WATER QUALITY STATUS OF SELECTED UNDISTURBED HEADWATERS IN SARAWAK

Nur Bazilah, I.[1], Geoffery, J.G.[2], Mohd. Zalek, S.[1], Robin, S.[1] and Mohizah, M.[1]

[1]Forest Department Sarawak, Sarawak (MALAYSIA)
[2]Universiti Putra Malaysia Bintulu Sarawak Campus, Sarawak (MALAYSIA)

Email: nurbi@sarawak.gov.my

Abstract

Humans and other living things depend on water for life and health. The world's most sustainable and high-quality freshwater sources come from forested catchments, and forests have long been recognized as essential sources of clean drinking water. In addition, forested catchments provide a high proportion of the water for domestic, agricultural, and environmental needs in both upstream and downstream areas. However, the hydrological studies, particularly on aspects of water quality, are still in their infancy stage in the upper reaches of Sarawak's tropical forested catchments. Therefore, a water quality assessment of upper forested catchments is needed as it provides the knowledge and information in managing the forest for water conservation. Hence, this study compares and quantifies *in-situ* physico-chemical quality of surface water in three forested catchments in Sarawak; Long Banga, Bukit Kana and Kelingkang Range. Selected *in-situ* physico-chemical parameters such as pH, temperature, conductivity, dissolved oxygen, total dissolved solids, and ammoniacal nitrogen were taken based on a total of 81 samples based on 9 sampling stations for each catchment during three different scientific expeditions. The mean values of these parameters were compared and classified according to the National Water Quality Standards for Malaysia (NWQS). The data indicate that the measured parameters were still within permissible limits and characterized by good water quality with an average between class I and IIA, which is interpreted as unpolluted and preserved in its natural condition. Therefore, the upper forest area needs to be protected as it performs the function of a water catchment area that provides clean and undisturbed water that can be used by humans without costly treatment. In addition, good stream water quality is vital to a healthy river ecosystem as it offers the best conditions for aquatic life to thrive in the water and ensures the long-term sustainability of clean water resources. This preliminary result can update the baseline data of selected water quality parameters and could serve as a tool for assisting relevant government bodies in regulating the water resources policies in the future.

Keywords: Water quality, physico-chemical parameters, forested catchments

1.0 INTRODUCTION

Surface water resources have played an important function as basic national water resource. The quality of water is affected by a wide spectrum of natural and human influences. The major natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available (Ashraf et al., 2010). The most sustainable and best quality freshwater sources in the world originate in forested watersheds (Barten and Ernst, 2004). Healthy forests are critical to provide clean water and according to Clare and Janet (2013), forested catchments serve as guarantors of high value surface and drinking water.

In Malaysia, the use of the National Water Quality Standards (NWQS) is enforced by the Department of Environment (Ainon and Yanti, 2008). NWQS is a standard which was orientated on quality of water according to the beneficial uses which can be considered to be suitable for a specific use as long as it is within the range specified for the designated classes. The classes ranged from class I to V (I, IIA, IIB, III, IV and V). According to Yisa and Jimoh (2010), it is an important standardization measurement that is most helpful in assessing and monitoring surface water.

Good stream water quality is important for a healthy river ecosystem to provide optimal conditions for aquatic life to thrive and for sustainable clean water resources. Such a benchmark for undisturbed upper forested catchments is needed and essential to compare and evaluate the magnitude of impacts due to other land-use activities at other locations, particularly in downstream catchments. The outcome of this study suggested to provide baseline data on selected water quality parameters and serve as a tool to support relevant government bodies in future water resource policy regulation.

2.0 MATERIALS AND METHODS

2.1 Study area

Kelingkang Range is forest reserve area in Sri Aman, while Bukit Kana and Long Banga are totally protected areas in the Miri and Bintulu region in Sarawak respectively (Fig. 1). The Kelingkang Range runs along the Sarawak-Kalimantan border in the east of Serian Division and the west of Sri Aman Division and has an elevation of 610m. Meanwhile, Bukit Kana is located at Tatau District, Bintulu, which covers an area of 4,923 hectares of hilly forests (FDS) and has an elevation of 645m. Long Banga, Ulu Baram Miri, is one of the areas covered under the Heart of Borneo initiatives and it is located at 437m above sea level and near Kalimantan, Indonesia border. The vegetation within all catchments consists of riverine forest and is predominantly covered with mixed hilly dipterocarp and non-dipterocarp trees.

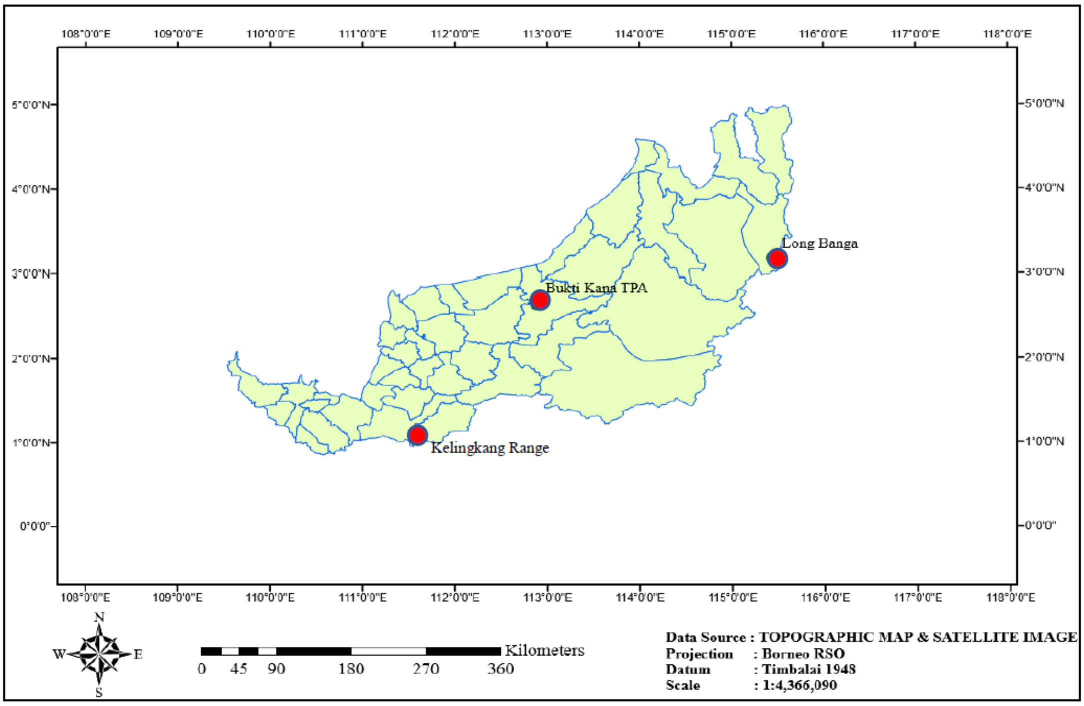


Fig. 1 Map showing location of Long Banga, Kelingkang Range and Bukit Kana

2.2 Methodology

A total of 81 samples from 9 sampling stations for each location were chosen based on accessibility and homogeneity in order to obtain a representative sample. Simple characteristics and general description of sampling station chosen were recorded. This study only involves *in-situ* parameters and each of the parameter has significant impact on the water quality. A multi-parameter handheld Eutech Cyberscan PCD650 is used at every sampling point to measure pH, temperature, conductivity, dissolved oxygen and total dissolved solids. Ammonia nitrogen is detected by using HACH test kit, while portable turbidimeter Eutech TN-100 is used to measure water turbidity.

Results from sampling were compared to the Malaysia National Water Quality Standards (NWQS). NWQS classifies six classes (I, IIA, IIB, III, IV and V) of water quality in accordance with the highest beneficial uses attainable in each class. NWQS is also a preliminary means of assessing a river which provides a number that pollutants should not exceed.

3.0 RESULTS AND DISCUSSION

General descriptions of each sampling station are shown in Table 1, whereas the physico-chemical water parameters results are summarized in Table 2.

Table 1 The characteristics of each station surveyed in Long Banga, Kelingkang Range and Bukit Kana streams.

Catchments	Sampling station	Description of sampling station
Long Banga	LB1 (Sg. Puak)	Swift flowing, semi-clear water, rocky bottom
	LB2 (Sg. Ma'o Kecil)	Swift flowing, clear water, rocky bottom
	LB3 (Sg. Ma'oBesar)	Swift flowing, clear water, rocky bottom
	LB4 (Sg. Sekuan)	Swift flowing and semi-clear water, rocky bottom, some parts with small waterfalls
	LB5 (Sg. Pesi)	Slow flowing, clear water, rocky bottom
	LB6 (Sg. Kabok)	Swift flowing, semi-clear water, rocky bottom
	LB7 (Sg. Sena)	Swift flowing, semi-clear water, rocky bottom
	LB8 (Sg. Ano)	Slow flowing, partially covered by forest canopy at the downstream. Swift flowing, rocky bottom, has a waterfall at the upper stream (Arol Ano Waterfall)
	LB9 (Sg. Baleh)	Swift flowing, semi-clear water, rocky bottom
Kelingkang Range	KR1 (Sg. Keroh)	Slow flowing, semi-clear water, has small waterfall
	KR2 (Sg. Keroh)	Slow flowing, semi-clear water
	KR3 (Sg. Keroh)	Slow flowing, semi-clear water
	KR4 (Sg. Keroh)	Slow flowing, semi-clear water
	KR5 (Sg. Selepong)	Swift flowing, clear water, rocky bottom
	KR6 (Sg. Selepong)	Slow flowing, clear water, rocky bottom, some parts with small waterfall
	KR7 (Sg. Selepong)	Slow flowing, semi-clear water
	KR8 (Sg. Nibong)	Slow flowing, clear water, rocky bottom
	KR9 (Sg. Selepong)	Slow flowing, clear water, rocky bottom
Bukit Kana	BK1 (Sg. Kana Kiri)	Swift flowing, clear water, rocky bottom, some parts with small waterfalls
	BK2 (Sg. Kana Kiri)	Swift flowing, clear water, rocky bottom
	BK3 (Sg. Kana Kanan)	Swift flowing, clear water, has waterfall
	BK4 (Sg. Kana Kanan)	Swift flowing, clear water, rocky bottom
	BK5 (Sg. Kana Kiri)	Slow flowing, semi-clear water
	BK6 (Sg. Kana Kiri)	Slow flowing, semi-clear water
	BK7 (Sg. Kana Kiri)	Swift flowing, clear water
	BK8 (Sg. Kana Kanan)	Swift flowing, clear water, rocky bottom, some parts with small waterfalls
	BK9 (Sg. Kana Kanan)	Swift flowing, clear water, rocky bottom, some parts with small waterfalls

Table 2 Average range of selected water quality parameters in each station

SAMPLING STATION	PARAMETERS/RESULTS AND NWQS CLASS						
	Temp (°C)	pH	Turbidity (NTU)	DO (mg/L)	Conductivity (µS/cm)	TDS (mg/L)	NH_3N (mg/L)
LB 1	24.3±0.31 N	8.1±0.58 I	11.96±0.81 IIA	7.01±0.78 I	73.64±0.14 I	69.50±0.30 I	0.06±0.03 I
LB 2	22.6±0.62 N	8.1±0.17 I	2.43±0.99 I	8.72±0.35 I	147.3±0.88 I	14.00±0.37 I	0.04±0.02 I
LB 3	23.3±0.43 N	8.15±0.62 I	3.07±0.26 I	8.54±0.89 I	75.0±0.46 I	70.79±0.14 I	0.06±0.04 I
LB 4	22.4±0.55 N	7.72±0.42 I	20.9±0.33 IIA	9.11±0.91 I	68.23±0.61 I	64.42±0.62 I	0.12±0.06 I
LB 5	22.9±0.36 N	7.53±0.77 I	26.73±0.11 IIA	8.03±0.84 I	50.66±0.98 I	47.81±0.81 I	0.05±0.02 I
LB 6	22.0±0.53 N	7.53±0.36 I	24.63±0.07 IIA	7.11±0.32 I	85.62±0.64 I	80.80±0.73 I	0.05±0.01 I
LB 7	22.1±0.73 N	7.70±0.22 I	5.43±0.19 I	6.92±0.46 IIA	72.47±0.23 I	68.55±0.11 I	0.08±0.01 I
LB 8	23.8±0.38 N	7.34±0.31 I	8.2±0.22 IIA	6.83±0.67 IIA	61.48±0.69 I	58.00±0.51 I	0.13±0.02 IIA
LB 9	21.9±0.93 N	7.22±0.71 I	10.34±0.27 IIA	7.81±0.21 I	18.2±0.71 I	17.18±0.16 I	0.15±0.01 IIA
KR1	24.8±0.05 N	7.10±0.85 I	11.41±0.54 IIA	7.40±0.10 I	12.16±0.09 I	13.50±0.04 I	0.1±0.01 I
KR2	24.8±0.05 N	6.53±0.10 I	11.80±0.42 IIA	7.55±0.13 I	8.89±0.13 I	9.68±0.17 I	0±0.00 I
KR3	24.8±0.05 N	6.48±0.07 IIA	9.48±0.48 IIA	7.76±0.01 I	6.71±0.11 I	7.44±0.08 I	0.1±0.01 I
KR4	25.4±0.05 N	5.97±0.02 III	13.96±0.25 IIA	5.77±0.08 IIA	9.20±0.15 I	10.23±0.15 I	0±0.00 I
KR5	25.6±0.05 N	6.23±0.01 IIA	15.11±0.17 IIA	6.82±0.01 IIA	8.72±0.05 I	9.62±0.03 I	0.1±0.01 I
KR6	25.8±0.05 N	6.35±0.10 IIA	15.71±0.51 IIA	7.56±0.02 I	8.51±0.04 I	9.43±0.02 I	0.1±0.02 I
KR7	25.6±0.05 N	6.17±0.02 IIA	15.03±0.06 IIA	6.73±0.02 IIA	8.99±0.04 I	10.09±0.07 I	0±0.00 I
KR8	25.7±0.05 N	5.72±0.03 III	19.65±0.37 IIA	7.20±0.05 I	4.00±0.04 I	4.42±0.05 I	0±0.00 I
KR9	25.7±0.05 N	6.29±0.06 IIA	14.60±0.29 IIA	6.84±0.16 IIA	7.97±0.05 I	8.77±0.06 I	0.1±0.02 I
BK 1	23.2±0.41 N	7.25±0.30 I	5.67±0.19 I	5.58±0.09 IIA	13.20±0.44 I	6.41±0.23 I	0.1±0.01 I
BK 2	22.6±0.53 N	8.27±0.11 I	5.79±0.29 I	6.58±0.24 IIA	18.79±0.12 I	9.05±0.74 I	0±0.00 I
BK 3	24.5±0.67 N	7.10±0.13 I	1.74±0.47 I	8.21±0.11 I	14.16±0.19 I	6.89±0.25 I	0.1±0.01 I
BK 4	23.8±0.77 N	8.29±0.21 I	1.69±0.77 I	8.75±0.54 I	13.54±0.08 I	6.60±0.09 I	0±0.00 I
BK 5	22.3±0.47 N	7.71±0.18 I	13.79±0.79 I	7.21±0.66 I	11.68±0.36 I	5.63±0.04 I	0.1±0.01 I

BK 6	23.3±0.83 N	7.88±0.38 I	12.97±0.92 I	9.09±0.71 I	11.52±0.31 I	5.61±0.08 I	0.1±0.02 I
BK 7	23.0±0.27 N	7.09±0.74 I	1.76±0.08 I	6.51±0.58 IIA	14.38±0.58 I	7.00±0.30 I	0±0.00 I
BK 8	24.3±0.66 N	7.02±0.61 I	3.25±0.32 I	6.52±0.36 IIA	13.81±0.47 I	6.72±0.22 I	0±0.00 I
BK 9	23.3±0.28 N	7.30±0.22 I	2.31±0.15 I	7.36±0.81 I	15.01±0.56 I	7.30±0.04 I	0±0.00 I

This study found that the temperature values varied from 21.9°C to 24.3°C at Long Banga (LB), 24.8°C to 25.8°C at Kelingkang Range (KR) and 22.6°C to 24.5°C at Bukit Kana (BK). This condition is considered normal for waterbodies despite the differences in temperature range. The thick forest canopy provides cover for waterbody hence the low temperature. In general, the stream temperature can be affected by the factors such as sampling location, time, weather conditions and biological activity within the stream.

Next, parameter pH is one of the commonly performed water quality tests and is a measure of the amount of free hydrogen ions in the water and neutral levels have a pH of 7 (Miroslav et al. 2007). Generally, pH value is an indicator of the relative acidity or alkalinity of a solution. The pH of the stream ranged from 7.22 to 8.15 at LB, from 5.72 to 7.10 at KR and between 7.02 to 8.29 at BK. Based on the NWQS, all three sampling stations showed an average pH level within class I and IIA. The pH of the water body is very important in determining its water quality since it affects other chemical reactions (Fakayode, 2005). Besides, most aquatic animals and plants have adapted to life in water with a specific pH and may suffer from even a slight change (Cole et al., 1999).

Turbidity gives an indication of the clarity of water and is influenced by the number of suspended materials in the water (Nguyen & Cai, 2019). It is the measure of how suspended particles in water will affect its clarity. Submerged aquatic plants in the deeper parts of streams would be affected by turbidity as turbid water would reduce the penetration of sunlight into the water. In LB, turbidity values ranged from 2.43 NTU to 26.73 NTU, while KR ranged from 9.48 NTU to 19.95 NTU and BK ranged from 1.74 NTU to 13.79 NTU. Overall, all catchments showed turbidity index within class I and IIA.

As a parameter, dissolved oxygen (DO) is also used to measure water quality. The DO reading shows the amount of dissolved oxygen in a waterbody. According to Holgate (1979), the DO parameter is important for aquatic biology. In LB, the average DO reading was 7.79 mg/L and KR and BK were 7.07 mg/L and 7.31 mg/L respectively. According to NWQS, all sampling stations were classified under class I, which represents excellent condition of oxygen rate. Concentration below 5 mg/L may adversely affect function and survival of biological communities, and below 2 mg/L can lead to death of fish that are not adapted to such conditions.

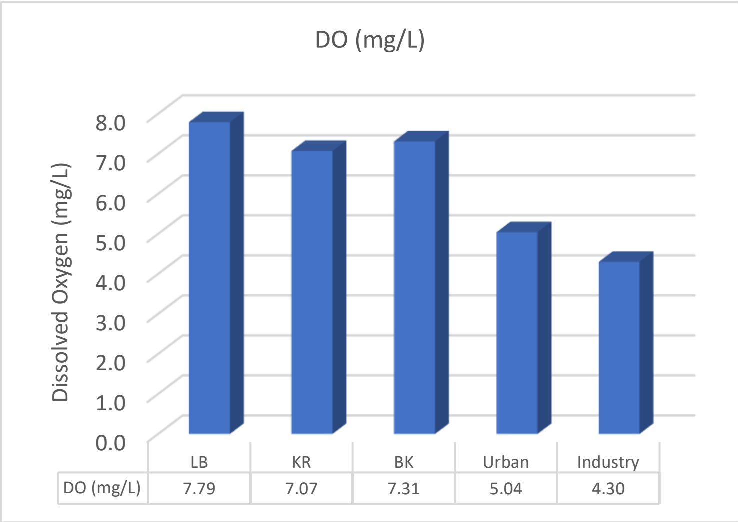
Conductivity is directly related to the amounts of dissolved ions in water. It is a measure of the ability of water to pass an electrical current. The conductivity value at LB was high, ranging from 18.2 – 147.3 µS/cm compared to KR and BK, which recorded 11.52 – 18.79 µS/cm and 11.52 – 18.79 µS/cm respectively. The conductivity values obtained from all sampling stations were found to be in class I, which is within the suggested level of NWQS.

The values of total dissolved solids (TDS) at LB are ranging from 14.00 mg/L to 80.80 mg/L, 4.42 mg/L to 13.50 mg/L at KR and 5.61 mg/L to 9.05 mg/L at BK. The highest value obtained was 80.80 mg/L recorded at sampling station LB6, and the lowest value obtained was 4.42 mg/L recorded at sampling station KR8 (Table 2). TDS results for all sampling stations were within the standard allowable levels of Malaysian rivers and classified as class I determined by NWQS.

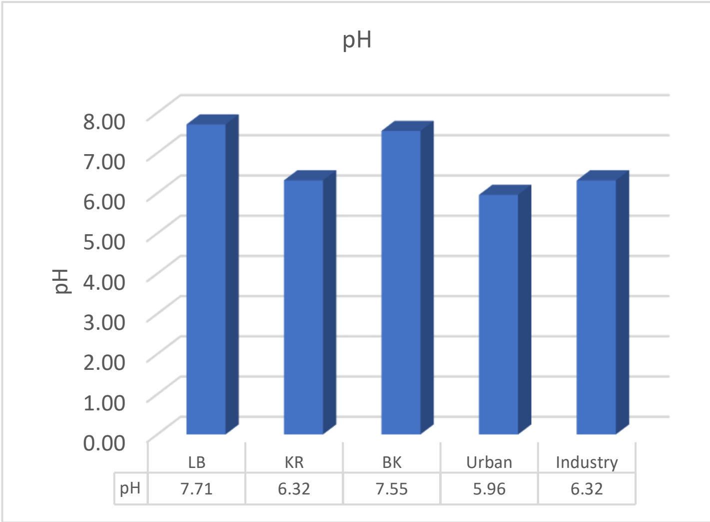
The only nutrient parameter tested in this study was ammoniacal nitrogen (NH_3N)**.** A form of inorganic nitrogen, ammoniacal nitrogen is a measure for the amount of ammonia which is a toxic pollutant. The average amount of ammoniacal nitrogen was 0.08 mg/Lat LB, 0.05 mg/L at KR and 0.04 mg/L at BK. LB showed the highest concentration and this could be due to the decomposition of organic matter. All the sampling stations fall under class I, in which most of the catchments showed no significant pollution with concentrations less than 0.1 mg/L, an expected value for natural and undisturbed water bodies.

Comparison of physico-chemical patterns under different locations

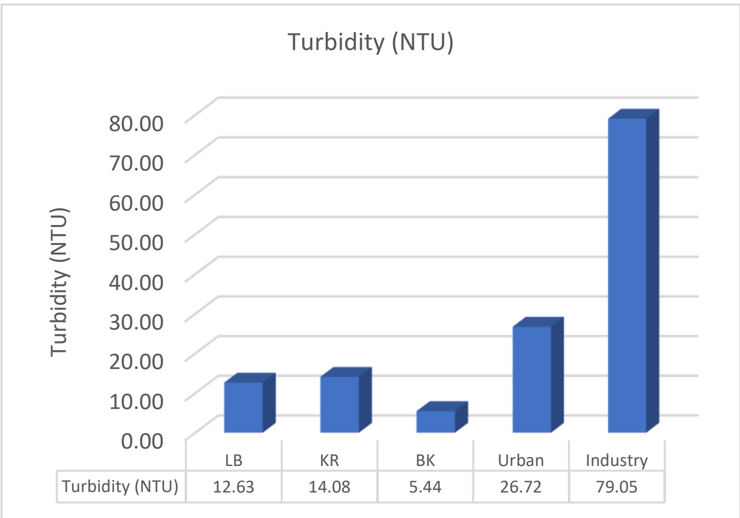
Fig. 3 compares the physico-chemical results generated from this study against previous water quality studies conducted in urban and industrial area. These findings revealed the water quality of undisturbed forest catchments to be excellent, when compared to water bodies in urban and industrial area.



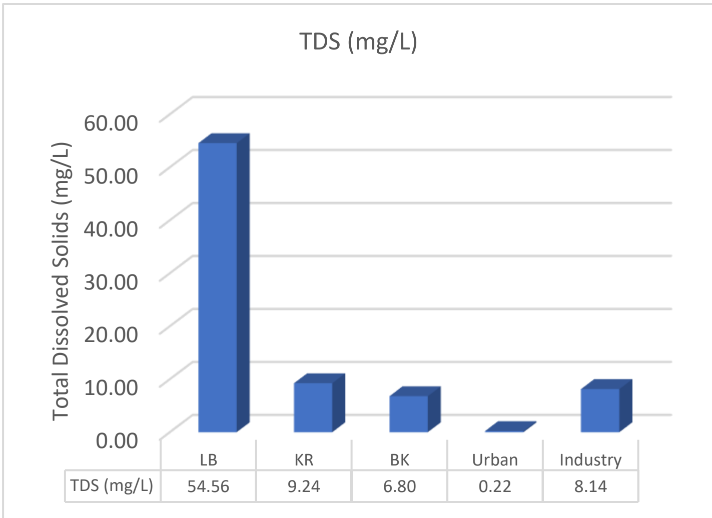
(a) Dissolved oxygen



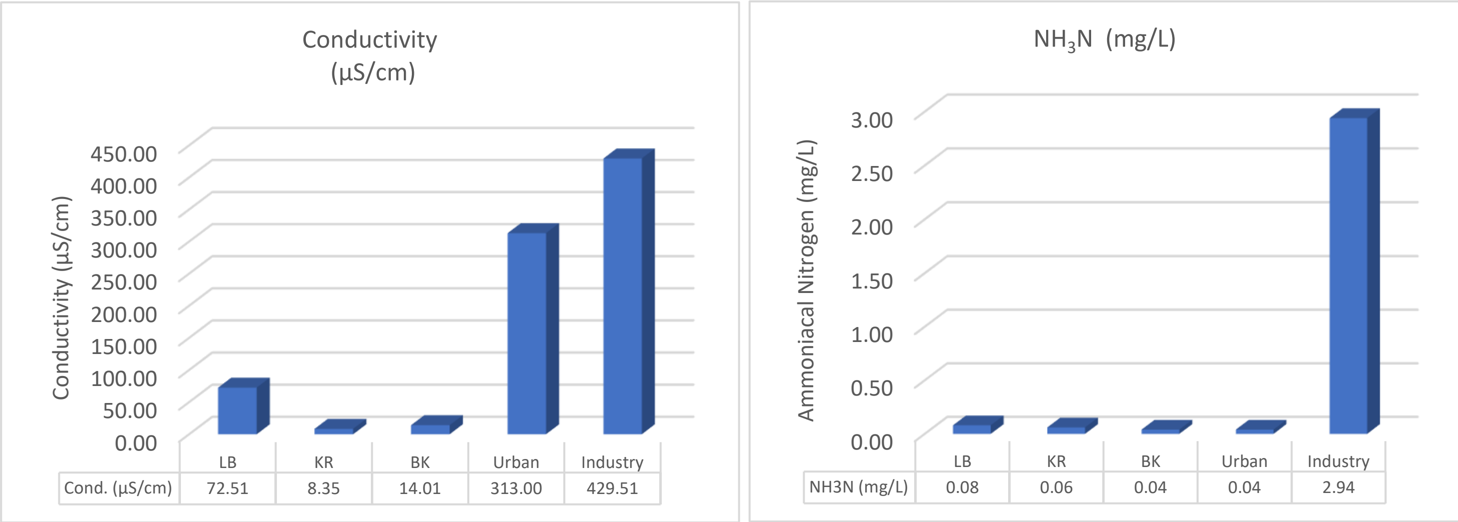
(b) pH



(c) Turbidity



(d) Total dissolved solids



(e) Conductivity (f) Ammoniacal nitrogen

Fig. 3 Comparison of physico-chemical readings in different location

Note: LB – Long Banga, KR – Kelingkang Range, BK – Bukit Kana
Urban – Selected rivers in Kota Marudu, Sabah (Ahmad Zaharin et al., 2014)
Industry – Gebeng Industrial Area, Kuantan Pahang (Salah et al., 2017)

4.0 CONCLUSION

Based on findings and *in-situ* physico-chemical parameters supported by the NWQS classification, the water quality in the Long Banga, Kelingkang Range and Bukit Kana catchments are still in good condition. The average NWQS for all catchments falls under class I and IIA, which is an expected value for undisturbed forest catchments area and showed a similar pattern. The river water quality status can be used as an indicator of forest health and thus, forested catchments need a well-balanced ecosystem through proper conservation techniques in order to sustain the river water quality.

Besides, benchmarking for water quality patterns of perennial upstream in undisturbed hilly tropical forest ecosystems is crucial to compare and assess the degree of impacts due to other downstream land-use conversion activities. As some development activities have started to focus on the hill forest, information on such b on undisturbed hill forest is needed to support management decisions for sustainable use of hilly tropical forests. This aspect of hydrological study results should also increase knowledge and provide understanding about the perennial behavior related to water quality flowing from the pristine hilly tropical forest ecosystem. It is recommended that continuous water quality monitoring should be conducted so that the water quality changes in hill forested catchments can be tracked over time.

REFERENCES

Ainon, H and Yanti, H. 2008. Water Quality and Bacterial Study in Tasik Chini, Pahang. Proceedings of Taal 2008, the 12th World Lake Conference: 184-189.

Ahmad Zaharin, A., Wan, Y. L., Sarva, M. P. Mohd Kamil, Y. 2014. Water Quality Status of Selected Rivers in Kota Marudu, Sabah, and its Suitability for Usage. Sains Malaysiana 43(3)(2014):377-388

Ashraf, M. A., Mohd. Jamil. M., Yusoff, I. 2010. Study of Water Quality and Heavy Metals in Soil and Water Ex-Mining Area Bestari Jaya, Peninsular Malaysia. International Journal of Basic and Applied Sciences IJBAS-IJENS 10 (3): 7-23.

Barten, P. K., Ernst, C. E. 2004. Land Conservation and Watershed Management for Source Protection. J. Amer. Water Work Assoc. 96: 121-135.

Clare, M and Janet, C. 2013. An Impending Storm Impacts of Deforestation on Weather Patterns and Agriculture. Green Pace Research Laboratories Technical Report (Review) 04-203. Amsterdam, Netherlands: 31. Retrieved from: http://www.greenpeace.to/greenpeace/wp-content/uploads/2013/11/An-Impending-Storm.pdf.

Cole, S., Codling, I., Parr, W., & Zabel, T. 1999. Guidelines for Managing Water Quality Impacts within UK European Marine Sites. English Nature, Scottish Natural Heritage. Retrieved:https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=UK-MARINE-SACS_water_quality.pdf.

Fakayode, S. O. 2005. Impact Assessment of Industrial Effluent on Water Quality of the Receiving Alaro River in Ibadan, Nigeria. Ajaem-Ragae 10:1-13.

Forest Department Sarawak Official Website. 2021. Retrieved from: http://www.forestry.sarawak.gov.my. Retrieved on 29 March 2021.

Holgate. M. W. 1979. A Perspective of Environment Pollution. Cambridge: Cambridge University Press.

Nguyen, C. T. T. and Cai, Y. 2019. Physicochemical Characteristics of Streams in Bukit Timah Nature Reserve, Singapore. Gardens' Bulletin Singapore 71 (Suppl. 1): 491-556.

Miroslav, R., Mohd, H. A. & Ahmad, Z. A. 2007. Analisis Air. Scholar Press (M) Sdn. Bhd. Malaysia 105pp.

Salah, M. G., Sujaul, M. I., Arafat, M. Y., Abdulsyukor, R., Idris, A. 2017. Surface Water Quality Assessment of the Gebeng Industrial Area Using Water Quality Standard and Index. Journal of Engineering and Science Research, 1(2): 117-125

Yisa, J. and Jimoh, T. 2010. Analytical Studies on Water Quality Index of River Landzu. American Journal of Applied Science 7: 453-458.