MICROBIOLOGICAL ANALYSES AND WATER QUALITY ASSESSMENT IN FIVE MUNICIPALITIES ALONG LAKE LANAO, PHILIPPINES

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ABSTRACT: *Lake Lanao is one of the ancient lakes in the world and the second largest lake in the Philippines. At present, the lake is considered pristine, however, the biodiversity potential of the lake is now being threatened by various human activities such as the discharge of wastes from municipal sewers. Municipal sewage contains human faeces and water contaminated with these effluents may contain pathogenic (disease-causing) organisms and consequently, may be hazardous to human health if used as drinking-water or in food preparation. Meranao, the local dwellers of the lake depend largely on this body of water as their source of food and drinking water. Hence, the present study evaluates the water quality of Lake Lanao using microbiological analyses specifically along with five municipalities: Tamparan, Taraka, Wato-Balindong, Tugaya, and Bacolod-Kalawi Lanao del Sur. The study was conducted for three months of sampling periods. Findings showed the presence and the estimated number of coliform bacteria that may be associated with the occurrence of waterborne diseases in the surrounding municipalities.*

Keywords: Microbiological analyses, Water quality, Environmental monitoring, Lake Lanao

I. INTRODUCTION

Lake Lanao is one of the most important inland body of water in the Philippines. It is considered the second largest inland aquatic resource and the biggest and deepest freshwater lake in the Philippines. The Lake has been a very important source of living for most of the dwellers around the lake for years [1]. Meranao, the local dwellers of the lake depend largely on this body of water as their source of food and drinking water. Thus, important monitoring researches and water quality studies must be done on this God-given gift to mankind so that proper conservation and protection policy will be formulated along with the protection and preservation of human health.

Previous researches about Lake Lanao in the past focused on its status [2], limnology [2, 3], watershed [3], management [4], fisheries [5,6], and phytoplankton [7]. The only microbial study focusing on water quality assessment of the lake was conducted by Omar [8] and recently by Angagao [9]. Omar [8] studies on microbiological water quality analyses on selected stations in Lake Lanao revealed that the lake water is unsafe for direct water consumption. Angagao *et al.*, [9] further showed that Lake Lanao can be categorized as "Class A" or whose waters require complete treatment to meet national standards of drinking water.

A study has shown that microorganisms are widely distributed in nature, their diversity and density may be used as an indicator for the suitability of water for human [10]. The use of bacteria as water quality indicators can be viewed in two ways. Firstly, the presence of such bacteria can be taken as an indication of fecal contamination of water, and secondly, it can be taken as an indication of the potential health risk that fecal contamination poses. The higher the level of indicator bacteria, the higher is the level of fecal contamination, and the greater the risk of water-borne diseases [11]. Fecal contamination of surface waters used for recreation, shell fishing, or drinking water can pose a serious threat to human health [10,12].

Continues monitoring and water quality analysis another part of the lake is therefore needed in order for the residents to gain awareness on the present condition of the lake and consequently, enlighten the local residents as to how human activities, industrial activities, and agricultural activities can affect the water quality of the lake not only in ecological aspects but especially on the potential health risks associated with improper wastes disposal like water-borne diseases. Levels of fecal coliform bacteria in streams and lakes are often used as indicators of microbial water quality instead of specific monitoring for disease-causing organisms. In-depth information for assessing microbiological water quality in lake Lanao is important for the regulatory agencies for creating regulatory policies. Hence, the present study aims to further monitor the quality of lake water in Lake Lanao along with the five selected sampling sites.

2. METHODOLOGY

A. Locale of the Study

The study was conducted in June, September, and October 2016 around five municipalities at Lake Lanao, Lanao del Sur particularly along Wato-Balindong, Tugaya, and Bacolod Kalawi on the western bank; Tamparan and Taraka on the eastern bank. Figure 1 shows the plotted coordinates of the five sampling sites using google GPS.

Figure 1. Topographic view of Lake Lanao in Lanao del Sur showing the five sampling sites (in red) (gps.visualizer.com. Accessed on Dec 17, 2017).

B. Collection of Water Samples

Water samples from each of the five sites were obtained from the shoreline moving towards the middle of the lake in five stations, which were five meters apart. Using 300 ml pre-labeled sterilized glass bottles, a water sample was obtained within one meter deep in three replicates and mixed together as a composite sample. and brought and processed in the Microbiology laboratory of the Biology department, Mindanao State University-Marawi.

D. Coliform Tests for Water Quality Analysis

Multiple Tube Fermentation Test-Presumptive Test. Double Strength Lactose Broth (DSLB) and Single Strength Lactose Broth (SSLB) were used following the Multiple tube fermentation testing. The tubes were incubated at 37°C for 48 hours for total coliforms. After incubation, the gas formation was observed in the broth tubes. Gas formation (presence of a bubble in the inverted tube), indicates that coliforms are present in the water sample. The number of tubes positive for gas formation were noted and used to determine the most probable number of coliforms in the water sample. The most probable number (MPN) of coliforms was determined using the MPN Table [13].

Confirmed Test. For the confirmatory test, Eosin Methylene Blue (EMB) Agar was used following the confirmed test method for Coliform testing. After incubation, EMB plates were checked for the presence of a colony showing a metallic green sheen which indicates the presence of coliform [14].

Completed Test. EMB agar plates showing metallic green sheen colonies were subjected to a completed test. The completed test was done by inoculating a loopful of bacteria from positive EMB plates into tubes of Single Strength Lactose Broth culture medium and incubated for 24 hours at 35 degrees Celsius. After incubation, tubes were examined again for gas and acid production to confirm the presence of coliforms. Bubble inside the inverted Durham tube and red color turning into yellow color of the medium indicates positive results for gas and acid formation respectively. A smear was then prepared for positive results [14] observed under the phase-contrast microscope with a built-in camera and examined for the presence of Gram-negative (pink to red in color) short rod-shaped bacteria under HPO and OIO.

3. RESULTS AND DISCUSSION

Table 1. Summary of bacterial abundance obtained from the surface water of Lake Lanao collected from the five sampling sites during the three sampling periods.

Table 1 shows the summary of bacterial abundance

SAMPLING SITES	COLONY FORMING UNITS (CFUs) /ml			
	June 2016	September 2016	October 2016	Mean
Bacolod-Kalawi	1.65E+07	8.07E+03	7.36E+02	**5.50E+06**
Wato	6.59E+06	9.08E+02	4.88E+02	**2.20E+06**
Tugaya	6.26E+02	2.55E+04	1.06E+03	**9.07E+03**
Taraka	9.95E+03	1.13E+04	7.68E+02	**7.33E+03**
Tamparan	6.10E+03	1.35E+04	6.42E+02	**6.76E+03**
Mean	**4.62E+06**	**1.19E+04**	**7.38E+02**	**1.54E+06**

Table 1 shows the summary of bacterial abundance in the five sampling sites during the three months sampling period. Mean bacterial abundance obtained ranged from 6.76E+03 to 5.50E+06cfu/ml. Abundance varies from one sampling site to another and also varies from one period to another. June 2106 had the highest total mean bacterial abundance with a value of 4.26E+06 cfu/ml followed by September 2016 with 1.19E+04 cfu/ml and lastly October 2016 had the lowest abundance with only 7.38E+02 cfu/ml.

One possible reason for the increased abundance in June 2016 was that the month of June 2016 marked the onset of the rainy season after the country has experienced long months of drought due to El Niño phenomenon from December 2015 to May 2016. Heavy rains wash off nutrients and other organic matter from the soil and other environment and cause entry of runoff from land carrying litter and other organic material. Loads of organic matter and nutrients serve as carbon and other nutrients sources used by the microorganisms for their metabolism and reproduction, thus, increasing their abundance. It was also observed that as a result of long months of drought, the water level was very low (as low as twelve inches) for stations 5-10 meters away from the shore. For this reason, some microorganisms in sediments might have mixed up onto the surface water column, increasing the bacterial abundance in the water.

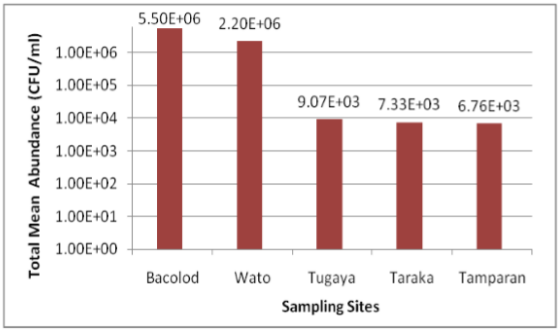

Figure 2 Comparison of Total Mean Bacterial Abundance among Five Sampling Sites.

Figure 2 shows the comparison of the total mean abundance of bacteria among the five sampling sites. As shown, the highest total means an abundance of bacteria was observed in Bacolod-Kalawi with a total mean abundance of 5.50E+06 cfu/ml, followed by Wato (2.20E+06 cfu/ml), Tugaya (9.07E+03 cfu/ml), Taraka (7.33E+03 cfu/ml) and the lastly in Tamparan with only 6.76E+03 cfu/ml.

The observed differences in the bacterial abundance in the surface water of the five sampling sites could be attributed to the characteristics of each sampling site that may lead to increased or decreased abundance. This may include the availability of oxygen and nutrients in the site that could support bacterial growth. Figure 3-7 shows the characteristics of the five sampling sites.

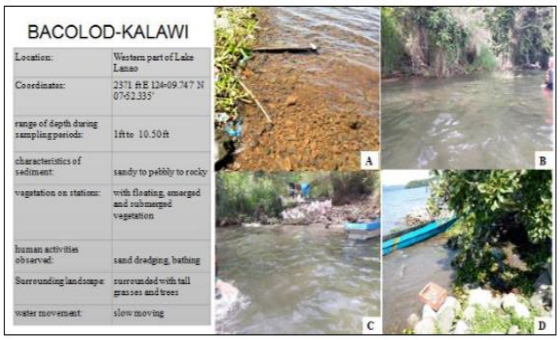

Figure 3 Photograph of Bacolod-Kalawi sampling site showing its clear water (A), thick surround ding vegetation (B), and bags of sands coming from the sand dredging activity in the area (C&D).

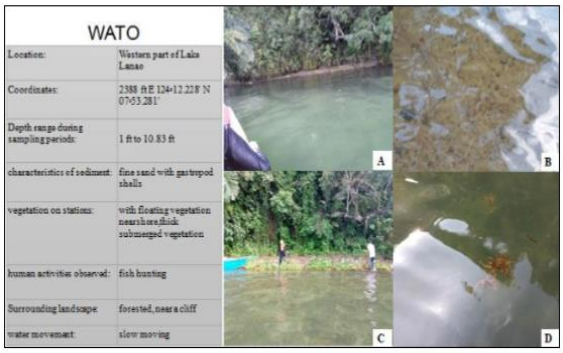

Figure 4. Photograph of Wato sampling site showing the forested landscape surrounding the site (A), its clear waters (B), and its floating and submerged vegetation (C&D).

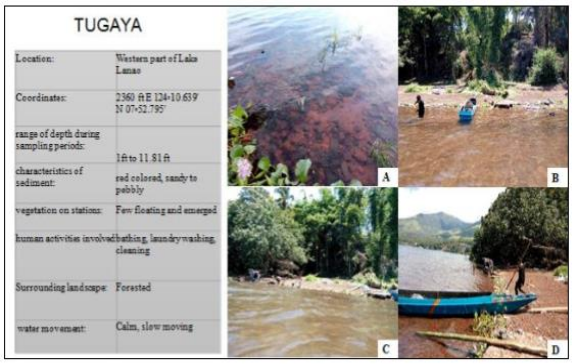

Figure 5. Photograph of Tugaya sampling site showing clear water and reddish pebbly sediment (A), forested landscape (B), and human activities observed (C&D).

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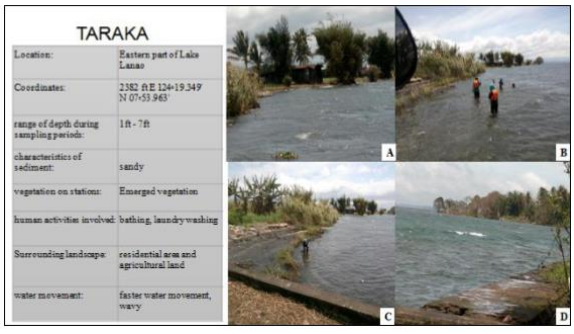

Figure 6. Description and photograph of the Taraka sampling site showing the presence of residential houses and some human activities observed in the area (A&B) sandy sediments (C) and dense vegetation (D).

Figure 7. Description and photograph of Taraka sampling site showing the presence of residential house and some human activities observed in the area (A&B) sandy sediments (C) and dense vegetation (D).

In summary, the abundance of bacteria in the surface water of Lake Lanao could be attributed to the amount of organic matter received from external (allochthonous) sources of organic matter from the surrounding terrestrial landscape. Most of the allochthonous materials end up in lakes as dissolved organic carbon (DOC) which are actually a diverse mix of root exudates, microbial metabolites and decaying plant material and organism remain which presence may affect the physical, chemical and biological properties of the lake. Moreover, various allochthonous compounds can be metabolized by microorganisms, primarily heterotrophic bacteria, thus, contributing to the high bacterial abundance during the sampling periods.

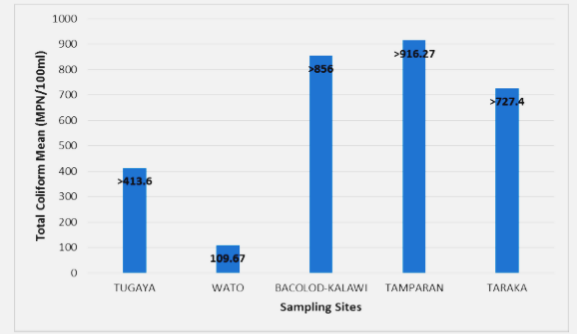

Figure 8 Comparison of the average total coliform (MPN/100ml) in every sampling site.

Figure 8 shows the comparison of the total coliform in the five sampling sites for all the sampling periods. THE Highest MPN with a value of > 916.27/100ml was recorded in water samples collected from Tamparan, followed by Bacolod-Kalawi (>856/100 ml), Taraka (>727/100 ml), and Tugaya (>413.6/100 ml). THE lowest MPN was recorded in Wato with the only 109.67/100ml. The five selected sampling sites showed different physiognomies and anthropogenic activities observed, hence, the level of coliform contamination also varies.

Recreational water quality standard which has to be met to be considered safe for swimming purposes should have an MPN of 200/100mL. Based again on the results, all the sampling sites were considered unsafe for this purpose except for Wato with an MPN of the only 109.67/100ml. DENR classified Lake Lanao as a water source of class A [15].

Class A are sources of water supply that will require complete treatment (coagulation, sedimentation, filtration,

and disinfection) in order to meet the National Standards for Drinking Water (NSDW) and has maximum limits of total coliform of 1,000/100 ml MPN and maximum limit for fecal coliform of 100/100ml [15]. Based on the results of multiple tube fermentation tests, all the sampling sites still met the criteria for the class A water source. It means it can still be used as a water supply source given that it has to undergo complete treatment[8].

The results of this study further confirm the findings of Omar [7] who also detected the presence of total and fecal coliform in the water of Lake Lanao along with Ganassi, Marantao, Ramain, and Marawi City, which implies unsafe water quality for direct consumption

4. CONCLUSIONS

This study focused on the assessment of water quality and evaluation of coliform contamination of the surface water of Lake Lanao along with the five sampling sites for three months sampling periods.

Coliforms were present in all of the established sampling sites and in all sampling periods. All sampling sites showed positive results for the presence of indicator bacteria, *Escherichia coli* which suggests that lake water cannot be used as a source of drinking water unless purified. The Most Probable Number of total coliforms ranged from 109.67/100 ml to >916.27/100 ml. THE lowest MPN index of total coliform was recorded in Wato while the highest MPN was recorded in Tamparan. All sampling sites had an MPN index exceeding the Philippine standard for drinking water which is <1.1/100ml. However, Lake Lanao has still met the criteria set by DENR for Class A water source for having an MPN not exceeding 1000/100ml which means that Lake Lanao can still be a source of water given that it undergoes processes of purification.

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