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Physicochemical Properties of the Water in Bao River, Ormoc City, Leyte, Philippines

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ABSTRACT

The Bao River in Ormoc City, Leyte is economically important for the people living in the barangays along the river. This study was conducted to determine the physicochemical properties of the river water during the months of September 2016, November 2016 and January 2017 using standard methods and assess the quality of the river water by comparing the values of the determined properties with standard limits set by DENR, and USEPA. Sampling was done in three sampling sites representing the upstream (Brgy Tongonan), midstream (Brgy Montebello) and downstream (Brgy Maticaa). The sampling sites were selected through reconnaissance survey and based on flow volume, pollutant loading, free from tidal effects and accessibility. Results revealed that pH, water temperature, dissolved oxygen, biological oxygen demand, total suspended solids, hardness, total dissolved solids, conductivity, total alkalinity, phosphates and sulfates were within the standard limits set by the various environmental protection agencies. Results also suggest that the quality of the river water is good for Class C and potential inland surface water for various uses.

Keywords: DENR, physicochemical properties, river system, USEPA, water quality

INTRODUCTION

Rivers constitute a major inland surface water source for domestic, agricultural and industrial purposes and is essential for the development of human civilization. The availability of good quality water is indispensable in preventing diseases and improving quality of life. However, surface water has the highest susceptibility to pollution because of waste and wastewater accessibility (Ahmed et al 2011). Alterations in the physicochemical and biological characteristics due to water pollution affect the quality of the stream environment reducing the life support function of this ecosystem. Water quality in urban streams, in particular, is deteriorating an alarming extent (Langhammer 2010; Martinez & Galera 2011; Teresa et al 2011; Orozco & Zafaralla 2012). Various factors affect water quality include substances present in the air, namely; dust, volcanic gases, and natural gases (oxygen, carbon dioxide and nitrogen) that have dissolved in entrapped water. Moreover, runoff from urban areas collect debris littering the streets, animal

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wastes, petroleum products, and road salt and take these to the receiving water body. Industrial activities can increase the concentration of metals, toxic chemicals and suspended sediments, increase temperature and lower dissolved oxygen in water (FAO 2009). Farm activities like spraying of chemical pesticides, herbicides and fungicides, deposit residue at receiving water bodies. Increased concentrations of these chemical can kill fish and other aquatic species (Adegoke 2005). Wastes entering these bodies of water are both in solid and liquid forms, mostly derived from industrial, agricultural and domestic activities (Osibanjo et al 2011). Moreover, changes in flow rate of rivers between the rainy season and dry season could bring difficulties in maintaining the river's water quality (Lee 2005).

Ormoc City is the center of commerce and industry in the western part of Leyte, Philippines. Among its major industries are geothermal energy, sugar-based alcohol and industrial gases. Because of the city's fertile soil and fishing ground, the residents are engaged in agriculture and fishing.

One of the major rivers in Ormoc City is the Bao River. The river is used as a source of water for domestic uses, agricultural irrigation, food and recreation. Due to the increasing human population living along the river, there is a need for information on the quality of the river water. Currently, there is insufficient to no published information on the water quality of Bao River system. Thus, this study was conducted to provide baseline information on physicochemical properties of the river water. Results of this study could be useful to the Local Government Unit of Ormoc City, as basis for developing plans for the river system's protection and conservation.

MATERIALS AND METHODS

Selection of Sampling Sites

Sampling sites of the Bao River representing the upstream (Brgy. Tongonan), middle stream (Brgy. Montebello) and downstream (Brgy. Maticaa) were identified and selected through a reconnaissance survey and based on flow volume, pollutant loading, free from tidal effects and accessibility. Exact coordinates and topographic locations of the sampling sites were measured and described using a Global Positioning System.

Sampling

One-liter acid-washed Light-Density Polyethylene (LDPE) bottles were used as sample containers. Collection of river water samples was done starting from the downstream and moving upstream at 7:00am to 11:00 am on September 2016, November 2016, and January 2017. Five representative water samples were collected at five sampling points namely right, left, center, upstream, and downstream in each sampling site and were pooled. Thereafter, a 1.0 L river water sample was set aside for laboratory analyses.

The collected samples for *ex-situ* analyses were stored in a cooler packed with ice for transport to the laboratory. Field observations were also made during sampling periods.

Physico-Chemical Analyses

The physicochemical analyses were done in triplicates following the American Public Health Association standard methods for examination of water and wastewater (APHA, 1999). Water temperature (°C) and pH were obtained *in-situ* using calibrated mercury-in-glass thermometers and a pre-calibrated handheld pH meter (HANNA pHep Tester) (standard buffers at pH of 4, 7, and 10), respectively. Moreover, total dissolved solids (TDS) and conductivity were determined using a factory-calibrated with NIST solutions multimeter (Ultrameter IIITM 9P); total alkalinity by the titrimetric analysis, total hardness (as $CaCO_3$) following through the ethylenediaminetetraacetic acid titrimetric method, dissolved oxygen (DO) following the Winkler- Azide method and biochemical oxygen demand (BOD) following dilution technique and five days incubation at 20°C; total suspended solids (TSS) using gravimetric method; and the phosphates (as reactive phosphorous) and sulfates following ascorbic acid method and turbidimetric method respectively, using the UV-Visible spectrophotometer (Shimadzu UV-1800).

Experimental Design and Statistical Analysis

The study was conducted following a Complete Randomized Design (CRD). Physicochemical properties of the river water between sampling sites were analyzed statistically using univariate Analysis of Variance (ANOVA) and Tukey's Honesty Significance Difference (HSD) test at 5% level of significance. Assessment of the river water quality was done by comparing the obtained values of the different physicochemical parameters with the permissible limits set by DENR (2016) and US EPA (2005) using t-test.

RESULTS AND DISCUSSION

General Characteristics of the Bao River and its Sampling Sites

The location and the respective Geographical Positioning System (GPS) coordinates of the three sampling sites along the Bao River are shown in Figure 1. Tongonan which is located in a mountainous area (~600 m above sea level) served as the sampling area for upstream, Montebello (~ 67.7 m above sea level) as midstream and Maticaa (~ 37.9 m asl) as downstream.

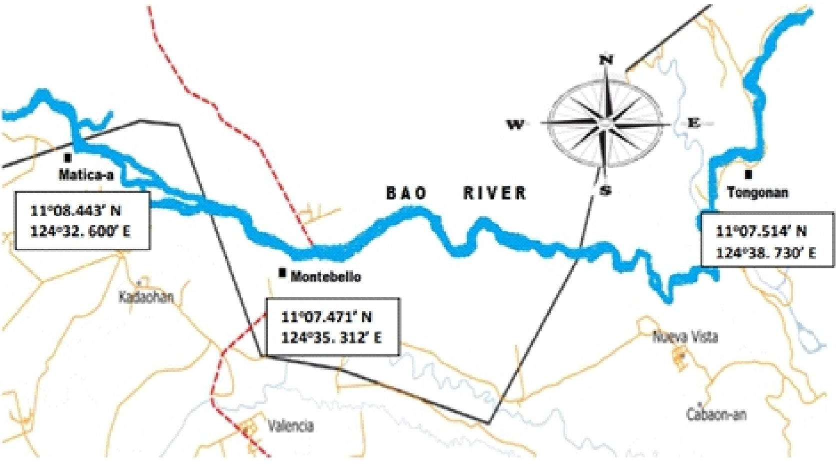

Figure 1. Sampling points of the Bao River (Ormoc City Planning and Development 2016)

The general characteristics of the water along the Bao River are shown in Table 1. Turbidity of the river water was determined through the comparison of water samples with distilled water using visual method (APHA 1999). Throughout the sampling periods, it was observed that the river water was turbid in general, in all the sampling sites but this was pronounced downstream. The variation in the turbidity of the river water in each sampling site may possibly be due to the heavy anthropogenic disturbance on the river bed especially downstream (Brgy. Maticaa) (Fig. 3). This had a sandy, muddy, clay and pebbly type of river bed (Table 1). In addition, the seasonal variation throughout the sampling periods may have also affected the turbidity of the river water. Heavy rains occurred in October 2016 (643.4 mm) and January 2017 (974.7 mm) (Fig. 2). During these periods, the heavy rainfall may possibly have resulted to soil erosion, increased velocity of the river flow, and mixing of colloidal suspended matter and plankton through the run-off sewage (Tidame & Shinde, 2012). Thus, the suspended materials in the river may have increased (Table 2) contributing significantly to the turbidity of the river water.

Water quality and safety in the Bao River had been threatened by the dumping of garbage along the river banks, the presence of residential houses, and several human activities observed in each sampling site such as sand and gravel quarrying, washing of clothes and motorized vehicles, bathing of humans and animals, and even fishing (Table 1 & Fig. 3).

Table 1. Field observations in the sampling sites at different sampling periods during the water sample collection

Sampling Period	Sampling Site	Weather Condition	Water Depth(m)	Water Condition	Nature of River Bed	Activities and Other Observations
September, 2016	Tongonan (upstream)	Partly cloudy; short rain to sunny	0.38	Fast flowing	Sandy/Pebbles Bottom	Fishing, washing of dump trucks, backhoeing river side of bed
	Montebello (midstream)	Partly cloudy	0.25	Fast flowing	Sandy/Pebbles Bottom	Washing of clothes, children bathing, dumping of garbage under the Bao bridge, backhoeing river side of bed
	Maticaa (downstream)	Sunny Day	29.7	Fast Flowing	Sandy/Muddy Bottom	Motorized vehicles and canter crossing the river; carabaos wading the river
November, 2016	Tongonan (upstream)	Partly cloudy; short rain to sunny	0.48	Fast flowing	Sandy/Pebbles Bottom	Hauling of river, backhoeing river side and bed
	Montebello (midstream)	Sunny; partly cloudy with occasional rain shower	76	Fast Flowing	Sandy/Pebbles Bottom	Washing of clothes, children bathing, dumping of garbage under the Bao bridge
	Maticaa (downstream)	Partly cloudy	95	Fast Flowing	Sandy/ Muddy Bottom	Motorized vehicles and canter crossing the river; carabaos wading the river
January, 2017	Tongonan (upstream)	Partly cloudy, cold air/ windy	0.23	Fast flowing	Sandy/Pebbles Bottom	Hauling of river, backhoeing river side and bed
	Montebello (midstream)	Sunny; partly cloudy with occasional rain shower	0.58	Fast flowing	Sandy/Muddy Bottom	Washing of clothes, children bathing, dumping of garbage under the Bao bridge
	Maticaa (downstream)	Partly Cloudy	50	Fast Flowing	Sandy/Muddy Bottom	Motorized vehicles and canter crossing the river; carabaos wading the river

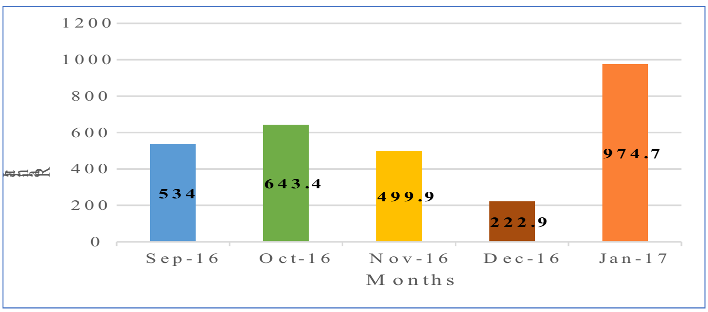

Figure 2. Rainfall data (mm) for the months of September, 2016 to January, 2017. (Source: VSU PAGASA, 2016-2017)

Figure 3. Anthropogenic activities along the banks of the Bao River, Ormoc City, Leyte, Philippines. A] Children bathing, playing and hauling river sand Brgy. Tongonan_upstream); B] People washing their clothes (Brgy. Montebello_midstream); C] Carabaos wading (Brgy. Montebello_midstream); E] Truck crossing the river (Brgy. Maticaa_downstream).

pH of the river water

Table 2 shows that the pH of the river water in the Bao River ranged from 7.1 to 7.7 suggesting that the water was weakly basic, which is typical for hard water. Moreover, the pH of the river water collected from the upstream was significantly lower (pH=7.1) compared to that in the downstream (pH 7.7). Results imply that the river water in the downstream (Brgy. Maticaa) contained higher amounts of ions like bicarbonate, carbonate and hydroxide ions.

The more pronounced increasing pH of the river water from the upstream to the downstream along the Bao River was also observed by Sagliba (2023). Several researchers also reported a similar trend in the pH of the water in the Sindangan River at Zamboanga del Norte (Laranjao et al 2023) as well as in Surigao River at Surigao City (Escatron et al 2020), Philippines. However, an opposite decreasing trend in pH of river water from upstream to downstream was observed in the other major river systems in Leyte such as the Pagbangan River (Villarmino & Quevedo, 2021) and Palhi River in Baybay City (Impas 2019), Salog River in Hilongos (Añora 2016; Pepito 2016), Anilao River in Ormoc City (Laurente 2018), Daguitan-Marabong River in Leyte (Arcillas 2023),Bulaco River (Maglangit et al 2014) and

Sapangdaku River (Sanchez et al 2020) in Cebu province in Zamboanga del Norte. On average, the pH of the water in the Bao River is very close to that in Pagbangan River (Villarmino & Quevedo 2021), Bulacao River (Maglangit et al 2014), most of the river systems in Zamboanga del Norte (Laranjao et al 2023), Meycauayan River (Pleto et al 2020); Subarnarekha River, India (Karem & Panda 2014) and Turag River, Bangladesh (Rhaman et al 2021).

The pH values of the river water from each sampling site at the different river systems varied probably due to the differences in topography, location, geology and soil. Unlike in the other major river systems in Leyte, the upstream site (Brgy. Tongonan) of the Bao River has an existing geothermal plant which may have released a small amount of sulfur dioxide and carbon dioxide that triggered an increase in hydrogen ions when dissolved in water. Thus, a lower pH of the water in the upstream.

Nonetheless, the pH values of the river water in the Bao River as well as those reported for most of the river systems in the Philippines were within the tolerable limits (6.5 - 9.0) set by the DENR (2016) and US EPA (2005). This indicates that the pH of the water in Bao River and other river systems in the Philippines were within the preferable range for the growth and survival of aquatic life.

Water Temperature

Water temperature which influences the rate of physiological processes of aquatic organisms was observed to be significantly highest (29.0 ˚C) in the river water samples collected from the upstream (Brgy. Tongonan) and the lowest (25 ˚C) from the downstream (Brgy. Maticaa) (Table 2). A similar decreasing trend in the temperature of the river water from upstream to downstream at the Pagbanganan River in Baybay City was reported by Villarmino and Quevedo (2021) although the values did not differ significantly. However, in the other major river systems in Leyte such as Salog River (Añora 2016; Pepito 2016), Palhi River (Impas 2019), and Anilao River (Laurente 2018); in Cebu province such as the Bulacao river (Maglangit et al 2014); in Benguet provinces with semi-temperate climate (Bestre et al 2018), Meycauayan River segment of the Marilao-Meycauayan-Obando River system in Bulacan (Pleto et al 2020); Surigao River in Surigao City (Escatron et al 2020); Zamboanga del Norte (Laranjao et al 2023) and Carangan Estero in Ozamiz City (Enguito et al 2013), the temperatures of the water collected from the upstream were lower compared to that from the midstream and downstream. On average, the water temperature of the water in the Bao River is close to the reported readings made in Surigao River (Escatron et al 2020).

The variation in water temperatures may possibly be due to biological activities, geographic location, exposure of the river water to the atmosphere, vegetation on the stream bank, weather conditions, and sampling time (Banerjee & Ghosh; Hoque et al 2012). The higher temperature of the river water at the upstream (Brgy. Tongonan) in the Bao River was probably due to the natural water discharged from the hot springs in the mountain area as well as from the geothermal power plant. Nevertheless, the water temperature readings fall within the reported 25-32˚C acceptable limits of DENR (2016) and USEPA (2014) for good quality Class C surface water suggesting that the water in the Bao River is suitable for aquatic lives.

Dissolved Oxygen

The dissolved oxygen varied along the length of a river with latitude and elevation. Its importance was reported by many researchers because DO in aquatic ecosystem brings out various biochemical changes that can influence metabolic activities of organisms (Kalwale & Savale 2012). The dissolved oxygen (DO) content of river water in the Bao River ranged from 5.87 to 6.36 mg L^{-1} which significantly increased going downstream (Brgy. Maticaa) (Table 2). The low DO content in the upstream (Brgy.Tongonan) may possibly be caused by the higher water temperature which was probably brought about by the geothermal power plant and the river water coming from the hot springs. This observation is consistent with those reported by several authors that dissolved oxygen is inversely related with water temperature (EPA, 2001; Iqbal et al 2004). This means that when temperature increases, DO decreases.

Table 2. Assessment of the water collected from the different sampling sites of the Bao River, Ormoc City, Leyte, Philippines through physicochemical properties, the standard limits of DENR (2016) and US EPA (2005 & 2014)

Sampling Sites	pH	WT (°C)	DO (mg L^{-1})	BOD (mg L^{-1})	TSS (mg L^{-1})	TH (mg L^{-1})	TA (mg L^{-1})	TDS (mg L^{-1})	Cond (µS m^{-1})	PO_4^{3-} (mg L^{-1})	SO_4^{2-} (mg L^{-1})
Upstream (Brgy. Tongonan)	7.1 ^{b}	29.0 ^{a}	5.87 ^{b}	3.40 ^{b}	66.8 ^{b}	68.0 ^{c}	48.4 ^{c}	216.3 ^{a}	331.6 ^{a}	0.07 ^{a}	14.2 ^{b}
Middle stream (Brgy. Montebello)	7.3 ^{ab}	26.4 ^{ab}	6.06 ^{b}	3.71 ^{ab}	83.7 ^{b}	84.4 ^{b}	53.8 ^{b}	199.4 ^{a}	301.9 ^{a}	0.05 ^{b}	24.8 ^{a}
Down Stream (Brgy. Maticaa)	7.7 ^{a}	25.0 ^{b}	6.36 ^{a}	3.94 ^{a}	114.1 ^{a}	95.1 ^{a}	60.4 ^{a}	156.9 ^{b}	236.8.5 ^{b}	0.03 ^{c}	26.6 ^{a}
DENR (2016)	6.5 – 9.0	25 – 31	5-10	$\leq$7	80	none	none	1000	none	0.50	275
USEPA (2005) (2014)	6.5 -9.0	$\leq$32 32	5	$\leq$7	30%*	$\leq$ 500	20 -200	$\leq$ 500	50 -1500	none	250
REMARK S	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Failed (up stream)	Passed

[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 to the previous data obtained

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

Meanwhile, an opposite decreasing trend in the DO of the waters from the upstream to the downstream was reported at the Pagbangan River (Villarmino & Quevedo 2021), Anilao River (Laurente 2018), Palhi River (Impas 2019), Bulacao river (Maglangit et al2014) as well as in the Surigao River (Escatron et al 2022). Compared to the reported DO of the water in the major river systems of Benguet province (Bestre et al 2018), Cebu province such as the upstream of the Bulacao River (Maglangit et al 2014) and the Sapangdaku River (Sanchez et al 2023) as well as the Surigao River (Escatron et al 2022), the values obtained in the Bao River are generally lower but higher than those reported for Meycauayan River (Pleto et al 2020). Nonetheless, the values are also comparable with those reported in the river waters of Phnom Phen, Cambodia (Seng et al 2018). Meanwhile, the recommended dissolved oxygen value for optimum fish health is 5-10 mg L^{-1} (DENR 2016; USEPA 2014); below this level can cause harmful effects. Results revealed that the DO concentrations of the water in the Bao River are within the permissible limit (DENR 2016; USEPA 2014). This suggests that the water in the Bao River system has enough DO to support aquatic life.

Biological Oxygen Demand

Biochemical oxygen demand (BOD) which measures the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter was determined after 5 days of incubation. Results show that the BOD of the river water in the Bao River which ranged from 3.40 mg L^{-1} – 3.94 mg L^{-1} was significantly higher in the downstream (Brgy. Maticaa) (3.94 mg L^{-1}) than in the upstream (Brgy. Tongonan) (3.40 mg/L). A similar increasing trend in the BOD of the river water from the upstream to the downstream was reported at the Anilao River in Ormoc City (Laurente, 2018), the Pagbanganan River (Villarmino and Quevedo 2021), Sapangdaku River in Toledo City (Sanchez et al., 2020) and Bulacao River, Cebu City (Maglangit et al., 2014). However, the BOD values in the water of the Bao River as well as those in the other major river systems in the Philippines were lower than those in Turag River in Bangladesh (Rhaman et al., 2021) and Zab River in Iraq (Mohammed et al., 2021). Results suggest that the water in most of the major river systems in the Philippines are less polluted with organic-containing wastes. This also implies a lower population of aerobic bacteria that uses oxygen to degrade organic wastes, hence the observed relatively lower BOD.

The variation of the BOD in the water of the Bao River as well as in other river systems was probably brought by the continuous urban runoff and sewage discharge from dwellers along the river. As pointed out by Cabuhal (2004), this situation primarily leads to the aerobic breakdown of organic matter in the river, thus, oxygen uptake by microorganisms lowers the concentration of dissolved oxygen and increases the BOD.

Nonetheless, the mean BOD values of the water in the Bao River were below the permissible 7 mg L^{-1} limit set by the DENR (2016) indicating that the river water is less polluted with organic wastes.

Total Suspended Solids

The total suspended solids (TSS) composed of carbonates, bicarbonates, chlorides, and phosphates of calcium, magnesium, manganese, organic matter, silt and other particles affect the turbidity of water (Manahanda et al 2005). The total suspended solids in the Bao River (66.8 mg L^{-1} – 114.1 mg L^{-1}) was significantly higher in the downstream (Brgy. Maticaa) than the comparable values in the upstream (Brgy. Tongonan) and the midstream (Brgy. Montebello). The increasing trend in the TSS of the water from the upstream to the downstream was also commonly observed in most of the other major river systems in Leyte (Añora 2016; Pepito 2016; Laurente 2018; Villarmino & Quevedo 2021 and Arcillas, 2023), in Bulacao River, Cebu City (Maglangit et al2014) as well as in the Dapitan, Dipolog, Dicayo, and Patawag Rivers in Zamboanga del Norte such as (Laranjao et al2023). Nonetheless, the average TSS of the waters in the major river systems of the Philippines are generally lower than those in Turag River, Bangladesh (Rhaman et al2021) and Subarnarekha River, India (Karem & Panda 2014).

The higher TSS of the river water in the downstream (Brgy. Maticaa) than in the other sampling sites in the Bao River was probably due to sewage discharge from the surrounding that was washed downstream from the upstream. In addition, anthropogenic activities like sand and gravel quarrying and hauling of riverbed sand (Table 1 & Figure 2) may have contributed to the increase in TSS value. Nevertheless, the values obtained were within the limits (1000mg L^{-1}) set by DENR (2016) suggesting that the water in the Bao River is good and capable of supporting aquatic life.

Total Dissolved Solids

Total dissolved solids (TDS) which is used to measure the general quality of the water refers to the combined content of all organic and inorganic substances contained in a liquid in ionized, molecular or suspended form (Kolekar 2017). Results show that the TDS of the river water of the Bao River which ranged from 156.9 to 216.3 mg L^{-1} were comparably higher in the upstream and midstream than in the downstream (Table 2). This trend is corroborated by the report of Sagliba (2023) who conducted a similar study in the Bao River. Laurente (2018) also obtained a similar trend in the TDS content in the water at the Anilao River, and Escatron et al. (2022) at the Surigao River. On the other hand, studies in other river systems in Leyte such as in the Palhi River (Impas 2019), the Pagbanganan River (Villarmino & Quevedo 2022), the Daguitan-Marabong river (Arcillas 2023). Bulacao River in Cebu province (Maglangit et al 2014) as well as in the Meycauayan River (Pleto et al 2022) showed an increase of TDS concentrations from upstream to downstream. The increasing trend in TDS may probably be due to the accumulation of the pollutants in the downstream from the upstream site. Meanwhile, this study also demonstrated lower TDS values compared to the water of the other river systems in the Philippines such as Sapangdaku River (Sanchez et al 2020), Meycauayan River (Pleto et al 2020) and the; Sumber Maron River, in Indonesia (Tawate et al 2018); Turag River in Bangladesh (Rhaman et al2021);

Subarnarekha River (Karem & Panda 2014) and Basantar River in India (Kour et al 2021).

The higher TDS in the water collected in the upstream of the Bao River might be due to the increase in the amount of ions or ionic compounds which usually include carbonate, bicarbonate, chloride, fluoride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, and potassium, and other ions present that contribute to the total. Anthropogenic activities such as the intensive sand and gravel quarrying activities which were observed in the upstream (Brgy. Tongonan) and in most of the river systems in the Philippines may caused presence of calcium carbonate and other minerals from inorganic materials such as rocks. In addition, the relatively low pH of the river water in the upstream (Brgy. Tongonan) may have solubilized some of the minerals in the rocks around it speeding up the erosion process. In turn, weathering rate was increased which resulted in an increase in the input of dissolved materials to the river.

Higher TDS can be toxic to aquatic life through increase in salinity or change in the composition of the water (Annalakshmi & Amsath 2012) and reduces water potability (Kour et al 2021). Although, the TDS values differed significantly between sampling sites, the values were within the 1000 mg L^{-} acceptable limit set by DENR (2016) and $\leq$ 500 mg L^{-} by (USEPA 2014). Results suggest that the water pollution in Bao River was minimal, and the water in Bao River is still safe and can support aquatic life.

Water Hardness

Water hardness (as $CaCO_3$) of the river water in the Bao River fluctuated from 68.0 mg L^{-1} to 95.1 mg L^{-1} and increased significantly down the river. The observed trend on water hardness of the river water in the Bao River was also similar to that reported in the Pagbangan River (Villarmino & Quevedo 2021). Its water hardness was also similar to that in Subarnarekha River (Karem & Panda 2014) but lower compared to that in the Pagbangan River (Villarmino & Quevedo 2021); Turag River, Bangladesh (Rhaman et al 2021); and Basantar River, India (Kour et al 2021).

The variations in water hardness in the Bao River may possibly be due to the household wastewater that contains calcium and magnesium ions from cleaning agents, food residue, and human wastes. The increased hardness of the river water from upstream to downstream suggested more sewage outflow from domestic and commercial sources (Enguito et al 2013). Although water hardness has no direct impact on health, it can cause scaling of pipes (Kour et al 2021).

Based on hardness, water is classified into three different categories: soft water (0 to 75 mg L^{-1}), moderately hard water (76 to 150 mg L^{-1}) and hard water (151 to 300 mg L^{-1}) (Soni et al., 2013). Accordingly, Bao River water falls within the range of moderately hard water which implies that the water is unsuitable for drinking. Nonetheless, the obtained values were all below the maximum limits ($\leq$500mg L^{-1}) set by USEPA (2005) for good quality surface water.

Total Alkalinity

Alkalinity which measures the buffering capacity of the water is generally imparted by the salts of carbonates, bicarbonates, phosphate, nitrates etc. (Yellavarthi 2002). High alkalinity in water is detrimental to agricultural crops. Result of this study shows that the alkalinity levels of the water in the Bao River which ranged from 48.4 mg L^{-1} to 60.4 mg L^{-1} were observed to increase significantly from the upstream to the downstream. This result is similar to that obtained by Impas (2019) in the Palhi River. Moreover, the values were lower than those reported in Turag River, Bangladesh (Rhaman et al 2021) and Basantar River in India (Kour et al 2021).

Nonetheless, the TA values of the water in the Bao River were within the 20-200 mg L^{-1} acceptable limit set by USEPA (2005). Results suggest that the river water is suitable for agricultural field irrigation and domestic use.

Electrical Conductivity

The capability of water to carry out electrical flow is referred to as conductivity. Dissolved ions such as sulfates, nitrates, and chlorides are its conductors (Chandra et al 2018). Although electrical conductivity has no health significance but it is correlated with the total dissolved solids. Results revealed that the electrical conductivity of the water in the Bao River which ranged from 236.8 to 331.6 µS m^{-1} were comparably higher in the upstream (Brgy. Tongonan) and midstream (Brgy. Montebello) than in the downstream (Brgy. Maticaa). The higher electrical conductivity values of the water in the upstream of the Bao River were consistent with those obtained by Sagliba (2023) as well as in the water of the Anilao River (Laurente 2018). Moreover, the EC values in the Bao River were lower compared to those reported for Meycauayan River (Pleto et al 2020); Subarnarekha River (Karem & Panda 2014) and Turag River (Rhaman et al 2021).

The higher EC values of the water in the upstream of the Bao River indicate the presence of high amount of dissolved inorganic substances in their ionized form (Sankpal & Naikwade 2012) or the presence of reduced level of ionic species (Weldemariam 2013). Elevated levels of EC can have certain physiological effects on food plants and on the habitat that forms plant species (Islam et al 2015). Nevertheless, all values were within the recommended 50-1500 µS m^{-1} permissible limits set by USEPA (2014) implying that the water in the Bao River water as well as those in other studies (Karem & Panda 2014; Rhaman et al 2021) is safe for biodiversity.

Phosphate Content

Phosphate is a vital nutrient for all living things. However, excessive introduction of phosphorus in the form of phosphates in the aquatic environment can cause eutrophication (Gebreyohannes et al 2015). Table 2 shows that the phosphate concentration in the river water of the Bao River ranged from 0.03 to 0.07 mg L^{-1} and decreased significantly from the upstream to the downstream. The highest value (0.07 ppm) was obtained from the upstream (Brgy. Tongonan) and lowest (0.03ppm), at the downstream (Brgy. Maticaa). This result is similar to that reported by Villarmino and Quevedo (2021) on a higher phosphate content of the water collected in the upstream of the Pagbanganan River in Baybay City, Leyte. However, an opposite increasing trend in the phosphate contents of the water collected from the upstream to the downstream in the Anilao River, Ormoc City, Leyte was obtained by Laurente (2018) and Tan (2022), the Daguitan-Marabong River by Arcillas (2023) and the Bulacao River, Cebu by Maglangit et al (2014).

The higher phosphate level in the water from the upstream at the Bao River was possibly due to higher water temperature (Brgy. Tongonan). Phosphate and water temperature are positively correlated with each other (Li et al 2013). This means that when temperature increases, phosphate increases. Phosphate-containing rocks at the upstream may have possibly dissolved readily as a result of high temperature which resulted to the higher amount of phosphate in the water. The higher temperature can dissolve minerals from the rock that it is in (https://water.usgs.gov/edu/temperature.html). The higher phosphate content in the river water at the midstream (Brgy. Montebello) than in the downstream (Brgy. Maticaa) was probably due to disposal of phosphate-containing domestic sewages and surface runoff from phosphate containing fertilizers applied in agricultural areas located in the upper slope along the Bao River (Bestre et al 2018; Korostynska et al 2012). However, the decrease in phosphate content going downstream may be due to less pollution load from waste disposals from the surrounding or possibly due to dilution as the water moves downstream (Gebreyohannes et al 2015).

Compared with the reported phosphate contents in the water of the other major river systems in the Philippines such as the Salog River (Jimenez et al 2016), Bulacao River (Maglangit et al 2014), the Agno, Galiano and Sinacbat Rivers in Benguet Province (Bestre et al 2018), in Zamboanga del Norte (Laranjao et al 2023), in the Damodar River, India (Banergee & Gosh 2012), Phnom Phen Rivers (Seng et al 2018), Tiaoxi River in China (Jen et al 2022), Basantar River in India (Kour et al 2021) and Zab River in Iraq (Mohammed et al 2021), the value obtained in the water of the Bao River is lower and within the 0.05 mg L^{-} permissible limit set by DENR (2016) for good quality freshwater.Results suggest that the river water in the Bao River is safe from phosphate pollution and suitable for growth and development of aquatic ecosystems.

Sulfate Content

One of the major anions in natural waters which is contributed by industrial and household discharges, as contaminants from tanneries, textiles, is sulfates (Gebreyohannes et al 2015). In addition, sulfates in bodies of water are also coming from the dissolution of sulfate minerals as well as oxidation of sulfides. Sulfates present in water can cause many health problems such as diarrhea, bowel problems among others (Kour et al 2021). In this study, the sulfate content in the water at the Bao River which ranged from 14.2 mg L^{-1} to 26.6 mg L^{-1} were comparably higher in the midstream (Brgy. Montebello) and downstream (Brgy.

Maticaa) than in the upstream (Brg Tongonan). A similar increasing trend in the sulfate contents of the water from the upstream to the downstream was observed in the Pagbangan River (Villarmino & Quevedo 2021), Anilao River (Laurente 2018; Tan 2022), and Palhi River (Impas 2019). The increasing trend of the sulfate content in the water from the upstream to the downstream may possibly be the results of industrial and domestic activities which resulted in its accumulation accumulated at the downstream. The downstream being located at lower elevation serves as the catching basin for the sulfates containing pollutants originating from the upstream and midstream.

Although, the sulfate concentrations in the water collected from the different sampling sites in the Bao River vary, the values were lower than that in the river waters of Phnom Phen (Seng et al 2018) and below the 250 mg L^{-1} limit set by USEPA (2014). Results suggest that the water in the Bao River was not much contaminated with sulfate and still safe for domestic use.

CONCLUSION AND RECOMMENDATIONS

The physicochemical properties of the water in the Bao River such as pH (7.1-7.9), water temperature (25 – 29°C), DO (5.87 - 6.36 mg L^{-1}), BOD (3.4 – 3.95 mg L^{-1}), TSS (66.8 – 114.1 mg L^{-1}), hardness (68.0 – 95.1 mg L^{-1}), TDS (156.9 - 216.3 mg L^{-1}), conductivity (236.8-331.6 µS m^{-1}), alkalinity (48.4 - 60.4 mg L^{-1}), hardness (68.0 -95.1 mg L^{-1}), phosphates (0.03- 0.07 mg L^{-1}) and sulphates (14.2 – 26.6 mg L^{-1}) were determined to be within the permissible limits of the standards set by DENR (2016) and USEPA (2014). The quality of the water in Bao River is considered good for surface water and is still very useful for its intended uses especially for agricultural purposes.

For further comprehensive studies necessary to assess the impact of seasonal changes for better protection and conservation, monitoring of the physicochemical properties of the river water in the Bao River should be done periodically.

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