UNIVERSIDAD PERUANA UNIÓN

FACULTAD DE INGENIERÍA Y ARQUITECTURA

Escuela Profesional de Ingeniería Ambiental

Micro plásticos como agentes de contaminación en los principales afluentes del río Cumbaza

Tesis para obtener el Título Profesional de Ingeniero Ambiental

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Tarapoto, Setiembre del 2024

DECLARACIÓN JURADA DE ORIGINALIDAD DE TESIS

Yo Richer Garay Montes, docente de la Facultad de Ingeniería y Arquitectura, Escuela Profesional de Ingeniería Ambiental, de la Universidad Peruana Unión.

DECLARO:

Que la presente investigación titulada: **"MICRO PLÁSTICOS COMO AGENTE DE CONTAMINACIÓN EN LOS PRINCIPALES AFLUENTES DEL RÍO CUMBAZA"** de los autores Glicerio Jefferson Roca Malparida y Edwin Junior Flores Ruiz tiene un índice de similitud de 7 % verificable en el informe del programa Turnitin, y fue realizada en la Universidad Peruana Unión bajo mi dirección.

En tal sentido asumo la responsabilidad que corresponde ante cualquier falsedad u omisión de los documentos como de la información aportada, firmo la presente declaración en la ciudad de Tarapoto a los 10 días del mes de setiembre del año 2024.

Richer Garay Montes

ACTA DE SUSTENTACIÓN DE TESIS

En San Martín, Tarapoto, Morales, a....2.9...... día(s) del mes de........a.g.o.s.t.o...................del año 20.2..4.... siendo las..1...5..:.0..0 .. horas, se reunieron los miembros del jurado en la Universidad Peruana Unión Campus Tarapoto, bajo la dirección del (de la) presidente(a): ……Mtra. Betsabeth Teresa Padilla Macedo……, el (la) secretario(a): ……Dr. Victor Hugo Muñoz Delgado…… y los demás miembros: ……Mtro. Carmelino Almestar Villegar y Mtro. Andres Erick Gonzales López…… y el (la) asesor(a) ……Mtro. Richer Garay Montes…… con el propósito de administrar el acto académico de sustentación de la tesis titulado: **“Micro plásticos como agentes de contaminación en los principales afluentes del río Cumbaza.”** …… del(los) bachiller/es: a) ……Glicerio Jefferson Roca Malpartida…… b)……Edwin Junior Flores Ruiz…… c)…… conducente a la obtención del título profesional de: ……Ingeniero Ambiental……

(Denominación del Título Profesional)

El Presidente inició el acto académico de sustentación invitando al (a la) / a (los) (las) candidato(a)/s hacer uso del tiempo determinado para su exposición. Concluida la exposición, el Presidente invitó a los demás miembros del jurado a efectuar las preguntas, y aclaraciones pertinentes, las cuales fueron absueltas por al (a la) / a (los) (las) candidato(a)/s. Luego, se produjo un receso para las deliberaciones y la emisión del dictamen del jurado.

Posteriormente, el jurado procedió a dejar constancia escrita sobre la evaluación en la presente acta, con el dictamen siguiente:

Bachiller (a): ……Glicerio Jefferson Roca Malpartida……

CALIFICACIÓN	ESCALAS			Mérito
	Vigesimal	Literal	Cualitativa	
Aprobado	18	A -	Muy Bueno	Sobresaliente

Bachiller -(b): ……Edwin Junior Flores Ruiz……

CALIFICACIÓN	ESCALAS			Mérito
	Vigesimal	Literal	Cualitativa	
Aprobado	18	A -	Muy Bueno	Sobresaliente

Bachiller -(c): ……

CALIFICACIÓN	ESCALAS			Mérito
	Vigesimal	Literal	Cualitativa	

(*) Ver parte posterior

Finalmente, el Presidente del jurado invitó al (a la) / a (los) (las) candidato(a)/s a ponerse de pie, para recibir la evaluación final y concluir el acto académico de sustentación procediéndose a registrar las firmas respectivas.

Presidente/a		Secretario/a
Asesor/a	Miembro	Miembro
Bachiller (a)	Bachiller (b)	Bachiller (c)

(*) Tabla de Calificación

CALIFICACIÓN	ESCALAS			Mérito
	Vigesimal	Literal	Cualitativa	
APROBADO	20	A+	Con nominación de **Excelente**	Excelencia
	19	A		
	18	A-	Con nominación de **Muy Bueno**	Sobresaliente
	17	B+		
	16	B	Con nominación de **Bueno**	Muy Bueno
	15	B-		
	14	C	Con nominación de **Aceptable**	Bueno
DESAPROBADO	Menos de 14	D	Con nominación de **Deficiente**	Insuficiente

Microplastics as pollution agents in the main tributaries of the Cumbaza River

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ABSTRACT

The study focused on identifying the presence of microplastics (MP) in the main tributaries of the Cumbaza River, Morales district, San Martín Region, Peru. Eight sampling points were defined, with 3 samples collected at each point during August 2023, the dry season, with temperatures between 18.3°C and 32.5°C and a monthly precipitation of 68 mm. Sampling sites included Juan Guerra, La Banda de Shilcayo, Tarapoto, Morales, and San Antonio. 2582 MPs were identified: 46.28% filaments (1195 MPs), 42.84% fragments (1106 MPs), and 10.88% microspheres (281 MPs). Cluster analysis showed that filaments and fragments share similar profiles, suggesting common sources, while microspheres come from different sources. Principal component analysis (PCA) indicated that filaments are more dispersed, while fragments and microspheres are often found together, depending on the sampling point. The abundance of MPs was highest in filaments, followed by fragments and microspheres. The MPs' sizes varied: filaments between 1.87 µm and 4934.18 µm, fragments between 1.38 µm and 2104.94 µm, and microspheres between 0.19 µm and 512.72 µm. The predominant color was blue, followed by red, with a consistent distribution at all sampling points. This study reveals a considerable presence of PMs in the tributaries of the Cumbaza River, highlighting the need to implement measures to mitigate microplastic pollution in the region. The diversity and abundance of MPs suggest multiple sources of pollution, mainly anthropogenic, that affect these freshwater bodies.

Keywords: Pollution, rivers, Forms an MPs

Microplásticos como agentes de poluição em principais afluentes do rio Cumbaza

RESUMO

O estudo se concentrou em identificar a presença de microplásticos (MP) nos principais afluentes do rio Cumbaza, distrito de Morales, região de San Martín, Peru. Foram definidos 8 pontos amostrais, coletando 3 amostras em cada ponto durante o mês de agosto de 2023, no período seco, com temperaturas entre 18,3°C e 32,5°C e precipitação mensal de 68 mm. Os locais de amostragem incluíram Juan Guerra, La Banda de Shilcayo, Tarapoto, Morales e San Antonio. Foram identificados 2.582 MPs: 46,28% de filamentos (1.195 MPs), 42,84% de fragmentos (1.106 MPs) e 10,88% de microesferas (281 MPs). A análise de agrupamento mostrou que filamentos e fragmentos compartilham perfis semelhantes, sugerindo fontes comuns, enquanto as microesferas vêm de fontes diferentes. A análise de componentes principais (PCA) indicou que os filamentos estão mais dispersos, enquanto fragmentos e microesferas são frequentemente encontrados juntos, dependendo do ponto de amostragem. A abundância de MPs foi maior em filamentos, seguido por fragmentos e microesferas. Os tamanhos dos MPs variaram: filamentos entre 1,87 µm e 4.934,18 µm, fragmentos entre 1,38 µm e 2.104,94 µm e microesferas entre 0,19 µm e 512,72 µm. A cor predominante foi o azul, seguido do vermelho, com distribuição consistente em todos os pontos amostrais. Este estudo revela uma presença considerável de PMs nos afluentes do Rio Cumbaza, destacando a necessidade de implementar medidas para mitigar a poluição por microplásticos na região. A diversidade e abundância de MPs sugerem múltiplas fontes de poluição, principalmente antropogénicas, que afectam estas massas de água doce.

Palavras-chave: Poluição, rios, Formas e MPs

1. INTRODUCTION

The world population and economic growth affect the demand for natural resources, services, and products to satisfy the population's basic and secondary needs. With this situation, industries have looked for alternatives to using natural resources such as rubber, wool, or cellulose. Thus, in the 1940s, plastic was marketed as an alternative for many applications (Chen et al., 2023). Plastics play an essential role in production and people's lives, but their indestructibility and leaching are pressing environmental problems (Li, Xiu, and Hao, 2024).

The presence and abundance of plastics in continental and oceanic waters is a global problem. According to the Organization for Economic Development (OECD), in 2022, only 9% of plastics were recycled, 19% were burned as fuel, 50% were dumped in landfills, and 22% escaped waste management and were lost to the environment. Plastic waste is mainly the product of poor municipal solid waste management and is often buried, burned, or dumped in informal landfills near rivers (Mghili, Keznine, Hasni, and Aksissou, 2023). The most commonly used plastic products are plastic bags, synthetic clothing, paints, plastic straws, toothbrushes, plastic bottles, tires, cosmetics, disposable coffee cups with lids, and product containers (Lee and Jeong, 2023). Furthermore, they have become persistent and ubiquitous pollutants in the ocean. (Hitchcock and Mitrovic, 2019).

Plastic pollution is now recognized as a global crisis, and we are working to achieve a global agreement to address it (Monteiro et al., 2022). It has become a persistent pollutant in recent decades (Long et al., 2022). Unlike larger plastics, microplastics (MPs) are almost invisible and contribute significantly to plastic pollution, so their environmental impact needs to be investigated (Rahman et al., 2024). MPs have been found in plankton samples since the 1960s and have increased abundance over time. These range in size from 1 µm to 5 mm and include primary plastics such as microspheres, microfibers, or secondary plastics formed by breaking down large plastics into smaller particles (Frias & Nash, 2019).

Nowhere can we do without this material, from the bottom of the sea to Mount Everest, Antarctica to the North Pole (Pazos, 2021). They were also found in salt, bottled water, and human blood (Leslie et al., 2022), releasing toxic and carcinogenic substances due to environmental exposure, affecting food safety and, ultimately, human health (González- Soto et al., 2022). Prolonged exposure to microplastics may even be of serious concern due to its potential dose-dependent cumulative effects (Yang, Man, Wong, Owen, and Chow, 2022).

Research carried out in Europe (Scherer et al., 2020) entitled comparative evaluation of microplastics in water and sediments of a large European River demonstrated a higher concentration of microplastics in the sediments, on average 600,000 times higher than the concentration in the body of water of the German River Elbe.

In addition, (Islam et al., 2022) carried out research called Omnipresence and Characteristics of Microplastics in Surface Waters and sediments of the Buriganga River, Bangladesh; the result was that in the sediments of the Buringaga River, there were 85.5% of fragmentary type polymers and in the surface waters it had 72.7%. On the other hand, the abundance of polypropylene (PP) in sediments was 61%. In a lesser quantity in the surface water, with 46%, it was also obtained that in the surface waters and the sediment samples, there was a differentiation of 5% of polyethylene, with 26% in the surface waters and 21% in the sediment samples.

Likewise, (Huanaco, 2019a) monitored the Rímac River, which tells us that microplastics are particles less than 5 mm long in marine and River ecosystems. 538.9 MPs/m2 were identified in November 2017 and 16,566.7 MPs/m2 in August 2018 in the 7 monitoring points of the Rímac River. The recognized MPs belong to polystyrene, polypropylene, and polyethylene terephthalate.

In addition, research was carried out by (Rico et al., 2023) in the Amazon River; in this study, we carried out an extensive monitoring campaign to evaluate the presence and risks of PM in the freshwater ecosystems of the Amazon. We investigated PM contamination in 40 samples collected over 1500 km in the Brazilian Amazon, including the Amazon River, three major tributaries, and several streams close to major urban areas. MPs in the size range of 55 to 5000 μm were characterized (size, shape, color) by microscopy and identified (polymer composition) by infrared spectroscopy; this study shows that MPs are ubiquitous contaminants in freshwater ecosystems of the Amazon, with measured concentrations (55– 5000 μm) ranging between 5 and 152 MP/m 3 in the Amazon River and its main tributaries, and between 23 and 74 550 MP/m 3 in urban streams. The calculated hazardous concentration for 5% of species (HC 5) derived from SSDs for the entire MP range (1–5000 μm) was 1.6 × 10 7 MPs/m 3 (95% CI: 1 .2 × 10 6 – 4.0 × 10 8) for food dilution and 1.8 × 10 7 MPs/m 3
(95% CI: 1.5 × 10 6 – 4.3 × 10 8) for translocation. Rescaled exposure concentrations (1–5000 μm) in the Amazon River and its tributaries ranged between 6.0 × 10 3 and 1.8 × 10 5 MPs/m 3 and were significantly lower than the calculated HC 5 values. Rescaled concentrations in urban streams ranged from 1.7 × 10 5 to 5.7 × 10 8 MPs/m 3 and exceeded both calculated HC 5 values at 20% of locations.

In the local context, studies on microplastic pollution in freshwater environments in the Amazon are scarce, especially in the northeastern area. The Cumbaza River and its main tributaries, located in the Amazon region of Peru, are being significantly affected by this form of pollution, threatening the biodiversity and health of human communities that depend on these water resources where the ecological impacts of microplastics in the rivers they are multiple and varied. Recent studies have shown that these particles can be ingested by aquatic organisms, causing negative effects on their health and potentially affecting local food chains.

Therefore, the research objective was to identify the presence of microplastics in the waters of the Cumbaza River tributaries in the district of Morales, province of San Martín, department of San Martín.

2. MATERIAL AND METHODS

2.1. Study area

The water network of the Cumbaza basin is made up of the Cumbaza River as the main tributary, with its main tributaries on the left bank being the Shilcayo River and the Ahuashiyacu and Pucayacu streams and on the right bank Shupishiña. The flow of these bodies of water is highly variable throughout the year and depends on the intensity of the rains. The Cumbaza River originates northwest of Tarapoto, in the mountains of Cerro Escalera, at more than 1,700 m altitude. It originates from the union of the Shucshuyacu and Cumbacillo streams. It runs northwest to southeast, passes through the city of Tarapoto, and empties into the left bank of the Mayo River. Its main tributaries also originate in Cerro Escalera. On the left bank, the Yuracillo, Atunquebrada, Añaquihui, Curiyacu, Huacamaillo, Pintuyacu, Canela Ishpa, Cachiyacu, Sedamillo, Ahuashiyacu, and Pacayacu streams are important, as is the Shilcayo River, which passes through the city of Tarapoto. The Chumchiwi, Incato, and Shupishiña streams originate on the Shicafilo hill and are important on the right bank.

The Cumbaza River is approximately 52 km long and 140 m wide near the mouth; its basin covers 57 120 ha2. This body of water is used for various anthropogenic activities, such as agriculture, fishing, livestock, tourist activities, solid and liquid waste, and artisanal processes, which influence the pollution of the River by different inorganic waste, especially microplastics. Regarding the flow of the Cumbaza River, it plays a vital role in collecting samples and transporting microplastics. The River tends to have a variation dependent on its meteorological conditions. During rainy seasons, its flow increases, and the Mps dilute faster. Therefore, their Mps concentrations are low; however, in drought, the flow decreases, and the dilution is lower. Therefore, the concentration of Mps is higher.

2.2. Sample collection

The present study included 8 different sampling points (1 - 8) of the Cumbaza River; 3 samples were collected at each point, of which a total of 24 surface water samples were collected during August; the samples up to h were harvested during August 28 and 29, 2023 in times of drought (T max. 32.5° C, T min.18.3° C; precipitation of 68 mm) (SENAMI, 2023). The sampling locations were in Juan Guerra, La Banda de Shilcayo, Tarapoto, Morales, and the district of San Antonio. The georeferencing of the sampling points is presented in Table 1, set in Figure 1. Subsequently, sampling was carried out according to Melgarejo (2022), where 1 liter of surface water was included in airtight glass jars (1 liter), for which they were previously labeled. The jars were introduced to a depth of approximately 10 cm and subsequently put in a cooler for transport to the laboratory for analysis. During drought, the investigation collected samples at low flows in the upper, middle, and lower parts of the Cumbaza River.

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Tabla 1. Coordenadas geográficas de los puntos de muestreo

UE	River	Altitude	UTM Coordinate (WGS 84)18 S	
			EAST	NORTH
1	Union of the Cumbaza River with the Mayo River	191	353178 m	9270203 m
2	Union of the Pucayacu stream with the Cumbaza River	206	352227 m	9274474 m
3	The union between the Ahuasiyacu stream and the Cumbaza river-Las Palmas town center	221	349974 m	9276819 m
4	Shilcayo Union (Chontamuyo sector) with the Cumbaza River	229	348562 m	9278144 m
5	Atumpampa Sector block 22 Alfonso Ugarte –Patacusi	255	346809 m	9281869 m
6	Cancún-morales sector	269	346491 m	9284427 m
7	Bocatoma	299	347011 m	9286191 m
8	San Antonio de Cumbaza	424	343858 m	9291597 m

Sorce: Created by the authors.

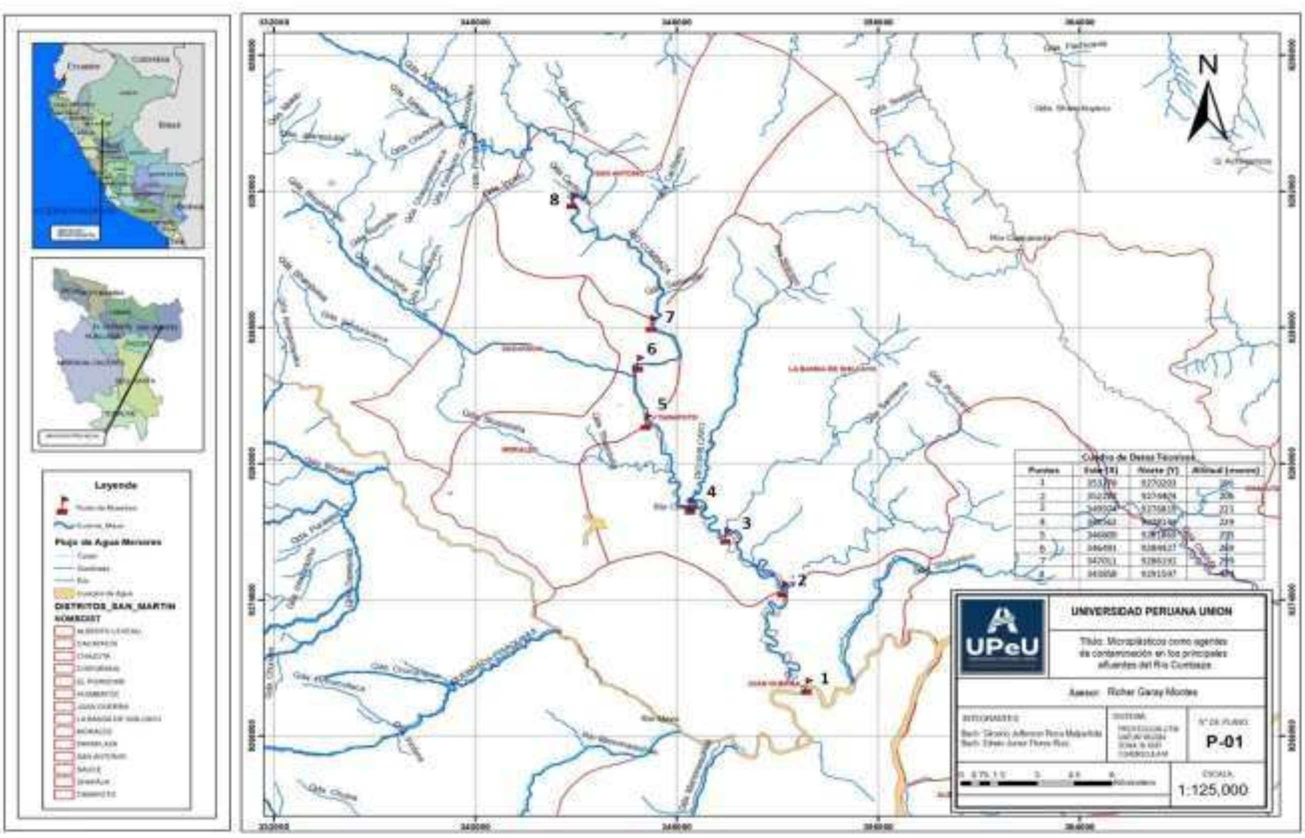


Figure 1. Location map of the sampling points in the Cumbaza River in the districts of Juan Guerra, Banda de Shilcayo, Tarapoto, Morales, and San Antonio

Source: Created by the authors.

2.3. Microplastic analysis

For the microplastic analysis, the procedure of Melgarejo (2022) was used with its respective modifications, of which the samples of 1 liter of water were filtered through an ASTM N°4 steel mesh sieve (4.75 mm) and then through Whatman paper No. 40. The retained particles were transferred to beakers (250 ml) containing 200 ml of hypersaline solution (5M NaCl) and allowed to settle for 24 hours. The supernatant was filtered through Whatman No. 40 paper, where they were placed in Petri dishes and subsequently dried at room temperature for their respective identification and counting in a stereoscope model SMZ-168 with a 5x magnification degree to determine the color, shape, size, and quantity of microplastics. To prepare the hypersaline solution (5M NaCl), 300 g of table salt was dissolved in 1 liter of drinking water and filtered through the Whatman No. 40 paper to avoid contamination.

3. RESULTS AND DISCUSSION

3.1. Images of microplastics sampled in the Cumbaza River

The distributions of microplastics are divided by their forms, which are filaments (a), fragments (b), and microsphere (c), and their colors: blue, light blue, red, transparent, black, orange, yellow, green, and purple in the samples of water from the 8 monitoring points of the Cumbaza River. In Figure 2, you can see the 3 forms of microplastics from the research, while in Figure 3, Only the filaments of the different colors found are displayed, as in the fragments of Figure 4 and microspheres in Figure 5.

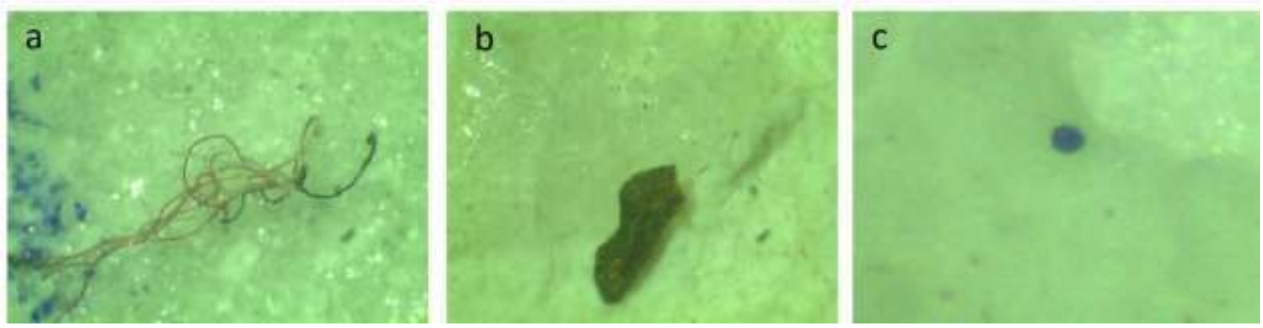


Figure 2. a. Microplastic filaments. b. Microplastic fragments. c. Microplastic microsphere.

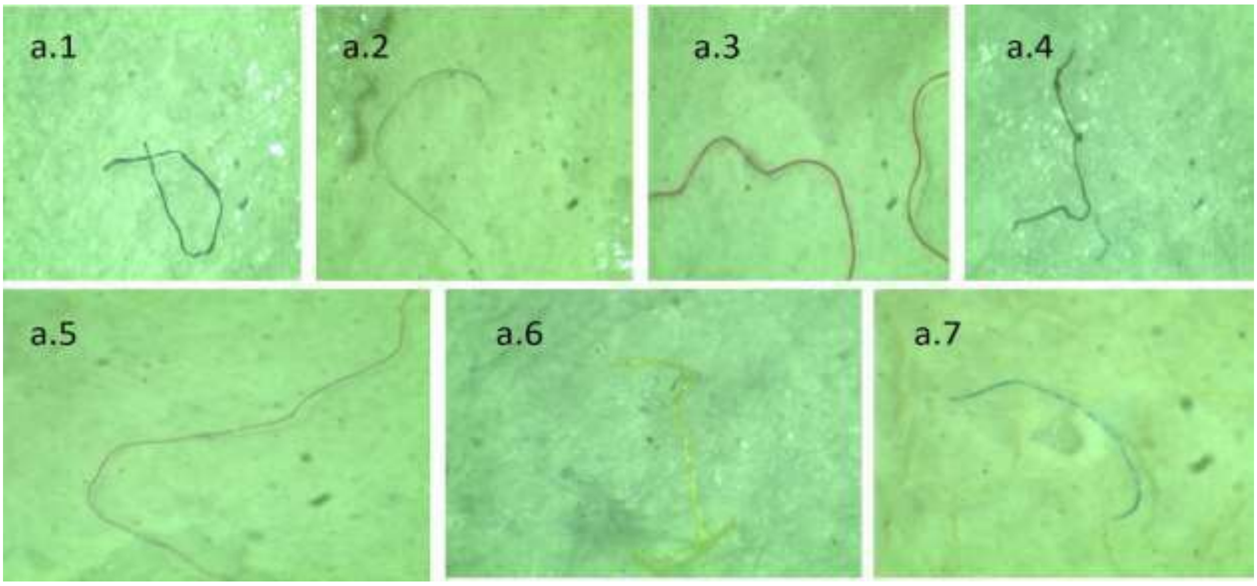


Figure 3. a1. Blue filament a2. Transparent colored filament. a3. Red filament. a4. Black filament. a5. Purple filament. a6. Yellow filament. a7. Light blue filament.

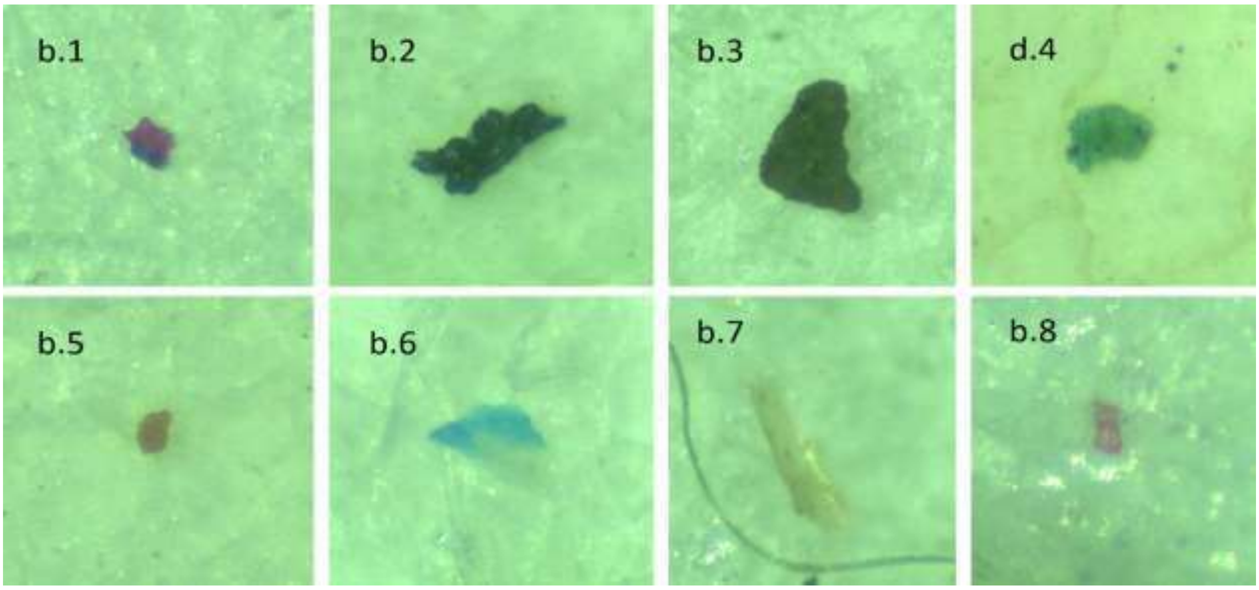


Figure 4. b1. Purple fragment. b2. Blue fragment. b3. Black fragment. b4. Green fragment. b5. Orange fragment. b6. Light blue fragment. b7. Transparent color fragment. b8. Red fragment.

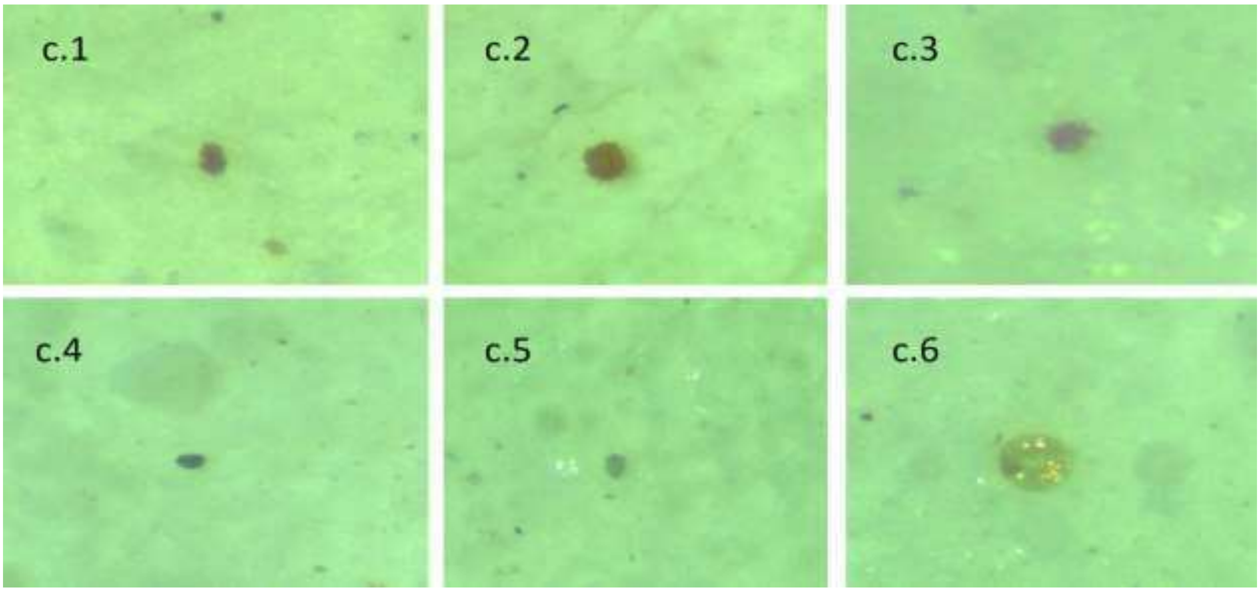
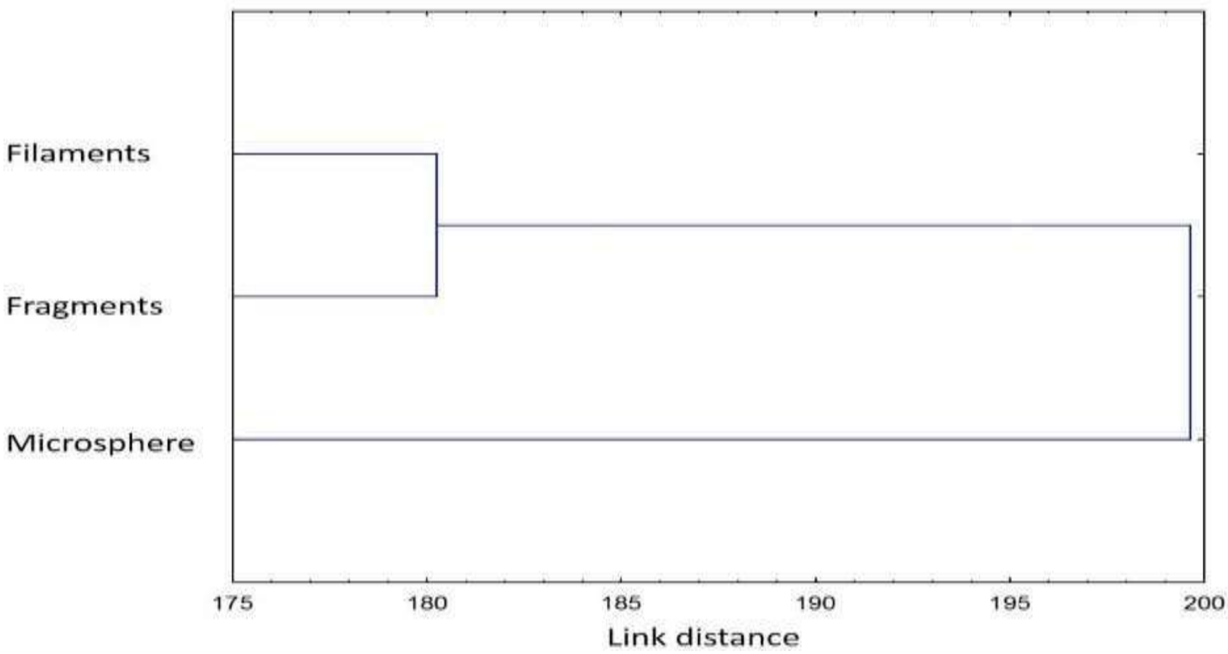


Figure 5. c1. Red microsphere. c2. Orange microsphere. c3. Purple microsphere. c4. Blue microsphere. c5. Black microsphere. c6. Transparent color microsphere.

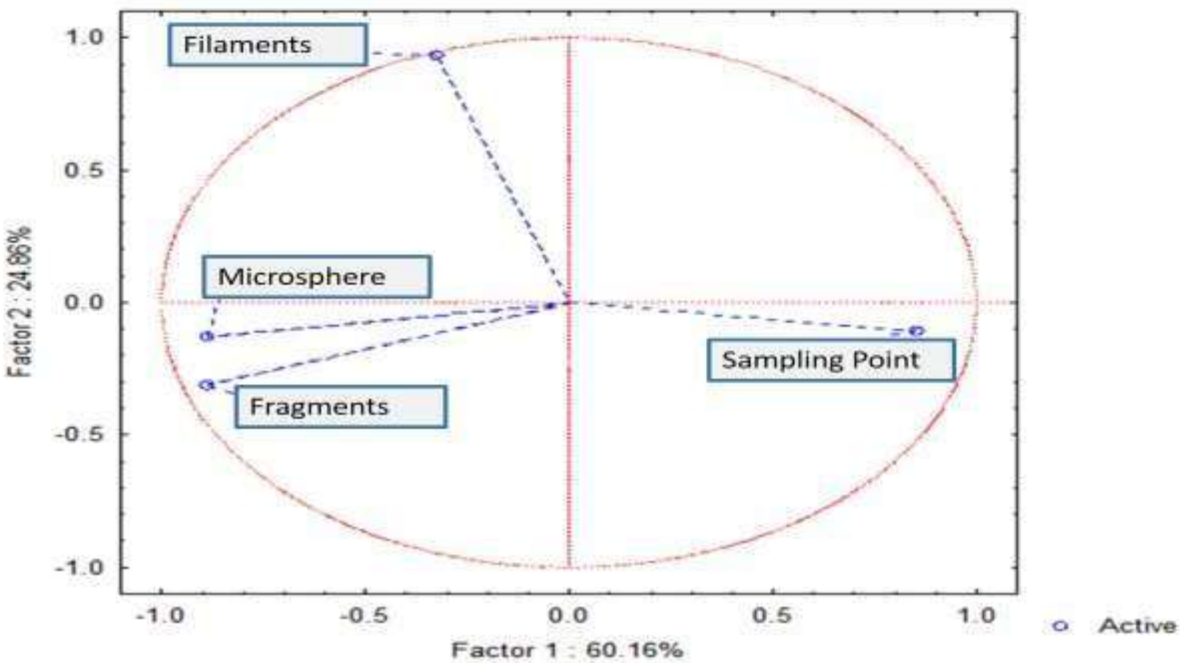
3.2. Dendrogram - Cluster analysis of the abundance of MPs according to their shape



Graph1. MP abundance dendrogram

According to Graph 1, in our study, it can be observed that filaments and fragments are grouped at a lower bond distance (Approx. 180); this indicates that these types of MPs have similar presence profiles at the sampling points, which implies that the sampling points with high levels of filaments also have high concentrations of fragments, and vice versa. This is related to the fact that both come from similar sources or more extensive plastic materials and behave the same in the aquatic environment. One author who has worked extensively on the characterization and origin of microplastics in aquatic environments is Richard C. Thompson. Thompson and his colleagues have conducted detailed research on microplastics' sources, distribution, and fate in marine and freshwater ecosystems. (Thompson, Moore, Saal, and Swan, 2009) discusses how different microplastics, including filaments and fragments, behave in the environment and how their sources may be similar. It also addresses how these microplastics can clump and distribute in aquatic environments due to similar degradation processes of larger plastics. On the other hand, the microsphere binds to filaments and fragments at a greater bond distance (Approx. 200), indicating a greater contrast in their presence profiles than filaments and fragments. Because they come from different sources, they are not present in the exact quantities or locations as the products that generate the filaments and fragments, and they have physical properties that affect their distribution in the River differently. Hence (Zhang et al., 2017) examine how different types of microplastics, such as microspheres, filaments, and fragments, are variedly distributed in an aquatic environment due to their different physical properties and sources of origin.

3.3. Principal Component Analysis (PCA) of the MPs, by sampling points



Graph 2. Graph of the active variables studied in the microplastic samples at the 8 sample points

Graph 2 represents the coefficients of each variable of the shapes of the microplastics understudy for the first PC1 versus the coefficients for the second component PC2; sample points associated with a second component fragment, microsphere, and filament are observed for the variable, showing positive influences of microplastics in the 8 sample points of the Cumbaza River (Union of the Cumbaza River with the Mayo River, Union of the Pucayacu stream with the Cumbaza river, Union between the Ahuasiyacu stream and the Cumbaza river-Las Palmas town center, Shilcayo Union (Chontamuyo Sector) with Cumbaza River, Atumpampa Sector block 22 Alfonso Ugarte -Patacusi, Cancún-Morales Sector, Bocatoma, San Antonio de Cumbaza) PC1 (60.16%) and PC2 (24.86%) representing the most significant contribution to the classification in the factor space.

This gives us a grouping of microplastics according to their shapes (filaments, fragments, and microspheres); it is observed that the samples are different from each other, that the filaments are more separated than the fragments and microspheres, which means that the filaments are distributed in a differently way in the tributaries. On the other hand, it can be seen that the fragments and microspheres are united, which means that in most cases, they can be found together, although the same shapes cannot always be found in each one. This has to do with sampling at different points of the Cumbaza River.

3.4. MP Frequency

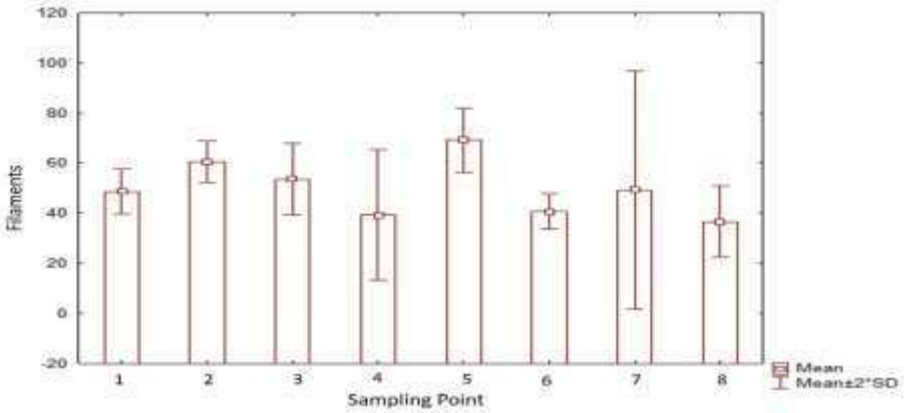


Figure 6. Average of each sampling point of MPs in water in the form of filaments.

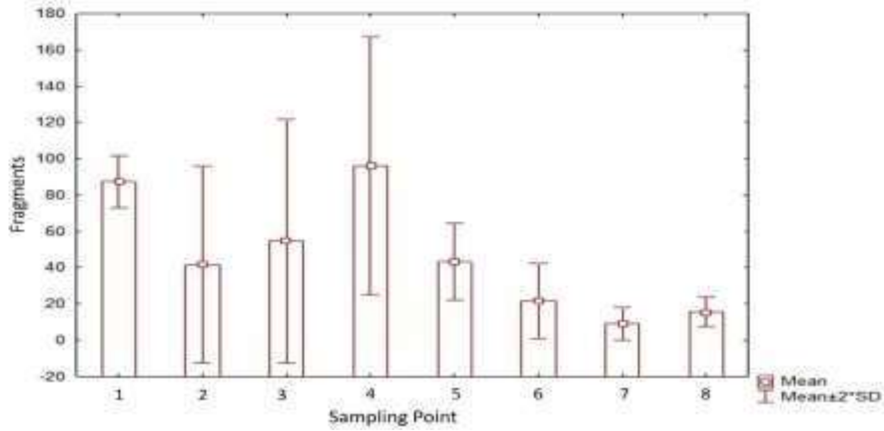


Figure 7. Average of each sampling point of MPs in water in the form of filaments.

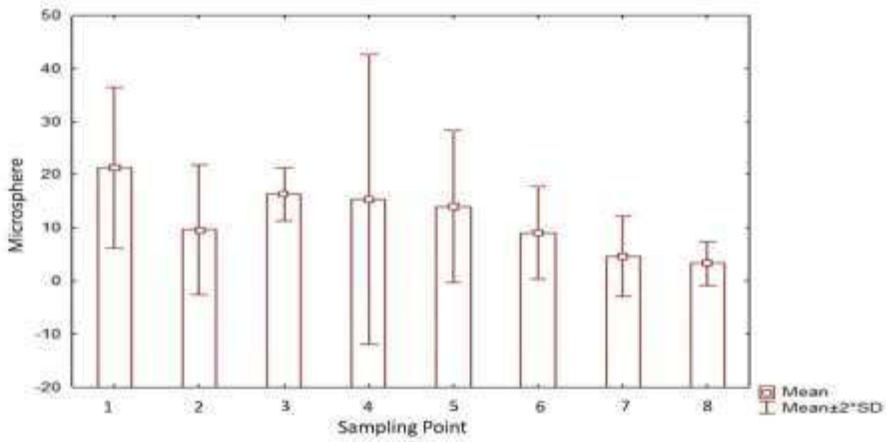


Figure 8. Average of the sampling points of MPs in water in microspheres.

In **Figure 6**, the abundance of microplastics according to the shape of filaments of the present study concerning the sampling points that are: 1, 2, 3, 4, 5, 6, 7, and 8 with their respective amount of 48 MPs/L, 60 MPs/L, 53 MPs/L, 39 MPs/L, 69 MPs/L, 40 MPs/L, 49 MPs/L, and 36 MPs/L respectively, a higher concentration of MPs can be observed at sample point "5" with 69 MPs/L and a lower amount of MPs concentration at sample point "8" with 36 MPs/L, these concentration levels vary at layer point due to its proximity to urban areas. Likewise, in **Figure 7**, the abundance of microplastics according to the form of fragments of the present study about the sampling points that are 1, 2, 3, 4, 5, 6, 7 and 8 with their respective amount of 87 MPs/L, 41 MPs /L, 54 MPs/L, 96 MPs/L, 43 MPs/L, 21 MPs/L, 21 MPs/L, 9 MPs/L and 15 MPs/L respectively. A higher concentration of MPs was obtained at sample point “4” with 96 MPs/L and a lower amount of MPs concentration at sample point “7” with 9 MPs/L; these concentration levels vary depending on the layer point due to its proximity to urban areas. Finally, in **Figure 8**, the abundance of microplastics according to the microsphere shape of the present study concerning the sampling points that are 1, 2, 3, 4, 5, 6, 7 and 8 with their respective amount of 21 MPs/L, 9 MPs /L, 16 MPs/L, 15 MPs/L, 14 MPs/L, 9 MPs/L, 4 MPs/L, 3 MPs/L respectively. A higher concentration of MPs was obtained at sample point “1” with 21 MPs/L and a lower amount of MPs concentration at sample point “8” with 3 MPs/L; these concentration levels vary by layer point due to its proximity to urban areas. Respectively, the abundance according to the forms described, fragment, filament, and microsphere, vary significantly in concentrations and factors of climatic conditions for their respective decomposition and contamination present in the receiving body, which would be the water or the study area, which is the Cumbaza river.

Table 2. Mean and standard deviation of microplastic abundance

Sampling point	Filament	Fragment	Microsphere
1	48.67±4.51 ba	87.33±7.23 a	21.33±7.57 a
2	60.67±4.16 ba	41.67±27.21 ba	9.67± 6.11 a
3	53.67± 7.09 ba	54.67± 33.53 ba	16.33± 2.52 a
4	39.33±13.01 ba	96.00± 35.55 a	15.33 ± 13.65 a
5	69.33±6.43 a	43.00±10.58 ba	14.00 ±7.21 a
6	40.67±3.51 ba	21.67±10.26 b	9.00±4.36 a
7	49.33± 23.80 ba	9.00±4.58 b	4.67±3.79 a
8	36.67±7.09 b	15.33±4.04 b	3.30 ±2.08 a

The values represent the average ± Std. Dev. The letters (b-a) represent statistically significant differences between the averages evaluated for each station using the Tukey test.

According to Table 2, the analysis of the 24 samples extracted from the 8 monitoring points of the Cumbaza River, the presence of microplastic was observed in the stereoscope, where the variation of the average concentration of microplastic in the water sample can be seen about the type of treatment; that is, for both filament and fragment if there is a significant difference ($p<0.05$). Treatment “5” presents more significant contamination in the filaments due to filament-shaped microplastics, unlike the rest of the treatments 2, 3, 7, 1, 6, 4, and 8.

Likewise, in the Fragments, treatments "4" and "1" present the most significant contamination due to the presence of microplastics in the form of fragments, unlike the rest of the treatments 3, 5, 2, 6, 8, and 7.

Concerning the microsphere, the variation in the average concentration of microplastics in the water sample can also be seen about the type of treatment; that is, there is no significant difference ($p>0.05$) in the water sample treatments in “1”, likewise for stations 2, 3, 4, 5, 6, 7, 8 between the averages evaluated for each station using the Tukey test.

3.5. Size of MPs in water samples

We used a Stereoscope SMZ-168c model to differentiate sizes at a 5x magnification degree. The sizes were worked out in "µm."

According to the size of the MPs related to the previously studied filaments of **Table 3**, 1195 MPs were found in filaments, with a variation in sizes. Sample point "5" was 4934.18 µm; therefore, this point is considered the most dominant size, followed by point "1" with 4923.32 µm. On the other hand, the same point, "5," found a minimum value of 1.87 µm.

Table 3. Their filament shape determines the size of the MPs in microns.

Sampling point	**Amount**	**Filament**				
		x Average	**Vmin**	**Vmax**	**SD**	**CV**
1	146	894.49	15.11	4923.32	987.60	1.10
2	182	795.16	26.82	3717.38	699.50	0.88
3	161	743.61	24.63	4191.05	700.10	0.94
4	118	813.87	16.99	4635.47	810.40	1.00
5	208	766.28	1.87	4934.18	825.90	1.08
6	122	776.67	17.05	4744.94	762.84	0.98
7	148	721.01	23.53	3782.65	728.94	1.01
8	110	736.15	49.78	4733.25	838.82	1.14

For the size of the MPs related to the fragments of **Table 4**, A total of 1106 MPs were found, so it can be seen that at sample point "1, the size related to the maximum value is 2104.94 µm followed by 126.72 µm at sample point "6". Furthermore, the minimum value related to size can be observed at sample point "3" with 1.38 µm respectively to the sample points.

Table 4. Size of MPs according to their fragment form

Sampling point	**Amount**	**Fragment**				
		x Average	**Vmin**	**Vmax**	**SD**	**CV**
1	262	89.39	23.10	2104.94	159.98	1.79
2	125	136.25	136.25	1061.13	150.45	1.10
3	164	97.76	1.38	1104.89	111.76	1.14
4	288	75.40	26.54	853.73	67.31	0.89
5	129	111.28	19	772.60	106.90	0.96
6	65	148.84	32.07	1266.72	208.47	1.40
7	27	198.59	37.96	585.46	165.72	0.83
8	46	234.78	38.47	968.36	222.19	0.95

In the case of sizes in microspheres, 281 MPs were identified. Sample point "7" has a maximum value of 512.72 µm, this being the largest size, and a minimum size value at point "1" with 0.19 µm, according to **Table 5.**

Table 5. The size of MPs depends on their microsphere shape.

Sampling point	Amount	Microspheres				
		x Average	Vmin	Vmax	SD	CV
1	64	45.47	0.19	159.44	22.83	0.50
2	29	51.99	27.67	107.82	21.51	0.41
3	49	48.71	21.56	122.88	20.04	0.41
4	46	45.95	27.34	147.37	19.98	0.43
5	42	49.01	27.45	120.50	17.72	0.36
6	27	48.20	27.35	120.73	20.27	0.42
7	14	109.57	7.39	512.72	126.50	1.15
8	10	114.93	42.58	197.36	70.42	0.61

3.6. MPS colors according to their shape

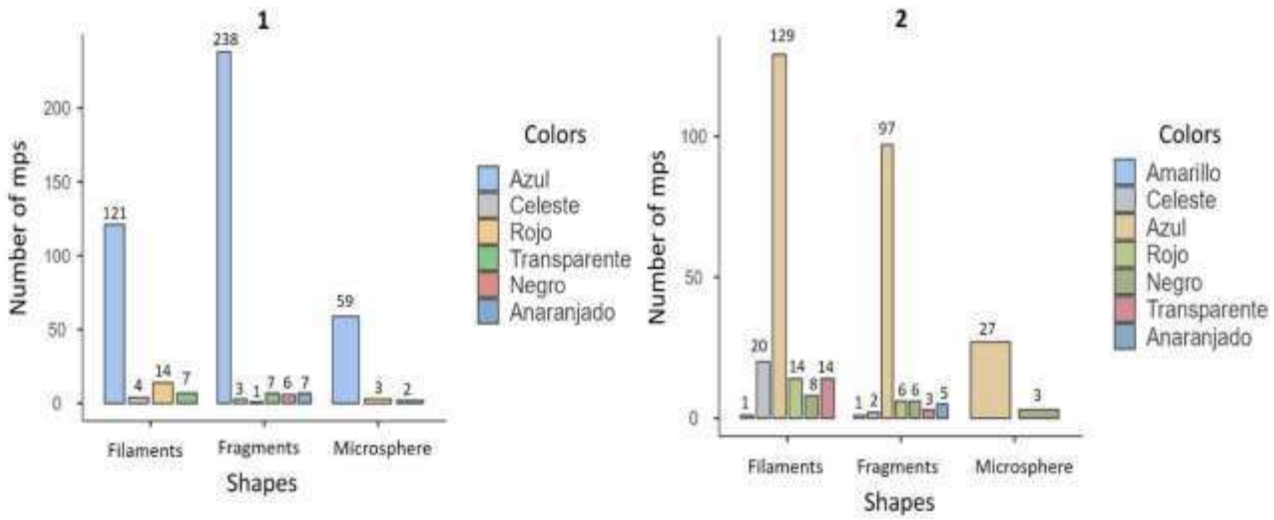


Figure 9. Colors of the MPs at sampling point "1" and "2"

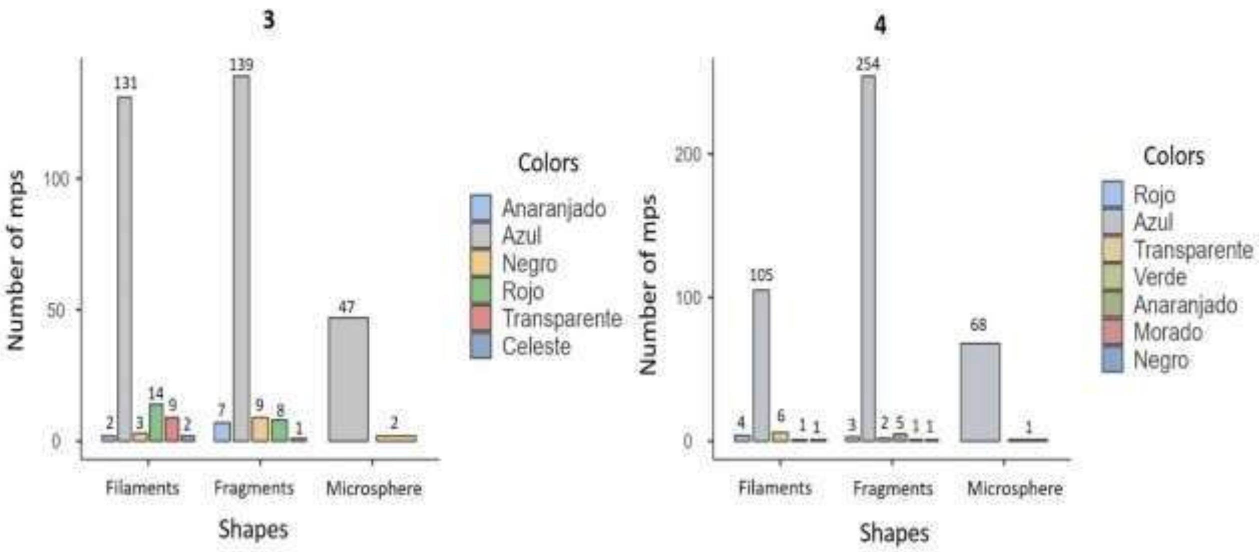


Figure 10. Colors of the MPs at sampling point "3" and "4".

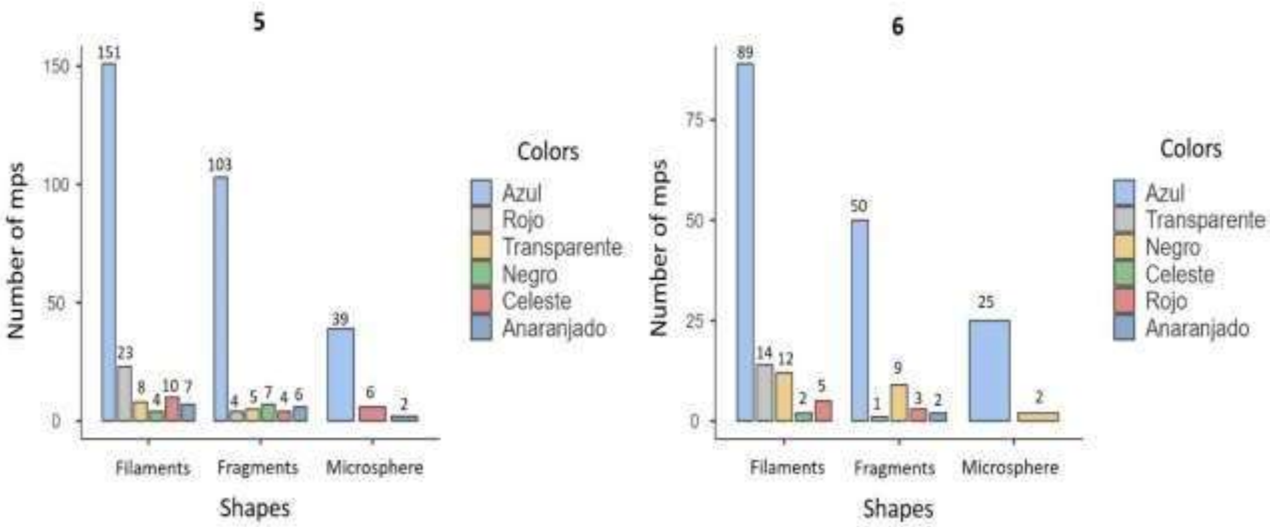


Figure 11. Colors of the MPs at sampling point "5" and "6".

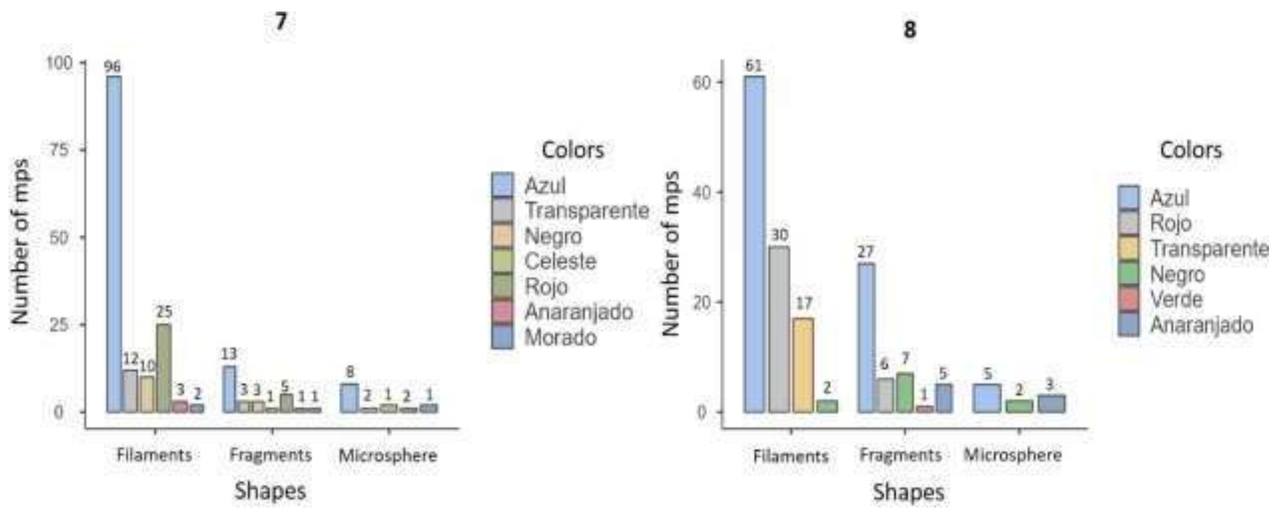


Figure 12. Colors of the MPs at sampling point "7" and “8".

According to the results of the quantification of MPs for the visualization of colors, a total of 9 colors could be observed, of which they were Blue, light blue, red, Transparent, Black, orange, yellow, green, and purple. In **Figure 9**, at point “1,” the most predominant color was blue in both filaments, fragments, and microsphere, followed by red. At point “2” the most predominant color was also blue, as well as at points “3”, “4”, “5”, “6”, “7”, and “8”. At sampling point “5” according to **Figure 11**, 151 blue MPs in the form of filaments were found in greater abundance than the other sampling points according to the filament shape, followed by point “3” with 131 blue MPs. In the case of fragments at point “4” there were 254 blue MPs, followed by point “3” with 139 MPs. For microspheres, the highest amount of blue MPs was at point "4" with 68 MPs of that color present, followed by 59 MPs at sampling point "1". The least abundant colors were at points "4" and "8" with the green color as a filament and fragment, respectively. In the case of the purple color, a smaller amount was found at point “4” in the form of a fragment and at point “7” in the form of a filament, fragment, and microsphere, as can be seen in **Figure 10 and Figure 12.**

4. DISCUSSION

In the present investigation, the presence of three forms of Microplastics (Fragments, filaments, and microspheres) from the main tributaries of the Cumbaza River can be demonstrated. The filaments were abundant in the environment and could be linked to some source of contamination from adjacent areas. In this way, filaments, as the main microplastics, would generate negative impacts not only on the ecosystem of the Cumbaza River but also on the population that benefits from this resource, thereby further exacerbating the impact generated by anthropogenic waste (Deng et al., 2024). The abundance of filaments in the water was observed at point “5” with 69.33±6.43 (MPs/L), also with fragment at point “4” with 96.00±35.55 (MPs/L) and microsphere in Point “1” with 21.33±7.57 (MPs/L) evaluated in the Cumbaza River, indicate that these microplastics come from the exposure of plastics to the outdoors where they are fragmented for various reasons including poor waste management generated in people (L. Yang, Zhang, Kang, Wang, and Wu, 2021). Likewise, in another investigation (Vidal, Molina, and Duque, 2021), the abundance of the different types of PM studied was higher in 2019 (521,275 ± 103,671.2 particles/km²) compared to 2015 (242,759.8 ± 42,203.2 particles/km²), observing a progressive accumulation of these elements on the water surface where differences in densities and sizes were found. Furthermore, it is evident that urban cities around rivers greatly influence PM pollution, as described in the research carried out in the Jiangsu South Canal, where an increase in PM between 26% and 211% could be seen in the significant difference in upstream and downstream (Jin, Fu, Lu, and Wang, 2023). Furthermore, the investigation of (Vidal et al., 2021) mentioned that the increase in abundance may result from the different characteristics of the study site and its environment. Only these characteristics, combined with inefficient management of solid waste and little or no environmental culture among its inhabitants, increase the amount of waste. Related to the size of microplastics found, filaments (4934.18 μm) at sample point "5," fragments (2104.94 μm) at sample point "1" and microspheres (512.72 μm) at point of sample "7" you can see variation in the sizes related to the shape due to the different phenomena that occur in the course of a River that can modify the concentration of microplastics in the different sample points to carry out the analyzes (L. Yang et al., 2021). This is the case with bottled water. Several studies identified the presence of plastic particles in all the samples analyzed. In these studies, particles larger than 5 μm34 and more significant than 1 μm35 were considered microplastics (Bollaín Pastor and Agulló, 2019). Unlike other pollutants, microplastics do not biodegrade quickly and can remain in the environment for hundreds of years. Its ability to fragment into even smaller particles complicates its removal and increases its potential to penetrate all ecosystem levels. The accumulation of microplastics in the sediments of water bodies can alter the structure of the benthic habitat and affect the organisms that depend on these habitats. (Ali et al., 2024). The predominant color is blue in the various forms of microplastics; this can be connected to the food chain since the population benefits from this water resource and, in turn, consumes the fish. Just as other research mentions, it dramatically influences both the reproduction and the environmental conditions for degradation along with its accumulation in rivers near the population because, without having a proper supply, they opt for more practical measures without considering their health (Okamoto, Nomura, Horie, and Okamura, 2022). In addition, (Iannacone et al., 2021) in their research, they found relevant data regarding the colors of MP; the most abundant was blue, followed by black and white, fuchsia and green. Besides (Peláez et al., 2023) regarding the color of the microplastics, green corresponded to 13.89%, red 8.33%, blue 14.44%, yellow 3.89%, white 31.11%, gray 2.22%, black 1.12%, and brown 2.22%. 22.78% lacked color (transparent). Our research results and the studies mentioned above highlight the urgent need to address microplastic pollution at a global level. It is essential to improve waste management and develop effective policies to reduce the release of plastics into the environment. Furthermore, it is crucial to increase public awareness of the risks associated with microplastics and promote sustainable practices that minimize their production and release. Protecting water resources and food security depends on our ability to address this environmental challenge effectively.

5. CONCLUSIONS

In the Cumbaza River micro basin, 3 different forms of MPs were observed: fragments, filaments, and microspheres. The most significant amount of MPs was obtained in the filaments with 1195 Mps (46.28%), followed by fragments with 1106 MPs (42.84%) and microspheres with 281 MPs (10.88%), thus obtaining a total of 2582 MPs. The sizes found in filaments obtained a minimum value of 1.87 µm and a maximum value of 4934.18 µm; for fragments, their minimum value is 1.38 with a maximum value of 2104.94 µm, and for microspheres, a minimum value of 0.19 µm and a maximum value of 512.72 µm. Regarding the color of the MPs, blue is the most predominant color in all sampling points (1-8) compared to the other different colors found.

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CONSIDERANDO:

Que la Universidad Peruana Unión tiene autonomía académica, administrativa y normativa, dentro del ámbito establecido por la Ley Universitaria Nº 30220 y el Estatuto de la Universidad;

Que la Facultad de Ingeniería y Arquitectura de la Universidad Peruana Unión, mediante sus reglamentos académicos y administrativos, ha establecido las formas y procedimientos para la sustentación de la tesis en formato artículo;

Que el Comité Dictaminador ha emitido su dictamen aprobando el informe de tesis titulado "Micro plásticos como agentes de contaminación en los principales afluentes del río Cumbaza", presentado por los(las) bachilleres **Glicerio Jefferson Roca Malpartida** y **Edwin Junior Flores Ruiz**, reuniendo de esta manera las condiciones previas para la declaratoria de expedito para la programación de la sustentación;

Estando a lo acordado en la sesión del Consejo de la Facultad de Ingeniería y Arquitectura de la Universidad Peruana Unión, celebrada el 13 de agosto de 2024, y en aplicación del Estatuto y el Reglamento General de investigación de la Universidad;

SE RESUELVE:

1. Declarar expedito a los (las) bachilleres **Glicerio Jefferson Roca Malpartida** y **Edwin Junior Flores Ruiz,** para que sustenten la tesis en formato artículo titulada "Micro plásticos como agentes de contaminación en los principales afluentes del río Cumbaza", conducente a la obtención del título profesional de Ingeniero Ambiental, el 29 de agosto de 2024, a las 15:00 horas, en la modalidad Virtual u online sincrónica.

2. Designar el Jurado de Sustentación, encargado de gestionar la sustentación respectiva, el mismo que queda constituido por los siguientes miembros:

   Presidente: Mtra. Betsabeth Teresa Padilla Macedo
   Secretario: Dr. Victor Hugo Muñoz Delgado
   Asesor: Mtro. Richer Garay Montes
   Vocal 1: Mtro. Carmelino Almestar Villegas
   Vocal 2: Mtro. Andres Erick Gonzales López

Regístrese, comuníquese y archívese.

Dra. Erika Inés Acuña Salinas
DECANA

Ph.D. Silvia Pilco Quesada
SECRETARIA ACADÉMICA

cc:
-Interesado
-Jurado (04)
-Secretaria General
-Archivo