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Physicochemical Characterization of the Water in Pagbanganan River, Baybay City, Leyte, Philippines

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Abstract:- Pagbanganan River that traverses Baybay City, Leyte, is one of the major rivers in Leyte. The river plays a significant role in catering the necessities for all types of organism's dependent on it. This study was conducted in order to establish baseline data on the physicochemical characteristics of the water in Pagbanganan River through its pH, water temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), total hardness (as $CaCO_3$), total alkalinity, total dissolved solids (TDS), water conductivity, phosphates (as reactive phosphorous) and sulfates level and assess the quality of the water by comparing the values obtained with the standard limits set by DENR (2016) and US EPA (2005). Sampling was done on a one-month interval from August, 2016 to December, 2016 following standard method. Results revealed that the water in Pagbanganan River system had an average pH of 7.4±0.3, water temperature of 27.8±0.3°C, DO of 5.6±0.4mg/L, BOD of 2.6±1.6mg/L, TSS of 67.7±45.8mg/L, total hardness of 128.6±5.9mg/L (as $CaCO_3$), total alkalinity of 151.1±6.7mg/L, TDS of 25.6±15.2mg/L, water conductivity of 0.0195±0.0022S/m, phosphate of 0.04±0.01mg/L (as reactive phosphorous) and sulfates of 14.7±5.8mg/L. The results of water physicochemical properties in the Pagbanganan River system are within the permissible limits as compared with the standard limits set by the DENR (2016) and US EPA (2005).

Keywords:- *DENR; Environmental Monitoring; Pagbanganan River; US EPA; Water Index.*

I. INTRODUCTION

Water is distributed in nature in diverse forms, such as fresh water, rain water, spring water and mineral water. River water belongs to freshwater which constitutes only 3% of the whole water systems (Ganaoulis, 2009). Nowadays environmental contamination of river system generally comes from increasing industrialization, urbanization, agricultural modernization and proliferating human population (Gashi et al., 2010). River water is naturally a free-flowing system. Unfortunately, due to the dissolved contaminants originating from industrial infrastructure and by-products induced from farming practices which causes the free-flowing property of rivers to be defiled (Ibanez et al., 2007). If these activities continued to persist, at some point water's capability to support life will decline through time. Ensuring the ideal quality and quantity of water in river systems is extremely important to monitor water quality (Sharma, 2007).

Pagbanganan River is one of the largest river systems that crosses Baybay City, Leyte. This river provides the food source, irrigation needs, laundry area, and the receiving reservoir for the disposed wastes coming from the agricultural and household sectors. Furthermore, published data on physicochemical properties of the water in Pagbanganan River is very limited to none. Hence, this study was essentially conducted to assess the quality of the water in the river. Specifically, this study was conducted to determine the physicochemical properties of the river water in terms of conductivity,temperature, total dissolved solids, total suspended solids, total alkalinity, biochemical oxygen demand, dissolved oxygen, total hardness, pH, phosphates and sulfates; analyze the level of variation in the physicochemical quantities in the different sampling sites of the river system, and assess the quality of the water in Pagbanganan river by comparing the obtained values with the permissible limits set by the Department of Environment and Natural Resources (DENR, 2016) and the United States Environmental Protection Agency (US EPA, 2005).

Results of this study demonstrated significant features of river environments and revealed how human activities on the landscape influenced water quality in both progressive and destructive ways. The results of this study would provide the baseline information on the physicochemical properties of the water in the Pagbanganan River. This information could be made available not only for the academe, the non-government organization (NGO), the community but more importantly to the local government unit (LGU) of Baybay City and would be very helpful in the environmental mitigation plans for the protection, restoration, and conservation of this natural resources.

II. MATERIALS AND METHODS

Selection of sampling sites was established through reconnaissance survey. Three sampling points were identified representing upstream (Brgy. Ciabu), midstream (Brgy. Bubon), and downstream (Brgy. Canipa). Global Positioning System was used to measure and describe the exact coordinates and describe the topographic locations of sampling points.

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Sample containers used were one-liter acid-washed Light-Density Polyethylene (LDPE) bottles. Collection of river water samples for analyses were done at one month-interval from August, 2016 to December, 2016 from 7:00AM to 10:00AM. Representative samples of river water were obtained starting from the downstream, middle stream, and to the upper stream. Field observations were also done during sampling periods.

All physicochemical analyses were carried out following the American Public Health Association standard methods for examination of water and wastewater (APHA, 1999) in triplicates. Water temperature and pH were obtained *in-situ* using calibrated mercury-in-glass thermometers indegrees centigrade and a handheld pH meter (HANNA pHep Tester), respectively. Moreover, *ex-situ* analyses were total dissolved solids and conductivity using a multimeter instrument (Ultrameter III^{TM} 9P);total alkalinity, total hardness (as $CaCO_3$), dissolved oxygen and biochemical oxygen demand using volumetric analysis; total suspended solids using gravimetric method; while the phosphates (as reactive phosphorous) and sulfates following ascorbic acid method and turbidimetric method respectively, using UV-Visible spectrophotometer (Shimadzu UV-1800).

The study was carried out in a Complete Randomized Design (CRD). Significance and differences of physicochemical quantities between sampling sites were determined using univariate Analysis of Variance (ANOVA) and Tukey's Honesty Significance Difference (HSD) test at 5% level of significance. Water quality was evaluated by comparing the obtained values of the different physicochemical parameters with the permissible limits of DENR (2016) and US EPA (2005) standards using T-test.

III. RESULTS

Sampling Period	Sampling Site	Weather Condition	Water Depth (cm)	Water Flow Condition	Nature of River Bed	Color of the Water	Other Observations
August	Ciabu	Sunny Day	15	Fast flowing	Sandy Bottom	Clear	Residential houses near river banks
	Bubon	Sunny Day	40	Slow Flowing	Sandy/Muddy Bottom	Slightly Turbid	Presence of garbage
	Canipa	Sunny Day	32	Fast Flowing	Sandy/Pebbles Bottom	Turbid	Presence of water pump for irrigation
October	Ciabu	Slightly Raining	8	Fast flowing	Sandy Bottom	Clear	Residential houses near river banks
	Bubon	Slightly Raining	42	Slow Flowing	Sandy/Muddy Bottom	Slightly Turbid	Presence of garbage
	Canipa	Slightly Raining	40	Fast Flowing	Sandy/Pebbles Bottom	Highly Turbid	Presence of water pump for irrigation
December	Ciabu	Sunny and Windy	11	Fast flowing	Sandy Bottom	Clear	Residential houses near river banks
	Bubon	Sunny and Windy	40	Slow Flowing	Sandy/Muddy Bottom	Slightly Turbid	Presence of garbage
	Canipa	Sunny and Windy	37	Fast Flowing	Sandy/Pebbles Bottom	Slightly Turbid	Presence of water pump for irrigation

Table 1. Field observations of the sampling sites at the different sampling periods during the water sampling.

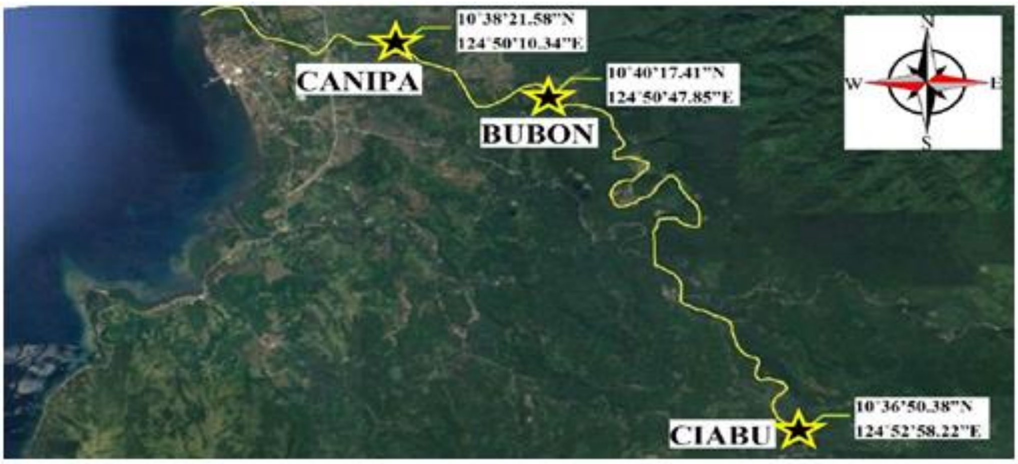

Figure 1. Sampling points in Pagbanganan River system, Baybay City, Leyte, Philippines. Source: Google Earth, 2016

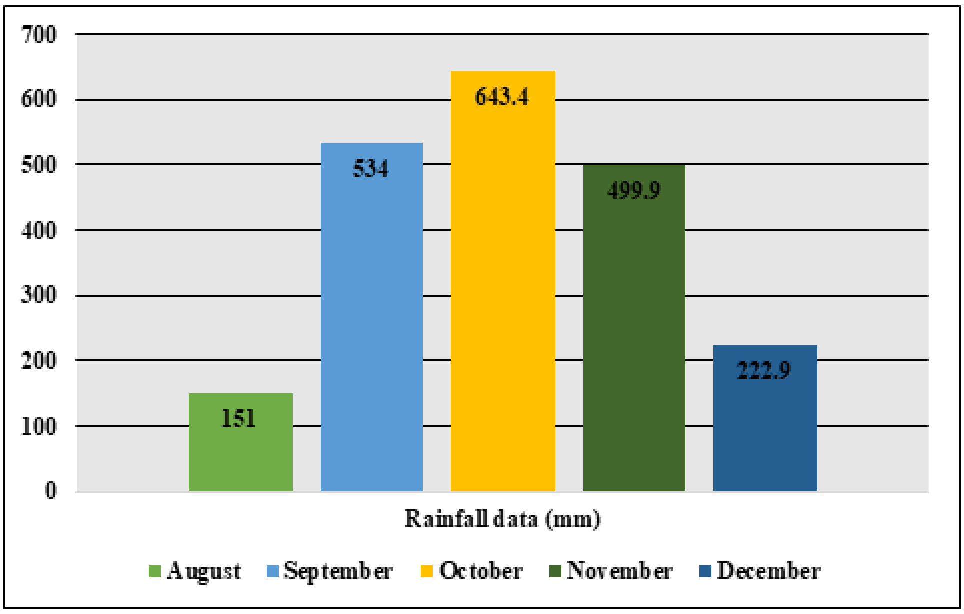

Figure 2. Rainfall data (mm) for the months of August, 2016 to December, 2016. Source: VSU PAGASA, 2016

Figure 3. Anthropogenic activities along the banks of the Pagbanganan River: A. bulldozer pushing massive rocks alongside of the river banks (Brgy. Bubon); B. backhoe moving river bedrocks (Brgy. Canipa); C. washing of motorcycle (Brgy. Bubon); D. washing of clothes (Brgy. Canipa); E. fishing (Brgy. Ciabu); F. bathing of people.

Table 2. Physicochemical parameters result of the river water between sampling sites and the standard limits of DENR (2016) and US EPA (2005).

Sampling Sites	pH	WT (°C)	DO (mg/L)	BOD (mg/L)	TSS (mg/L)	TH (mg/L)	TA (mg/L)	TDS (mg/L)	Cond (S/m)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)
Brgy. Ciabu	7.7[a]	28.0	6.0[a]	1.1[c]	20.5[c]	121.8[b]	157.8	108.1[b]	0.01692[b]	0.04[a]	9.92[c]
Brgy. Bubon	7.3[b]	27.9	5.5[ab]	4.3[a]	70.5[b]	131.6[ab]	144.5	135.0[a]	0.02092[a]	0.03[b]	12.98[b]
Brgy. Canipa	7.2[b]	27.4	5.2[b]	2.5[b]	112.0[a]	132.4[a]	151.1	133.7[a]	0.02065[a]	0.04[a]	21.23[a]
DENR (2016)	6.5 – 9.0	25 – 31	≥ 5	≤ 7	≤ 80	no data	no data	no data	no data	no data	≤ 275
US EPA (2005)	6.5 – 9.0	≤ 32	≥ 5	≤ 7	30%*	≤ 500	20 – 200	≤ 500	no data	no data	≤ 250

[1/]Averages followed with the same letter are not significantly different from each other based on the 5% level of Tukey's HSD test
*Thirty percent (30%) increase of TSS values compared from the previous data obtained

Remarks:
WT – Water Temperature
DO – Dissolved Oxygen
BOD – Biochemical Oxygen Demand
TSS – Total Suspended Solids
TH – Total Hardness (as $CaCO_3$)
TA – Total Alkalinity
TDS – Total Dissolved Solids
Cond – Conductivity
PO_4^{3-} – Phosphates (as reactive phosphorous)
SO_4^{2-} – Sulfate

IV. DISCUSSION

The location and the respective Geographical Positioning System (GPS) coordinates of the three sampling sites along the Pagbanganan River System namely; Ciabu (upstream), Bubon (midstream) and Canipa (downstream) is showed in Fig. 1. The general characteristics of the three sampling sites are shown in Table 1. Throughout the sampling periods, it was observed that the water was clear in general, except for the midstream and downstream sites. Clarity of the river water sample was determined through comparison of water sample with distilled water using visual method (APHA, 1999). The variation on river water clarity in each sampling sites may possibly be due to the heavy or thorough anthropogenic disturbance on the river bed especially at Bubon (midstream) and Canipa (downstream) sites (Fig. 3), which have a sandy, muddy and pebbly type of river bed (Table 1). In addition, the seasonal variation throughout the sampling periods may had also affected the river water clarity. As observed from the rainfall data, heavy rain had occurred during October, 2016 (643.4 mm) and December, 2016 (222.9 mm) (Fig. 2). The heavy rainfall during these periods which may had contributed significantly in the increased suspended materials in the river due to soil erosion and increased in velocity of the river flow, thus, reducing the water clarity of the Pagbanganan River.

Meanwhile, the variation on the water depth may be accounted by the different topographical location of each sampling sites. Contamination of the Pagbanganan river water was most likely to happen as evident by the presence of garbage along the river banks, residential houses, presence of water pump for irrigation (Table 1), and several human activities observed in each sampling sites. The most prominent activities observed in the river were massive quarrying, washing of clothes and motorcycle, bathing of human and animals, and even fishing (Fig. 3). All these activities in the river system posed a risk on water quality and safety.

The average pH of the river water samples collected at Brgy. Bubon (7.3) (midstream) and Brgy. Canipa (7.2) (downstream) were comparably low but significantly different from that in Brgy. Ciabu (upstream) (7.7) (Table 2). In general, pH of the river water samples decreases down the river. The observed variation in the average pH values of the water samples from each sampling sites was probably due to the varied topographical location of each sampling points (Fig. 1) and the different kinds of anthropogenic activities on each site (Fig. 3). Seasonal variation affects the photosynthetic activities of algae and plants that uses hydrogen which could increase the pH of the river water. Likewise, respiration and decomposition of biotic fauna can lower the pH of the river water (Patil et al., 2012). Although the pH of the river water in the different sampling sites varied significantly, however, the values were within the tolerable limit (6.5 - 9.0) set by the DENR (2016) and US EPA (2005). This implies that the pH of the Pagbanganan river was within the preferable range for aquatic organisms to grow and survive.

Water temperature influences the rate of physiological processes of aquatic organisms. Water temperature was observed highest in the river water sample collected from Brgy. Ciabu (28.0 ˚C) while the lowest (27.4 ˚C) at Brgy. Canipa. However, there was no significant differences in the water temperature between sampling sites (Table 2). The higher temperature of the river water at Brgy. Ciabu was probably due to its being shallower than in the other sampling sites (11.3 cm) (Table 1). The shallow river water at the upstream (Brgy. Ciabu) was prone to heating by solar radiation (Patil et al., 2012). In addition, Usharani et al. (2010) pointed out that the rise in temperature of water increases the metabolic activities of aquatic organisms. Nonetheless, the river water temperature values in all sampling sites were within the permissible limits (25 ˚C to 31 ˚C) set by DENR (2016) and 32 ˚C maximum as set by US EPA (2005). This further suggests that the water temperature of Pagbanganan river was within the optimum range for ideal freshwater.

Dissolved oxygen (DO) is an indicator of how aquatic life will survive (Olawale, 2016). The highest dissolved oxygen which was noted in the river water samples obtained from the upstream (Brgy. Ciabu) (6.0 mg/L) differed significantly from the lowest value in the downstream (Brgy. Canipa) (5.2 mg/L). Variation on the DO values between sampling sites may be attributed to the reaeration of water samples based on the differences of water flow condition and water depth in each sampling sites (Table 1). Other sources of variations on the DO content of water sample may be attributed to anthropogenic activities (Fig.3) in each sampling sites. These activities possibly contributed to thermal pollution hence increasing the water temperature and thereby decreasing the DO values of the river water (Daintith, 2004). Nonetheless, the values DO of the river water sample in the upstream and midstream sampling sites were within the minimum permissible limit (5 mg/L minimum) set by the DENR (2016) and US EPA (2005). This indicates that the water quality in general was safe for aquatic organism propagation especially in the upstream and midstream sampling points.

Biochemical Oxygen Demand (BOD) refers to the amount of oxygen used by microorganisms to oxidize organic matter in water (CPCB, 2011). The BOD of river water in each sampling sites differed significantly (Table 2). BOD of the river water at Brgy. Bubon (midstream) was found highest (4.3 mg/L) and may be attributed to the leaves and woody debris, decaying solid materials, dead plants and animals and animal manure piggery (Singare et al., 2012) (Table 1). Meanwhile, the BOD values (2.5 mg/L) of the river water at Brgy Canipa (downstream) may be due to the excess fertilizer discharged in the river from nearby rice fields which nurtures the growth of plants and algae in the river (Fig. 3). The microbial decomposition of this biotic fauna would entail oxygen consumption. The higher the BOD, the higher the amount of organic matter, which consequently leads to water pollution (Perez et al., 2014). The BOD of the river water from Brygy. Ciabu (upstream) was the lowest (1.1 mg/L) probably due to less anthropogenic activities and the absence of sand and gravel quarrying activities. Nevertheless, the BOD values of the river water were within the permissible limit (7 mg/L maximum) set by the DENR (2016) and US EPA (2005). This suggests that the water pollution in Pagbanganan River was within the tolerable limit and was not significantly polluted.

River water samples collected from Brgy. Canipa (downstream) had significantly the highest TSS (112.0 mg/L) while the lowest in Brgy. Ciabu (20.5 mg/L). The significantly high TSS in Canipa (downstream) may be explained by the massive sand and gravel quarrying on the river water bed (Fig. 3) which increased the availability of suspended sediments on the river water samples. In addition, the run-off of soil particles caused by continued heavy rainfalls may also increase the TSS concentrations in each sampling sites (Table 1). This further support the findings of Aragoncillo et al (2011) on the effect of heavy rains on TSS. Suspended materials absorbs heat from direct sunlight causing thermal pollution which affects the solubility of DO. The TSS results in this study shows positive correlation with the DO values, wherein the highest TSS value on the river water samples in Brgy. Canipa has also the lowest DO values among sampling sites. Except for the TSS value of the river water samples in Brgy. Canipa (downstream), all the other values were lower than the reported permissible limit (80 mg/L maximum) set by DENR (2016). Meanwhile, the river water samples in all the sampling sites did not have a 30% increase in TSS value after every sampling period thus, conforming to the US EPA (2005) guidelines for a good quality freshwater. This further implies that the water quality of Pagbanganan river in the upstream (Brgy. Ciabu) and midstream (Brgy. Bubon) is good and capable of supporting aquaculture.

Total hardness in water is a measure of the total concentration of the calcium and magnesium ions expressed as calcium carbonate. The total hardness of the river water obtained in the Brgy. Canipa (132.4 mg/L) was significantly higher than those in Brgy. Ciabu (121.8 mg/L) but comparable with that of Brgy. Bubon (131.6 mg/L) (Table 2). The results suggest that the river water in the downstream (Brgy. Canipa) contained the most calcium carbonate. This is due primarily to the presence of bicarbonates, sulfates, chlorides, nitrates, calcium and magnesium (Olawale, 2016). Meanwhile, based on the Central Pollution Control Board (CPCB, 2011) classification on the degree of hardness of river water, the Pagbanganan river water was considered to be medium hard water to hard water (60 mg/L to 180 mg/L). Although the total hardness values of river water varied significantly, the obtained values were within the permissible limits (500 mg/L maximum) set by US EPA (2005) suggesting that the water in Pagbanganan river was safe for its intended usage.

Alkalinity is the buffer capacity of water. Although the highest water alkalinity value was obtained at Brgy. Ciabu (157.8 mg/L) and the lowest in Brgy. Bubon (144.5 mg/L) however, the total alkalinity values were not significantly different between each sampling sites (Table 2). The intensive sand and gravel quarrying activities at Brgy. Bubon (midstream) and Brgy. Canipa (downstream) which promoted the availability of some dissolved solids from inorganic materials such as rocks that contains calcium carbonate and other minerals may possibly account for the high-water alkalinity. Possible source of water alkalinity in each sampling sites may also be attributed to the type of river bedrock in which the river water passes through (Table

1), especially those bedrocks which contains carbonate, bicarbonate and hydroxide compounds. Nonetheless, the water alkalinity values of Pagbanganan river were within the tolerable limit (20 mg/L - 200 mg/L) set by US EPA (2005). The relatively high total alkalinity values obtained in Pagbanganan river water suggests that the river water partakes a good buffering capacity which allows the survival and growth of biotic organisms dwelling on the river.

The presence of mineral and salt impurities such as calcium, magnesium, sodium, potassium, manganese etc. contributes to the often-called total dissolved solids (TDS) (Manahanda, 2010). Average TDS value of the river water samples from Brgy. Bubon (135.0 mg/L) and Brgy. Canipa (133.7 mg/L) were significantly higher compared to that at Brgy. Ciabu (108.1 mg/L) (Table 2). The significantly higher TDS of the river water at Brgy. Bubon (midstream) and Brgy. Canipa (downstream) may possibly be due to the intensive sand and gravel quarrying activities which promoted the availability of some dissolved solids from inorganic materials such as rocks that contains calcium carbonate and other minerals. Although the TDS of the river water from each sampling sites differed significantly, the values were within the acceptable limit (500 mg/L maximum) set by US EPA (2005). This further suggests that the water in Pagbanganan river was safe for mobility of aquatic organisms and the extent of water pollution was not significant.

Conductivity gives rapid and practical estimate of the variations in the dissolved mineral contents of the water body. The conductivity of the river water samples collected at Brgy. Bubon (0.02092 S/m) and Brgy. Canipa (0.02065 S/m) were comparably higher and differed significantly with that at Ciabu (0.01692 S/m) (Table 2). The observed variation in the water conductivity between sampling sites may be explained by the anthropogenic activities, seasonal variation, the difference in the surrounding geology between sampling sites, and the make-up of riverbed rocks. The DENR (2016) and US EPA (2005) do not have imposed permissible limits for conductivity.

Phosphates that respond to colorimetric tests without preliminary hydrolysis or oxidative digestion of the sample is termed as, "reactive phosphorous" (APHA, 1999). Average phosphate level of the river water samples in Brgy. Ciabu (0.04 mg/L) and Brgy. Canipa (0.04 mg/L) were comparably higher and differed significantly with that in Brgy. Bubon (0.03 mg/L) (Table 2). Variation in the phosphate level was probably due to the different point sources of pollution coming from the waste water of local household near each sampling sites, fertilizer run-off and laundry activities (Table 1) (Fig. 3). Moreover, it may also be attributed to the natural process of weathering driven by the seasonal changes. Phosphorous reserves are found naturally in rocks and other minerals. During the process of weathering, rocks gradually release phosphorous as phosphate ions which are soluble in river water and the mineralize phosphate compounds also breakdown in the process. The DENR (2016) and US EPA (2005) do not have permissible limit for the phosphate concentration as reactive phosphorous for good quality freshwater.

Sulfate level of the river water in all sampling points differs significantly (Tables 2). The sulfate level in the river water samples from Brgy. Canipa was found the highest (21.23 mg/L) while that in Brgy. Ciabu the lowest (9.92 mg/L). The observed variation of sulfate in the water of the Pagbanganan River can be naturally occurring, as well as the result of municipal or industrial discharges. When naturally occurring, sulfates are often the result of the breakdown of leaves that fall into river streams, water passing through rock or soil containing gypsum and other common minerals, and atmospheric deposition. Even though the sulfate levels of the river water differed significantly, the values were within the maximum tolerable limit of 250 mg/L set by DENR (2016) and US EPA (2005). This implies that the sulfate level in the Pagbanganan river was utmost tolerable and capable of supporting aquaculture.

V.CONCLUSIONS AND RECOMMENDATIONS

The physicochemical characteristics of the water in the Pagbanganan River were determined using standard methods from August, 2016 to December, 2016. Using statistical analysis of the data, level of variation in the physicochemical quantities in the different sampling sites were compared. The quality of the river water was assessed by comparing the values obtained with the permissible limit set by DENR (2016) and USEPA (2005). The physicochemical properties of the water in the Pagbanganan River were analyzed and found to have pH (6.5 ± 0.1 to 8.8 ± 0.1), water temperature (26.0 ± 0.0 ˚C to 30.0 ± 0.0 ˚C), dissolved oxygen (4.8 ± 0.4 mg/L to 6.5 ± 0.8 mg/L), biochemical oxygen demand (0.9 ± 0.9 mg/L to 5.9 ± 0.9 mg/L), total suspended solids (16.0 ± 1.5 mg/L to 127.4 ± 33.4 mg/L), total hardness (100.0 ± 4.0 mg/L to 138.7 ± 2.3 mg/L) (as $CaCO_3$), total alkalinity (126.7 ± 11.5 mg/L to 173.3 ± 6.7 mg/L), total dissolved solids (97.3 ± 0.8 mg/L to 146.9 ± 0.1 mg/L), water conductivity (0.01512 ± 0.2 S/m to 0.02283 ± 0.2 S/m), phosphate (as reactive phosphorous) (0.02 ± 0.0 mg/L to 0.05 ± 0.0 mg/L) and sulfates (6.45 ± 0.1 mg/L to 29.70 ± 1.4 mg/L) were determined.

The water quality parameters showed significant differences except for water temperature and total alkalinity in all the sampling points. The T-test revealed a no significant difference between the obtained values and the standard limits imposed by the DENR (2016) and US EPA (2005). This further implies that based on the physicochemical parameters assessed in this study, the quality of the water in the Pagbanganan river could be classified as Class C surface water based on the freshwater classification of DENR (2016).

The quality of the water in Pagbanganan river especially in the midstream and downstream should be improved, maintained and preserved. Periodic monitoring of the physicochemical characteristics of the water in the Pagbanganan River for better quality assessment should be done. Total coliform/fecal coliform, turbidity and linear

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alkylbenzene sulfonates should be measured. The data should serve as the baseline information in the environmental impact assessment and other water quality monitoring purposes.

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