

Microplastic Characteristics and Abundance in Water, Sediment, and *Sulcospira testudinaria* in a Freshwater Aquaculture System

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(Received: 20 July 2026 / Revised: 22 July 2026 / Accepted: 25 July 2026 / Available Online: 10 September 2026)

Abstract—Microplastic contamination is a problem for our environment because microplastics last a time and are found everywhere which can hurt the animals that live in the water. Freshwater aquaculture systems are very susceptible to buildup from the surrounding area and from the activities that happen there. This study looked at the characteristics, abundance, and contamination status of microplastics in water, sediment, and the freshwater gastropod *Sulcospira testudinaria* along the Freshwater Aquaculture Installation (IBAT) Punten, Indonesia. Samples were collected from six stations, including the inlet, culture ponds, and outlet. Microplastics were identified by type and color using an inverted microscope. The levels of contamination were measured using the Microplastic Contamination Factor (MCF) and Microplastic Pollution Load Index (MPLI). Four microplastic types were identified: fibers, fragments, films, and pellets. Films dominant in water and *S. testudinaria*, and fragments dominant in sediment. The common colors of microplastics were brown and yellow. Sediment showed the highest abundance, indicating its role as the primary reservoir. Most sites showed significant contamination based on MCF, while MPLI values indicated very high pollution in water (3.48), sediment (4.34), and *S. testudinaria* (3.16), confirming widespread contamination and supporting *S. testudinaria* as effective bioindicators for freshwater microplastic monitoring.

Keywords— microplastic, characteristic, abundance, *Sulcospira testudinaria*, contamination, freshwater aquaculture

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I. INTRODUCTION

Indonesia has a problem with waste that it just cannot seem to solve. Indonesia generates a lot of waste, so much that it is second in the world, with only China generating more plastic waste than Indonesia. Each year, Indonesia generates around 3.22 million metric tons of plastic waste, of which an estimated 0.48 to 1.29 million metric tons ends up in aquatic environments. With targets being higher and higher, pollution will increase in water-based plastic as well. Given a global boost in population as well, it will put the increase in production waste by humans at higher risks [2]. When plastic gets into water, it starts to break down because of things like heat, sunlight, and tiny living things. After a while pieces of plastic turn into small bits that are less than 5 mm across, and these are called microplastics [3]. Due to their small size and pervasiveness in aquatic systems, microplastics are both pervasive and readily accessible to aquatic life, raising the risk of ingestion by numerous aquatic species [4]. These particles are also capable of adsorbing persistent organic pollutants, which can be released once ingested by organisms such as fish, worms, and gastropods—potentially resulting in toxic effects, including mortality [5][6].

Primary and secondary microplastics are the two types of microplastics based on their origin [7]. Primary microplastics refer to plastic particles manufactured at a microscopic scale for direct use in industrial and consumer products, including cosmetics, cleaning products, resins, and plastic pellets [8]. Conversely, secondary microplastics are produced when bigger plastic objects that have been exposed to environmental weathering break down. These come from things like food packaging, shopping bags, fishing nets, plastic bottles, pipes, and worn vehicle tires [9]. Microplastics come in shapes—pellets, films, fibers and fragments—each of which can harm water creatures like fish, worms and snails [6]. In addition to shape microplastics can also be different in color. This color shows what kind of plastic they are and what kind of color was added; darker plastics, like black and blue usually break down more slowly than lighter ones like yellow and red which lose their color faster [10]. These differences in type and color help scientists find where the pollution came from and see how much the particles have broken down because of sunlight, in water environments [11].

Gastropods are mollusks that live on virtually any substratum and perform essential functions in freshwater communities, such as herbivores, detritivores, and consumers of predators [12][13]. Since they are directly dependent on substrate conditions for both habitat use and food use, gastropods are sensitive to changes in environmental conditions and, for this reason, are frequently utilized in water pollution studies as bioindicators [14]. One such species, *Sulcospira testudinaria* is widely distributed across freshwater habitats in Indonesia, especially on Java, where it acts as a deposit feeder [15]. This species is known for being very sensitive to changes, in the environment problems caused by water pollution [16]. Because of this *Sulcospira testudinaria* is used as a sign to check how

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clean the water is and how healthy the whole water environment is [17].

Potential risks to freshwater aquaculture due to MPs are entry into the aquatic environment through the upstream environment or from aquatic environments in aquaculture systems [18]. Microplastics can get into these systems through rivers that carry wastewater from domestic, agricultural, and urban sources or through the breakdown of plastic equipment used in aquaculture, such as nets, pipes, feed containers, and ropes [19]. The food that people give to the fish and the activities at aquaculture sites also add to the microplastic problem in the water. The slow rate of water flow and exchange in some sections of an aquaculture facility can facilitate the settling down of microplastics to form accumulations in water and sediments, enhancing the opportunities for organisms to ingest them [20]. For this reason, freshwater aquaculture systems deserve closer attention as potential hotspots for microplastic accumulation, given their capacity to compromise water quality and threaten the organisms living within them.

Research by Buwono et al. [21], found microplastics present in both the water and the gastropod *Sulcospira* sp. in the upstream section of the Brantas River, with fiber-type particles occurring most frequently. Similarly, Islamy et al. [22], documented microplastic accumulation across three freshwater gastropod species—*Pomacea canaliculata*, *Filopaludina javanica*, and *Sulcospira testudinaria*—noting that accumulation patterns varied depending on each species' habitat and feeding behavior. However, both study cases took place in natural rivers, and a complete characterization of microplastics among water, sediments, and *Sulcospira testudinaria* in a freshwater aquaculture facility is impossible to do so far. In addition, there are still no studies performing a complete assessment on microplastic pollution (abundance and contamination levels) across entire flow paths (from the inlet of the

system through cultivation ponds to the outlet) in an aquaculture facility. A freshwater aquaculture system is significantly different from the river system due to the possible impacts from aquaculture activities (e.g., species cultivated, types of feed, and plastic materials in the pond) and flow dynamics that might influence microplastic distribution. To fill the gap and to understand clearly how the microplastics behaved throughout the aquaculture system in different part-components (water, sediments, and *S. testudinaria*), the present study aims to evaluate the abundance and the characteristics and pollution levels of microplastics in waters and sediments and in *Sulcospira testudinaria* collected from different parts of the flow stream in a Punten Freshwater Aquaculture Facility (IBAT).

II. METHOD

A. Research Time and Location

This study was conducted from January to March 2026 and used in situ and ex situ sampling methods at the stream of the Punten Freshwater Aquaculture Facility (IBAT) at Batu City by collecting samples 3 times with time intervals of 2 weeks between sample collections. Purposive sampling was used in determining sampling location, and there were 6 observation stations selected to represent the potential of microplastic settlement and flow of water within, across, and around fish culture facilities, with selected as input, culture ponds, and outlet streams, which is aiming to give a thorough visualization regarding the distribution and microplastic profile in the environment related to the water course of aquaculture. The analysis and examination of microplastic samples took place at the Hydrobiology Laboratory, Aquatic Environment Division, Faculty of Fisheries and Marine Sciences, Brawijaya University. Figure 1 illustrates the sampling locations.

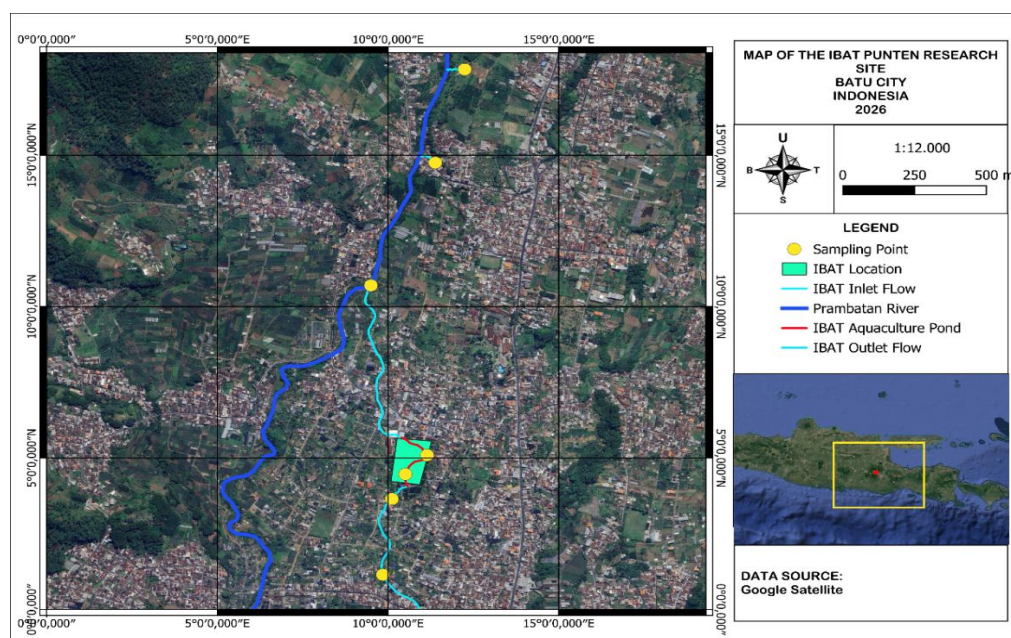


Figure 1. Location Map of Sampling Sites

B. Method Research

This research used a descriptive method along with an analytical approach. A quantitative descriptive method aimed at objectively describing the conditions that happen, according to facts as they are, or that occurred or happened [23]. Here, this method was used to characterize and measure microplastics present in water, sediment, and *Sulcospira testudinaria* along the IBAT Puntan stream in Batu City. The method was formulated to comprehensively report upon circumstances of research subjects based on observation and measures, giving a representation of microplastic occurrences, kinds, and coloring, as well as mass in every medium reviewed in the test.

C. Sampling Method

Simple random sampling was employed in this study to collect *Sulcospira testudinaria* specimens from six distinct locations. This technique is among the most straightforward sampling approaches, giving every unit an equal probability of selection. Its advantages include ease of application in both sampling and parameter estimation, along with reliance on relatively uncomplicated formulas [24]. Sampling was carried out in three replicates at two-week intervals to capture variations in microplastic contamination and water quality that might influence the biological responses of *Sulcospira testudinaria* across the study sites. For water sampling, 15 liters were collected using a 5-liter bucket and passed through a 45- μ m plankton net, which was subsequently rinsed to ensure all trapped microplastic particles were retained in the sample. The filtered material was then placed into a 250 mL bottle, labeled by collection site, and kept in a coolbox until laboratory analysis for microplastics. Sediment collection involved lowering an Ekman grab to the bottom of the water body and releasing its weight. The grab was then retrieved, and the sediment obtained was placed into a ziplock bag holding roughly 500 grams, minimizing contamination from outside particles, before being stored in a coolbox [25]. Three specimens of *Sulcospira testudinaria* were gathered using the road sampling technique, which entails walking along the riverbank and collecting the organisms directly by hand [26].

D. Sample Analysis

Water samples were analyzed for microplastics following the National Oceanic and Atmospheric Administration (NOAA) [27]. Samples were first passed through 0.5 mm and 0.3 mm stainless steel filters, after which the retained residue was transferred to a glass beaker and dried at 90°C for 24 hours. The dried residue was then treated with 20 mL of 0.05 M Fe(II) solution and 20 mL of 30% H₂O₂ and heated to 75°C until the reaction was complete. A NaCl solution was subsequently added to raise the density of the mixture, enabling microplastics to be separated through flotation. The resulting supernatant was filtered using Whatman No. 42 filter paper with the assistance of a vacuum pump. Microplastics captured on the filter paper were then examined under an inverted microscope at 40×

magnification to determine their type and color. Microplastic abundance in the water samples was calculated using Equation 1.

$$\text{Abundance (particles/m}^3\text{)} = \frac{\text{Number of microplastics}}{\text{Dry sediment weight(kg)}} \quad (1)$$

Sediment samples were analyzed for microplastics using the National Oceanic and Atmospheric Administration (NOAA) method [27]. A 400-gram wet sediment sample was placed in a glass beaker and dried in an oven at 90°C for 24 hours. Once dried, the sample was ground and passed through 0.5-mm and 0.3-mm sieves, from which 100 grams of the dried sediment were taken for further analysis. This portion was treated with 20 mL of 0.05 M Fe(II) solution and 20 mL of 30% H₂O₂ to break down organic matter, then heated to 75°C on a hotplate. The 0.05 M Fe(II) solution was prepared by combining 7.5 g of FeSO₄·7H₂SO₄ and 3 mL of H₂SO₄ in 500 mL of distilled water. Following this, NaCl solution was added at a rate of 6 grams per 20 mL to increase the density of the mixture, which was then heated until fully dissolved. After cooling until a precipitate formed, the supernatant was filtered through Whatman No. 42 filter paper using a vacuum pump, and the results were examined under a microscope. Microplastic abundance in the sediment samples was calculated using Equation 2.

$$\text{Abundance (particles/kg)} = \frac{\text{Number of microplastics}}{\text{Dry sediment weight(kg)}} \quad (2)$$

Microplastics in *Sulcospira testudinaria* samples were analyzed following the method of Buwono et al. [28]. The process began by cracking the shells and extracting the soft tissue, which was then weighed and dried in an oven at 70°C–80°C for 24 hours. A solution of 6 g NaCl per 20 mL was added to increase density, along with 10 mL of 30% H₂O₂ to break down organic matter, and the samples were left to stand for 24 hours. They were then incubated in a water bath at 80°C to speed up the chemical oxidation process. The samples were subsequently filtered using Whatman No. 42 filter paper with a vacuum pump, and the resulting material was examined under a microscope. Microplastic abundance in *Sulcospira testudinaria* was calculated using Equation 3.

$$\text{Abundance (particles/g)} = \frac{\text{Number of microplastics}}{\text{sample weight (gr)}} \quad (3)$$

E. Data Analysis

The Microplastic Pollution Load Index (MPLI) builds upon the conventional Pollution Load Index (PLI), adapted specifically to assess microplastic contamination levels. It offers a comprehensive means of evaluating relative pollution across each monitoring station. This calculation relies on Microplastic Contamination Factor (MCF) values from each station, where MCF reflects the relative abundance of microplastics compared to the lowest concentration recorded within the study area. MCF values fall into four contamination categories: low (MCF < 1; risk category I), moderate (1 ≤ MCF < 3; risk

category II), high ($3 \leq \text{MCF} < 6$; risk category III), and very high ($\text{MCF} \geq 6$; risk category IV) [29]. MPLI was calculated in accordance with the approach outlined in the most recent microplastic risk assessment research, using Equation 4.

$$\text{MCF}_i = \frac{\text{MP}_i}{\text{MP}_{\min}} \quad (4)$$

The MP_i denotes the number of microplastics observed at the station where sampling was collected, and $\text{MP}_{\min}$

denotes the smallest amount of microplastics amongst all the stations used for calculating the index.

MPLI for the sites was generated by taking the geometric mean of each site's derived MCF value using Equation 5 and plotting it against the relevant reference value in Table 1 [30].

$$\text{MPLI} = (\text{MCF}_1 \times \text{MCF}_2 \times \text{MCF}_3 \times \dots \times \text{MCF}_n)^{1/n} \quad (5)$$

TABLE 1.

MPLI VALUE CLASSIFICATION BY POLLUTION LEVEL AND MICROPLASTIC RISK CATEGORY	
Range of Values	Risk Classification
$\text{MPLI} < 1$	Low
$1 \leq \text{MPLI} \leq 2$	Moderate
$2 < \text{MPLI} \leq 3$	High
$\text{MPLI} > 3$	Very High

III. RESULTS AND DISCUSSION

A. Characteristics of Microplastics in Water

Microplastics identified in the water samples were categorized by type and color based on particle identification carried out at each observation station. The quantity of each microplastic type detected is presented in the Figure 2. Across all study sites, four types of microplastics were identified: fragments, fibers, films, and pellets. According to the graph, film was consistently the most abundant type at every observation site, peaking at Site 2 and Site 5 with 66 ± 4.58 particles and 66 ± 7.21 particles, respectively, while the lowest count occurred at Site 1, with 13.67 ± 1.53 particles. Fragments ranked second in abundance, reaching their highest level at Site 2 (46.67 ± 1.15 particles) and their lowest at Site 1 (10 ± 1.00 particles). Fibers appeared in comparatively small numbers across all points, ranging from 0.33 ± 0.58 to 6.67 ± 2.89 particles, with Site 2 showing the highest count (6.67 ± 2.89 particles) and Site 1 the lowest (approximately 0.67 ± 0.58 particles). Pellets were the rarest type overall, being entirely absent at Site 1 and found only in minimal amounts at other sites, with the highest recorded count reaching just 3 ± 1.00 particles at Site 2. Figure 3 illustrates examples of each microplastic type identified within the samples.

Film-type microplastics were the most dominant form found across all observation sites, likely originating

from the breakdown of single-use plastic bags and food packaging swept into aquaculture areas by river currents. This type of microplastic typically forms through the fragmentation of plastic bags and similar packaging materials, which have a naturally low density that makes them more susceptible to breaking apart into microplastic particles [31]. Because of this low density, film-type microplastics disperse more readily throughout the water column compared to other microplastic types [32]. The high amount of film microplastics at Site 2, which is the inlet, and at Sites 5 and 6, which are the outlet, shows that these particles come mainly from domestic and agricultural waste that builds up near the site, which correlates closely with high levels of human disturbance. Film microplastics are usually plastic sheets that come from plastic bags and single-use packaging. The amount of these particles depends on how much plastic the community uses [33]. Similar environmental studies have identified domestic and agricultural practices as main sources of the plastic-type microplastic found in films, the majority due to poor plastic disposal management close to watercourses. [34]. Pellets were the least common type detected, perhaps as a result of their being mostly comprised of microbeads made from personal and beauty care products, both of which are of minimal usage and thus have a lesser effect on overall microplastic pollution in waters [35].

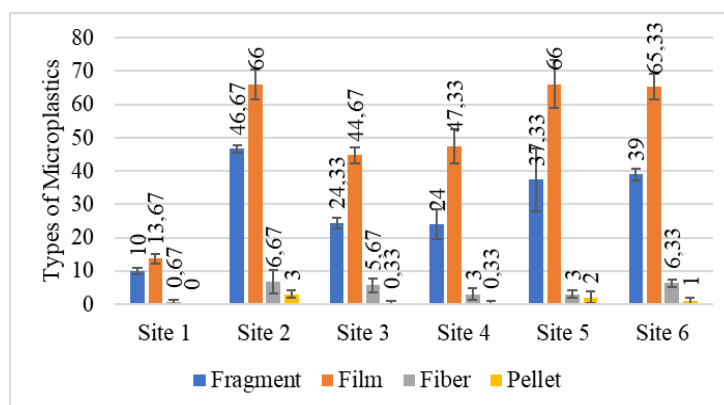


Figure 2. Microplastic Particle Types in Water

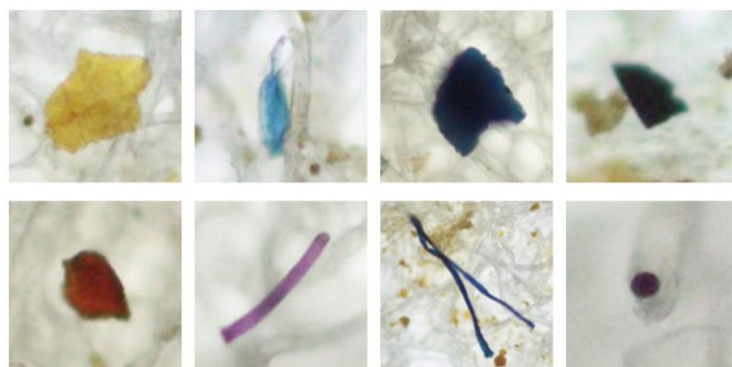


Figure 3. Examples of the Types and Colors of Microplastics Identified at Sampling Sites
TABLE 2.

COLOR CHARACTERISTICS OF MICROPLASTICS IN WATER						
Color	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Black	4 ± 1.00	19.33 ± 7.23	8.67 ± 1.53	8.67 ± 1.15	24.67 ± 1.53	21.67 ± 6.43
Brown	8.33 ± 2.08	51.33 ± 6.03	22 ± 6.24	23.67 ± 10.02	30 ± 2.00	29.67 ± 1.15
Yellow	9.67 ± 0.58	40.33 ± 2.08	25.67 ± 1.53	25.33 ± 5.13	33.67 ± 3.21	38.67 ± 3.21
Transparent	3 ± 1.00	7.67 ± 3.06	14 ± 7.94	15.33 ± 4.62	16.33 ± 4.93	19 ± 3.46
Blue	0.33 ± 0.58	0.67 ± 0.58	2.33 ± 1.15	1.33 ± 0.58	0.67 ± 0.58	1.33 ± 1.53
Red	-	2.33 ± 1.53	3.33 ± 1.53	0.33 ± 0.58	2.33 ± 1.53	1 ± 1.73
Purple	-	-	-	-	0.67 ± 1.73	0.33 ± 0.58

Table 2 shows information about the colors of the microplastics found in the water samples. Brown and yellow were the common colors at almost every place where samples were taken. Brown reached its highest concentration at Site 2, with approximately 51.33 ± 6.03 particles, and at Site 5, with around 30 ± 2.00 particles. Yellow was also seen in numbers at Site 2 with 40.33 ± 2.08 particles. Black followed with a notably high value, particularly at Site 5 with 24.67 ± 1.53 particles. Transparent particles were seen in amounts with the highest number at Site 6 with 19 ± 3.46 particles. Site 1 generally recorded the lowest average values across nearly all color categories. Blue, red and purple were found in small amounts at all places. Purple was only found at Site 5 with 0.67 ± 1.73 particles and, at Site 6 with 0.33 ± 0.58 particles. Figure 3 shows the colors of the particles found in this study.

The color of microplastics is different because they come from places and have broken down in different ways. The brown and yellow categories comprised most

of the sample group, possibly suggesting a majority of these particles experienced photo-oxidation during chronic UV irradiation exposure [36]. Moreover, brown and yellow-colored particles were often considered a breakdown from polyethylene terephthalate (PET) [37]. In contrast to those, black-colored particles were believed to result from the degradation of shopping bags and are capable of adsorbing several environmental contaminants, such as polycyclic aromatic hydrocarbons (PAHs), which are common for polystyrene (PS) and polyporylene (PP) [38]. was often considered to be a characteristic of PP polymers with very little degradation yet experienced [39], while red, blue, and purple colors were attributed to plastic waste packaging, bottles, fishing line, and fibers from textiles [40].

B. Microplastics Abundance in Water

The microplastic abundance in water measured at all observation sites is shown in Figure 4.

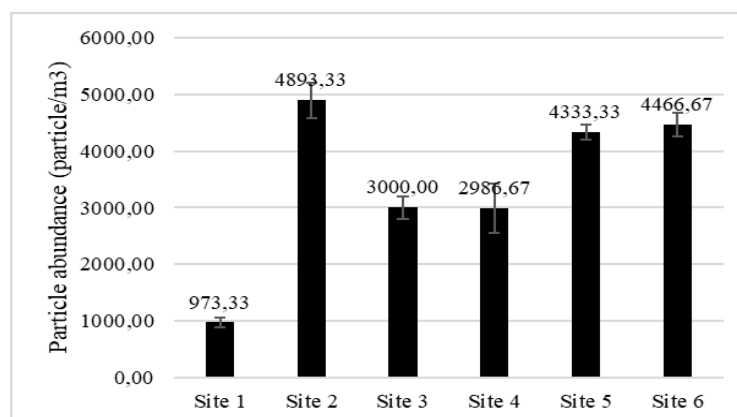


Figure 4. Microplastics Abundance in Water

Average microplastic abundance ranged from 973.33 ± 83.27 particles/m³ to 4893.33 ± 305.51 particles/m³. The highest concentration was recorded at Site 2 (4893.33 ± 305.51 particles/m³), followed by Site 6 (4466.67 ± 201.33 particles/m³) and Site 5 (4333.33 ± 128.58 particles/m³). Sites 3 and 4 showed moderate abundance levels, at 3000 ± 200.00 particles/m³ and 2986.67 ± 440.61 particles/m³, respectively. Site 1, by contrast, recorded the lowest microplastic abundance, at 973.33 ± 83.27 particles/m³.

The high abundance of microplastics at Site 2, which is an aquaculture inlet area, is believed to be related to high levels of anthropogenic activity around the site—such as residential areas, commercial activities, and plastic waste disposal—which increase the influx of plastic waste into the water body. This is consistent with findings from Pradiptaadi and Fallahian [32], who note that higher population density contributes to increased microplastic pollution in water bodies. Site 1 has comparatively low microplastic abundance, which can potentially be a result of somewhat unpolluted environmental conditions at Site 1 and the insignificant human interaction there, and also Site 1 is relatively far from microplastic-contaminated sources. Though Site 1 has a lower number of microplastics than Site 2, it reflects how microplastics can get into the water sources via water, winds and surface runoff even though there is minimal disturbance of human factors at that site [41].

C. Characteristics of Microplastics in Sediment

Microplastics identified in the sediment samples were categorized by type and color based on particle identification conducted at each observation station. The quantity of each microplastic type detected is presented in Figure 5. According to the graph, fragments were the most prevalent microplastic type across all observation sites. The highest fragment abundance occurred at Site 6 (60.67 ± 6.81 particles), followed by Site 5 (60.33 ± 7.09 particles) and Site 2 (58.33 ± 4.04 particles), while Site 1 recorded the lowest value (12.67 ± 2.89 particles). Film-type microplastics were also present in relatively large quantities, particularly at Site 2 (55.67 ± 8.33 particles), Site 6 (52.33 ± 2.89 particles), and Site 5 (50.33 ± 4.16

particles), with the lowest count again found at Site 1 (12.33 ± 2.08 particles). Unlike the water samples, which were dominated by film-type particles, sediment samples showed a greater prevalence of fragment-type microplastics. Fibers, meanwhile, occurred only in relatively small numbers across all sites, ranging from 0.33 ± 0.58 to 5.00 ± 1.00 particles, with the highest count at Site 2 and the lowest at Site 1. Pellets were the least common type, being absent entirely at Site 1 and appearing only in minimal quantities elsewhere, with a maximum of 2.00 ± 0.00 particles at Site 2. However, the fragments in the sediment probably point to accumulation from long-term degradation and fragmentation of a variety of plastic debris that was deposited before being fragmented.

The high abundance of fragment-type microplastics in Sites 5 and 6 sediments might be accumulated from further fragmentation of macroplastic bottles and items like containers, plastic sheets or pipes present in the study area through aquafarming activities as well as human settlements. Fragment types of microplastics derive from degraded pieces of macroplastic products like bottles, food packaging or plastic-related consumer products discarded in the nearby waters [42][43]. Because fragments have a higher density than films and fibres, they tend to settle and accumulate more readily in sediments [44]. This tendency is further reinforced by the relatively weak current flow at both stations: slower water movement allows microplastics to settle and accumulate in sediment rather than being carried elsewhere, while also slowing further fragmentation, so particles tend to remain concentrated in the area [45]. Taken together, the combination of fragment sources originating from aquaculture activities and surrounding settlements, along with the weak-current hydrodynamic conditions at Sites 5 and 6, appears to be the main driver behind the high accumulation of microplastic fragments in the sediments at both stations. In addition, the abundance of film particles in sediments may be influenced by biofouling processes that increase particle density, as well as hydrodynamic conditions favouring settlement, particularly in slow-flowing waters [33][34].

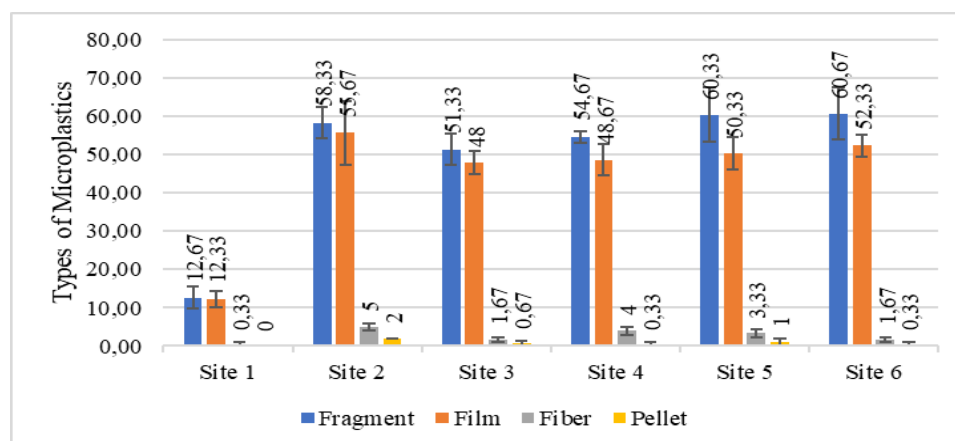


Figure 5. Microplastic Particle Types in Sediment

The color characteristics of the microplastics identified in the sediment samples are presented in Table 3. Brown was the dominant color at nearly all observation sites, reaching its highest abundance at Site 4 (40.67 ± 4.93 particles), followed by Site 2 (39.33 ± 1.15 particles) and Site 5 (37.33 ± 2.52 particles). Yellow was also fairly abundant, ranging from 8.67 ± 0.47 to 35.67 particles, while black showed notable concentrations, particularly at Site 2 (29.33 ± 1.53 particles), Site 6 (26 ± 4.58 particles), Site 3 (22.33 ± 6.43 particles), and Site 5 (21.67 ± 2.08 particles). Transparent microplastics peaked at Site 6, with 23.33 ± 2.89 particles, while blue, red, and purple microplastics appeared only in relatively small amounts. These colors can be due to a difference in the types of pollutants—such as household or plastic refuse—as well as in the specific physical or biological conditions, for example, current velocity, sunlight, or even microbiological presence in the water itself, where plastic material goes

under changes.

Factors controlling color in microplastics, such as water and sediment microplastics, show changes in color associated with degradation and properties and environmental conditions. Environmental exposure can lead to photodegradation/oxidation via ultraviolet (UV) radiation, which can alter particle color, and particle colors reflect polymer composition, and pigments incorporated at the time of production can impart differential environmental resistance [48][49]. The color of microplastics can also serve as an indicator of their origin, such as plastic bags, food packaging, fishing line, or other plastic products. Additionally, environmental factors—including exposure duration in water, interactions with organic and mineral matter, and biofilm formation (biofouling)—contribute to changes in the surface characteristics and coloration of microplastics, particularly for particles that have accumulated in sediments over extended periods [50][51].

D. Microplastics Abundance in Sediment

abundance in sediments tends to be greater at sites

TABLE 3.
COLOR CHARACTERISTICS OF MICROPLASTICS IN SEDIMENT

Color	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Black	4.33 ± 1.25	29.33 ± 1.53	22.33 ± 6.43	19.67 ± 2.89	21.67 ± 2.08	26 ± 4.58
Brown	7.33 ± 0.47	39.33 ± 1.15	26.33 ± 5.13	40.67 ± 4.93	37.33 ± 2.52	33 ± 9.85
Yellow	8.67 ± 0.47	35.67 ± 4.16	16.67 ± 4.62	34.33 ± 1.15	32.67 ± 2.31	30.67 ± 2.08
Transparent	3.33 ± 1.70	14 ± 4.36	8.67 ± 6.43	9.33 ± 9.29	13.67 ± 7.64	23.33 ± 2.89
Blue	0.67 ± 0.47	0.67 ± 0.58	1.67 ± 0.58	1 ± 1.00	3.33 ± 1.53	0.67 ± 0.58
Red	-	1.33 ± 1.15	1 ± 1.00	1.67 ± 1.15	3.67 ± 2.89	1.67 ± 0.58
Purple	-	0.33 ± 0.58	0.67 ± 0.58	-	1 ± 1.00	0.33 ± 0.58

Figure 6 presents the microplastic abundance in sediments recorded at all observation sites. Microplastic abundance in sediments across the six observation sites ranged from 243.33 ± 45.04 particles/kg to $1,210 \pm 52.92$ particles/kg. The highest abundance occurred at Site 2 ($1,210 \pm 52.92$ particles/kg), followed by Site 5 ($1,153.33 \pm 128.58$ particles/kg) and Site 6 ($1,150 \pm 95.39$ particles/kg), while Site 1 recorded the lowest value (243.33 ± 45.04 particles/kg). Overall, microplastic

influenced by anthropogenic activities, including residential areas, aquaculture operations, and drainage channels, whereas Site 1, subject to less human activity pressure, shows the lowest level of microplastic contamination. This pattern mirrors the distribution observed in water samples, where microplastic levels similarly increase in areas with more intensive human activity.

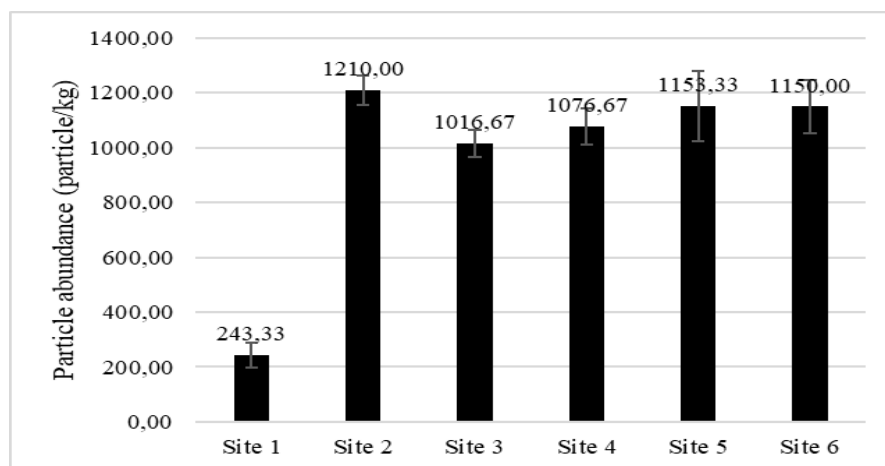


Figure 6. Microplastics Abundance in Sediment

Site 2 got a higher microplastic amount by comparison with other sites due to it being influenced by processes of anthropogenic actions and water body

features. Situated near human activity centers such as densely populated settlements and extensive plantations, this site receives a greater input of plastic waste

compared to others. Population growth around river areas tends to increase plastic waste entering water bodies, thereby raising the risk of microplastic pollution [32]. Sediment characteristics also play a key role in shaping the distribution and accumulation of microplastics. The sandy mud sediment found at Site 2 features finer particles and higher porosity, making it more effective at trapping and retaining microplastics compared to coarser sediments [52]. Identification results further indicate that fragments were the dominant microplastic type in the sediment, likely because their higher density relative to films and fibers allows them to settle and accumulate more readily on the water bottom while remaining relatively resistant to being carried away by currents [53].

E. Characteristics of Microplastics in *Sulcospira testudinaria*

Microplastics found in the *Sulcospira testudinaria* samples were categorized by type and color based on particle identification carried out at each observation station. The quantity of each microplastic type identified is shown in Figure 7. The graph shows that film was the dominant microplastic type at nearly all sites, recording the highest values at Site 6 (26.33 ± 6.66 particles), Site 5 (24.67 ± 8.14 particles), and Site 2 (18 ± 7.81 particles), with the lowest value found at Site 1 (4.33 ± 0.58 particles). Fragments were the second most abundant type, particularly at Site 5 (17.33 ± 1.53 particles), Site 2 (17.33 ± 1.53 particles), and Site 6 (15.67 ± 4.04 particles), with Site 1 again showing the lowest value (4.67 ± 0.58 particles). Fiber occurred in small quantities at select sites, with the highest counts at

Site 2 (2.33 ± 1.15 particles) and Site 4 (2 ± 1.00 particles), and was entirely absent at Site 1. Pellets were the least common type, found only at Site 2 (approximately 1 ± 0.00 particles), Site 5 (1.67 ± 0.58 particles), and Site 6 (1 ± 1.00 particles), and were completely absent at Sites 1, 3, and 4.

The findings of this study diverge from those of Islamy et al. [22], who identified microplastic pellets and microfibrils as the predominant types present in *Sulcospira testudinaria* within the Brantas River Basin. By comparison, this study found that film-type microplastics were most prevalent in *S. testudinaria* along the Punten IBAT watercourse. This discrepancy is likely attributable to differences in pollution sources and site-specific environmental conditions, since the Punten IBAT aquaculture system receives inputs of thin plastic materials—such as plastic bags and single-use packaging—that are more prone to fragmenting into film-shaped particles [54]. Because film particles are thin, lightweight, and easily dispersed, they tend to mix with detritus and organic matter that serve as food sources for *S. testudinaria*, increasing the likelihood of ingestion during feeding [55]. Fragments were the second most abundant microplastic type across all study sites, a pattern likely tied to their tendency to accumulate heavily in sediment due to their higher density, which makes them more prone to settling and interacting with benthic organisms [53]. In contrast, the relatively low abundance of fibers and pellets suggests that their associated pollution sources—such as textile waste, fishing nets, ropes, plastic industry activities, and microbead use—are comparatively limited at the study sites [56][57].

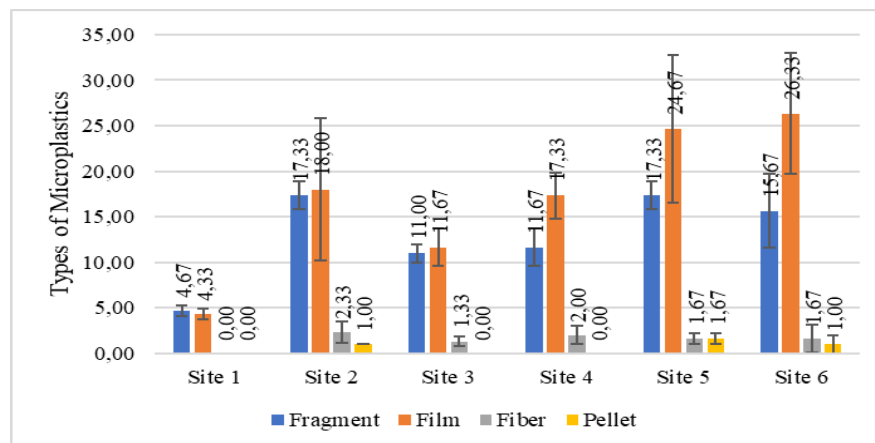


Figure 7. Microplastic Particle Types in *Sulcospira testudinaria*

The color characteristics of the microplastics identified in the *Sulcospira testudinaria* samples are presented in Table 4. Brown was the most prevalent color among microplastics found in *Sulcospira testudinaria* across all observation sites, reaching its highest abundance at Site 6 (14 ± 2.65 particles), followed by Site 5 (12.67 ± 0.58 particles) and Site 4 (10.33 ± 1.53 particles), with the lowest value recorded at Site 1 (3 ± 0.00 particles). Yellow also showed relatively high abundance, peaking at Point 6 (13.67 ± 4.16 particles) and reaching its lowest level at Point 1 (2

± 1.00 particles). Black ranked third in prevalence, with the highest abundance at Point 6 (11 ± 3.61 particles) and the lowest at Point 1 (2.67 ± 1.15 particles). Transparent microplastics were most abundant at Point 5 (7 ± 3.61 particles) and least abundant at Point 1 (0.67 ± 1.15 particles), while blue, red, and purple microplastics occurred only in very small amounts across all observation points.

The dominance of brown microplastics in *Sulcospira testudinaria* mirrors the pattern observed in the water and sediment samples. This color suggests that most

particles have undergone photodegradation and oxidation from prolonged UV exposure, causing them to change color as the material ages [48]. Because degraded microplastics often resemble organic particles or natural food sources, they may be more prone to accidental ingestion by *S. testudinaria* [58]. Additionally, the

notable abundance of black microplastics—particularly at Points 5 and 6—is thought to originate from the breakdown of black plastic bags, which may carry toxic compounds such as polycyclic aromatic hydrocarbons (PAHs) capable of affecting the physiological functions of the organisms [38].

TABLE 4.
COLOR CHARACTERISTICS OF MICROPLASTICS IN *SULCOSPIRA TESTUDINARIA*

Color	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Black	2.67 ± 1.15	8.33 ± 2.31	5 ± 3.00	5.33 ± 0.58	10.33 ± 1.53	11 ± 3.61
Brown	3 ± 0.00	11.67 ± 1.15	7.33 ± 1.53	10.33 ± 1.53	12.67 ± 0.58	14 ± 2.65
Yellow	2 ± 1.00	10.67 ± 2.89	6.67 ± 2.08	9.33 ± 1.53	12.33 ± 4.04	13.67 ± 4.16
Transparent	0.67 ± 1.15	4.67 ± 1.15	2.67 ± 3.79	3.67 ± 2.08	7 ± 3.61	3.67 ± 1.53
Blue	0.33 ± 0.58	0.33 ± 0.58	0.67 ± 0.58	1.33 ± 0.58	1.33 ± 0.58	0.67 ± 0.58
Red	-	0.67 ± 1.15	0.67 ± 0.58	1 ± 1.00	1 ± 0.00	-
Purple	-	0.33 ± 0.58	-	0.67 ± 0.58	-	0.67 ± 0.58

F. Microplastic Abundance in *Sulcospira testudinaria*

The microplastic abundance in *Sulcospira testudinaria* measured at all observation sites is shown in Figure 8. Microplastic abundance in *Sulcospira testudinaria* ranged from 4.61 ± 0.55 to 21.74 ± 3.64 particles/g. The highest levels were found at Site 5 (21.74 ± 3.64 particles/g), followed by Site 6 (21.27 ± 1.10 particles/g) and Site 2 (18.41 ± 3.06 particles/g),

while Site 1 recorded the lowest value (4.61 ± 0.55 particles/g). Overall, the accumulation of microplastics was generally higher in *S. testudinaria* found on sites that had been more impacted by anthropogenic activities, such as aquaculture, settlements, and waste buildup, with the lower values on site 1 being explained by a lower level of stress from external pollution factors.

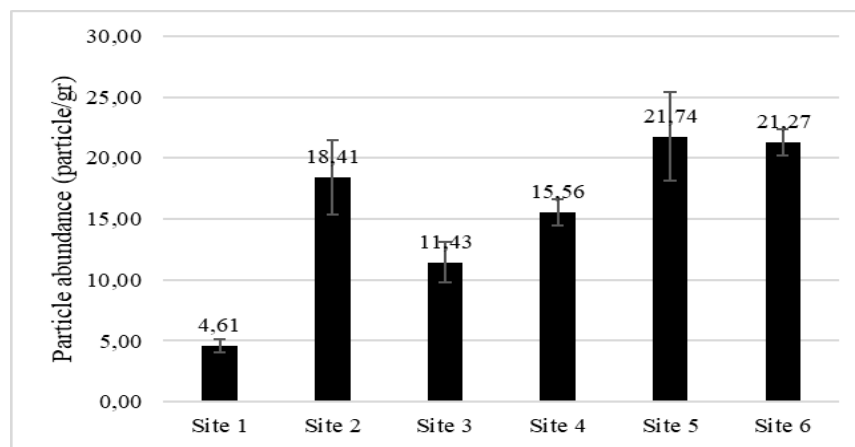


Figure 8. Microplastic Abundance in *Sulcospira testudinaria*

The *Sulcospira testudinaria* is a freshwater snail that belongs to the class Gastropoda. The presence of *Sulcospira testudinaria* has spread widely on the various freshwater bodies in Indonesia, especially on Java. As a detritivore, this species feeds on detritus and organic matter that accumulates on the water bottom [17]. Because its habitat and feeding habits are closely tied to the bottom substrate, the species has frequent contact with sediment, increasing its vulnerability to microplastics that accumulate there. Once ingested, microplastics are difficult for the organism to break down and can persist in its tissues for extended periods. These particles can also adsorb various toxic compounds and provide a surface for pathogenic microorganisms to colonize, potentially intensifying physiological disturbances in exposed organisms [59]. Water, sediment, or contaminated food sources can expose gastropods to microplastics. Nanoplastics and

microplastics can enter the body either as individual particles or as aggregates combined with organic matter, minerals, and other contaminants. After ingestion, these particles may move from the digestive tract into the circulating hemolymph and hemocytes, enabling them to spread throughout various tissues and organs [60].

G. The Microplastic Contamination Factor (MCF) and Microplastic Pollution Load Index (MPLI)

Table 5 presents the water MCF results, which range from 1.11 to 5.56, reflecting differing degrees of microplastic contamination among the six observation sites. Site 1 recorded the lowest MCF value (1.11), placing it in Risk Category II (Moderate Contamination) and suggesting a comparatively lower level of microplastic contamination relative to the other sites. In contrast, Site 2 registered the highest MCF value at 5.56, followed closely by Site 6 (5.08), Site 5 (4.92), Site 3

(3.41), and Site 4 (3.39). Together, these five locations fall within Risk Category III (Significant Contamination), pointing to a notably elevated level of microplastic pollution. The consistently high MCF values observed at most sites indicate that microplastic abundance in the water considerably exceeds the minimum reference value used in the index calculation. This pattern shows that human activities happening near the water are helping increase the amount of pollution in the IBAT Punten flow system, where those areas with higher inputs of anthropogenic matter are associated with a higher degree of microplastic contamination.

Table 6 presents the sediment MCF results, which range from 1.22 to 6.05 across the observation sites. Site 1 recorded the lowest value (MCF = 1.22), placing it in Risk Category II (Moderate Contamination). Site 2, on the other hand, showed the highest MCF value (6.05) and was the only location classified under Risk Category IV (Very High Contamination), reflecting a particularly severe level of microplastic contamination. This elevated value suggests that Site 2 functions as the primary hotspot for microplastic accumulation in sediment, likely driven by a combination of intense anthropogenic activity, finer sediment composition (sandy mud), and relatively slow current velocity—conditions that collectively favor the settling and retention of microplastic particles. Sites 3, 4, 5, and 6 recorded MCF

values between 5.08 and 5.75, placing them within Risk Category III (Significant Contamination). Taken together, these findings indicate that sediment acts as the main reservoir for microplastic accumulation, particularly at sites exposed to greater waste input, resulting in sediment microplastic concentrations that generally exceed those found in the water column. This pattern is attributed to the tendency of denser plastic particles to settle out of the water and become trapped within the sediment over time.

The MCF values for *Sulcospira testudinaria* range from 1.00 to 5.04, as shown in Table 7. Sites 1 (MCF = 1.00) and 3 (MCF = 2.67) fell into Risk Category II (Moderate Contamination), while Sites 2 (MCF = 4.30), 4 (MCF = 3.44), 5 (MCF = 5.04), and 6 (MCF = 4.96) were classified under Risk Category III (Significant Contamination). These high MCF values match results about microplastic numbers, which also showed Sites 5 and 6 having the most build-up of microplastics inside *S. testudinaria*. Because *S. testudinaria* is a benthic organism that touches the sediment directly, it is very likely to collect microplastics through eating and by touching the ground. These results show that the amount of pollution inside the organism is similar to the pollution in its environment. This supports the idea that *S. testudinaria* can be used as a bioindicator for checking pollution in freshwater ecosystems.

The Microplastic Pollution Load Index (MPLI) shown in Table 8. All three fall within the "Very High"

TABLE 5.
MICROPLASTIC CONTAMINATION FACTORS (MCF) IN WATER

Location	MCF	Risk	Interpretation
Site 1	1.11	Risk II	Moderate Contamination
Site 2	5.56	Risk III	Significant Contamination
Site 3	3.41	Risk III	Significant Contamination
Site 4	3.39	Risk III	Significant Contamination
Site 5	4.92	Risk III	Significant Contamination
Site 6	5.08	Risk III	Significant Contamination

TABLE 6.
MICROPLASTIC CONTAMINATION FACTORS (MCF) IN SEDIMENT

Location	MCF	Risk	Interpretation
Site 1	1.22	Risk II	Moderate Contamination
Site 2	6.05	Risk IV	Very High Contaminant
Site 3	5.08	Risk III	Significant Contamination
Site 4	5.38	Risk III	Significant Contamination
Site 5	5.75	Risk III	Significant Contamination
Site 6	5.75	Risk III	Significant Contamination

TABLE 7.
MICROPLASTIC CONTAMINATION FACTORS (MCF) IN *SULCOSPIRA TESTUDINARIA*

Location	MCF	Risk	Interpretation
Site 1	1	Risk II	Moderate Contamination
Site 2	4.30	Risk III	Significant Contamination
Site 3	2.67	Risk II	Moderate Contamination
Site 4	3.44	Risk III	Significant Contamination
Site 5	5.04	Risk III	Significant Contamination
Site 6	4.96	Risk III	Significant Contamination

TABLE 8.
MICROPLASTIC POLLUTION LOAD INDEX (MPLI)

Variables	MPLI	Interpretation
Water	3.48	Very High
Sediment	4.34	Very High
<i>Sulcospira testudinaria</i>	3.16	Very High

values obtained for water, sediment, and *Sulcospira testudinaria* were 3.48, 4.34, and 3.16, respectively, as

category, indicating that the study site as a whole is experiencing a substantial microplastic pollution burden.

Among the three compartments, sediment recorded the highest MPLI value, followed by water and then *S. testudinaria*. This pattern shows that sediment acts as the place where microplastics build up in the area being studied. At the time, the high MPLI value found in *S. testudinaria* suggests that this organism also takes in a lot of microplastics by being exposed through water, sediment and food. All these MPLI results show that the Punten IBAT stream has a lot of pollution in every part of the environment that was looked at. This highlights the importance of ways to handle plastic waste and keeping an eye on water quality so that more microplastics do not build up in the future.

IV. CONCLUSION

The study's results show that microplastics were found in water, sediment, and *Sulcospira testudinaria* samples in the IBAT Punten watershed. Film-type particles were the common type found in both the water and in *Sulcospira testudinaria*. Fragment-type particles were the common type found in sediment samples. Brown and yellow were the common microplastic colors at all the sites. Site 2 had the number of microplastics in both the water and the sediment. Site 5 had the number of microplastics in *Sulcospira testudinaria*. The MPLI values for water (3.48), for sediment (4.34), and for *Sulcospira testudinaria* (3.16) were all in the "very high" category. This shows that there is a problem with microplastic pollution in all parts of the IBAT Punten watershed. All these findings show that microplastics are everywhere in the water, sediment, and *Sulcospira testudinaria*. This means that microplastics are spread out and can be found by living things in the water. This is a problem because it could harm the animals in the water and the overall quality of the environment.

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