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WATER QUALITY ASSESSMENT AT ROYAL BELUM STATE PARK, PERAK, MALAYSIA

MOHAMAD N.D.[1,2], ABDUL HAMID N.S. [1,2], RAMLI R.R.[3], AHMAD KAMAL N.[2], ABDUL ADIS A.A.[4], AMIR A.[1,2]*

[1] Bioremediation Research Centre (myBioREC), School of Civil Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia
[2] School of Civil Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia
[3] Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia
[4] Faculty of Business, Economics and Accountancy, Universiti Malaysia Sabah, Sabah, Malaysia

(*) amnorzahira@uitm.edu.my

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ABSTRACT

This study demonstrated water quality study at the Royal Belum State Park, Perak. The Royal Belum State Park is one the major reservoir for water resource in Perak and under National Heritage Site UNESCO. The lake is surrounded by the reserved forest and rich with flora and fauna. The Royal Belum State Park is considered as one of the oldest, protected, undisturbed and pristine land mass in Peninsular Malaysia of more that 130 million years old. This lake provides biodiversity education, research, and ecotourism to the public. One of the major attractions is the houseboat. There are more than ten (10) houseboats operated every day due to the high demand from the local and international tourists. Due to this activity, water quality of the lake has been deteriorated and required short and long-term mitigation measures. Water quality study (ex-situ and in-situ measurements) was conducted at selected six (6) sampling locations (e.g., Royal Belum registration point, Sungai Tiang, Kg. Orang Asli, houseboat docking area, Kem Sg. Tiang and houseboat parking area). The water quality index (WQI) measurement of all sampling points is in the range of 60-80, indicating that the WQI value is under class II and III. The WQI values are significantly deteriorated by the concentrations of dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD). The water quality at Kg.Orang Asli, Sg. Tiang and houseboat parking area slightly deteriorated compared to other sampling points. This is probably due the leakage of petrol from the houseboat, stagnant water at certain area of the lake (e.g., Kem. Sg. Tiang),

discharge of wastewater and sullage water from the houseboat and unknown non-point source nearby the lake. Therefore, the Perak State Government, State Parks Corporation, and other relevant authority (e.g., NGOs) should play an important role to preserve and sustain the water quality at the Royal Belum State Park, Perak because this lake is one of significant source of clean water supply in Perak.

Keywords: Royal Belum State Park, Recreation and Tourisms, Water Quality, Water Resource Management and Water Pollution

INTRODUCTION

Belum State Lake is located in the Malaysian state of Perak, and it has been categorized as the world's oldest rainforest, which is older than the Amazon and the Congo. Belum State Lake covers 15,200 hectares which is dotted with hundreds of islands. The area has been identified as an Environmentally Sensitive Area (ESA) Rank 1 under the Malaysian National Physical Plan and has been gazette as an essential water catchment area for the State of Perak. This lake has become a tourist main attraction area due to its nature and development (e.g., roads, bridge, resorts, and house boats). Malaysia is blessed with an average annual rainfall of 2,940 mm, a number which implies that the availability of water resource is not an issue and can be taken for granted. However, due to an increase population and rapid socio-economic development, the country is faced with a host of water governance issues resulting in water stress in certain areas, river pollution, constant flooding, biodiversity loss, and environmental degradation. From the 672 rivers monitored, 9% were polluted while another 36% were moderately polluted (DOE, 2020). Constant and widespread flooding is also another water hazard, in which a total of 10% of Malaysia is categorized as a flood-prone area, affecting 21% of the total population (DID, 2021). On the other hand, there is also the issue of mild to moderate hydrological drought which may occur once in every 5 to 7 years, causing water stress in some developed states. Moreover, the current national score for the implementation status of Integrated Water Resource Management (IWRM) under the purview of SDG 6 is far from satisfactory (GWP, 2009). From the findings of a study that has been carried out, most of the issues identified were related to lack of water governance and water management, particularly at the river basin level.

The Malaysian federal government has categorized the whole Royal Belum State Park as an essential water catchment area and a part of the Central Forest Spine. Any activity and development at this lake will be controlled and protected under the Malaysian National Forestry Act. Currently, this area has been developed as a tourist attraction, where roads, bridge, resorts, hotels, and house boats were constructed for accessibility and logistic purpose. These facilities produce wastewater that can contaminate the Royal Belum State Park. Thus, water quality and maritime biodiversity may have affected. As this lake is utilized as a catchment area for the Perak State, the wastewater should be treated up to Standard A and the discharged point of treated wastewater should be allocated at the suitable area. Critical parameters that need to be monitored and controlled are suspended solid, oil spill from the houseboat, and other toxic chemicals that may discharge from the

surface runoff on the road, storm water, and discharge of wastewater from the resort and hotels (e.g., heavy metals and chlorinated organic contaminants). Due to this reason, the water quality of this lake needs to be strictly monitored because of the rapid development of tourists and recreation activities. The main objectives of this study are to investigate water quality of the Royal Belum State Park at selected locations, to compare the water quality with the standard water quality provided by DOE and to propose suitable mitigation measures to control and sustain the water quality at the Royal Belum State. The finding from this study is significant to provide baseline water quality data for Department of Environment (DOE) and Department of Irrigation and Drainage (DID) to manage wastewater from recreational, commercial and houseboats' activities for short and long-term impacts.

METHODOLOGY

A systematic study was done to identify the status of the water quality at the Royal Belum State Park. In this study, in-situ and ex-situ measurements were conducted at six (6) selecting points (Refer to Table 1 and Figure 1). These sampling points were selected based on the location of the intersection of rivers and land use (e.g., Orang Asli Villages, check points for houseboats, houseboat docking area and camping stations)

Table 1: Sampling points at the Royal Belum State, Perak.

Sampling Points	Locations
Point 1	Royal Belum Check Point
Point 2	Sg. Tiang (near Kg. Orang Asli)
Point 3	Kg. Kelewang Orang Asli
Point 4	Sg. Kooi (Houseboat docking Area)
Point 5	Kem Sg. Tiang (Camping Site)
Point 6	Houseboat Docking Area (near main jetty)

Figure 1: Sampling location at the Royal Belum State Park, Perak.
Source: ***Perbadanan Taman Negeri Perak (PTNP, 2021).***

Collection of samples

For in-situ study, measurement of pH, turbidity, total dissolved solid (TDS), dissolved oxygen (DO), salinity, redox potential and conductivity and temperature were conducted at each sampling points using a Multiparameter Water Quality Meter (Horiba, Japan). Water samples were collected at each sampling for detailed analysis on the biological oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N) and total suspended solid (TSS) were conducted at the Environmental Laboratory, School of Civil Engineering, UiTM Shah Alam. Samples were collected in duplicated for better accuracy of the WQI calculation.

Laboratory analysis for the measurement of WQI

After the sampling process, water samples were transported to the laboratory to analyze the river water quality. The following parameters that were examined in the laboratory including BOD, COD, NH_3-N and TSS. Determination of, NH_3-N, DO, BOD, COD using the HACH DR2800 method in line with the Nessler method according to HACH (2007). All the samples were measured using DR2800 Spectrophotometer.

NH_3-N was measured using the HACH DR2800 in line with the Nessler method according to HACH (2007). The Nessler reagent contains mercuric iodide (D009). 25 mL of water samples and deionized water (DIW) (blank sample) were transferred into graduated cylinder (25 mL). Added 3 drops of mineral stabilizer to each cylinder and mixed. Then added 3 drops of polyvinyl alcohol dispersing agent to each cylinder and mixed. Finally, pipet 1.0 mL of Nessler Reagent into each cylinder, stopper and invert several times. After prepared all samples, allowed one minute reaction for each sample. Pour 10 mL of each sample in square sample cell and placed it in the cell holder for measurement. DR2800 Spectrophotometer was used to determine the concentration of NH_3-N. The wavelength of spectrophotometer was set to 380mm (Hanafiah et al., 2018).

According to HACH (2007), TSS was measured using DR2800 Spectrophotometer. The wavelength of TSS was set to 630mm. Prepared blank sample by using the DIW. 10 mL of the DIW was poured into the glass cell, the outer surface of the glass cell was cleaned with tissue to avoid error during the measurement and inserted it into the cell holder. Then, 10 mL of water sample was poured in the glass cell and follow the same procedures as mentioned above.

According to the HACH (2007), the COD was measured using The Reactor Digestion Method. The water samples were poured into the glass bottle containing potassium dichromate (oxidizing agent). Turn on the DRB2000 Reactor and preheat to 150 °C. Collected samples (100 mL) need to be homogenize for 30 sec by using blender. If the samples containing large amounts of solids, increase the homogenization time. Pipet 2.0 mL of sample into the vials. Vials need to be capped and cleaned the outside of the vial. Then hold the vial by the cap over a sink. Invert gently several times to mix. The samples vials will become hot during the mixing. Placed the vial in the preheated DRB200 Reactor and closed the protective lid. The samples need to be heated for two (2) hours at 150 °C. Then, wait for 20 mins for the vial to cool to 102 °C or less and inverted the vials several times while still hot. Placed the vial into the rack to cool to room temperature. Then, insert the vial into the cell holder of DR2800 Spectrophotometer to measure concentration of COD.

Measurement of the BOD is referring to HACH standard (2007). The collected samples from the lake were placed in the incubator at temperature 20 °C. Prepared 1L solutions of ferric chloride (0.75g) calcium chloride (27.5g) and sulphate (22.5g). Phosphate buffer solution was prepare using Monopotassium phosphate KH_2PO_4 (62.46 mM), Monopotassium phosphate K_2HPO_4 (124.9 mM), Na_2HPO_4 $7H_2O$ (124.6mM), and Ammonium chloride (NH_4Cl_2) (60 mM). Then, nutrient solution was prepared by using dilution method (1:1000), each solution above was diluted in 1L of DIW. Then, 100 mL of water sample was mixed with the 200 mL nutrient solution. Initiation concentration of dissolved oxygen (DO_i) was measured using DO meter. After 5 days of incubation the final measurement of DO (DO_f) was measured. The BOD_5 value was obtained by using Equation 1 below (P is the decimal volumetric fraction of samples used):

$$BOD_5\ (mg/L) = DO_i - DO_f/P \qquad \text{(Eq .1)}$$

Water Quality Index (WQI) was calculated using guideline (DOE, 2020). The calculation of the WQI consists of six (6) sub-index values as below (Eq. 2). The value of the WQI was compared with the standard references in Table 2, Table 3, and Table 4.

WQI = (0.22 x SIDO) + (0.19 x SIBOD) + (0.16 x SICOD) + (0.15 x SIAN) + (0.16 x SITSS) + (0.12 x SIpH) (Eq.2)

Where:

SIDO = Subindex DO (% saturation)
SIBOD = Subindex BOD
SICOD = Subindex COD
SIAN = Subindex NH_3-N
SISS = Subindex SS
SIpH = Subindex pH

Table 2: National Water Quality Standards for Malaysia

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	>2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	>12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	>100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	<3	<1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5-9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	T	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	ºC	-	Normal + 2°C	-	Normal + 2°C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform	count/ 100 ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/ 100 ml	100	5000	5000	50000	50000	>50000

Source: *The DOE Environmental Quality Report, 2020*

Table 3 :DOE Water Quality Index Classification

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/L	<0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/L	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/L	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/L	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7	6 – 7	5 – 6	< 5	> 5
Total Suspended Solid	mg/L	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)		> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Source: *The DOE Environmental Quality Report, 2020*

Table 4 : Water Classes and uses

CLASS	USES
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very 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.

Source: *The DOE Environmental Quality Report, 2020*

RESULTS AND DISCUSSION

In this study, ex-situ and in-situ measurements were conducted during the water sampling works at the Royal Belum State Park. For the in-situ measurement, a Multiparameter Water Quality Meter (Horiba, Japan) was used to measure pH, turbidity, total dissolved solid (TDS), dissolved oxygen (DO), conductivity and temperature. For the ex-situ measurement, 2L of water was collected at each sampling locations. These samples were analysed and measured for biological oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N) and total suspended solid (TSS) at the Environmental Laboratory, School of Civil Engineering, UiTM Shah Alam.

Figure 2 shows the average pH measurement of the Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area. This data shows that the pH measurement at all locations were in the neutral pH condition (pH 6.0 to pH 7.6), indicating that the pH for all points were in the class 1 (pH 6.5 to pH 8.5). However, pH at the Sg. Tiang which the location near to Kampung Orang Asli was slightly lower (pH 6.22) than the other locations, indicating that this location significantly contained chemical discharged from the Kampung Orang Asli.

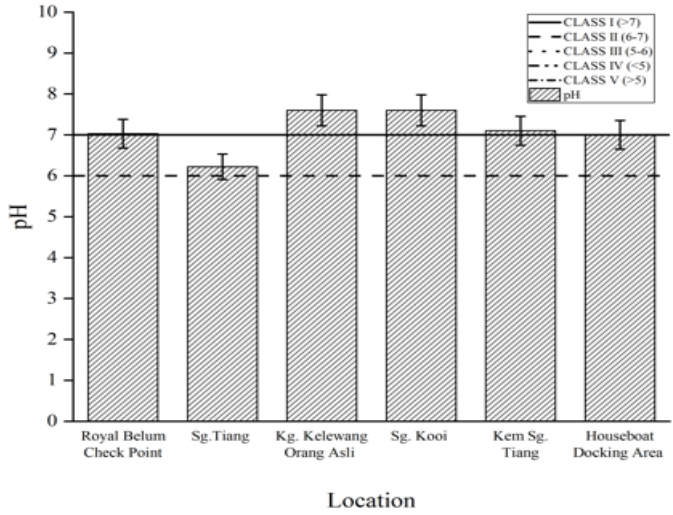


Figure 2: Measurement of pH at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area with 5% error bar

Figure 3 (a-b) shows that measurement of TDS (0.45 mS/cm) and conductivity (0.029 mg/L) at the Sg. Tiang were the highest among other locations (e.g., Belum Check Point (0.038 mS/cm), Kg. Kelewang Orang Asli (0.038 mS/cm), Sg. Kooi (0.038 mS/cm), Kem Sungai Tiang (0.038 mS/cm), Sg, Tiang (0.039 mS/cm), and Houseboat Docking Area (0.038 mS/cm). The overall measurements of conductivity and TDS were significantly lower than the 1000 µS/cm and 500 mg/L, indicating the value of conductivity and TDS of this lake was under class I. Due to this condition, the pH value of this lake was still at the neutral pH and safe for the ecosystem of the lake (e.g., under water organisms). Literature has reported that the low pH value significantly pose a risk to the ecosystem because they expedite the uptake of toxic elements by aquatic biota (Faragallah et al. 2009). Ustaoğlu and Tepe (2018) also represent that pH fluctuations in water may affect the toxicity of some compounds. pH values within safe limit (6.5–8.5) are considered safe for the skin, eyes, nose and ears.

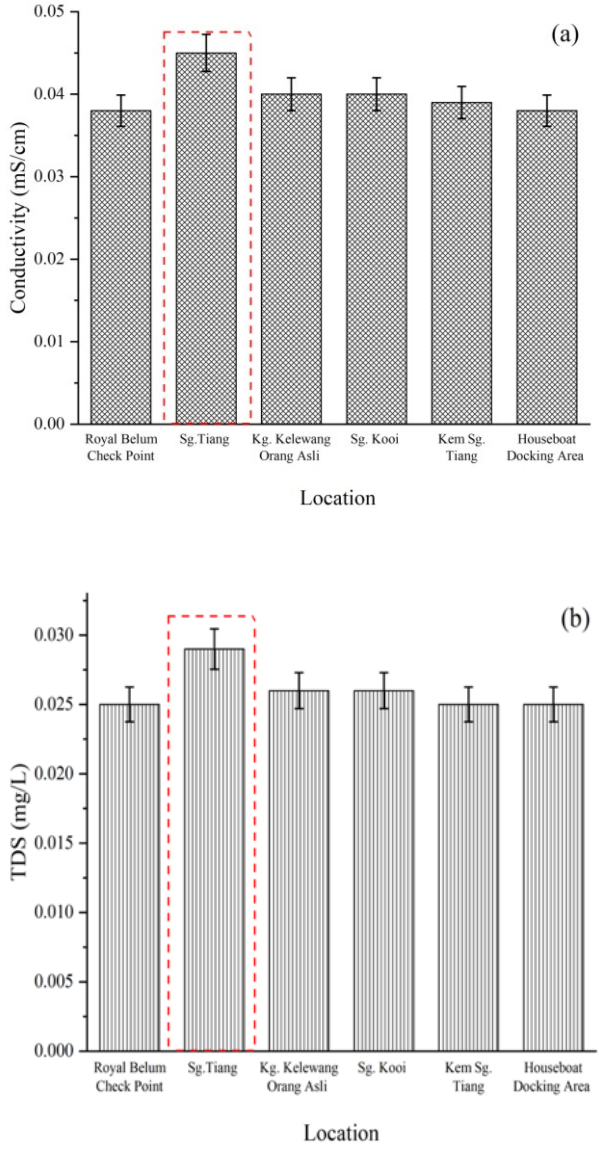
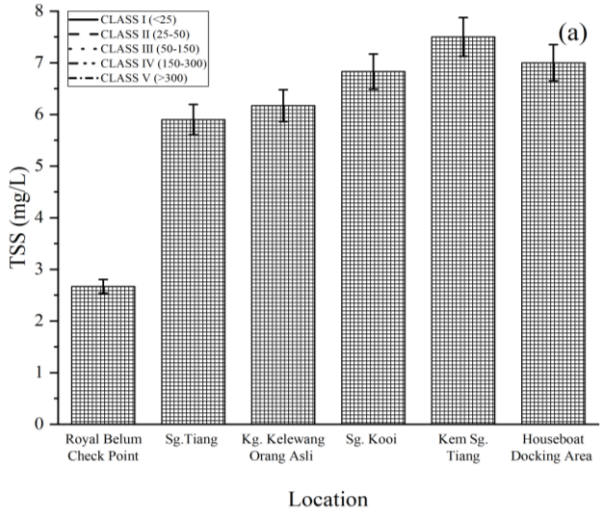


Figure 3(a-b): Measurement of Conductivity and TDS at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area with 5% error bar

Figure 4(a) shows the measurement of the TSS at the Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area. The concentration of the TSS was almost consistent in the range of 6.83 mg/L to 7.5 mg/L at the Sg. Kooi, Kem Sungai Tiang, and houseboat docking area. However, the concentration of TSS was significantly low at the Royal Belum Check Point (2.67 mg/L) and slightly increased at Sg. Tiang (5.9 mg/L). The concentration of the TSS was under the allowable limit (50 mg/L, Class 1), indicating that the lake was clean and safe to the underwater ecosystem. Interestingly, the TSS concentration at the Royal Belum Check Point was consistent with the measurement of the turbidity (8.4 NTU) (Figure 3b). While the measurement of the turbidity at other point (e.g., Sg. Tiang (26.9 NTU), Kg. Kelewang Orang Asli (16.1 NTU), Sg. Kooi (13.6 NTU), Kem Sg, Tiang (11.5 NTU), and Houseboat Docking Area (26NTU) were higher than the Royal Belum Check Point. Interestingly, the concentration of the TSS is significantly contradict with the concentration of the turbidity at all points except at the Royal Belum Check Point. According to National Water Quality Standards, the measurement of turbidity at all points were below 50 NTU, indicating that the concentration of the turbidity is not significant. Finding from this study is significantly contradict with the finding of the result from the previous study. Literatures have reported that low turbidity value indicates that the water is not significantly polluted by the inorganic and organic contaminants (Mekuria et al., 2021; Matta et al., 2020). This finding reveals that the concentrations of the TSS and turbidity were not significantly correlated and not critical during the weather condition at the Royal Belum State Belum Park.



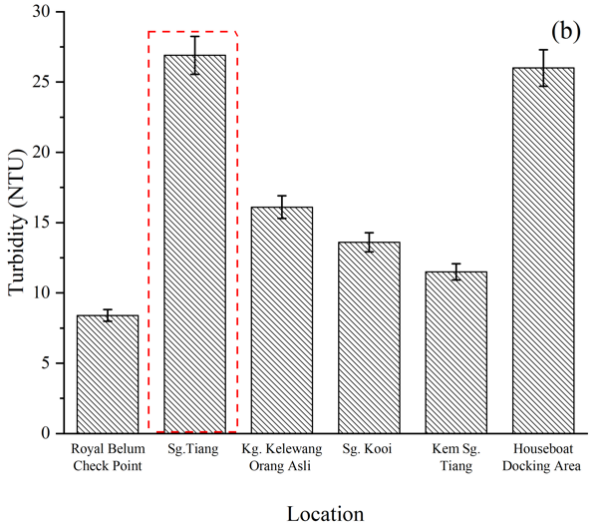


Figure 4(a-b): Measurement of TSS and Turbidity at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area with 5% error bar

Figure 5 shows the measurement of NH_3-N concentration at the Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area. Concentration of NH_3-H was detected at the Royal Belum Check Point (0.14 mg/L), Sungai Tiang (0.07 mg/L) and Houseboat Parking (0.035 mg/L) only. The concentration of the NH_3-N at these sampling points were lower than 0.2mg/L, indicating that the concentration of NH_3-N could be classified under class 2A ([NH_3-N]: 0.1 -0.2 mg/L) (DOE). Based on the literatures, potential sources of NH_3-N are fertilizers, human waste disposal, and animal manure (Yu et al., 2020; Lin et al., 2020; Jiang et al., 2019). Therefore, the potential sources of NH_3-N could be from the wastewater discharge from the houseboats (e.g. urine and faeces). The concentration of NH_3-N were significant low at the Royal Belum State Lake and will not be harmful to the ecosystem of the lake. However, if the concentration of the NH_3-N is not controlled and increased to 0.2 mg/L, the ecosystem of the river will be significantly deteriorated. For example, there will be odour issue from the water, eutrophication and fishes may die (Yang et al., 2020; John et al., 2020). Therefore, the concentration of the NH_3-N needs to be controlled and monitored.

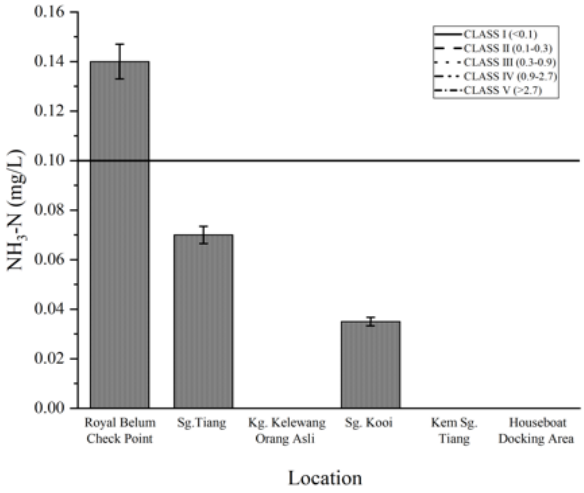


Figure 5: Measurement of NH_3-N at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area with 5% error bar

Figure 6 shows the COD concentrations at the Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area. The COD concentration was significantly higher at the houseboat docking area (22.5 mg/L, Class II) than other sampling points. Based on the observation at the houseboat docking area, the lake water was polluted by the leaking of diesel from the houseboat, wastewater and sullage water from the houseboat, floating solid waste (e.g., food waste, bottles and others) and construction of houseboat. Therefore, high concentration of COD at this sampling point was due to the high concentration of pollutant discharge from the houseboat. The concentration of CODs at the Sg.Kooi (5.5 mg/L), Sg. Tiang (7 mg/L), Kem Sg. Tiang (8.17 mg/L) and Royal Belum Check Point (8.83 mg/L) were under Class I (<10 mg/L). These sampling points were located at the middle area of the lake, moderate current of water and no houseboats were observed, indicating that the water was free from any source of pollution. As discussed above, value of turbidity (26 mg/L) and TSS (7 mg/L) were significantly higher at the houseboat docking area than other sampling area. Contradict result was measured for TDS and conductivity. Measurement of TDS (0.025 mg/L) and conductivity (0.038 mg/L) were the lowest among other sampling points. This result indicates that the high concentration of COD was due to the absorbed pollutants on the suspended solid in the water. Based on the literature, organic pollutants (e.g., tetrachloroethene and polyaromatic hydrocarbon) are significantly adsorbed on the surface of media or particles (e.g., soil minerals and plastic) (Mohamad et al., (2021) and Mohd-Towel., et al (2023)). Therefore, the presence of organic pollutant in this lake significantly adsorbed on the surface suspended solid and may significantly deteriorate the quality of the water.

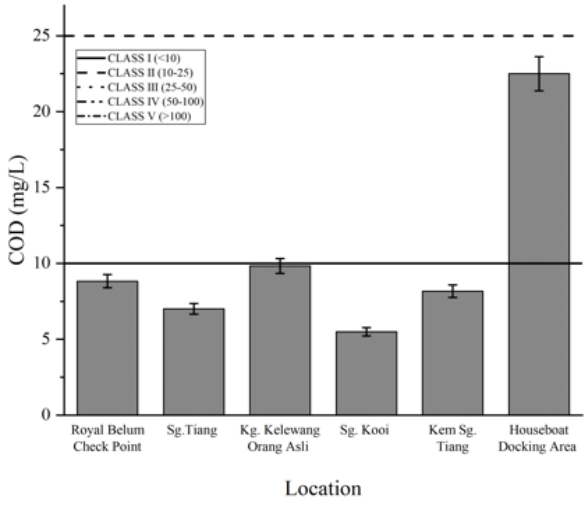


Figure 6: Measurement of COD at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Area with 5% error bar

Figure 7 shows concentration of BOD at the Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area. The BOD concentration was slightly similar at the Royal Belum Check Point (10.68 mg/L), Sg. Tiang (11.64 mg/L), Sg. Kelewang Orang Asli (12.48 mg/L) and Sg. Kooi (12.8 mg/L). The BOD measurements at these areas were classified as Class IV (12 mg/L). The BOD measurements at Kem. Sg. Tiang (22.13 mg/L) and Houseboat Docking Area (25.9 mg/L) were significantly higher than other sampling areas and classified as Class V (>12 mg/L). Interestingly, the patterns of the BOD concentrations were similar to the measurement of COD and TSS concentrations (refer to Figure 3a and Figure 5). These results indicate that the presence of microorganisms in the water is significantly correlated with the presence of organic pollutants and suspended solids in the water. Literatures have proved that the organic pollutant is a source of carbon for the microorganisms in the contaminated water (Mohd-Towel., et al (2023). Due to this reason, the BOD concentration was the highest at the houseboat docking area among other areas. At this docking area, sullage water from the houseboat kitchen may discharge into the lake and promote growth rate of microorganisms in the water. Finding from this study reveals that the concentrations of TSS, COD and BOD were significantly correlated and may significantly influence the water quality at the Royal Belum State Park.

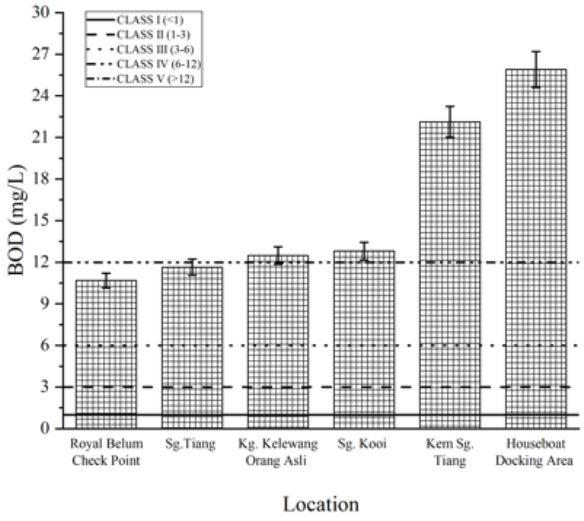


Figure 7: Measurement of BOD at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area with 5% error bar

Figure 8 shows the low DO concentrations at the Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area. The highest DO concentration was measured at the Houseboat Docking Area (5.04 mg/L) among other sampling locations. The lowest DO concentration was measured at Kg. Kelewang Orang Asli (2.3 mg/L) and Sg. Tiang (2.56 mg/L), indicating that these areas were classified under Class IV (DO < 3 mg/L). The DO concentration at the Royal Belum Check Point (3.64 mg/L), Sg. Kooi (3.72 mg/L) and Kem. Sg. Tiang (3.53 mg/L) were classified under class III (3mg/L < DO < 5 mg/L). Interestingly, the DO concentration was significantly high at the houseboat docking area, even though it had high concentration of BOD (25.9 mg/L), COD (22.5 mg/L) and TSS (7 mg/L). Based on the observation during the sampling of water, the condition of the water at the houseboat docking area was not significant stagnant due to movement of houseboats and speed boat crossing this area. Theoretically, the DO concentration will be low if the concentrations of BOD and COD are high (Iloms et al., 2020; Dutta et al., 2020). Literatures have reported that the DO concentration strongly influenced by the condition of water, either the water is stagnant or flowing (Tomić et al., 2018; Chen at al., 2020). This finding suggests that the concentration of DO is stable and promote good ecosystem for the underwater living organisms. Therefore, this lake become main attraction to the aquaculture activity due to the variety of fishes in the lake. For example, Toman (Giant Snakehead) and Sebarau (Hampala Barb-Jungle Perch). Therefore, the concentration of DO could be a good indicator to monitor quality of lake and river.

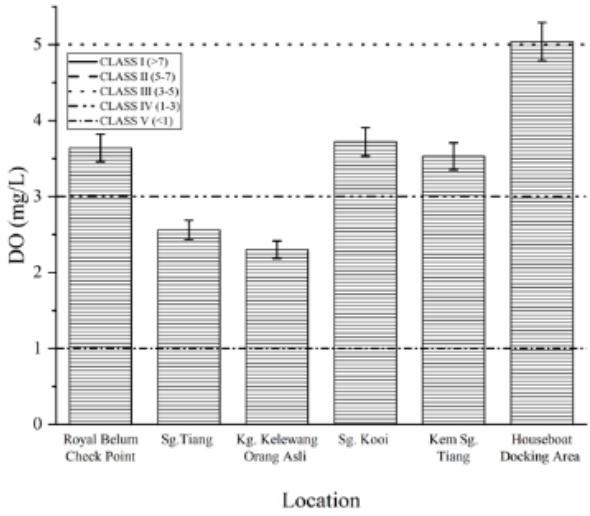


Figure 8: Measurement of DO at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area with 5% error bar

Figure 9 shows the WQI at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area. The measurement of WQI was calculated based on the guideline provided by the Malaysian Department of Environment Water Quality Index (DOE-WQI) (DOE, 2020). The WQI could be classified as Class I, II, III, IV and V (Refer to Table 2.0). Interestingly, the WQI at all samplings area were classified as Class III (WQI = 51.9 to 76.5), indicating that the water required extensive water treatment and the water needs to be protected to preserve economic value and tolerant species for livestock drinking. The most deteriorated water qualities were at Kg. Kelewang Orang Asli (69.9) and Kem. Sg. Tiang (70.9) compared to other sampling areas. The WQI at the Royal Belum Check Point (75.1) and the Kem Sg. Tiang (75.4) were considered good water quality compared to other sampling areas. This is due to the condition of the water was not stagnant and movement of the houseboat and speedboat that could promote formation of current and enhanced the concentration of DO. The WQI of these sampling areas were significantly affected by the concentrations of TSS, DO, BOD and COD. Figure 9 shows combination of results on the concentration of BOD, COD, TSS and DO at the Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area. Concentrations of BOD, COD and TSS show similar trend compared to the concentration of DO at all sampling area. Interestingly, the DO concentration at Kg. Kelewang Orang Asli was the lowest (DO<2.5mg/L) and it significantly decreased the value of WQI (69.9). Therefore, this finding suggests that the concentration of DO is crucial than other WQI parameters. The concentration of DO above 2.5mg/L shows good WQI except for the Kg. Kelewang Orang Asli. Even though, the concentration of BOD, COD and TSS were high, the WQI

of this area are above 70. This finding also shows that the main factor that deteriorated water quality at the lake is anthropogenic pollution (e.g., solid waste, wastewater, sullage water, and leakage of petrol from houseboat). Therefore, control pollution at source and increase awareness on the water quality is significantly required for the Royal Belum State Park.

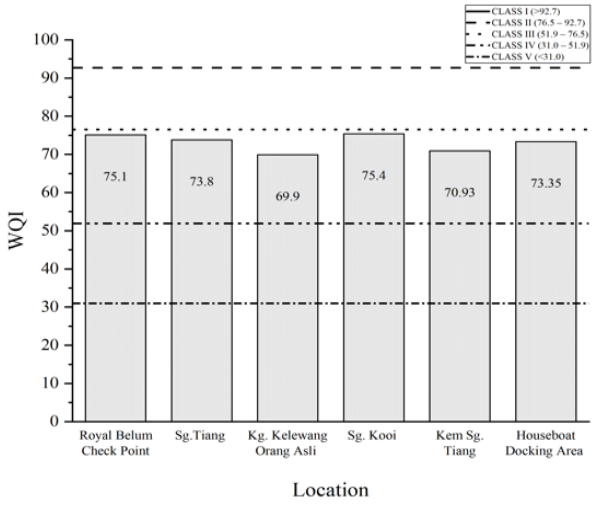


Figure 9: WQI at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area

Table 5 shows correlation analysis R^2 for water quality parameters (pH, DO, BOD, COD, NH_3-N, TDS, turbidity and conductivity). Correlation analysis for conductivity-TDS (R^2=0.98) and TSS-NH_3-N (R^2=0.80) were significantly correlated in this study. Figure 2(a-b) above also support similar trend of concentration of TDS and conductivity at all sampling points, indicating that measurement of conductivity and TDS were significant to detect the presence of abundant chemical species in the Royal Belum State Park. The correlation between TSS- NH_3-N may suggest that the source of TSS and NH_3-N may come from the sullage water and wastewater from the boathouse. However, further verification is required to provide more evidences of this correlation. Positive and meaningful correlation were determined by DO-BOD (R^2=0.39), DO-COD (R^2=0.37), BOD-COD (R^2=0.44). These correlation values support result and discussion in Figure 9. As mentioned in the Figure 9, concentrations of BOD, COD, DO and TSS significantly affect the value of WQI of the Royal Belum State Park. Weak correlation for TSS-BOD (R^2=0.22), TDS-pH(R^2=0.24), TDS-DO (R^2=0.20), conductivity-pH (R^2=0.22), and conductivity-DO (R^2=0.26) were also measured. Interestingly all parameters show negative correlation with TSS except for BOD and NH_3-N. This correlation analysis shows that the parameters of the water quality were significantly correlated to each other (e.g., conductivity-TDS, TSS- NH_3-N and BOD-COD) and may demonstrate good indication during the in-situ measurement of the water quality.

Table 5: Correlation analysis for water quality parameters

Parameter	Value R^2								
	pH	**DO**	**BOD**	**COD**	**NH_3-N**	**TSS**	**TDS**	**Turbidity**	**Conductivity**
pH		-0.24	-0.25	-0.25	-0.08	-0.22	0.24	0.16	0.22
DO	-0.24		0.39	037	-0.24	-0.23	0.20	-0.24	0.26
BOD	-0.25	0.39		0.44	0.26	0.22	0.04	-0.14	-0.004
COD	-0.25	0.37	0.44		-0.10	-0.20	-0.06	0.06	-0.001
NH_3-N	-0.08	-0.24	0.26	-0.10		0.80	-0.22	-0.14	-0.24
Turbidity	0.16	-0.24	-0.14	0.06	-0.14	-0.07	0.18		0.12
TSS	-0.22	-0.23	0.22	-0.20	0.80		-0.25	-0.07	-0.23
Conductivity	0.22	0.26	-0.004	-0.001	-0.24	-0.23	0.98	0.12	
TDS	0.24	0.20	0.04	-0.06	-0.22	-0.25		0.18	0.98

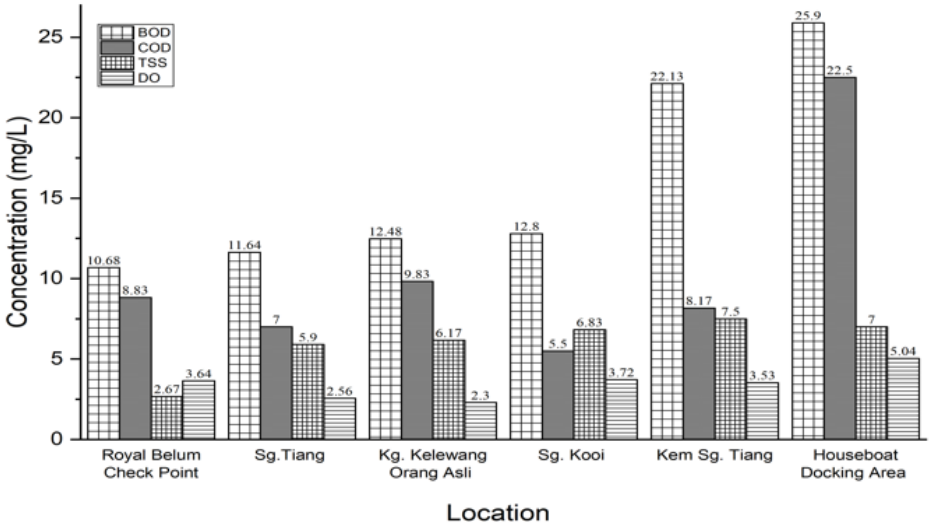


Figure 10: BOD, COD, TSS and DO at Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area.

CONCLUSION

This study demonstrates that the WQI of the Royal Belum State Lake was classified as Class (III) (WQI : 51.9 to76.5). The in-situ and ex-situ measurements of water quality parameters (e.g., BOD, COD, TSS, DO, NH_3 and pH) were determined at six (6) sampling area (e.g., Royal Belum Check Point, Sg. Tiang, Kg. Kelewang Orang Asli, Sg. Kooi, Kem Sg. Tiang dan Houseboat Docking Area). The WQI at each sample area was within the range of 69.9 and 73.35 (Belum Belum Check Point (75.1), Kg. Kelewang Orang Asli (73.8), Sg. Kooi (69.9), Kem Sungai Tiang (75.4), Sg, Tiang (70.93), and Houseboat Docking Area (73.35)). The WQI of these sampling areas were significantly affected by the concentrations of TSS, DO, BOD and COD. Concentrations of BOD, COD and TSS show similar trend compared to the concentration of DO at all sampling area. Interestingly, the DO concentration at Kg. Kelewang Orang Asli is the lowest (DO<2.5mg/L) and it significantly decreased the value of WQI (69.9). Therefore, this finding suggests that the concentration of DO is crucial than other WQI parameters. The correlation analysis shows that the parameters of the water quality were significantly correlated to each other (e.g., conductivity-TDS, TSS- NH_3-N and BOD-COD) and may demonstrate good indication during the in-situ measurement of the water quality. These findings show that the main factor that deteriorated water quality at the Royal Belum State Park is anthropogenic pollution (e.g., solid waste, wastewater, sullage water, and leakage of petrol from houseboat). Therefore, control pollution at source and increase awareness on the water quality is significantly required for the Royal Belum State Park. The state government and relevant authorities such as Department of Environment (DOE) and Perak State Government need to play an important role to manage, monitor and control sources of pollution (e.g., point source and non-point source of pollution). The water resource management and water quality control are very essential to provide clean water supply and support tourism activities at the Royal Belum State Lake.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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