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Physicochemical-assessment of the water quality of bulacao river, Cebu, Philippines

Fleurdeliz F. Maglangit*, Ritchelita P. Galapate, Eukene O. Bensig

Biology Program, Sciences Cluster, University of the Philippines Cebu, Philippines

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Abstract

The present investigation deals with the physico-chemical analysis of Bulacao River. The objective of the study was to provide baseline information on its physical and chemical characteristics as well as evaluate its water quality. Samples for analysis were taken monthly from three established sites along the river for a duration of six months. Temperature, pH and total dissolved solids (TDS) were measured on site. Levels of total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), nitrates and total phosphorus were analysed in the laboratory following the recommended standard APHA methods for water examination. Results showed that pH, TDS, DO, and total P differ significantly across location ($p<0.05$). All the measured parameters except for the downstream DO level were within the DENR standards which could be an indicative of organic pollution in the downstream area.

***Corresponding Author:** Fleurdeliz F. Maglangit ✉ ffmaglangit@up.edu.ph

Introduction

Quality and quantity of freshwater sources worldwide are under pressures due to rapid population growth, inefficient agricultural practices, untreated discharges of domestic and industrial wastes, modification of river courses, atmospheric deposition, deforestation, climate change, and land use development. The quantity of water available for specific uses declines with massive pollution. When the quality of water deteriorates, it loses its economic values (Banerjee and Ghosh, 2012, Hoque *et al*., 2012).

In the Philippines, forty of the more than 400 main rivers are polluted in varying degrees (Dayrit, 2001). Bulacao River with an approximate length of 12.7 kilometers is one of the major river systems in Cebu City, yet no baseline data is available at present concerning its physico-chemical characteristics and water quality. Hence, this study was undertaken. The general objective of the study was to assess the water quality status of Bulacao River. Specifically, the study aimed to: (1) assess physico-chemical parameters of Bulacao River (temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD_5)) (2) assess nutrients (nitrate and total P) of the river water (3) compare the physico-chemical results of the three established sites in the river, and (4) compare the data obtained with the standard for freshwaters set by the Department of Environmental and Natural Resources (DENR).

Materials and methods

Study Site

The upstream portion of Bulacao River begins in the mountainous areas of barangays Candulawan, Jaclupan and Lagtang, Talisay City. The upstream site is the original water source of the municipality as this is located in the watershed area. The midstream portion covers the barangays of Bulacao and Pardo. The downstream includes the barangays of Alumnos and Inayawan before it empties into the sea off the South Road Properties (SRP). Barangay Inayawan is the host of practically all solid wastes being disposed of from the entire city. The southeastern coast of the barangay is a big garbage treatment facility where all garbage trucks in the city dump garbage loads and subsequently undergo sanitary treatment by way of a landfill process. The facility used to be equipped with a garbage incinerator but was not given clearance from the environmentalist group that it failed to operate.

Three sampling sites (upstream, midstream and downstream) were established along Bulacao River and were marked by the Global Positioning System (Table 1).

Table 1. Location of sampling sites.

Sampling Site	GPS Coordinates	Location
Upstream	N 10° 16' 49.6" E 123° 50' 26.4"	Candulawan
Midstream	N 10° 16' 18.2" E 123° 50' 49.4"	Bulacao
Downstream	N 10° 15' 54.6" E 123° 51' 23.3'	Inayawan

The upstream portion of Bulacao River (Fig. 1) is situated in Barangay Candulawan, which has a total population of 2,884 and 703 households. The barangay survey in 2011 revealed that 58 households have no toilets.

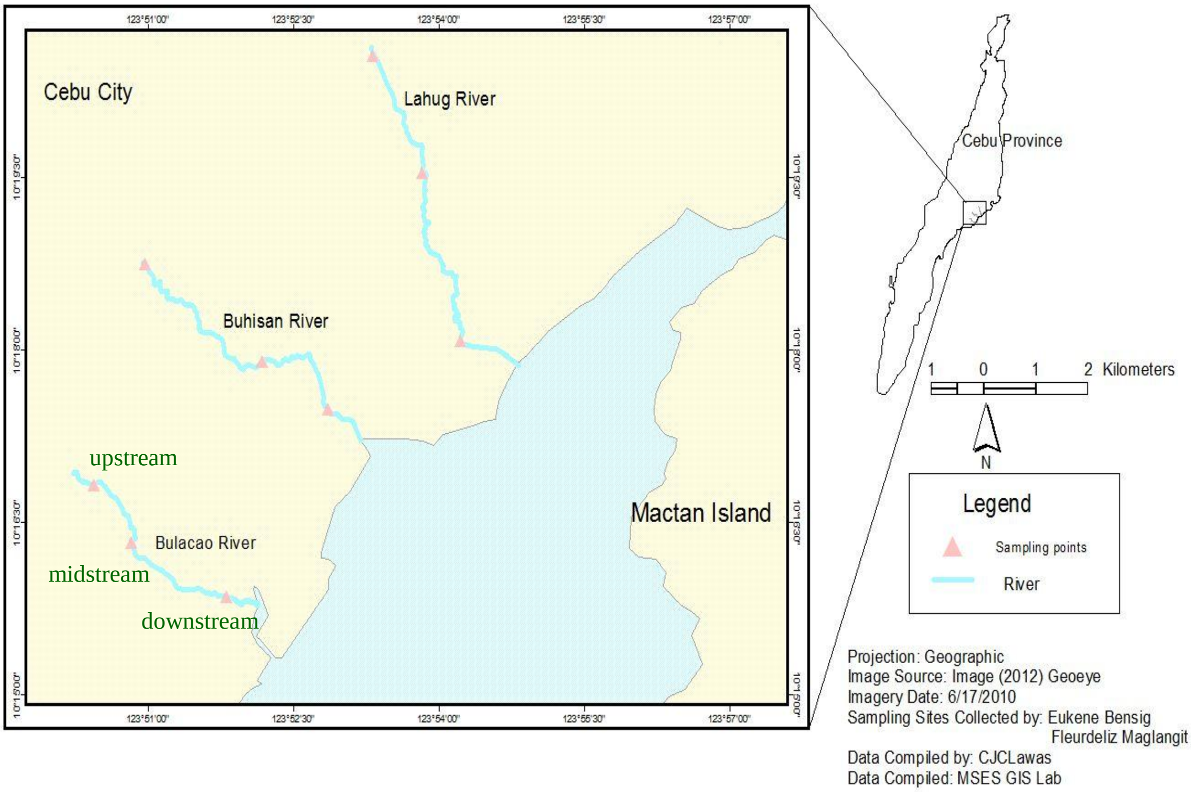

Fig. 1. Location of sampling sites along Bulacao River. (Source: Maglangit, *et al.* 2014)

The midstream site is situated in Barangay Bulacao (Fig. 1), Cebu City with a total land area of 68,194 hectares and 18 sitios. Based on the 2010 Census, the barangay has a total population of 10,555 and 3,267 households.

Bulacao River traversed downstream in Barangay Inayawan. Based on the NSO population survey in 2007, the total population of Barangay Inayawan is 24,990 with 4,242 households. Seventy percent (70%) of the households have backyard piggery.

Sample Collection

Reconnaissance survey was carried out to get acquainted with the study site and to determine possible sample collection points along Bulacao River. Three sampling points (upstream, midstream, downstream) in the river were identified using the Global Positioning System (GPS). Water samples were collected monthly from November 2011 to April 2012 following the standard procedures for sample collection described in APHA AWWA WEF (2005), US EPA Volunteer Stream Monitoring Manual (1997) and Maglangit, *et al.* (2014).

Water samples were taken in pre-cleaned polyethylene bottles by grab sampling. Samples were kept in a cool box at about 4°C and brought to the laboratory for chemical analysis.

Physico-chemical Analysis

Water temperature, pH, and TDS were measured in-situ using the multi probe Thermo Orion 5-star freshwater kit. Chemical parameter such as TSS, DO, BOD, NO_3^- and total P were determined and analyzed in the laboratory following the Standard Methods for the Examination of Water and Wastewater (APHA AWWA WEF, 2005) and as described in Maglangit, *et al.* (2014).

Data Analysis

Data obtained were analysed using the Statistical Package for Social Sciences (SPSS) version 19 software for Windows. One-way Analysis of Variance (ANOVA) was used to determine the relationships between two or more variables. The value $p < 0.05$ were considered as statistically significant. The parameters obtained from this study were then compared with the DENR guidelines for freshwater.

Results and discussion

Visual Observations

Rocks dominated the substrate of the upstream site. Yellow rock formation made of limestone was visible in the river bank. Small-scale quarrying activities were evident in the area resulting in the modifications of the riverbed. No quarrying activity was however noticed when the samples were collected. Few houses were found in the vicinity. The residents use the river water for laundry, bathing and other activities. Solid wastes were not observed.

In the midstream site, few patches of trees were seen in the river bank. During the sample collection, the water was found to be clear in spite of the presence of twigs and few solid wastes. The survey revealed that there were small-scale quarrying activities in the area however no visible impact was observed in the river bed.

The downstream area was surrounded relatively with more houses compared to other sites. The water appeared to be turbid due to the presence solid wastes as well as household wastewater discharged into the river. The survey revealed that 70% of the households found within the river perimeter raise hogs, the resulting wastes of which were discharged into the river. Few patches of grasses and few trees were observed along the riverbanks near the site.

Physico-chemical Parameters

Table 2 and Fig. 2 show the physicochemical results for the three sampling sites of Bulacao River as compared with the DENR standards.

Table 2. Mean physico-chemical results compared with the DENR standards.

Physico-chemical Parameter	Upstream site	Midstream site	Downstream site	DENR standard (Class D)
Temperature (°C rise)	28.05	28.53	29.53	3
pH	8.04	7.45	7.35	6.0-9.0
TDS (mg/L)	240.33	283.33	348.50	1000
TSS (mg/L)	7.47	15.67	14.50	Not more than 60 mg/L increase
DO (mg/L)	8.07	3.47	2.13	3.0
BOD (mg/L)	1.22	7.83	7.83	10 minimum 15 maximum
Nitrates (mg/L)	0.86	1.15	0.47	-
Total P (mg/L)	0.05	0.17	0.48	-

-means the standard of these substances are never considered necessary at present, considering the stage of the country's development as well as DENR capabilities, equipment and resources

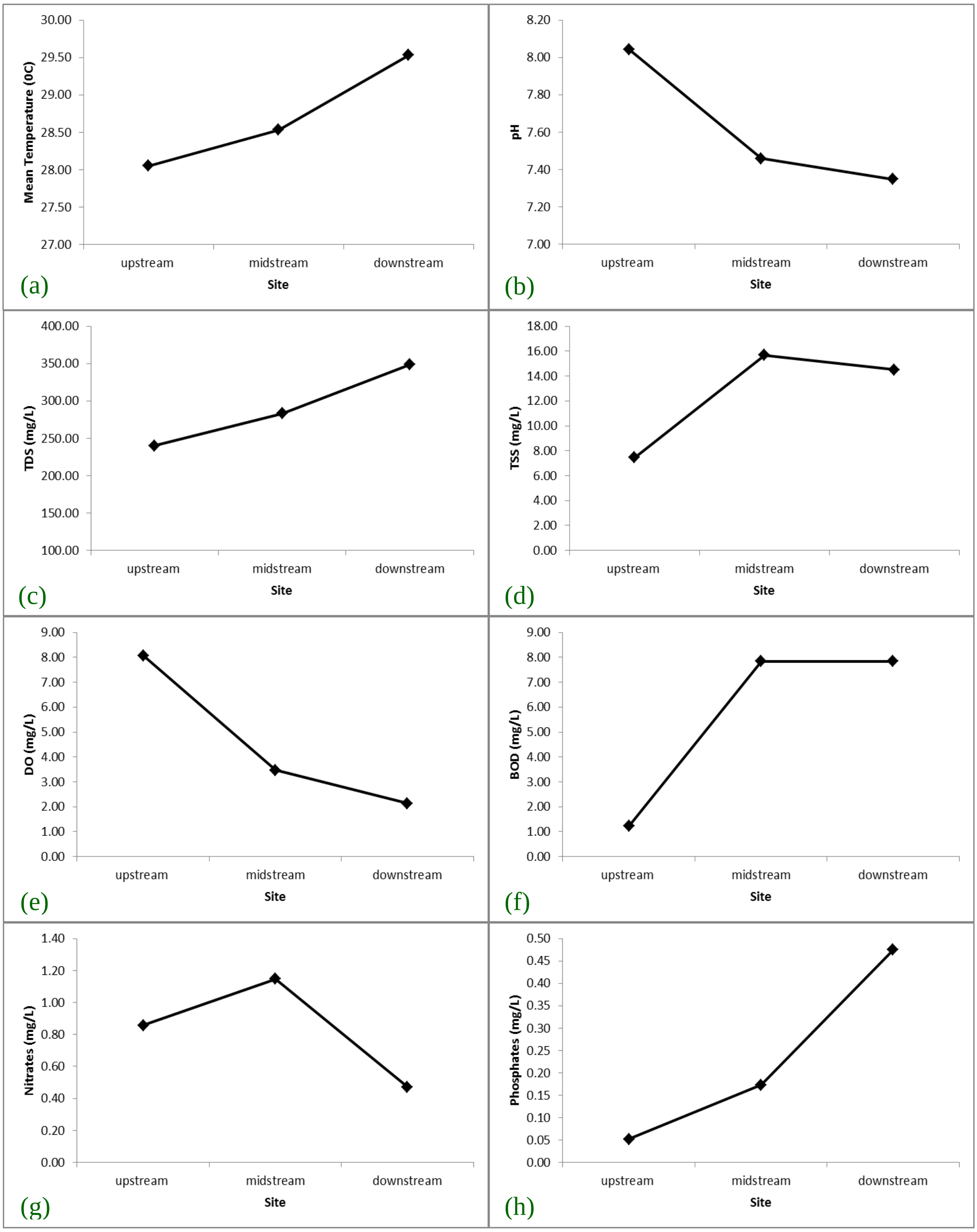

Fig. 2. Mean (a) temperature, (b) pH, (c) TDS, (d) TSS, (e) DO, (f) BOD, (g) nitrates and (h) total P of Bulacao River.

Temperature affects physical, chemical and biochemical processes in a water body (Pradhanang, 2012). The temperature readings (Fig. 2a, Table 2) at all sites fall within the DENR guideline of not more than 3°C increase over ambient temperature and has been found to varying from 28°C to 29.5°C. The variation could be due to biological activities, geographic location, exposure of the river water to atmosphere, vegetation on the streambank, weather conditions, and sampling time (Banerjee and Ghosh, 2012; Hoque, *et al.,* 2012; Flores and Zafaralla, 2012). There was no significant spatial variation (p=0.228).

pH is a vital chemical parameter since most of the aquatic organisms are adapted to an average pH and cannot tolerate sudden pH changes (Rankhamb and Raut, 2012). The river water was slightly alkaline with values that ranged from 7.35-8.04 (Fig. 2b, Table 2) were within the DENR standard of 6.0-9.0 for Classes AA to D surface waters.

pH increased significantly (p=0) towards upstream direction. The high pH in the upstream site could be attributed to the release of bicarbonates and carbonates from limestone rock observed in the area. pH also depends on many factors such as air, temperature, wastewater discharges (US EPA, 1997).

The total concentration of dissolved solids or ions in water body is an important parameter to maintain the water balance in cells of aquatic organisms (Weber-Scannell and Duffy, 2007; US EPA, 1997). In the present study, the TDS values ranged from 240-349 mg/L (Fig. 2c, Table 2) and were found to be below the 1000mg/L limit for Class D surface waters. The values showed significant spatial variation (p=0) which could be the result of increased precipitation, salt-water intrusion, and impacts of anthropogenic activities in the area such as small-scale quarrying activities (Weber-Scannell and Duffy, 2007).

Total suspended solids contain much of the inorganic matter and any increase thereof tends to increase the degree of pollution in water (Ombaka, *et al.,* 2012). TSS levels ranged from 7.5-15.7 mg/L (Fig. 2d, Table 2) and were within the DENR limit of no more than 60mg/L TSS increase. The values did not exhibit significant spatial variation (p=0.518).

Oxygen content is important to all aquatic forms of life. The level of dissolved oxygen in water points to the degree of organic pollution (Pradhanang, 2012). DO levels declined sharply (p=0) towards the downstream direction with mean values 8.0 mg/L, 3.5 mg/Land 2.1mg/L (Fig. 2e, Table 2), respectively. The downstream DO level was below the acceptable 3.0mg/L limit for Class D surface waters which could be attributed to the decomposition of organic matter from decaying solid wastes dumped in the area, wastewater discharges from pigpens and household activities near the river perimeter and runoffs from nearby vicinity which contain organic pollutants (Shakirat and Akinpelu, 2012).

Biochemical Oxygen Demand is an index of organic pollution to measure the level of dissolved oxygen required by microbial community in the breakdown of organic matter (Chauhan and Sagar, 2013). The mean BOD values 1.2 mg/L, 7.8 mg/L, 7.8 mg/L (Fig. 2f, Table 2) for upstream, midstream and downstream sites were acceptable (DENR limit: 15 mg/L). The values did not differ significantly across location (p=0.087).

Nitrates are formed in water due to oxidation of ammonia by bacterial action. They are the most important nutrients which account for the productivity in water (Lianthuamluaia *et al.,* 2013). The presence of little higher value of nitrates in water is an indication of river pollution and will cause eutrophication as a nutrient, hence reducing water quality. Algal bloom and aquatic plant growth will decrease pH, alkalinity, oxygen, light penetration so less rate of photosynthesis and increase TSS (Chauhan and Sagar, 2013). In the present investigation, the mean nitrate values were low ranging from 0.5-1.1 mg/L (Fig. 2g, Table 2) and did not cause significant aquatic plant growth in the area. The values did not vary significantly across location (p=0.139).

Phosphorus in aquatic systems occurs as organic and inorganic phosphate (US EPA, 1997). Phosphate is often the limiting nutrient in aquatic ecosystem. Phosphate deficiency retards plant growth however in excess amount in the aquatic ecosystem accounts for eutrophication (Chauhan and Sagar, 2013). The total mean phosphorus levels ranged from 0.05-0.5 mg/L (Fig. 2f, Table 2) and showed significant spatial difference (p=0). High levels of total P towards downstream direction could be attributed to domestic sewage, detergents, failing septic systems, agricultural effluents with fertilizers (Ombaka *et al.,* 2012; Manjare *et al.,* 2010). However, no excessive plant growth was observed in the area during the study period.

Conclusion

The physico-chemical assessment of Bulacao River for a period of six months indicated that temperature, pH, TDS, TSS, BOD, nitrates and total P lies within the DENR standards set for Class D surface waters, while DO level in the downstream site exceeded the minimum 3.0 mg/L limit. Low DO content indicated organic pollution in the area. There is therefore the need for regular monitoring to reduce the pollution level.

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