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Microbial Water Quality Assessment in Lake Lanao Along Marawi City, Lanao Del Sur, Mindanao, Philippines

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Abstract

Surface waters such as lakes and rivers are utilized by many individuals for domestic use including drinking. However, waterborne disease outbreak due to poor quality water of these natural resources has continually caused high morbidity and mortality rates in many areas of the world. Our study focuses on assessing the microbial quality of water in Lake Lanao along Marawi City, Lanao Del Sur, Mindanao, Philippines. We used Heterotrophic Plate Count (HPC) to determine the general load of heterotrophic bacteria and Multiple Tube Fermentation for total coliform count and determine the presence of the fecal coliform, *E. coli*. We also run a household survey covering the inhabitants' use of the lake's water and self-reported waterborne-related diseases to trigger formulation of right actions in relation to the resulting water quality. Our results showed positive presence of the mentioned water quality indicator bacteria that goes beyond the accepted value of HPC (HPC >500 CFU/ml) and MPN (MPN >16/100ml). These figures indicate that Lake Lanao has poor microbial quality of water and could be risky for human use and consumption. Our team recommends improvement of sources for safe drinking water and sanitation, health teaching with high emphasis on boiling the water prior to use, and further development of this research which includes regular monitoring, identification of specific type of microbial indicators, and correlational studies.

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Introduction

The uses of freshwater, from man's basic activities like cooking and bathing, to its functions in the industries, and more importantly, to its role on health, is vital for man's survival. However, poor water quality seems to leave a devastating mark on human lives. Water-borne disease outbreaks (Gall *et al.*, 2015) from various water resources continually cause mortality rate (Gargano *et al.*, 2017) in many parts of the world.

Surface water such as rivers and lakes is used for more than one reason including recreation, agriculture, and household activities particularly in underdeveloped countries (Teklehaimanot *et al.*, 2015). However, because of the natural processes and some anthropogenic undertakings, the quality of water could be affected (Edokpayi, 2017) which makes it too risky for human use or consumption (WHO, 2016).

In the Philippines, specifically in Mindanao Island, water quality has been a top concern (Walag *et al.*, 2018) and the large amount of water pollution of lakes and rivers have led to an overall depreciation of public health in this country (Andrews, 2018). Waterborne microbes have tremendously afflicted Filipinos with diarrhea, cholera, and some skin diseases (World Bank, 2013). In order to meet Sustainable Development Goals by 2030 (United Nations, 2017), the World Health Organization (2016) created the structure of protecting the surface water for health which includes assessment and monitoring of microbial hazards.

Lake Lanao, the largest lake in Mindanao (EMB, 2014), is one of the 17 ancient lakes on earth and is located along Marawi City, in the Province of Lanao del Sur, Autonomous Region in Muslim Mindanao, Philippines (Naga, 2010). Lake Lanao serves as the heart of its people's spiritual, cultural, social, political and economic life. It is an integral part of the inhabitants' domestic use as well, including as a source of drinking water (Naga, 2010). As such, this study was conducted to check the quality of surface water in Lake Lanao through microbial hazard assessment of heterotrophic bacteria and total coliforms particularly, the fecal coliform, *Escherichia coli*. A household survey was also done covering the residents' use of the lake's water, some hygiene and sanitation practices, and self-reported waterborne-related diseases.

The outcome of this study could provide public health safety awareness to the lake's dwellers and form a basis for action in preventing or eradicating negative health consequences of "dirty" water consumption. Moreover, this may serve as a guide for fellow researchers who might feel the urgency to advance or initiate related studies on water quality and safety.

Materials and methods

The study area

The study was conducted in the surface waters of Lake Lanao along Marawi City, Lanao del Sur running along three different barangays (smallest political unit), particularly from those areas near the shore which were mostly populated by the lake's inhabitants. Site A, Barangay Pagalamatan, is located at 07°59′40″N, 124°18′52″E while Site B, Barangay Ambolong, is located at 07°59′42.6″N, 124°18′56.1″E and Site C, Barangay Cadayonan, is located at 07°59′34.5″N, 124°18′48.4″E. These three barangays have a total population of 1, 877 as of May 1, 2010.

Ethical approval

This study was conducted with ethical clearance from the Local Government Unit (LGU). The residents, volunteers, and all those involved were informed about the reasons and importance of this study in their community.

Water sample collection

Five composite surface water samples were obtained by mixing five subsamples that were collected from five different substations within each sampling sites. Collection of water samples in a z-shaped (Fig. 1) pattern were done using sterile glass bottles. All samples then were placed in a cooler and transported to the laboratory.

Estimation of Heterotrophic Bacteria (Heterotrophic Plate Count)

Serial Dilution (10^0, 10^{-1}, and 10^{-2}) and plating (with Nutrient Agar) was used to estimate the presence of heterotrophic bacteria. The triplicates were incubated at room temperature (37°C) for 24 to 48 hours and isolated colonies were counted and expressed in colony-forming units per milliliter (CFU/mL) of water sample.

Estimation of total coliform bacteria

We used Multiple Tube Fermentation technique to estimate the presence of coliforms from the composite water samples. Three critical steps were performed:

Presumptive test

Five 10-mL from each composites samples were inoculated separately into each of five tubes containing 20mL of Lauryl Tryptose Broth and were incubated at 35°C. By the end of 24 hours, tubes with gas formations were marked positive while those which did not (negative) were re-incubated for another 24 hours at the same temperature. All tubes that showed gas production on either 24-or-48-hours were considered to have presence of coliforms in the samples.

Confirmatory test

Tubes that showed positive results from presumptive test were confirmed with EC medium broth and BGLB broth. While the samples inoculated in the former media were incubated at 24 hours at 35°C, the samples in the latter media were still incubated for 24 hours but at 44±0.5 °C.

Those that showed gas production were noted as positive but those which were on the contrary underwent re-incubation at similar temperature for another 24 hours. All tubes then that showed gas production from 24 to 48 hours were considered as positive confirmed tubes.

Completed Test (E. coli Identification)

The final step where organisms from positive confirmed tubes were grown for 24 hours at 35°C by streaking them on plates of Eosin Methylene Blue (EMB) agar. Bacterial growth with green metallic sheen pigment was determined as *E. coli*.

Household survey

Survey questionnaires were distributed to 90 randomly selected households within the barangays near the established sites. It covered self-reported and observed household demographics, sanitation and hygiene facilities, water source type and household drinking water practices. Questions pertaining to the respondent's self-reported diarrhea and reported diarrhea among any children under 5 years of age residing in the house were also included in the survey.

Results and discussion

Estimation of Heterotrophic Bacteria

The result of Heterotrophic Plate Count (HPC) (Fig. 2) showed highest average bacterial colony count in Site A, in Barangay Pagalamatan, with 1,113 CFU/mL; second in Site B, Barangay Ambolong with 870 CFU/ml and; lowest in Site C, in Barangay Cadayonan, with 743 CFU/mL. The data revealed that all three sites exceeded the 500 CFU/mL recommended value for HPC which indicate poor water quality (WHO, 2003).

Heterotrophic bacteria actually comprise a long list of bacteria that utilize carbon sources to thrive, including the non-pathogenic natural microbiota of water (WHO, 2003). And so even with the high HPC result, it does not entirely mean public health risk for it simply showed high general load of aerobic and facultative anaerobic bacteria in the composite water samples (Verhille, 2013). However, HPC method may also include opportunistic pathogens such as *Aeromonas*, *Klebsiella*, and *Pseudomonas* that could put health risk to immune-compromised individuals (Shar *et al.*, 2010).

The study of Amanidaz *et al.* (2015) revealed that whenever heterotrophic bacteria count is high, coliforms and fecal streptococci are high as well.

Table 1. Summary Results of the Multiple Tube Fermentation Technique for Estimating Total Coliforms.

Tube Number	Presumptive		Confirmatory				Completed	
	Lauryl-Tryptose BROTH		EC BROTH		BGLB		EMB from EC	EMB from BGLB
	24	48	24	48	24	48	24	24
A1	-	++	++		++		-	√
A2	-	++	+		++		-	√
A3	++		++		++		√	-
A4	-	++	+++		++		√	-
A5	++		+		++		√	-
B1	++		++		+		-	-
B2	++		++		++		-	-
B3	++		+		++		-	√
B4	++		++		+		-	-
B5	++		++		++		-	√
C1	++		++		++		-	√
C2	++		-	++	++		√	-
C3	++		-	++	++		-	√
C4	++		++		++		-	-
C5	++		-	++	++		-	√

In another study (Horn *et al.*, 2016), the researchers concluded that HPC bacteria have the potential of causing human diseases. These, and possibly more, have prompted regulatory health agencies and some microbiologists to consider HPC as a significant measure to safe water consumption (Allen *et al.*, 2004).

Estimation of total coliform

When HPC is >500 CFU/ml, Swistock *et al.* (2000) suggested to conduct further total coliform and fecal coliform testing which are also covered in this study.

Multiple Tube Fermentation method showed positive gas formation (lactose fermentation) in all composite samples for both presumptive and confirmatory tests suggesting that general types of coliforms are present (Table 1).

Table 2. MPN Index Value in Each Water Sample.

Site	Number of Positive Tubes	MPN index/100mL
A	5	>16
B	5	>16
C	5	>16

The resulting MPN value (>16 MPN/100mL) further proved high degree of positive presence as well. As for *E. coli* (completed test), these types of bacteria manifested in water samples in which Site A obtained the highest presence (100%) while Site B had the lowest (20%) (Table 2).

This study have similar results with Besagas *et al.* (2014) who mentioned that the heavy load of coliforms and *E. coli* in freshwater water sources in Misamis Oriental, Philippines, indicate high possibility of pathogenic microbes, putting great risks to consumers. Moreover, in the surface waters in Dhaka, Nadeem (2019) found out that the major sources of water in the city is abundant with fecal indicator bacteria pointing toward actions to keep the water safe for human activities.

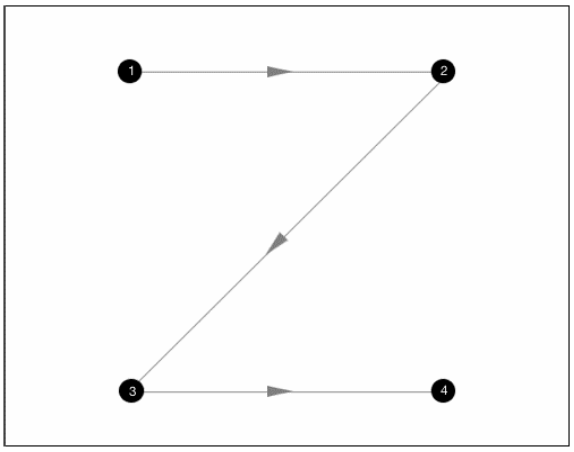

Fig. 1. Illustration of Collecting Samples in Z-shaped Pattern (Patil *et al.*, 1994).

High presence of total coliforms and *E. coli* is affected

by various factors. Total coliforms counts, for instance, are high during summer seasons (Haque *et al.*, 2018; Nadeem, 2019) while *E. coli* are less viable at high temperatures (An *et al.*, 2002). However, correlational method on the factors that affect the growth of microorganisms was never part of this study so it is difficult to point out the most probable causes of such high presence of heterotrophic bacteria, total coliforms, and *E. coli*. Regardless of the cause, it is clear in the results that Lake Lanao,

Mindanao, Philippines has poor microbial water quality that could pose great risks for human consumption (Pachepsky *et al.*, 2014).

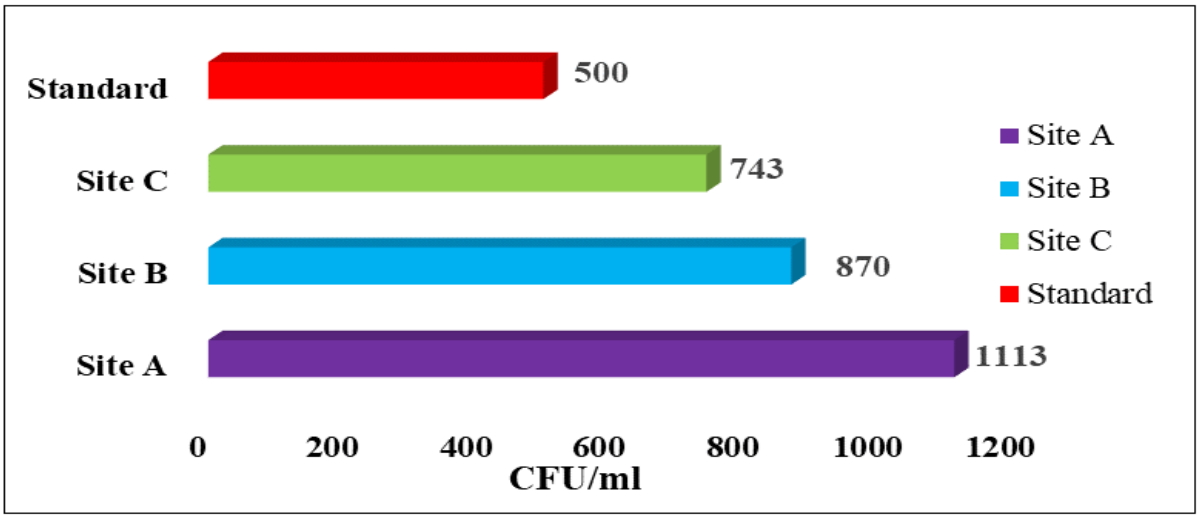

Fig. 2. Average Viable Colony Count (CFU/mL) Estimates in Each Site.

Insights from the household survey

We conducted a household survey simply to show the lifestyle of the residents related to the use of the lake water. The majority of the households surveyed, 80 out of 90 (88.90%), indeed use lake water for all domestic activities including bathing and drinking. Same percentage of households, 80 out of 90 (88.90%), do not boil the water they consume and even when most of the household solid wastes are collected regularly by garbage collectors, some still knowingly dump them into the lake.

In addition to that, 92 individuals had diarrhea two weeks prior to the start of this study. Upon knowing that heavy presence of microbial water indicators in Lake Lanao, it is not difficult to infer its health dangers (Majorin *et al.*, 2014; Okoh *et al.*, 2007) to nearby inhabitants of the lake because of their lifestyle and practices. But although we cannot establish a solid association between the results of our microbial assessment and the data obtained from the household survey, this is enough to trigger mitigating actions and further development of the study.

Conclusion

This study was primarily conducted to assess the microbial hazards in Lake Lanao along Marawi City, Lanao Del Sur, Mindanao, Philippines in the light of heterotrophic bacteria, total coliforms, and the fecal coliform, *E. coli*. Apparently, our results show high degree of microbial hazards (HPC >500 CFU/mL and MPN >16/100mL) which imply that Lake Lanao has poor microbial quality of water and consumption in every way poses great risks to human health. Although correlational study was not done, our household survey speaks a lot of the risks to various kinds of waterborne diseases.

Recommendations

Even when the results of this study do not totally indicate microbial contamination, this should not be neglected because it may still constitute health risks to the population especially to immuno-compromised individuals. In this connection, we suggest executing activities that may prevent disease outbreak related to high heterotrophic bacteria and total coliform count in the surface waters of Lake Lanao. Provision of

improved sources (regulated pipe and water treatments) for safe drinking water and sanitation is recommended for the improvement or maintenance of health by eliminating or reducing waterborne diseases including diarrhea. If other methods of water disinfection are not realistically possible as of this time, it is suggested to bring water to rolling boil as it is the easiest and most effective way to eliminate pathogenic microorganisms even in turbid waters.

The results of this study also calls for a health awareness campaign to the inhabitants of the study area centering on the risks of using the lake's water for all types of domestic use, to emphasize on the boiling of water for household use as an excellent option for disinfection, as well as highlighting the dangers of dumping garbage into the lake and open defecation.

For future developments of this study, it is recommended to conduct regular updating on the microbial water quality of the lake including identification of specific microbial indicators and measurement of physico-chemical parameters which could influence microbial activity. This could help further solutions to reduce microbial load and eventually, elimination of health risks in the area. Moreover, correlational research is also recommended to strongly establish and better understand the association of people's lifestyle or practices and existing waterborne diseases with the resulting microbial quality of surface waters.

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