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COMPARISON OF MICROBIOLOGICAL WATER QUALITY ASSESSMENT BETWEEN THE INDIGENOUS PEOPLE AND VISITORS WATER ACTIVITIES IN ROYAL BELUM STATE PARK

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Abstract: The waters within the Royal Belum State Park are predominantly utilized for recreational activities and are the main source of water for indigenous tribes. Changes in population density, tourism and climate changes may impact water quality and the consequences to human and ecological health are of economic and social importance. An assessment of water quality in Temenggor Lake, Royal Belum State Park has been conducted at two sampling locations, namely visitor water activity areas (fishing, swimming, canoeing) and indigenous people water activity areas (dishes washing, laundry, open bathing) to determine and compare the microbiological and physicochemical parameters and to classify the safety of water usage based on the National Water Quality Standards classification for water activity use with body contact. Six locations were selected and analysed in-situ for temperature, dissolved oxygen, pH level and turbidity while total suspended solids, biochemical oxygen demand, ammoniacal-nitrogen, total coliform, enterococci and *Escherichia coli* were analysed in the laboratory. Results indicated that all physicochemical parameters (temperature, turbidity, total suspended solids, dissolved oxygen and biochemical oxygen demand) except pH and ammoniacal-nitrogen at the six samplings stations were within the acceptable range for water activity use. All stations were within class I to IIB for microbiological parameters in comparison to the National Water Quality Standards classification for Malaysia. This indicates that the waters were safe for water activity with body contact. Visitor water activity areas were safe and clean compared to indigenous people's water activity areas and the differences were statistically significant. There is modest and visual evidence that the indigenous community may further reduce the water quality in their areas based on their daily sanitation practises of dishwashing and open defecation on land. Hence, the responsibility falls on the authorities to provide a good sewage management system and treated water at the indigenous people's settlement to protect the lake water quality from deteriorating in the future and contributing to the adverse health effects of its users.

Keywords: Faecal contamination, NWQS classifications, bathing area, water quality, recreational use.
Abbreviations: Royal Belum State Park (RBSP), Ammoniacal-Nitrogen (AN), Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), American Public Health Association (APHA), Environmental Protection Agency (EPA).

Introduction

Temenggor Lake in the Royal Belum State Park (RBSP) is an important water resource for the indigenous community, an ecosystem for aqua organisms and a place for water recreational activities for visitors. Recently, the Royal Belum State Park has been receiving higher visits from eco-tourists and recreational users. The Perak State Park Corporation (2019) has reported an increasing trend of tourists from 2,909 to 27,805 for the years 2006 and 2018, respectively. Two type of areas have been identified as having a source of hazard, namely visitor water activity areas and indigenous people water activity areas. The houseboats will stop at these visitor water activity areas where visitors can take part in recreational activities such as swimming, bathing, kayaking and fishing usually lasting anywhere between two to three hours and the whole night, depending on the trip package.

Additionally, the indigenous people routinely undertake cleaning activities in the nearby lake area to wash clothes and dishes as well as for bathing. Indigenous people, whose homes do not have any sanitation systems, prefer to use natural water for washing. These kinds of activities and population growth are seen to contribute to the deterioration of water quality if no preventive measures are taken. Liyanage and Yamada (2017) stated that population density as a major factor that should be well controlled to overcome the rapid deterioration and degradation of the water ecosystem. Furthermore, human activities pose a serious threat to the water quality of rivers when pollution levels reach the threshold limit.

Therefore, the increasing number of tourists and the indigenous population may contribute to the increase in sewage discharges from houseboats and settlements into the lake. Meanwhile, there is no uniform and structured management of the direct discharge of human excrement into the lake as the installation of holding tanks on houseboats has yet to be deployed in Temenggor Lake.

A major source of pathogenic faecal microorganisms are from wastewater discharges in fresh waters and coastal seawaters (Fenwick, 2006; WHO, 2008). The degradation of river quality has been exacerbated by the introduction of untreated home sewage, industrial by-products and agricultural waste into the river systems (Lim *et al*., 2006; Mohd Rozali *et al.,* 2006; Suratman *et al.*, 2009). Hence, the increasing number of houseboats and human population might promote the decline of Temenggor Lake's water quality and in the long-term may cause hazards to the user's health. E. *coli* was found to be present in the majority of the sample stations at Kenyir Lake, according to a prior study (Suratman *et al.,* 2018). *E. coli* in Kenyir Lake originating from animal and human faeces suspected to have been discharged from houseboats that had no suitable equipment and facilities for storage, treatment and removal of wastewater and sewage, whereby wastes from these houseboats were allowed to flow directly into the lake water. Hamzah and Hattasrul (2008) stated that the bacteriological parameters shown in the Chini Lake, Pahang was categorised as class V, meaning that the lake is polluted with total and faecal coliform exceeding the standard count permitted by the Department of Environment, Malaysia.

Domestic effluent and human and animal waste were the main sources of faeces contamination in Chini Lake, most probably due to lack of proper sanitation systems. When microorganisms that could infect or make people ill upon exposure are present, the microbial quality of water deteriorates (Rodrigues & Cunha, 2017). Numerous negative health effects of recreational water consumption have been identified by epidemiological research, including gastrointestinal disorders, eye infections, respiratory infections, issues with ear, nose, throat and skin conditions (Viau *et al*., 2011; Coldford *et al.*, 2012; Arnold *et al*., 2013).

An assessment of seasonal impacts to water conditions of Temenggor Lake, Perak was previously carried out in 2012 and the findings show that the physiological status of Temenggor Lake was considered clean (Khalik & Abdullah, 2012). However, since then, no thorough study on the microbiological water quality of Temenggor Lake has been done. Furthermore, the safety and health risks of water users should be accounted for by determining the safety of water bodies for water activity with body contact according to the related classification.

Majority of infections and illnesses brought on by contact with water are mild, making them challenging to find using regular surveillance systems. The evidence that is currently available indicates that enteric illnesses such as gastroenteritis are the most common adverse health outcome linked to exposure to faecal-contaminated recreational water. These illnesses are frequently transient and may not officially be reported in disease surveillance systems (World Health Organization, 2003). In the field of recreational water safety and health, the vast majority of research to date has focused on microbial risks, especially gastroenteritis effects resulting from the pollution of water by wastewater and excreta (Pond, 2005).

Consequently, the goal of this study was to ascertain and compare the microbiological and physicochemical water quality between different water activity areas and to classify whether the water activity areas are safe for recreational and daily activities with body contact based on the National Water Quality Standards classification.

Materials and Methods

Sample Collection

Two type of areas have been selected as sampling stations which are visitor water activity areas and indigenous people water activity areas. In total, there were six sampling stations namely A01, A02 and A03 which cover the indigenous people water activity areas, and V01, V02 and V03 which cover the common locations for visitor water activities during houseboat trips (Table 1). Water samples were collected in November 2020, December 2020, April 2021 and October 2021 using grab technique between 15 to 30 cm beneath the water surface. Water samples collected were measured for in–situ parameters, then stored at 4°C to be processed within six hours of collection for other analysis. All supporting information has been recorded before leaving the sampling station such as the weather condition, sample labelling and condition of the water.

Sample Analysis

In-situ measurements include dissolved oxygen (DO) and biochemical oxygen demand (BOD) measured using HANNA Dissolved Oxygen Meter while pH and temperature were measured using 4 in 1 pH/TDS/EC/Temperature Digital Meter. Calibration of probes were conducted before field sampling based on the manufacturer's guidelines. The amount of total suspended solids (TSS) was obtained by the filtration of water samples through a pre-

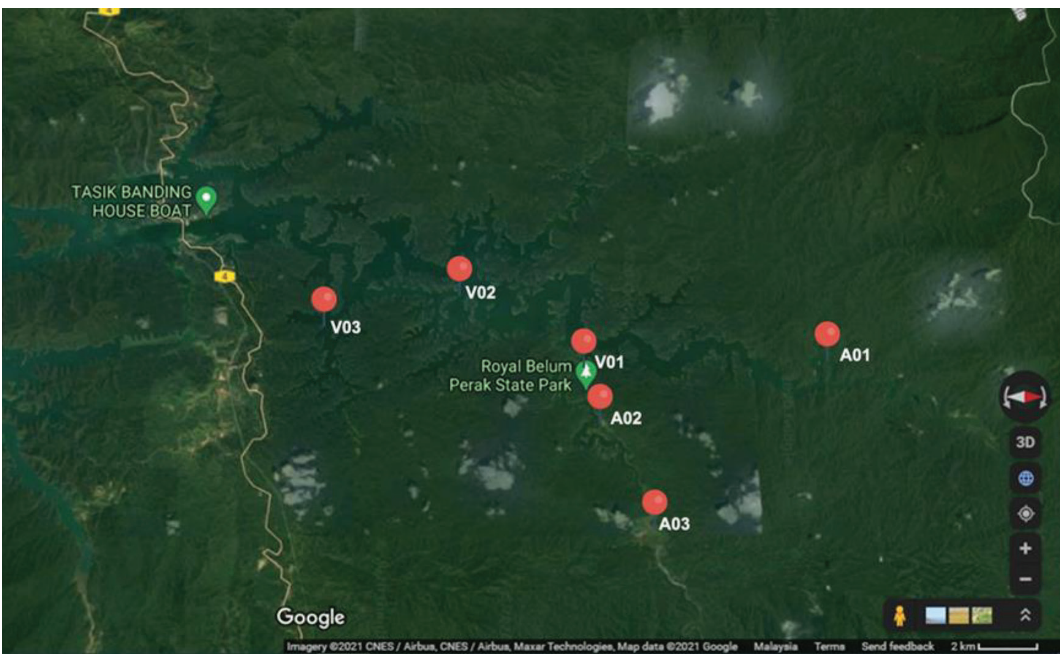

Figure 1: A map showing six stations of water sampling in Royal Belum State Park

Table 1: GPS coordinate for sampling stations

Station	Location Name	GPS Coordinate	Type of Areas
A01	Kg. Sungai Ta'hain	5.747500, 101.390833	Indigenous people water activity areas
A02	Kg. Klewang	5.680359, 101.409440	Indigenous people water activity areas
A03	Kg. Sungai Tiang	5.695500, 101.442400	Indigenous people water activity areas
V01	Houseboat Park Sg. Ko'oi	5.666759, 101.399956	Visitor water activity areas
V02	Houseboat Park Sg. Papan Luar	5.638055, 101.370555	Visitor water activity areas
V03	Houseboat Park Sg. Ruok	5.595114, 101.377868	Visitor water activity areas

weighed filter and dried in an oven between 103 to 105°C until no change to the filter weight was observed. The TSS is denoted by the increase in filter weight. Ammoniacal-nitrogen was computed using Spectrophotometer Hach DR2800 by Salicylate method. Total coliform, *E. coli* and enterococci were used in this study as markers for faecal contamination in Temenggor Lake water activity zones in RBSP. WHO (2003) and EPA (2012) advocate the use of enterococci and *E. coli* as faecal indicators in freshwater since they both showed the strongest link to swimming-associated gastroenteritis.

Bacterial analyses were conducted using membrane filtering technology according to standard procedures (EPA, 2002). Detection of total coliforms and *E. coli* were conducted using MI Agar while mEI Agar (membrane-enterococcus Indoxyl-β-D-Glucoside) was used for the detection and enumeration of enterococci. The results are reported in colony forming unit (CFU) per 100 mL of sample. Water samples were diluted as needed to yield between 20 and 80 coliform colonies of not more than 200 colonies per filter. Sterilized 47 mm, 0.45 m pore size cellulose ester membrane filters were used to filter the water samples. The filters were then placed on an agar plate and incubated for 24 hours at 35°C (MI agar) or 41°C (mEI agar).

The presence of colonies was recorded based on colony appearance characterization. Blue colonies on MI agar are shown as *E. coli* under normal light while all the fluorescent blue/green, fluorescent blue white and blue/green with fluorescent edges under longwave ultraviolet light (366 nm) was recorded as total coliform count. On mEI agar, all colonies with a blue halo were recorded as enterococci colonies.

Statistical Analysis

The data is displayed as mean and geometric mean for faecal coliform ± standard deviation (SD). The T-test was performed using MS Excel to compare the results between two areas of user activity. The results were then evaluated against the National Water Quality Standards (NWQS) classifications to determine which stations were safe for water activity with body contact.

Results and Discussion

Physicochemical Parameters

Table 2 presents the results of the water quality characteristics sampled at Temenggor Lake. The highest temperature value (32.6°C) was logged at station V03 while the lowest was from station A03 (25.1°C). The highest value of pH (8.2) was recorded at station A02 and the lowest (4.8) was recorded at A03. The highest and lowest value of dissolved oxygen (DO) were recorded at stations V01 (9.37 mg/L) and A01 (3.14 mg/L), respectively. The highest value of BOD was at station A03 (2.83 mgL^{-1}) while the lowest was recorded at station V01 (0.44 mgL^{-1}). The highest value of turbidity was recorded at A03 (96.0 NTU) while the lowest value was at V02 (0.68 NTU). The values of total suspended solid were in the range of 1 – 37 mg/L (mean 9.83 ± 8.62 mg/L). Station A03 recorded the highest value (37.0 mg/L) while the lowest value was at stations V01 and V03 (1.0 mg/L).

The concentration of ammoniacal-nitrogen (AN) at all sampling stations was within the range of 0.04 - 1.33 mg/L (mean 0.25 ± 0.36). The highest value of ammoniacal-nitrogen concentration was recorded at station V01 (1.33 mg/L) and the lowest recorded at several stations: A01, A02 and V01 (0.04 mg/L). The t-test for pH showed no significant difference in pH between indigenous people's areas (M = 6.65, SD = 1.19) and visitor areas (M = 6.74, SD = 0.60), t(11) = -0.349, $p = .367$.

Additionally, there is no significant difference in AN between indigenous people water activity areas (M = 0.23, SD = 0.31) and visitor water activity area (M = 0.27, SD = 0.42), t(11) = -0.383, $p = .355$. Similarly, there is no significant difference in turbidity between indigenous people water activity area (M = 10.61, SD = 26.94) and visitor water activity area (M = 1.76, SD = 1.01), t(11) = 1.150, $p = .137$. However, visitor water activity areas reported higher temperature (M = 31.02, SD = 1.30) than in indigenous people areas (M = 29.53, SD = 1.98), t(11) = -3.165, $p = .0045$.

There is also a significant difference in BOD between indigenous people water activity areas (M = 2.04, SD = 0.60) and visitor water activity areas (M = 1.01, SD = 0.45), t(11) = 4.491, $p < .001$. In visitor water activity areas, higher levels of DO (M = 7.61, SD = 0.86) was recorded as compared to indigenous people areas (M = 6.01, SD = 2.12), t(11) = -3.335, $p = .003$. Additionally, there is a significant difference in TSS between indigenous people water activity areas (M = 14.92, SD = 9.51) and visitor water activity areas (M = 4.75, SD = 2.90), t(11) = 4.050, $p < .001$.

A high reading for temperature in visitor water activity areas may have resulted from the high level of exposure to the sun as this area is used for open bathing from houseboats and is located far from the riverbank. Meanwhile, the lower temperature in indigenous people water activity areas might be due to the surrounding tree cover and the fact that it is located nearer to the riverbank of indigenous people's settlements. Another factor that could have affected this difference in water temperature is the sampling period.

The whole sampling process took approximately three hours to complete, leading to exposure to maximum daily temperature. According to Parker *et al.* (2021), the growth rates are the highest at the optimum growth temperature for the organism. The range of temperature recorded in this study was moderate temperature for pathogen growth. The pH value at A03 was slightly acidic probably due to being close to indigenous people who are producing waste from cleaning activities that have promoted the decomposition process. Therefore, carbon dioxide is released and accumulated, thus, the rising concentration of carbonic acid causes the pH to fall.

Generally, all sampling stations for indigenous people settlements recorded low DO values. Additionally, the higher rate of decomposition of organic matter may be due to food waste when washing dishes. The high BOD value at station A03 is suspected to be due to the presence of food waste, sewage and dead plants in the lake that contributed to microorganism's decomposing activity. When compared to the BOD values from Khalik and Abdullah (2012), it is considered low.

The highest value of turbidity at A03 was mainly because of heavy rain that occurred almost daily prior to sampling in November 2020. The water levels had risen and the stream had a strong flow causing soil to be washed from the banks into the water. Although turbidity is not

Table 2: Mean, standard deviation and range of parameters at sampling stations

Parameters	Min	Station	Max	Station	Mean (SD)
Temperature (°C)	25.1	A03	32.6	V03	30.3 ± 1.8
pH	4.8	A03	8.2	A02	6.7 ± 0.9
Dissolved Oxygen (mgL^{-1})	3.14	A01	9.37	V01	6.91 ± 1.90
Biological Oxygen Demand (mgL^{-1})	0.44	V01	2.83	A03	1.53 ± 0.71
Total Suspended Solid (mgL^{-1})	1	V01, V03	37	A03	9.83 ± 8.62
Turbidity (NTU)	0.68	V02	96	A03	6.19 ± 19.18
Ammoniacal-Nitrogen (mgL^{-1})	0.04	A01, A02, V01	1.33	V01	0.25 ± 0.36
Total coliform (cfu 100 mL^{-1})	14	V03	5175	A03	2601 ± 1529 [a]
Escherichia coli (cfu 100 mL^{-1})	0	V03	415	A03	67 ± 114 [a]
Enterococci (cfu 100 mL^{-1})	0	V03	374	A03	43 ± 85 [a]

[a] Geometric mean

directly linked to faecal matter, it is frequently accompanied by an increase in the number of pathogens. Higher levels of suspended solids at indigenous people water activity areas were expected, especially at station A03 because this site has a large population and is the largest settlement in RBSP where their daily house chores such as cleaning and bathing, contribute to suspended solids. Not only that, but strong flow from the upper stream also helped wash away the sediments and solids.

Microbiological Parameters

The concentration of total coliform, *E. coli* and enterococci at Temenggor Lake ranged between 14 - 5.18 x 10^3 cfu/100 ml, 0 – 415 cfu/100 ml and 0 – 374 cfu/100 ml, respectively. The highest concentration of total coliform, *E. coli* and enterococci were recorded at A03 while the lowest concentration was at V03. The t-test for microbiological parameters shows that there is a significant difference in concentration *of E. coli* between indigenous people water activity areas (M = 123.92, SD = 141.03) and visitor water activity areas (M = 9.50, SD = 7.57), t(11) = 2.805, $p = .0086$.

Additionally, there is a significant difference in concentration of enterococci between indigenous people water activity areas (M = 78.38, SD = 111.29) and visitor water activity areas (M = 6.92, SD = 5.78), t(11) = 2.182, $p = .0258$. In contrast, there is no significant difference in concentration of total coliform between indigenous people water activity area (M = 3097.08, SD = 1442.62) and visitor water activity areas (M = 2105.50, SD = 1507.30), t(11) = 1.723, $p = .056$.

These results showed a higher concentration of microbial indicators in indigenous people areas, and this is probably due to surface runoff, rural stormwater overflows and resuspension of sediments caused by the early wet season that falls somewhere around November. Many other factors can cause a high concentration of bacteria in indigenous people areas, and this includes food and solid waste dumped into the lake near their settlements and waste from defecation and livestock. However, the number of *E. coli* is still considered low when compared to the recorded values for Chini Lake, Pahang which reported 52 x 10^4 as a maximum value (Hamzah & Hattasrul, 2008). As *E. coli* is associated only with the faecal material of warm-blooded animals, it can be related to defecating activity on the land by indigenous people. They have improper facilities such as limited toilets and sewage tanks, therefore, they defecated by digging holes on the land, producing underground sewage.

Heavy rainfall may trigger waste runoffs to the lake which could increase the concentration of *E. coli*. Increasing surface water runoff straight into the water and severe rains are two environmental conditions that, according to WHO (2003) can lead to sewage overflows and affect the microbiological water quality. The results of most of the parameters tested showed that both areas were significantly different due to being affected by a different type of users activity.

The comparison geometric mean of microbiological parameters with the National Water Quality Standards classification is shown in Table 3. Total coliform concentration for all stations was in Class II while the geometric mean of *E. coli* and enterococci for most stations were in Class I, except for stations A02 and A03 which were in Class IIA and IIB, respectively. According to the Department of Environment (2019), parameters within Class I to Class IIB are considered safe for recreational use and other activities with body contact (Figure 1).

However, the numbers of enterococci and *E. coli* at station A03, reported at 35 cfu/100 mL and 126 cfu/100 mL, respectively, exceeds the limit for recreational use in freshwater as recommended by the Environmental Protection Agency US (2012). There is limited available data to link disease outbreaks to activities associated with recreational water use in Malaysia, nevertheless, precautions need to be put in place. The major contributor to the low water quality of Temenggor Lake in RBSP is within the area of indigenous settlements caused by a lack of proper sanitation and sewage systems. New human settlements have emerged as a result of rising human population around the lake area that acts as a water resource and their activities have resulted in bacterial resuspension

Table 3: NWQS classification for microbiological parameters

Water Quality Parameter	**Stations**					
	A01	**A02**	**A03**	**V01**	**V02**	**V03**
Total coliform (cfu 100 mL^{-1})	II	II	II	II	II	II
Escherichia coli (cfu 100 mL^{-1})	I	IIA	IIB	I	I	I
Enterococci (cfu 100 mL^{-1})	I	IIA	IIB	I	I	I

Table 4: Water classes and uses of National Water Quality Standards for Malaysia, Department of Environment (2019)

Class	**Uses**
Class I	Conservation of natural environment Water supply I - Practically no treatment necessary Fishery I - Extremely sensitive aquatic species
Class IIA	Water supply II - Conventional treatment required Fishery II - Sensitive aquatic species
Class IIB	Recreational use with body contact
Class III	Water supply III - Extensive treatment required Fishery III - Common, of economic value and tolerant species: Livestock drinking
Class IV	Irrigation
Class V	None of the above

from sediments. In the future, these settlements and tourism areas may result in increasing pollutant inputs that will subsequently influence water quality deterioration.

Additionally, the precise disease burden caused by water activities is underestimated; since illness is often mild and visitors and indigenous people may not seek medical care causing cases of illnesses to be undetected. Thus, it is important to carry out preventive actions to safeguard public health which include identifying all potential sources of contamination, being aware of developments that can adversely influence water quality and providing the public with proper information.

Suggestions

One of the limitations of this study is the huge time gap between the period of sampling which might affect the results obtained. For this reason, future research needs to consider the seasonal influences on microbial water quality in RBSP. Sanitation infrastructure needs to be upgraded in the indigenous settlements to include environmentally appropriate sanitation solutions by the respective authorities. Additionally, appropriate sanitation options for visitors need to be provided including a suitable waste management system for houseboats. Thus, this study provides a baseline of data to help in future management strategies to ensure the conservation of the natural landscape and economic viability, in addition to the protection of the local community.

Conclusion

Although the results indicate that most physicochemical parameters were within the acceptable range for water activities, there are emerging concerns regarding the microbiological indicators, especially in indigenous people water activity areas that have shown a high number of bacteria concentrations. Future epidemiological surveys should therefore incorporate source attribution as part of quantitative microbial source apportionment and appropriate microbial source monitoring technologies.

Based on NWQS, all stations are considered safe for water activities in terms of microbiological hazards. This study demonstrated that Temenggor Lake is still safe for recreational and other water activities with body contact. However, this study also showed that the different type of human activities affects the water quality since the indigenous people water activity areas and visitor water activity areas were significantly different in most parameters. However, the presence of *E. coli* should not be disregarded as there is still a possibility that human infections have contaminated the water through faeces (Payment *et al.*, 2003).

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