Detention of Plastic Microparticles in the Drinking Water Treatment System Tomebamba in Cuenca and Mahuarcay in the City of Azogues, Ecuador

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Abstract

The manufacture of plastic has increased considerably worldwide. Consequently, environmental pollution caused by large amounts of plastic waste without proper management of recycling techniques degrades into microscopic particles in different natural resources, especially in water sources entering the trophic chain and generating the phenomenon of biomagnification. Therefore, the objective was to detect plastic microparticles through the techniques of Inverted Fluorescence Microscopy and Infrared Spectroscopy (FTIR) for the establishment of areas of higher concentration in the different stages of the Tomebamba water purification system of the city of Cuenca - Ecuador, through the analysis of 99 samples in the sampling points such as catchment, entry to the distribution network and home network. As a result, 100% of samples with observable microplastics with a higher incidence of fibers and fragments with a final average of 18.28 particles per 250 ml and a general range for fibers of 6.31 µm - 4966.77 µm and fragments of 6.95 µm - 243.87 µm. Similarly, the presence of microplastics was established through the analysis of samples taken from the drinking water network in the urban area of the city of Azogues, tested in the laboratory through 60 total samples of drinking water, some taken in the catchment, others in the distribution network and the home networks.

As a result, the study shows the presence of microplastics in the three areas analyzed, with the greatest impact on the household networks, followed by the catchment and finally the distribution network.

For the types of polymers found at each sampling point, a coincidence was found with polyethylene terephthalate (PET), high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyester and polybutylene. Finally, it was evaluated that there is no significant difference between sampling points.

Keywords: *Microplastics, Tomebamba System, fibers, fragments, FTIR.*

1. INTRODUCTION

In recent years, the demand for plastics has increased exponentially; consequently, uncontrolled environmental pollution due to their use and inadequate management of recycling techniques has generated the

permanence of this material in the ecosystem, causing its presence in various resources such as water, air and soil, which subsequently flow into the world's oceans with a very high permanence and distribution time, which by mechanical and photochemical processes degrade to become microscopic particles called microplastics (Espinosa et al., 2016)

Microplastics are imperceptible particles with a size of less than 5 mm, generated by the degradation of plastic, differentiated from each other based on their origin and size. Those of primary origin range from 5 mm to 1 mm and are obtained from frequently used products such as cosmetics or indirectly from plastic processing (Loganathan and Kizhakedathil, 2023). On the other hand, secondary ones range in size from 1 mm to 2 µm, are derived from large plastics and decompose into smaller fragments when exposed to high temperatures and ultraviolet radiation (Lin et al., 2018).

Plastic waste, favored by its physical and chemical characteristics, accompanied by excessive production, difficult recycling and excessive use, triggers its accumulation, constituting 10% of municipal waste worldwide (Barnes et al., 2009). On the other hand, plastics enter the oceans in exorbitant quantities each year from rivers, estimated at between 1.15 and 2.41 million tons (Lebreton et al., 2017).

Microplastics are solid, synthetic particles or polymeric matrices, regular or irregular in shape with a size range of 1 µm - 5 mm and insoluble in water (Frias and Nash, 2019). Therefore, their origin lies in two main sources: primary, developed to be smaller in size as nurdles or powders, and secondary, resulting from the fragmentation of larger particles (Thompson, 2015).

Humans are exposed to cosmetics, dietary habits, dust particles and plastic products, whose constant increase shows detrimental effects (Willis et al., 2017). Consequently, they have led to their bioavailability in the food chain, denoting a variable effect depending on the size of the particles since the smaller the particles, the more they accumulate in the tissue itself and disrupt physical processes (Campanale et al., 2020).

Therefore, contamination has been imposed as a social alarm; despite this, there is a deficit of studies on inland waters; however, in the few existing studies, it has been determined that there is a more significant contamination in urbanized areas than in those far from urban centers, ignoring the possibility of contamination through food containers, either by migration or transfer (Mintenig et al., 2019) generating that drinking water networks are the subject of research. Therefore, the development of this research has been proposed to answer the question: Is there the presence of microplastics in the Tomebamba water purification system in Cuenca and Mahuarcay in the city of Azogues, Ecuador?

2. Objectives

2.1 General Objective

To detect plastic microparticles using Inverted Fluorescence Microscopy and Infrared Spectroscopy techniques to establish the areas of highest concentration in the different stages of the water purification system Mahuarcay in the city of Azogues and Tomebamba in the city of Cuenca, Ecuador.

2.2 Specific objectives

By Inverted Microscopy, determine the quantity, size and dimension of microplastics in the water purification system Mahuarcay and Tomebamba.

Identify the type of plastic microparticles by FTIR for provenance analysis.

Evaluate the stages of the system where the highest concentration of microplastics is found for the establishment of corrective actions in the different stages of the water purification system Mahuarcay in the city of Azogues and Tomebamba in the city of Cuenca, Ecuador.

3. Hypothesis

Microplastics were detected in the Mahuarcay water purification system in Azogues and Tomebamba in Cuenca, so corrective actions must be taken at the stages involved.

4. Methodology

4.1 Research approach

According to the approach, the present study can be determined as quantitative and qualitative, given that the objective of the research work is based on the numerical description and characterization of the variable. In addition, the researcher's position is neutral, without considering the subject's values and beliefs. This research's logic is deductive, from the general to the particular.

4.2 Research level

The research is exploratory due to the limited information regarding the detection of microscopic particles derived from plastic, as well as descriptive since a complete detail of the situation investigated will be established at the time of data collection. The selected research level will help to analyze and interpret the figures obtained during the study in a clear and precise way, where those data or elements will help to conclude the research question that was previously posed in the water samples from the drinking water treatment systems Mahuarcay of the city of Azogues and Tomebamba of the city of Cuenca.

4.3 Research design

The research is of the documentary type, using documentary analysis techniques, bibliographic material was identified from databases, both printed (theses, books and degree works), as well as electronic databases (scientific journals, SCOPUS, NCBI and IEEE Explore), using instruments such as tables of records, classification of categories and also made use of content analysis in order to define the most effective technique for its application in this research. Additionally, there is a field design through which information was collected from samples taken from the drinking water treatment system and the home network, obtaining qualitative and quantitative data on the extraction, evaluation and identification of microplastics through observation and determination of size and dimension aided by inverted microscopy and spectrogram analysis for the classification of microplastics in the different water samples analyzed. These were carried out in the laboratory to generate parameters through standardized tests, which allowed us to establish data obtained from the catchment samples, entry to the distribution network and home network, using generally unstructured instruments such as field diary, camera and structured instruments such as a checklist.

4.4 Population and sample

The current research was carried out with a finite and accessible population since it is based on the Tomebamba Water Potabilization System that supplies 9,000 families in the city of Cuenca, Azuay province.

The random sampling was set at three points of the Tomebamba System: catchment, entry to the distribution network and home network. Taking into consideration that the samples taken are composite samples.

For the collection and entry into the distribution network, a simple random sampling was performed; in the standard, there is no parameter about microplastics; however, for the sampling, it was based on INEN 1108 appendix Y for microbiological analysis in the drinking water distribution system per year, it was calculated that for samples of less than 100,000 inhabitants, 12 samples should be taken for every 5,000, which is summarized in 18 samples per month and in this research it was decided to perform 33 composite samples for each of the processes mentioned above.

To determine the sample size in the home network, a representative sample of the population (90000 inhabitants) was considered, for which a simple random sampling was established, using the formula for calculating the number of samples, with a confidence level of 95% and a sampling error of 17.25, giving a result of 33 composite samples.

On the other hand, a joint work was carried out with a public water and sewage company of the city of Azogues, focusing on the Mahuarcay water treatment plant, which supplies approximately 3128 properties representing 15,640 service users in the area of Uchupucún, Miguel Heredia street and El Calvario sector.

Within this drinking water treatment system will be segregated into three well-defined areas, being these: before the entrance to the treatment plant Captación the distribution network Red and the home network Domicilios; given the lack of a sampling standard for the analysis of microplastics, it has been based on the appendix Y of the technical standard 1108:2011 which deals with the microbiological analysis of the drinking water network points out that 12 samples should be taken for every 5000 people in a year, performing a simple calculation relating it to our population (15640) and the collection time of one month, would result in the first two zones each zone will take a total of three one month.

A total of 45 samples will be taken from the home networks. This was obtained by calculating the sample size for the total population (15640) benefiting from the drinking water service of the Mahuarcay plant, with a confidence level of 95% and a margin of error of 14.75%.

According to the agreement, the sampling method used was a statistical sampling technique of the non-probabilistic and non-random type since the sites to be chosen for sampling were previously located according to accessibility and time availability to carry out the respective sampling.

4.5 Data Collection Techniques and Instruments

The techniques used in this research topic are of documentary type since it was based on documents within digital databases such as University Repositories, Scielo, IEEE, DSpace and NCBI. In conjunction with the observation technique, structured instruments such as the checklist and unstructured instruments such as inverted fluorescence microscopy using the NIS program, Fourier transform infrared spectroscopy with OMNIC and OMNIC Specta and photographic devices are used.

5. Analysis and results

5.1 Analysis and results for the Tomebamba water purification system in the city of Cuenca.

Some particle parameters found in each of the samples were evaluated, taking into account that 100% of the samples showed the presence of plastic microparticles, and the

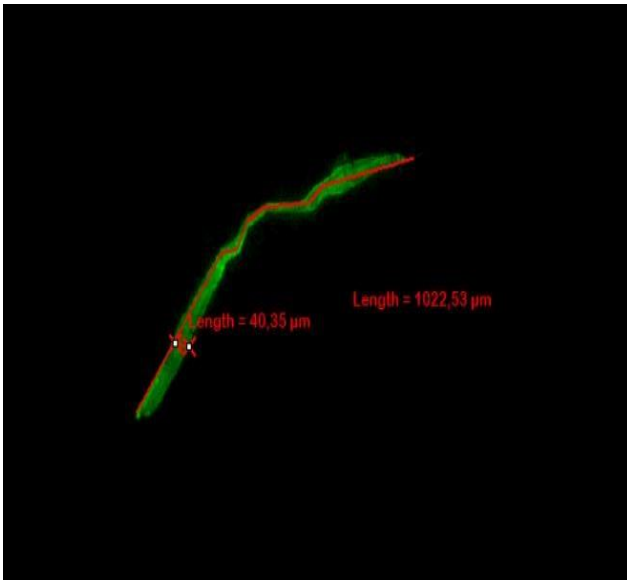
characterization of each of the samples is shown in the tables below.

5.1.1 Characterization of microplastics.

Observation under an inverted fluorescence microscope yielded the following results:

5.1.1.1 Microplastic morphology.

Figure 1. Dimensions of a microplastic fiber



Source: Own elaboration.

Figure 2. Size of a microplastic fragment.

Source: Own elaboration.

In the present investigation, the presence of fibers and fragments was found, as in a study of the Buenaventura Bay, Colombian Pacific, with 36 samples in the inner estuary (IE) and outer estuary (EE) for four years, the methodology used was optical microscopy, it was possible to identify fibers and fragments more frequently with percentages of 37% and 62.3% respectively (Vidal et al., 2021).

However, a study from Lima, Peru, mentions the presence of microplastics in sediments of irrigation canals in the center of the city; the main objective is to identify the size, shape and color of microplastics found in the samples. For the results, it was determined that the presence of particles between 6 - 1000 µm, and the shape of microplastics identified the fragments with the highest incidence, taking into account that neither pellets nor fibers were found and the color of the fragments found in the samples was blue, so in this research the highest incidence of color was red, blue and black when observed in bright field, taking into account that the same are fluorescent in green fluorescence field, confirming the presence of PM.

5.1.2 Amount of microplastics

This research shows the quantity as particles/250 mL, referred to below as concentration.

Table 1. Concentration and characterization of particles found in 250 ml.

Sampling Point	Sample No.	Fibers (particles)	Fragments (particles)	Concentration (particles/250 ml)
Catchment (Raw Water)	M01	4	1	5
	M02	12	9	21
	M03	19	3	22
	M04	10	3	13
	M05	19	2	21
	M06	11	8	19
	M07	28	3	31
	M08	11	9	20
	M09	10	11	21
	M10	6	9	15
	M11	12	5	17
	M12	7	7	14
	M13	13	8	21
	M14	12	7	19
	M15	5	3	8
	M16	9	10	19
	M17	9	5	14
	M18	9	2	11
	M19	10	9	19
	M20	8	7	15
	M21	11	4	15
	M22	9	10	19
	M23	13	7	20
	M24	8	13	21
	M25	6	14	20
	M26	13	13	26
	M27	9	13	22
	M28	10	12	22
	M29	5	4	9
	M30	16	18	34
	M31	10	15	25
	M32	6	17	23

	M33	7	18	25
	M01	12	6	18
	M02	12	1	13
	M03	18	2	20
Network Access	M04	5	6	11
Distribution	M05	3	8	11
(Drinking	M06	12	15	27
Water)				
	M07	13	3	16
	M08	13	6	19
	M09	11	3	14
	M10	10	1	11
	M11	13	3	16
	M12	14	10	24
	M13	14	9	23
	M14	8	6	14
	M15	2	6	8
	M16	10	6	16
	M17	12	5	17
	M18	9	6	15
	M19	7	4	11
	M20	6	4	10
	M21	11	1	12
	M22	3	2	5
	M23	11	19	30
	M24	14	12	26
	M25	10	17	27
	M26	16	9	25
	M27	10	17	27
	M28	7	6	13
	M29	9	3	12
	M30	17	14	31

	M31	-	5	5
	M32	6	9	15
	M33	-	5	5
Home Network	M01	14	-	14
	M02	19	6	25
	M03	19	4	23
	M04	14	4	18
	M05	6	6	12
	M06	7	7	14
	M07	14	3	17
	M08	18	4	22
	M09	7	10	17
	M10	16	9	25
	M11	1	3	4
	M12	11	5	16
	M13	11	9	20
	M14	9	18	27
	M15	7	11	18
	M16	10	6	16
	M17	4	6	10
	M18	14	9	23
	M19	13	7	20
	M20	4	6	10
	M21	12	7	19
	M22	2	5	7
	M23	7	12	19
	M24	12	18	30
	M25	23	13	36
	M26	16	9	25
	M27	7	15	22

M28	9	12	21
M29	20	9	29
M30	9	8	17
M31	5	6	11
M32	11	18	29
M33	13	8	21
Average / 250 ml			**18,28**

Note: Cells containing the following symbol (-) are defined as no microplastic particles of that shape.

Source: Own elaboration

The graph shows the final average of 18.28 particles/250 ml, i.e., approximate 73.12 particles/liter, taking into account that the research of Shen et al. (2021) evidences the presence of plastic microparticles in fresh water, with three sampling points, in the XiangJiang river; raw water, from the ETAP company; treated water and in the distribution networks; tap water, the study was carried out using microscopy and FTIR techniques having as results: 275.3 particles/L in the XiangJiang river, 351.9 particles/L from the ETAP company and 343.5 particles/L in the distribution networks, the results obtained in the research of Shen et al. Of course, the results obtained in the research of Shen et al. vary with the results obtained in this research, so this variation is attributed to the population density; however, the data follow the ratio of population density: particles/L.

Furthermore, in this study, 100% of the samples showed the presence of PM, i.e., 99/99 samples with the presence of PM, as in Brasilia, where 32 samples of drinking water were analyzed in a residential and commercial area in the north and south zone, 100% of the samples showed PM with a prevalence of 219±158 in the north zone and 97±55 p/500 mL in the south zone, the amount of microplastics found in the water is much higher. However, it is known that Brasilia is the second most populated city in Brazil, having 3.09 million inhabitants, mentioning that PM originated from anthropogenic activity, i.e., a directly proportional relationship according to Pratesi et al. (2021).

5.1.3 Identification of Microplastics

5.1.3.1 Type of Microplastics

The type of polymer found in each sampling point, i.e., in the collection, inlet to the distribution network and home network, was identified through FTIR and percentages of coincidence with the library found in OMINIC and OMINIC Specta.

Table 2. Percentage of polymers found in the sampling points.

Sampling Point	Type of polymer found					
	PET	PEHD	LDPE	Polyester	Polybutylene	Others
Catchment (Water Raw)	82.91%	0.64%	14.54%	0.64%	0.00%	1.28%
Distribution Network Intake (Water Drinking water)	80.44%	2.38%	14.63%	0.55%	0.00%	2.01%
Home Network	57.77%	7.85%	6.28%	0.47%	27.00%	0.63%

Source: Own elaboration

Table 2 shows the incidence of polyethylene terephthalate PET, high-density polyethylene HDPE, low-density polyethylene LDPE, polyester, polybutylene and others, as in the study conducted by Almaiman et al. (2021), where he analyzed water samples from bottled water as well as drinking water in 5 regions of Saudi Arabia, and determined the presence of PM in 17 of the 30 samples collected, using FTIR the presence of PET, PE, and PS was identified with a higher incidence than other types of polymers.

5.1.4 Evaluation of the stages of the Tomebamba water purification system

The particles/250 ml concentration will be compared in the catchment, inlet to the distribution network and home network.

5.1.4.1 Descriptive Statistics

Table 3. Descriptive statistics of the sampling points.

	Catchment (Cuda Water)	Network Access Distribution (Drinking Water)	Home Network
Media	18.69697	16.5757576	19.3030303
Standard error	1.05482733	1.27626223	1.21736555
Median	20	15	19
Fashion	21	11	25
Standard deviation	6.05952168	7.33156831	6.99323266
Variance of the sample	36.717803	53.7518939	48.905303
Kurtosis	0.81881521	-0.7541817	0.13171388

Coefficient of asymmetry	-0.0119887	0.37122396	0.04225131
Range	29	26	32
Minimum	5	5	4
Maximum	34	31	36
Sum	626	547	637
Account	33	33	33
Major (1)	34	31	36
Minor (1)	5	5	4

Note. The calculation of the descriptive statistics was performed in the Excel 2019 program, in the Data - Descriptive Statistics section.

Source: Own elaboration

As can be seen in Table 3, there is no significant difference between the standard deviations existing in the different sampling points, which are 6.06 for the collection, 7.33 for the entry to the distribution network and 6.99 for the home network, i.e., the data are not dispersed for the mean.

5.1.5 Normality test

To perform the parametric test, it is necessary to verify that the data comply with the normal distribution, for which Shapiro wilks was applied where:

The significance level determined for the Shapiro-Wilks test is as follows:

- Level of Significance; 0.05

The hypotheses determined for the Shapiro-Wilks test are as follows:

- Null Hypothesis (H0); The distribution is normal; $\sim N(\mu,\sigma 2)$.
- Alternative Hypothesis (H1); The distribution is not normal; $\nsim N(\mu,\sigma 2)$.

The values obtained for the Shapiro-Wilks test are greater than the significance level in this case, 0.05; therefore, the null hypothesis is accepted for this section, i.e., the values comply with the normal distribution and a parametric test should be performed to define their variance.

Table 4. Shapiro Wilks test, normality test

Shapiro Wilks normality test		
Sampling points	W	p-value
Uptake/Ingress to Distribution Network/Network domiciliary	0,99067	0,830

Level of Significance	0,05

Note: The calculation of the Shapiro-Wilks test was performed in the Rstudio program.

Source: Authors.

5.1.6 Analysis of Variance

For the analysis of variance, the ANOVA statistical method was applied, the principle of which is to test the variance between two or more means of data sets through hypotheses.

The significance level determined in this research is as follows:

- Level of Significance; 0.05

The hypotheses determined in this research are the following:

- Null Hypothesis (H0); All more means are the same
- Alternative Hypothesis (H1); At least one of the means is different.

Once the ANOVA table calculations have been made, it can be defined that the p-value (Probability) is: 0.2128917, the significance value is greater than 0.05, therefore: 0.2128917 > 0.05 which in turn p>0.05, is defined as:

The Null hypothesis is accepted and the Alternative Hypothesis is rejected; therefore, it is unnecessary to perform the Tukey test for multiple comparisons analysis.

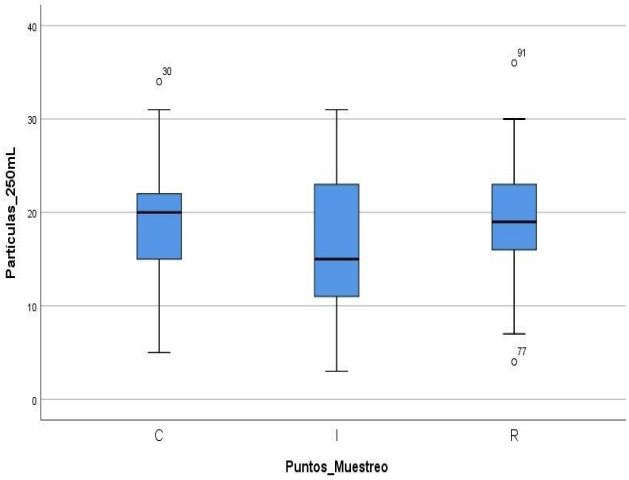
Table 5. Analysis of variance ANOVA of the data obtained in the research.

Origin of the variations	Sum of squares	Grades of freedom	Average of the squares	F	Probability	Critical value for F
Enter groups	146.08081	2	73.040404	1.5721701	0.21289173	0.0911913
Within the groups	4460	96	46.458333			
Total	4606.0808	98				

Note. The ANOVA analysis of variance was calculated in the Excel 2019 program in the "Data-Data analysis" section.

Source: Own elaboration.

Figure 3. Box and Whisker Diagrams



Note: The box-and-whisker diagram corresponds to Collection (C), inlet to the distribution network (I) and Household network (R).

Source: Own elaboration

It can be determined that in the three water sampling points, there is no significant difference, so it is assumed that the same concentration of microplastics in the water remains during the collection, entry into the distribution network and home network, as the presence of microplastics is evident from the source. It is assumed that the reason is due to tourist visits and anthropogenic activity in the area, it is also observed that it is maintained during the other two processes, it is worth mentioning that the type of polymer varies in each process, that is why polybutylene is found, the same that is part of the manufacture of pipes.

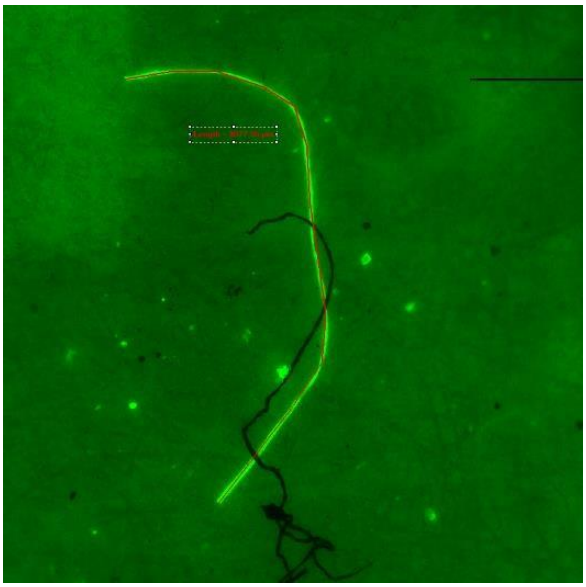
5.2 Analysis and results for the Mahuarcay water purification system in Azogues, Ecuador.

When the water samples from the different zones of the drinking water treatment system were evaluated, the presence of microplastics was observed in all 60 samples, which were characterized.

5.2.1 Microplastics Characterization

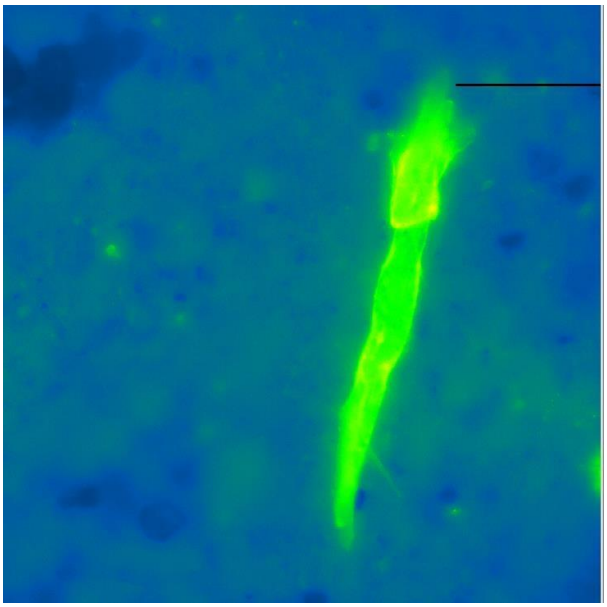
The type of Microplastics found in the study are fiber and particle shape; their thickness and length vary between them as shown in Figures 4 and 5.

Figure 4. Microplastic in fiber form.



Source: Own elaboration

Figure 5. Microplastic in fragment form.



Source: Own elaboration

5.2.2 Determination of the amount of microplastic particles.

During the observation process, using an inverted microscope with a 10x focus, the number of fibers and fragments were determined in each of the samples analyzed, as shown in Table 6.

Table 6. Number of fibers, fragments and concentration of plastics found in the water samples from the different zones of the Mahuarcay drinking water purification system.

Zona	N° de muestra	Fibras (partículas)	Fragmentos (partículas)	Concentración (partícula/250 ml)
Captación	M 01	19	28	47
	M 02	31	159	190
	M 03	0	0	0
	M 04	8	0	8
	M 05	12	66	78
	M 06	9	33	42
	M 07	18	20	38
	M 08	30	0	30
	M 09	13	110	123
	M 10	2	0	2
	M11	20	24	44
	M 12	8	70	78
	Promedio	13,7	43,8	57,5
Red	M 01	1	0	1
	M 02	39	57	96
	M 03	12	27	39
	Promedio	17,3	28,0	45,3
Domiciliarias	M 01	10	0	10
	M 02	19	100	119
	M 03	14	2	16
	M 04	45	0	45
	M 05	25	9	34
	M 06	8	19	27
	M 07	145	0	145
	M 08	48	7	55
	M 09	0	1	1
	M 10	230	242	472
	M11	62	17	79
	M 12	0	18	18
	M 13	17	13	30
	M14	47	4	51
	M 15	19	36	55
	M 16	57	1	58

M 17	22	10	32
M 18	75	34	109
M 19	29	0	29
M 20	37	15	52
M 21	18	19	37
M 22	77	21	98
M 23	30	21	51
M 24	39	21	60
M 25	28	10	38
M 26	57	3	60
M 27	60	68	128
M 28	0	30	30
M 29	49	108	157
M 30	40	2	42
M 31	52	67	119
M 32	25	158	183
M 33	64	77	141
M 34	0	175	175
M 35	8	9	17
M 36	100	18	118
M 37	70	23	93
M 38	45	23	68
M 39	24	26	50
M 40	48	68	116
M 41	41	50	91
M 42	23	25	48
M 43	28	6	34
M 44	109	172	281
M 45	39	92	131
Promedio	44,1	40,4	84,5
Promedio total	**36,8**	**40,2**	**77,0**

Source: Own elaboration

5.2.3 Determination of the size of microplastics

Table 7. Range of particle size distribution and shape of the particles found.

Zone	Sample no.	Fibers (µm)	Fragments (µm)
C	M 01	27.67 - 1327	3 - 176
	M 02	75.09 – 1488.14	20,6 – 247.37
	M 03	0	0
	M 04	124.09 – 575.39	0
	M 05	34.26 – 1847.53	6.19 – 108.35
	M 06	76.11 – 1399.24	10.33 – 131.81
	M 07	36.66 – 1004.03	20.615 – 116.16
	M 08	19.59 – 1208.46	0
	M 09	38.61 – 3395.9	13.04 – 185.815

	M 10	112.22 – 210.32	0
	M11	117.83 – 4236.19	18.06 – 115.37
	M 12	100.79 – 549.85	20.04 – 231.9
	Range	**27.67 – 4236.19**	**3 – 231.9**
R	M 01	75.28	0
	M 02	75.64 - 3186.49	14.21 - 155.21
	M 03	27.42 - 2882.26	13.85 - 74.72
	Range	**27.42 - 3186.49**	**13.85 - 155.21**
D	M 01	279.75 - 2601.43	0
	M 02	22.83 - 2220.06	10.44 - 163.26
	M 03	198.44 - 1246.63	53.7 - 91.4
	M 04	55.9 - 4401.83	0
	M 05	44.1 - 3148.15	31.01 - 180.56
	M 06	410.69 - 1979.32	9.21 - 185.32
	M 07	4.25 - 3827.71	0
	M 08	108.06 - 2228.97	39.1 - 190.49
	M 09	0	103.51
	M 10	46 - 3596.23	13.93 - 213.22
	M11	57.04 - 2491.8	31.855 - 168.17
	M 12	0	9.625 - 127.28
	M 13	93.19 - 3266.59	27.37 - 140.76
	M14	98.37 - 4470.5	77.53 - 163.5
	M 15	178.38 - 2546.15	6.64 - 48.64
	M 16	77.43 - 4828.3	33.29
	M 17	156.94 - 2347.97	18.03 - 123.81
	M 18	68.96 - 4752.84	4.845 - 113.77
	M 19	77.43 - 4828.3	0
	M 20	156.94 - 2347.97	13.7 - 179.53
	M 21	68.96 - 4752.84	14.95 - 84.21
	M 22	89.12 - 2918.05	19.3 - 237.53
	M 23	154.7 - 4352.27	41 - 174.85
	M 24	27.61 - 2398.42	12.51 - 157.81
	M 25	57.06 - 4168.64	32.86 - 100.6
	M 26	154.7 - 2757.39	108.51 - 136.01
	M 27	51.72 - 2647.34	7.41 - 195.91
	M 28	221.46 - 4653.89	25.41 - 169.22
	M 29	80.13 - 4988.73	14.81 - 180.27
	M 30	102.73 - 3715.47	29.89 - 172.12
	M 31	35.03 - 1788.62	17.4 - 219.3
	M 32	262.55 - 2253.82	19.86 - 210.42
	M 33	1.33 - 2747.43	9.21 - 106.19

M 34	0	13.93 - 214.24
M 35	391.68 - 1781	25.495 - 69.79
M 36	121.77 - 4991.47	16.305 - 77.5
M 37	54.36 - 1408.23	23.33 - 161.09
M 38	55.36 - 3089.23	16.695 - 161.13
M 39	35.85 - 147.88	16.73 - 90.88
M 40	95.12 - 3903.45	10.47 - 248.97
M 41	53.48 - 2896.48	18.99 - 159.52
M 42	33.6 - 590.58	12.43 - 115.78
M 43	62.22 - 3614.56	33.79 - 100.72
M 44	41.93 - 4075.88	11.32 - 246.6
M 45	51.9 - 1942.79	12.37 - 249.44
Range	**1.33 - 4988.73**	**7.41 - 249.44**
Total average	**1.33 - 4988.73**	**3 - 249.44**

Source: Own elaboration

In Table 7, it can be observed that the average range of fibers of the three zones oscillates between 27.67 - 4236.19 µm; 27.42 - 3186.49 µm and 1.33 - 4988.73 µm, corresponding to the catchment area, network and domiciles respectively, according to Ding et al. (2018) considers microplastic fibers to particles of small thickness and a variable length, but these being smaller 5 mm; which can be seen reflected in the same way in the research of Mukotaka et al. (2021) where he obtains results of the quantification of microplastics in tap water corresponding to 12 cities in 5 countries with a particle size between 19.2 µm to 4.2 mm, finding these values within the parameter indicated by Ding et al. in 2018 and at the same time adjusting to the one obtained in the water samples analyzed from the Mahuarcay drinking water treatment system.

On the other hand, in the case of the size distribution of the microparticle fragments in the present study, the ranges of the three zones are: 3 - 231.9 µm; 13.85 - 155.21 µm and 7.41 - 249.44 µm; given the parameter indicated according to Flores and Orozco (2022), they indicate that the size of microparticle fragments should be less than 250 µm; therefore, the values obtained in the different zones are adjusted to be below the determined limit.

5.2.4 Microplastics type identification by FTIR

5.2.4.1 Type of Microplastics

In order to identify the type of microplastic present in the water purification system, it was first necessary to observe through the inverted microscope to identify and point out those particles larger than 130 µm since, below this value, the FTIR could not perform a correct analysis.

Therefore, it was possible to determine the type of microplastic to be treated through the OMNIC software, generating spectra that would later be compared with the OMNIC Specta software, given the greater specificity it provides after its respective selection of libraries to be analyzed and the spectral subtractions of the nitrocellulose filter for greater data accuracy, the data of the polymers existing in each sample was tabulated, showing in Table 4 their abundance at each sampling point.

Table 8. Percentage of polymer present in the "Mahuarcay" water purification system.

Zone	Polymer type								
	PTFE	PE	PET	CPE	Polyamide	Polyvinyl	Nylon	Cellophane	Polyester
C	2.7	41.89	25.68	14.86		5.41		5.41	4.05
R		67.74	32.26						
D		47.98	28.25		4.48	13.9	1.35	4.04	

Source: Own elaboration

Table 8 shows the abundance of polymers in the different zones of the Mahuarcay water purification system, which increases or decreases in the different zones; however, it can be seen that PE and PET is the polymer that is present in all phases and in more significant quantities, which in the study by Pittroff et al. (2021) in the analysis of microplastics in drinking water the largest type of polymer is PE with 86% ± 111% and PET 10% ± 25%, showing that like our study are those polymers with the highest incidence and abundance, inferring that this type of plastic may come from food containers and pipes, This suggests that there may be wear of the pipes used during this system or contamination by the areas surrounding the catchments, which through biotic and abiotic degradation may reach water sources.

5.2.5 Evaluation of the stages of the drinking water treatment system

5.2.5.1 Descriptive statistics

Table 9. Numerical descriptive statistics of samples classified by zones.

Indicator	Zones		
	Capture	Web	Domiciles
Media	56.7	45.3	84.5
Standard error	15.9	27.6	12.1
Median	43.0	39.0	55.0
Fashion	78.0	...	119.0
Standard deviation	54.9	47.8	81.5
Sample variance	3016.8	2286.3	6639.7
Kurtosis	2.2	...	11.3
Asymmetry coefficient	1.4	0.6	2.9
Range	190.0	95.0	471.0
Minimum	0.0	1.0	1.0
Maximum	190.0	96.0	472.0
Sum	680.0	136.0	3803.0
Account	12.0	3.0	45.0
Confidence level (95.0%)	34.9	118.8	24.5

Source: Own elaboration

Table 9, which shows the descriptive statistics, shows that the maximum value among the three zones is accentuated in the home zone, while the lowest value is that of the distribution network, so it can be inferred that there is an increase in the concentration that may be since in some samples there is a greater amount of microplastic compared to others, as shown in the standard deviation of the same table.

5.2.6 Normality

The analysis of variance followed the descriptive statistical analysis; however, as a first step, the data's normality must be determined to determine the distribution of the data, through which hypotheses are put forward to be accepted or rejected according to the result.

The hypotheses are as follows:

- Null Hypothesis (H0) = The data have a normal distribution.

- Alternative Hypothesis (H1) = The data do not have a normal distribution On the other hand, a significance level of 0 is established,

Table 10. Normality test

	Kolmogorov - Smirnov		
	Statistician	**Gl**	**Sig**
Concentration	0,188	60	0,000015

Source: Own elaboration

5.2.7 Non-parametric tests

The Kruskal-Wallis type parametric test is an analog of the ANOVA tests, performed to test whether a group of data comes from a similar population. To analyze the non-parametric tests in the same way as the normality test, hypotheses with a significance level of 0.05 must be established; the hypotheses established are:

- Null Hypothesis (H0): Population medians are equal

- Alternative Hypothesis (H1): Population medians are not equal

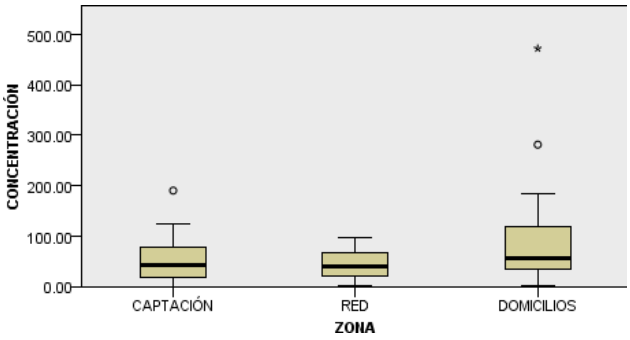
Table 11. Non-parametric test for the analysis of variance

Null hypothesis	Test	Sig.	Decision
The concentration distribution is the same among the zone categories	Kruskal- Wallis test for samples independent	0.290	Retain the null hypothesis

Source: Own elaboration

With the results obtained and visualized in Table 11, the null hypothesis can be adopted as the basis of the research, determining that the results of the microplastic concentration (fibers + fragments) of the water samples have distribution so that they belong to the same population.

Figure 6. Kruskal-Wallis test for independent samples.



Source: Own elaboration

Figure 6 shows how the medians of each zone are related to each other as they belong to the same group; therefore, the accepted hypothesis becomes relevant as the box-and-whisker plot supports it.

6. Conclusions and recommendations

6.1 Conclusions regarding the Tomebamba water purification system in the city of Cuenca.

In this study, it was possible to determine the presence of microscopic plastic particles in the Tomebamba system, which includes the El Cebollar drinking water treatment plant and its household supply, in three different processes: Collection (raw water), entry into the distribution network (drinking water) and in the household network. 1As a result, 00% of samples with observable

In addition, it was determined that in the year 2022, a final average of 18.28 particles per 250 ml was defined, thus having a general range for fibers of 6.31 - 4966.77 µm and fragments of 6.95 - 243.87 µm.

It is important to mention that it was possible to identify the types of polymers found at each sampling point. Thus, for the collection and entry to the distribution network, there was a coincidence with PET PEHD, LDPE and polyester, which means that from the source, there is a degradation of plastics generating microscopic particles that are maintained throughout the drinking water treatment process, taking into account that the polymers mentioned above are the most used by society both for food containers and for clothing.

However, in the home networks, a coincidence of the same mentioned above was found, in addition to polybutylene, which is interpreted as the material that belongs to the manufacture of several home pipes, which due to the use of the material in the home networks, is not only a material that is used in the manufacture of the pipes but also a material that is not used in the manufacture of the pipes.

The water and the existing friction with the water, over time, will detach and generate micro-particles.

In the evaluation of the sampling points, it is evident that the presence of microplastics is very similar among the processes, thus having a very similar standard deviation, which leads to the conclusion that the plastic microparticles are generated from the water sources through degradation and increased in the drinking water supply system in the city of Cuenca until it reaches the consumer.

Taking into account the data obtained in this study, it is concluded that it was possible to detect plastic microparticles through the techniques of Fluorescence Inverted Microscopy and Infrared Spectroscopy, in addition to identifying that there is no significance in the different stages of the Tomebamba water purification system in the city of Cuenca, Ecuador for the concentration of microplastics.

Finally, based on the information presented above, the research question was fully

answered and the research hypothesis was also accepted since the presence and characterization of microscopic plastic particles that alter the water resource of an urban area of Cuenca in the year 2022 could be verified through Inverted Microscopy and FTIR techniques.

Recommendations

- It is recommended to evaluate the action of methylene blue for fluorescent staining of microplastics since only Nile Red was used in this study.

- To verify the presence of microplastics observed in the fluorescence microscope, it is recommended to observe in bright field and identify the characteristic color of the plastics.

- Conduct a more in-depth investigation on the origin of microscopic plastic particles in the basin's water, as this will provide a more visible picture of the impact of plastic in water sources.

- Generate a baseline to consider particles per liter of water as an extra parameter to verify drinking water quality and recommend a different treatment in water purification that is directly related to the reduction of plastic microscopic particles.

6.2 Conclusions regarding the Mahuarcay water purification system in Azogues.

It was found that in the water purification system of Azogues, there is a higher concentration of plastic microparticles in the areas of home networks (84.5 particles/250 mL); it is inferred that the reason is due to the wear of the pipe that exists on the way from the plant outlet to the user.

The area with the lowest concentration of microplastics is in the distribution area because the three water sources that supply the plant have different concentrations of microplastics, with the Nudpud catchment having the highest concentration (82.66 particles/250 mL). After all, it is a catchment whose surrounding sectors are populated. Therefore, upon entering the plant, there is a homogenization of these three catchments, generating an average and a decrease in the values, which can be considered that the plant is eliminating certain particles of a certain size, thus decreasing the concentration in the distribution networks.

According to the study, it was established that the morphology of microplastics is within the parameters of previous studies to date, being <5 mm in the case of fibers and less than 250 µm in the case of fragments, which our study is within limits (1.33 - 4988.73 µm in fibers and 3 - 249.44 in fragments).

The area of microplastics has not been considered important for previous studies. However, it is an important indicator within the study of microplastics since this factor can determine the quality of drinking water treatment in the efficiency of microplastic removal.

Finally, the type of microplastic found in greater abundance is PE and PET, a plastic manufactured with greater intensity given the multiple uses that they offer, highlighting the pipes and food containers, so it is inferred that the presence of this type of plastic in the different water samples analyzed may be due to the wear of the pipe of the different stages that constitute the water purification system, being essential to analyze the durability and the time of use of the same within the plant.

The type of microplastic is a function of the sector of the sampling area because PTFE and CPE are found in the greatest amount in the catchment area, PTFE is a type of plastic used in the joints of the pipe, while CPE is a polymer

used to reduce the impact of PVC pipes improving their strength and durability, so it is inferred that there is wear in these areas due to the presence of this type of plastic.

It was determined that the three analyzed zones of the system are maintained in the same way in each of the processes, given that the statistical resources allow determining that in each zone, there is the same concentration of microplastics; however, it can be determined that there are certain samples of the household zone in which the level of microplastics are outside the average, this may be caused by the fact that the household networks are found with pipes in the process of deterioration.

We can mention that the presence of plastics in the environment is due to inadequate waste management, among other factors, so that it is present in the water resource of the beneficiary users of the drinking water service Mahuarcay of the city of Azogues, Ecuador. Therefore, control measures should be maintained in the different areas analyzed of the water purification system regarding the presence of plastics since this study determined the presence of the object of study, answering the research question

Recommendations

- Adequate control of the presence of microplastics in the sources should be established since one of them has a higher concentration than the other two.

- Determining whether climatic factors may influence the final concentration of microplastics in the catchment areas is advisable.

- It is recommended to study the impact of distance on the number of microplastics in distribution networks and home networks.

- It would also be essential to check whether the physical-chemical characteristics of the water are related to the wear of the piping, which could be a source of microplastics in the different stages of the drinking water treatment system.

- It is recommended that a study be carried out to determine the characteristics of microplastics that could be eliminated in water treatment

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