Journal of Tropical Resources and Sustainable Science

journal homepage: jtrss.org

Comparison of Water Quality and Heavy Metals Concentration between Lata Janggut and Lata Keding, Jeli, Kelantan

Nur Hanisah Abdul Malek[1]; Nur Madihah Mohd Isa[1]; Nurul Syazana Abdul Halim[1*]; Amal Najihah Muhamad Nor[1]

[1]Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli Campus, 17600, Jeli, Kelantan, Malaysia.

Received 29 May 2019
Accepted 23 September 2019
Online 30 June 2020

Keywords:
Water Quality Index; Heavy Metals; Physical Parameters; Chemical Parameters; Spearman Correlation

☒*Corresponding author:
Nurul Syazana Abdul Halim
Faculty of Earth Science,
Universiti Malaysia Kelantan,
17600 Jeli, Kelantan, Malaysia
Email: syazana@umk.edu.my

Abstract

Water quality change is caused by indirectly or directly sources such as human activities, uncontrolled sewage, or heavy metals and sediments. This study was conducted at two famous ecotourism places in Jeli, Kelantan which are Lata Janggut and the new ecotourism place, Lata Keding. The main objective of this study is to compare water quality index and heavy metals at the cascades. Twelve samples were collected from two points which are flowing water and stagnant water in each cascade. Mann Whitney test was used to determine whether there are significant differences in concentration of each physical and chemical parameters between Lata Keding and Lata Janggut. Spearman correlation was also used to determine the relationships between physical and chemical parameters. This study found that Water Quality Index (WQI) in Lata Janggut is 69.07 (Class III) and Lata Keding is 71.75 (Class III) which means that the water quality was slightly polluted for both cascades. Therefore, Lata Janggut and Lata Keding require extensive treatment if it will be used for water supply but still under control and safe to had body contact with the water. However, further monitoring are needed to avoid any environmental issues arise.

1. INTRODUCTION

Freshwater are comprising of rivers, wetland, waterfall, springs, aquifer and others. Freshwater ecosystem cannot be denied as the important of life support systems on Earth. Each of the freshwater body has the physical and chemical properties which are determined primarily by climatic, geomorphological and geochemical conditions (Meybeck *et al*,1996). Clean, safe and adequate freshwater is essential for the survival of all living organism and for the smooth functioning of ecosystems, communities and economics. Poor water quality will become global issues once industrial and agricultural activities expand, a human population growth and climate change threatens that causing major changes to the hydrological cycle (WHO, 2011). Bad water quality had direct impact on the quantity of water in several ways. Contaminated water cannot be used for drinking, bathing, industry or agriculture. About 700 million people today in 43 countries are experiencing the lack of water, in which there is adequate water resources to meet long term needs (Enderlein et al, 1996). By 2025, 1.8 billion people will be lived in countries or regions with absolute water shortages, and two-thirds of the world's population can live under water pressure (WHO, 2011). Access to safe and clean water for human consumption is declared as human rights by the United Nations General Assembly in 2010 and water quality is essential to realize the rights (Boylan, 2008).

In Malaysia, in addition to being used in producing agricultural products, aquatic inland reserves, Malaysia also serve as habitat for wildlife, including endemic and endangered species (Hendry *et al*, 2006). In addition, some efforts have been undertaken by the Department of Environment to maintain a reasonable standard of water quality despite the rapid urbanization of the reservoir catchment area. The DOE uses the Water Quality Index (WQI) to assess the quality status of water bodies in Malaysia which is the basis for Environmental Impact Assessment (EIA), from any waterways, pollutant load categories and usage classifications used under the National Water Quality Standards for Malaysia ("ASEAN IWRM Performance Reports", 2015).

Correlation is one of the most common and useful statistics, which is a statistical measurement of the relationship between two variables. In this study, Spearman's correlation was used to determine the strength and direction of the monotonic relationship between two variables (Schober, Boer & Schwarte, 2018).

Lata Janggut is one of the potential geotourism sites in Jeli, Kelantan (Adriansyah, Busu, Eva & Muqtada, 2015). People come to Lata Janggut during their leisure time to do recreational activities such as swimming, jungle trekking, camping, and barbeques. Literally, Lata Janggut would crowd with visitor during school holidays or weekend. Therefore, the water quality might be affected due to the overcrowding and increase of human activities such as fishing and barbeque. This condition is very worrying because possibility for water quality gets polluted might high if there is no essential measure to control the entry of the sewage, manage the quality of water and the

eISSN Number: 2462-2389

sediments from river, and utilize water for various purposes.

Lata Keding is also one of the new attraction places that have been discovered recently by community of Jeli. Lata Keding is a small waterfall in front of Universiti Malaysia Kelantan (UMK) Jeli Campus. As Lata Keding is a new attraction place, people were overwhelmed with the cascade. Almost every weekend Lata Keding was crowded with people. Most of them tend to do recreational activities such as camping, picnic, bathing and trekking. Although Lata Keding was a new place, the water monitoring and measure still needed to avoid any contamination occurred. Therefore, this study will compare the water quality index and classification in Lata Janggut and Lata Keding, Jeli, Kelantan.

2. MATERIALS AND METHODS

2.1. Study area

This study is conducted at Lata Janggut and Lata Keding in Jeli, Kelantan. Both cascades are selected as study area because they are known as famous ecotourism place in Kelantan. The coordinate of Lata Janggut is between N 5’40’0” to N 5’42’30” and E 101’44’00” to E 101’47’00”. It is located 12 kilometres in the southwest of Jeli and approximately 7 kilometres from the Jeli town. Lata Janggut is part of the Long River, a tributary of Pergau River, and situated within the Gunung Basor Forest Reserve (Adriansyah et al, 2015).

Meanwhile, Lata Keding is located in coordinate N 5’44’48.1” to N 5’44’48.4” and E 101’50’53.7” to E 101’50’53.6”. Lata Keding was chosen as the research area because it is a new developed recreational area compared to the Lata Janggut. Literally Lata Keding, has been exist for a long time ago, but it is not very well known as it only serves as bath and picnic area for the locals. Before the Jeli Council takes action to promote the Lata Keding publicly and provide a proper accommodation there, the pathway to go there was quite difficult and dangerous as it is surrounded by long bushes. But after promoting openly to the community, the cascade was gaining more attention and more visitors day by day.

2.2. Sampling method

The water samples were collected at two different points in each of the study area. Six samples from flowing water area and six samples from stagnant water area in Lata Janggut were collected. Another six samples from flowing water area and six samples from stagnant water area were collected in Lata Keding. The water samples were collected according to each parameter sampling procedures. The sampling bottles were put into icebox that was filled with ice to give cold temperature to the water samples. After that, water samples were transferred into chiller by 4° C before doing the laboratory test to preserve the content of the sample and to lengthen holding time.

In the study area, the equipment or tool that being used to measure in-situ water quality parameter is YSI 556 MPS (Multiprobe System). It provides extreme flexibility for the measurement of dissolved oxygen, salinity, total dissolved solid (TDS), pH, and temperature. The collected water sample also were analysed for the chemical parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH3-N) and Total Suspended Solid (TSS). The collected water samples were analysed using APHA Spectrophotometer method for the chemical parameters.

2.3. Heavy metal analysis

For the selected heavy metals which are copper, zinc and iron analysis, DR 6000 UV-VIS Spectrophotometer was used to determine the concentration of the heavy metals in water samples. The selected heavy metals were measured using powder pillows method for characterization of the samples.

3. RESULT AND DISCUSSION

3.1 Physical parameters

The physical parameters to measure water quality are pH, Dissolved Oxygen (DO), salinity, conductivity and Total Dissolved Solids (TDS). The mean of pH at Lata Janggut were 6.50 which is lower than pH at Lata Keding which is 6.54 as showed in Table 1. However, the mean concentration of DO at Lata Janggut (6.37 mg/L) was higher than Lata Keding (5.23 mg/L). The main factor that control dissolved oxygen concentration is biological activity such as photosynthesis that producing oxygen while respiration and nitrification consumes oxygen (Yap & Pang, 2011). The high organic enrichment and turbulence nature of waterfall has become the possible reason responsible for low oxygen values in certain period. The water in Lata Keding may lack aquatic plants which produced oxygen through respirations as well as having decomposing activities organic compounds by aerobic organism which consumed oxygen thus resulting in low DO.

The water salinity at Lata Keding (0.0200%) are higher than Lata Janggut (0.0167%). For TDS and conductivity, both parameters were also higher at Lata Keding compared to Lata Janggut (Table 1). If the conductivity of the water increases, it indicates that there must be a source of dissolved ion in the vicinity, in which electric conductivity measurements can be an effective way to allocate any potential water quality problems (Prommi & Payakka, 2015).

eISSN Number: 2462-2389

Table 1: Descriptive Statistics for Physical Parameters

Places		pH	Dissolved Oxygen (mg/L)	Salinity (%)	Total Dissolved Solids (mg/L)	Conductivity (µS/cm)
Lata Janggut	N	12	12	12	12	12
	Mean	6.5042	6.3650	0.0167	0.0235	0.0356
	Std. Deviation	0.3825	1.8769	0.0049	0.0012	0.0018
Lata Keding	N	12	12	12	12	12
	Mean	6.5370	5.2317	0.0200	0.0314	0.0486
	Std. Deviation	0.1313	0.4246	0.0000	0.0036	0.0055
Total	N	24	24	24	24	24
	Mean	6.5206	5.7983	0.0183	0.0275	0.0421
	Std. Deviation	0.2802	1.4512	0.0038	0.0048	0.0078

3.2 Chemical parameters

The chemical parameters to measure water quality are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), NH3-N and Total Suspended Solid (TSS). The mean concentration of BOD at Lata Janggut were 1.1845 which is higher than BOD at Lata Keding which is 0.8027 as showed in Table 2. According to the National Water Quality Standards of Malaysia, the BOD value must around 3 mg/L to categorize as good conditions. BOD is a major water quality parameter because it gives big influence to the concentration of DO in the water. Higher concentration of BOD indicates lower level of water quality (Penn, Pauer & Mihelcic, 2009). If any effluent with high BOD level enter into the cascades, it will accelerate bacterial growth and consume oxygen in the water.

COD is the measurement of oxygen required to oxidize soluble and particulate organic matter in water. Higher level of COD indicates greater amounts of oxidized organic matter in the sample which can reduce the concentration of dissolved oxygen (DO). The mean concentration of COD at Lata Janggut was 10.8500 which is higher than COD at Lata Keding which is 5.6500. According to Department of Environment (DOE), the standard value for COD in Class II is 10-25 mg/L. Therefore, based on DOE standards, COD in Lata Janggut is still in the standard range but Lata Keding is away from the standard.

Total suspended solids is also an important factor in observing water clarity, as more solids are present in water, less the clarity of water (Environmental Fondriest, 2014). Based on DOE standards, TSS value must in range from 0 – 25 mg/L. Therefore, based on the results, the mean concentration of TSS at Lata Janggut (25.7667) is slightly higher than standard while Lata Keding (2.1667) has a very low concentration of TSS.

NH_3-N is a form of toxic ammonia. Once toxicity increases, pH will also increase. Ammonia levels that exceed the recommended limits can endanger the aquatic life (Environmental Fondriest, 2014). According to DOE standards, NH3-N must range from 0.1 – 0.3 mg/L. But once the toxicity of ammonia at higher level, it can relatively lead to skin, eye and gills damage for aquatic life (Brian, 2014). NH3-N concentration at Lata Janggut are higher than Lata Keding (Table 2). However, both cascades still in the range of DOE standards.

Table 2: Descriptive Statistics for Chemical Parameters in Lata Janggut and Lata Keding

Places		BOD	COD	TSS	NH_3-N
Lata Janggut	N	12	12	12	12
	Mean	1.1845	10.8500	25.7667	0.1667
	Std. Deviation	0.97135	5.8553	33.3126	0.0547
Lata Keding	N	12	12	12	12
	Mean	0.8027	5.6500	2.1667	0.1000
	Std. Deviation	0.6542	4.0444	1.7536	0.0367
Total	N	24	24	24	24
	Mean	0.9936	8.2500	13.9667	0.1333
	Std. Deviation	0.8331	5.5923	26.0289	0.0569

3.3 Heavy metals

Selected heavy metals concentration such as copper, zinc, and iron were analysed to determine the water quality in the cascades. Based on Figure 1, the average value of Cu for Lata Janggut is 0.384 mg/L, while for Lata Keding is 0.064 mg/L, in which Lata Janggut had higher amount of copper compared to the Lata Keding. In this case, the concentrations of Cu for both cascades are below

eISSN Number: 2462-2389

the standard either from WHO or USEPA water quality standard. The value standards of copper that been provided by WHO is 2 mg/L, meanwhile for USEPA standards is 1 mg/L (Balentine, 1995). Copper is an important nutrient at low concentration, but it bad and toxic to aquatic organisms at higher concentration, because it can give bad effect such as death and chronic exposure which is lead to abnormal growth, retard reproduction and changes in brain function, enzyme activity, blood chemistry and metabolism (EPA, 2012).

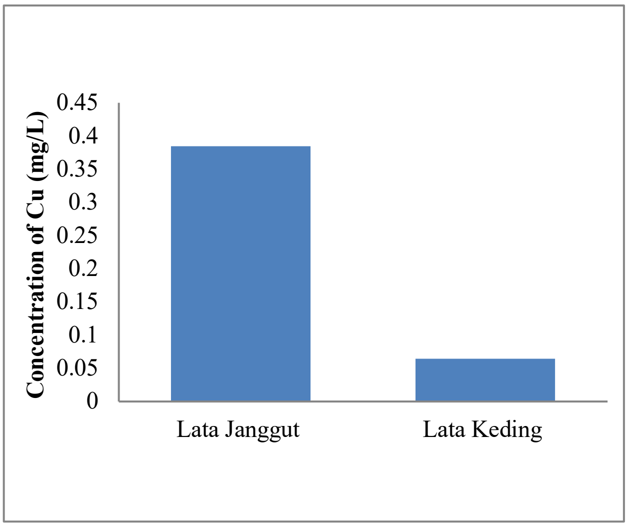

Figure 1: Mean Value of Copper for Lata Janggut and Lata Keding (mg/L)

In Figure 2, the mean concentration of Zn at Lata Janggut is 0.4 mg/L while Lata Keding has lower value which is 0.2 mg/L. Both of the cascades are still below the WHO and USEPA standard, which is 5 mg/L respectively (Balentine, 1995).

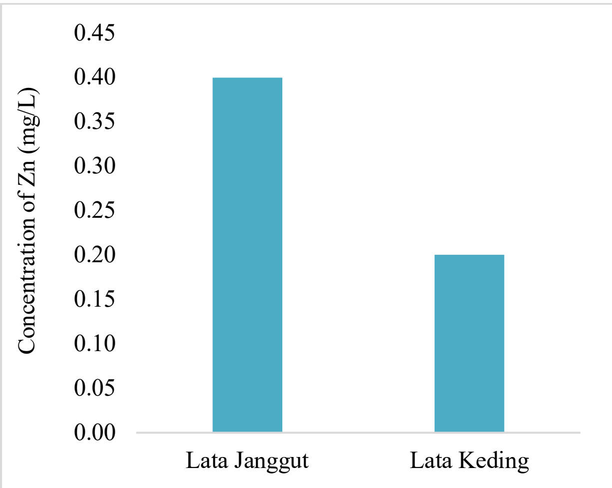

Figure 2: Mean Value of Zinc for Lata Janggut and Lata Keding (mg/L)

Based on Figure 3, the mean concentration of iron at Lata Janggut is achieving 1 mg/L, too high compared to the Lata Keding, which is 0.14 mg/L. The iron comes in several forms in the water. At normal levels, iron does not kill aquatic organisms, but at higher levels when iron is insoluble in water, fish and other creatures cannot process all the iron they take, in the form of water or their food (Andromeda Ricky, 2016). The concentration of Fe for Lata Keding is still within the standard by WHO which range from 0.12 – 0.74 mg/L. However, for Lata Janggut the concentration of Fe is over the WHO standards (Figure 3).

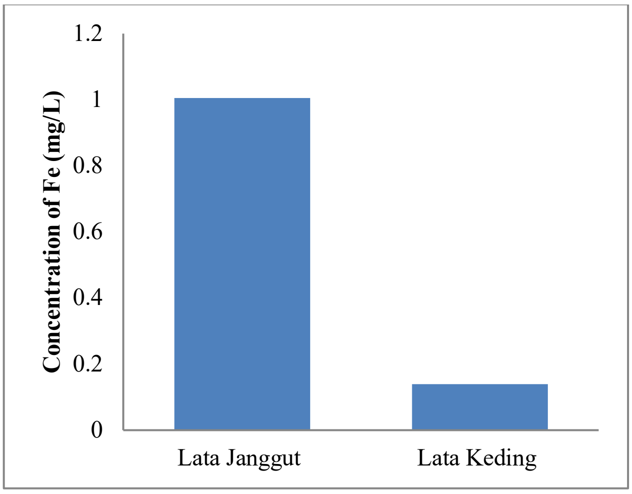

Figure 3: Mean Value of Iron for Lata Janggut and Lata Keding (mg/L)

3.4. Mann-Whitney Test

Mann-Whitney test was conducted to test the equality between two population means. Therefore, Mann Whitney test was used to test whether there are significant differences in concentration of each physical and chemical parameters between Lata Keding and Lata Janggut. Based on the result, Salinity (p-value=0.032), TDS (p-value=0.00), Conductivity (p-value=0.00), COD (p-value=0.016), TSS (p-value=0.007) and NH_3-N concentration (p-value=0.004) showed significant differences between Lata Keding and Lata Janggut. However, pH (p-value=0.885), DO (p-value=0.751) and BOD concentration (p-value=0.371) showed no significant differences between the two cascades.

3.5. Correlation Analysis

Correlation is a test to measure the relationship between two variables. Correlation was used in this study to determine whether there are any relationships among physical parameters and chemical parameters. Correlation analysis showed the magnitude of relationship whether the relationship is very weak, weak, moderate correlation, strong or very strong based on correlation value (Ahmad et al., 2017).

Based on the correlation test result for physical parameters at Lata Janggut (Table 3), pH has moderate positive correlation with DO (r=0.592), strong negative correlation with TDS (r = -0.641) and salinity (r = -0.717) and moderate negative correlation with conductivity (r=-0.545). Meanwhile, DO was found to has strong negative correlation with TDS (r= -0.671) and conductivity (r= -

0.724). Negative correlation means that when TDS are decreasing, DO will be increased. TDS has strong positive relationship with salinity (r=0.804) and conductivity (r=0.908). Salinity also has strong positive correlation with conductivity (r=0.709). Positive correlation means that when salinity increases, the conductivity will be increased.

Table 3: Correlation between physical parameters at Lata Janggut

			pH	DO	TDS	Salinity	EC
Spearman's rho	pH	Correlation Coefficient	1.000	.592*	-.641*	-.717**	-.545
		Sig. (2-tailed)	.	.043	.025	.009	.067
		N	12	12	12	12	12
	DO	Correlation Coefficient	.592*	1.000	-.671*	-.410	-.724**
		Sig. (2-tailed)	.043	.	.017	.185	.008
		N	12	12	12	12	12
	TDS	Correlation Coefficient	-.641*	-.671*	1.000	.804**	.908**
		Sig. (2-tailed)	.025	.017	.	.002	.000
		N	12	12	12	12	12
	Salinity	Correlation Coefficient	-.717**	-.410	.804**	1.000	.709**
		Sig. (2-tailed)	.009	.185	.002	.	.010
		N	12	12	12	12	12
	EC	Correlation Coefficient	-.545	-.724**	.908**	.709**	1.000
		Sig. (2-tailed)	.067	.008	.000	.010	.
		N	12	12	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4: Correlation between physical parameters at Lata Keding

			pH	DO	Salinity	TDS	EC
Spearman's rho	pH	Correlation Coefficient	1.000	-.311	.	-.776**	-.327
		Sig. (2-tailed)	.	.325	.	.003	.300
		N	12	12	12	12	12
	DO	Correlation Coefficient	-.311	1.000	.	.789**	.952**
		Sig. (2-tailed)	.325	.	.	.002	.000
		N	12	12	12	12	12
	Salinity	Correlation Coefficient	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.
		N	12	12	12	12	12
	TDS	Correlation Coefficient	-.776**	.789**	.	1.000	.782**
		Sig. (2-tailed)	.003	.002	.	.	.003
		N	12	12	12	12	12
	EC	Correlation Coefficient	-.327	.952**	.	.782**	1.000
		Sig. (2-tailed)	.300	.000	.	.003	.
		N	12	12	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Based on the Table 4.15, at the Lata Keding; the physical parameters was been correlate, for pH – the weak negative relationship were found between at pH; DO (r= -0.311) and at pH; EC (r= -0.327), which is means, the variables parameter were not had any relationship, and not dependable into each other. Meanwhile, at Lata Keding, the positive strong correlation was found between DO; TDS (r= 0.789) and between TDS; EC (r= 0.782). But the strongest positive relationship was found between DO; EC (r= 0.952), whereas when DO increases, EC also followed increases. According to Table 5, BOD did not show any significant relationship with COD, TSS and NH3-N since all significant values are greater than α=0.05. Strong positive relationship was found between COD and TSS (r = 0.648). It means that when TSS increases, COD also will be increased. Other chemical parameters did not show any significant relationship.

Based on the Table 6, the chemical parameters based on the Lata Keding area, was correlate to determine the chemical parameters and to find out the relationship between it. As for, BOD, the negative weak was found between BOD; NH_3-N (r = -0.298). The very negative weak relationship was found at BOD; TSS (r=-0.298). But the moderate positive correlation was found between COD; TSS (r=0.530) and at COD; NH_3-N (r= 0.621), which is both had relationship but in low level.

3.6. Water Quality Index (WQI) and Classification at Lata Janggut and Lata Keding

Water Quality status classification was determined by using Water Quality Index (WQI). WQI value for Lata Janggut and Lata Keding was calculated by

eISSN Number: 2462-2389

entering the mean values of water quality parameters which are DO, BOD, COD, TSS, NH_3-N and pH into the following equation:

WQI = (0.22*SIDO) + (0.19*SIBOD) + (0.16*SICOD) + (0.15*SIAN) + (0.16*SISS) + (0.12* pH)   (1)

Based on Table 5, the WQI values of Lata Janggut and Lata Keding were 69.07 and 71.75 respectively which can be categorized into Class III. It means that both cascades were slightly polluted.

Table 5: Correlation between chemical parameters at Lata Janggut

			BOD	COD	TSS	NH_3-N
Spearman's rho	BOD	Correlation Coefficient	1.000	-.165	-.336	.074
		Sig. (2-tailed)	.	.609	.286	.819
		N	12	12	12	12
	COD	Correlation Coefficient	-.165	1.000	.648*	-.027
		Sig. (2-tailed)	.609	.	.023	.935
		N	12	12	12	12
	TSS	Correlation Coefficient	-.336	.648*	1.000	.032
		Sig. (2-tailed)	.286	.023	.	.922
		N	12	12	12	12
	NH_3-N	Correlation Coefficient	.074	-.027	.032	1.000
		Sig. (2-tailed)	.819	.935	.922	.
		N	12	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6: Correlation between the chemical parameter at Lata Keding

			BOD	COD	TSS	NH_3-N
Spearman's rho	BOD	Correlation Coefficient	1.000	.280	-.170	-.298
		Sig. (2-tailed)	.	.379	.598	.346
		N	12	12	12	12
	COD	Correlation Coefficient	.280	1.000	.530	.621*
		Sig. (2-tailed)	.379	.	.076	.031
		N	12	12	12	12
	TSS	Correlation Coefficient	-.170	.530	1.000	.754**
		Sig. (2-tailed)	.598	.076	.	.005
		N	12	12	12	12
	NH_3-N	Correlation Coefficient	-.298	.621*	.754**	1.000
		Sig. (2-tailed)	.346	.031	.005	.
		N	12	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

Table 7: WQI Values and Classification for Lata Janggut and Lata Keding

Study area	WQI Value	Classification
Lata Janggut	69.07	Class III: Slightly polluted
Lata Keding	71.75	Class III: Slightly Polluted

4. CONCLUSION

In conclusion, all parameters in WQI which are DO, BOD, COD, TSS, NH3-N and pH mostly classified under class I and II according to WQI and classification provided by Department of Environment (DOE). However, based on WQI calculated, both Lata Janggut and Lata Keding were fall under class III which mean the cascades were slightly polluted. Water quality in Class III can only be used as water supply after extensive treatment and not suitable for recreational use with body contact. However, there is no case that had been reported in both cascades regarding water pollution. Therefore, basically both cascades were still under control and people are safe to had body contact with the water. The heavy metals concentration in both cascades are still under standard limit. However, further action should be taken to conserve the cascades and improve water quality from getting polluted in future.

For future work, sample size for the study should be increased to get more accurate result. Although it will be costing and take longer time to be conducted, the result will be more reliable and unbiased. This study also recommends researchers to add more water quality parameters such as microbial activity parameter, temperature and so on at both cascades, and add more heavy metals parameter such as arsenic, lead, cadmium etc.

REFERENCES

Adriansyah, D., Busu, I., Eva, H., & Muqtada, M. (2015). Geoheritage as the basis of geotourism development: a case study in Jeli district, Kelantan, Malaysia. GeoJournal of Tourism and Geosites, 15(1), 25-43.

Ahmad, W. M. A. W., Ahmad, B., Abdullah, S., & Mohamad, N. A. A. (2017). Statistical analysis using SPSS for health sciences. Malaysia: University Science of Malaysia.

Andromeda Ricky. (2016). The Effects of Iron in Water on Aquatic Life. Retrieved December 8, 2018, from https://www.cuteness.com/article/effects-iron-water-aquatic-life_

ASEAN IWRM Performance Reports & Monitoring Indicators. (2015, April). Retrieved from https://aseaniwrm.water.gov.my

Balentine, B. (1995). Permissible limits for metals, 95, 9–10. Retrieved from file:///C:/Users/Bianca.Southon/Desktop/metals-limits.pdf

Boylan, M. (Ed.). (2008). International public health policy and ethics. Dordrecht: Springer.

Brian, O. (2014). Water Research Center - Ammonia Nitrogen Fish Toxicity Surface Water. Retrieved December 7, 2018, from https://www.water-research.net/index.php/ammonia-in-groundwater-runoff-and-streams

Enderlein, S., Enderlein, R. E., & Williams, W. P. (1996). Chapter 2* - Water Quality Requirements.

Environmental Fondriest. (2014). Turbidity, Total Suspended Solids & Water Clarity - Environmental Measurement Systems. Retrieved December 7, 2018, from https://www.fondriest.com/environmental-measurements/parameters/water-quality/turbidity-total-suspended-solids-water-clarity/

EPA. (2012). Aquatic Life Criteria for Nonylphenol. Retrieved December 7, 2018, from https://www.epa.gov/wqc/aquatic-life-criteria-copper

Hendry, K., Sambrook, H., Underwood, C., Waterfall, R., & Williams, A. (2006). Eutrophication of Tamar Lakes (1975-2003): A case study of land-use impacts, potential solutions and fundamental issues for the Water Framework Directive. Water and Environment Journal, 20(3), 159–168. https://doi.org/10.1111/j.1747-6593.2006.00034.x

Meybeck, M., Kuusisto, E., Mäkelä, A., & Mälkki, E. (1996). Quality

eISSN Number: 2462-2389

Water. https://doi.org/0 419 22320 7

Penn, M. R., Pauer, J. J., & Mihelcic, J. R. (2009). Biochemical oxygen demand. Environmental and ecological chemistry, 2, 278-297.

Prommi, T., & Payakka, A. (2015). Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. Sains Malaysiana, 44(5), 707-717.

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: appropriate use and interpretation. Anesthesia & Analgesia, 126(5), 1763-1768.

WHO. (2011). Guidelines for Drinking-Water Quality; World Health organization: Geneva Switzerland, 1, p342. https://doi.org/10.1016/S1462-0758(00)00006-6

Yap, C. K., & Pang, B. H. (2011). Assessment of Cu, Pb, and Zn contamination in sediment of north western Peninsular Malaysia by using sediment quality values and different geochemical indices. Environmental Monitoring and Assessment, 183(1-4), 23-39.