A Pristine Water Quality of Repeatedly Logged Forest River in Kawag Forest Area, Ulu Segama Malua Forest Reserve, Sabah

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ABSTRACT Water chemistry of Kawag Forest Area was studied based on the major ion chemistry and in-situ water quality parameters. The sampling stations were selected in two streams of Kawag Forest Area. The water quality were analysed for major cations (Ca, Mg, Na), dissolved metals, suspended solid and in-situ physico-chemical parameters: temperature, pressure, conductivity, dissolved oxygen (DO), turbidity, and pH in the rivers of Kawag Forest Area. Major cations and dissolved metals were analysed using ICP-OES while the in-situ parameters were tested using YSI multi parameters. The results show the concentrations trend of major cations in the order of Ca>Na>Mg>K. The rivers are classified between Class I and Class IIA based on the National Water Quality Standards for Malaysia (NWQSM). Despite of the forest background that it had been repeatedly logged, the water quality in Kawag Forest Area is unexpectedly in pristine condition, and much better than most of the undisturbed tropical forest elsewhere.

KEYWORDS: Hydrochemistry; Water Quality; Kawag Forest Area; Ulu-Segama Malua; Logged Forest

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TRANSACTIONS ON SCIENCE AND TECHNOLOGY

INTRODUCTION

In remote areas of Sabah, where treated water supply is unavailable, often the drinkable raw river water became the only solution for consumption. Water quality of a river can be affected by many factors such as deforestation, active land development and land conversion (Harun et al., 2015; Wong et al., 2018). Kawag Forest Area is a secondary forest located inside 242, 000 ha Ulu Segama-Malua Forest Reserve. The area was logged several times and the logging activities had ceased in the year 2007. High soil erosion rate in most tropical rainforest especially Sabah can affect the stream health in term of suspended sediment concentration and turbidity of the water such as reported by previous studies in Danum Valley Conservation Area and SAFE Experimental Area (Nainar et al., 2015; Cleophas et al., 2017). There are two main rivers in Kawag Conservation Area namely Kawag river and its tributary Alibaba river. Due to the absence of connecting treated water supply from Sabah state water department, Kawag Danum Forest Lodge and Ulu- Segama Malua forestry district office receive gravity water supply from the upstream of Alibaba river. This study focuses on the assessment of the selected water quality parameters status in Kawag Forest Area excluding the biological parameters. The Parameters that were aimed to be studied are major cations (Ca, Mg, Na), suspended solid in the river water and in-situ water physico-chemistry parameters. The water quality is a concern since the water supply to the Ulu- Segama Malua forestry district office and Kawag Danum Forest Lodge is from un-treated water source. Thus, the results of this study serve as baseline data in Kawag Forest Area for future study references and facility development.

METHODOLOGY

Surface water samples were collected from the main streams of Kawag Forest Reserve catchment namely Kawag river and its tributary Alibaba river. The average discharge of Kawag river and downstream of Alibaba river during the sampling were 86400 m^3/day and 2073.6 m^3/day respectively. The selections of sampling stations were based on the observation of possible

contamination and practicality of collecting samples. S1 (N05° 02′ 50.3″, 117° 57′ 15.6″) was located at the upstream of Kawag river while station S2 (N05° 03′ 05.4″, 117° 57′ 50.3″) at the downstream after the Alibaba river merged with Kawag river. Station S4 (N05° 02′ 56.3″, E117° 58′ 48.4″) was located at the upstream of Alibaba river and it is the water source intake point for Kawag Danum Resort Lodge (KDRL). Station S3 (N05° 03′ 02.1″, 117° 58′ 15.9″) is located at the downstream of Alibaba river which receive water discharge from the resort drainage. Figure 1 shows the map of sampling locations.

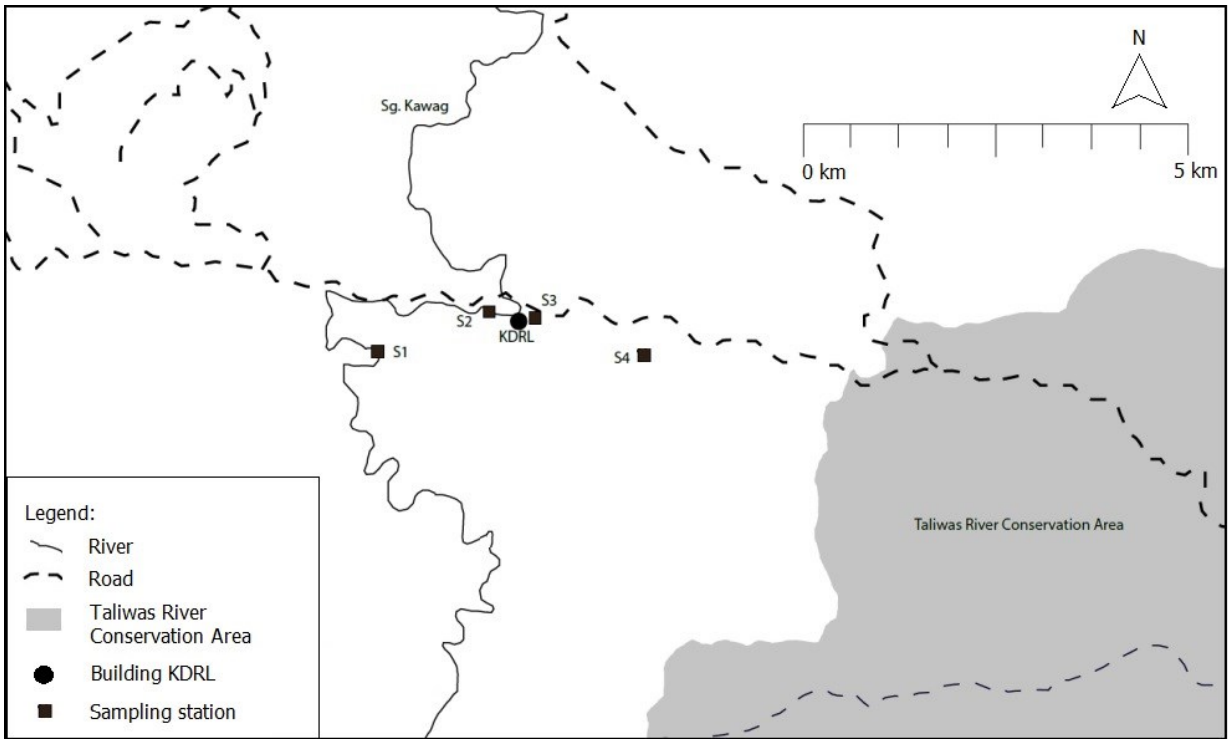

Figure 1. The locations of the sampling stations at the Kawag Forest Area.

There were four sampling campaigns carried out from 25th-28th may 2016. The samples were collected using polyethylene bottles that were prewashed with 10% acid bath and distilled water. Two replicates were taken for each sample to ensure the validity and reliability of the analysis. In-situ water quality parameters: temperature, pressure, dissolved oxygen, conductivity, turbidity, and pH were measured in the field using YSI multiparameters. Dissolved metals and major cations were analysed using Perkin Elmer Optima 5300DV Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) according to the Standard Methods recommended by APHA (2005). Total suspended solid was measured using gravimetric method. The water samples were filtered using 0.45 μm Whatman GF/C filter paper and vacuum pump. The samples were then dried in an oven with 105°C temperature until a constant weight was achieved.

RESULT AND DISCUSSION

The statistics for physico-chemical parameters of in-situ water quality data for each sampling point is tabulated in Table 1 and the results for concentration of dissolved metals, suspended solid and major cations in selected stations are tabulated in Table 2. The result of water quality for Kawag river water is unexpectedly in a pristine condition. This is unusual for recently logged over forest environment in tropical region (e.g. Douglas, 1993; Mokhtar et al., 2008; Walsh et al., 2011; Ismail, 2015).

Table 1. In-Situ Water Quality Parameters

Locations		Temp (°C)	DO (mg/L)	Conductivity (mS/cm)	Turbidity (NTU)	TSS (mg/L)	pH
Kawag Forest Area	Upstream Kawag river (S1)	26.2	8.2	0.114	1.1	0.0	7.6
	Downstream Kawag river (S2)	27.68	6.1	0.140	1.9	0.0	7.1
	Downstream Alibaba river (S3)	30.2	6.8	0.158	2	0.0	7.5
	Upstream Alibaba river (S4)	27.35	7.6	0.195	1.45	0.0	7.5
Tembaling river, Danum Valley Conservation Area, Sabah (Lee et al., 2004)		23.65	7.5	200	-	8.3	7.8
Eucaluptus river, Maliau Basin, Sabah (Mokhtar et al., 2008)		-	7.8	0.070	2.48	-	4.7
Liwagu river, Tambunan, Sabah (Cleophas et al, 2013)		22.52	6.9	0.08	-	1.9	7.8
Deramakot Forest Reserve, Sabah (Andaman, 2015)		-	-	-	-	27.2	7.1
Crocker range park rivers, Sabah (Rahim et al., 2002)		22.33	8.4	0.088	60.9	-	8.2
Northern Gunung Rara Forest Reserve, Sabah (Andaman, 2015)		-	8.0	-	-	8.5	6.9
Temenggor Forest Reserve (Lion et al., 2012)		22.30	8.0	0.100	12.28	-	6.7
Relau river of National Forest Reserve, Merapoh, Pahang (Nadarajah et al, 2012)		24.04	15.22	-	6.13	38.02	6.335
Gunung Benom Forest Reserve, Pahang (Lion et al., 2010)		23.76	7.14	-	4.63	-	5.39

The in-situ parameters that were measured at the water intake point had shown a good result as a water source to the Kawag Danum Rainforest Lodge. The DO value of water can be affected by a few environmental variables such as temperature, pressure, turbidity and moving water (Ebbert, 2002). The DO in moving water tends to have a higher value compared to stagnant water due to the transfer of oxygen across atmosphere air and water that was caused by ripples and waves. The water samples were taken from a natural unrestricted flowing river thus the DO value may vary in concentration. The surface water temperature ranged between 26.2°C and 30.2°C during the sampling period regardless of the hot weather throughout the sampling period while the pressure value varies from 747.3 to 750.5 mmHg in the sampling area. According to the pressure data recorded during the sampling period, there are slight differences in the results due to the change in elevation. The highest result of DO was observed in the upstream of Kawag river (S1) due to the area to have the lowest pressure compared to the other sampling stations. Two of the sampling stations have DO of Class I where the samples were taken from the upstream of Kawag river and upstream of Alibaba river; while two of the samples were classified as Class IIA which were taken from the downstream of Alibaba river and downstream of Kawag river. The DO level in these river samples were almost similar to the DO level in Liwagu river (6.19-7.79 mg/L), Tembaling river (7.52 mg/L), Eucalyptus river (7.89 mg/L) and Deramakot river (6.03 mg/L) (Cleophas et al, 2013; Lee et al., 2004; Mokhtar et al., 2008 and Andaman et al. 2015). The benchmark that had been determined in NWQSM for DO in water supply (Class I) is 7.0 mg/L. Therefore, the water sources from upstream of Alibaba river and upstream of Kawag river are better than the described standard and they do not require conventional water treatment for DO. However, high concentration of DO such as in the

water intake point will have a higher risk of corrosion to the pipelines. The risk of corrosion can be prevented by using non-corrodible pipeline materials (Jung et al, 2009).

Table 2. Dissolved metals concentration (mg/L) in selected stations

Sample	Location	Fe	Mn	Se	Pb	Cr	Cu	Zn	K	Mg	Na	Ca
S1	Upstream Kawag river	0.0119	0.0006	0.0064	0.0035	0.0026	ND	ND	1.2263	4.4796	6.7509	11.3842
S2	Downstream Kawag river	0.0820	0.0110	0.0127	0.0023	0.0021	ND	ND	1.3373	6.2774	8.0341	11.9670
S3	Alibaba river	0.0485	0.0068	0.0094	0.0017	0.0020	ND	ND	1.0337	10.1023	5.3422	12.9772
W1	Pipe water	0.0148	ND	0.0119	0.0063	0.0024	0.0056	0.0471	1.1227	4.4818	6.5748	10.9848
W2	Upstream Alibaba river (water intake point)	0.0145	0.0011	0.0035	ND	0.0022	ND	0.0052	1.3040	4.9368	6.7197	11.4862

ND = Not Detected

The turbidity result for the samples was ranged from 1.1 to 1.9 NTU which was considered to be lower compared to the other turbidity values from undisturbed and logged forest such as in Maliau Basin, 1.01-4.48 NTU (Mokhtar et al., 2008), Temenggor forest reserve, 12.28 NTU (Lion et al., 2012); Relau river Forest Reserve, 6.13 NTU (Nadarajah et al, 2012), Gunung Benom Forest Reserve, 0.3-8.6 NTU (Lion et al., 2010) and Crocker range Park rivers, 38.9-105.3 NTU (Rahim et al., 2002). The turbidity parameter is an important indicator of suspended sediment in the water (Huey and Meyer, 2010). The low turbidity result in the water samples might also be due to the geological factors such as porosity, soil properties, and low suspended sediment in the water. Turbidity is affected by both dissolved and suspended solids in the water thus low value of turbidity result in the samples shows that the water is minimally affected by dissolved organic matter such as tannins and suspended solids (Bilotta and Brazier, 2008). According to the result, the values for suspended solid in the sampling stations are below the detection limit. Low suspended solid characteristic in these river encourage DO in the water because the light can easily penetrate the water body thus photosynthesis can occur in the water (Kale, 2007). The result of suspended solid in this study was compared to the minimally disturbed river in Liwagu 1.9 mg/L (Cleophas et al., 2013) and rivers in undisturbed forest such as Tembaling river 6.17-10.46 mg/L (Lee et al., 2004), Eucalyptus river of Maliau Basin 4.19-5.13 mg/L (Mokhtar et al., 2008) and also river in previously logged forest such as in Deramakot Forest Reserve 27.2 mg/L (Andaman, 2015); and Northern Gunung Rara Forest Reserve 8.5 mg/L (Andaman, 2015). The suspended solid result in rivers above was reported higher than the Kawag Forest Reserve. Heavy metal was analysed to determine whether there is any heavy metal enrichment in the suspended solid. However, all of the analysed samples show that the concentration of dissolved metals to be well below Drinking Water Quality Standards of Malaysia. Concentrations of Cu, Zn, Pb and Mn were below detection limit in some of the sampling sites. The result indicated that there is a very little to none influence of metals to the suspended solid in the water. Therefore, the river in Kawag Forest Area had shown that it is naturally able to recuperate to its pristine condition.

The Electrical Conductivity (EC) values in the river sampling stations ranged between 0.114 and 0.195 mS/cm at different locations as indicated by the in situ readings. The EC parameter measures the ability of water to allow electric current to flow. The value of EC indicates the presence of

dissolved salts in the river water. The dissolved salts in river water are usually dominated by the carbonates and sulphates of calcium, magnesium and sodium. The low EC value in river water samples might be due to the natural characteristic of the rivers and lack of pollution source. The value is comparable to, Tembaling river 0.197-0.203 mS/cm (Lee et al., 2004) and Temenggor Forest reserve 0.100 mS/cm (Lion et al., 2012). The trend of major ions in sampling stations are Ca>Na>Mg except for Kawag river the trend is Ca>Mg>Na. These three elements are soluble cations which mainly contributed by rock weathering processes. The concentrations of Mg and Ca are under the general USGS classification guidelines below 60 mg/L. Most of the samples were classified as soft water except for samples of Station S2 taken at the downstream of Kawag river. Station S2 water is classified as moderately hard (60 mg/L to 120 mg/L) by the USGS classification guidelines.

CONCLUSION

This study found that Kawag river and its tributaries around the Kawag Danum Rainforest Lodge are classified into Class I-Class IIA based on the National Water Quality Standards for Malaysia (NWQSM) which demonstrates a healthy forest ecosystem. The water samples were taken for analysis at the existing and possible water sources of the rivers. A number of water quality parameters of the Alibaba and Kawag rivers show a narrow variation from the upstream to the downstream of both rivers. In conclusion, regardless of the biological parameters, these rivers are producing a clean water supply for consumption.

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