These accumulated microplastic particles act as pollutants, gradually entering the food chain and becoming integral to the aquatic ecosystem over time. Microplastics have the potential to transfer from plankton to fish, with fish ingesting them as part of their diet [22]. The presence of microplastics has been observed in various fish species across different aquatic ecosystems. Considering that global fish consumption totals 156 million tons annually, humans, likely positioned at the end of the food chain, are inevitably affected by this situation. The relationship between fish, human exposure to microplastics, trophic transfer, and potential health implications is a crucial issue that warrants thorough examination [23].

The verified existence of microplastics in aquatic ecosystems and fish warrants meticulous scrutiny concerning environmental impact, food safety, and human health. While numerous studies have explored microplastics in the Marmara Sea [24], the Mediterranean Sea [25], the Black Sea [26], and the Aegean Sea [27] in Turkey, research on Lake Van, the country's largest lake, remains limited. There is a need to investigate the extent of microplastic exposure in Lake Van's aquatic ecosystem, potential food safety implications arising from this exposure, trophic transfer to humans, and potential health issues resulting from this transfer. A comprehensive examination of microplastic dynamics in Lake Van is crucial for understanding and addressing the broader environmental and health implications in the region.

Therefore, the aim of this study was to investigate the presence of microplastics in the sediment of Lake Van, a source of food, livelihood, and bathing for the people of the region. This study will provide an opportunity to raise awareness and inform people living in the coastal areas of Lake Van about this microplastic pollution. In October 2021, four settlements/districts were selected, namely Van, Tatvan, Gevaş and Erciş. Sediment samples (lake bottom sediment) were collected from three different stations in each of the selected settlements and this collection process was carried out in three parallel situations. In addition, lake water samples were collected from the same stations for microbiological analysis.

2. Material and Method

2.1. Sampling Stations and Collection of Samples in Lake Van

In October 2021, four settlements on the shores of Lake Van were selected. These settlements are Van, Tatvan, Gevaş, and Erciş. Sediment samples (lake bottom sediment) were collected from three different stations at each of the mentioned settlements and the collection process was carried out in three parallel samples. Additionally, lake water samples for microbiological analysis were also collected from the same stations. The selection of settlements and the parallel sampling approach provide a comprehensive framework for assessing the distribution of microplastics in Lake Van sediment and its potential correlation with microbiological parameters in the lake water.

The GPS coordinates of the stations are presented in Table 1 and their locations are shown on the map in Figure 1. During sample collection, points of potentially intense human activity were deliberately selected. Cotton clothing and nitrile gloves were worn to prevent plastic contamination during the process. The sediment samples collected from the shore were transported to the laboratory in a kg glass jar with metal lids, using metal spoons and maintaining the cold chain. A 100 ml portion was taken from each collected lake water sample.

2.2. Microplastic isolation from sediment samples

Microplastic particles in sediment samples collected from 3 stations in 4 settlements were categorized according to their size. The primary objective was to exclude particles larger than 5 mm, which is an important criterion for identifying microplastics. For this purpose, stainless steel sieves with pore sizes of 5 mm, 1 mm, 0.3 mm, and 0.125 mm were used. Rigorous precautions were taken to avoid plastic contamination during both the sample processing and analysis phases. Laboratory equipment was thoroughly rinsed with distilled water before use and researchers wore cotton lab coats to minimize plastic contamination. The work area was kept closed and no windows or doors were opened during procedures. With a few exceptions, glass and metal materials were preferred over plastic whenever possible.

In the first analysis step, a sieve system was created by ordering the sieves from the largest pore size to the smallest. Before the sediment samples were poured into the 4-stage sieve system, they were shaken vigorously, and the glass jars were sprayed with distilled water to transfer all available material to the sieve system. Non-plastic materials such as stones, grass and glass were physically removed. Sediment samples were labelled according to the relevant settlement and station code. After the samples were classified into 1 mm, 0.3 mm and 0.125 mm sizes, the sediments remaining on the sieve surface were collected in glass jars using distilled water. Residues on the 5 mm sieve surface were excluded from the analysis as they did not meet the size criteria for microplastics.

Methods derived from Budimir et al. [28], Sainio et al. [29] and Thiele et al. [30] were adapted and applied for the removal

of organics from sediment samples. The most important aspect was to remove organics using chemicals at concentrations and temperatures that would not damage the microplastic particles. The collected samples were treated with 30 ml of 10% potassium hydroxide (KOH) per sample using a heated magnetic stirrer set at 40°C and 450 rpm for 60 min. Following this, sediment samples were mixed with 5 ml of 30% hydrogen peroxide (H_2O_2) per sample for 15 min using a heated magnetic stirrer set at 40°C and 450 rpm. The samples were then mixed with 20 ml of 0.05 mol ferrous sulphate (Fe_2SO_4) for 60 min at 40°C and 450 rpm using a heated magnetic stirrer. After these treatments, the sediment samples were oven dried in glass jars at 50°C for 24 h [28-30].

2.3. Decontamination and filtration of samples

The dried sediment samples were rinsed with distilled water on filter paper to remove any remaining chemicals. This step was crucial to obtain accurate measurements for plastic/microplastic identification, especially since FTIR analysis was planned for the samples. Sediment samples were allowed to drain on filter papers. After completely filtered, the samples were dried together with the filter paper in an oven at 50°C for 24 h. This process prepared the samples for further analyses [28, 30].

2.4. Isolation and Quantification of Microplastic Particles from Sediment Samples with Chloroform

Following removal of organic matter, elimination of chemicals and drying of sediment samples on filter paper, chloroform was used to bring microplastic particles in the sediment to the surface. A modified method based on Papini et al. [31] was used in this analysis. Samples were treated with chloroform, dissolved, and placed in glass tubes. The tubes were then vortexed for 1-2 minutes and allowed to rise to the surface for 2 minutes due to the gradient difference created by chloroform. Then, centrifugation was performed at 5000 rpm for 5 min to allow the sediment to settle to the bottom completely. To collect the microplastics remaining in the chloroform, the supernatant was carefully removed with a micropipette and transferred to new tubes. To remove chloroform, ultrapure water was added at a ratio of 1:1 and the centrifugation process was repeated. This step was repeated several times until the chloroform was completely removed. Chloroform-free samples were then oven dried at 50°C for 24 h and then weighed using a precision balance.

2.5. Microscope Examination of Samples

The microplastics isolated from the sediment samples were analyzed using the TT-TECHNI-C Binocular Stereo model microscope. These microplastics, placed on a slide, were measured for size using a millimeter ruler. The samples were then examined under a light microscope at x2 magnification. Microplastics were categorized based on number, color, and form. To group microplastics by size, ranges of <0.5 mm, 0.5-1 mm, 1-3 mm, and 3-5 mm were established. The ImageJ program from the National Institutes of Health was employed for the categorization of microplastics within the defined size ranges [31].

2.6. Fourier Transform Infrared Spectroscopy (FTIR) Analysis

FTIR spectroscopy was utilized to analyze the collected sediment samples and identify the type of microplastic polymer present in the samples. For the FTIR analysis, sediment samples were placed in Agilent Cary 630 and analyzed using Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) technique. The instrument parameters were set with a spectral range of 4000-500 cm^{-1}, a background scan repeated 16 times, sample scan repeated 16 times, and resolution set at 8 cm^{-1}. The obtained spectra were processed using Origin 2021 version (OriginLab Corporation, USA), and graphs were generated. These graphs facilitated the analysis of the presence of microplastics derived from LDPE, PP, PS, and PET. Reference peaks for the identification of these microplastics were based on data obtained from the Spectroscopy Online site [32].

2.7. Enumeration of Generic *Escherichia coli* and Total Coliform Populations in Lake Water Samples by Membrane Method

A 100 ml aliquot of each collected lake water sample was extracted, and this process was repeated three times. The samples were then vacuum filtered through cellulose filter papers (Millipore, Billerica, MA, USA) with a pore size of 0.45 µm. These filter papers were then carefully placed on CHROMagar™ (ECC, Paris, France) using sterilised forceps. Samples were incubated at 35-37°C for 24 h. After the incubation period, distinctive colonies on the selective medium were identified and counted as generic Escherichia coli and total coliforms [33].

2.8. Statistical Analysis

The spectra obtained from FTIR spectroscopy analysis used for the identification of polymers in the investigated samples were processed using Origin (Version 2021, Massachusetts, USA). In addition, two-way ANOVA analysis was performed on the spectra using JAPS software. For statistical analyses, a significant level of $p<0.05$ was considered as an indicator of a significant result.

3. Results and Discussion

3.1. Sampling Stations and Collection of Samples in Lake Van

In this study, four settlements on the shores of Lake Van were selected in October 2021. These settlements are Van, Tatvan, Gevaş, and Erciş. Lake water and sediment (lake bottom sediment) samples were collected from three different stations within the designated settlements (Figure 1, Table 1). Microbiological analysis was conducted on lake water samples, and the presence of microplastics was investigated in sediment samples.

Figure 1: Map locations of stations where sediment samples were collected for microplastic analysis

Station code	Station name	GPS coordinate information
Van1	Tuşba Kordon	*38.52761144383133, 43.318230138529074*
Van2	Kampüs Sahil	*38.5609453442602, 43.2790568411033*
Van3	15 Temmuz Şehitler Parkı	*38.520585642191335, 43.31729835508139*
Tatvan1	Sahil Park	*38.497232820531806, 42.29422033001634*
Tatvan2	Fuar/ Lunapark	*38.490247419736285, 42.29543363584693*
Tatvan3	İskele	*38.491262849295374, 42.29507234720348*
Gevaş1	Akdamar İskelesi	*38.309167373747485, 43.039822639428195*
Gevaş2	Çetin Kamping	*38.32611257271536, 42.981734766231185*
Gevaş3	Akdamar Piknik	*38.32233056345922, 42.98220946253595*
Erciş1	Öğretmenevi/Lunapark (Gezi bandı)	*38.997562023632256, 43.4174109224879*
Erciş2	Eriş Atık Su Arıtma tesisi	*38.984043604949335, 43.366443760223206*
Erciş3	Bitlis Van Yolu	*38.9441994483381, 43.1226463036969*

Table 1: Stations sampled for microplastic analysis and coordinate information.

3.2. Microplastic Isolation from Samples

Some examples of the microplastics that are visible during the sieving of the collected sediment samples are shown in Figure 2. The microplastic particles were then isolated from the sediment samples after removal of organic matter using chloroform and weighed accurately with a balance and quantified in micrograms (µg). The enumeration of microplastics isolated from the sediment samples was conducted using a stereo microscope, and their morphotypes were categorized based on their color and form.

Analyses of the plastic and microplastic particles indicate that the source of these particles is probably related to human activities entering the aquatic ecosystem. According to the Group of Experts on Scientific Aspects of Marine Environmental Pollution

(GESAMP), in 2015, about 80% of microplastic particles in the aquatic environment originated from terrestrial sources [34, 35].

Figure 2. Microplastics isolated from some sediment samples

The data obtained by weighing and averaging the microplastic particles isolated from sediment samples using chloroform with a precision balance are presented in Table 2. As a result of the analysis, Tatvan region showed the highest weight, which is a surprising result considering the population of the compared settlements. Literature studies show that there is a positive correlation between the amount of microplastics and population [29, 36]. This unexpected result found in Tatvan may be attributed to the high number of daily visitors from neighboring provinces, the popularity of the region, the presence of many cafes, restaurants and parks along the shore, the visitor activities concentrated in certain areas and the collection of samples from these densely populated areas. The significant accumulation of plastic in the aquatic ecosystem of Lake Van, which can be seen even without magnification, can be attributed to the lack of environmental awareness. There is growing concern about the risks to human health from exposure to microplastics. However, empirical data on exposure and associated hazards still need to be improved. Therefore, more research-based evidence is necessary to fully understand the impact of microplastic exposure on human health. This study concludes that microplastic pollution around Lake Van will likely have negative effects on human health. Raising environmental awareness, addressing the factors that contribute to microplastic accumulation, and implementing necessary legal regulations will help mitigate these risks [37, 38].

Station code	**Sieve Pore Diameter**		
	1 mm	**0.3 mm**	**0.125 mm**
Van1	1.8 µg	1.1	0.7 µg
Van2	30.5 µg	5.4 µg	3.9 µg
Van3	17.4 µg	3.1 µg	2.9 µg
Van Average	**7.4 µg**		
Tatvan1	324.5 µg	6.4 µg	0.7 µg
Tatvan2	74 µg	10.3 µg	0.5 µg
Tatvan3	27.5µg	1.4 µg	0.3 µg
Tatvan Average	**49.5 µg**		
Erciş1	3.9 µg	1.6 µg	0.1 µg

Erciş2	12.3 µg	1.2 µg	0.1 µg
Erciş3	4.7 µg	1.6 µg	0.4 µg
Erciş Average	**2.8 µg**		
Gevaş1	18.8 µg	2.2 µg	1.4 µg
Gevaş2	41.3µg	1.3 µg	1.1 µg
Gevaş3	1.9µg	1.4 µg	1.0 µg
Gevaş Average	**7,8 µg**		

Table 2. The results of weighing microplastic particles isolated from sediment samples (µg).

3.3. Examination of Samples with Stereo Microscope

Microscopic techniques are the most used methods for the physical characterization of microplastics (MPs), as they provide detailed structural information essential for identification [39]. The capable of extracting various information from microplastic (MP) images, including morphological, optical, and chemical features. For example, thickness, surface roughness, refractive index, and birefringence of plastic materials can be simultaneously determined along with their spectral response [40-42]. The microplastic particles isolated from the sediment samples were analysed after removal of organic matter and photographed using a stereo microscope. Some of the photographs and the station codes where the samples were taken are shown in Figure 3.

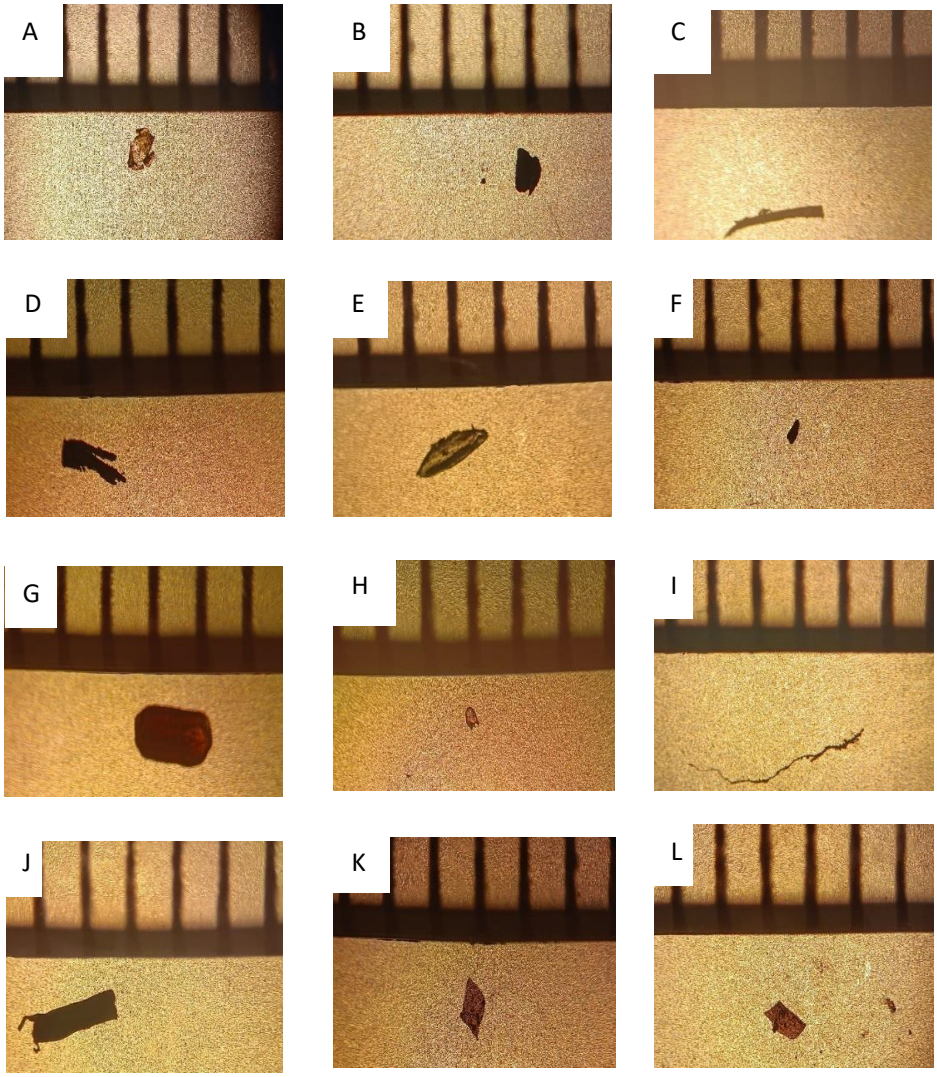

Figure 3. Microplastics examined and photographed with a stereo microscope.
A) film isolated from Van1 station, B) fragment isolated from Van2 station, C) film isolated from Van3 station, D) fragment isolated

from Tatvan1 station, E) film isolated from Tatvan2 station, F) fragment isolated from Tatvan3 station, G)fragment isolated from Gevaş1 station, H) film isolated from Gevaş2 station, I) fiber isolated from Gevaş3 station, J) fragment isolated from Erciş1 station, K) film isolated from Erciş2 station, L) film isolated from Erciş3 station.

The microplastics analysed by stereo microscope were counted and the total number of microplastics detected at the stations is given in Figure 4. According to the data, the highest number of microplastics was detected at Tatvan3 station with 16 microplastics. A total of 93 microplastic particles were detected in all sediment samples collected.

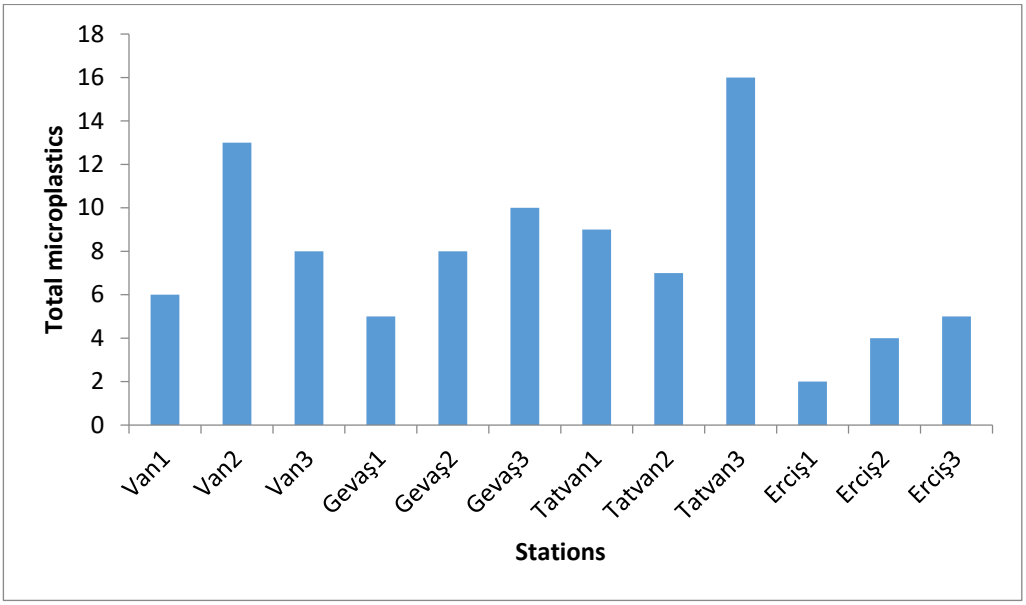

Figure 4. Total Number of microplastics detected and microscopically identified at stations

Various forms of microplastic particles were detected in the analysed sediment samples. Microplastics found in sediment samples can be categorized into five types: fibres, foam, films, fragments, and microbeads [43]. Considering these data, microplastic forms were analysed and the related proportional data are shown in Figure 5. When the microplastic forms detected at all stations were analyzed, it was determined that the dominant form was fragment with 45%, followed by the film form with 34%. Proportional data regarding this determination are given in Figure 6. Kaushik et al. reported that the fibres were found to be the dominant species with a contribution of 40–41 % among all the MPs, followed by fragments and films with 31 % and 28 %, respectively, in 2016 and 35 % and 25 %, respectively in 2020 in their study [44].

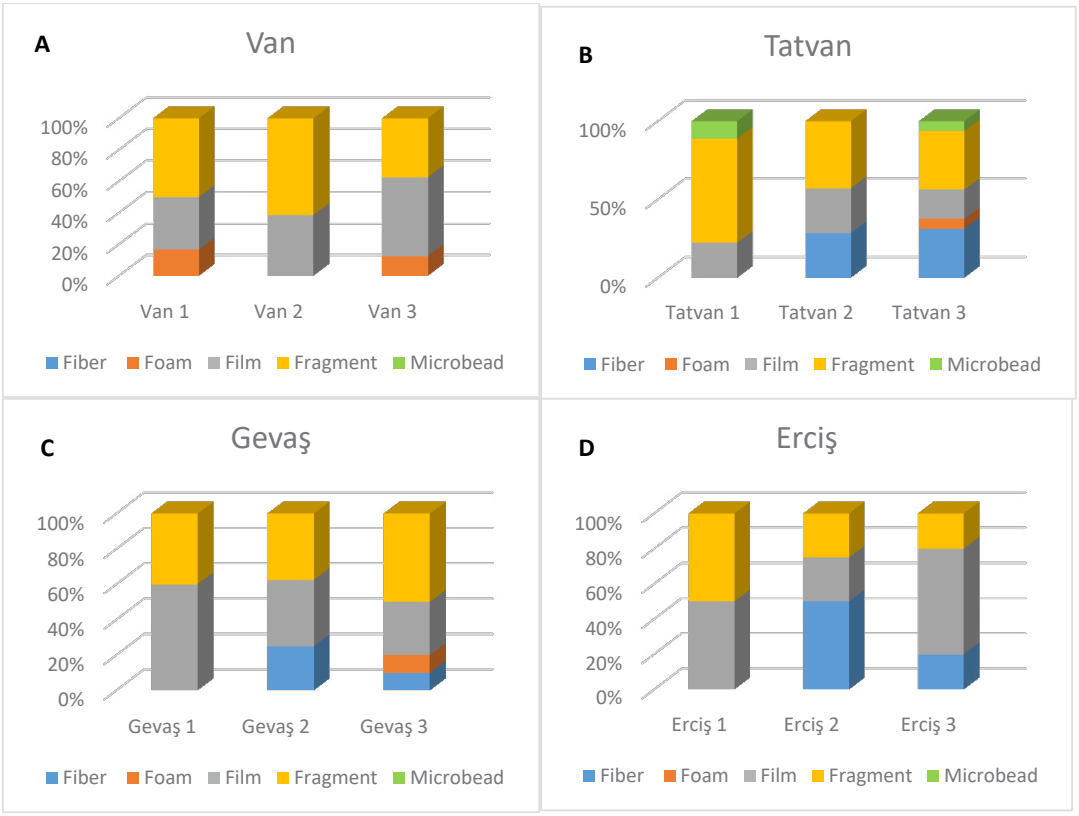

Figure 5. Proportional data on the forms of microplastics by stations. A) Van, B) Tatvan, C) Gevaş, E) Erciş

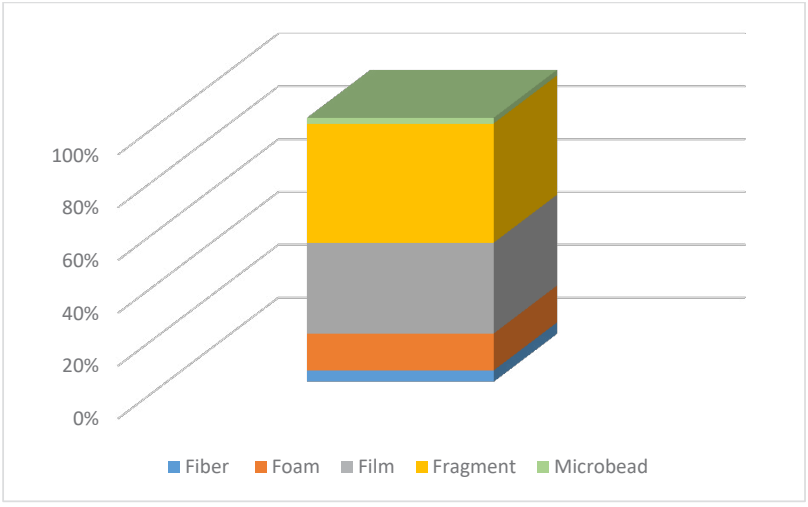

Figure 6. Proportional data on the forms of all microplastics detected at the stations

When wastewater is discharged into aquatic ecosystems, it is often unfiltered and released directly into aquatic environments [45]. Lake Van is one such aquatic environment where this direct release occurs. Studies have indicated that synthetic polymers, such as polyester used in clothing production, release microplastic fibers into the environment during washing. It is believed that these microplastic fibers subsequently enter the sewage system and then reach aquatic ecosystems [46-51]. The source of the detected microplastics in the form of fibers can be attributed to polymer-derived clothes washed with washing machines [52]. Microplastic transfer to aquatic ecosystems is also possible through fishing activities [45]. Fishing activities may be one of the sources of microplastics in fiber form that we detected in the study.

Some studies suggest that microplastics tend to float or sink according to their density after entering the water environment, and microplastics that are denser than water is likely to accumulate on the water floor [53, 54]. Analyzing sediment samples is

important in this regard. Microplastics have been detected in lake water in studies conducted in lakes around the world such as Lake Victoria in West Africa, Lake Taihu in China, Lake Superior in the USA [55-57]. Considering the studies, it can be concluded that microplastics in lake water may accumulate in sediments. Although only sediment samples from Lake Van were analyzed in this study, microplastics threaten all living and non-living elements in aquatic ecosystems. They pose a threat to various species living in aquatic ecosystems, such as phytoplankton, zooplankton, and seabirds [58].

As can be understood from the colored plastics we see in our environment, microplastics can be in many different colors [59]. In this study, microplastics were detected in different colors such as red, black, blue, green, white/transparent, and yellow. Microplastic colors were categorized according to these 6 colors and the proportional data according to the stations are given in Figure 7. As shown in Figure 7, 50% white/transparent microplastics were found to be the dominant color in all sediment samples examined. It is thought that these mostly originated from plastic water bottles and shopping bags. This ratio is followed by blue colored microplastics with 22%.

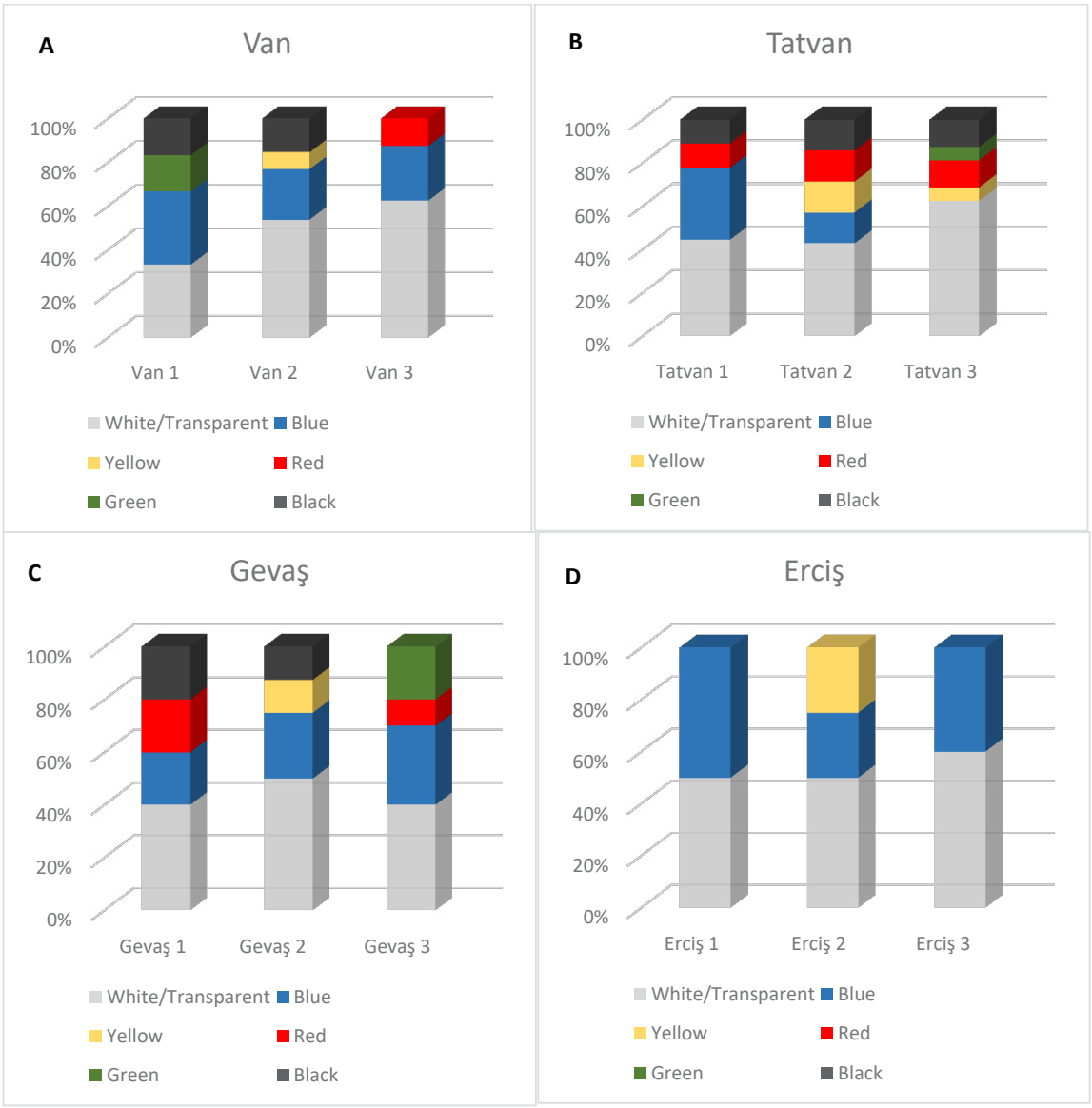

Figure 7. Proportional data of microplastic colors according to stations A) Van, B) Tatvan, C) Gevaş, E) Erciş

Microplastics were photographed under a stereo microscope with a scale and ImageJ (National Institutes of Health) software was used to categories these photographs according to sizes ranging from <0.5 mm, 0.5-1 mm, 1-3 mm, and 3-5 mm. The numbers of microplastics detected because of their classification according to their size are given in Table 3.

Station code	Size Range				
	<0,5 mm	0,5-1 mm	1-3 mm	3-5 mm	Total Particle
Van1	2	1	2	1	6
Van2	0	6	4	3	13
Van3	0	0	4	4	8
Gevaş1	0	0	5	0	5
Gevaş2	5	1	2	0	8
Gevaş3	0	0	0	5	10
Tatvan1	3	0	2	4	9
Tatvan2	0	0	3	4	7
Tatvan3	5	1	5	5	16
Erciş1	0	0	1	1	2
Erciş2	0	1	0	3	4
Erciş3	0	0	2	3	5

Table 3. Categorizing microplastics according to their size

The proportional data regarding the categorization of microplastics in sizes ranging from <0.5 mm, 0.5-1 mm, 1-3 mm, and 3-5 mm were examined according to the settlement areas and are given in Figure 8.

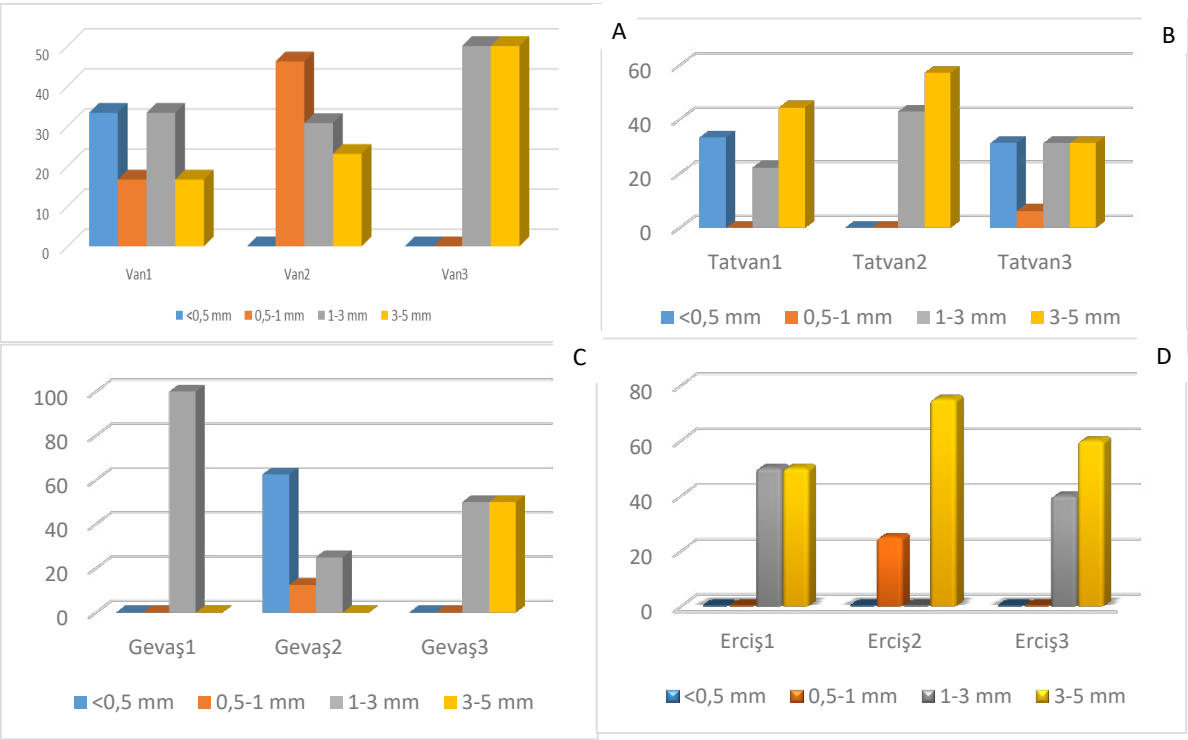

Figure 8. Size categorization of microplastics detected at stations. A) Van, B) Tatvan, C) Gevaş, D) Erciş

When the microplastics detected at Van1 station were analyzed; the ratio of <0.5 mm and 1-3 mm microplastics was found to be 33%. When the microplastics detected at Van2 station were analysed, the ratio of microplastics in the range of 0.5-1 mm was determined as 46%. At Tatvan1 station, the ratio of microplastics in the range of 1-3 mm was 22%, and the ratio of microplastics detected at Tatvan2 station in the range of 3-5 mm was 57%. At Gevaş2 station, the ratio of microplastics smaller than 0.5 mm was determined as 62%. At Erciş2 station, the ratio of microplastics in the range of 3-5 mm was determined as 75%.

3.4. Fourier Transform Infrared Spectroscopy (FTIR) Analysis of sediment samples

The presence of LDPE, PP, PS, PET derived microplastics was analyzed in these graphs obtained because of FTIR analysis of the collected sediment samples. The data obtained from the Spectroscopy Online site were used as reference peaks for the presence of these microplastics (Smith, 2022). These reference peaks were compared with the peaks obtained because of FTIR analysis and if there is a peak in the absorbance range of ±20 cm -1, it is assumed that the peak examined in the analyzed sample is present. The presence of peaks was expressed as (+) and their absence as (-). A similarity percentage was then calculated based on the presence of peaks. The samples were analyzed by two-way analysis of variance (ANOVA). The FTIR wavelength measurements obtained for the microplastic types in the analyzed samples show statistically significant differences according to the regions. Differences were determined according to the Bonferroni post-hoc test to determine the source of the difference. The spectral graph obtained from the analyzed sediment samples is given in Figure 9. According to the peaks analyzed in the graph, some stations were identified in the sediment samples taken from various stations, which are compatible with the spectral peaks of the polymers (LDPE, PP, PS and PET). The stations showing 100% similarity with the absorbance peaks of PP are: Van1, Van2, Van3, Tatvan1, Tatvan2, Tatvan3, Gevaş2, Erciş1 and Erciş2. As a result of FTIR analysis, data on the presence of microplastics and their similarity ratios are shown in Table 5-8 (LDPE, PP, PET and PS). In the light of these data, it can be concluded that the presence of microplastics in the sediment, one of the components of Lake Van aquatic ecosystem, has been confirmed. It can be assumed that if the plastics are detected in the sediment precipitate, it will be more difficult to remove microplastics from the environment in this area as compared to lake water. In Lake Onego, the second largest lake in Europe, Lake Anchar in Northwest Himalaya, Lake Ziway in Africa, and Lake Ontario in Canada, microplastics have been detected in sediment samples [18-21]. The findings of this study and the existing studies in the literature lead to the conclusion that microplastics can be found in lake sediments almost everywhere in the world.

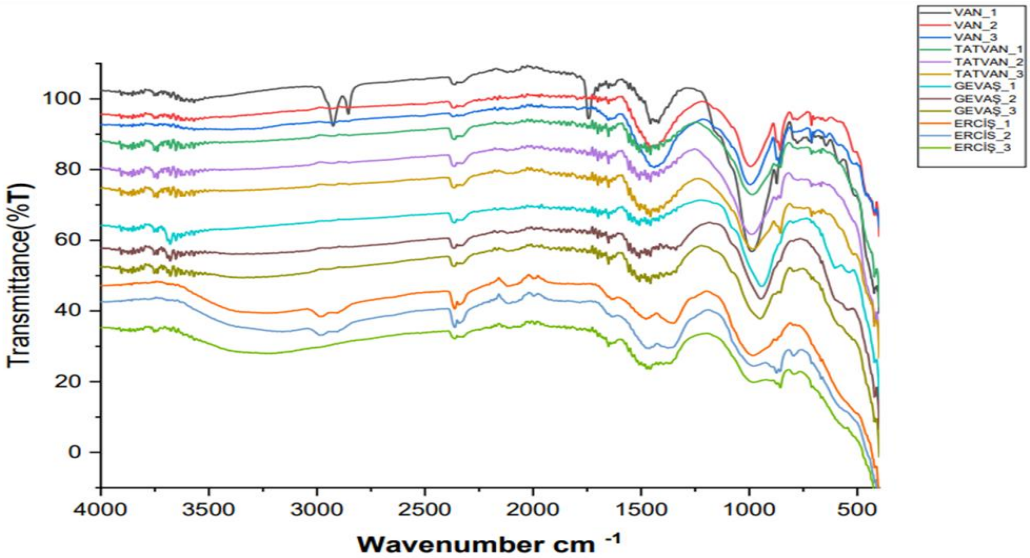

Figure 9. FTIR spectra obtained from sediment samples

Table 4 shows the results of repeated ANOVA measurements to compare whether the results of FTIR analysis of sediment samples to determine the presence of microplastics differed according to the different microplastic types and regions studied.

	Source of variation	Sum of square	df	Mean square	F	p
LDPE	**Within groups**	15359,44	11	1396,31	275,938	<,001
	Error	1391,57	275	5,06		
PET	**Within groups**	7060,432	11	641,857	125,864	<,001
	Error	1009,720	198	5,100		
PP	**Within groups**	9988,037	11	908,003	278,597	<,001
	Error	645,323	198	3,259		
PS	**Within groups**	19350,831	11	1759,166	339,537	<,001

	Error	1709,752	330	5,181		

Table 4. ANOVA test results of FTIR analysis of sediment samples

LDPE	Van1	Van2	Van3	Tatvan1	Tatvan2	Tatvan3	Gevaş1	Gevaş2	Gevaş3	Erciş1	Erciş2	Erciş3
2917	+	+	+	+	+	+	+	+	+	+	+	-
2852	+	+	+	+	+	+	-	-	-	+	+	+
1377	+	-	+	-	+	+	+	+	+	+	+	+
718	+	+	+	+	+	+	+	+	+	-	+	+
Smilarity	**100%**	**75%**	**100%**	**75%**	**100%**	**100%**	**75%**	**75%**	**75%**	**75%**	**100%**	**75%**

Table 5. Presence and similarity rates of LDPE because of FTIR analysis of sediment samples (Wavenumber cm^{-1})*

PP	Van1	Van2	Van3	Tatvan1	Tatvan2	Tatvan3	Gevaş1	Gevaş2	Gevaş3	Erciş1	Erciş2
2956, 2875	+	+	+	+	+	+	+	+	+	+	+
2921, 2840	+	+	+	+	+	+	-	+	-	+	+
1377	+	+	+	+	+	+	+	+	+	+	+
Smilarity	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**67%**	**100%**	**67%**	**100%**	**100%**

Table 6. Presence and similarity rates of PP because of FTIR analysis of sediment samples (Wavenumber cm^{-1})*

PET	Van1	Van2	Van3	Tatvan1	Tatvan2	Tatvan3	Gevaş1	Gevaş2	Gevaş3	Erciş1	Erciş2	Erciş3
1721	+	+	+	+	+	+	+	+	+	+	+	+
1245	+	+	+	+	+	+	-	-	+	+	-	+
1100	-	+	+	-	-	-	+	+	+	-	-	-
Smilarity	**67%**	**100%**	**100%**	**67%**	**67%**	**67%**	**67%**	**67%**	**100%**	**67%**	**34%**	**67%**

Table 7. Presence and similarity rates of PET because of FTIR analysis of sediment samples (Wavenumber cm^{-1})*

PS	Van1	Van2	Van3	Tatvan1	Tatvan2	Tatvan3	Gevaş1	Gevaş2	Gevaş3	Erciş1	Erciş2	Erciş3
3081, 3059,3025	+	+	+	+	+	-	+	+	+	+	+	-
2923, 2850	+	-	+	+	+	+	-	+	+	+	+	-
1600, 1492	+	+	-	+	+	+	+	+	+	+	+	+
756	+	+	+	+	+	+	+	+	+	+	+	+
698	+	+	+	+	+	+	-	+	+	-	+	+
Smilarity	**%100**	**%80**	**%80**	**%100**	**%100**	**%80**	**%60**	**%100**	**%100**	**%80**	**%100**	**%60**

Table 8. Presence and similarity rates of PS because of FTIR analysis of sediment samples (Wavenumber cm^{-1})*

The FTIR wavelength measurements (Table 4) obtained for microplastic species show statistically significant differences when compared with the Bonferroni post-hoc test to determine the source of the difference indicated in Table 9. The FTIR measurements are $F(11,275)=275,938$; $p=0,00$;$p<0,05$ for LDPE, $F(11,198)=125,864$; $p=0,00$;$p<0,05$ for PET, $F(11,198)=278,597$,; $p=0,00$;$p<0,05$ for PP and $F(11,330)=339,537$; $p=0,00$; $p<0.05$ for PS.

The spectrum data obtained from FTIR analysis were compared with the spectra available on the Spectroscopy Online site and in the virtual spectrum library Know It All [60]. As a result of the comparison, the results for 4 polymer derivatives out of 36 samples analysed were examined and the polymers that matched the reference spectrum by 70% or more were considered valid. In 23 samples, FTIR data did not give results compatible with the library. However, in the remaining 13 samples, the dominant microplastic polymer type was determined as PS. Vasudeva et al. [61]reported that out of six microplastics, two were identified as polyethylene (PE), two as polypropylene (PP), and the remaining two as polyethylene terephthalate (PET). The accuracy in identifying polymer classes was cross-validated using confocal Raman spectroscopy and ATR-FTIR spectroscopy, with the results aligning with the characteristic bands of the respective polymer classes.

Sediment Samples	Region	High difference	Low difference	Similarity
LDPE	**Van1**	10,11,12	2,3,4,5,7,8	6,9
	Van2	6,8,9,10,11,12	7	3,4,5
	Van3	6,9,10,11,12	4,7	5,8
	Tatvan1	6,9,10,11,12	7	5,8
	Tatvan2	6,9,10,11,12	7	8
	Tatvan3	10,11,12	9	7,8
	Gevaş1	8,9,10,11,12	2,3,4,5	6
	Gevaş2	10,11,12	1	3,4,5,6,9
	Gevaş3	10,11,12	6	1,8
	Erciş1	1,2,3,4,5,6,7,8,9	12	11
	Erciş2	1,2,3,4,5,6,7,8,9	12	10
	Erciş3	1,2,3,4,5,6,7,8,9	10,11	-
PET	**Van1**	2,3,4,5,6,7,8,9	10,11,12	6
	Van2	6,9,10,11,12	7	3,4,5,8
	Van3	6,10,11,12	4,7	5,8,9
	Tatvan1	6,10,11,12	7	5,8,9
	Tatvan2	6,10,11,12	7,8	2,9
	Tatvan3	10,11,12	7,8	9
	Gevaş1	1,8,9,10,11,12	2,3,4,5,6	6
	Gevaş2	10,11,12	5,6	9
	Gevaş3	10,11,12	-	3,4,5,6,8
	Erciş1	3,4,5,6,7,8,9	1,2,12	11
	Erciş2	2,3,4,5,6,7,8,9	1,12	10
	Erciş3	2,3,4,5,6,7,8,9	1,10,11	-
PP	**Van1**	10,11,12	2,3,4,5,6,7,8	9
	Van2	6,8,9,10,11,12	1,7	3,4,5
	Van3	9,10,11,12	4,5,7	6,8
	Tatvan1	6,8,9,10,11,12	1,3,7	5
	Tatvan2	6,8,9,10,11,12	1,3,7	2,4
	Tatvan3	2,4,5,10,11,12	7,8	3,9
	Gevaş1	8,9,10,11,12	1,2,3,4,5,6	-
	Gevaş2	2,4,5,7,10,11,12	1,6	9
	Gevaş3	2,3,4,5,7,10,11,12	-	1,6,8
	Erciş1	1,2,3,4,5,6,7,8,9	12	11
	Erciş2	1,2,3,4,5,6,7,8,9	12	10
	Erciş3	1,2,3,4,5,6,7,8,9	10,11	-
PS	**Van1**	10,11,12	2,3,4,5,7,8	6,9
	Van2	4,5,6,8,9,10,11,12	1	3,7
	Van3	6,8,9,10,11,12	1,7	2,4,5
	Tatvan1	2,6,9,10,11,12	1,7	3,5,8

	Tatvan2	2,6,9,10,11,12	1,7	3,4,8
	Tatvan3	2,3,4,5,10,11,12	7,8,9	1
	Gevaş1	8,9,10,11,12	1,3,4,5,6	2
	Gevaş2	2,3,7,10,11,12	1,6	4,5,9
	Gevaş3	2,3,4,5,7,10,11,12	6	1,8
	Erciş1	1,2,3,4,5,6,7,8,9	12	11
	Erciş2	1,2,3,4,5,6,7,8,9	12	10
	Erciş3	1,2,3,4,5,6,7,8,9	10,11	-

Table 9. Differences of FTIR analysis results of sediment samples according to Bonferroni post-hoc test

3.5. Enumeration of Generic *Escherichia coli* and total coliform populations in lake water samples by Membrane Method

Water samples collected from 3 different stations in 4 settlements in three parallel on the shore of Lake Van were used for microbiological analysis. Generic *Escherichia col*i and total coliform populations were counted by membrane method. The results of the counts are shown in Table 10.

Station code	***Escherichia coli***	**Total Coliform CFU/100 ml**
Van1	**6**	**28**
Van2	**0**	**27**
Van3	**0**	**1**
Tatvan1	**0**	**17**
Tatvan2	**0**	**10**
Tatvan3	**0**	**17**
Erciş1	**2**	**8**
Erciş2	**0**	**58**
Erciş3	**0**	**7**
Gevaş1	**0**	**0**
Gevaş2	**0**	**1**
Gevaş3	**0**	**0**

Table 10. Microbiological analysis of lake water samples

E. coli is used as an indicator microorganism to assess pollution [62]. No significant correlation was found between the number of microplastic particles and the levels of *E. coli* and total coliform at high-risk stations. The highest amount of microplastic E. coli was detected in lake water samples from Tatvan Van1 (6 cfu/100 ml) and Erciş2 (2 cfu/100 ml), despite the relatively high population in these two stations. Similar results have been recorded in previous studies [63-65]. However, more detailed research is needed to obtain definitive results. Total coliform bacteria serve as an indicator of the sanitary status of food and water [66]. In the analysed lake water samples, the highest total coliform measurement was recorded at Erciş2 station with 58 cfu/100 ml, followed by Van1 station. These results are consistent with E. coli measurements. Considering both data sets, it can be concluded that Van1 and Erciş2 stations are microbiologically rich and indicate significant pollution. No significant correlation was observed between the presence of microplastic particles and total coliform count [64, 66]. More in-depth research on this subject is required to obtain definite results.

4. Conclusion and Suggestions

Pollution in ecosystems is increasing day by day because of human activities. Plastics, which play a major role in this pollution, transform into microplastics, taking plastic pollution from being just waste to a different dimension. Microplastics can enter aquatic ecosystems in various ways and pose a significant risk to the biodiversity of global aquatic ecosystems.

In this study, we examined the presence of microplastics in sediment samples around Lake Van and tried to reveal the serious dimensions of microplastic accumulation in these areas. The study revealed the presence of microplastic particles in sediment, which is an important element of the aquatic ecosystem of Lake Van, as well as details such as the amount, shape, color, polymer type and density of microplastic particles in different regions.

The risks posed by microplastics to the aquatic ecosystem and fish arise not only from the material itself but also from their tendency to absorb, concentrate, and accumulate pollutants from the aquatic

environment. When fish ingest a microplastic cocktail of these contaminants, microplastic particles can transfer to humans through the food chain, posing serious risks to food safety. Important questions such as whether fish can distinguish microplastics from food, how their suitability as a food source is assessed prior to ingestion, whether fish readily reject microplastics, and whether ingestion is intentional should be investigated in depth.

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Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics

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