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Microplastics in Yliki Lake, Greece: An Explorative Study †

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Abstract: Microplastics can enter waters from surface run-off and atmospheric deposition. An exploratory study was undertaken to assess microplastic pollution in the natural lake of Yliki, an auxiliary drinking water reservoir supplying the network of Athens, Greece. Samples taken over the ~25 km^2 area of the lake revealed the presence of fragments and fibers at three out of ten locations, possibly from agriculture in the surrounding area or fishing in the lake. The findings highlight the ubiquitous nature of plastics and the need for regulated assessment of water supplies for environmental and human health protection.

Keywords: drinking water; human health; microplastics; water resources; Yliki Lake

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1. Introduction

Microplastics (MP) are classified as plastic particles with a length of less than 5 mm [1]. Such particles can enter the aquatic environment through direct deposition, surface water and soil run-off, and the *in situ* breakdown of larger plastics [2]. Atmospheric deposition of MP has also been observed, allowing the spread of MP to remote and/or protected areas that are not affected by direct water and soil inputs [3]. Numerous studies [4–8] have indicated that MP can cause adverse effects on organisms either as a result of their chemical composition, including additives such as plasticizers [9], stabilizers [1], or from sorbed materials such as organic pollutants [1] and metals [10].

In aquatic organisms, effects including neurotoxicity, increased mortality rate, growth effects, and impact on reproductive capacity have been observed [1,2,5,6], and although, at present, there is no conclusive scientific evidence of negative effects on humans, research in this area has become a priority.

Humans can be exposed to MP through both water and food consumption [11]. Public water supplies in Europe are protected through EU legislation and policy, and public health, in relation to the consumption of drinking water, is ensured through the drinking water directive [12]. The legislation does not specifically address MP, and while MP can be removed in water treatment processes [13–15], particles have nevertheless been detected in drinking water supplies [16].

Yliki Lake is situated in eastern central Greece in the prefecture of Viotia. The lake and the surrounding area are part of the Natura 2000 network (site code GR2410001) [17]. Used primarily for the irrigation of crops, the lake also provides a reservoir for the auxiliary supply of drinking water to the capital city of Athens. Water protection zones are in place to safeguard the water quality of the lake that is, along with the closed water inlets from Yliki and Morno, institutionally protected by the Sanitary Decree "on the protection of the waters for the water supply of the capital" [18]. A number of additional provisions are also in place with the aim of limiting industrial and agricultural activities related to waste disposal [19]. The water quality of the lake is monitored by the Athens Water Supply and Sewerage Company (EYDAP S.A.) in accordance with the requirements of Community

Directives [12] and harmonized national legislation [20]. Considering the ubiquitous nature of MP, this exploratory study aimed to determine whether the freshwater reservoir was affected by MP pollution despite legislation in place for the protection of the water source and to assess potential sources and impacts of anthropogenic activities.

2. Methods and Materials

2.1. Site Description

With coordinates 38°24′ N 23°16′ E, Lake Yliki is situated in the prefecture of Viotia and borders the Municipality of Orchomenos in the southeast and the Municipality of Thebes in the northwest (Figure 1). The lake lies in the basin formed by Mount Messapio to the east, Mount Ptoos to the north, Mount Sphingeio to the west, and lower hills to the south.

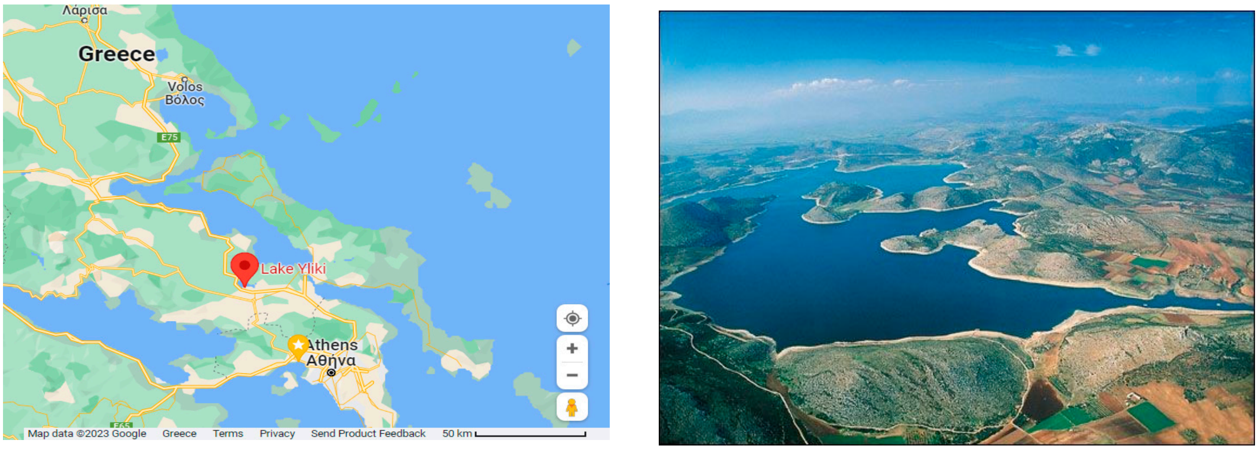

Figure 1. Yliki Lake, Greece [21].

The lake has a surface area of approximately 25 km^2, a maximum depth of 38.5 m, a watershed of 2423 km^2, and a maximum volume capacity of 590 million m^3 [21]. Although Yliki Lake was added to the water supply system of Athens in 1956 as an auxiliary water source to support the main water suppliers of Mornos and Evinos Lake in periods of increased demands such as droughts, it is primarily used to provide water for irrigation [22].

2.2. Sampling Procedure

Prior to use, all containers were rinsed with distilled water and sealed. Glass containers and stainless steel equipement were used as appropriate, and the use of plastic was avoided throughout. Ten locations with different environmental burdens were selected for the collection of water samples (Figure 2). During sampling, weather conditions were fair, with a temperature of between 22 and 24 °C and a wind speed of 2–3 Beaufort. Grab samples were collected at six locations L1–L6: the eastmost point of the lake (L1), four locations over the central lake area (L2–L5), and the outfall of Boiotiko Kifisos River (L6) (Figure 2). At these locations, a 1 L glass container was immersed to a depth of 15 cm from the water surface and filled to the top, thus allowing the collection of any particle matter. Containers were then closed with metal lids. In three areas (A1–A3), particles > 250 µm were collected with a plankton net (250 mm diameter opening, 45 cm height, 250 µm with collection container). The net was attached to the back of the boat (10 m rope length) and swept across the water surface at a boat speed of 8 km h^{-1} for approximately 2 min around each location. Following sample collection, the net was rinsed with distilled water, the rinse with all particulate matter transferred into a 1 L glass container, and immediately sealed with a metal lid. Sampling commenced at location L1, and subsequent locations were accessed by means of a speedboat provided by EYDAP S.A. (Figure 3). Samples were transferred to the Laboratory of the Environmental and Occupational Health, University of West Attica, Greece, for analysis.

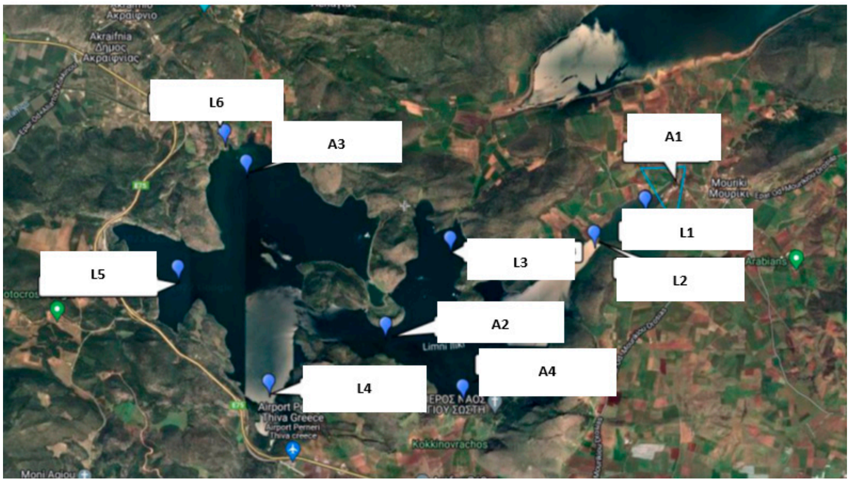

Figure 2. Sampling locations and areas in Yliki Lake, Greece.

Figure 3. Starting point of sampling, Yliki Lake, Greece.

2.3. Sample Analysis

All samples were visually inspected. Where necessary, samples were sieved (0.295 mm sieve) in the laboratory, and retained particles were transferred into a glass beaker with washing. Beakers were placed into an oven heated to 90 °C for 24 h to dry. Natural organic matter, where present, was not digested. Naked-eye identification of MP was performed.

3. Results and Discussion

Samples were generally clear on visual inspection. Grab samples L1–L6 contained little or no natural organic matter, and no MP particles were visible, with the exception of one translucent fiber identified at L2 (Figure 4).

Figure 4. Microplastic fiber (**left**), organic matter (**middle**), and blue microplastic fragment (**right**) in water samples from Yliki Lake, Greece.

Samples collected with the plankton net had visible organic matter content (Figure 4). Microplastics were identified in two samples: At location A2, one off-white MP piece was detected. At location A3, one blue fragment (Figure 4) and a light grey fiber were identified. Since no digestion of samples was performed during the analysis, additional MP could have been present in organic matter, particularly in the form of fibers or small clear particles that are difficult to detect visually.

While sources cannot be accurately determined, the MP fragments were probably linked to anthropogenic activities in the surrounding areas. Yliki Lake is fed largely by the waters of the Boiotiko Kifisos River, and MP could originate from agricultural activities wastes from which are transported in the water flow. At A2, waters from Kalamitis Stream, which crosses a number of Theban villages before its exit in Yliki, enter the reservoir carrying associated urban run-off. Additionally, the reservoir is in close proximity to the national highway to the west, from where MP can be transported from road surface run-off. Fishing, which is known to occur in the waters, could also be a source of MP despite restrictions in place for the protection of the water source [18].

4. Conclusions

In this study, the occurrence of MP in Yliki Lake, a freshwater auxiliary drinking water reservoir protected by national and European legislation, was explored. Microplastics were detected in surface water from three out of 10 locations assessed, with potential inputs from agriculture, fishing activities, and urban run-off. The identification of MP in the freshwater system, despite processes in place for the protection of the lake, highlights the need for MP monitoring and assessment both in the waters and the surrounding environment. Given that the environmental burden of MP is likely to increase as a result of increasing population growth, urbanization, and technological developments, these results provide an impetus for further study not only of Yliki Lake but also of other freshwater reservoirs.

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