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WATER QUALITY OF BAKUN HYDROELECTRIC DAM RESERVOIR, SARAWAK, MALAYSIA, DURING THE CONSTRUCTION OF MURUM DAM

Lee Nyanti[1], Teck-Yee Ling[2] and Theresa Muan[3]

[1,3]Aquatic Science Department, [2]Department of Chemistry, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia.
[1]tyling@frst.unimas.my; [2]lnyanti@frst.unimas.my; [3]theremuan2991@rocketmail.com;

ABSTRACT

Since Bakun Hydroelectric Reservoir was filled, there has not been any published literature on its water quality. A previous study conducted during its filling stage showed that the DO level dropped very rapidly and the water was turbid. Since water quality was expected to improve over time, this study was carried out. Six stations and 3 depths at each station were investigated. Results show that dissolved oxygen at 0.5 m depth ranged from 6.25 to 7.02 mg/L but the water was anoxic at 15 m and 30 m depths. pH at 0.5 m depth in the reservoir ranged from 7.37 to 7.73 and decreased with depth to acidic condition. In the reservoir, turbidity at the subsurface were 0 NTU but at 15 m depth, it ranged from 19.5-105.4 NTU. BOD_5 were higher at 15 m and 30 m than 0.5 m depth. There was some improvement of water quality for stations in the reservoir compared to the previous study, especially in terms of pH and DO, but turbidity was still high at deeper regions. Stations in the Murum River and its downstream showed extremely high turbidity attributed to the construction of the Murum Dam. Thus, the river was not suitable for sensitive aquatic organisms.

Keywords: Murum River; dam construction; dam water quality; dissolved oxygen; turbidity.

1. INTRODUCTION

A hydroelectric dam is a source of renewable energy which is economical. Twelve hydroelectric dams had been planned in Sarawak and some have been completed for the generation of electricity (SIWRM, 2008; SEB, 2013). The Bakun Hydrolectric Dam is the second and the biggest hydroelectric dam constructed in Belaga District in the upper Rajang River in Sarawak with the power generating capacity of 2400 MW. It was constructed across the Balui River, a tributary of the Rajang River. Murum River is another tributary of the Balui River which flows into the Bakun Dam and it was in the process of being constructed. Since Bakun Hydroelectric Reservoir reached its full supply level, there had not been any published literature on its water quality. Previous study was conducted two months prior to it reaching the full supply level and the results showed that the DO (dissolved oxygen) level dropped very rapidly and turbidity increased with depth. Since water quality is expected to improve over time, its monitoring is important. Therefore, this study was conducted 13 months after the reservoir reached its full supply level and at that time, the construction of the Murum Dam on Murum River was on-going.

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2. MATERIALS AND METHODS

The study was conducted at Bakun Dam which was located between latitudes 1.5°N and 3.0°N and longitudes 113.5°E and 115.3°E, about 37 km upstream of Belaga in Sarawak on Balui River. The erected height of the dam is 206 meters and is the highest Concrete Faced Rock fill Dam in the world, with the total catchment area of approximately 14,750 km^2 with dam reservoir gross volume of about 44 billioncubic meters (SIWRM, 2008). The impoundment commenced on the 13^{th} of October 2010 and it reached its full supply level of 228 m above sea level on the 9^{th} of March 2012 with an area of 695 square kilometers (Nyanti, Ling & Grinang, 2012). The study was carried out on the 9^{th} – 12^{th} of April 2013. The study site, as shown in Figure 1, involved six stations; Station 1, near the dam site, Station 2 at Long Liko, Station 3 at Linau, Station 4 at upstream of Murum river, Station 5 at Ulu Wat and Station 6 at the downstream of the Murum River.

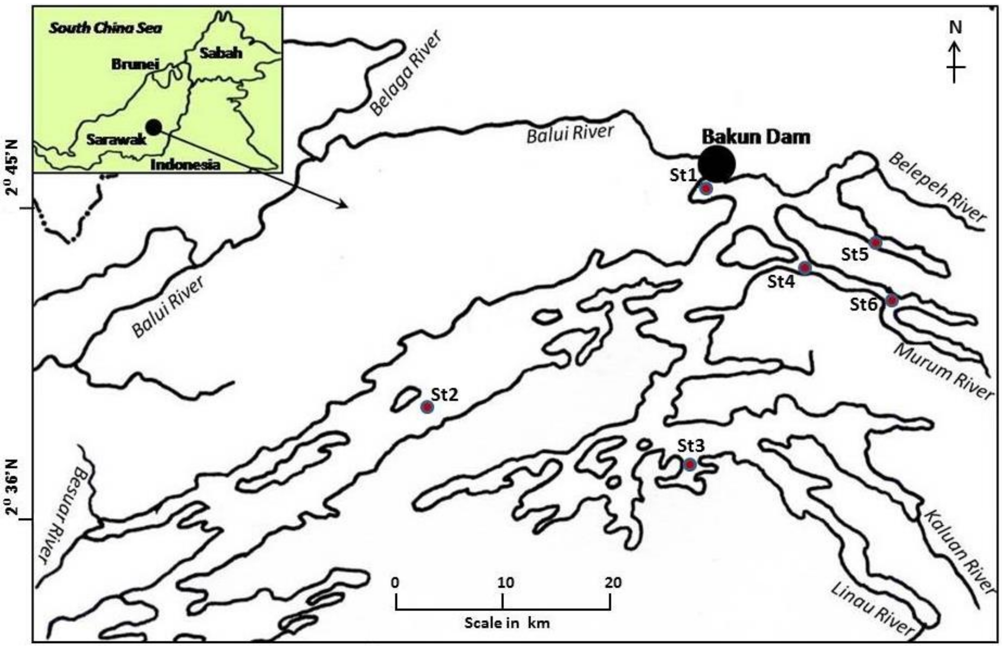

Figure 1: Map of the sampling stations in Bakun Hydroelectric Dam Reservoir.

In-situ variables, temperature, dissolved oxygen (DO), pH, conductivity and turbidity were measured using a YSI 6820 multiparameter sonde. At each station, data was collected at three different depths, 0.2 m, 15 m and 30 m. At each depth, triplicate water samples were collected using a Van Dorn water sampler. BOD_5 analyses of the samples were done according to the Standard Methods for the Examination of Water and Wastewater (APHA, 1998). The initial DO reading was recorded and the water was poured into a 300 ml BOD glass bottle, filling it completely and was kept incubated. On the 5^{th} day, the DO reading was recorded again. BOD_5 was calculated by using equation (1).

$$BOD_5\,(mg/L) = \frac{D_1 - D_5}{P} \quad (1)$$

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where D_1 is the initial DO reading, D_5 is day five of the DO reading and P is the volumetric fraction of the sample which is the ratio of sample volume to total volume.

The differences of water quality parameters for comparison among stations and depths were analysed by using one way ANOVA with three replicates for each station and each depth with a level of significant at 5% using SPSS PASW Statistics, v. 18.0 software.

3. RESULTS AND DISCUSSION

Figure 2 shows the temperature at the stations in Bakun Reservoir and Murum River. The range of temperature of the six stations at the Bakun reservoir and its tributaries were 24.08 – 33.01^{0}C. The highest mean value recorded was at Station 4, 33.01 ^{0}C, at 0.2 m, whereas, the lowest mean was detected at Station 6 at 30 m depth with a temperature of 24.08 ^{0}C. All subsurface temperatures were above 30 ^{0}C , except for Station 6 which is located in Murum River. Little difference was observed between 15 m and 30 m depths and temperature ranged from 24 to 26 oC at those depths. Temperature at all stations shows significant difference at 30 m depth ($p < 0.0005$) but no significant difference among Stations 1 – 3 at 0.2 m depth ($p \leq 0.973$) and among stations at 15 m ($p \leq 1.000$), except at Station 6 which is significantly different from the other stations at that depth ($p < 0.001$). Compared with the study done 2 months before the reservoir's complete filling, at the subsurface level, the temperature were reported to be 29.63-30.96 ^{0}C, showing that the subsurface temperature in this study (31.28-33.01 ^{0}C) were higher as the filling has been completed.

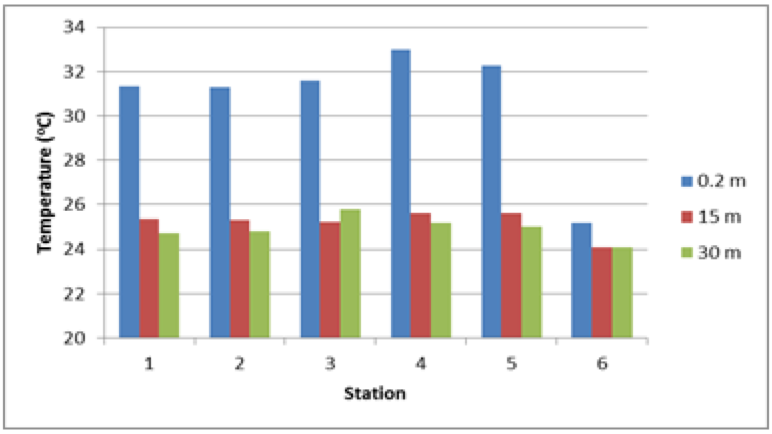

Figure 2: Temperature at the six stations.

According to the temperature profile measured on the 10th of April 2013 at Station 1, temperature at the surface was the highest (31.34 ^{o}C) and the temperature decreased as depth increased (Figure 3). There was a drastic drop beginning 6 m depth to 8 m depth, indicating that thermocline occurred at 6-8 m depth from the surface. This is in contrast with previous study results (Nyanti, Ling & Grinang, 2012) whereby in the present study, the temperature drop was more drastic and the drop was about 4.5 ^{o}C whereas previously, the decline was less drastic and the temperature drop was about 2 ^{o}C only. In addition, though the temperature at the surface was higher than that of January 2012, the temperature at 20 m depth was lower than before. The thermocline curve also looked more refined and distinct compared to that of Jan 2012. This difference was due to the completion of the filling of the reservoir and water is relatively stagnant compared to when the reservoir was still being filled with cooler water flowing in. The

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profile obtained in the present study is similar to the profile of the 27 year old Batang Ai Hydroelectric Reservoir though the depth of occurrence of thermocline does differ slightly whereby in Batang Ai Reservoir, it occurred at 8-11 m for the same month of the year (Ling, Lee & Nyanti, 2013a; Ling, Nyanti, Leong & Wong, 2013b).

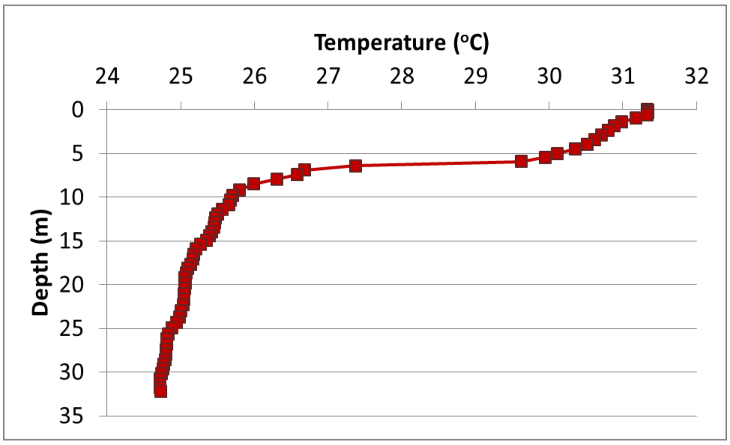

Figure 3: Temperature profile at Station 1 in the Bakun Reservoir on 10th April 2013.

pH recorded at the selected stations ranged from 5.49 to 7.73 where the highest pH was recorded at Station 2 at 0.2 m, whereas the lowest pH was recorded at Station 1 at 15 m (Figure 4). Comparing among depths, pH was the highest at 0.2 m depth ranging from 7.38 to 7.73 indicating alkaline condition except at Station 6 where at all depths, the pH was acidic (5.71-5.87). At 0.2 m depth, there was a significant difference in pH among stations except for Stations 3–5. The high values of pH at 0.2 m depths at most of the stations were in contrast to previous observations of 5.74-5.82 (Nyanti et al. 2012). At 0.2 m depth, pH has improved from Class III (Nyanti et al. 2012) to Class I according to Interim National Water Quality Standard of Malaysia (INWQS) in the present study except for Station 6 which fall in Class III. For 15 m depth, Station 2 pH value falls in Class I, Stations 3-5 fall in Class II and Stations 1 and 6 falls in Class III. For 30 m depth, at Stations 1-5, pH value obtained fall in Class II. All the stations with Class II pH values show an improvement from previous record of below pH 6 in January 2012 (Nyanti et al., 2012). pH at 0.2 m depth were similar to the mean value of 7.25 reported at 0.5 m depth at Batang Ai Reservoir (Ling, Paka, Nyanti, Norhadi & Emang, 2012).

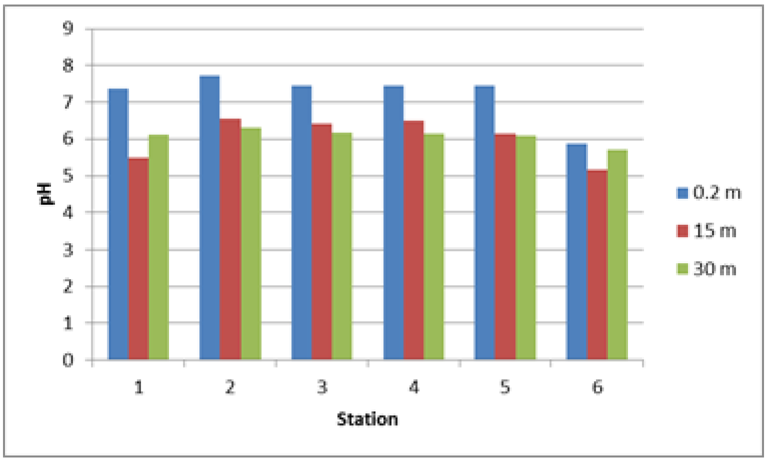

Figure 4: pH at the six stations.

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The overall range of turbidity at the stations was 0 – 1141 NTU. The lowest turbidity, 0 NTU was observed at 0.2 m at Station 1, 2 and 3, whereas, the highest turbidity with a value of 1141 NTU was observed at Station 6 at 30 m (Figure 5). Turbidity increased as depth increased for all stations except station 1 whereby it was the highest at 15 m. The turbidity at Station 6 which was on the Murum River was the highest among the stations at all depths (611-1141 NTU) followed by Station 4 (6.3-206.3 NTU). This is due to the sediment originating from the land clearance and soil disturbance during the construction of the Murum Dam on Murum River upstream of Stations 6 and 4. In addition, there were logging activities to remove vegetation in preparation for dam filling. The highest turbidity was much higher than that reported (120.5 NTU) at 18 m depth at an innundated station on the former Batang Balui and this trend of increase with depth was also observed in January 2012 (Nyanti et al., 2012). Values at 0.2 m depth at Stations 1, 2, 3, 5 complied with Class I of INWQS; values at 15 m depths of Stations 2, 3, 5 and 30 m depth of Station 5 complied with Class II limit whereas the other values exceeded Class II limit of 50 NTU. This implies that Station 6 is not suitable for sensitive aquatic organisms at all depths.

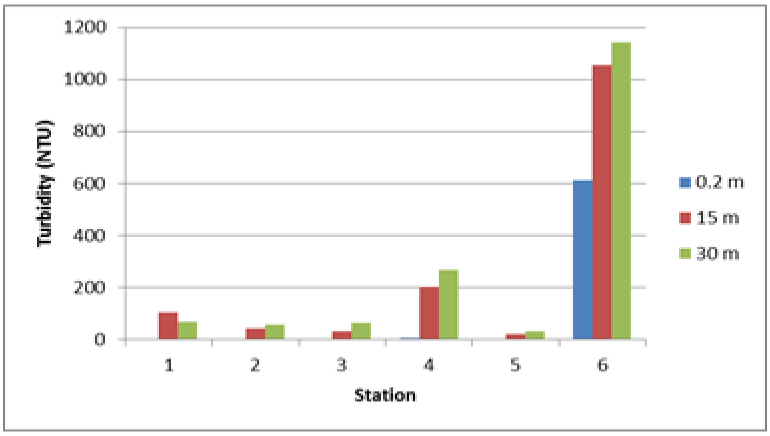

Figure 5: Turbidity at the six stations.

DO was the highest at 0.2 m depth at all the stations except at Station 6 whereby the highest was observed at 30 m depth (Figure 6). In addition, at Station 6, DO was high (7.05-7.67 mg/L) at all the depths due to the aeration from the fast flowing Murum River. That aeration also aided the 15 m and 30 m depths of Station 4 where DO values of 1.90 and 3.17 mg/L respectively were observed instead of zero as observed at Station 1, 2, 3 and 5 at those depths. There were significant difference among all the stations at 0.2 m depth and among Stations 4 – 6 at both 15 m and 30 m depths ($P<0.001$).

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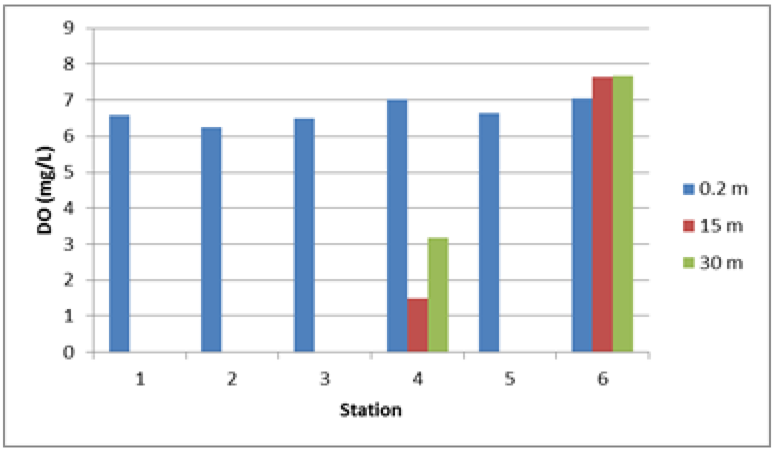

Figure 6: Dissolved oxygen (DO) at the six stations.

Figure 7 shows the dissolved oxygen profile taken at Station 1 on the 10th of April 2013 compared to that of 6th of January 2012 (Nyanti, Ling & Grinang, 2012). It shows that DO was constant at about 6.5 mg/L up to the depth of 5 meters. Starting from 5 m depth, DO dropped drastically to undetectable at 9 m depth and it was above 5 mg/L, the minimum required for healthy aquatic organisms (Chapman, 1996) up to 6.4 m depth only; whereas measurement made on the 6th of January 2012 at the same station showed that the DO was above 5 mg/L up to only 0.41 m depth and it was undetectable at 4.1 m depth. This shows that the DO has improved compared to the previous study.

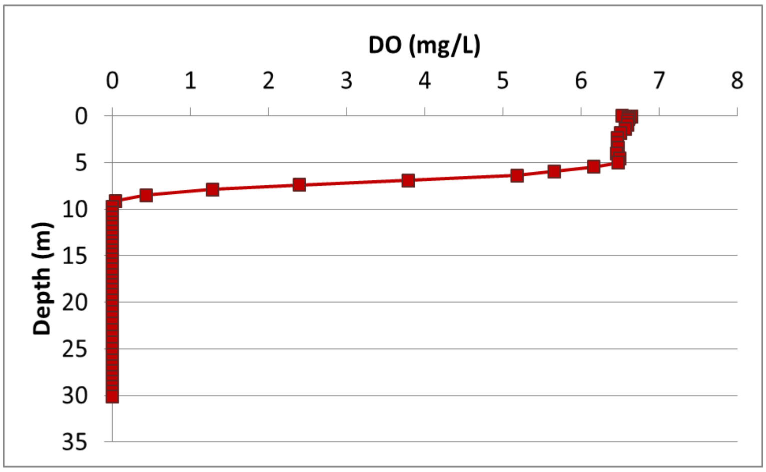

Figure 7: Dissolved oxygen profile at Station 1 in the Bakun Reservoir on 10th April 2013.

The overall range of mean BOD_5 in the selected stations was 0.37 – 4.32 mg/L. The highest BOD_5 value was at 15 m of Station 5 with a value of 4.32 mg/L, whereas, the lowest was at 0.2 m of Station 3 with a value of 0.37 mg/L (Figure 8). Comparing among stations, at 0.2 m depth, Station 6 showed the highest value, followed by Station 5; at 15 m depth, Station 5 showed the highest value followed by Station 2 and at 30 m depth, the highest occurred at Station 5 again and the second highest at Station 1. For each station, the highest value of BOD_5 occurred at either 15 m or 30 m depth as the submerged living things settled at the bottom and some vegetation were still standing. The difference among the stations could be due to the difference in the dispersion rate as some stations may have experienced more input from larger rivers than

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others. The values at 3 depths, namely, 15 m depth of Station 2 and 15 m and 30 m depths of Station 5 fall in Class III (3-6 mg/L) of INWQS whereas the others fall either in Class I or Class II of INWQS. The BOD_5 values at 0.2 m, 15 m and 30 m depth for the reservoir stations were lower than 0.5 m, 14 m and 27 m depth values in Batang Ai. However, there is a similarity in that; the values in deeper regions were higher than the subsurface.

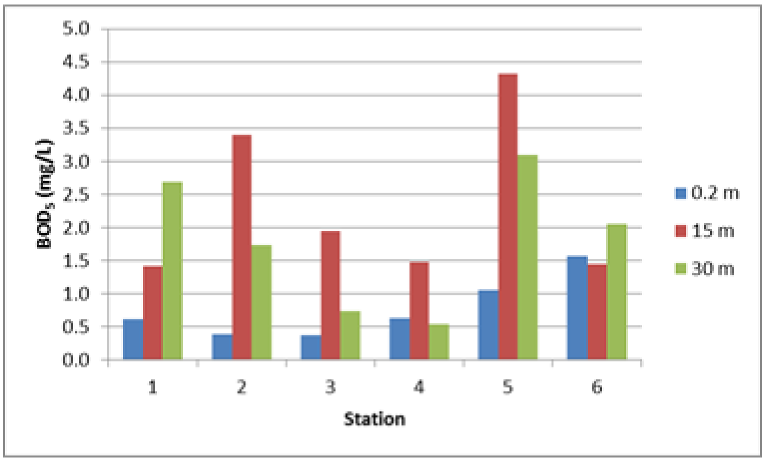

Figure 8: Five-day biochemical oxygen demand (BOD_5) at the five stations for the two trips.

4. CONCLUSIONS

This study shows that the temperature for stations in the reservoir were high at the subsurface with values of above 30 °C and it dropped about 6 °C as the depth increased to 15 m. In addition, thermocline occurred at 6-8 m depth and dissolved oxygen was in Class II in the top 6.4 m layer. At each station, the highest BOD_5 occurred either at 15 m or 30 m depth, indicating higher organic matter at deeper regions of the reservoir. On the other hand, in the Murum River, though dissolved oxygen was high, the water was acidic and the turbidity was very high which rendered it unsuitable for sensitive aquatic organisms. Since BOD_5 of some stations fall in Class III, there is a need to continue to monitor the water quality of the reservoir.

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