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Assessment of Physico-Chemical Parameters in Surface Waters of Lake Mahucdam Basin, Tubod, Surigao del Norte, Philippines

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Abstract

The community needs adequate water resources and supplies for vital purposes. The current study was carried out for water profiling in terms of physicochemical parameters of Lake Mahucdam in one (1) year starting February 2019 to January 2020, prior to sustainable lake ecosystem management. The physicochemical analysis was determined using a water checker multiparameter Hanna HI 9829 device. The device measured the Temperature (° C), Dissolved Oxygen (ppm) and percent DO(mg/L), Conductivity(Ms/cm), ORP(mV), pH, Salinity(PSU), Pressure(mmHg), resistivity, TDS (ppt), and Turbidity(FNU). The results indicate the importance of physicochemical assessment in Lake Mahucdam Basin. Primary physicochemical parameter water criteria such as surface water temperature increase 5 °C from cooler months to summer, pH is from neutral to slight alkalinity level, dissolved Oxygen and saturation of DO is low, and salinity level is within the freshwater saline quality. Among the physico-chemical parameters, water temperature, conductivity, pH, total dissolved solids and turbidity is within permissible limits, but the dissolved Oxygen is very low as compared to the set international and national water quality standards at the time of the study.

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Introduction

Management of Lake Ecosystem prevents the possibility of deterioration and safeguarding aquatic organisms and provides safety with direct needs of its services such as waters and food sources. Several scientific procedures and tools are available to measure water quality analysis, such as physicochemical properties to determine its present conditions prior to management and further use.

Clean drinking water is now recognized as a fundamental right of human beings and to ensure safety, physical and chemical Analysis is basically carried out (Rahmanian *et al.,* 2015). These procedures include the Analysis of different parameters such as pH, turbidity, conductivity, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), and heavy metals. These parameters can affect the drinking water quality if their values are in higher concentrations than the safe limits set by the World Health Organization (WHO) and other regulatory bodies (WHO, 2011). The quality of water generally refers to the component of water present at the optimum level for suitable growth of plants and animals. Aquatic organisms need a healthy environment to live in and adequate nutrients for their growth; the productivity depends on the physicochemical characteristics of the water body (Umerfaruq and Solanki, 2015). Knowledge of the hydrological conditions of a body of water is most vital when assessing its productivity and other characteristics (Adebisi, 1981). Water quality standards for recreation are focused on the prevention of waterborne infections (Schroeder, 2003). Most standards group substances into five categories: Microbiological; Inorganic with consequences on health; Organic with consequences on health; Appearance; and Radioactive components (Scholz, 2016). The limits set by World Health Organization-WHO designated 'permissible apply to a water that would be generally acceptable by consumers; values greater than those listed as ' excessive ' would markedly impair the potability of the water (Wagner and Lanoix, 1959). However, authorities for setting standards for domestic wastewater discharges are given under the Clean Water Act, while standards for recreational waters and wastewater are determined by the individual states (Gerba and Pepper, 2019).

Since water is of necessity to man, animals, and plants, it is of greater importance to assess its quality so as to proffer guidelines for its sustainable usage or take corrective steps to ensure its quality. Lake Mahucdam in Tubod Surigao del Norte was reported by Palma and Bartolome (2015) of BFAR that the Lake has potential for multi-purpose uses for fisheries, navigation, source of raw materials for handicraft, drinking water, domestic water supply, and recreation, and for tourism activities, and in line with the biodiversity partnership and the proposal for declaring the lake basin as a protected watershed reserve and need for water profiling.

The Community Watershed in Mt. Maniayao is delineated and declared where crater Lake Mahucdam basin is located and as the water source is protected and easements. A one (1) year study was conducted in Lake Mahucdam focused on the physic-chemical parameters of the Lake Mahucdam basin and compared them to the water quality standards. The result of the study would provide the basis for the sustainable management of Lake Mahucdam.

Methodology

Study area

A reconnaissance and communications letter for the LGU, Tubod and barangay officials was prepared and approved for the conduct of the study. The study was conducted in Lake Mahucdam, Tubod, Surigao del Norte, Philippines. The Lake Mahucdam basin is a crater lake formed beneath the foot of Mt. Maniayao rich with biodiversity and eminent with tall coconut, tree species, fern allies and shrub plants. The west south portion of the Lake vicinity is inhabited by households. The deepest part is the northeast portion of the Lake and the lake outlet at the south is dominated by *Nymphae sp.* The basin of the Lake is used for navigation, fishing, and the very shallow areas are used for cattle wallowing.

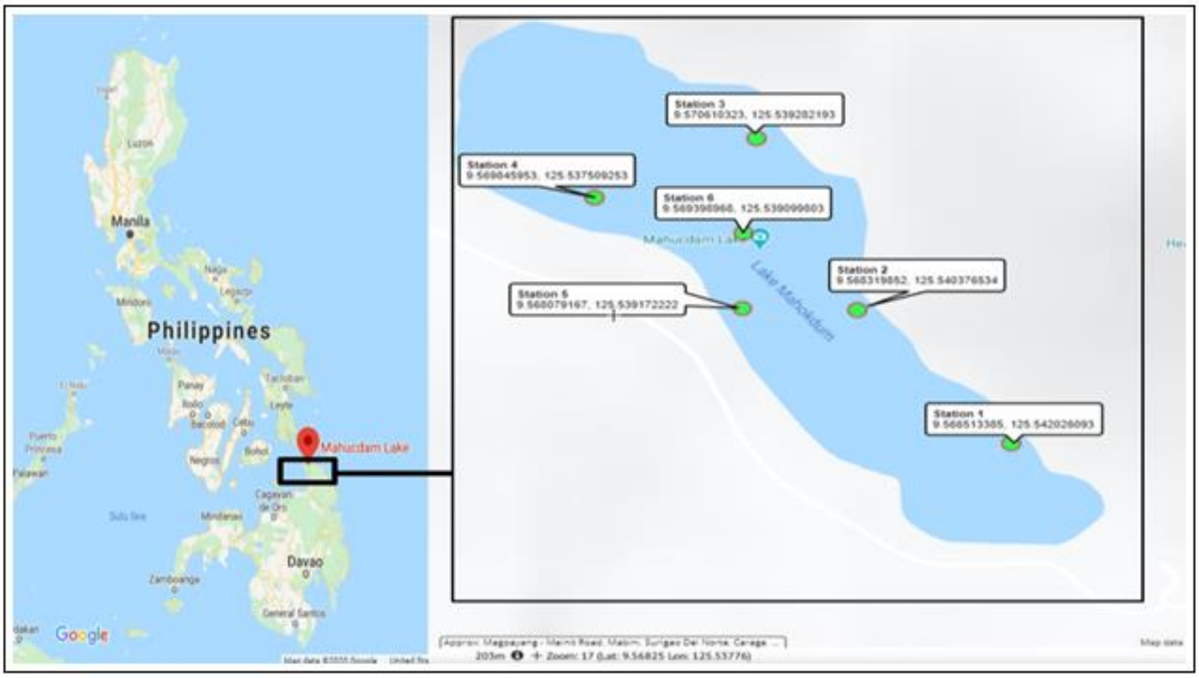

Fig. 1. The Research locale of the study area. [Coordinates: (Station 1, 9.566513385, 125.542026093) ; (Station 2, 9.568319852, 125.540376534); (Station 3, 9.570610323, 125.539282193); (Station 4, 9.569845953, 125.537509253); (Station 5, 9.568079167, 125.539172222); (Station 6, 9.569398968, 125.539099803)].

The coordinates of the area and respective sampling sites were obtained using GPS and mapped using a scribble map created, as shown in Fig. 1.

Establishment of Sampling Sites

A total of six (6) stations were established in the Lake Mahucdam. The Station 1 located at the lower portion in the Lake where runoffs or n area as outlet of the Lake. Station 2 and 3 were located at the east and north upper part of the Lake and the station 4 and 5 located at the west opposite shore of station 2 and 3. Station 6 was located at the center of the Lake.

Data Gathering Procedure

The physic-chemical parameters measured such as Temperature (o C), Dissolved Oxygen (ppm) and percent DO(mg/L), Conductivity(Ms/cm), ORP(mV), pH, Salinity(PSU), Pressure(mmHg), resistivity, TDS (ppt), and Turbidity(FNU). The Analysis of physico-chemical was done with the used of water checker multiparameter Hanna HI 9829 device.

The probe was immersed 30 cm from the surface to the water column. The sampling was done only once a month started from February 2019 to January 2020.

Data analysis

The descriptive Analysis was performed using the MS. Excel 2010 to determine the mean of each physic-chemical parameter. The data was compared to the water quality standards of WHO and DENR.

Results

Physico-chemical Analysis

The physico-chemical parameters are essential and important to test the water before it is used for drinking, domestic, agricultural, or industrial purposes. Water must be tested with different physico-chemical parameters. The selection of the tested parameters depends on the purpose of using that water and to what extent we need its quality and purity (Dirican, 2015). However, the physico-chemical analyses in the Lake Mahucdam were limited to and used only the water checker multiparameter Hanna HI 9829. The parameters such as temperature, Dissolve Oxygen, conductivity, pH, resistivity, salinity, TDS, Turbidity, Pressure, Oxidation-Reduction Potential, were measured in six (6) stations of the Lake Mahucdam for one (1) year duration started February 2019 to January 2020 was presented in Table 1.

Table 1. The physico-chemical Analysis obtained from the water column of Lake Mahucdam from February 2019 to January 2020.

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Temperature (°C)	29.78	29.74	30.15	30.56	30.61	30.07
Dissolved Oxygen (ppm)	2.23	2.62	2.75	3.03	3.15	3.01
%DO(mg/L)	36.45	41.88	43.70	46.80	49.88	47.52
Conductivity(Ms/cm)	47.33	48.08	48.00	48.11	47.81	48.00
ORP(mV)	144.46	157.05	159.93	153.91	162.96	162.28
pH	7.85	7.93	8.16	8.19	8.13	8.17
Salinity(PSU)	0.02	0.02	0.02	0.02	0.19	0.02
Pressure(mmHg)	14.48	14.50	14.49	14.49	14.50	14.49
resistivity	0.02	0.02	0.02	0.02	0.02	0.02
TDS (ppt)	23.58	24.03	23.97	24.03	23.83	24.00
Turbidity(FNU)	5.63	5.73	6.39	6.50	6.83	6.58

Legend: DO- dissolved Oxygen, ORP- Oxidation-Reduction Potential, TDS-Total Dissolve Solids, FNU-Formazin Nephelometric Unit. PSU- Practical Salinity Unit.

The value of the temperature ranged from 29.78 °C to 30.61 °C, whereas station 4 has the highest water temperature. Dissolved Oxygen values ranged from 2.23 ppm to 3.15 ppm, whereas the lowest DO was observed in station 1, and as the DO increased, the percent dissolve(%DO) also increased. Conductivity values ranged from 47.33 to 48.11 Ms/cm, whereas the highest conductivity was recorded in station 4. The ORP- Oxidation-Reduction Potential mean values ranged from 144.46 mV to 162.96 mV, whereas station 5, was the highest ORP value. The pH mean values ranged from 7.85 to 8.19. Uniform salinity of 0.02 was recorded in all five (5) stations except station 5 with a 0.19 salinity level.

The water pressure mean values were recorded within 14 mmHg. Uniform values of resistivity were recorded in all stations. The TDS-Total Dissolve Solids mean values ranges from 23.58-24.03 ppt and Turbidity values ranged from 5.63 to 6.83.

Table 2. The Physico-Chemical Parameters of the surface water of Lake Mahucdam basin from February 2019 to January 2020.

Parameters	Feb (2019)	Mar	Apr	May	Jun	Jul	Aug	Sep
Temperature (°C)	27.68	29.12	30.65	32.05	31.85	30.07	30.90	30.99
DO (ppm)	0.25	0.37	0.13	0.33	0.00	0.00	5.96	5.55
%DO(mg/L)	3.15	4.92	1.47	4.65	3.55	73.53	82.71	76.80
Conductivity (Ms/cm)	42.39	43.61	45.89	48.50	49.72	59.56	50.56	52.33
ORP (mV)	285.4	234.6	203.7	152.82	164.24	135.54	159.61	98.7
pH	7.54	7.63	7.92	7.82	7.87	8.07	8.21	8.87
Pressure(mmHg)	14.57	14.54	14.60	14.48	14.45	14.44	14.44	14.47
resistivity	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Salinity(PSU)	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
TDS (ppt)	21.06	21.89	22.33	24.67	24.94	30.00	25.17	26.1
Turbidity (FNU)	4.41	3.32	3.23	3.62	4.44	4.51	5.66	7.26

Legend: DO- dissolved oxygen, ORP- Oxidation-Reduction Potential, TDS-Total Dissolve Solids, FNU- Formazin Nephelometric Unit. PSU- Practical Salinity Unit.

Monthly variations of physico-chemical Analysis

Furthermore, the monthly variations of phsyico-chemical parameters were measured from February 2019 to January 2020 and presented in Table 2. The lowest mean water temperature was recorded in January and the highest mean was recorded in the month of May. No detected level of Dissolved Oxygen in the month of June and July, but the percent dissolved Oxygen was the lowest mean recorded in the same months. This might be due to the early or morning sampling time, where the surface basin of the lakes is not yet hit by the sun's rays. However, the highest mean values of DO were observed in the month of October and had the highest percent DO. The lowest mean values of conductivity were recorded in January and the highest mean was observed in July. The Oxidation-Reduction Potential mean values were recorded lowest in the month of October. The pH mean values highest recorded in the month of October and other months are within the pH of 7 above. The water pressure mean values are within the 14 mmHg all throughout the months. A uniform water resistivity mean values were recorded in all months and salinity was below 0.35 in all months. The total dissolved solids mean values were recorded as highest in the month of July and lowest in January. Turbidity was observed in the month of November and less turbidity mean values in the month of April.

Table 3. The annual mean of the physico-chemical parameters of Lake Mahucdam and set of water standards for permissible limits in Domestic Use and Aquaculture.

Physico-Chemical Parameters	Present Study (Annual Mean)	Permissible Limits	
		WHO	DENR
Temperature (°C)	30.15	40 °C	25-32
DO (ppm)	2.80	4-6 ppm	5 ppm
% DO	44.37	nd	40-70
Conductivity (Ms/cm)	47.89	500	nd
pH	8.07	6.8	6.0-90
TDS (ppt)	23.91	1000 mg/L	500-1000 mg/L
Turbidity	6.28	5	*nd*

Comparison of physico-chemical parameters to the standards.

The annual mean of the measured physic-chemical parameters was compared to the international and national water quality standards of the WHO and DENR, respectively.

Table 3 shows the selected primary parameters with available permissible limits criteria. The seven (7) selected parameters were determined to compare to the present study to the permissible limits in domestic and aquaculture as set by the World Health Organization and states agency, i.e., DENR. Dissolved Oxygen, conductivity and TDS is below the set standards. Turbidity is above the WHO permissible limit.

Discussion

The differences and pattern of physico-chemical parameters measured in six (6) sampling stations and 12 months observed may be associated with the adjacent ecological conditions of the forested ridge in the east portion, the residences nearby, the emergence of aquatic vegetation in the outlet of the Lake Mahucdam and local weather patterns. Lakes physicochemical parameters are considered one of the most important factors that are capable of influencing the aquatic environment and have shown wide temporal and spatial differences (Rameshkumar *et al.*, 2019). The water temperature in Lake Mahucdam increases with 5 °C in the beginning of the year as it reaches the peak of the summer months, i.e., in May and the value means 29 °C to 30 °C across stations in one year which all values are within the values range classified to Class D (DAO, 1990). Water temperature is influenced by a wide range of heat inputs and outputs such as solar radiation, convection from the air, conduction from the soil, and net longwave radiation from the local environment to the river system (Harvey *et al.*, 2011). Dissolved Oxygen recorded at zero ppm or non-detectable in the month of June and July may be due to the sampling time early in the morning and DO level being within Class D with 2 mg/L of DENR classification. The dissolved oxygen content of the water of fish ponds is one of the most important parameters of water quality, as Oxygen is a vital condition for all the organisms living in the water and having an aerobic type of respiration. The solubility of Oxygen is influenced by several factors (e.g., air pressure, hydrostatical pressure, salt content), but in pond fish farms, it is generally enough to consider only water temperature (Kepenyes & Váradi, 1983; Trick *et al.*, 2018). In freshwater, DO reaches 14.6 mg/L at 0 °C and approximately 9.1, 8.3, and 7.0 mg/L at 20, 25, and 35 °C, respectively, and 1 atm pressure. At temperatures of 20 ºC and 30 °C, the level of saturated DO is 9.0-7.0 mg/L. Low Oxygen in water can kill fish and other organisms present in water. For a living organism, about 4 mg/L of minimum DO should be in the water (Patel and Vashi, 2015).

Furthermore, the water pH in Lake Mahucdam Basins was slightly alkaline in four stations (Stations 3, 4,5,& 6). Neutral pH was recorded at stations 1 & 2 where aquatic plants emerged. Further, water pH in the sampling area was observed to be neutral from December and January to June however an increase in pH 8 from July to November. The highest pH of 9 makes the lake waters slightly alkalinity level. The pH level of Lake Mahucdam across the station is within the DENR freshwater standards, but monthly it is classified as Class D. The increasing and dropping of pH from 7.51 to 9.0 was probably due to the stirring effect of the incoming flood from the rivers and streams that converged towards the Lake resulting in the mixing of the poorly alkaline or acidic bottom waters with alkaline surface waters to reduce pH Also the decrease in pH of the surface waters in November and December was due to decomposition of the inundated terrestrial vegetation of the littoral zone following increased water levels. Decomposition reduces the amount of Oxygen while increasing the amount of carbon dioxide in the affected environment (Araoye, 2009). Further, pH was the most important predictor of the distribution of macrophytes (Pereira *et al.*, 2012). The ORP was observed lower at the station of the present study due to the emergence of aquatic plants. However, the slow kinetic of dissolved Oxygen, mixed potentials from aerobic systems are dominated by traces of reductants rather than by the actual oxygen concentration. The aerobic respiration that is the cause for the parallel decline of Oxygen and pH when stratifications start did not measurably affect the redox conditions. pe7 values remained positive between 7 and 9 as long as traces of Oxygen were present (Eckert and Trüper, 1993). Horizontal water pressure is chronic that is constant at 14 mmHg in this present study. Horizontal pressure gradients will be important in lakes where there are significant inflows of water with markedly different densities from ambient lake density or where significant differential surface heating occurs (Rafferty, 2011). The turbidity is founded clearer during the months of less rainfall, considering that Surigao del Norte has type II climatic conditions and high turbidity recorded in the months of higher rainfall or rainy seasons that due to loads of soil particulates or suspended solids in the lake basin. The variation of turbidity in the reservoir has clear seasonal trends, which is considered a result of the seasonal variation of inflow and outflow volume (Wang *et al.*, 2010). This phenomenon is often due to terrigenous particles delivered to lakes and reservoirs and the turbidity load from the tributary usually enters the reservoir as a turbid density current during runoff events, at a depth predicted well by stream temperature (Prestigiacomo *et al.,* 2008). The total dissolved solids in the horizontal surface waters of the Lake were recorded only between 23 and 24 parts per thousand; however, variations in TDS level are highly affected by season based on the monthly monitoring. The TDS-Total dissolved solids have a relation to the conductivity. Water conducts electricity, but the dissolved minerals (ions) in water are what actually conduct the electricity, so the more dissolved minerals in the water, the more conductive the water becomes (Scherer, 2019). In theory, natural waters contain a mixture of various different salts and the depression of EC& with increasing total salt concentration, then becomes even greater due to both physical and electrical ionic interactions. The bicarbonate ion, in particular, has a rather low molar conductance, and since it is often a dominant ion in natural (fresh) water systems, it often exerts a marked depressive effect on the conductivity of freshwater, so that the TDS/EC relationship (K value) increases dramatically (Walton, 1989). Moreover, the salinity and resistivity were recorded in uniform throughout the year. In theory, resistivity is the ability of a material (such as water) to resist the flow of electricity (APHA, 2005). Resistivity is the reciprocal of conductivity, such that values of conductivity of 40 to 60 mV in all stations and in all months reciprocate to the value of resistivity of 0.02 in the present study. Aquifer resistivity values can change rapidly within a short distance reflecting the rapid changes in salinity (Attwa *et al.,* 2016). Freshwater is less saline means also less conductivity. However, dissolved solids help conduct electricity when TDS is high; it also reflects levels or the ability of water in conduction, while as TDS increase, salinity increase, resistivity decrease due to high ions availability once TDS or salinity increase (Parry, 2018). Tropical lakes are more sensitive than temperate lakes to increases in nutrient supply and show greater proportionate changes in water quality and biotic communities in response to eutrophication. Tropical lakes are especially prone to loss of deep-water Oxygen, and in order to maintain ecological stasis, therefore, require more stringent regulation of organic and nutrient loading than temperate lakes (Lewis, 2020).

Conclusion

The results indicate the importance of physicochemical assessment in Lake Mahucdam Basin. Primary physicochemical parameter water criteria such as surface water temperature increase 5 ^{o}C from cooler months to summer, pH is from neutral to slight alkalinity level, dissolved Oxygen and saturation of DO is low, and salinity level is within freshwater saline quality. Among the physicochemical parameters, water temperature, conductivity, pH, total dissolved solids and turbidity is within permissible limits, but the dissolved Oxygen is very low as compared to the set international and national water quality standards at the time of the study. Future research will address the integration of the reservoir's physical factors with chemical and biological dynamics. This will further our understanding of reservoir systems and strengthen our decision-making capability for Lake Mahucdam regulation and management.

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