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***RESEARCH ARTICLE***

# WATER QUALITY ASSESSMENT OF ANTIAO RIVER IN SAMAR, PHILIPPINES

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**ABSTRACT**

The study was carried out to assess and provide a baseline data on the water quality of Antiao River in Samar, Philippines. Samples were collected in the upstream, midstream and downstream sections of the river. Based on the results obtained from the samples, the mean average of pH in upstream is 5.29 level while the downstream section showed higher acidity which gives 2.57 both surface and bottom of the water column. On the other hand, dissolved oxygen found to have 4.3 and 4.1 mg $L^{-1}$ concentration at the upstream and decreases to 3.2 and 3.0 mg $L^{-1}$ downstream. Water temperature also increases from 26.2 $^0$C in the midstream to 28.5 $^0$C at the downstream. Salinization were observed from the midstream to downstream with an average salinity concentration of 29.3 g $L^{-1}$ to 30.3 g $L^{-1}$ respectively. Furthermore, Biochemical oxygen demand (BOD) conformed with the water quality standard. Likewise, microbial counts in most probable number (MPN) in both surface water columns of the midstream and downstream portions to 160,000 MPN/100mL higher than the usual 5,000 MPN/100mL standard. *Escherichia coli* with highest concentration at downstream of 92,000 MPN. Arsenic (As) was detected at 0.60 mg $L^{-1}$ to 0.656 mg $L^{-1}$ which is higher to the standard level while Lead (Pb) and Cadmium (Cd) are within the standards. Based on the results, the water quality of the river exceeded by the Department of Environmental and Natural Resources – Environmental Management Bureau (DENR – EMB) standards for Class C water bodies.

**KEYWORDS**

Antiao river, heavy metals, microbiological, river pollution, Samar Philippines, water quality

## 1. INTRODUCTION

River water is an important natural resource and an important component of economy. Communities tend to live near a river mainly because of the availability of fresh water for daily use, and to irrigate their land for agriculture. Aside from providing habitat for fish and wildlife, it also serves as channel for transport especially because of the wide and deep waters. However, due to increasing urbanization, water river quality often compromised. Most river systems suffer from anthropogenic activities and are impacted by both natural and anthropogenic causes (Häder et al., 2020; Khatri and Tyagi, 2015). Hence, there is a need to monitor surface waters to detect the status and trends in water quality, and to identify whether observed trends arise from natural or anthropogenic causes (Rode and Suhr, 2007).

Water quality alteration constitutes a major environmental impact of many water uses and water development activities. The most obvious source of quality alteration resulting from water use is the discharge of municipal, agricultural and industrial wastewater. There are also residents living along the river banks and coastal areas. Some have no sanitary toilets and directly dispose their wastes to the water body which affects the water quality. Wastewater coming from all these sources contributes to the increased of Biochemical Oxygen Demand (BOD) load constituting water pollution. According to Salla and Gosh (2014), about 75.0% of surface water are contaminated by certain pollutants. In a recent study conducted out of 77.24 tons of waste generated daily, 26.06 tons are discharged in the waterways and some are directly to the river (Moya, 2013). Due to lack of sufficient and effective sewage treatment, sanitary facilities, improper solid wastes disposal, the river became a polluted water body.

In the Philippines, the Republic Act (R.A.) No. 9003 also known as Ecological Solid Waste Management Act of 2000 mandates the proper segregation and collection of solid waste at the community specifically for biodegradable, compostable and reusable wastes. Similarly, R.A. No. 9275 also known as the Philippine Clean Water Act of 2004 was promulgated to protect the country's water bodies against pollution from land-based sources. The R.A. no. 9275 also prohibits discharging or depositing any pollutant to water bodies. There are intensive drives conducted by the local and national agencies to clean up the river system. However, the efforts of the government to maintain the quality of the river and its tributary creeks and canals are not effective because of the lack of participation of some residents and other commercial establishments.

Antiao River in Catbalogan City, Samar, Philippines is one of the existing bodies of water that is a typical ecosystem disturbed by anthropogenic activities. The 4.0-km stretch of the river was classified as alluvial in midstream and downstream while the upstream section is bedrock type which is composed of sandstone and limestone formation (Orale, 2015). Soil erosion in the upstream is severe and is mostly caused by surface runoff during heavy precipitation which are deposited into the entire riverbed. Currently, there are no specific studies conducted on the floras and faunas of the river water.

The river is still an unclassified water body due to lack of data on water characteristics that will support for classification by the DENR-EMB. Therefore, there are no specific standards on water usage and beneficial purposes of the river. However, for the purpose of the study, it is presumed

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to be classified as Class C, the lowest level of water classification which is intended for navigation, agriculture, irrigation, livestock watering, and industrial water supply for class II of DENR Administrative Order (DAO) 34 series of 1990.

In determining water quality of an aquatic ecosystem such as rivers and lakes, parameters that are frequently sampled or monitored include temperature, dissolved oxygen (DO), pH, electrical conductivity, and turbidity. For water monitoring, measurements may include biological and microbiological parameters such as total algae, total coliform; or chemical parameters such as total hardness (TH) and calcium hardness (Ca-H), chemical oxygen demand (COD), biochemical oxygen demand (BOD), sulphate, nitrate and chloride levels. Some heavy metals like Iron, Zinc, Cadmium, Mercury, Nickel and Chromium are also analyzed from samples taken from the study sites (Gorde and Jadhav, 2013; Alam, Islam, Muyen, Mamun and Islam, 2007).

Currently, there are no sufficient information on regular monitoring activities of Antiao River. Assessing the water quality is very important for quantifying the level of pollutants and degree of pollution. The result of this study can be used to acquire necessary information that can support in policy formulation, water usage, classification and potential rehabilitation of the river.

## 2. MATERIALS AND METHODS

### 2.1 Sampling Site

The study site is Antiao River which has a total length at about 4.08 km. The flowing water originates from the Antiao watershed which is approximately about 1,942.4 hectares with one tributary river in the east side of Barangay San Andres. The river is used for navigation and for water irrigation of crops and other agricultural plants.

Three sampling stations were assessed in the study as shown in Figure 1. This are upstream, midstream and downstream sections of the river. The criteria of the sampling points are based on geographical location of the selected villages were densely populated along the riverbank. The upstream section of the river was located along the vicinity of San Andres village at the coordinates of $11^{0}47'13.99''$ N and $124^{0}53'46.51$ E with a depth of 0.8 meter. The midstream also covered Canlapwas village at $11^{0}47'1.25''$ N and $124^{0}53'8.74''$ E at a depth of 3.5 meters. While, the downstream section with a depth of 6.5 meters was stationed along Mercedes village at $11^{0}46'48.02''$ N and $124^{0}52'47.38''$ E. Surface and bottom collection of the water column were collected to determine the vertical variations of each stations.

#### *2.1.1 Sample Collection, Handling and Preservation*

Van Dorn sampler were used to collect samples at the bottom of the water column using polyethylene bottles as sampling container. A separate container was used for heavy metals and microbiological test with designated label. For microbiological (Fecal, Total coliform and *Escherichia coli*) and BOD test, samples were stored and preserved in a cooler box with enough ice while for heavy metals (Lead, Cadmium, Arsenic) was preserved in 1.0% nitric acid ($HNO_3$, Sigma, USA) at Ph < 2.0. Samples were immediately transported to the Department of Science and Technology – Regional Standards and Testing Laboratory (DOST-RSTL) for laboratory test.

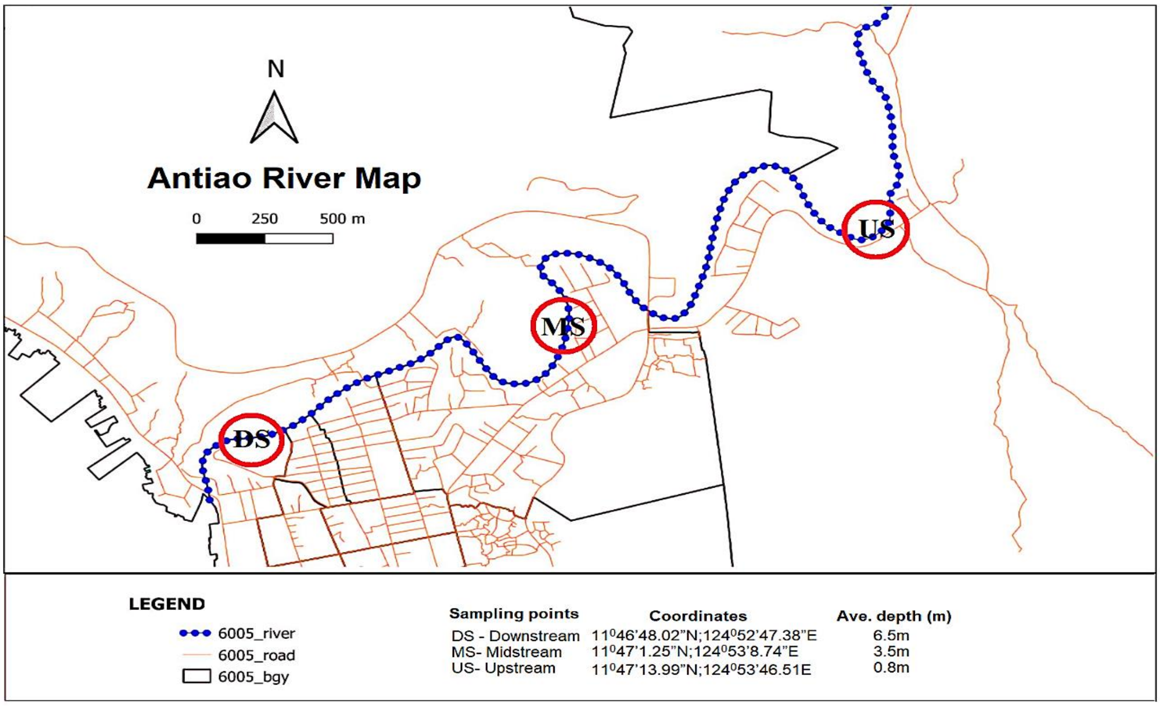


**Figure 1:** Map of Antiao river and sampling points along Catbalogan, Samar, Philippines

### 2.2 Test Method

#### *2.2.1 Physico – chemical test*

A Membrane Electrode method were employed using a calibrated multi-parameter water tester (Lutron WA-2015, Victoria, Australia) to measure the pH, dissolved oxygen (DO), and temperature while the salinity concentration was analyzed using handheld salinity refractometer (Atago, Saitama, Japan). For the BOD analysis, a 5-Day BOD test was used to determine the concentration of the samples (Baird, Eaton and Rice, 2017).

#### *2.2.2 Heavy metals*

Direct Flame Atomic Absorption Spectrophotometric method were used for Lead and Cadmium tests while Hydride Vapor Generation-Direct Flame Atomic Absorption Spectrophotometric for Total Arsenic test. All reagents and standard solutions used in the analysis are analytical grade and trace metals grade chemicals (Baird, Eaton and Rice, 2017).

#### *2.2.3 Microbiological test*

A Multiple Dilution Tube Fermentation were employed to determine the Most Probable Count (MPN) of coliform (*Escherichia coli*, Fecal and Total Coliform) present in a 100mL of sample. Resultant coding was translated by mathematical probability tables into population numbers (Baird, Eaton and Rice, 2017).

### 2.3 Statistical Analysis

The test results were summarized as mean ± standard deviation. Analysis of Variance (ANOVA) at 95% level of confidence will be used to determine significant different differences to sampling stations to its water quality. Post-hoc tests namely Fisher and Tukey were used if there were significant differences found in ANOVA.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Physico-chemical characteristics of Antiao River

The statistical summary of the selected physico-chemical parameters for determining surface and bottom water quality are presented in figure 2 which shows the trends in the measured parameters. The surface pH of the upstream is slightly acidic at 6.38 ± 0.21 on average while the bottom

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water column is slightly basic at 7.53 ± 0.34. The acidity of Antiao river increases as it proceeds downstream, reaching a surface and bottom water column pH of 2.57 ± 0.01. The results of ANOVA indicate that there is significant difference between measurements of the surface and bottom water column quality between sampling points (P = 0.00) with significantly acidic pH at the downstream compared to the midstream, and upstream.

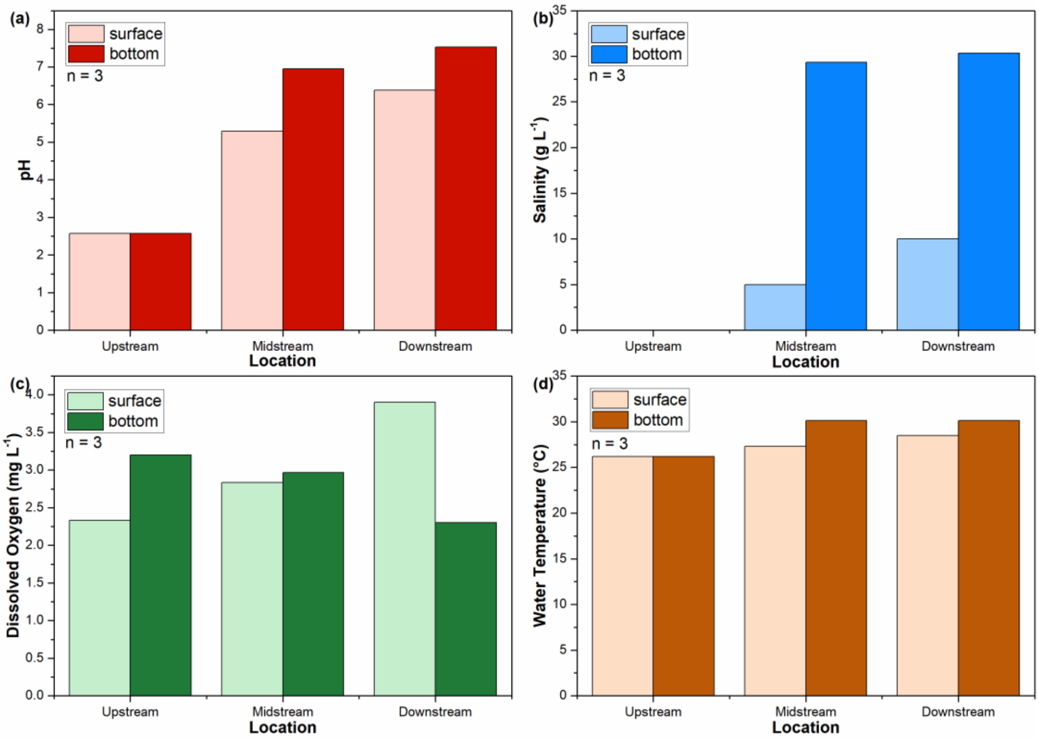


**Figure 2:** Physico-chemical characteristic of surface and bottom of the Antiao River water: (a) pH, (b) salinity, (c) dissolved oxygen, and (d) water temperature.

Salinity concentration was also analyzed in the samples to determine if there is an evident of salinization process of the river. Salinization is a natural process by depositing ionic substance by natural factors such rainfall, rock weathering, seawater intrusion and aerosol deposits (Williams, 2002). Results showed an increase from 0.0 g $L^{-1}$ in the upstream to 10.00 ± 1.00 $L^{-1}$ to 30.3 ± 0.58 $L^{-1}$ in surface and bottom water columns of the downstream respectively. Similarly, results from ANOVA indicate significant difference in the surface salinity in the upstream compared to the midstream and downstream. However, no significant difference in the bottom water column salinity between the midstream and downstream. However, both locations had significantly higher salinity than the upstream.

Dissolved oxygen (DO) is one of the most important indicators of water quality. It is a by-product from aquatic plants photosynthesis, wave and wind actions by aerating the air to the surface of the water. The surface DO in the water column increases from 2.33 ± 0.06 mg $L^{-1}$ in the upstream to 2.83 ± 0.06 mg $L^{-1}$ in the midstream and to 3.90 ± 0.35 mg $L^{-1}$ downstream. The bottom column's DO decreases from 3.20 ± 0.00 mg $L^{-1}$ in the upstream to 2.30 ± 0.17 mg $L^{-1}$ at the downstream. The ANOVA showed that there were significant differences between the location points for both the surface (P = 0.00) and bottom (P = 0.000) samples. The Fisher and Tukey Tests indicate that the downstream and midstream had no significant difference with each other, but both had significantly higher DO than the upstream.

On the other hand, the surface and bottom water column temperatures of the upstream of Antiao River are both at 26.2 ± 0.00 °C. The surface temperature then increases in the midstream towards the downstream, reaching an average of 28.5 ± 1.61 °C. The bottom water column remains constant at 30.1 ± 0.10 °C. The ANOVA showed that there was no significant difference in the surface temperature of each location (P = 0.066). However, there were significant difference in the bottom water column samples (P = 0.000) of which, the Fisher and Tukey tests indicates a higher temperature at the midstream and downstream compared to the upstream.

Healthy freshwater bodies usually have pH range of 6.5 – 8.5, water temperature at 26.0 – 30.0 °C and DO levels of 8 mg $L^{-1}$ or higher. Although, DO of at least 5 mg $L^{-1}$ can still support aquatic species (FEI, 2013; VWREC, 2019; DENR DAO 2016-08, 2016). Acidity of the river can significantly affect the established parameters by chemical, biological and physical components of the river such as the availability of nutrients like phosphorus, nitrogen and other organic and inorganic compounds. Likewise, the increase in acidity for freshwater systems are typically attributed to atmospheric deposition of nitric and sulfuric acids (Angelier, 2003) or through anthropogenic stresses (Hader and Gao, 2015). Increasing acidity can also be caused from increasing humic or organic inputs as the river travels downstream. The midstream and downstream portion of Antiao River are surrounded by several households which increases the chance of domestic and organic wastes reaching the river and therefore increases the acidity of the system. Edokpayi et al. (2017) further illustrated that low pH level can be a result of domestic discharge and water runoffs from industrial and agricultural effluents in an area. Also, according to Cebu and Orale (2017), one of the major factors in the degradation of the quality of water is due to human-induced factors such as poor solid and water waste disposal management of the residents. These human and industry-induced factors could have also led to the increased salinity of the Antiao River towards the downstream. The cause of the increase in acidity and likewise the increase in salinity and temperature are determining factors for solubility of oxygen in the river. Dissolved gases are typically affected by partial pressure, temperature, salinity, respiration and photosynthesis (FEI, 2013; Deacutis, 2015). As such, increasing temperature generally reduces the solubility of gases and hence DO reduces. A similar effect is observed with increasing salinity of the stream for samples at the downstream and is consistent with other studies (FEI, 2013; Deacutis, 2015). The uncontrolled introduction of waste particularly organic materials into the river potentially increased the decomposition rates in river which is facilitated by microbial organisms and consumes oxygen in the process. Though it is already alarming for the Antiao River to have low DO even at the upstream.

### 3.2 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand measures how much oxygen is consumed by bacteria as they break down organic pollutant in the water. It is measured by observing how much dissolved oxygen levels decreases in a sample over a 5-day period. It gives an indication of the amount organic matter in the river. A low BOD indicates good water quality while a high BOD means that the body of water is polluted (Sharma and Kansal, 2011). Unpolluted waters typically have BOD values of 2 mg $L^{-1}$ or less, while those than potentially receive organic waste and wastewater can increase BOD values to 10 mg $L^{-1}$ or more (Prandi-Rosa and Farache Filho, 2002).

Results of BOD analysis was presented in Figure 3. Based on DENR Administrative Order No. 2016-08 (2016) specifies that the standard for BOD is 3.0 mg $L^{-1}$.

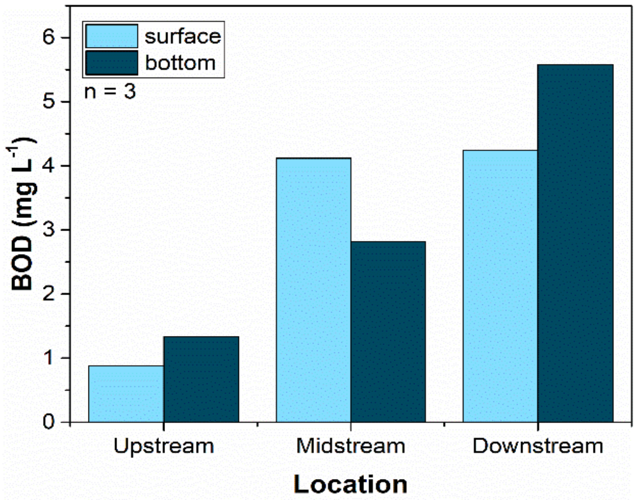


**Figure 3:** BOD results in different sections of the river.

Based on these results, BOD level in the surface and bottom column of upstream section found low concentration at 0.88 and 1.34 mg $L^{-1}$ respectively. This indicates that the water quality of the river is clean and free from pollutants. However, in the midstream and downstream section, it is found out that there is a high BOD concentration at 4.12 mg $L^{-1}$ and 4.24 mg $L^{-1}$ in the surface of midstream and downstream area while 5.58 mg $L^{-1}$ in the bottom column of downstream section. However, BOD concentrations are still below the standard limits set by the DENR-EMB. ANOVA tests show there is significant difference between the BOD of the river surface ($P = 0.00$). Fisher and Tukey tests indicate that the midstream and downstream surface BOD were significantly higher than the upstream BOD. The bottom BOD measurements were also found significant difference using ANOVA ($P = 0.00$). And that the downstream has greater bottom BOD compared to the midstream and the upstream. Higher BOD load in the water columns shows of midstream and downstream portions of the river are much more polluted. Since BOD is an indication of pollution level, this result show than there is potentially a high discharge volume of wastewater being introduced into the river. The sources of discharge are possibly coming from domestic and industrial facilities which affects the water quality of the river water. The higher BOD in the midstream and finally downstream signifies the accumulation of organic wastes towards the end of the river and are hence of higher values. This observation is common in other areas with industries and households surrounding an inland water system such as in Pasig River, Philippines (Cruz, 1997) and Meycauayan River, Philippines (Pleto, Migo and Arboleda, 2020). Industries surrounds the Pasig river are tanneries, textiles, food processing plants and distilleries while in Meycauayan river were meat and fish processing, agri-aqua crops and limestone industry.

## 3.3 Microbiological characteristics

Microbial contamination of water with pathogenic organisms could result in the transmission of waterborne diseases for people who use the water resource for domestic and other purposes (Chigor et al, 2013). The DENR – EMB water quality standards for Class C water bodies indicate that the Fecal coliform is 400 MPN/100 mL while Total coliform is 5,000 MPN/100 mL. Figure 4 illustrates the trend in microbial count as the river. The highest counts of total coliform and fecal coliform were obtained at downstream section of the river with 160,000 MPN/100 mL respectively while in the surface and bottom column in midstream has a count of 160,000 MPN/100m beyond DENR – EMB standards. *Escherichia coli* also found in all sampling points which indicates of human and animal waste discharges in the river.

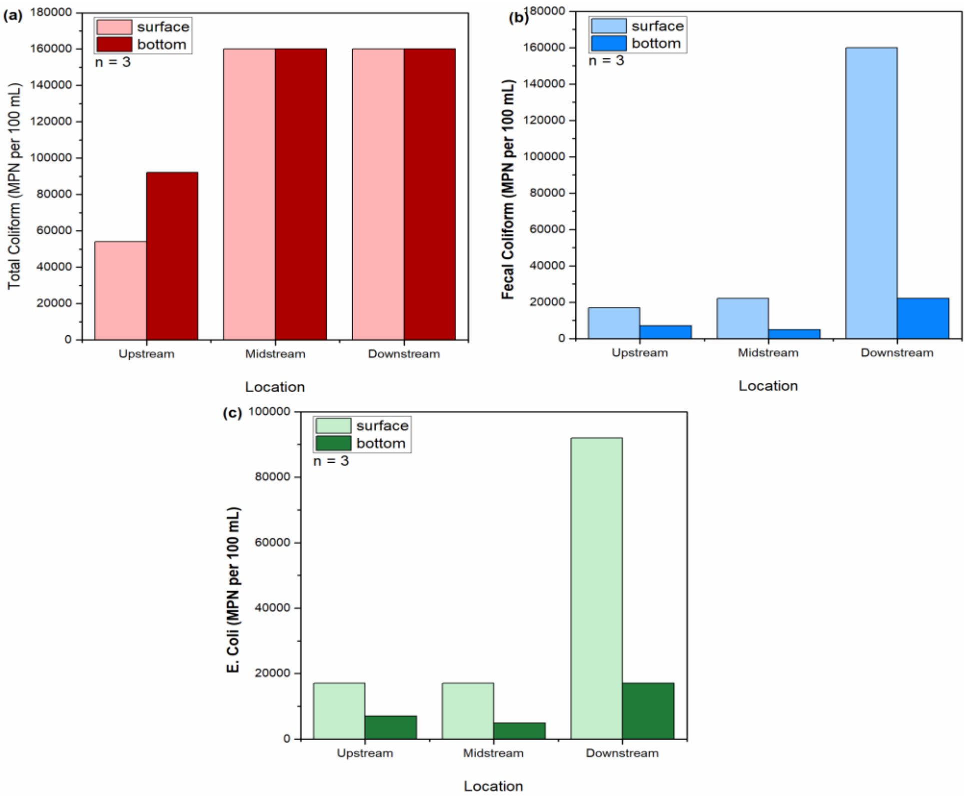


**Figure 4:** Sampling stations counts (a) Total Coliform, (b) Fecal Coliform and (c) *E. coli* in Antiao River.

The presence of pathogenic bacteria in the river water can affect post-harvest quality, not just of wild fishery resources, but also of aquaculture commodities, as the water for fish farming is also sourced from the bay and its river tributaries. The presence of pathogenic bacteria in dried fish products was supported by the study of Amascual et al. (2023), in which Staphylococcus aureus, a histamine-forming bacteria and an indicator of human pollution, was detected along the supply chain. Health of the consumers, therefore, is greatly at risk especially since people tend to consume more fishery resources because of its healthier reputation. Due to the characteristics of coliforms, they are used in detecting human and animal fecal contamination in bodies of water. The World Health Organization uses coliforms as a microbiological parameter for assessing water quality due to high occurrence of the bacteria in the feces of humans and warm-blooded animals, high counts in wastewater and polluted waters and absence from pure water and other environments which do not have any contact or intervention with humans and other animals (Ashbolt, Garrbow and Snozzi, 2001).

## 3.4 Heavy metals contamination

Heavy metals are poisonous substances than can cause damage or death to plant and animal life. These are totally non-degradable or practically speaking, indestructible, and so they accumulate in the environment. The DENR – EMB standards for Lead (Pb) is 0.05 mg $L^{-1}$, 0.05 mg $L^{-1}$ for Cadmium (Cd) and 0.01 mg $L^{-1}$ for Arsenic (As).

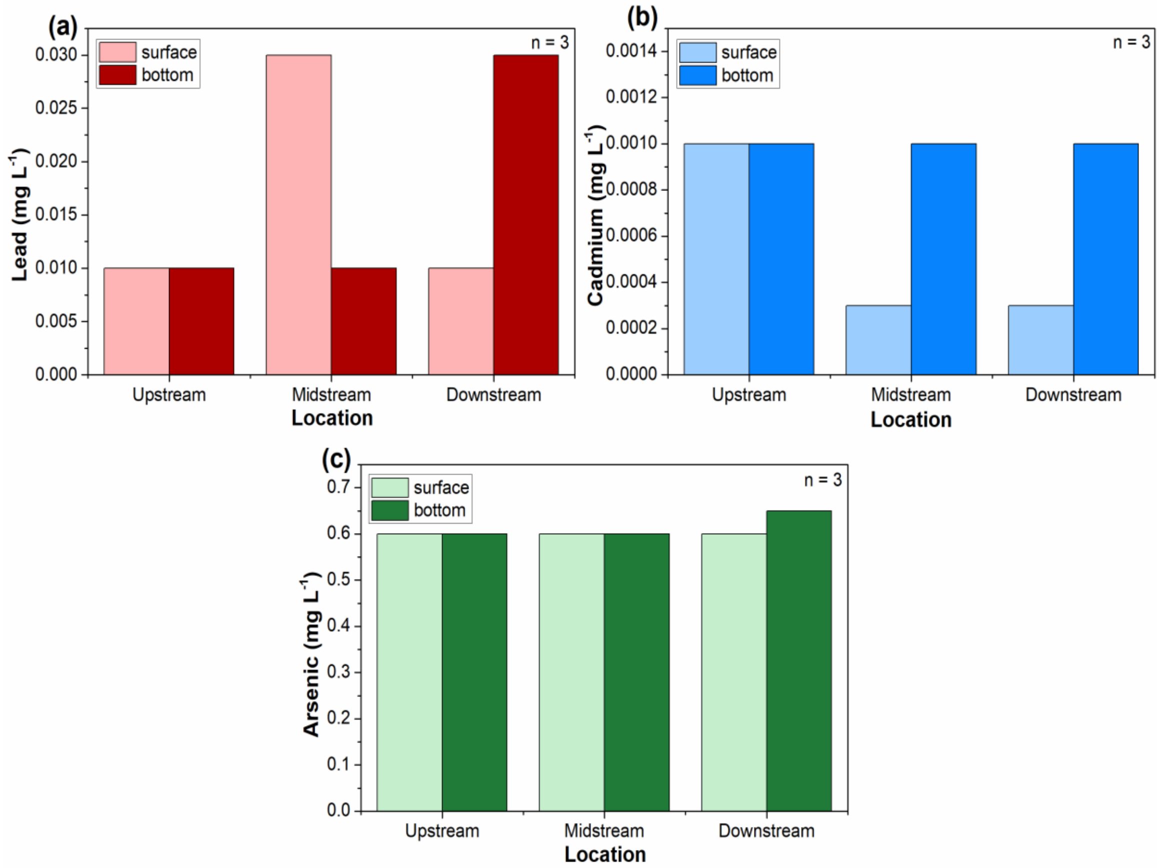


**Figure 5:** Concentrations of (a) Lead, (b) Cadmium, and (c) Arsenic in Antiao River.

Accumulation of heavy metals concentrations such as Pb, and Cd is below the DENR – EMB standards in all sections of the river except for the As which contain 0.600 mg $L^{-1}$ in surface and 0.600 to 0.656 mg $L^{-1}$ in bottom column. Arsenic (As), a naturally occurring element, is found throughout the environment. The International Agency for Research on Cancer (IARC, 2012) has classified inorganic arsenic in their Group 1 of substances that are carcinogenic to humans. Inorganic arsenic may be present in soil, either from natural mineral deposits or contamination from human activities, which may lead to dermal or ingestion exposure (Agency for Toxic Substances and Disease Registry, 2007). Heavy metal contaminates river systems through different scenarios. It can be due to point sources such industrial wastes and discharges or non-point sources such as runoff of landfills (Duncan, de Vries and Nyarko, 2018). In the study conducted by Echapare, et.a. (2019), copper metals has been traced in Maqueda Bay in Samar. These metals should be given utmost importance in measuring pollution level of Antiao River as they have relatively high toxicity, persistence and tendency to bioaccumulate in aquatic resources or biota. The heavy metals in inland water systems such as Antiao River tend to accumulate in sediments. And it there, they act as sinks and sources of contaminants in water (Aguilar et al., 2012). These Heavy metals have severe effects on the receiving environment. And because of bioaccumulation, there is potential for these toxic materials to go into in the food chain and ultimately reach human consumers (Favour and Obi, 2014).

## 4. Conclusion

Based on findings, some of the pollutants analyzed from the water samples of Antiao River exceeded by the DENR – EMB standards for Class C water bodies. The pH level showed highly acidic at downstream while slightly acidic at the midstream sections of the river. Other parameters such as water temperature, BOD and DO are below the standard level. Salinization process were observed along the midstream and upstream of the river detecting a salinity from 5.0 – 10.0 g $L^{-1}$ in surface columns while 29.3 to 30.3 in the bottom column of the river indicating that there is salt intrusion of seawater. Microbial contamination in the water system such Total Coliform, Fecal and *E. coli* were detected in all sections of the river. However, in the downstream section showed the highest coliforms and *E. coli* which indicates that there is human and animal waste discharges to the river. Inorganic Arsenic were also detected above the normal value of 0.01 mg $L^{-1}$. Primarily, inorganic arsenic is a naturally occurring element which can be found throughout the environment. However, study showed that ingestion of inorganic arsenic in humans has been associated with an increased risk of nonmelanoma skin cancer and also to an increased risk of bladder, liver, and lung cancer. The DENR - EMB has classified inorganic arsenic as a human carcinogen. Future study should also be conducted in a larger sample size and extended period of times in all seasons. Furthermore, the local government units and environmental agencies should have a sustainable long-term environmental monitoring programs for the protection and conservation of the river.

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