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Identification of Microplastics in the Upper Cimanuk Watershed and Waste Management Analysis in Garut Regency, Indonesia

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ABSTRACT: The Cimanuk River was a vital component supporting water resources in West Java. However, further downstream, the water quality decreased due to industrial and household waste disposal. Plastic pollution was a serious issue because plastics in water degraded into microplastics, which were harmful to both ecosystems and human health. This study aimed to assess the abundance and characteristics of microplastics in the Upper Cimanuk Watershed and to explore how waste management was implemented in Garut Regency. The water sampling method for microplastic analysis used non-probability sampling with a purposive sampling technique. The waste management analysis was a descriptive study using a qualitative approach. Microplastics were found in the waters of the Upper Cimanuk Watershed, with the highest abundance recorded at Station 8 (2.14 particles/liter) and the lowest at Station 1 (0.62 particles/liter). The microplastics identified were dominated by fragments (52%), black-colored particles (47%), and sizes smaller than 1 mm or small microplastics (97%). These findings reflected a high level of microplastic pollution related to human activities around the river. Waste management in Garut Regency had not met its targets, leading to plastic accumulation that could form microplastics. Improvements in facilities, community participation, and policies were needed to control pollution and protect the environment. The results of this study provided baseline data that could inform stakeholders in the Upper Cimanuk Watershed for effective watershed management planning.

KEYWORDS: Cimanuk watershed; microplastics; plastic waste; pollution; waste management

1. Introduction

Rivers were places where water flowed and played a very important role in the balance and sustainability of ecosystems [1]. Humans utilized rivers for a variety of purposes, including household needs, environmental sanitation, industry, agriculture, sports, tourism, fisheries, hydroelectric power generation, transportation, defense, and many others. West Java Province had rivers that were a major force in supporting various aspects of life, one of which was the Cimanuk River [2]. The Cimanuk River was a long river, approximately 180 km in length, with a catchment area of about 350,000 hectares. With its length and vast catchment area, the Cimanuk River flowed into the Jatigede Reservoir. Its source was Mount Papandayan at an altitude of approximately 2,500 meters above sea level, and it flowed into the Java Sea in the northern part of Indramayu Regency [3].

The Cimanuk Watershed was divided into three parts, namely the upstream, middle, and downstream Cimanuk Watershed. Activities taking place in the upstream area had an impact on conditions in the downstream area, considering that the upstream area played an important role in maintaining the sustainability of the overall hydrological function of the watershed. The headwaters of the Cimanuk River were located in Cikajang District, at the foot of Mount Papandayan in Garut Regency, extending to the boundary of the Jatigede Reservoir inundation area in Sumedang Regency. Administratively, the upstream Cimanuk Watershed covered Garut Regency and Sumedang Regency.

Water quality decreased downstream along the Cimanuk River and was largely influenced by human activities near the river [4]. According to [5], environmental pollution was caused by several factors, including densely populated settlements, waste directly dumped into waterways, and poor environmental sanitation. River pollution due to waste, especially plastic waste, had become a global problem. Indonesia ranked fifth in the world for poor plastic waste management [6].

Plastic waste was persistent, difficult to decompose, and difficult to recycle. The continued increase in plastic waste production and low recovery rates led to high accumulations of plastic particles on beaches, in water bodies such as rivers, both at the surface and at depth, and in sediments [7]. Plastic polymers were highly resistant to biodegradation in water, including rivers. However, exposure to UV radiation and water currents could break these polymers into smaller fragments, known as microplastics [8,9]. Microplastic contamination in water had negative impacts on aquatic organisms because microplastic particles were able to absorb harmful compounds and, when ingested by aquatic organisms, could have negative effects on humans through the food chain [10–12]. According to [13], residential areas around rivers provided various sources of microplastic contamination, for example from household washing water, cleaning products, and household waste. These human activities, particularly improper waste management, led to the accumulation of plastic waste in rivers, which eventually broke down into microplastics. Plastics in water degraded into microplastics and were transported by currents from upstream to downstream.

Plastics degraded and produced smaller sizes and different shapes [14]. The characteristics of microplastics found in the environment varied based on their shape, color, size, and polymer type [12]. The forms of microplastics included filaments, films, foam, granules, pellets, and fragments [15]. The colors of microplastics found in the environment varied and included blue, black, yellow, transparent, white, and red [12]. The color of microplastics depended on the type of plastic products used [16] and could change as they underwent degradation due to prolonged exposure to UV light, known as photodegradation. Microplastics that remained dark in color indicated that they had not undergone significant color changes [17]. Fragmentation was the cause of differences in microplastic sizes [18]. The longer microplastics remained in water, the longer the fragmentation process occurred, resulting in smaller particle sizes [19]. Microplastics were divided into two categories: large microplastics and small microplastics. Small microplastics were abundant in water bodies due to the breakdown of larger plastic waste into smaller particles. Microplastics with low density generally remained on the water surface. The smaller the microplastic, the greater the risk, as they were more likely to be consumed by aquatic organisms [20]. The distribution of microplastics in water bodies had been reported in many areas. Several studies in Indonesia had quantified microplastic pollution in rivers, as summarized in Table 1.

Table 1. Abundance, forms, and types of microplastics in rivers in Indonesia.

No	Author/location of the research	Conclusions and Findings
1.	Sei Sikambing River, Medan [21].	Microplastics were detected with an average amount of 114.4 particles/liter of river water.
2.	Kalimas River, Surabaya, East Java [22].	The river was reported to be contaminated by microplastics with an average concentration of 0.000007 particles/liter.
3.	Labuh Pond and Blangor River, Palang District, Tuban [23].	The average abundance of microplastics reached 13.33 ± 5.03 particles/liter.
4.	Ciwalengke River, Majalaya Regency, Indonesia [24].	The mean abundance of microplastics found on the surface water was 5.85±3.28 particles/liter.
5.	The Upper Bengawan Solo River [25].	The average abundance of microplastics was recorded at 0.31 particles/liter.
6.	Mahakam River in Sebulu Modern Village, Sebulu District [26].	Microplastics were found at 13 particles/liter at point 1, 20 particles/liter at point 2, and 21 particles/liter at point 3.

Research on microplastics in the water column is still very limited in Indonesia [27]. Research on microplastics based on abundance, size, shape, color, and polymer type in rivers is still very limited when compared to microplastics in the sea [28]. Most investigations have focused primarily on abundance and polymer types without integrating watershed-scale waste management conditions. This study provides novel insights by focusing on the Upper Cimanuk Watershed, an area that has received limited scientific attention, while explicitly linking microplastic distribution with local solid waste management practices. Therefore, this study aims to investigate the abundance and characteristics of microplastics in the Upper Cimanuk Watershed, providing baseline data for policymakers and local authorities in plastic waste management in Garut district. The findings will contribute to river management strategies and pollution mitigation efforts in West Java, particularly in areas that are vulnerable to upstream pollution impacts.

2. Materials and Methods

2.1.Research methods.

The method used was a descriptive research method with a quantitative approach employed to observe, analyze, and describe the study subject. The results in this study will be presented in numbers, and conclusions will be drawn based on the phenomena seen during the research. This research activity was carried out ex-situ, which included water sampling at sampling points, abundance calculations, and identification of microplastic characteristics carried out in the laboratory. The water sampling method for microplastic calculations used non-probability sampling using a purposive sampling technique. The waste management analysis is a descriptive study using a qualitative approach, focusing on waste management by the Environmental Affairs Agency of Garut Regency. Data collection was obtained through interviews and secondary data derived from the Garut Regency Waste Management Report, 2024, issued by the Environmental Affairs Agency of Garut Regency.

2.2. Sampling time and sampling point.

The research was conducted for approximately 4 months, from July to October 2025. The sampling location was in the Cimanuk upstream watershed. Sampling locations were carried out at 8 station points. The selection of sampling points was carried out based on land use and demographic conditions around the sampling location. The locations of the research stations is shown on Table 2 and Figure 1.

Table 2. Research station location.

Sampling Point	Coordinate Points	Land Use
Station 1	7°20'04.6"S 107°47'49.4"E	Secondary dryland forest, tofu industry, and car wash
Station 2	7°17'37.5"S 107°48'14.8"E	Dairy cattle farming group (KTSP) Bojong 3
Station 3	7°16'15.0"S 107°48'51.3"E	Bayongbong intersection market
Station 4	7°15'55.4"S 107°49'33.4"E	Agriculture and plantations
Station 5	7°14'51.3"S 107°51'38.3"E	Secondary dryland forest
Station 6	7°13'19.1"S 107°54'01.9"E	Densely populated urban area with few restaurants or small businesses
Station 7	7°12'57.0"S 107°54'41.8"E	Leather industrial area
Station 8	7°11'07.6"S 107°54'28.5"E	Residential area.

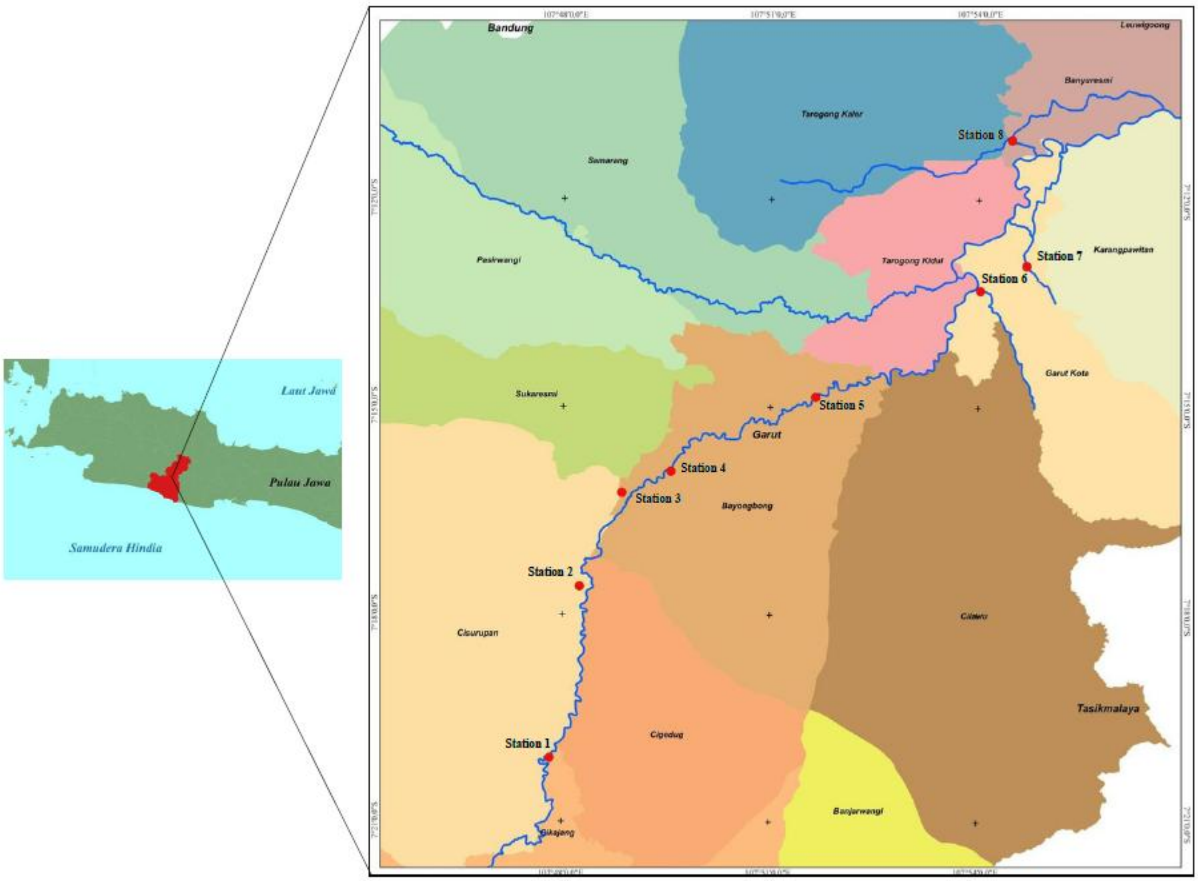

Figure 1. Research location of the Upper Cimanuk watershed.

2.3. Tools and materials.

This research was carried out through two main stages: field sampling and laboratory sample processing. The equipment used included a cool box for storing water samples, a 300 μm plankton net for filtering microplastics from the water, and a Global Positioning System (GPS) to accurately determine sampling site coordinates. In addition, label paper was used to provide identification marks for each sample, sample bottles served as containers for storing water, a camera was used to document research activities, and a bucket was used for the direct collection of water samples in the field.

During the laboratory sample processing stage, various instruments were used to support the identification and analysis of microplastics. A microscope served as the main instrument for identifying microplastic particles, while aluminum foil was used to cover beaker glass to prevent sample contamination. Beaker glass functioned as a container for holding samples, and a measuring cylinder was used to measure the volume of solutions used in the processing procedure. An Erlenmeyer flask assisted in the filtration process, while Zen software was used to facilitate digital observation of microplastics. A glass funnel was employed to hold filter paper during filtration. Additionally, a water bath was used to maintain a stable temperature during sample treatment, a needle was used to distinguish microplastic particles from organic matter, and metal tweezers were used to handle Whatman filter papers. To minimize contamination, all laboratory personnel wore cotton laboratory coats and gloves, and samples were processed in a clean environment. Procedural blanks were prepared and analyzed alongside the samples. All glassware was rinsed with filtered distilled water prior to use.

2.4. Sampling technique and preparation.

Water sampling for microplastic identification in this study began with determining the water sampling stations, selecting the sampling method, and preparing the tools and materials required for sampling. Water sampling followed the protocols described in [29] and [30]. The water samples were collected from surface waters in the Upper Cimanuk Watershed. The total abundance of microplastics in surface waters at a depth of 0–10 cm showed relatively high values, as microplastics generally have low density and tend to remain suspended or float within the water column [31].

A total of 150 L of surface water was filtered using a 300 μm plankton net by collecting surface water with a 10 L stainless steel bucket repeated 15 times. The use of a 300 μm plankton net may have underestimated microplastic particles smaller than 300 μm; however, this mesh size is commonly used in riverine microplastic studies to balance sampling efficiency and contamination control. The filtered water sample retained in the plankton net collection bottle was transferred to a measuring cup to determine the volume of filtered water. Subsequently, the water sample was transferred into a glass sample bottle, and the walls of the measuring cup were rinsed to ensure that no microplastic particles were left behind. The glass bottle was then tightly closed, labeled, and stored in a cool box with a blue ice pack. The samples were stored in a refrigerator at 4°C prior to laboratory analysis.

The method for identifying microplastic types followed the National Oceanic and Atmospheric Administration (NOAA) manual [32] and the procedure described by [33]. Identification included wet filtration, sample drying, wet peroxide oxidation (WPO), and microplastic identification. In the laboratory, samples obtained from plankton net filtration were re-filtered. The filter was carefully rinsed with double-distilled water (DDW) to ensure the transfer of all microplastic particles. The filtered sample was placed into a test tube, and a wet peroxide oxidation (WPO) procedure was performed by adding 20 mL of 30% H_2O_2 and 20 mL of $Fe(II)SO_4$**,** followed by overnight incubation. Hydrogen peroxide was used to remove organic matter, while $Fe(II)SO_4$ acted as a catalyst for Fenton's reagent.

The sample was then heated and stirred using a magnetic stirrer for 2 hours and incubated at 40°C for 36–48 hours or until the solution became clear. The treated sample was filtered using sterile Whatman filter paper (0.45 µm pore size, 47 mm diameter). Microplastic particles retained on the filter paper were identified under a microscope at 4×10^{-1} magnification. Images of the microplastics were captured and measured using Zen 2 software. Summary of microplastic sampling and analysis procedures is shown in Table 3.

Table 3. Summary of microplastic sampling and analysis procedures.

Step	Process
Water sampling	150 liters of surface water were filtered using a plankton net (300 µm)
Wet peroxide oxidation	A total of 20 ml of 30% H_2O_2 and 20 ml of Fe(II)SO_4 were added to the sample and left overnight for the incubation process.
Filtration	The sample was then filtered using sterile Whatman filter paper
Identification	Microplastic identified under the aid of a microscope.magnification $4x10^{-1}$. Then, images of microplastics were taken and measured using Zen 2 software.

The calculation of microplastic abundance was conducted using water samples collected from each sampling station. A specific procedure was applied to determine the abundance of microplastics in water samples from the Cimanuk Watershed, and the results were expressed in particles per liter. Microplastic abundance was calculated using the following formula.

$$c = \frac{n}{V}$$

where C represents microplastic abundance (particles per liter), n denotes the number of microplastic particles per sample, and V refers to the total volume of water sampled.

3. Results and Discussion

3.1. Microplastic abundance.

The abundance of microplastics at Station 1 was 0.63 particles/liter. At Station 2, the microplastic abundance was 1.09 particles/liter. Station 3 showed a microplastic abundance of 1.63 particles/liter. At Station 4, 1.03 particles/liter of microplastics were detected. At Station 5, the abundance was 0.71 particles/liter. At Station 6, microplastics were detected at 2.01 particles/liter. At Station 7, the abundance was 2.03 particles/liter. At Station 8, microplastics were detected at 2.14 particles/liter. The abundance of microplastics is shown in Figure 1.

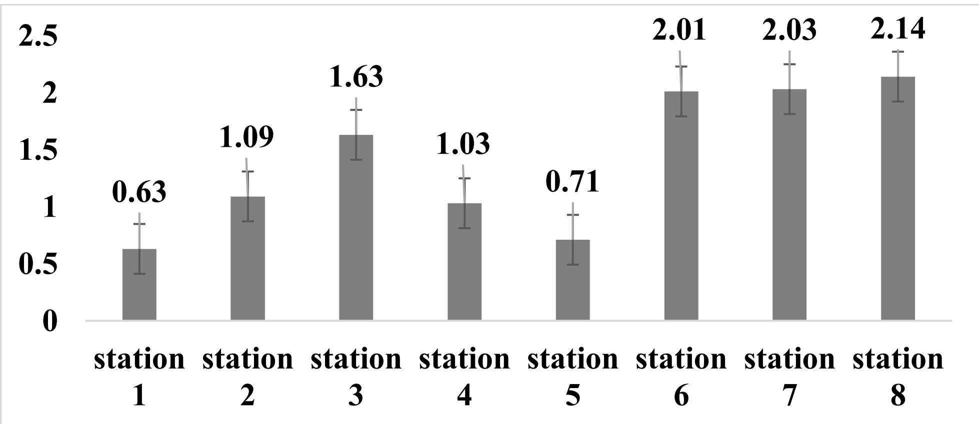

Figure 1. Abundance of microplastics in waters.

the study confirmed that the presence of microplastics in the Upper Cimanuk Watershed was strongly influenced by anthropogenic activities, including both industrial and domestic waste inputs. Based on the data obtained, the highest abundance of microplastics was found at

Station 8, with a total of 2.14 particles/liter. The highest microplastic values occurred in areas with diverse waste inputs, particularly at Station 8, which is located in Haurpanggung Village, Tarogong Kidul District, Garut Regency, West Java. Land use at this station consisted of former rice fields that had been converted into residential areas. Residential areas contributed various sources of microplastics, such as laundry effluents, personal care products, and domestic waste [34]. In contrast, the lowest abundance of microplastics was found at Station 1, with a value of 0.62 particles/liter. Although several anthropogenic activities were present in this area, such as tofu production and car washing, the site was dominated by natural vegetation, which likely resulted in lower microplastic abundance compared to other stations. The abundance of microplastics in the Upper Cimanuk Watershed was also influenced by waste accumulation around the sampling locations, as field observations indicated the presence of accumulated waste at all sampling sites.

The average abundance of microplastics in the surface waters of the Upper Cimanuk Watershed was 1.41 particles/liter, indicating a moderate level of microplastic pollution when compared to rivers with mixed land use, such as residential areas, agricultural land, and local trade activities. For example, the Ciwalangke River, a sub-watershed of the Citarum River, exhibited a higher microplastic abundance of 5.85 ± 3.28 particles/liter. Differences in microplastic abundance among rivers were attributed to variations in land use patterns, population density, and waste management systems in each region. The microplastic abundance in the Upper Cimanuk Watershed was lower than that reported for the Thames River, the main river in southern England, where the average abundance along the river reached 12.27 particles/liter. This higher abundance was associated with intense urbanization in the Thames region, as well as inputs from textiles, laundry activities, and urban runoff, which generated large quantities of microplastic particles despite relatively advanced wastewater treatment systems. This comparison indicated that microplastic abundance was influenced not only by the effectiveness of waste management but also by the degree of urbanization and the concentration of human activities along river systems [35]. Urbanization and industrial activities further exacerbated microplastic pollution, as household waste, wastewater, and stormwater runoff introduced substantial amounts of microplastics into aquatic environments [36].

3.2.Characteristics of microplastics.

3.2.1. Microplastic frms.

Microplastics in water were identified based on their varying forms, including fragments, filaments, films, foam, pellets, and granules [15]. In the waters of the Upper Cimanuk Watershed, several forms of microplastics were identified, namely fragments, fibers, films, and pellets. The distribution of microplastic forms found in the Upper Cimanuk Watershed is presented in Figure 2. The number of microplastics based on shape is shown in Table 4. Based on the data, microplastic fragments were the dominant form at all sampling stations. A total of 887 microplastic fragments were identified, accounting for approximately 52% of all microplastics detected. This result indicated that more than half of the microplastics present in the Upper Cimanuk Watershed consisted of fragments. This number was considerably higher than that of other forms, such as fibers, with 424 particles (25%), films, with 336 particles (20%), and pellets, with 45 particles (3%). Microplastic fragments generally originated from anthropogenic waste disposal [37], which was consistent with the study area being predominantly residential and therefore susceptible to direct waste inputs into the river. This finding was further supported by previous research [38], which identified microplastic fragments on Oeseli Island and suggested that they originated from domestic activities in Oeseli Village. Microplastic fragments resulted from the degradation and fragmentation of larger plastic debris (macroplastics) [20]. Due to their relatively low density, these fragments could float on the water surface [15]. Microplastic fragments typically consisted of rigid synthetic polymers, such as fragments from plastic bottles, jars, gallon containers, hard plastics, and PVC pipes [39]. Considering the substantial accumulation of waste observed around the sampling locations, the microplastic fragments identified in this study were likely derived from beverage and food packaging, plastic containers, gallon jugs, hard plastics, and small pieces of PVC pipes associated with local community activities.

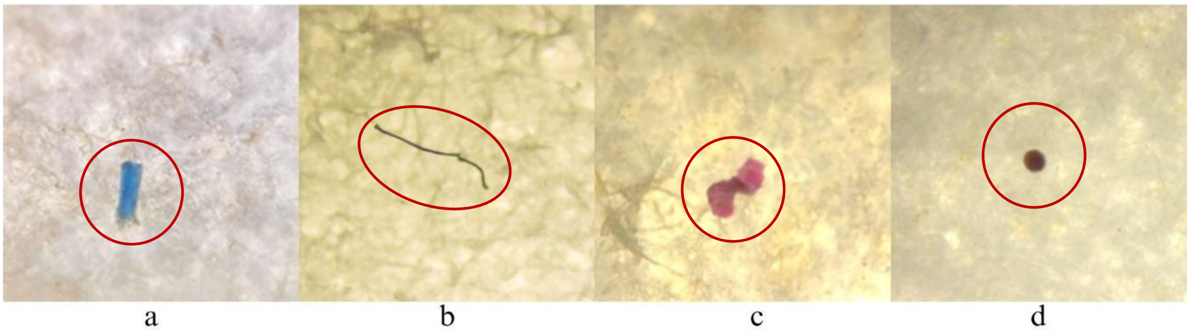

Figure 2. Microplastics based on form: (a) Fragments, (b) Fibers, (c) Films, (d) Pellets.

Table 4. Number of microplastics based on shape.

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	%
Fragment	34	76	153	80	38	172	113	221	52%
Fiber	18	60	23	42	46	76	96	63	25%
Film	21	28	45	33	23	53	96	37	20%
Pellets	21	0	24	0	0	0	0	0	3%
Total	**94**	**164**	**245**	**155**	**107**	**301**	**305**	**321**	**100%**

3.2.2. Microplastic color.

The colors of microplastics found in aquatic environments varied considerably. According to [12], microplastics in the environment can be grouped into six categories: blue, black, yellow, transparent, white, and red. In the waters of the Upper Cimanuk Watershed, several microplastic colors were identified, including transparent, black, brown, green, red, yellow, and blue. The distribution of microplastic colors observed in the Upper Cimanuk Watershed is presented in Figure 3, while the number of microplastics based on color is presented in Table 5. Black microplastics dominated the samples at almost all stations, with a total of 800 particles, accounting for approximately 47% of the total microplastics identified. Transparent microplastics ranked second, with 460 particles (27%), followed by brown microplastics with 272 particles (16%). Blue microplastics accounted for 80 particles (5%), red microplastics for 52 particles (3%), yellow microplastics for 17 particles (1%), and green microplastics for 11 particles (1%).

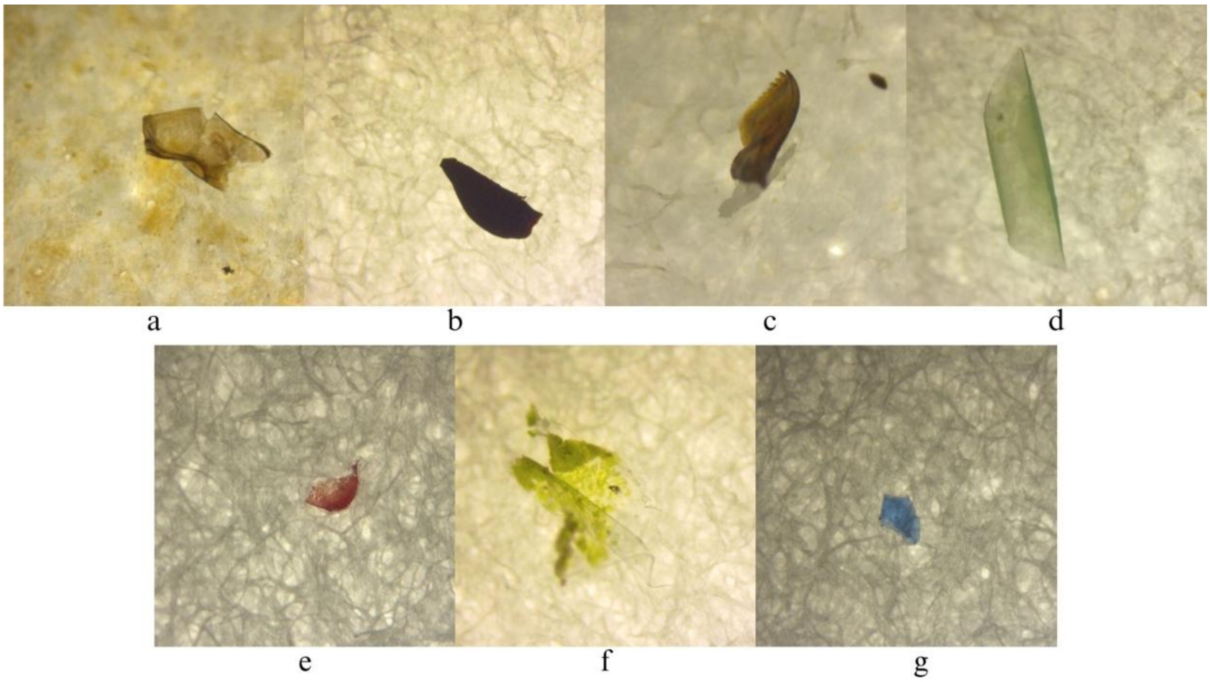

Figure 3. Microplastics based on color (a) transparent, (b) black, (c) brown, (d) green, (e) red, (f) yellow, (g) blue.

Table 5. Number of microplastics based on color.

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	%
Transparent	22	46	108	50	28	104	49	53	27%
Black	37	80	105	76	55	97	190	160	47%
Chocolate	25	27	0	19	5	70	43	83	16%
Green	0	0	7	0	0	0	2	2	1%
Red	5	5	9	1	8	0	8	16	3%
Yellow	0	0	0	0	0	17	0	0	1%
Blue	5	6	16	9	11	13	13	7	5%

The color of microplastics provided valuable information for predicting both their sources and degradation processes [34]. Black microplastics indicated particles that had remained relatively intact and had not undergone significant color changes [37]. The persistence of dark coloration suggested limited photodegradation, implying that these particles had retained much of their original polymer structure. Most black microplastics were likely derived from plastic bags and packaging materials. In addition, the dark coloration of microplastics commonly found in aquatic environments may indicate a high capacity for contaminant adsorption. This observation was consistent with previous findings [40], which reported that black microplastics tend to absorb higher levels of contaminants. The predominance of black microplastics therefore suggested strong associations with anthropogenic sources such as domestic waste, plastic packaging, and degraded rubber materials. Similar results were reported by [37], indicating that black microplastic particles frequently originated from everyday consumer products transported into waterways through improper waste disposal or surface runoff. Furthermore, variations in color intensity reflected different stages of degradation, with darker particles often representing materials that had undergone partial oxidation rather than complete photodegradation. Consequently, color analysis served as an important indicator not only of pollution sources but also of the degradation status of plastic debris in aquatic environments.

3.2.3. Microplastic size.

Based on their size, microplastics were categorized into Large Microplastics (LMP) and Small Microplastics (SMP). Large Microplastics (LMP) were microplastics measuring 1–5 mm, while Small Microplastics (SMP) were microplastics measuring <1 mm and >1 μm [41]. The most dominant microplastic size was Small Microplastic (SMP), which accounted for 1,645 of the 1,692 microplastic particles found in the waters of the Upper Cimanuk Watershed. Small Microplastic (SMP) represented 97% of the total microplastics, whereas Large Microplastic (LMP) accounted for 3% of the total. The number of microplastics by size is presented in Table 6. In aquatic systems, Large Microplastics (LMP) were found less frequently compared to Small Microplastics (SMP). This occurred because larger microplastics tended to sink in water [42], whereas smaller microplastics tended to float due to their lower density [24]. Small Microplastics (SMP) were found more frequently in waters because larger plastic waste could break down into smaller particles [43]. The dominance of smaller microplastics indicated significant fragmentation in the waters of the Upper Cimanuk Watershed. Furthermore, the prevalence of smaller microplastics increased the potential for consumption by microorganisms. This is consistent with [44], who stated that microplastics are very small wastes in water that can be easily consumed by aquatic organisms, making them one of the most hazardous types of waste in aquatic environments.

Table 6. Number of microplastics by size.

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	%
SMP	94	158	239	155	99	301	292	307	97%
LMP	0	6	6	0	8	0	13	14	3%

3.3. Waste management analysis.

Waste management in Indonesia was regulated under Law Number 18 of 2008, which defined waste as the remaining material from daily human activities or natural processes in solid form. This regulation established the legal foundation for national waste management, aiming to enhance public health, maintain environmental sustainability, and transform waste into valuable resources through the implementation of reduce, reuse, and recycle (3R) principles. According to data published by the National Waste Management Information System (SIPSN), Indonesia generated approximately 33.6 million tons of waste in 2024, illustrating the magnitude of waste production at the national level. Despite existing regulations, reports indicated that Indonesia still ranked fifth worldwide among countries with inadequate plastic waste management systems, highlighting ongoing challenges in handling plastic pollution effectively [6].

Poorly managed plastic waste was one of the primary contributors to the increasing presence of microplastics in river ecosystems. Improper disposal practices allowed plastic materials to enter aquatic environments, where they fragmented into microplastics that polluted water bodies [31]. Addressing this issue, the government was responsible for establishing and maintaining waste management facilities, developing relevant policies, and exercising regulatory oversight. Meanwhile, community participation was equally essential, particularly in waste sorting and local-level management initiatives.

Operationally, waste management in many regions remained concentrated around Temporary Collection Sites (TPS) and Final Disposal Sites (TPA) administered by local governments. In Garut Regency, the Environmental Agency developed several waste management facilities; however, ongoing evaluation was necessary due to the growing volume of plastic waste generated within the region. These facilities included a Unit Waste Bank, a TPS3R (Inorganic Waste) managed by KSM, large- and small-scale collection at stalls (Inorganic Waste), creative product recycling (Ecovillage/Pro-Climate), and other facilities. Strengthening local waste management capacity was crucial to prevent the escalation of microplastic pollution and to ensure that waste handling aligned with national regulatory objectives.

Referring to the national policy and strategy for waste management set out in Presidential Decree No. 97 of 2017 concerning the National Policy and Strategy for the Management of Household Waste and Household-Similar Waste, efforts to reduce waste were carried out through three main activities: limiting the amount of waste generated, recycling waste materials, and reusing waste products. These actions were intended to minimize the volume of waste entering landfills by encouraging resource efficiency and extending the lifecycle of materials.

Furthermore, according to Presidential Regulation Number 97 of 2017 on the National Policy and Strategy for the Management of Household Waste and Household-Equivalent Waste, the national target for 2024 was to achieve 28% waste reduction through the 3R approach and 72% proper waste management through processing and final disposal systems. This target served as a national benchmark and guided regional governments in implementing integrated waste management systems. Overall, Garut Regency had not been able to meet these targets. As of December 2024, the waste reduction rate in Garut Regency only reached 13.76%, and the waste management rate was 21.29%. The complete data are presented in Table 7.

Table 7. Waste reduction and management achievements in 2024.

No	Indicator	Target		Achievements	
		Tons/Year	%	Tons/Year	%
1	Waste generation	418.262,61	100	418.262,61	100
2	Waste reduction	110.555,65	28	57.526,80	13.76
3	Waste management	294.815,07	72	89.060,00	21.29

Waste management efforts had not yet achieved their targets. Both waste reduction and handling remained far below the intended goals. This demonstrated the need to improve the effectiveness of waste reduction and management programs in terms of facilities, community participation, and supporting policies. As mandated by Law Number 18 of 2008 on Waste Management, which emphasizes waste reduction and handling through source separation at the household level, inadequate waste segregation, limited waste treatment facilities, and illegal dumping practices along riverbanks could significantly increase the input of plastic waste. This waste then undergoes fragmentation processes that lead to the formation of microplastics. Therefore, strengthening the implementation of local waste management policies in alignment with Government Regulation Number 81 of 2021 on the Management of Household Waste and Household-Like Waste was essential, particularly through the optimization of waste banks, expansion of waste collection services, and enhanced monitoring and law enforcement against illegal dumping within watershed areas. Furthermore, integrating waste management strategies with an integrated watershed management approach is consistent with Law Number 32 of 2009 on Environmental Protection and Management and is expected to reduce sources of plastic pollution and, subsequently, decrease the microplastic load entering riverine environments.

4. Conclusions

The results of the study showed that the abundance of microplastics in the waters of the Upper Cimanuk Watershed varied. The highest abundance of microplastics was observed at Station 8, located in a residential area, with 2.14 particles/liter, while the lowest abundance was at Station 1, situated around secondary dryland forest, a tofu industry, and a car wash, with 0.62 particles/liter. The forms of microplastics found included fragments, fibers, films, and pellets, with fragments dominating at 52% of the total microplastics. These fragments originated from the breakdown of larger plastic waste, such as bottles and pipes. The colors of microplastics identified in the watershed included transparent, black, brown, green, red, yellow, and blue. Black microplastics were the most common, accounting for 47% of the total, generally originating from plastic bags and showing minimal discoloration. The most dominant microplastic size was <1 mm, classified as Small Microplastics (SMP), comprising 97% of the total, indicating a high level of fragmentation in these waters. Overall, the color and size distribution of microplastics reflected the combined influence of local anthropogenic activities, waste management practices, and hydrological transport processes. The dominance of small, dark-colored particles highlighted both continuous waste inflow and active fragmentation, making the Upper Cimanuk Watershed a critical point source for downstream microplastic pollution. These results indicate high levels of microplastic pollution strongly associated with human activities near the river, particularly inadequate waste management. The effectiveness of waste reduction and management programs needs to be improved in terms of facility availability, community participation, and support from local government policies. Failure to achieve these targets may lead to increased accumulation of plastic waste in the environment, which over time will degrade into microplastics and contaminate aquatic ecosystems. Future research should analyze polymer composition and conduct temporal monitoring to assess seasonal variations and long-term accumulation trends.

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Author Contributions

Afiefah Salsabila: Conceptualization, Methodology, Data Collection, Data Analysis, and Writing. Sunardi: Conceptualization and Supervision. Titin Herawati : Conceptualization and Supervision.

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