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REVISTA INGENIO

Analysis of the Biodegradability Index of Organic Matter in the Water of the Machangara River in Quito City

Análisis del Indice de Biodegradabilidad de la Materia Orgánica en el Agua del Río Machángara en la Ciudad de Quito

Suly Margoth Rodríguez Ayala | Universidad Central del Ecuador - UCE, Quito - Ecuador
Montserrat Rodríguez Ayala | Universidad de Madrid - UAM, Madrid - España
Silvia Elizabeth Garcia Gonzalez | Universidad Central del Ecuador - UCE, Quito - Ecuador
Darwin Rodolfo Caina Aysabucha | Universidad Central del Ecuador - UCE, Quito - Ecuador

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Biodegradability, contaminants, treatment, parameters, Machángara river.

ABSTRACT

The evaluation of the water quality in rivers is essential to identify the impact of human activities and establish mitigation strategies. The aim of this project is to analyze the biodegradability index of organic matter in the water of the Machángara river in Quito city of Ecuador. It flows through some places of Quito such as “Las Cuadras”, “El Recreo”, “La Recoleta”, and “Nayon”. Through sampling in the aforementioned sectors, the parameters necessary for the calculation of biochemical (BOD), and chemical (COD) oxygen demand were analyzed, along with other physicochemical parameters such as turbidity and watercolor. In addition, a survey was conducted in the study areas in March 2023. The results showed a significant variability in the level of contamination among the sectors analyzed. A higher level of contamination was found in the areas of La Recoleta and El Recreo compared to Las Cuadras, and Nayon, which is attributed to direct discharges of pollutants from illegal pipes connected to both industries and households. The biodegradability index obtained suggests the need to implement chemical, and biological treatments for the efficient removal of organic and inorganic pollutants present in the river. The physicochemical analysis showed that the turbidity, and color of the water also correlated with the high levels of pollution observed, especially in the most affected sectors. The information gathered through interviews showed that the local population suffers directly from the negative effects of this contamination, manifesting symptoms such as headaches, nausea, vomiting, fatigue, lack of concentration, and depression, especially in children, and older adults. In conclusion, the results of this study highlight the need for immediate corrective measures, such as chemical, and biological treatments, to mitigate the environmental, and health impacts of the Machángara River and improve the quality of life of the affected population.

PALABRAS CLAVE
Biodegradabilidad, contaminantes, tratamiento, parámetros, río Machángara

RESUMEN

La evaluación de la calidad del agua en rios es esencial para identificar el impacto de las actividades humanas y establecer estrategias de mitigación. El objetivo de este proyecto fue analizar el índice de biodegradabilidad de la materia orgánica en el agua del río Machángara en la ciudad de Quito en Ecuador. Este rio atraviesa algunos lugares de Quito tales como: Las Cuadras, El Recreo, La Recoleta y Nayón. Mediante un muestreo en los sectores mencionados, se analizaron los parámetros necesarios para el cálculo de la demanda bioquímica (DBO5) y química (DQO) de oxígeno, junto con otros parámetros fisicoquímicos como la turbidez y el color del agua. Además, se realizó un levantamiento de información en marzo de 2023 en las zonas de estudio. Los resultados mostraron una variabilidad significativa en los niveles de contaminación entre los sectores analizados. Se identificó un mayor nivel de contaminación en las zonas de La Recoleta y El Recreo en comparación con Las Cuadras y Nayón, lo cual se atribuye a descargas directas de contaminantes provenientes de tuberías ilegales conectadas tanto a industrias como a domicilios. El índice de biodegradabilidad obtenido sugiere la necesidad de implementar tratamientos químicos y biológicos para la remoción eficiente de los contaminantes orgánicos e inorgánicos presentes en el río. El análisis fisicoquímico reveló que la turbidez y el color del agua también se correlacionan con los altos niveles de contaminación observados, particularmente en los sectores más afectados. El levantamiento de información a través de encuestas demostró que la población local sufre de manera directa los efectos negativos de esta contaminación, manifestando síntomas como cefalea, náuseas, vómitos, fatiga, falta de concentración y depresión, especialmente en niños y adultos mayores. En conclusión, los resultados de este estudio resaltan la necesidad de aplicar medidas correctivas inmediatas, como tratamientos químicos y biológicos, para mitigar el impacto ambiental y sanitario del río Machángara y mejorar la calidad de vida de la población afectada

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fing.revista.ingenio@uce.edu.ec

1. INTRODUCTION

The problem of water pollution is a contemporary challenge worldwide. This phenomenon is not only limited to industrialized or developing countries but affects all levels of our society [1]. The water quality in river basins is primarily determined by natural factors such as soil type, and geology. However, human activities, particularly agriculture, livestock, and urbanization along river sub-basins, are the predominant sources of pollution in Ecuador [2].

In Ecuador, the situation reflects a mixed response to water treatment efforts. By 2019, 70.1% of Ecuador's autonomous decentralized municipal governments (GADMs) had implemented urban wastewater treatment processes. In contrast, 26.3% had no treatment at all, opting to discharge directly into water bodies [3]. This uneven implementation has led to significant pollution, especially in urban basins. The highland region hosts the largest number of treatment plants, representing 50% of the total in Ecuador, while 31% are located in the coast region, 18.5% in the amazon region, and 0.5% in the insular region.

The direct discharge of sewage and waste into urban drainage basins is the main source of water pollution [4]. Rivers are affected by fecal coliforms, detergents, nitrates, phosphates, oils, and fats that exceed the limits set by national environmental regulations. Rivers with compromised water quality often lose their self-purification capacity, resulting in severe ecological imbalances that threaten biodiversity, and the sustainability of these ecosystems [5].

To satisfy human needs, a daily consumption of three liters of drinking water, and a total of twenty liters for anthropogenic activities is required. Ecuador has the remarkable advantage of having at its disposal a freshwater supply of 22500 , a figure that exceeds the 1000 , recommended by the World Health Organization (WHO) [6]. This situation reflects the amount of water consumed by the population, which increases the pollution of rivers and seas. It affects not only the supply of drinking water, but also the health of the organisms that depend on it. It also causes adverse health effects such as reproductive problems, kidney damage, neurological diseases, and cancer [7].

The Quito city exemplifies the water quality challenges faced by urban centers. Historically, the wastewater of it was discharged directly into nearby streams and rivers. However, rapid population growth has exacerbated wastewater production, significantly degrading the quality of these water bodies [8]. The high population density of cities is a factor that aggravates the pollution of their water resources, since there is a greater emission of waste, and liquid effluents [9]. With a current population of 2.8 million, expected to reach 4.2 million by 2040, the pressure on Quito's water resources is expected to intensify [4].

Nowadays, the Machángara river is the main destination of wastewater of Quito. It has a total length of 22.5 kilometers, where it receives 76% of the entire city's effluent [10]. The river is the result of the confluence of various small rivers, including the "Rio Grande", "Quebrada Ortega", "Quebrada Rumipamba", and "Quebrada El Batán" [11]. The Machángara river sanitation project carried out by the German Cooperation Agency in 1991, identified the main types of industries in the Quito city, and their potential environmental impacts. The food industry produces high pH, sulfites, detergents and sediments, while the textile industry produces high pH, fats, oils, heavy metals, sulfites and sulfates. Tanneries, on the other hand, emit high levels of pH, floats, sulfide, sulfite, sulfate, dyes, and salts. The chemical industry is responsible for emissions of solvents, floating sulfates, sediments, fats, greases, heavy metals, dyes, biocides, surfactants, halogenated hydrocarbons, fats, oils, ammonium, nitrates, and phosphates [10].

In recent years, several environmental assessment studies have been conducted on the Machángara river. They have revealed environmental impacts due to the generation of odors, and the discharge of industrial effluents that exceed the limits allowed by environmental legislation. In response to this alarming situation, the Environmental Sanitation Program (PSA) of the Metropolitan Public Company of Drinking Water and Sanitation of Quito (EPMAPS-Q) implemented the "Plan for the Decontamination of Quito's Rivers" in 2007. It included the collection and treatment of wastewater from parts of the city. In 2017, the first wastewater treatment plant was inaugurated in "Quitumbe" sector, the first in the city, but no noticeable results have been seen. Therefore, pollution is still visible. A press release published in the newspaper "El Comercio" in September 2019 showed that, despite the inauguration of the first wastewater treatment plant in southern Quito, the pollution situation of the Machángara river remains alarming. The treatment plant built in the "Quitumbe" sector has the capacity to treat up to 9.5 million liters of wastewater per day. However, the plant is not operating at 100% capacity due to technical problems. In addition, illegal discharges of wastewater into the river have been detected from areas surrounding the treatment plant, which has led to criticism from environmental organizations, and citizens in general [12]. The study perfomed by Campaña et al. [4], evaluated various environmental parameters of the river, including temperature and pH, which are in compliance with ecuadorian regulations. However, the values of Biochemical Oxygen Demand (), Chemical Oxygen Demand (), dissolved oxygen, and turbidity exceed the limits established by the regulations. Furthermore, the presence of heavy metals such as chromium (Cr), and cadmium (Cd) exceeds acceptable levels for agricultural use [13], highlighting the urgent need for more effective environmental management and pollution control measures.

1.1 LOCATION OF STUDY

The Machángara river is one of the main ones in Quito. It crosses the entire city, originating in the south in the “Cutuglagua” sector [14], spanning a total length of 22 kilometers. The river receives domestic and industrial effluents from the city [15]. It joins the “San Pedro” river in “Nayon”, which, together with the “Pisque” river, forms the “Guayllabamba” river, a tributary that reaches “Esmeraldas”, and flows into the pacific ocean [16].

As a river located in an urban environment, the Machángara river presents significant problems for the inhabitants of this sector, such as unpleasant odors, the proliferation of harmful animals, and vectors that transmit diseases [17]. Likewise, like many rivers in Quito, it is characterized by deep riverbeds, and steep slopes, which limit access for any type of sampling. Along the riverbanks, abandoned structures in an advanced state of deterioration can be observed, which has an unfavorable impact on the aesthetics of the city [18].

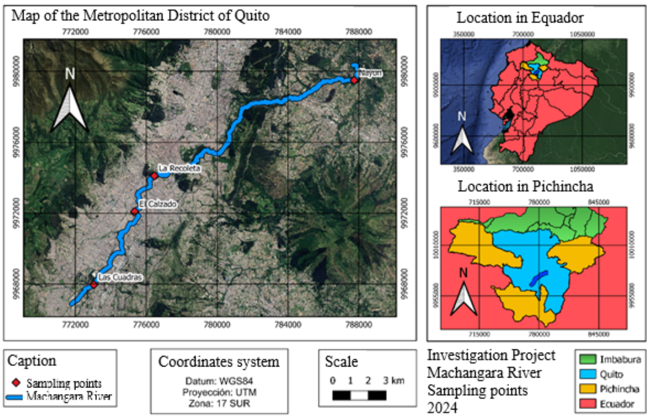
2. METHODS

To assess the biodegradability index of the organic matter in the Machángara river, wastewater sampling from discharge pipes located along the riverbanks was conducted, following the methodology described by Larrea et al. [19]. According to their study, *“sampling aims to provide accurate information for evaluating the presence of emerging pollutants”*, which in this case, helped to identify the types of contaminants present in the river and to determine the most appropriate treatment methods based on the biodegradability index [28, 29, 30].

The sampling of wastewater from the outfall pipes was performed during the period between 2022 and 2023, specifically in the months of October, December, February, April, June, August and October. Four strategic points along the Machángara river were considered, as shown in Figure 1.

Figure 1.

Map of sampling site locations (The map of strategic points for water samples collection)



These points were chosen to take different points along the river. The point 1 (P1) is located in the “Las Cuadras” park in the southern part of the city, the point 2 (P2) is located in the “El Calzado” park, the point 3 (P3) is near to the place “La Recoleta” (located close to Quito’s historic center), and the point 4 (P4) is in the rural community of “Nayon”, located in the northern part of the city.

Table 1 below shows the UTM coordinates obtained from Google Maps with the sectors corresponding to the selected sampling points along the Machángara river.

Table 1.

Coordinates of the sampling points (WGS84 UTM 17S)

Point	Sector	Coordinates	
P1	Las Cuadras	773041.77 E	9967956.90 N
P2	El Calzado	775349.40 E	9972083.50 N
P3	La Recoleta	776456.37 E	9974102.29 N
P4	Nayon	787752.00 E	9979495.70 N

Subsequently, a reconnaissance and characterization of each sampling point was conducted to gather primary data. Observations were made regarding the pollutants present in the river, and along its banks. The anthropogenic activities taking place, as well as an evaluation of the existing flora and fauna at each sampling site. Surveys were also administered to gather the perceptions of the local population regarding river contamination.

At the first sampling site P1, located in “Las Cuadras” park in Quitumbe, the presence of both solid urban waste and foam in the water was documented. As described by Cevallos [20], “the presence of surfactants and detergents can generate foam, while solid materials serve as sources of pollution, impeding the proper ecological function of the river if their composition is incompatible with the aquatic environment”. Among the waste observed were plastic covers, cups, soda bottles, cleaning containers, water bottles, food wrappers, and fragments of household items and textiles. Despite this contamination, diverse plant species, including cedar, walnut, pumamaquis, and nettle, were recorded. Additionally, wild birds, insects, and rodents were noted in the area.

The second sampling site P2, located in the “Parque Lineal Machángara “ within the “El Calzado” park, featured a variety of flora such as cedar, eucalyptus, nettle, and zambo trees. However, solid waste, including branches carried by the current, was also present. This area is affected by several sources of pollution, particularly plastics and organic waste from pets, which are often left uncollected by their owners. As noted by Cevallos [20], “biological contaminants from human and animal feces pose risks to river health by fostering the proliferation of bacteria, fungi, viruses, and protozoa”. In this location, a low diversity of large shrubs, and trees was observed, with undergrowth surrounding the discharge pipe. Regarding fauna, terrestrial species were absent, though birds such as pigeons and blackbirds were seen in the vicinity.

The third site P3, situated in the "Parque Río Machángara", exhibited substantial urban waste, including bottles, plastic bags, polypropylene containers, organic matter, and surfactants. Although this location is easily accessible, it poses a significant safety risk due to an old, deteriorating bridge needed to cross the river, which is in disrepair. Wastewater at this site is discharged directly into the river via a concrete channel. The steep slopes in this area lead to the accumulation of debris on the embankments, further exacerbating pollution. The dominant plant species observed was Kikuyo grass, described by Gonzalez [21], as "drought-resistant and acting as a natural herbicide". Although, it is considered an invasive species and commonly used to feed livestock in nearby areas. Additionally, the accumulation of garbage has attracted rodents and insects, which have significant environmental and public health implications.

The fourth sampling point P4 in "Nayon", known as "Quebrada de Tanda or Quebrada Urahuaycu", near the Nayon hydroelectric plant. The presence of solid waste, mainly plastic, and polypropylene, has been detected on the banks of the river, as well as a large number of surfactants floating on the surface of the water. Despite this, the site is easily accessible and has adequate infrastructure to carry out the activity without physical risks. Regarding the pollution in the sector, there is an accumulation of garbage on the river banks, including plastic bags, food leftovers, and glasses. In addition, to the presence of a hydroelectric plant, and numerous nearby housing developments. In terms of flora, native shrubs, and plants such as ferns, chilcas, and kikuyo were observed. As for the fauna, a wide variety of species were recorded, such as wild birds and chickens, as well as cows, rats, and some insects near the discharge point.

In addition, in this investigation, information was collected in March 2023, obtaining a high margin of contamination observed by the population in the surrounding areas. Since more than 70% of those surveyed consider them to have a high level of contamination. More than half of those surveyed at all four sampling points reported noticeable foul odors emanating from the Machángara river. The highest percentage of this perception was reported at point 3, which is the "La Recoleta" sector, with 99%. The presence of foul odors can be a sign of water contamination, and although it does not always directly indicate the presence of toxic substances, it is important to consider this perception of the respondents as a warning sign about the quality of the river water [22]. The presence of these odors has been related to various symptoms, including headaches, nausea, vomiting, diarrhea, fatigue, difficulty concentrating, and depression. According to the respondents, children are the most affected population by the contamination of the Machángara river, with the highest percentage on point 2 "Parque el calzado" (63%), and the lowest in point 4 "Nayon" (44%). Therefore, it can be affirmed that all respondents in the different sectors agree that the child population is the most affected by this contamination. Furthermore, 97% of all surveyed agreed on the necessity of mass environmental education campaigns to promote social responsibility and increase awareness about environmental protection.

The process of determining the biodegradability of organic matter was carried out by sampling in the areas of interest. Considering their representativeness in the study, four sampling points were selected as there was evidence of the presence of pipes with direct discharges to the effluent. Several parameters such as pH, total dissolved solids (TDS), conductivity, temperature, alkalinity, turbidity, total suspended solids (TSS) and residual chlorine were measured in situ. While for the Biochemical Oxygen Demand () and the Chemical Oxygen Demand () of the water resource was analyzed directly in the laboratory. Subsequently, the biodegradability index was quantified according to the following ratio formula [23]. Equation 1 shows the formula for the biodegradability index.

Depending on the value obtained, the nature of the effluent is indicated, and interpreted. If the effluent contains organic matter, degradation is relatively easy. Although, there are exceptions such as fats, and oils, as well as inorganic matter [24]. The range that classifies the two types of effluents is shown in Table 2.

Table 2.
Organic and inorganic waste by biodegradability value [24]

Type of discharge	
Inorganic	<0.2
Organic	>0.6

The intermediate ranges in the COD ratio, between 0.2 and 0.5, could indicate the combined presence of organic and inorganic effluents.

The ability to degrade organic compounds provides another variation for the result, which is reflected in Table 3, where the biodegradability capacity of the effluent is shown according to the ratio.

Table 2.
Relationship between the ratio and biodegradability in water [26]

Biodegradability	
Highly biodegradable water	>0.6
Fairly biodegradable water	0,4-0,6
Poorly biodegradable water	0,2-0,4
Non-biodegradable water	<0.2

The results will also serve to establish an optimal purification mechanism for the organic matter present in the Machángara river, as shown below:

Table 3.
Relationship between the ratio and the type of water [26]

Type of water	
Highly biodegradable water	>0.6
Can be treated biologically	0,3-0,6
Not biologically treatable	<0.3

2.1 BIOCHEMICAL OXYGEN DEMAND (BOD5) AND CHEMICAL OXYGEN DEMAND () ANALYSIS

2.1.1 Determination of BOD by the APHA 5210 – B method.

The Biochemical Oxygen Demand (BOD) test is used as an indirect measure of the amount of organic matter in a sample. This analysis involves measuring the change in dissolved oxygen (DO) concentration, caused by microbial activity that degrades organic matter in a sample. That is kept in a closed bottle and incubated under specified temperature and dark conditions for 5 days. DO measurements are taken before and after incubation, and BOD is calculated from the difference between these measurements. The first DO measurement is taken shortly after sample dilution, and any additional oxygen consumption that occurs after this measurement is added to the BOD [25].

2.1.2 Determination of Chemical Oxygen Demand (COD) by the APHA 5220 – D method.

In Chemical Oxygen Demand (COD) analysis, the dichromate ion is used to oxidize the constituents present in the sample. This process induces a change in the state of chromium from hexavalent (VI) to trivalent (III), with both coloring properties and absorption in the visible region of the spectrum. The dichromate ion shows high absorption in the 400 nm region, while the absorption of the chromic ion is significantly lower in this region. On the other hand, the chromic ion shows strong absorption in the 600 nm region, where dichromate has hardly any absorption. In 9M sulfuric acid solution, the molar extinction coefficients for these forms of chromium are approximately as follows: is 50 L/mol cm at 604 nm, is 380 L/mol cm at 444 nm, and is 25 L/mol cm at 426 nm. Therefore, the point of maximum absorbance is at 420 nm. For COD concentrations between 100 and 900 mg/L, there is an increase in concentration in the 600 nm region. It is possible to dilute the sample to obtain higher values. For COD concentrations equal to or less than 90 mg/L, the reduction of the dichromate ion is determined at 420 nm. Although, the corresponding formation of causes a slight increase in absorbance at 420 nm, this effect is accounted for in the calibration procedure [25].

3. RESULTS

The following are the results of the analysis of the 5-day Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) at four sampling points during a period of one year.

In terms of BOD5, sampling point 2 (El Recreo) had the highest mean value with 199.71 ± DE 66.67 mg/L, followed by point 3 (La Recoleta) with 205.43 ± DE 58.00 mg/L, point 1 (Las Cuadras) with 106.14 ± DE 75.50 mg/L, and finally point 4 (Nayon) with the lowest mean value of 19.29 ± DE 21.55 mg/L (Table 5). The minimum BOD5 value was recorded in P4 with 5 mg/L and the maximum in P1 with 285 mg/L. These results indicate that P2 and P3 have significantly higher and variable BOD5 values throughout the year, with notable peaks in February, June and August. In contrast, P4 showed low variability with a peak in October 2022.

For COD, the sampling points followed a similar pattern as for BOD5. The point P2 had the highest mean value with 395.86 ± DE 104.68 mg/L, followed by the point P3 with 395.86 ± DE 104.68 mg/L, P1 with 221.86 ± DE 117.17 mg/L and the point P4 with the lowest mean value of 31.00 ± DE 28.77 mg/L. The minimum COD value was observed in point P4 with 9 mg/L and the maximum in point P2 with 531 mg/L, indicating significant variations. As with BOD5, point P2 and point P3 showed significantly high and variable COD values, with peaks in February, April, and August, while in point P4 showed less variability and a peak in October 2022. When comparing the four sampling points, it is observed that in point P2 and P3 have higher and more variable organic pollution levels, both in BOD5 and COD, especially in certain periods of the year such as February and August. This could indicate environmental influences or specific activities that affect water quality at these points. In point P1, although it also shows variability, it shows moderate levels of contamination compared to the two previous points. On the other hand, point P4 stands out for its consistently low levels of organic contamination, with little variability throughout the year.

Table 5.

BOD5 and COD parameters of the sampling points in the period of one year (2022-2023)

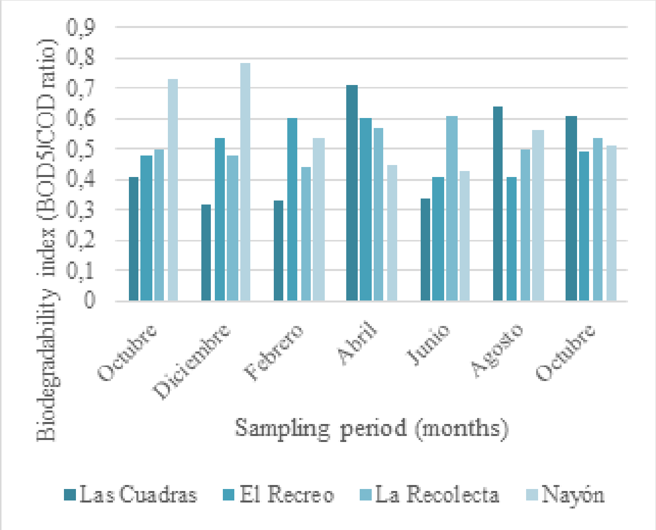
		Study period						
Sampling points	Parameters	October	December	February	April	June	August	October
		2022	2022	2023	2023	2023	2023	2023
Las Cuadras (P1)	BOD5	65	38	102	77	93	285	83
	COD	158	120	307	108	276	448	136
El Recreo (P2)	BOD5	120	146	316	232	193	161	230
	COD	248	269	531	387	470	397	469
La Recoleta (P3)	BOD5	159	163	205	266	277	252	116
	COD	320	341	468	469	451	508	214
Nayon (P4)	BOD5	66	18	7	9	6	5	24
	COD	91	23	13	20	14	9	47

Since the biodegradability index values are moderate to high (minimum 0.32, maximum 0.78) in the different measurements over a year (Table 6). It could be concluded that water contains a significant amount of biodegradable organic matter. In addition, there are seasonal variations that should be taken into account in the implementation of wastewater treatment. At the sampling point P1, April 2023 and August 2023 stand out as the periods with the greatest influence on the biodegradability index, with values of 0.71 and 0.64, respectively (Table 6 and Figure 2). At the sampling point P2, the months of February 2023 and April 2023 show a higher biodegradability with indexes of 0.60, while June and August 2023 show lower indexes around 0.41. On the other hand, the sampling point P3 shows significant variations with a maximum in June 2023 with a biodegradability index of 0.61 and a minimum in February 2023 of 0.44. At the sampling point P4, December 2022 stands out with an index of 0.78, showing high biodegradability compared to June 2023, which shows an index of 0.43. These differences highlight the importance of taking into account seasonal variations when evaluating the capacity of wastewater to biodegrade organic matter, which is crucial for effective water resource management and environmental protection.

Over the one-year period, the total biodegradability indexes (BOD5/COD) were 0.48, 0.50, 0.52, and 0.57 for P1, P2, P3, and P4 sampling points, respectively (Table 7). The sampling point P1 has the lowest index with 0.48, which indicates that approximately 48% of the COD load at this point is biodegradable. This suggests a significant presence of non-biodegradable organic matter or complex chemical compounds that require more specific treatment methods for their effective removal. On the other hand, the sampling point P2 has an index of 0.50, which indicates a similar proportion of biodegradable organic matter compared to P1, but with a slight improvement in biodegradability. As for P3, a biodegradability index of 0.52 was recorded, indicating a moderately high level of biodegradable organic matter in relation to the total COD load. This could be due to the environmental conditions and the composition of the pollutants, which favor greater degradation by the microorganisms present in the water. Finally, the sampling point P4 has the highest index at 0.57, indicating that approximately 57% of the COD load at this sampling point is biodegradable. This could indicate a simpler pollutant composition or a lower total organic load, which is favorable from a water quality perspective.

Figure 2.

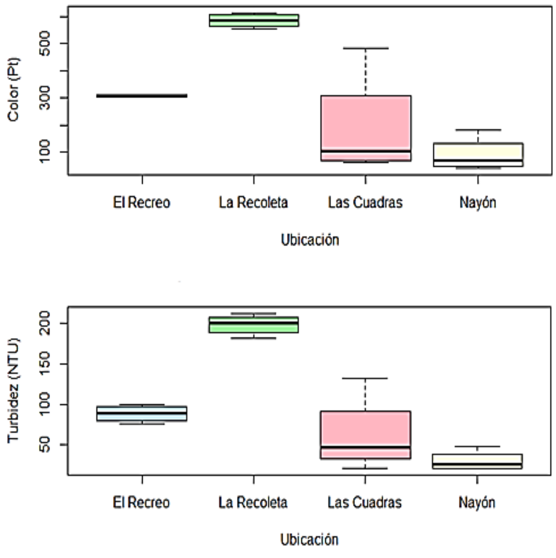
Temporal variation of the biodegradability index (DBO5/DQO) at the sampling points over a one-year period



The results obtained for the biodegradability index (BOD5/DQO) for the different wastewater sampling points classify the water as fairly biodegradable, with values ranging from 0.48 to 0.57 (Table 7). This biodegradability is related to the presence of mixed discharges with a significant proportion of biodegradable organic matter. At sampling points such as P2, P3, and P4 could be considered that there is a tendency towards organic matter. In relation to the recommended treatment, the analyses indicate that the evaluated wastewater requires mainly a biological treatment approach to effectively reduce the organic load. Effective treatment of this water resource is likely to include aerobic biological processes, such as biological oxidation, to break down biodegradable organic matter to reduce COD levels. In addition, initial physicochemical treatment may be required to adjust pH, remove suspended solids, and other contaminants that could interfere with biological processes.

In addition, during the development of this research, color and turbidity were measured in situ at the four sampling points and analysis of variance (ANOVA) was applied as described below:

Figure 3.
Sampling location-related relationship between color and turbidity.



From the information obtained in Figure 3, it was determined that there are significant differences in the color and turbidity measurements taken in the water of the Machángara river with respect to the sampling locations. Therefore, there is a greater variation in water quality for points P2, and P3 with respect to the rest of the sampling points in the river.

Finally, this study also aims to be a contribution to the study of the biodegradability index in the rivers of Ecuador. In this regard, there are already some contributions in this regard, as can be seen in a study carried out by Molina [27], on the quality of water in a sector of the city of Manta. The results obtained by calculating the biodegradability index indicate that the levels of contamination are high, falling within the range of high biodegradability of organic matter, as indicated by other similar studies.

4. CONCLUSIONS

Through the physicochemical analysis of the water of the Machángara river, data on biochemical, and chemical oxygen demand were obtained from October 2022 to October 2023. The biodegradability index was determined with these values, to establish, as a recommendation in this research, the application of a biological treatment to reduce the organic load, which can be accompanied by a chemical treatment to avoid interference from suspended solids and other impurities present in the water.

Likewise, this tributary was characterized as fairly biodegradable with the presence of mixed discharges containing organic and inorganic pollutants coming mainly from the anthropogenic activities developed in the study area. The presence of illegal pipes coming from homes and industries that discharge directly into the river. In addition, by measuring in situ parameters such as color and turbidity in the water coming from the Machángara river. It was concluded that in the point P2 and P3, there are high levels of contamination that significantly affect water quality, while in the point P1 and P4, there are moderate levels. Urgent interventions, alongside stronger public awareness efforts, are essential to restore water quality and mitigate the river's environmental and public health impacts.

On the other hand, we must point out that there are various types of biological treatments that can be carried out in these cases, taking into consideration many aspects, among which may be, depending on the type of contaminant and the medium to be treated. Among the most common are aerobic biological treatment and anaerobic biological treatment. Aerobic biological treatment, this process is mainly used for the treatment of urban and industrial wastewater, where microorganisms decompose organic matter in the presence of oxygen. While anaerobic biological treatment is used in the treatment of wastewater from the food and agricultural industry, where microorganisms decompose organic matter in the absence of oxygen, generating biogas as a byproduct.

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ANNEXES

Table 6.
Biodegradability index calculated for each sampling point over a one-year period (2022-2023).

	Study period						
Biodegradability index (BOD5/ COD)	Oct. 2022	Dec. 2022	Feb. 2023	Apr. 2023	Jun. 2023	Aug. 2023	Oct. 2023
Las Cuadras	0,41	0,32	0,33	0,71	0,34	0,64	0,61
El Recreo	0,48	0,54	0,60	0,60	0,41	0,41	0,49
La Recoleta	0,50	0,48	0,44	0,57	0,61	0,50	0,54
Nayon	0,73	0,78	0,54	0,45	0,43	0,56	0,51

Table 7.
Type of discharge, biodegradability of the water and recommended treatment according to the ratio.

	Biodegradability index (BOD5/COD)	Type of discharge	Water biodegradability	Recommended treatment
Las Cuadras	0.48	Mixed	Fairly biodegradable water	Biological
El Recreo	0.50	Mixed	Fairly biodegradable water	Biological
La Recoleta	0.52	Mixed	Fairly biodegradable water	Biological
Nayon	0.57	Mixed	Fairly biodegradable water	Biological