J. Appl. Environ. Biol. Sci., 8(4)1-12, 2018
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ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Water Quality and Phytoplankton Density in Alinsaog River, Zambales, Central Luzon, Philippines: Implications on Its Land Use

***Sazon, Rowena R. [1,2] and Migo, Veronica P.[3]**

[1] School of Environmental Science and Management, University of the Philippines at Los Baños, College, Laguna 4031, Philippines.
[2] Department of Biology, College of Arts and Sciences, Ramon Magsaysay Technological University, Iba, Zambales 2201, Philippines.
[3] College of Engineering and Agro-Industrial Technology, University of the Philippines at Los Baños, College, Laguna 4031, Philippines.

Received: December 3, 2017
Accepted: February 28, 2018

ABSTRACT

The study aimed to assess the water quality and phytoplankton density of Alinsaog River in Zambales, Central Luzon, Philippines. Water quality on the four designated stations along the stretch of the river was evaluated based on physicochemical parameters such as temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), salinity, total dissolved solids (TDS), Secchi disk visibility, nitrate-nitrogen, phosphate, and chemical oxygen demand (COD); hydrologic properties like stream flow; and biological characteristics like phytoplankton density. The results were compared with the water quality standards for freshwater using the Department of Environment and Natural Resources Administrative Order 34, series 1990. The results showed that TDS and COD, and the DO concentration during the dry season exceeded the standard limit for Class C water. A high density of non-toxic red tide organism *Peridinium* sp. of up to 111,982 cells/L was recorded two months after storm-induced flooding caused by typhoon *Koppu*. This result was concurrent with increased level of nitrate and phosphate in the upstream and downstream stations. There was a negative correlation between dinoflagellates density and EC, TDS and salinity and between total phytoplankton density and EC. The results suggest that the water quality of Alinsaog River failed to meet the local regulatory standards in terms of DO, COD and TDS. Some land-based activities were found to influence the health status of the river. These findings can be used as a basis for the formulation of river management plan including the policies and strategies for its protection and rehabilitation.

KEYWORDS: *Peridinium* sp., typhoon *Koppu*, chemical oxygen demand, stream flow

INTRODUCTION

Streams, rivers, lakes and ponds comprise the freshwater biomes that can provide economically valuable goods (fishes and other aquatic resources) and services such as navigation, recreation, water purification, and flood control. They also serve as a natural medium for the growth and survival of a variety of life forms, which continuously interact with each other and the environment in freshwater ecosystems [1]. In some locations, however, these ecosystems are being degraded at an alarming rate.

The degradation of freshwater ecosystems is usually associated with a decrease in water quality and quantity. This can be brought about by natural and anthropogenic factors. Natural processes such as weathering of bedrock minerals, leaching of organic matter and nutrients from the soil, and biological processes such microbial decomposition, can alter the chemical composition of water. Furthermore, as the freshwater ecosystems are tightly linked with the water catchment or watershed in which they are located, their condition is easily influenced by land-based activities. These include runoff from agriculture, aquaculture, mining, quarrying, and direct discharge of industrial or domestic wastewater. Runoff transports different substances such as fertilizers, grease, sediment, [1] pesticides, and others to ecosystems downstream of the discharge. Once these pollutants gain entry into the river system, they alter the physical, chemical and biological properties of water, properties that serve as indicators of its quality and ability to support life. Given that some aquatic ecosystems are sensitive to small changes in the properties of water, such changes lead to the degradation of ecosystem services and loss of biological diversity [2]. Furthermore, resultant poor water quality can lower the economic value of the freshwater resources that support the livelihood of the people including the irrigation water that is being used for agricultural activities [3]. The effect of declining water quality in freshwater biomes is now becoming a global concern. It is compounded by the continually

***Corresponding Author:** Sazon, Rowena R., Department of Biology, College of Arts and Sciences, Ramon Magsaysay Technological University, Iba, Zambales 2201, Philippines.
+6329466660776; rsazon@yahoo.com/rsazon1@up.edu.ph

growing human population, the corresponding increase in water consumption, the increase of industrial and agricultural activities, and the alterations in the hydrologic cycle brought about by the changing climate [4].

Measurement of water chemistry and physical parameters from samples of a freshwater biome can indicate its water quality and can provide a clear picture of the degree and extent of water pollution, where it exists. These parameters are compared with established water quality standards that identify unacceptable levels of substances that are toxic to aquatic organisms or to humans, based on scientific studies [4]. Likewise, the composition and diversity of biological communities reflect the quality of the aquatic environment. Various aquatic organisms, known as the "engineers of aquatic ecosystem," can serve as good water quality indicators due to their sensitivity to physical and chemical changes occurring in their environment [2]. Hence, these biological indicators, which include the phytoplankton, are extremely useful in evaluating the impacts of anthropogenic stress on aquatic habitats [5].

The Philippines, being an archipelago, is endowed with significant surface freshwater resources. It has 412 principal river basins in 119 proclaimed watersheds [6]. The country's vast river systems and coastal waters provide income sources to a large percentage its population. However, the fisheries productivity of water bodies in some parts of the country has declined in recent years as a result of deteriorating water quality due, in part, to watershed deforestation and increasing soil erosion [7]. In Central Luzon, the rivers and coastal waters of Sta. Cruz, Zambales are experiencing heavy siltation due to increased runoff from the mountain ridges and slopes and soil erosion from the adjoining farmlands. Aside from agriculture, mining is considered a profitable industry in the municipality since it started in 2007. After several years of mining operation, however, some environmental issues arose stemming from mine sites, access roads, and other deforestation activities; these issues include, *inter alia,* increased turbidity and changes in color of the water bodies, especially during the rainy season. To address these issues, the quality of marine water was assessed by the Bureau of Fisheries and Aquatic Resources in 2013. No study yet has been conducted on the freshwater environment, where silt deposition is already evident.

To understand the complex relationships within freshwater biomes necessitates the need for the assessment of the ecological status of the affected surface waters such as Alinsaog River. It drains its water to the West Philippine Sea, which harbors diverse species of fishes, seaweeds, corals and other marine resources. It serves as the source of irrigation water for farmlands and as fishing ground for the locals as well. The results of such an assessment can provide scientific information and insights to the policy makers in the formulation of river rehabilitation measures and regulatory policies pertaining to land use optimization and water resource management. Furthermore, the information generated can be utilized as basis for future studies related to remediation and removal of pollutants in water.

This study was conducted to assess the water quality of the Alinsaog River in terms of its physicochemical and hydrologic characteristics; to evaluate its phytoplankton community composition and density during the wet and the dry seasons; and to determine the correlation of water quality parameters with phytoplankton density.

MATERIALS AND METHODS

The Study Area and Sampling Stations

Sta. Cruz, the northernmost municipality in the province of Zambales, is situated at $15^0 46'1"$ north latitude and 119^0 54' 32" east longitude (Figure 1). Farming, fishing, and mining serve as its major industries. One of its two watersheds, the Nayom Watershed, drains its water into a series of springs, creeks, and other tributaries cascading down the mountainside, including the four rivers that support the major irrigation systems in the area. The Alinsaog River that is draining its water into the West Philippine Sea was selected as the study area due to its high laterite deposits in the sediments and along the stream banks. The sampling stations were designated as: S1 (upstream), S2 (midstream), S3 (downstream), and S4 (pond-like). S1 is vegetated with shrubs and trees while S2 has patches of mangrove species such as *Sonneratia alba*, *Avicennia* sp., *Rhizophora* species and *Nypa fruticans*. The downstream station (S3) is bordered with commercial establishments and residential houses of the fisherfolks. The pond (S4) is vegetated with mangroves *Sonneratia alba* and *Avicennia* sp. This station is receiving water from S3 during high tide.

Water Sampling and Analysis

In-situ measurement of water quality parameters was done at mid-depth in the months of October (2014), April, June, August, September and December (2015) to represent the wet and dry seasons. Zambales is characterized by Type 1 Climate with two pronounced seasons: dry season from November to April and wet season from May to October. The physicochemical properties of water were measured using portable devices: multiparameter water quality meter (HANNAH® HI9828/4/-2, Hannah Instruments) for temperature and dissolved oxygen (DO); hand-held conductivity meter (SARTORIUS PT20) for salinity, electrical conductivity (EC) and total dissolved solids (TDS); WTW pH meter for pH; and the water transparency using Secchi disk.

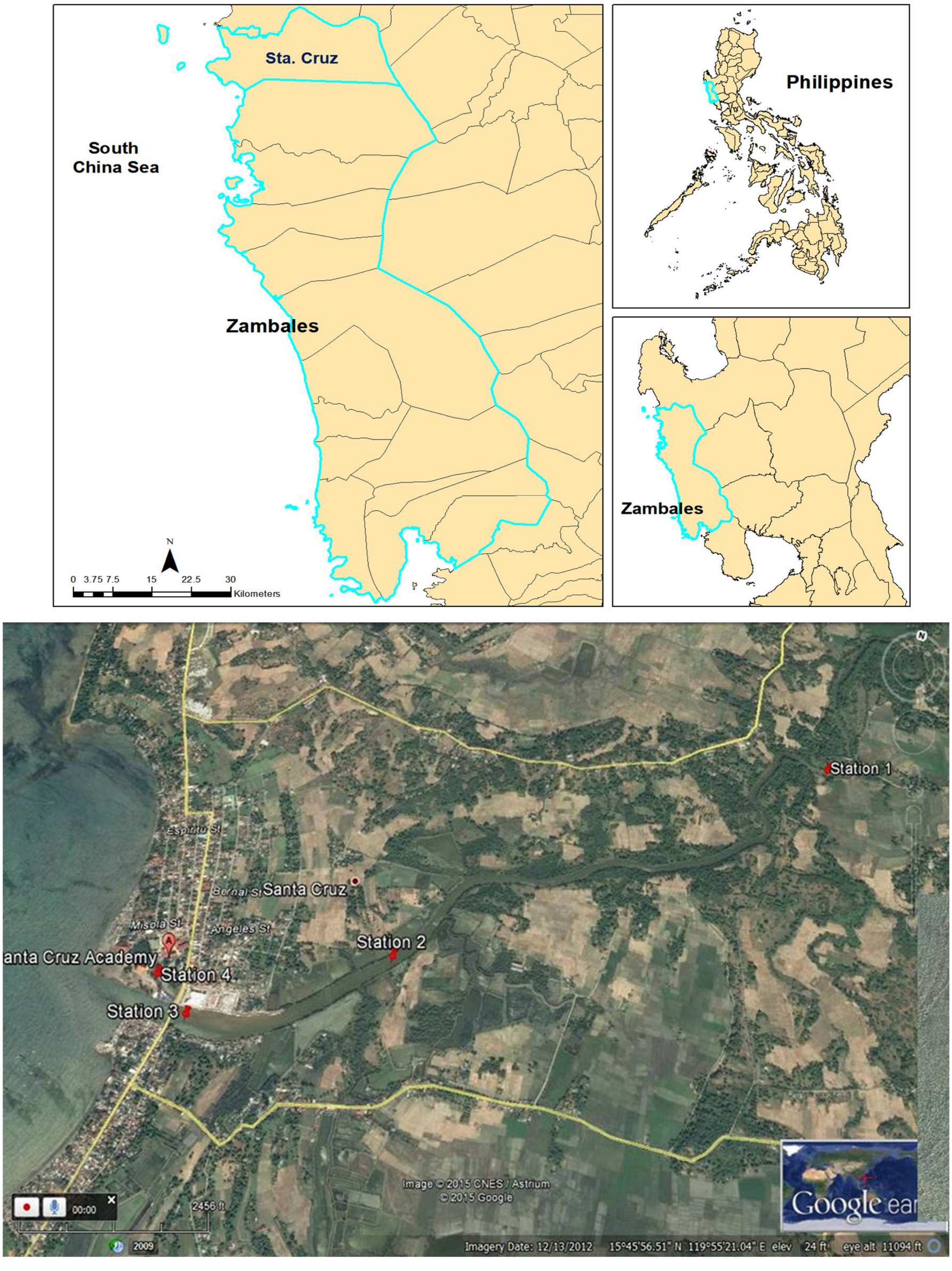

Figure 1. Map showing the location of Sta. Cruz and the sampling stations in Alinsaog River, Sta. Cruz, Zambales, Philippines

GPS coordinates (Station 1: 15.77727 N, 119.93640 E, Station 2: 15.76382 N, 119.91927 E, Station 3: 15.75941 N, 119.91185 E, Station 4: 15.76065 N, 119.90997 E).

The water sampling for analyses of chemical oxygen demand (COD), nitrate-nitrogen (NO_3^- - N) and phosphate (PO_4^3) was likewise carried out at mid-depth using a fabricated water sampler. The sampler was designed following the weighted bottle catcher of the Department of Environment and Natural Resources-Environmental Management Bureau Water Quality Monitoring Manual [8]. The improvised sampler had no weighted sinker because it is already made up of metal. A removable polyethylene plastic bottle was used instead of glass bottle. This sampler was designed in such a way that once it is lowered to the desired depth, the lid would open filling it up with water and would close by pulling the string before lifting it to the surface. The stirring up of the bottom sediments was avoided during sampling in order to maintain the integrity of the water samples. The composite samples from the left, middle and right sections of each station were transferred to pre-washed glass bottles, and placed in an ice box during their transport. The COD was analyzed by open reflux method and NO_3^- - N and PO_4^3 by colorimetric method at the National Institutes of Molecular Biology and Biotechnology (BIOTECH) Central Analytical Service Laboratory (CASL), University of the Philippines Los Baños (UPLB).

Stream Flow Measurement

The stream flow or river discharge was measured using the float method [8] during the months of August and December to represent the wet and dry season, respectively. Two transect lines representing the upstream and the downstream sections of each station were laid perpendicular to the river banks. The average depth and width of each transect at four interval points were used to calculate the cross-sectional area of a 6 m-long stretch of river. The time it took for the floating material to travel between the transects was determined, and the stream flow was calculated using the formula: Flow = ALC/T, where A is the average cross-sectional area of stream, L is the length of the stream reach measured (6 m), C is the coefficient of correction factor (0.8 for rough, rocky bottom; 0.9 for smooth sandy, muddy and smooth bedrock), and T is the time (s) for traveling through L.

Phytoplankton Sampling and Identification

The Bucket method was followed in the sampling of phytoplankton [1] but only 60 L was collected at each station using a graduated pail. The sample was filtered through a plankton net (25 µm mesh size), transferred to a polyethylene bottle, and added with 1.0 ml of 4% formalin as preservative. In the laboratory, the samples were allowed to settle for 24-48 hours, filtered using 26µm sieve and the residuum was diluted with 50 ml of water filtrate. One (1) ml of thoroughly mixed aliquot was dispensed on a Sedgwick-Rafter counting chamber (20 mm x 50 mm). The phytoplankton was identified to the lowest possible taxon. The number of plankton in three (1 ml) replicate subsamples was counted (cells/ml) and the density was extrapolated into number of cells/L by multiplying the number of plankton with 50 ml and dividing it with the total volume of the water samples (60 L).

Data Analysis

The data were evaluated using the Department of Environmental and Natural Resources Administrative Order (DAO) No. 34, series of 1990 and DAO 1990-35 (Revised Effluent Regulation of 1990). The seasonal variations in water quality parameters were tested by One -way Analysis of Variance (ANOVA) and the differences among the means by Duncan's Multiple Range Test (DMRT). The linear association between the water quality variables and phytoplankton density was determined by Pearson Correlation Coefficients using the SAS software.

RESULTS AND DISCUSSION

Physicochemical Characteristics

Water in the four sampling stations along the stretch of Alinsaog River in Sta. Cruz, Zambales was characterized during the wet and dry seasons using various physicochemical parameters which include temperature, dissolved oxygen, pH, salinity, total dissolved solids, electrical conductivity, Secchi disk visibility, nitrate-nitrogen, phosphate, and chemical oxygen demand.

Temperature, dissolved oxygen and pH. The water temperature, ranging from 28.27 – 35.31 ^{0}C (Table 1), had the highest value in August though this was considered as part of the rainy period. The study area is characterized by Type 1 climate, having two pronounced seasons; the dry which starts from November to April and the wet season on the rest of the months. The delayed onset of the rainy season could explain the recorded warm temperature in August. In general, the temperature was high during the dry season and before the onset of rainy season (April, June). Water temperature can directly regulate the concentration of dissolved oxygen in water, the metabolic rate and the other life processes of aquatic organisms [9].

The amount of oxygen dissolved in water is commonly used as an indicator of water quality since it is required in the metabolism of aerobic organisms. High oxygen concentration indicates good water quality [2]. The mean level of dissolved oxygen (DO), ranging from 3.73 – 8.77 mg/L, was higher during the rainy months. This showed that the solubility of oxygen in water increased at lower temperature. Most of the stations during the dry season (October, December) had a DO below the standard limit for Class C water (5 mg/L). Aside from temperature, other factors could influence the amount of oxygen in water such as pollution, and water movement. The demand for oxygen escalates in polluted water because microorganisms used up the oxygen for the decomposition of organic pollutants leading to oxygen depletion. DO should be at least 5 mg/L for the water body to sustain aquatic [10]. Organic pollution in the stream may have originated from wastewater from the commercial establishments, domestic sewage from the migrant settlers along the river banks, and agricultural runoff. The upstream and middle stations (S1, S2) are situated closed to the farmlands which are flooded during heavy rainfall events due to river overflow.

Among the sampling sites, S4 had the lowest DO. It can be due to the high amount of autochthonous organic materials (OM) or instream primary production in the area, particularly the litterfall from the mangrove trees in the riverbanks. Furthermore, low DO can be explained by the limited water movement in the pond (S4), as indicated by its low flow (Table 3). The slower the water movement at the water-air interface, the lower the level of dissolved oxygen. The configuration of S4, having a narrow water inlet and outlet, did not allow the materials that enter to flow out of the station. Consequently, the oxygen in the area might have been used up by the decomposing organisms.

Table 1. Seasonal changes in water quality parameters at different sampling stations in Alinsaog River, Sta. Cruz, Zambales

Parameters	Stations	Sampling Period						Class C limit	Class D limit
		Oct. 2014	Apr. 2105 (D)	June 2015	Aug. 2015 (W)	Sept. 2015 (W)	Dec. 2015 (D)		
Temperature (^{0}C)	S1	29.47 C	33.16 B	33.36 A	31.26 C	26.86 D	29.67 B	3 ^{0}C rise [b]	3 ^{0}C rise [b]
	S2	32.61 B	32.14 C	33.20 A	32.34BC	29.03 C	29.73 B		
	S3	30.39 C	30.61 D	32.58 A	32.68 B	30.35 B	30.37 A		
	S4	34.61 A	35.30 A	31.79 A	35.31 A	34.82 A	28.27 C		
pH	S1	n.d.	7.84 C	7.84 A	7.84 B	7.92 A	7.34 B	6.5 – 8.5 [b]	6.5 – 9.0 [b]
	S2	n.d.	7.90 B	7.91 A	8.20 A	7.56 A	7.88 A		
	S3	n.d.	7.99 A	7.77 A	8.13 A	7.86 A	7.93 A		
	S4	n.d.	7.89 B	8.04 A	8.13 A	8.15 A	7.52AB		
Dissolved oxygen (mg/L)	S1	5.08 A	n.d.	6.04 A	5.09 B	6.28 B	3.73 B	5.0 [b]	3.0 [b]
	S2	4.94 A	n.d.	6.15 A	5.82 AB	5.40 C	4.20 B		
	S3	3.50 B	n.d.	6.17 A	7.00 A	5.21 C	6.56 A		
	S4	4.83 A	n.d.	5.03 B	7.53 A	8.77 A	3.97 B		
Salinity (ppt)	S1	0.97 C	2.00 A	2.33 A	1.80 AB	0.10 C	1.17 B		
	S2	2.63 B	1.67 B	1.73 B	1.47 B	1.10 B	1.37 B		
	S3	2.63 B	1.23 C	1.70 B	1.73 AB	1.97 A	1.37 B		
	S4	3.10 A	1.27 C	1.17 C	2.20 A	2.70 A	2.3 A		
Electrical conductivity (mS/cm) = ds/m	S1	3.81 C	4.48 A	3.53 A	3.53 AB	0.26 C	2.25 B		
	S2	3.26 B	3.35 AB	2.88 B	2.88 B	2.24 BC	2.68 B		
	S3	2.56 B	3.28 C	3.38 B	3.38 AB	3.79 AB	2.16 B		
	S4	3.00 A	2.65 BC	4.21 B	4.21 A	5.04 A	4.63 A		
Total dissolved solids (mg/L)	S1	968 C	1897 A	2230 A	1717 AB	131 C	1110 B	1,000 [b]	1,500 [c]
	S2	2453 B	1603 B	1673 B	1440 B	1095BC	1277B		
	S3	2473 B	1215 C	1643 B	1683AB	1887AB	1343 B		
	S4	2890 A	1247 C	1172 C	2080 A	2547 A	2160 A		
Secchi disk visibility (cm)	S1	57.0	123.0	129.0	103.7	27.7	136.7		
	S2	61.7	102.7	99.0	153.7	27.2	117.5		
	S3	71.0	140.3	80.3	150.7	30.8	121.2		
	S4	n.d.	39.7	64.0	39.0	41.3	46.5		

[a] Means having the same letter within the same column are not significantly different from each other
[b] DAO 34, s. 1990 (for freshwater)
[c] DAO 35, s. 1990 (for inland water)
- standard of these substances are not considered necessary for the present time, considering the stage of the country's development and the capabilities of the Department of Environment and Natural Resources (DENR), equipment and resources (DAO 34)
n.d. - no data

The pH values (7.34 – 8.20), on the other hand, were all within the permissible limit (6.5 – 8.5) suggesting that the water pH was favorable for aquatic life. The pH range is said to be typical for most drainage basins worldwide [11]. The river studied by [12] also shifted towards the alkaline side of neutrality and this was attributed to the geological characteristics of the area which is primarily composed of limestone.

Salinity, electrical conductivity, total dissolved solids and water transparency. Water salinity is a measure of the concentration of salts dissolved in water. Table 1 shows that the lowest salinity was 0.10 ppt at the upstream (S1) and 3.10 ppt at S4. According to [13], freshwater has a salinity of less than 0.5 ppt while brackish water ranges from 0.5-35 ppt. The river under study could then be classified as brackish. This could explain why several species of mangroves are thriving very well on the riparian zone of the river. Salinity was generally high on S3 and S4 due to their proximity to the river mouth.

When these salts in water dissolve, they form both negative and positive ions, the mobility of which allows current to flow between two electrodes placed in the water (i.e. with a conductivity meter); thus salinity is considered to be a strong contributor to EC. When the salt concentration in water is high, EC correspondingly rises [14]. The EC varied over sampling periods and had no distinct trends over time though the lowest value (0.26 mS/cm) was observed at the upstream in September, parallel with that of salinity. The local regulatory agencies had no standard limit yet for EC. The lowest value was considered normal for freshwater. In the mangrove ecosystem on the southwest coast of India, the minimum EC of 0.26 mS/cm was observed in July but its maximum EC reached only 29.8mS. This variation was due to the influx of freshwater and mixes up with ebb and flow [15]. It was likewise reported by [16] that water evaporation during warm months and tidal changes are possible causes of fluctuations in EC.

Since the river water is primarily used for irrigation of the adjacent farmlands, it is important to consider the influence of this parameter to crop productivity. According to [17], high EC of stream water makes it unfit for irrigation. The guidelines for salinity hazard of irrigation water based on EC [18] showed that the EC values of Alinsaog River had limitations with regards to its use. It reported that EC of 1.51-3.00 dS/m and more than or equal to 300 dS/m had moderate to severe limitation as irrigation water. The EC unit of milliSiemens/cm (Table 1) is equivalent with that of deciSiemens/meter. When this type of water is used for irrigation, it requires a good drainage. It was explained by [18] that at high EC of water, the usable plant water in the soil solution decreased due to the reduced ability of the plants to compete with ions in the soil solution leading to physiological drought. This would eventually affect plant germination and crop yield.

Furthermore, the total dissolved solids (TDS), with the exception of September sampling at the upstream (131 mg/L), exceeded the limit for Class C water (1000 mg/L). The elevated levels of solids in water could be a result of siltation due to various land uses upstream. As the river flows, it carries the sediments from the river bed and eroding river banks. In areas with mining activities, [19] reported that the TDS was usually high due to the dissolution of minerals from the rocks. This condition could lead to a decline in fishery resources [20] because these solids could reduce light penetration in the water column thereby lowering the photosynthetic activity of the phytoplankton, the primary producers in freshwater habitats. The photic zone or the layer of water that can be reached by sunlight is reduced when the water is turbid. Among the stations, S4 had the highest TDS which can be due to its enclosed feature and low stream flow. As a result, the particulate matters that flowed in the pond during high tide simply settled along the banks.

TDS can be associated with water transparency or secchi disk visibility which is a measure of the depth at which sulight can penetrate water. The month of September had the lowest Secchi reading (27.7 and 27.2 cm at S1 and S2, respectively) which can be due to excessive turbidity of water brought about by rainfall. There was a downpour of rain the day before the sampling such that the water appeared murky during the measurement. The rain increased the volume of water in the stream, hence increasing the water flow. This led to the resuspension of settled sediments and erosion of the river banks [21] with heavy silt deposits. The recorded low water transparency can also be due to runoff. Excessive precipitation caused the flow of water over the land surface where it picked up silt, clay and other small particles, and deposited them in the river [16]. The transparency values of less than 30 cm, according to [22], indicate excessive turbidity, which when further lowered could lead to a reduction in concentration of oxygen dissolved in water. The report added that if the sources of turbidity are the suspended solids, it could lower the productivity of the water body.

The measured water transparency at S4 (39.0 - 46.5 cm), on the other hand, mostly corresponded with the site depth. The Bureau of Fisheries and Aquatic Resources (2013) reported that the safe optimum level for transparency was 30-45 cm. At this condition, light can penetrate the entire water column. When the water is clear, the photic zone or the layer of water that can be reached by sunlight is deeper, hence an increased photosynthetic activity [16] of the plankton. This transparency range could indicate good condition of the pond if the turbidity is due to the presence of phytoplankton [22]. Other stations at different sampling periods had a secchi reading of >60 cm, which could indicate inadequate primary productivity.

Analysis of variance (ANOVA) at 5% level of significance revealed that, in general, the measured parameters differed significantly across the stations except for temperature and pH in June and pH in September sampling period. Table 1 presents which among the stations exhibited significant variations at each sampling period.

Other water quality parameter that was observed visually was the color. During sampling, the water appeared brownish and clear but a slight stirring of the sediments immediately turned the water reddish. This has already reduced the aesthetic value of the rivers in the area which have undeniably high potential for tourism activities like swimming and boating.

Chemical oxygen demand, nitrate and phosphates. Table 2 presents the measured COD, nitrate-N and phosphates at different sampling periods. Chemical oxygen demand principally measures the amount of oxygen that is required for the oxidation of organic matter (OM) into carbon dioxide and water under strong oxidizing agents and acidic conditions [23], although it also oxidizes non-organic matter constituents such as ammonia and nitrates. The COD levels, ranging from 110-210 mg/L, exceeded the standards for Class C water. The high amount of COD was a result of the existing land uses in the area. The presence of commercial establishments and communities that directly discharged their sewage and solid wastes contributed to the high COD in the downstream station (S3). The riparian vegetation likewise provides a large input of organic matter via leaf litter and its decomposition in other stations. High COD levels indicate organic pollution. In an environment with high OM, oxygen depletion might become a problem since microorganisms utilize oxygen for the decomposition process. The results show that the high COD at S1 and S2 in August and December paralleled to low DO concentration. Lowering of DO to 3 mg/L might lead to hypoxia, a condition that could trigger the release of pollutants in the sediments [24]. High COD could also indicate high ammonia, high nitrates, or a toxic condition and the presence of biologically resistant organic substances that cannot be acted upon by bacteria [25]. Moreover, the blue green algae *Oscillatoria* sp. was found to be present at S2 and S4, the stations that are vegetated with mangroves. It was reported as early as 1999 that *Oscillatoria* sp. could indicate organic pollution [26]. The litter fall of mangroves contributed to the enrichment of organic matter (OM) in the area in the form of detritus and living organisms [27].

The measured NO_3^- - N, ranged from 0.023 ± 0.011 to 0.616 ± 0.007 mg/L. The concentration was lower during the rainy months due to the dilution effect of rainfall. The limit for Class A to C water is 10 mg/L while the measured nitrate-N was even less than 1 mg/L indicating that the water has limited nutrient hence, the river can be considered as oligotrophic. The nitrate measured was typical for freshwater, according to [28].

The phosphate level, on the other hand, ranged from non-detectable to 0.002 mg/L in the first two sampling periods. Though there were potential non-point sources of phosphates in the river water such as natural rock weathering, erosion and agricultural runoff, phosphate enrichment was not observed. Most of the phosphates probably bound to the river sediments. The sediment has both the capacity to retain and release phosphorous depending on the existing environmental condition. It was reported that the deposition of inorganic P from the overlying water to the sediments exceeded the rate at which it is released by desorption or diffusion [29]. The phosphate level in the upstream (0.31 mg/L) and in the pond (0.267 mg/L) in December was beyond the permissible limit. This could be a result of river bank erosion and runoff from the adjacent rice farms during the typhoon-induced flood (*Koppu*) in October. During the storm, the fields that were routinely fertilized by nitrogen and phosphorous were inundated by floods, causing it to overflow. Since P tends to be associated with the particulate and organic matter in the soil, it was carried in the runoff causing the enrichment of phosphates.

Table 2. Seasonal variations in chemical oxygen demand, nitrate-N and phosphate in Alinsaog River

Station	COD (mg/L)		Nitrate-N (mg/L)			Phosphate (mg/L)		
	1-Aug-15	19-Dec-15	26-Oct-14	1-Aug-15	19-Dec-15	26-Oct-14	1-Aug-15	19-Dec-15
1	139 ± 8	204.31 ± 13.12	0.172 ± 0.005	0.116 ± 0.00	0.616 ± 0.007	nd	0.002 ± 0.001	0.310 ± 0.000
2	210 ± 0	175.26 ± 6.56	0.128 ± 0.032	0.051 ± 0.001	0.464 ± 0.004	nd	0.003 ± 0.002	0.003 ± 0.001
3	110 ± 2	152.76 ± 0.94	0.117 ± 0.004	0.065 ± 0.004	0.191 ± 0.016	nd	0.009 ± 0.002	0.005 ± 0.001
4	125 ± 7	137.77 ± 6.56	0.023 ± 0.011	0.064 ± 0.006	0.204 ± 0.020	nd	0.012 ± 0.002	0.267 ± 0.001
Class C	100 [b]		10 [a]			0.2 [a]		
Class D	200 [b]		-- [a]			0.4 [a]		

[a] DAO 34, s. 1990 (for freshwater); [b] DAO 35, s. 1990 (for inland water); nd – non detectable

Hydrologic Characteristics

The stream flow is the volume of water that moves over time in a water course [8]. This affects the transport of sediments and consequently influences the quality of surface water. Table 3 shows that stream flow varied between seasons and among stations. The flow was higher during the wet season because high amount of precipitation brought large volume of water causing an increase in the width and cross sectional area of the stream. A study of [30] also reported high stream flow during the period of increased precipitation.

The stream flow was increasing from the upstream going to the downstream (S1 to S3). The highest flow was measured in the downstream (S3), which was $22.17 m^3/s$ and $20.48 m^3/s$ during the wet and dry seasons, respectively. Though stream flow is not technically classified as a measure of water quality, monitoring of this parameter needs to be done because it can affect both the chemical and biological components of a freshwater system [2]. Water movement can influence the transport of sediments [31]. At high flow, more stress is exerted on the river bed and this contributed to elevated levels of TDS and low water transparency during the rainy months (Table 1). The lowest flow was measured in S4. Due to its limited water flow, sediments together with other particulate matters that are bound to it, just settled at the bottom and might be resuspended only if the flow is increased by strong tidal fluctuations or increased precipitation.

Table 3. The stream flow (m^3/s) of the sampling stations in Alinsaog River on the wet and dry season

	Wet Season (August)				Dry Season (December)			
	S1	S2	S3	S4	S1	S2	S3	S4
Ave. width (m)	31	56.8	105	24	26	52	105	42.4
Ave. depth (m)	2.09	1.85	1.10	0.61	1.35	1.10	1.15	0.34
Ave. cross sectional area (m^2)	64.96	105.08	115.64	14.67	34.97	57.2	120.75	14.26
Stream flow (m^3/s)	11.82	18.69	22.17	0.47	4.52	4.86	20.48	0.46

Phytoplankton Composition and Density

Investigation of the state of the biological communities thriving in the freshwater habitat likewise reflects the quality of its water. In this study, the phytoplankton composition and density was assessed in relation to physicochemical properties of water. Five major taxonomic groups of phytoplankton were identified, namely; Bacillariophyta (diatoms), Chlorophyta (green algae), Cyanophyta (blue green algae), Dinophyta (dinoflagelates) and Protista. The diatoms had the most number of taxa (22) which is due to their preference to alkaline conditions [32]. The stream under study had a neutral to slightly basic pH. The diatoms possess inorganic cell wall that is comprised of hydrated silica [33]. The solubility of silica that is required for the synthesis of diatoms cell wall increased at higher pH [34].This could probably explained the abundance of diatoms relative to other taxa in the study area.

The study sites had more taxa and higher phytoplankton density during the dry season (Table 4a, Table 4c). The high plankton productivity was a consequence of high temperature and increased light penetration in the water column during the dry months. The fewer taxa and lower density per taxon during the period of high precipitation, on the other hand, could be due to high water velocity [35] and dilution effect of the rain. This was also the same explanation offered by [36] in their study on variability of plankton community in India. Another study stated that rainy season, cloudy weather, low transparency and flood can contribute to lower phytoplankton density [37]. The short residence time of water at enhanced river flow could limit phytoplankton growth [38].

Pyrodinium sp. was detected on August 2015 (Table 4b) but at a low density (0.83 cells/L). Some species of *Pyrodinium* are known to be causative agent of red tide. The cases of PSP (paralytic shellfish poisoning) in the coastal waters of Zambales occurred from April to August in 1988 [39] and the bloom of dinoflagellates was found to be due to *Pyrodinium bahamense* var. *compressum* [40]. This finding suggests the need for periodic monitoring of red-tide causing organisms since there were recurrent occurrences of red tide toxins in Zambales and Bataan coastal waters in the past.

A very high density of dinoflagellates *Peridinium* sp. (74 – 111,982 cells/L) was detected in December. This can be linked with the sudden upsurge in phosphate levels of Stations 1 and 4 (0.31 mg/L and 0.267 mg/L, respectively) after the typhoon-induced flooding in October. An increase in nitrate-N concentration, another limiting factor for the growth of dinoflagellates, was also observed. The flood could transfer these dissolved and particulate matters from the land to the river [41]. The upstream and middle stations (S1, S2) are adjacent to the rice fields where nitrogen and phosphorous-based fertilizers are intensively applied every cropping season. Two more factors could probably cause the bloom of *Peridinium* sp.; seeding due to temperature – induced germination and trace metal stress [42]. The warm temperature in December, reaching up to 30.37^0 C, and the high water transparency (117.5 - 136.7 cm) triggered the germination of cysts in the sediments. When low concentration of metal is present in water, the plankton could accumulate them several fold higher than their levels in water. This might reduce the grazing pressure of the zooplankton hence increasing the density of phytoplankton in water. In a separate study of [43], the levels Fe, Cr, Ni and Mn in the river sediments exceeded the standard limit, however, detection of trace elements in water and plankton was not covered by the study. A study of [44] also reported the dominance of these dinoflagellates in a mangrove habitat in Oman. This was due to their ability to survive various environmental conditions such as high salinity and temperature enabling them to outcompete the other plankton species including diatoms.

The massive growth of *Peridinium* sp., though considered as a non-toxic red tide organism, could kill fishes and invertebrates by depleting the oxygen in water [42]. This species, based on available data, had no record yet in the area.

Table 4a. Phytoplankton density in the four sampling stations during the dry season (October 2014).

Phytoplankton Group	Density (cells/L)				
	S1	S2	S3	S4	Total
Bacillariophyta	7.92	13.33	6.81	4.31	32.36
Chlorophyta	3.61	437.92	6.39	4.58	452.50
Cyanophyta	0.14	0.83	0.00	3.47	4.44
Grand Total	15.42	452.08	13.19	12.36	946.25

Table 4b. Phytoplankton density in the four sampling stations during the wet season (August 1, 2015)

Phytoplankton Group	Density (cells/L)				
	S1	S2	S3	S4	Total
Bacillariophyta	0.00	1.67	2.22	37.08	40.97
Chlorophyta	3.47	0.00	1.39	0.83	5.69
Cyanophyta	0.00	0.00	0.00	0.28	0.28
Dinophyta	0.00	0.83	0.00	0.00	0.83
Grand Total	3.47	2.50	3.61	38.19	47.78

Table 4c. Phytoplankton density in the four sampling stations during the dry season (December 19, 2015)

Phytoplankton Group	Density (cells/L)				
	S1	S2	S3	S4	Total
Bacillariophyta	5.00	0.83	8.75	6.67	21.25
Chlorophyta	0.28	0.00	0.00	0.00	0.28
Dinophyta	111,981.81	104,393.89	87,255.97	66.25	303,697.92
Protista	0.00	0.00	0.00	1.25	1.25
Grand Total	111,987.08	104,394.72	87,264.72	74.17	303,720.69

Correlation of Phytoplankton and Water Quality Parameters

Table 5 shows the positive correlation between the density of Cyanophyta and the three related parameters: salinity (P>0.0283), EC (P>0.0371) and TDS (P>0.0295). The high TDS in water became favorable for the growth of blue green algae because the dissolved solids in water contained the minerals that served as nutrient source for the Cyanophyta [45]. However, this was only up to a certain limit because osmotic stress could negatively affect the aquatic organisms.

Table 5. Pearson correlation coefficients (r) between the phytoplankton group density and the physicochemical properties of water

Density of Phytoplankton Group	Physicochemical Parameters					
	Temperature	pH	DO	Salinity	EC	TDS
Bacillariophyta	0.50067	0.23899	0.49432	0.23112	0.21571	0.23237
Chlorophyta	0.18105	0.14963	-0.06471	0.35384	0.31879	0.34657
Cyanophyta	0.50035	---	-0.10139	0.62944*	0.60505*	0.62569 *
Dinophyta	-0.41768	-0.47394	-0.22184	-0.53510	-0.60047*	-0.55592
Protista	-0.45676	-0.46501	-0.29410	0.19034	0.25441	0.18649
Total density	-0.41730	-0.47391	-0.22204	-0.53437	-0.59988 *	-0.55522

* Correlation is significant at the 0.05 level (2-tailed)

The density of Dinophyta (*Pyrodinium* sp., *Peridinium* sp.) and the total density of phytoplankton, on the other hand, were negatively correlated with EC (P> 0.0390). This implies that the density of the phytoplankton is reduced with increasing electrical conductivity. It was also reported by [46] that EC, together with water temperature, were the most common factors negatively controlling phytoplankton density. The high EC suggested the presence of high concentration of salts dissolved in water including silt and clay particles and other particulate matters that could reduce light penetration in water [21] and consequently impaired the photosynthetic activity of plankton.

CONCLUSIONS

The study showed the influence of land uses on the stream water properties and the interconnection between the physicochemical and biological components of the aquatic system. Furthermore, the impacts of land-based activities on water quality was found to be intensified by natural calamities such as typhoon that transported huge amount of silt from the eroded river banks and overflow of the adjacent farms and from the mountain slopes where mineral extraction is being carried out.

The water quality could provide information on the current condition of the river ecosystem under study. This showed the need for periodic monitoring and assessment of the stream characteristics specifically those that pose impacts to the phytoplankton and higher organisms in the food chain.

LIMITATIONS AND FUTURE RESEARCH

The conducted study was limited to the evaluation of river water quality in terms of physicochemical and biological properties; thus it is suggested that further studies be done on the levels of toxic elements in water in order to determine the suitability of the river as source of irrigation water and to ensure public health. Investigation on the seasonal occurrence of red tide organisms in Zambales surface and marine waters is likewise recommended.

Acknowledgments

This study was supported by Accelerated Science and Technology Human Resource Development Program - National Science Consortium (ASTHRDP-NSC) and Student Research Support Fund (SRSF) of the Department of Science and Technology (DOST).

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