A Water Quality Analysis of the Pasig River in Manila City, Philippines

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A Water Quality Analysis of the Pasig River in Manila City, Philippines

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Abstract: *The Pasig River in Metro Manila, Philippines, has been considered "biologically dead" for decades, as its waters do not support most kinds of life due to its waste content. It is considered one of the most polluted rivers globally, with rehabilitation efforts being largely unsuccessful. This study assesses the current state of the river's water quality by testing three river samples, all from Manila City. The results showed that the water near a glass packaging factory had the highest concentration of almost all water quality indicators in the study's scope, suggesting that industrial waste is one of the river's most significant pollutants. There were also high levels of fecal coliform in the samples, averaging 5.27 × 10^5 MPN/100mL, while oil/grease concentrations were consistently present in all the samples. These findings highlight the importance of proper waste disposal, especially in industrial areas, as well as proper wastewater treatment.*

Keywords: Pasig River; biologically dead river; water quality; water quality analysis

1. INTRODUCTION

The Philippines has a reputation for being heavily polluted (i.e., air, waste, and water) [1], which is especially abundant in Manila, the capital city of the country. A prime example of how pollution affects the Philippines can be seen in the Pasig River, which runs through the National Capital Region (NCR) of the Philippines. It is one of the most well-known waterways of the Philippines and has historical significance in the Philippine context, once being a major transportation route, as well as a prime spot for fishing and bathing [2,3]. However, its quality began to deteriorate in the 20th century. Consequently, in 1990, it was deemed "biologically dead" due to the rapid urbanization in the area severely degrading its water quality [1,4]. Decades have passed, and it is still "dead," with its condition only worsening as time progresses. In 2022, the river made it onto a list of the top 10 most polluted rivers worldwide, placing eighth [5]. A study in 2021 stated that the river topped the list of polluting rivers in the world, as it contributes around 63,000 tons of plastic waste per year to the Earth's oceans [2,6].

There are many pollutants that contribute to what is occasionally referred to as Manila's "toilet bowl" [2], such as but not limited to:

- Wastewater from sewage systems
- Waste, both industrial and domestic
- Solid waste / garbage
- Microplastics

These pollutants affect not just the river's waters, but also its connected waterways. Water pollution has a large impact on human health; a study by Lin et al. [7] stated that it is "the cause of many human diseases such as diarrhoea, skin diseases, cancer and various childhood diseases". Individuals are put at risk of such diseases when contamination occurs, or when they come into direct contact with the river water. Additionally, the solid waste pollution can clog waterways and causes floods [8], which put people in danger during instances of intense rainfall. On the other hand, biodiversity no longer thrives in the river, with janitor fish and water hyacinth being the sole survivors of the river's murky waters [2].

Government and non-governmental initiatives have hoped to remedy this problem. Examples include the International Container Terminal Services (ICTSI) Foundation, which aims to recycle waste that goes into the river [9], the Pasig River Rehabilitation Program (PRRP), and the Pasig River Rehabilitation Commission (PRRC), which was more successful until its dissolution in 2019 [8, 10],. It can be said that there is little support from the general public towards projects formed to restore the river; as a result, efforts to rehabilitate the Pasig River end up being generally unsuccessful [8].

When the current state of the Pasig River is discussed, knowledge of its biochemical state is necessary. This study aims to add to that discussion by analyzing some known pollutants that are found in the waters of the Pasig River using data obtained from analyzing samples of the river, as well as some related literature to help strengthen the claims of this paper. Analyses such as those present in this study could help future researchers who may be interested in pursuing a related topic or restoration efforts, whether biochemical or not.

This paper, however, is limited to only three particular sampling points near the mouth of the river in Manila; thus, it cannot ascertain the water quality in all areas of the river. Additionally, the samples were tested to check for the following 5 water contaminants, namely: thermotolerant (fecal) coliform, biochemical oxygen demand, lead, cadmium, and oil and grease.

2. METHODOLOGY

This study uses a predominantly quantitative approach to study some of the pollutants that can be found in the waters of the Pasig River. In Fig. 1 (see below), an overview of the methodology is shown.

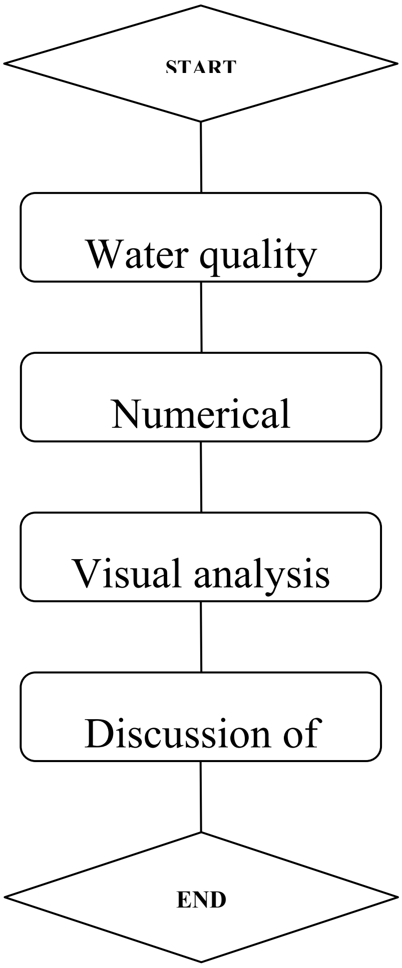

Fig. 1. Flowchart summarizing the methodology.

The methodology has four key steps that will be taken to complete this study. To start, water quality testing will be done on samples of the Pasig River. Next, a simple numerical analysis of the data gathered from the test will be done; visual analysis will be done next in order to make it easier for readers to process the data. Lastly, there will be a "discussion of data" step wherein the findings of the study will be discussed. The methodology will then end. A more detailed description of the process is listed below.

2.1 Water quality testing


Fig. 2. Map showing the data collection points.

Water quality testing will be done at three different points in the Pasig River, all located within Manila City in the NCR, Philippines. Referring to Fig. 2, the following points are around the:

1. Glass packaging factory in Barangay 275 of Manila City (denoted by yellow dot)
2. Residential area in Barangay 275 of Manila City (denoted by blue dot)
3. Port area in Barangay 20 of Manila City (denoted by red dot)

Two four-liter samples are collected from each point, totaling eight liters of water per point. The samples were then sent to a water testing laboratory in Quezon City, Philippines (Aqua Lab Center). The laboratory tested the samples to determine their concentrations of the following water quality indicators:

- Thermotolerant (fecal) coliform
- Biochemical oxygen demand (BOD)
- Lead
- Cadmium
- Oil and grease

Once the results have been delivered to the researchers, the next steps may be undertaken to complete the study.

2.2 Numerical analysis

The data collected from the samples will be analyzed to bring more quantitative insight into the river's quality at the different sample points. The raw data will be presented, alongside its mean ($\bar{x}$) and standard deviation (s). The latter two shall be computed by

$$\underline{x} = mean = \frac{\sum x_i}{n}$$

$$s = standard\ deviation = \sqrt{\frac{\sum (x_i - \underline{x})^2}{n-1}}$$

and rounded off to the rules of significant figures to maintain precision.

The results for fecal coliform will be presented in the unit of MPN/100mL, which is the most probable number (MPN) of pollutant per 100 mL of sample. On the other hand, the results for the rest of the water quality indicators will be presented in the unit of mg/L - milligrams per liter.

2.3 Visual analysis

In addition to the numerical analysis, the data will be visualized to show the results aesthetically. Quantum Geographic Information System (QGIS) models will illustrate the pollutant concentration per sample point. On the other hand, bar graphs (constructed on Google Sheets) will be used to effectively show the correlation and comparison between the different concentrations.

2.4 Discussion of data

The numbers extracted from the data shall be analyzed and discussed alongside the analyses mentioned above to gain more insight into the pollutants of the waters in the Pasig River. The discussion will also be strengthened with related literature.

3. RESULTS AND DISCUSSIONS

The samples were obtained on the morning of January 25, 2025, and sent to Aqua Lab Center for water quality testing on the same day. The photo of the samples is shown in Fig. 3.


Fig. 3. All collected samples before being sent to the laboratory for testing. The first two (from the left) are

the samples from the area near the glass packaging factory, the middle two are the samples from the residential area, and the last two (on the right) are the samples from the port area.

The water quality laboratory results for the thermotolerant (fecal) coliform, biochemical oxygen demand, lead, cadmium, and oil and grease are presented in Tables 1 to 5, respectively. The results reveal the following concentrations of pollutants in the Pasig River's water. *(Note that the yellow point refers to the glass packaging factory, the blue point refers to the residential area, and the red point refers to the port area.)*

3.1 Results for thermotolerant (fecal) coliform

Table 1. Fecal coliform concentrations

Point	Amount (MPN/100mL)
Yellow	1.1×10^6
Blue	2.4×10^5
Red	2.4×10^5
Mean	5.27×10^5
Standard dev	4.97×10^5

Table 1 shows the results of the water quality test for thermotolerant coliform, better known as fecal coliform, which was conducted on the same day the samples were acquired, January 25, 2025.

The area in front of the glass factory had the highest amount of fecal coliform at 1.1×10^6 MPN/100mL, while the sites around the residential and port area had very similar results, with both being 2.4×10^5 MPN/100mL. Consequently, the mean was 5.27×10^5 MPN/100mL, and the standard deviation was very large, at 4.97×10^5.

The data visualized in QGIS and bar chart form are shown in Fig. 4 and Fig. 5, respectively.

Fig. 4. QGIS map of the amount of fecal coliform in the three sample points. The lighter the shade of brown, the fecal coliform there is in that area.

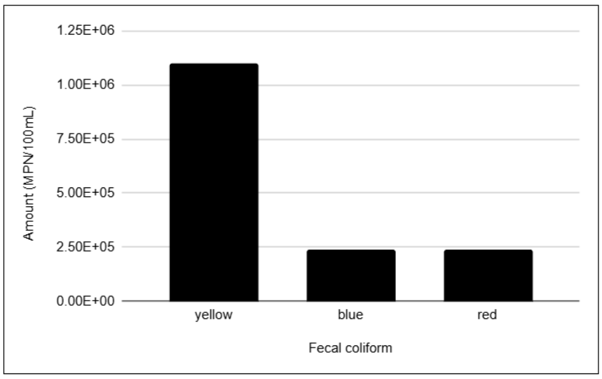

Fig. 5. Bar graph illustrating the amount of fecal coliform in the three sample points

3.2 Results for biochemical oxygen demand (BOD)

Table 2. BOD concentrations

Point	Amount (mg/L)
Yellow	11.0
Blue	1.60
Red	8.26
Mean	6.95
Standard dev	4.83

Table 2 shows the results of the water quality test for biochemical oxygen demand (BOD), which was conducted from January 27, 2025, up until February 17, 2025.

Similar to the amount of fecal coliform, the area in front of the glass factory had the highest amount of BOD at 11.0 mg/L. On the other hand, the site by the port area had the second greatest amount of BOD, at 8.26 mg/L; and the site near the residential area had the least amount of BOD, significantly lower than the other two sites, at 1.60 mg/L. Consequently, the mean was 6.95 mg/L, and the standard deviation, at 4.83, was a lot larger than that of the fecal coliform.

The data visualized in QGIS and bar chart form are shown in Fig. 6 and Fig. 7, respectively.

Fig. 6. QGIS map of the amount of BOD in the three sample points. The lighter the shade of green, the less BOD there is in that area.

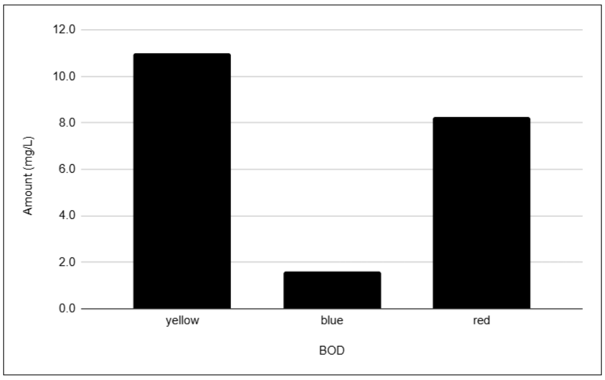

Fig. 7. Bar graph illustrating the amount of BOD in the three sample points

3.3 Results for lead

Table 3. Lead concentrations

Point	Amount (mg/L)
Yellow	0.185
Blue	0.129
Red	0.010
Mean	0.108
Standard dev	0.089

Table 3 shows the results of the water quality test for lead, which was conducted from January 27, 2025, up until February 11, 2025.

Generally, based on the results, there is not a lot of lead found around the areas. Yet still, the area in front of the factory had the highest amount of lead at 0.185 mg/L. The site near the port area had the lowest amount at 0.010 mg/L. On the other hand, the sample from the site near the residential area had 0.108 mg/L. Consequently, the mean of the data is 0.108 mg/L, and the standard deviation is small at 0.089.

The data visualized in QGIS and bar chart form are shown in Fig. 8 and Fig. 9, respectively.


Fig. 8. QGIS map of the amount of lead in the three sample points. The lighter the shade of gray, the less lead there is in that area.

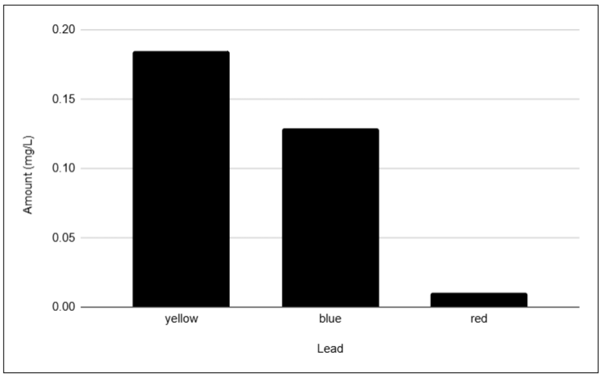

Fig. 9. Bar graph illustrating the amount of lead in the three sample points

3.4 Results for cadmium

Table 4. Cadmium concentrations

Point	Amount (mg/L)
Yellow	<0.001
Blue	<0.001
Red	<0.001
Mean	<0.001
Standard dev	Unknown; cannot be determined

Table 4 shows the results of the water quality test for cadmium, which was conducted from January 27, 2025, up until February 11, 2025.

As per the documents given to the researchers containing the results of the water quality test, the amount of cadmium in all three sites is less than 0.001 mg/L, suggesting that the amount of cadmium in all three sample points fall below the detection limit of the laboratory, and there is very little cadmium to be found. Specific concentration values of cadmium were not given as they are below the detection limit. The mean and standard deviation could not be determined as the exact amount of cadmium in each sample is unknown.

The data, visualized in a QGIS map, is shown in Fig. 10.


Fig. 10. QGIS map of the amount of cadmium in the three sample points. No gradients can be seen in this map, as the exact amounts of cadmium are unknown.

3.5 Results for oil and grease

Table 5. Oil and grease concentrations

Point	Amount (mg/L)
Yellow	1.33
Blue	1.56
Red	1.22
Mean	1.37
Standard dev	0.174

Table 5 shows the results of the water quality test for oil and grease, which was conducted from January 27, 2025, up until February 11, 2025.

The sector of oil and grease is the only sector determined not to have its highest concentration in the area near the glass packaging factory. Instead, the site near the residential area has the highest amount of oil and grease at 1.56 mg/L. The area in front of the factory had 1.33 mg/L, and lastly, the site near the port area had the lowest amount of oil and grease at 1.22 mg/L. Consequently, the mean was 1.37 mg/L, while the standard deviation was small at 0.174.

The data visualized in QGIS and bar chart form are shown in Fig. 11 and Fig. 12, respectively.


Fig. 11. QGIS map of the amount of oil and grease in the three sample points. The lighter the shade of orange, the less oil and grease there is in that area.

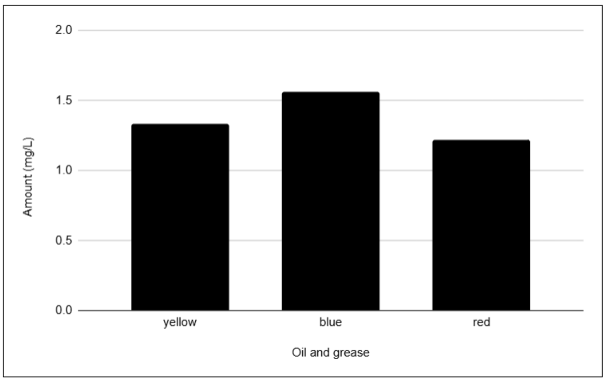

Fig. 12. Bar graph illustrating the amount of oil and grease in the three sample points

3.6 Data analysis

There are many things that we can conclude or at least infer from the given data. For instance, it can be seen that there is a large abundance of fecal coliform at all three points, with a mean of 5.27×10^5. Fecal coliform is known to cause illness in humans and animals, which range from mild to severe [11,12]. This is an unsurprising result, given that sewage systems in the Philippines are heavily lacking, with only 10% of wastewater treated, 58% of groundwater contaminated, and 5% of the total population connected to a sewer network, while most citizens use toilets that lead to septic tanks; as a result, around 2 million cubic meters of wastewater is generated every day in Metro Manila [13]. Direct discharge of feces may also contribute to the fecal coliform concentration in the river's waters.

Meanwhile, concentrations of lead and cadmium are very low, suggesting that these chemicals, known to leave individuals vulnerable to heavy metal poisoning [14], are handled and disposed of properly in those areas. On the other hand, as seen in Fig. 12, the concentrations of oil and grease (1.22 mg/L, 1.33 mg/L, 1.56 mg/L) are quite similar in all three points, suggesting that they are common pollutants of the river's waters.

The yellow point (near the glass packaging factory) has the highest concentration of all but two pollutants that the samples were tested for. It cannot be determined if it also has the highest concentration of cadmium amongst the three points because of the vague data given, and this area had the second highest concentration of oil and grease. Naturally, because there is a factory nearby, there will be more pollutants (i.e., industrial waste) in this area. Industrial waste encapsulates metals, lumber, oils, chemicals, dirt, concrete, and many others [15], and is one of the leading river pollutants [16]. There may be an abundance of glass waste in the area, which can pose high risks to bodies of water, especially when mixed with other materials such as plastic [17]; they are especially harmful in the form of nanoparticles, as they may enter food chains and subsequently hurt the organisms in the water [18,19]. It is possible that industrial wastes from the factory spread easily to its surroundings, including the section of the river near it, because of improper waste disposal procedures.

On the other hand, the blue point (near the residential area) had the highest concentration of oil and grease. This is presumably an effect of kitchen waste from the houses in the area, as oil is a common kitchen staple. However, as aforementioned, the levels of oil and grease were similar for all points, with the yellow and red points not too far behind in terms of concentration. After all, oil is also common in factories as a fuel [20] and lubricant, and in port areas, also as fuel and a transported good.

Lastly, the red point (near the port area) had the lowest concentration in most of the tests, implying that some issues affecting the other two points have a slightly less impact on this area. Due to the vague data for cadmium, it cannot be confirmed if it also has the lowest concentration there; on the other hand, it had the second-highest concentration of BOD, 8.26 mg/L, as compared to the blue point that had 1.60 mg/L. Organic pollution may be rampant in the port area due to the organisms found in various activities related to the port.

4. CONCLUSION AND RECOMMENDATIONS

Utilizing water quality testing techniques, this paper examined the water quality at three points of the Pasig River. A simple numerical and visual analysis was then undertaken. While the river spans across multiple municipalities in Metro Manila, all three sample points were located in Manila City, meaning that the data this study offers may not apply to all points of the Pasig River.

This study concludes that the data processed reflects the current state of the Pasig River: filled with bacteria and chemicals that pollute its waters. This could also be seen as a reflection of poor waste and wastewater management practices that frequently occur in the Philippines, which are large driving factors of the heavy pollution in the country as a whole. Changing the way that these practices are done will not just help the current state of the Pasig River's waterways, but also that of the Philippines' environment and surroundings as a whole.

Considering that the area near the glass packaging factory turned out to be the most abundant in most pollutants, it may need the most improvement out of the three sample points, especially considering that industrial waste is one of the biggest pollutants of the river. It is recommended that the glass packaging factory, as well as other factories, recheck their disposal measures and ensure that their waste will be contained properly. They may also find new uses for wastes; for instance, waste stone powder, which is present in some industrial plants, could be used as an additive to alluvial soil to stabilize it; stabilizing alluvial soil makes it usable for construction purposes [23].

Fecal coliform, which was found to have very high amounts per 100 mL of sample water, can be reduced by improving the sewage system in the Philippines and ensuring that piped sewerage systems are more accessible; this can help avoid the use of septic tanks. Offering restroom services could also aid in reducing the amount of coliform that ends up in the water (via feces).

On the other hand, oil and grease, whose concentration was similar across all three sample points, can be reduced by reusing oil when possible and disposing of waste oils properly in appropriate containers to prevent leakage and contamination [21,22].

As for the Pasig River itself, there are many ways to exert effort in helping the rehabilitation efforts of its waters. Filtration measures or dams, which have a long service life as long as they are stable and properly maintained [24], can be placed in order to prevent the spread of pollutants. Solutions can be engineered into life, including chemical treatments that will aid in disinfecting the water, and appropriate urban planning in the areas surrounding the river (e.g., green space models) that would encourage cleanliness and eco-friendliness. Such green spaces could even be designed to be safer from the risk of floods when we use applications such as machine modeling to estimate ground elevation from borehole information, which is made possible with regression models [25]. Awareness campaigns on the Pasig River's state and how it affects our community could also be started in order to encourage more funding and support from the general public when it comes to the restoration efforts.

When such actions like those mentioned above are taken, regular monitoring and accountability of such measures should also be implemented; this way, the effort will constantly strive to improve the river instead of being a short-lived effort. After all, by exerting these efforts, we are not just helping the water quality of the Pasig River improve. We are restoring a place that has a lot of historical significance to the Philippines while also improving public health, especially for those living near the area, and the biodiversity that once thrived there long ago.

Should future researchers be interested in pursuing a similar topic, it would be recommended that they focus on other areas of the river that were not covered in this paper. As there are surely many other chemicals and bacteria residing in the river's waters, other pollutants besides the ones included in the scope of this research may also be tested on and analyzed.

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