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Bacteriological examination of the water and sediments in Palhi and Salog rivers in Western Leyte, Philippines

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ABSTRACT

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Rivers around the world are threatened by destruction caused by anthropogenic activities despite the important services they provide for humanity. This study was conducted to determine the water classification and recommended beneficial uses of Palhi and Salog Rivers based on the most probable numbers of total coliforms, and also to evaluate the abundance of heterotrophic bacteria present in the water and sediments of the rivers as potential indicators of environmental disturbance. A Multiple-tube fermentation test was conducted to determine the most probable number of total coliforms in the river waters. Heterotrophic plate count of total aerobic heterotrophic bacteria was determined by counting the colony-forming units that grew on nutrient agar. Geometric most probable number means of total coliforms revealed that only the upstream of Palhi and Salog Rivers could be used for contact recreational activities. The midstream and downstream of both rivers are recommended for non-contact recreational activities only, due to elevated total coliforms. The heterotrophic plate count of total aerobic heterotrophic bacteria of water and sediment samples for the three stations in Palhi River were not significantly different while in Salog River higher numbers of total aerobic heterotrophic bacteria occurred in the downstream compared to the upstream. However, no significant differences on the heterotrophic plate count of total aerobic heterotrophic bacteria levels were found between the water and sediments for the two rivers. The results of this study imply that monitoring and proper management of the rivers should be done by all sectors of the community for the protection of these invaluable resources.

Keywords: Freshwater ecology, indicator bacteria, water quality monitoring, total coliforms, river system, heterotrophic plate count

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INTRODUCTION

Rivers are important natural resources for human consumption, use, and development. Various ecosystem services such as freshwater sources for domestic and agriculture consumption, water regulation, primary production, as well as transportation and recreation purposes are provided by rivers (Martinico-Perez 2019). Beneficial usage of water depends on its water quality, thus maintaining and protecting the quality of water bodies is an important environmental health and resource issue (Bakaj et al 2017).

Despite the services that can be provided, the inland water ecosystem and its catchments are continually altered by human activities. These activities include land conversion, sand and gravel extraction, and indiscriminate disposal of domestic, agricultural, and industrial wastes into water bodies (Martinico-Perez 2019). These wastes could cause chemical pollution and entry of microbial pathogens into the waterways, deteriorating their quality. Such activities and natural processes cause river ecosystems to encounter various water quality problems. These problems include organic pollution, eutrophication, suspension of solids, increased salinity, heavy metal accumulation, presence of nitrate, organic micro-pollutants, and acidification (Meybeck and Helmer 1989, Duong et al 2014, Murray et al 2010, Wang et al 2016). In relation to this, several methods are used to evaluate the overall health and status of rivers, such as assessment based on the physico-chemical parameters and biological indicators.

Microorganisms, as one of the major biological components of rivers, play key roles in ecological processes. They also pose a threat to human health when present in excessive numbers (Apostol et al 2012, Milanez et al 2020). On the other hand, viral, bacterial, and protozoan pathogens can also be used to measure the quality of natural and drinking waters (Ashbolt 2015, Lugo et al 2021). Many studies have used bacteria as a biological indicator in assessing water quality since their presence could provide links to the source of a certain environmental pollutant (Wen et al 2020). Also, they are used as ideal sensors for monitoring microbial pollution because they respond to the changing environment rapidly (Kavka and Poetsch 2002). Therefore, bacteria are used in this study to assess the water quality of Palhi and Salog Rivers found in the province of Leyte, Philippines.

Bacteria are single-celled microbes with no nucleus. They are amongst the most diverse and abundant organisms on Earth and range from helpful organisms that break down dead materials, which provide nutrients and maintenance of the geochemical cycles for ecosystems, to pathogenic bacteria that can cause diseases (Robb 2015). Most of the pathogenic bacteria are found in the feces of animals and humans but some occur naturally in the environment (Ishii and Sadowsky 2008). Water pollution can have several possible sources, so it is better to study bacterial groups rather than just one species. For example, a high abundance of aerobic heterotrophic bacteria could indicate high organic pollution since they makes use of organic compounds as a source of energy and carbon, while the abundance of coliforms can be used as a parameter in the classification and the determination of recommended uses of a particular water body (Bitacura 2019).

Water and sediments are two of the substrates that serve as habitats for bacteria. Biological pollutants as well as physical and chemical pollutants negatively influence the microbial community in the water and sediments (Filimon et al 2010). It was found that sediments have a higher bacterial distribution than water since they act as a reservoir providing food and protection for the microbes. The microbial community is linked to the sources and quality of the organic matter input (Fagervold et al 2014). This may cause increased diversity and abundance of microbes in the sediments where most organic matter settles. This study emphasizes the difference in the populations of total aerobic heterotrophic bacteria (TAHB) in the water and sediments to determine if various disturbances, like livelihood activities or sand and gravel quarrying affect their normal distribution.

Palhi and Salog Rivers are among the many rivers of Western Leyte that are of economic importance to nearby residents. A study regarding the composition and dynamics of plankton communities has already been conducted in Palhi River (Galinato and Evangelio 2016). However, information regarding bacterial examination of the river is not yet available. Examination of the bacteriological components in the two rivers may aid in determining if there are signs of pollution or deterioration of water and sediment qualities. Thus, this study aimed to use biological components, namely total coliforms, and aerobic heterotrophic bacteria as bioindicators to examine the current status of the water and sediments in the Palhi and Salog rivers, and identify possible sources causing the deterioration of the rivers.

MATERIALS AND METHODS

Collection of Water and Sediment Samples

Water and sediment samples were collected in Palhi River of Baybay City and Salog River of Hilongos, according to the method described by Bitacura (2019) and Zhang et al (2015). Three replicates of water and sediment samples were taken from every station (upstream, midstream, and downstream) established at each site. Physical observations such as turbidity, odor, and suspended solids of the water were recorded. Interviews concerning the uses and importance of the two rivers to the locals were conducted for additional information. Geographic coordinates were taken at each station using a handheld Global Positioning System (GPS) during sampling and coordinates were mapped using Google Earth Pro (2018) (Figure 1).

Bacteriological Analyses

Media preparation

Lactose broth was used to determine the most probable number (MPN) of total coliforms (TC) per 100mL of water samples (MPN per 100mL) (APHA 1946) while nutrient agar (NA) was used to quantify total aerobic heterotrophic bacteria (TAHB) present in the water and sediment samples (Ichor et al 2014). They were prepared according to the method described by Bitacura (2019). All prepared media were autoclaved at 121ºC, for 15mins (Bartram and Ballance 1996, Black 1993).

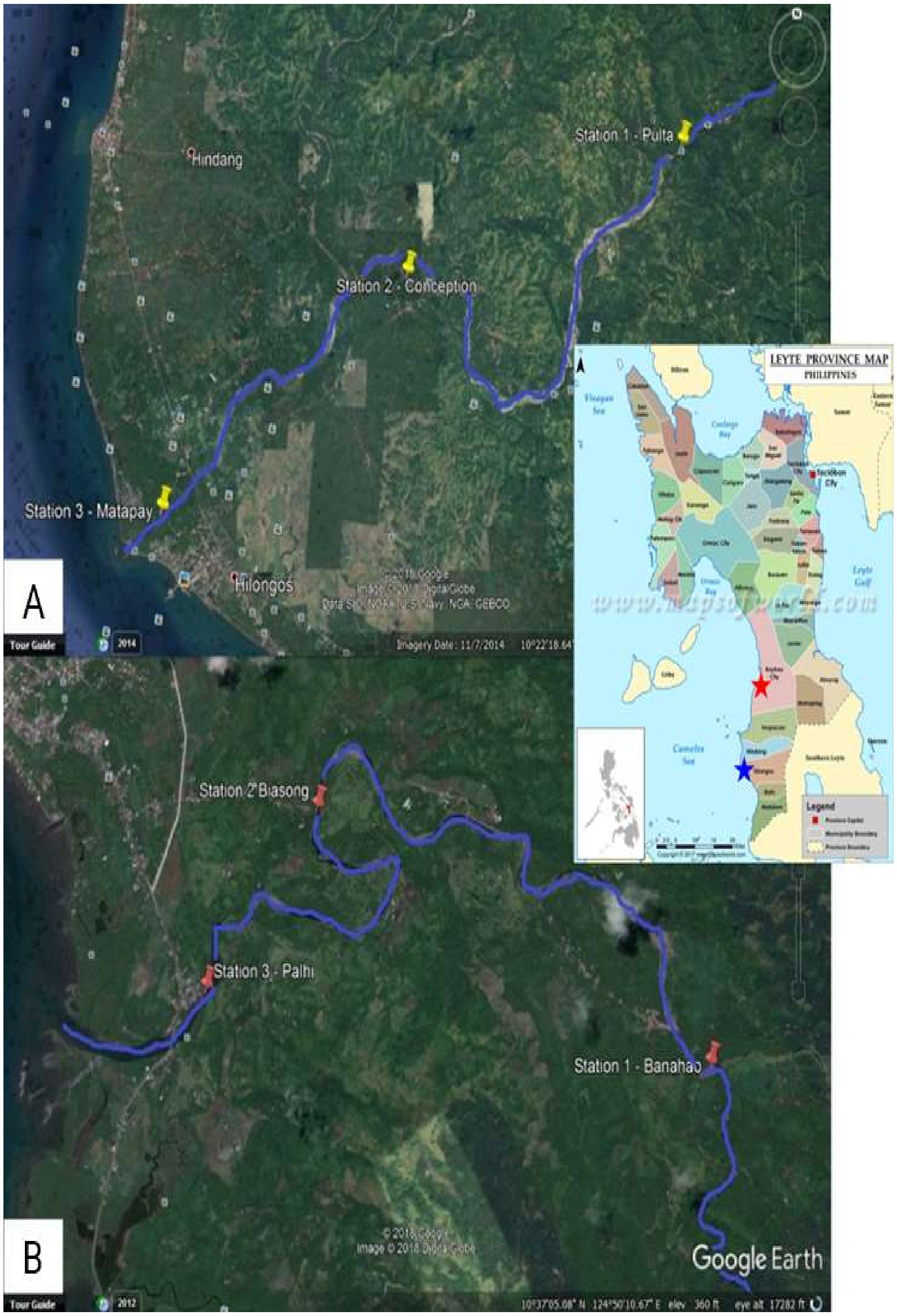

Figure 1. Map of the two sampling sites located in Western Leyte: (a) Salog River, Hilongos (yellow pins for stations) and (b) Palhi River, Baybay City (red pins for stations). Map source: Google Earth Pro, 2018. Photo insert is the map of Leyte showing the location of Baybay City (red star) and Hilongos (blue star)

Bacteriological examination of the water and sediments

Determination of the most probable number of total coliforms

The Most Probable Number (MPN) of total coliforms in the water samples was determined by Multiple Tube Fermentation Test (MTFT) according to the method described by Bitacura (2019). The geometric mean of the MPN values was then referred to the DENR Administrative Order No. 34, Series of 1990 to determine the water classification and recommended beneficial uses of the river stations.

Quantification of total aerobic heterotrophic bacterial load

The water samples were initially diluted at 1:10 (or 1^{-1}) and further diluted until 1:100000 (or 1^{-5}). The diluted tubes of 1^{-3}- 1^{-5}mL were were transferred into 9.9mL of molten nutrient agar in triplicates. The plates were sealed, inverted after the medium solidifies, and incubated at room temperature for 24-48h. The same method was applied for sediments except, 1g of sediment sample was used in the dilution process. Aliquots of the diluted samples (0.1mL) were plated on sterile nutrient agar. After incubation, the number of colonies was counted. From the colonies counted on the plates, the total aerobic heterotrophic bacteria (TAHB) of the water and sediment samples was determined and recorded as heterotrophic plate count (HPC) expressed as colonies forming unit (CFU) mL^{-1} or g, respectively. For each specific station, CFU mL^{-1} and CFU g^{-1} were compared to see whether the water or the sediment count was higher.

Determination of Physico-Chemical Parameters

The physico-chemical properties of each sampling station were measured using different parameters including air and water temperature, water depth, current velocity, dissolved oxygen (DO), and pH. Water and air temperatures were determined using a thermometer. Water depth was measured using the calibrated meter stick. Current velocity was determined through the Drift Method using a ping-pong ball. DO meter was used to determine the level of dissolved oxygen in the water while water pH was determined using pH paper. Three readings were recorded for each of these factors at each sampling station.

Statistical Analysis

Two-stage Nested design was used to incorporate the mean HPC results for the samples and the three stations in a site. ANOVA was used to determine if there are significant differences in the abundance of TAHB in the waters and sediments among the three sampling stations in the Palhi and Salog rivers followed by post-hoc comparison of means using Tukey's Honesty Significant Differences (HSD) to determine which among the sources of variation the differences lay. SPSS was used for the Two-stage Nested Design.

RESULTS AND DISCUSSION

Classification and Recommended Beneficial Uses of Palhi and Salog Rivers Based on the MPN 100mL^{-1} of TC

Anthropogenic activities affecting Palhi River (Figure 2) were observed to be small-scale indicating that locals contribute to protecting and maintaining the health of the river. The locals believe that the water quality is still clean, thus most of their domestic and recreational activities are done in the river. Their drinking water, on the other hand, is provided by the Baybay City Water District or they personally buy from water refilling stations. The result for the classification of each station in Palhi River based on DAO (No. 34, s. 1990) is presented in Table 1.

The upstream of Palhi River that is Barangay (Brgy.) Banahao (Figure 2a) is commonly used by the residents for bathing and washing of clothes, however, farmers from this area let their farm animals such as carabaos and horses wallow in the river. This station is classified as "A or B" since both classifications has 1,000 MPN 100mL^{-1} of TC limit. Water class A can be used as Public Water Supply Class II applicable for sources of water supply that will require complete treatment (coagulation, sedimentation, filtration, and disinfection) to meet the Philippines National Standards for Drinking Water (NSDW). On the other hand, class B are those waters which can be used as Recreational Water Class I applicable for contact recreational activities such as bathing, swimming, and washing clothes (DAO 1990).

For the midstream in Brgy. Biasong (Figure 2b) and downstream in Brgy. Palhi (Figure 2c), both are classified as "C" applicable as 1) fishery water; 2) recreational water supply class II; and 3) industrial water supply or for agriculture, irrigation, livestock watering and the likes. Fishery waters are those recommended for the propagation and growth of fish and other aquatic resources. Recreational water supply class II, on the other hand, are those waters that could only be used for non-contact recreational activity like boating, and those classified as industrial water are waters recommended for manufacturing processes after treatment.

Table 1. Water classification and recommended beneficial uses (DAO no. 34, s. 1990) of Palhi and Salog Rivers based on the MPN 100mL^{-1} of Total Coliforms.

River Stations	Geometric Mean of MPN 100mL^{-1} ±SE (*n*=3)	Water Class	Recommended Beneficial Uses
Palhi River			
Banahao (Upstream)	558.15 (±167.56)	A or B	Public Water Supply Class II Recreational Water Class I
Biasong (Midstream)	1,106.37 (±226.67)	C	(1) Fishery Water; (2) Recreational Water Supply Class II; (3) Industrial Water Supply Class I
Palhi (Downstream)	1,113.98 (±353.33)	C	(1) Fishery Water; (2) Recreational Water Supply Class II; (3) Industrial Water Supply Class I
Positive Control (DBS Pondwater)	1,373 (±392.60)	C	(1) Fishery Water; (2) Recreational Water Supply Class II; (3) Industrial Water Supply Class I
Negative Control (Sterile distilled H_2O)	000 (±000.00)	AA	Public Water Supply Class I

Table 1. continued

River Stations	Geometric Mean of MPN $100mL^{-1}$ ±SE (n=3)	Water Class	Recommended Beneficial Uses
Salog River			
Pulta (Upstream)	964.06 (±416.67)	A or B	Public Water Supply Class II Recreational Water Class I
Conception (Midstream)	1,330.48 (±226.67)	C	(1) Fishery Water; (2) Recreational Water Supply Class II; (3) Industrial Water Supply Class I
Matapay (Downstream)	>1,600 (±000.0)	C	(1) Fishery Water; (2) Recreational Water Supply Class II; (3) Industrial Water Supply Class I
Positive Control (DBS Pondwater)	>1,600 (±000.0)	C	(1) Fishery Water; (2) Recreational Water Supply Class II; (3) Industrial Water Supply Class I
Negative Control (Sterile distilled H_2O)	0000.0 (±000.0)	AA	Public Water Supply Class I

Figure 2. Sampling stations in Palhi River: (a) Upstream in Brgy. Banahao, (b) Midstream in Brgy. Biasong and (c) Downstream in Brgy. Palhi.

Figure 2. continued

On the other hand, the MPN 100mL^{-1} values in upstream of Salog River (Sitio Pulta) is classified as A or B the same case as the upstream of Palhi River. The midstream (Brgy. Conception) and downstream (Brgy. Matapay) of Salog River are classified as "C" the same classification as the midstream and downstream of Palhi River. The result in the upstream validates the activities commonly done by the residents near the area. Residents are minimal in the upstream, however, livestock and domestic animals like cows, goats and dogs were still found along the riverbanks, which contribute to the addition of nutrients into the river through their manure. This may have caused the presence of coliforms in the area, thus the locals recommended it to be a swimming area only, and not for consumption.

The Conception Dam is in the midstream region of Salog River (Figure 3b). The LGU described it as a tourist spot, however its primary purpose is to irrigate the rice fields of nearby barangays. Livestock animals were also found pasturing in the area and consuming water from the river. More houses were found in this area than in the upstream. The increased anthropogenic activities may have resulted in the abundance of coliforms in the area.

The downstream of River Salog in Brgy. Matapay (Figure 3c) is located near the town center, close to the open sea. According to Young and Thackson (2006), downstream areas are repository sites of accumulated materials flowing in the river. Hence, this could be the prevalent factor resulting in the high total coliform count. It was observed that the water was very turbid, and some organic wastes were also present. Despite this, some children were still observed swimming in the area. Houses were also observed to be very close to the river, mostly belonging to families with low income. Feces were found in the river, indicating that the nearby residents do not have proper sanitary facilities.

Anthropogenic activities influence the abundance of coliform in a water body (Ayobahan et al 2014). Land use and hydrology both control the presence of coliforms like *E. coli* which contaminates rivers (Causse et al 2015). Outdoor defecation of humans and livestock continuously feeds the stock of bacteria in the topsoil. Through overland flow during rainy days, the bacteria-laden waste subsequently mobilizes to the adjacent rivers, which adds to the rise of total coliform count (Dutta and Khajuria 2016). This could have been the case for both Palhi and Salog River.

Figure 3. Sampling stations in Salog River: (a) Upstream in Sitio Pulta, (b) Midstream in Brgy. Conception and (c) Downstream in Brgy. Matapay

Abundance of Aerobic Heterotrophic Bacteria

Palhi River

The total aerobic heterotrophic bacteria (TAHB) in the water and sediments of Palhi River are shown in Table 2. The HPC of TAHB in the river ranges from 55,000 up to more than 80,000 CFU mL^{-1} for the water samples and from 65,000 to 100,000 CFU g^{-1} for the sediment samples. Values within 10,000-100,000 are categorized as "impure" by the WHO (2003) and values exceeding 100,000 bacteria are considered "very impure". Normally, in freshwater systems, sediments can impact the quality of water and can have higher bacterial load from 100 to 1000 times than the overlying water (Van Donsel and Geldreich 1971). According to Cavallo et al (1999), the sediments serve as reservoirs of 'free-living bacteria' associated with settled organic or mineral particles. Higher concentrations of bacteria present in the water than in the sediments may indicate the presence of pollutants, which render bacteria to be more abundant in the waters, or disturbances that alter their natural distribution.

Comparison of TAHB present in the water and sediments among the three stations of Palhi River revealed that no significant differences in the abundance of TAHB were present across all the stations and between the two samples (Table 2). Studies reported by Yeung-Cheung (2009) and Edokpayi et al (2015) revealed that there is a significant difference between rivers' upstream and downstream abundance of TAHB, which is attributed to various anthropogenic activities and the presence of effluents in the downstream where higher human populations are found. Given the results of this study, having no significant differences among Palhi River's stations may indicate that all stations receive almost equal amounts and similar types of disturbance. No significant differences between the samples would imply that the TAHB load in the waters is high enough to be rendered equal to the TAHB load in the sediments.

Table 2. TAHB load (CFU mL^{-1} or g^{-1} ±SE) recovered from the water and sediments samples in the stations of Palhi River and the corresponding statistical analysis results

River Stations	Abundance of TAHB	
	Water HPC (CFU mL^{-1} ±SE)	Sediment HPC (CFU g^{-1} ±SE)
Palhi River		
Banahao (Upstream)	66,889 (±8,056.1) ^{ns}	65,000 (±8,113.77) ^{ns}
Biasong (Midstream)	56,000 (±14,714.9) ^{ns}	91,333 (±16,892.6) ^{ns}
Palhi (Downstream)	84,556 (±17,744.4) ^{ns}	100,333 (±10,399.0) ^{ns}
Positive Control (DBS Pondwater)	31,111 (±10,370.4)	-
Negative Control (Sterile distilled H_2O)	0.000 (±00000.0)	-
Salog River		
Pulta (Upstream)	56,444 (±9,798.1) ^{a}	62,222 (±11951.0) ^{a}
Conception (Midstream)	78,778 (±12,536) ^{ab}	142,333 (±29512.7) ^{ab}
Matapay (Downstream)	129,111 (±27,458) ^{b}	175,444 (±29671.9) ^{b}
Positive Control (DBS Pondwater)	48,333 (±9,672.4)	-
Negative Control (Sterile distilled H_2O)	0.000 (±0000.0)	-

Means separated by letters are significantly different from each other ($p<0.05$), ns=not significant ($p>0.05$)

In Palhi River, farm animals pasturing in or near the river were very common. This could cause fecal contamination due to agricultural run-off from cow dungs and other manures. Kavka and Poetsch (2002) pointed out that the pasturing of farm animals could induce the presence of other indicator organisms such as fecal coliforms that could thrive in the sediments (Crabill et al 1999). Wallowing of carabaos and small-scale quarrying by the locals had also been observed, which potentially disturbed the sediments in the river. Recreational activity and different modes of disturbances can release bacteria bound to sediments and contribute to poor water quality (Ishii et al 2007), which may be the case for the elevated TAHB load in the waters upstream (Brgy. Banahao).

Salog River

The abundance of aerobic heterotrophic bacteria in Salog River is also shown in Table 2. Results revealed that there was a significant difference between the upstream (Sitio Pulta) and downstream (Brgy. Matapay) for both water and sediment samples, however, between the water and sediment samples no significant difference was found. The TAHB of the positive control showed the load for waters considered as “impure” by WHO (2003), and the absence of TAHB for the negative control implies that there was no contamination in the media and diluent used.

The TAHB in the Salog River ranged from 55,000 up to more than 120,000 CFU mL^{-1} for the water samples, and from 60,000 to 170,000 CFU g^{-1} for the sediment samples. The numerical difference between the water and sediment samples can be explained by Cavallo et al (1999) who reported higher bacterial load in sediments, where minimal hydrodynamic (disturbance) allows the organic matter of wastes to be deposited on the bottom, and this degradation is mainly aerobic, causing high TAHB in the sediments. However, an increased hydrodynamic effect would cause the bacteria to be released into the waters. The result of having no significant differences between the water and sediments may indicate elevated levels of disturbances affecting the sediments of the river. The TAHB increased for both water and sediments as downstream (Brgy. Matapay) was approached (Figure 3c), in agreement with the results of Edokpayi et al (2015) and Yeung-Cheung (2009).

Heterotrophic bacteria have been referred to be of the greatest importance in the degradation and final stabilization of organic matter (Prakasam and Dondero 1967), wherein nutrients are released by these materials. Consequently, organic matter could also support the excessive growth of other bacteria such as the pathogenic ones. Thus, any improper disposal of wastes, agricultural runoff, and improper usage of water bodies could increase the bacterial load (LeChevallier et al 1996, Konrad et al 2005). Observations made during the sample collection in Salog River imply that some domestic and agricultural wastes are being discharged into the river which adds organic materials to the waters. Although, assessment for organic matter concentration was not included in this study, presence of organic matter is evident verified by the suspended solids and foul water odor observed especially in the downstream (Brgy. Matapay) (Figure 3c).

In a study by Sado-Inamura and Fukushi (2018), physical observation, specifically unpleasant odor was used to analyze the water quality of urban rivers. This considered the fact that the emission of odor is influenced by decomposition of organic matter (eg, rotting materials and sewage) by microorganisms, including heterotrophic bacteria. Thus, the foul odor can be related to the underlying bacteriological examination results. At the upstream area (Sitio Pulta), however, minimal disturbances were observed. Very few residents live nearby, but some of their farm animals and pets were observed near the river (Figure 3a).

For the midstream, samples were taken from the Conception Dam. Compared to the river's upstream (Sitio Pulta), water discharge was lower, specifically in the dam's catchments. This caused sedimentation to occur in the reservoir of the dam since the dam decreases the capacity of the water to carry the sediments leaving the catchment with minimal sediment load. Conception Dam is also considered to be a tourist spot and more houses were observed along the river (Figure 3b). Quarrying is also reported, and farm/livestock animals were seen pasturing on the upper part of the dam. All these disturbances may have contributed to the increased bacterial load in the water and sediments since agricultural wastes are carried by surface runoff to the river channel during heavy downpours. These wastes settle into the sediments resulting in an increased bacterial load in the sediment samples.

In Brgy. Matapay (downstream), physical observations such as the gray color of water, foul smell, and turbidity implying high levels of suspended solids, revealed that various wastes are being discharged. This is in the urban area near the town center where various establishments were observed (Figure 3c). It was suspected that the wastes coming from houses near the river contribute to the increased amount of bacteria present. Construction businesses along the river could have also increased the disturbance level. Arnone and Walling (2007) discussed that pathogens in the urban environment easily enter waters through a number of pathways. These pathways include discharge of inadequately treated sewage, stormwater runoff, combined sewer overflows and sanitary sewer overflows. Some of these pathway sources were observed in the downstream (Brgy. Matapay), the larger population around the area, where some households had no proper sanitary facilities or waste disposal.

Compared to the other stations, sediment loads in the downstream (Brgy. Matapay) were observed to be finer and more abundant. This could be the reason for the increased TAHB load since generally, microbial populations are more abundant in muddy sediments than in sandy ones (Lakshmanaperumalsamy 1986). The entry of waste discharges, presence of various environmental disturbances, and increased sediment loads caused the elevated TAHB levels in the downstream (Brgy. Matapay), compared to the upstream (Sitio Pulta) and may pose a health risk to the residents who use this resource. The range for TAHB at this station was within the set guidelines by the WHO (2003) for waters classified as "very impure", inadvisable for consumption and other usage. Thus, action plans from the Local Government Unit are suggested to be implemented that would prevent locals from discharging wastes and from bathing in the river in Brgy. Matapay.

The TAHB load for both water and sediments in the Salog River increases as downstream (Brgy. Matapay) is approached. Anthropogenic pressures caused by multiple development activities can cause water quality deterioration (Dutta and Khajuria 2016). As rivers receive various effluents from different sources, it was reported that high levels of suspended solids and nutrients in the drainage water can affect the survival of aquatic microflora (Hader et al 1998). Increased TAHB is primarily affected by the nutrients present in its habitat, thereby agricultural discharges (eg, manure), which provide nutrients to the water body, would induce the survival of these bacteria and presence of pathogenic bacteria. Serious environmental and human health concerns caused by the discharge of wastes and agricultural processes into surface waters has also been reported (Adama and Kolo 2006, Dutta and Khajuria 2016), thus this is an issue that should be addressed. From the various activities described above, microbial contamination attributed to the discharge of sewage, entry of human and animal excreta, wastes from slaughterhouses, industrial effluents, immersion of dead animals, bathing and washing, and poor animal husbandry practices (Dutta and Khajuria 2016), may occur in both rivers since some of these activities had been observed in Palhi and Salog Rivers. This signifies that both rivers are susceptible to microbial contamination.

A study conducted by Aragoncillo et al (2011) in Baho River, Rizal, Philippines showed that the heterotrophic plate count ranged from 160,000-17,000,000 which is relatively higher than the results for both Palhi and Salog Rivers. Although there is no exact range of total aerobic heterotrophic bacteria, a rapid increase could mean that there is poor water maintenance, as well as regrowth of bacteria in the distribution after water treatment (Bartram et al 2003). Usually, high numbers of bacterial cells are found where waters are not deep and where there are a large number of organisms surrounding the area (Cavallo et al 1999). These characterizations describe both Palhi and Salog Rivers wherein both have consequent low water levels and grazing farm animals along the riverbanks (Figures 2 and 3). Under these conditions, leaves and other plant and animal residues settle on the bottom before metabolization and this represents a good nutritional substrate for heterotrophic bacteria and favors bacterial growth (Cavallo et al 1999).

Physico-chemical Characteristics of the Rivers

The average of the physico-chemical parameters from the three stations in Palhi and Salog Rivers are shown in Table 3. The water temperature in Palhi River ranges from 25.6-27°C, and 28.6-31.6°C for Salog River. For the air temperature, Palhi River ranged from 25.7-28°C, and 29.3-33.6°C for Salog River. These temperature ranges, being above 15°C, are favorable for bacterial growth especially for coliform bacteria which is thermotolerant (Murray et al 2010).

Table 3. Average of Physico-chemical parameters collected during the sample collection in the stations of Palhi and Salog Rivers

Parameters/Stations	Palhi River			Salog River		
	1	2	3	1	2	3
Water temp (°C)	26.33	25.67	27.00	28.67	31.67	31.50
Air temp (°C)	27.67	25.70	28.00	29.33	33.67	32.67
pH	7	7	7	7	7	7
Water depth (cm)	33.50	26.67	31.50	34.07	17.00	30.40
Current velocity (m s^{-1})	0.08	0.65	0.30	0.35	0.48	0.12
DO (mg L^{-1})	5.47	5.67	5.11	5.03	4.98	4.87

Note: 1- Upstream, 2- Midstream, 3 - Downstream

It is expected that water would have a lower temperature compared to the air temperature, considering the high heat capacity of water. Air and water temperatures are highest for Palhi River at the downstream (Brgy. Palhi), while midstream for Salog River (Brgy. Matapay). This may have been caused by the varying sampling time since sample collection was done at these stations during noon when the highest temperatures can be observed, and the channels were not covered by vegetation. Rates of biological and chemical processes depend on temperature (Kepuska 2016), and considering the high temperatures for both rivers, high metabolic rates and optimal growth of microorganisms can be expected. A study conducted by Tiefenthaler et al (2009), indicates that there is a positive relationship between temperature and bacterial levels which suggests that heat induced growth may be a contributing factor to seasonally high bacterial levels. Thus, it is recommended that further examination during the wet season should be conducted to compare the two seasons in Palhi and Salog Rivers.

Most aquatic plants and animals are sensitive to variations in pH (Shah and Joshi 2017). The results from the pH determination showed that the waters from all the stations in both rivers were neutral (pH7), which is within the standards set by WHO (2006) of 7-8.5 for recreational waters. This result implies that no abnormalities or water quality degradation takes place in the rivers. Furthermore, the water velocity impacts the survival and microorganism diversity found in the water. Fast-flowing streams hold suspended sediments in the water column longer, while slow-moving rivers allow immediate deposition of carried sediments, thus bacteria could easily settle on the bottom. The flow of water impacts the organisms living in the stream, as well as the overall water quality (Burden and Guenther 2002). Both Palhi and Salog Rivers showed low average water depth (27.2-30.6cm) and slow average water velocity (0.32-0.34m s^{-1}) compared to the results of other studies ranging from 1-5m (for small rivers) (Shestopalov 2002) and 1.6-3.1m s^{-1} (Swift 2006) for depth and water velocity, respectively. Slow water velocity also results in lower levels of dissolved oxygen, so this could be expected for both rivers. The water depth for midstream (Brgy. Conception) in Salog River (17.00cm) is notably the lowest among all the stations because of the dam operation which lowers the streamflow (Snoussi et al 2002). The water velocity for the downstream in Salog River (0.12m s^{-1}) is likewise notably low, which could be a cause for the high TAHB load results for this station.

Diaz and Rosenberg (2008) argued that the dissolved oxygen (DO) content is one of the most important indicators of aquatic ecosystem health and in the study of Spietz et al (2015), DO was found to have a role stronger than that of the other abiotic factors assessed such as pH, salinity, and temperature. DO levels fluctuate naturally with the change of seasons since colder water holds more oxygen than warm water. Thus, it is expected that low DO levels were obtained in the stations for the two rivers since high temperatures were observed. In 1986 the United States Environmental Protection Agency (USEPA 1986) proposed standards that DO lying between 4-6mg L^{-1} ensures better aquatic life in water bodies (Leo and Dekkar 2000, Burden and Guenther 2002). However, Gupta et al (2017) found that an oxygen range of 5-14.5mg L^{-1} is suitable for natural waters, depending on turbulence, temperature, salinity, and altitude.

The physico-chemical parameters of all the stations in the two rivers were within these standards, which signifies that the DO concentrations were still at the levels that could support the high loads of TAHB. However, finding these values at the lower limits for standard DO levels may have been caused by different factors such as low water velocity, high temperature, and salinity. Temperature affects the oxygen content of water since oxygen levels become lower as temperature increases (Almeida et al 2012). DO levels also tend to decrease, as a result of increased metabolic activities by microbes in decomposing organic materials that use up oxygen quicker. This is verified by the abundance and activity of TAHB in the two rivers. Additionally, natural processes may also contribute to the lower DO levels such as the influx of seawater, since higher salinity results in lower DO concentrations (Leader 1971), and this is applicable to the lowest DO concentrations for the downstream of Palhi and Salog Rivers.

Physical observations done including turbidity, foul smell, and suspended solids showed that the downstream of Salog River is affected by the various activities affecting the river. The water during the sample collection was murky gray in color, as disturbed sediments resulted in high sediment loads. The unpleasant odor observed in the downstream (Brgy. Matapay) of Salog River may have been a result of various effluents from the nearby establishments and houses. This type of water quality analysis was emphasized in a study by Sado-Inamura and Fukushi (2018), that the use of cultural services of surface water resources is influenced by the appearance and odor since many people recognize water degradation through sensory perception.

CONCLUSION

This study has shown the bacteriological quality of Palhi and Salog Rivers in Western Leyte. The MPN of TC revealed that it is only in the upstreams of Palhi and Salog Rivers that contact recreational activities could safely be done. The midstreams and downstreams of both rivers are recommended for non-contact recreational activities only. The HPC of TAHB in the water and sediment samples for the three stations in Palhi River were not significantly different while in Salog River higher TAHB occurred in the downstream compared to the upstream, which can be an indication of improper waste disposal by the nearby residents. However, no significant differences on the TAHB levels were found between the water and sediments for the two rivers. The results of this study imply that monitoring and proper management of the rivers should be done by all sectors of the community for the protection of these invaluable resources.

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