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## Assessing Water Quality of Murum Reservoir Halfway Through Impoundment (Menilai Kualiti Air di Empangan Murum pada Separuh Perangkuman)

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### ABSTRACT

*This paper reports the water quality of Murum Hydroelectric Reservoir, eight months after impoundment of the dam. A total of nine stations were selected in the reservoir. Temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD<sub>5</sub>), chlorophyll-a and total suspended solids (TSS) were studied. The results showed that the water was warmer at 0.5 m depth. As the depth increased, temperature in the reservoir decreased in the range of 4.40°C to 7.35°C from 0.5 to 20 m depth. The concentration of DO dropped to zero at 4 - 6 m depth leading to anoxic level. pH at 0.5 m depth ranged from 6.40 to 7.20 and they were significantly higher ( $p < 0.05$ ) than those at 10 and 20 m. Chlorophyll-a at 0.5 m were in the range of 4.61 to 20.50 mg/L, relatively higher compared to 10 m and 20 m depths. The results obtained indicates that impoundment of Murum River generally caused water quality deterioration. In addition, this could be due to anthropogenic activities such as plantation and logging activities that are still going on within the catchment during the impoundment. Therefore, further continuous monitoring and investigation is required to determine the long-term water quality condition and identify factors that influence water quality in Murum Reservoir.*

*Keywords: Early impoundment; hydroelectric dam; Murum Dam; thermocline*

### ABSTRAK

*Kertas ini melaporkan kualiti air empangan hidroelektrik Murum, lapan bulan selepas perangkuman empangan. Sebanyak sembilan stesen telah dipilih di dalam takungan. Suhu, pH, oksigen terlarut (DO), permintaan oksigen biokimia (BOD<sub>5</sub>), pepejal klorofil-a dan jumlah pepejal terampai (TSS) telah dikaji. Keputusan menunjukkan bahawa air lebih panas pada kedalaman 0.5 m. Apabila kedalaman meningkat, suhu dalam takungan menurun dalam lingkungan 4.40°C hingga 7.35°C daripada 0.5 hingga 20 m kedalaman. Kepekatan DO jatuh ke sifar pada kedalaman 4 - 6 m yang membawa kepada tahap anoksik. pH pada kedalaman 0.5 m adalah dari 6.40 hingga 7.20 dan mereka jauh lebih tinggi ( $p < 0.05$ ) berbanding dengan 10 dan 20 m. Klorofil-a pada 0.5 m berada dalam lingkungan 4.61 hingga 20.50 mg/L, lebih tinggi berbanding dengan 10 dan 20 m kedalaman. Hasil yang diperolehi menunjukkan bahawa perangkuman Sungai Murum secara amnya menyebabkan kemerosotan kualiti air. Di samping itu, ini boleh disebabkan aktiviti antropogenik seperti aktiviti perladangan dan pembalakan yang masih berlaku dalam semasa perangkuman. Oleh itu, pemantauan dan penyelidikan yang berterusan diperlukan untuk menentukan keadaan kualiti air jangka panjang dan mengenal pasti faktor yang mempengaruhi kualiti air di Empangan Murum.*

*Kata kunci: Empangan hidroelektrik; Empangan Murum; perangkuman awal; termoklin*

### INTRODUCTION

In Sarawak, hydroelectric power generation is highly potential and suitable because the average annual precipitation is about 4000 mm. Sarawak has three existing hydroelectric power (HEP) dams, namely Batang Ai HEP dam in Lubok Antu, Murum HEP Dam and Bakun HEP Dam in Kapit division. Murum Dam is the second largest hydroelectric power dam, built to cater electricity to the State of Sarawak. It is located about 70 km upstream of Bakun Dam. The construction of the dam began in 2008 and was completed in 2013. The dam was impounded in September 2013. Murum Dam is a roller-capacity concrete dam that was built over the Sungai Murum with a height of 141 m covering a catchment area of 2750 km<sup>2</sup> where the size of reservoir was 245 km<sup>2</sup>. The construction and operation of the reservoirs affect the

stream habitats, riparian vegetation and aquatic fauna at various scales (Quist et al. 2005). The impoundments of the rivers can directly affect stream ecosystems and communities through alteration of hydrologic regimes (Brian et al. 2007; David 2000) and water quality (Yao et al. 2006) and act as barrier to the movement of fish towards upstream and thus influence and change the fish assemblages and compositions (Xiaoan et al. 2010). The full supply level (FSL) of Murum Dam is 540 m above sea level with a total output capacity of 944 MW. Till 16th May 2014, eight months after impoundment, the water level has reached up to 521 m above sea level (ASL). This indicates that 74% of the intended level of reservoir has been achieved where the minimum and maximum water level for operation were 515 m and 540 m ASL, respectively.

In Bakun Dam, pH of the water in the reservoir were reported acidic with the range of 5.1 to 5.5 during fifteen months after impoundment (Nyanti et al. 2012). Nyanti et al. (2012) also observed the low dissolved oxygen (DO) in Bakun Dam and anoxic level at 1 to 4 m depths due to decomposition of submerged carbonaceous materials. Changes in water quality could affect the aquatic life by altering the habitats which ultimately decreases the primary productivity (Rossiter et al. 2010). Therefore, it is important to identify the changes in water quality upon impoundment how it would affect the aquatic life. However, despite the increasing development of hydroelectric dams in Sarawak, there is limited information on water quality during the impoundment. Continuous monitoring of water quality is crucial in order to provide the baseline data needed for future reservoir planning and conservation of aquatic fauna albeit it was built to cater electricity to the state. Therefore, the objective of this study was to determine water quality of Murum Reservoir during eight months after impoundment.

## MATERIALS AND METHODS

### WATER QUALITY SAMPLING

Water samplings were carried out at 9 stations (Figure 1) on 14th to 16th May 2014. Dissolved oxygen (DO) and temperature profiling were measured *in-situ* using YSI Pro20 (Professional Series) from subsurface (0.5 m) to 20 m depth. Water samples were collected in triplicates at different depths with 10 m intervals (Subsurface - 0.5 m, 10 m and 20 m) using Horizontal Van Dorn water sampler were for pH and *ex-situ* parameters such as total suspended solids (TSS), five-day biochemical oxygen demand (BOD) and chlorophyll-*a*. pH was measured using Extech SDL100 pH/ORP Meter. The procedure for determining total suspended solids (TSS) follows the standard method (2540-D) used by APHA (2000). Glass microfiber filter disc with the size of 0.45  $\mu\text{m}$  were used to filter water sample. Clean filter paper were rinsed, dried and weighed to constant weight using analytic balance equipment and recorded before being placed on the base which connects the flask and before samples were being poured on top of it. Then, one funnel was placed on top of the base with the filter paper and clamped with clamp spring to avoid samples from spilling from the funnel. A 500 mL of sample was shaken vigorously and transferred to the filter. Vacuum pump was applied to let the water sample pass through the flask quickly. The filter paper was then removed from the base carefully and wrapped in aluminium foil. The wet filter paper was then dried in the oven for an hour at 103°C to 105°C. After that, the dried filter paper were left cooled in desiccators and then weighed to a constant weight. The calculation for TSS is as follows:

$$\text{TSS} = ((A-B) \times 1000)/C$$

where, A is the weight of filter paper + residue (mg); B is the weight of filter paper (mg); and C is the volume of water sample filtered (mL).

Biochemical oxygen demand (BOD) test was conducted according to the procedures in Standard Methods APHA 5210-B (APHA 2000). All the samples were filled to overflowing in airtight 300 mL. The bubbles in the bottle were removed properly by knocking the bottle with its cap and incubated at 20°C for five days. The BOD bottles were labelled with sampling stations number and date the test was conducted to avoid mix ups. Initial DO was measured before incubation and final DO was measured after five days of incubation. General equation for the determination of a BOD<sub>5</sub> value is shown below:

$$\text{BOD}_5 \text{ (mg/L)} = (D_1 - D_2),$$

where,  $D_1$  is the initial DO of the water sample; and  $D_2$  is the final DO of the water sample after 5 days.

Chlorophyll-*a* analysis was conducted by using 0.70  $\mu\text{m}$  glass fiber filter of 47 mm in diameter. After the filtration, the filtered substances were grinded with mortar and pestle in 5-6 mL of 90% acetone for approximately 5 min. Then, the grinded sample was transferred into the capped centrifuge tube and added 90% acetone to make a total volume of 10 mL. The centrifuge tube then were wrapped with aluminium foil and placed in refrigerator for 4 to 16 h to facilitate complete extraction of the pigments. Later, the sample was centrifuged for 10 min at 3000 rpm. Then, the extract was transferred into 1 cm cuvette and extraction were measured at wavelength 750, 664, 647 and 630 nm using Spectrophotometer Hach DR2800. Concentration of chlorophyll-*a* was then determined based on equation:

$$\text{Chl-}a = [11.85 (E_{664} - E_{750}) - 1.54 (E_{647} - E_{750}) - 0.08 (E_{630} - E_{750})] \times v/V$$

where,  $E_{750}$ ,  $E_{664}$ ,  $E_{647}$  and  $E_{630}$  are absorbance at 750, 664, 647 and 630 nm wavelength, respectively.  $V$  is the volume of water sample filtered in L and  $v$  is the volume of acetone in mL. Data obtained were statistically tested using one-way ANOVA and Tukey's test for multiple comparison. All were performed using SPSS Statistics 22.0. The coordinates and location of the sampling stations were listed in Table 1.

## RESULTS AND DISCUSSION

The results of the water temperature and dissolved oxygen at selected depths from the 9 sampling stations are presented in Table 2 while result of pH, chlorophyll-*a*, BOD<sub>5</sub> and TSS are shown in Table 3.

### TEMPERATURE

The mean water temperature in Murum Reservoir is 25.72  $\pm$  2.39°C. The readings ranged from 23.50°C to 32.30°C,

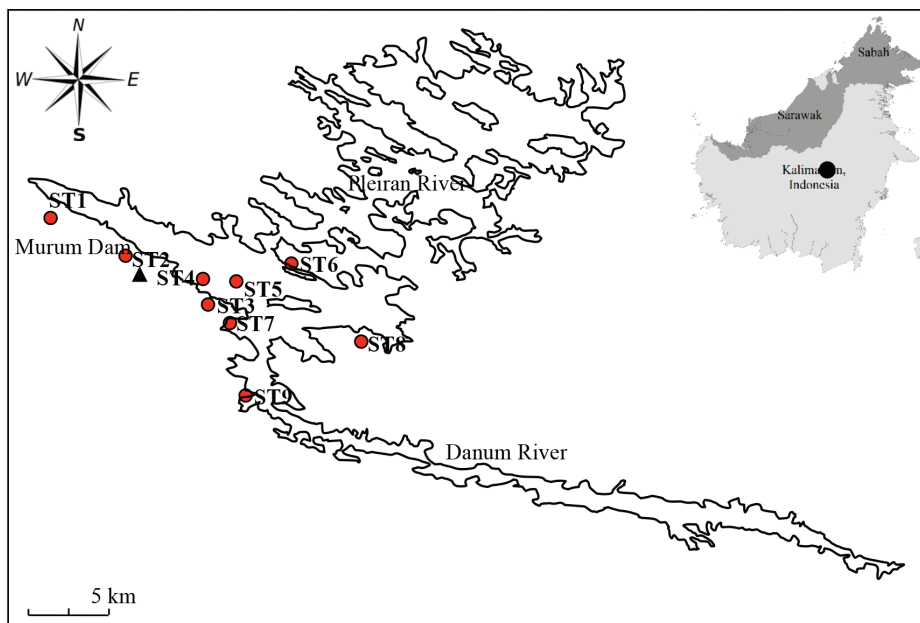


FIGURE 1. Location of nine sampling stations in Murum Reservoir

TABLE 1. Coordinates and locations of the 9 sampling stations

| Station | Coordinate                            | Location                                   |
|---------|---------------------------------------|--|
| ST1     | N 02° 41' 05.50"<br>E 114° 18' 49.00" | 200 m away from the intake point           |
| ST2     | N 02° 39' 17.90"<br>E 114° 21' 56.30" | 400 m from the dam                         |
| ST3     | N 02° 38' 27.60"<br>E 114° 24' 32.60" | 5 km from ST2                              |
| ST4     | N 02° 39' 17.20"<br>E 114° 24' 22.60" | At the mouth of Sungai Pleiran             |
| ST5     | N 02° 39' 02.70"<br>E 114° 25' 23.90" | 2 km from the mouth of Sungai Pleiran      |
| ST6     | N 02° 39' 38.10"<br>E 114° 26' 57.60" | Upstream of Sungai Pleiran                 |
| ST7     | N 02° 37' 15.70"<br>E 114° 24' 52.80" | 2 km from the mouth of Sungai Danum        |
| ST8     | N 02° 37' 01.20"<br>E 114° 29' 26.80" | 7.5 km from ST9, tributary of Sungai Danum |
| ST9     | N 02° 35' 25.70"<br>E 114° 25' 43.40" | Uptream of Sungai Danum                    |

which almost similar to Tasik Bera with range between 23.70°C and 31.20°C (Shuhaimi-Othman et al. 2008). Baharim et al. (2012) reported Sembrong Reservoir has warmer water temperature (mean 29.51°C) as compared to Murum Reservoir. At the subsurface (0.5 m depth), the range of water temperature was 29.80°C to 31.00°C (Table 2). It is similar to the water temperature at the subsurface of Bakun Reservoir and Batang Ai Reservoir, with ranged from 29.63°C to 30.96°C (Nyanti et al. 2012) and 26.90°C to 31.10°C (Ling et al. 2013), respectively. Temperature profile (Figure 2) shows that as the depth increases,

temperature decreases. Among the stations, the mean water temperature in Murum Reservoir was highest at ST 9 (26.00 ± 2.57°C) and lowest at ST 5 (25.55 ± 2.38°C). As compared among depths, water temperature were highest at 0.5 m and lowest at 20 m (ranged from 23.50°C to 23.70°C), at all stations. There were no significant differences ( $p > 0.05$ ) in mean water temperature among the stations and among depths at all stations. Temperature is a good indicator to determine thermocline (Dodson et al. 2007), in the early stage of this study, thermocline occurrence was observed at 4 to 8 m depths. Table 2 shows the water temperature

TABLE 2. Temperature and dissolved oxygen at the nine sampling stations at selected depths

| Depth (m) | Station                                   |   |                                       |                                       |                                       |                                       |                                       |                                       |   |
|-----------|---|---|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---|
|           | ST 1                                      | ST 2                                    | ST 3                                  | ST 4                                  | ST 5                                  | ST 6                                  | ST 7                                  | ST 8                                  | ST 9                                    |
|           | Temperature (°C)                          |   |                                       |                                       |                                       |                                       |                                       |                                       |   |
| 0.0       | 30.50 ± 0.00                              | 30.30 ± 0.00                            | 29.80 ± 0.00                          | 31.00 ± 0.00                          | 31.30 ± 0.00                          | 31.60 ± 0.00                          | 30.10 ± 0.00                          | 30.80 ± 0.00                          | 32.30 ± 0.00                            |
| 2.0       | 28.80 ± 0.00                              | 29.90 ± 0.00                            | 29.70 ± 0.00                          | 28.90 ± 0.00                          | 29.20 ± 0.00                          | 28.70 ± 0.00                          | 29.80 ± 0.00                          | 30.00 ± 0.00                          | 29.50 ± 0.00                            |
| 4.0       | 28.50 ± 0.00                              | 28.60 ± 0.00                            | 28.90 ± 0.00                          | 28.80 ± 0.00                          | 28.60 ± 0.00                          | 28.00 ± 0.00                          | 28.80 ± 0.00                          | 28.70 ± 0.00                          | 28.90 ± 0.00                            |
| 6.0       | 26.50 ± 0.00                              | 26.30 ± 0.00                            | 26.30 ± 0.00                          | 26.10 ± 0.00                          | 26.10 ± 0.00                          | 26.00 ± 0.00                          | 26.30 ± 0.00                          | 25.90 ± 0.00                          | 27.60 ± 0.00                            |
| 8.0       | 24.70 ± 0.00                              | 24.80 ± 0.00                            | 24.90 ± 0.00                          | 24.90 ± 0.00                          | 24.80 ± 0.00                          | 24.90 ± 0.00                          | 24.70 ± 0.00                          | 24.70 ± 0.00                          | 25.30 ± 0.00                            |
| 10.0      | 24.20 ± 0.00                              | 24.20 ± 0.00                            | 24.30 ± 0.00                          | 24.30 ± 0.00                          | 24.30 ± 0.00                          | 24.70 ± 0.00                          | 24.20 ± 0.00                          | 24.20 ± 0.00                          | 24.60 ± 0.00                            |
| 12.0      | 24.00 ± 0.00                              | 24.00 ± 0.00                            | 24.00 ± 0.00                          | 24.00 ± 0.00                          | 24.10 ± 0.00                          | 24.40 ± 0.00                          | 24.10 ± 0.00                          | 24.00 ± 0.00                          | 24.20 ± 0.00                            |
| 14.0      | 23.90 ± 0.00                              | 23.90 ± 0.00                            | 23.90 ± 0.00                          | 23.90 ± 0.00                          | 23.90 ± 0.00                          | 24.20 ± 0.00                          | 24.00 ± 0.00                          | 23.90 ± 0.00                          | 24.00 ± 0.00                            |
| 16.0      | 23.80 ± 0.00                              | 23.80 ± 0.00                            | 23.80 ± 0.00                          | 23.80 ± 0.00                          | 23.80 ± 0.00                          | 24.00 ± 0.00                          | 23.90 ± 0.00                          | 23.80 ± 0.00                          | 23.80 ± 0.00                            |
| 18.0      | 23.80 ± 0.00                              | 23.80 ± 0.00                            | 23.80 ± 0.00                          | 23.80 ± 0.00                          | 23.80 ± 0.00                          | 23.90 ± 0.00                          | 23.80 ± 0.00                          | 23.80 ± 0.00                          | 23.80 ± 0.00                            |
| 20.0      | 23.70 ± 0.00                              | 23.70 ± 0.00                            | 23.70 ± 0.00                          | 23.70 ± 0.00                          | 23.70 ± 0.00                          | 23.50 ± 0.00                          | 23.70 ± 0.00                          | 23.70 ± 0.00                          | 23.70 ± 0.00                            |
| Mean      | 25.62 ± 2.28                              | 25.70 ± 2.44                            | 25.71 ± 2.36                          | 25.66 ± 2.34                          | 25.55 ± 2.38                          | 25.72 ± 2.26                          | 25.73 ± 2.46                          | 25.68 ± 2.50                          | 26.00 ± 2.57                            |
|           | Dissolved oxygen (mg/L)                   |   |                                       |                                       |                                       |                                       |                                       |                                       |   |
| 0.0       | <sup>a</sup> 5.23 ± 0.02 <sup>7</sup>     | <sup>a</sup> 4.57 ± 0.01 <sup>5</sup>   | <sup>a</sup> 4.42 ± 0.02 <sup>4</sup> | <sup>a</sup> 4.61 ± 0.01 <sup>5</sup> | <sup>a</sup> 4.37 ± 0.02 <sup>5</sup> | <sup>a</sup> 4.85 ± 0.01 <sup>3</sup> | <sup>b</sup> 4.94 ± 0.01 <sup>4</sup> | <sup>a</sup> 4.71 ± 0.01 <sup>4</sup> | <sup>a</sup> 5.22 ± 0.02 <sup>5</sup>   |
| 2.0       | <sup>b</sup> 4.81 ± 0.01 <sup>6</sup>     | <sup>a</sup> 4.30 ± 0.01 <sup>4</sup>   | <sup>a</sup> 4.39 ± 0.01 <sup>3</sup> | <sup>a</sup> 4.21 ± 0.01 <sup>4</sup> | <sup>b</sup> 4.17 ± 0.01 <sup>4</sup> | <sup>d</sup> 4.51 ± 0.01 <sup>2</sup> | <sup>a</sup> 4.58 ± 0.01 <sup>3</sup> | <sup>a</sup> 4.58 ± 0.01 <sup>3</sup> | <sup>a</sup> 5.07 ± 0.01 <sup>4</sup>   |
| 4.0       | <sup>f</sup> 2.93 ± 0.01 <sup>5</sup>     | <sup>d</sup> 3.40 ± 0.01 <sup>3</sup>   | <sup>b</sup> 4.09 ± 0.01 <sup>2</sup> | <sup>c</sup> 3.86 ± 0.01 <sup>3</sup> | <sup>b</sup> 0.23 ± 0.01 <sup>2</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>e</sup> 3.28 ± 0.02 <sup>2</sup> | <sup>g</sup> 1.13 ± 0.01 <sup>2</sup> | <sup>a</sup> 4.94 ± 0.01 <sup>3</sup>   |
| 6.0       | <sup>e</sup> 0.01 ± 0.01 <sup>1,2</sup>   | <sup>e</sup> 0.02 ± 0.00 <sup>2</sup>   | <sup>h</sup> 0.03 ± 0.01 <sup>1</sup> | <sup>h</sup> 0.06 ± 0.01 <sup>2</sup> | <sup>e</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>e</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>b</sup> 0.05 ± 0.00 <sup>1</sup> | <sup>e</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>a</sup> 0.06 ± 0.01 <sup>2</sup>   |
| 8.0       | <sup>h</sup> 0.00 ± 0.00 <sup>1</sup>     | <sup>h</sup> 0.00 ± 0.00 <sup>1</sup>   | <sup>h</sup> 0.02 ± 0.01 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1,2</sup> |
| 10.0      | <sup>e</sup> 0.00 ± 0.00 <sup>1</sup>     | <sup>h</sup> 0.01 ± 0.00 <sup>1,2</sup> | <sup>e</sup> 0.02 ± 0.01 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>b</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>a</sup> 0.04 ± 0.00 <sup>1,2</sup> |
| 12.0      | <sup>h</sup> 0.05 ± 0.00 <sup>4</sup>     | <sup>h</sup> 0.02 ± 0.00 <sup>2</sup>   | <sup>h</sup> 0.02 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.30 ± 0.00 <sup>3</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1,2</sup> |
| 14.0      | <sup>h</sup> 0.04 ± 0.00 <sup>3,4</sup>   | <sup>h</sup> 0.02 ± 0.00 <sup>2</sup>   | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.30 ± 0.00 <sup>3</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup>   |
| 16.0      | <sup>h</sup> 0.04 ± 0.00 <sup>3,4</sup>   | <sup>h</sup> 0.02 ± 0.00 <sup>2</sup>   | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.30 ± 0.00 <sup>3</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup>   |
| 18.0      | <sup>h</sup> 0.03 ± 0.00 <sup>2,3,4</sup> | <sup>h</sup> 0.02 ± 0.00 <sup>2</sup>   | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.30 ± 0.00 <sup>3</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup>   |
| 20.0      | <sup>h</sup> 0.02 ± 0.00 <sup>1,2,3</sup> | <sup>h</sup> 0.01 ± 0.00 <sup>1,2</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.30 ± 0.00 <sup>3</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.04 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup> | <sup>h</sup> 0.03 ± 0.00 <sup>1</sup>   |
| Mean      | 1.10 ± 1.88                               | 1.08 ± 1.75                             | 1.05 ± 1.83                           | 1.02 ± 1.77                           | 0.95 ± 1.55                           | 0.83 ± 1.71                           | 1.12 ± 1.88                           | 0.92 ± 1.74                           | 1.40 ± 2.18                             |

Means in the same row with the same superscript (denoted as a, b, c, d, e, f, g, h, and i) was not significantly different at 5% significant level. Means in the same column with the same superscript (denoted as 1, 2, 3 and 4) was not significantly different at 5% significant level

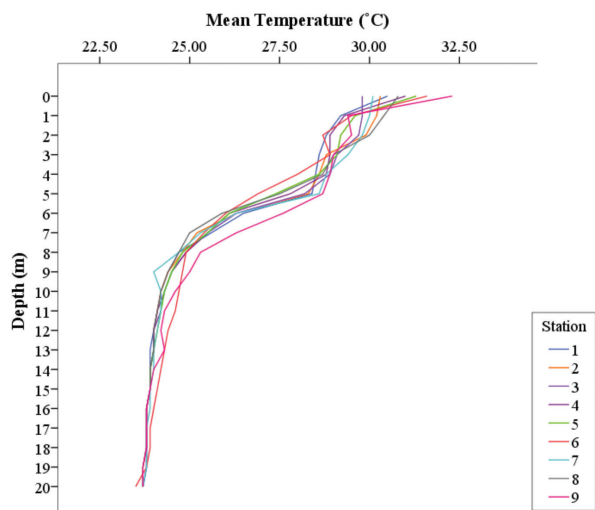


FIGURE 2. Temperature profile of the 9 stations in Murum Reservoir

at 0.5, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 m depths for all sampling stations. Figure 2 shows the profile of water temperature at all stations.

#### DISSOLVED OXYGEN

The dissolved oxygen concentration is a crucial environmental parameter in the dynamics and characterisation of aquatic ecosystems (Rodgher et al. 2005). Figure 3 shows the profiles of dissolved oxygen at all stations. The DO concentration in Murum Reservoir ranges from 0.00 to 5.25 mg/L with a mean value of  $1.05 \pm 1.81$  mg/L (Table 2). This study has lower concentration of DO as compared to Batang Ai Reservoir (Ling et al. 2013). Overall, concentration of DO was highest at 0.5 m depth with the range between 4.37 mg/L at ST 5 and 5.23 mg/L at ST 1 and relatively lower than a typical flowing river due to stagnant water at the reservoir. The concentration of DO further decreased to zero, reaching an anoxic level at all stations, starting from an average depth of 4-6 m to 20 m. However, there is a slight increase in DO at ST 1 from 10 m depth (0.00 mg/L) to 12 m depth (0.05 mg/L). This could be due to the influence of inflowing water from small tributaries that channelling into the reservoir. The concentration of DO were significantly different ( $p < 0.05$ ) among stations and depths. At the depth of 0.5 to 10 m, the concentration of DO were significantly different ( $p < 0.05$ ) among stations. The concentration of DO was significantly highest at ST 1 (5.23 mg/L) and significantly lower at ST 1 and ST 2 (both at 8 m depth - 0.00 mg/L). There were no significant differences ( $p > 0.05$ ) in the concentration of DO at the depth 10 to 20 m among the stations. Comparing by depths, there were significant differences ( $p < 0.05$ ) in the concentration of DO at all stations. Higher concentration of DO at the subsurface of the water due to atmospheric diffusion. The decreased in concentration of DO at the bottom could be due to the fact that decomposition taking

place and microorganisms consumes oxygen to breakdown excess feed and physiological waste (Ling et al. 2013; Sahoo & Luketina 2006). As the concentration of DO drops below 3 mg/L, the rough fish will eventually dies, while high DO concentration are also toxic to fish and will caused physiological dysfunctions and development abnormalities in fertilised eggs and larvae (Ali et al. 2000). At Murum Reservoir, the concentration of DO reduced to 0 mg/L as it went deeper indicating anoxia state as a result of intensive decomposition of organic matter and submerged vegetation leading to depletion of oxygen. This result is similar to that reported in Barra Bonita Reservoir in Brazil (Rodgher et al. 2005) and Bakun Reservoir in Malaysia (Nyanti et al. 2012). Figure 3 shows the profile of DO concentrations at all stations.

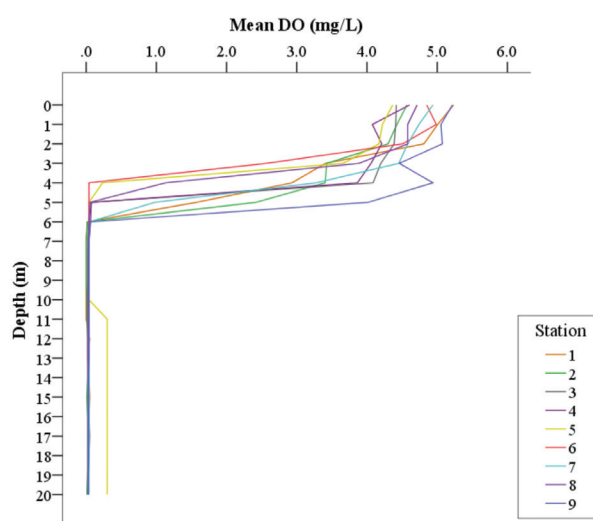


FIGURE 3. Dissolved oxygen profile of the 9 stations in Murum Reservoir

#### TOTAL SUSPENDED SOLIDS (TSS)

The mean total suspended solids (TSS) in Murum Reservoir was  $19.24 \pm 17.17$  mg/L with values ranging from 0.40 to 64.80 mg/L. At 0.5 m depth, TSS at all stations range from 0.67 to 2.07 mg/L (Figure 4). The concentration of TSS was significantly lower ( $p < 0.05$ ) at ST9 and significantly higher at ST6 ( $p < 0.05$ ). At 10 m depth, TSS concentrations were significantly higher at ST7 and significantly lower at ST4, both at  $p < 0.05$ . The concentration of TSS were found significantly higher ( $p < 0.05$ ) at ST1 and significantly lower ( $p < 0.05$ ) at ST8. Across depths, concentration of TSS were significantly different ( $p < 0.05$ ) at all stations. Concentration of TSS at selected depths for all stations was shown in Table 2. Concentration of TSS was recorded higher at the bottom at all stations because sediments were settling down at the bottom as no mixing of water occurred due to the stagnant water body. Suspended solids possibly came from surface runoff from the logging in upstream within the catchment especially upstream of Sungai Pleiran. High concentration of TSS is harmful to

aquatic life especially fish as it can alter their vision and clog their gills (Lawson 1995).

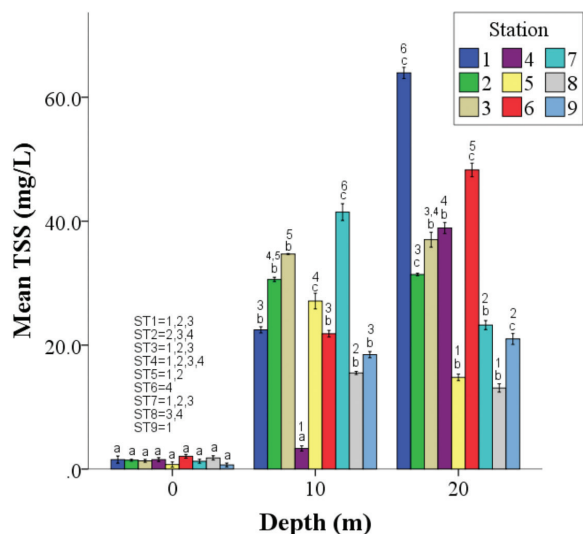


FIGURE 4. Mean TSS of the 9 stations in Murum Reservoir. Bars from the same group with same alphabet were not significantly different at 5% significant level among depths. Bars from the same group with same number were not significantly different at 5% significant level among stations at the same depths

#### pH

Mean pH value in Murum Reservoir was  $6.09 \pm 0.64$ . The mean pH among the sampling stations ranged from 5.44 to 6.28 and all below neutral value (Figure 5). This result consistent with pH value in Batang Ai Reservoir in April 2012 with range 5.78 to 6.58 (Ling et al. 2013). The pH of all stations in Murum Reservoir at 0.5 m depth ranged from 6.40 to 7.20 (Table 2). At 0.5 m depth, the pH was found to increase in the order of  $ST3 < ST2 < ST4 < ST8 < ST5 < ST7 < ST6 < ST9 < ST1$ . pH value was significantly higher at ST 1 ( $pH 7.20 \pm 0.10$ ) and significantly lower at ST 3 ( $pH 6.40 \pm 0.17$ ), both at  $p < 0.05$ . At 10 m depth, the pH was seen to decrease and became acidic, ranging from  $5.00 \pm 0.10$  (ST 1) to  $5.97 \pm 0.06$  (ST 4) and there were significant differences among the stations ( $p < 0.05$ ). As the depth increases to 20 m, the pH appeared to increase slightly in ST2 to ST4 and ST7 to ST9 whilst pH at ST1 and ST6 continued to reduce. At 20 m depth, pH was significantly higher at ST 7 ( $pH 6.10 \pm 0.00$ ) and significantly lower at ST 1 ( $pH 4.13 \pm 0.06$ ), both at  $p < 0.05$ . Among the stations, the mean pH value of water in Murum Reservoir fall in Class II (6-9) of National Water Quality Standards of Malaysia (NWQS) (DOE 2013). Low pH value at 10 and 20 m depths was mainly contributed by dissolved carbon dioxide from decaying of organic matter and decomposing of submerged vegetation that also contributed to total acidity (Iqbal et al. 2004).

#### BIOCHEMICAL OXYGEN DEMAND (BOD)

The mean biochemical oxygen demand (BOD) in Murum Reservoir was  $2.25 \pm 0.79$  mg/L, which ranges from 1.04

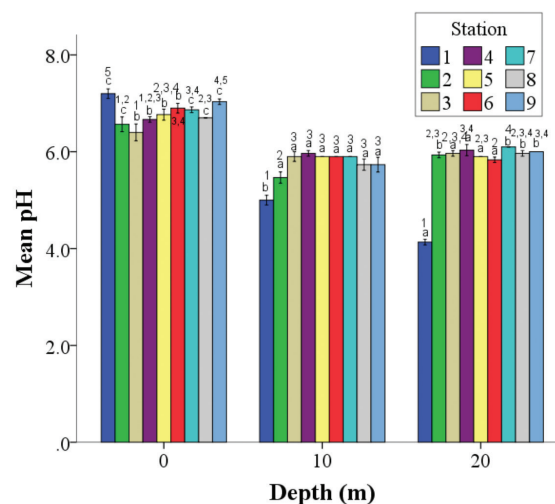


FIGURE 5. Mean pH of the 9 stations in Murum Reservoir. Bars from the same group with same alphabet were not significantly different at 5% significant level among depths. Bars from the same group with same number were not significantly different at 5% significant level among stations at the same depths

to 4.68 mg/L. The range of BOD obtained in this study fall in the range of study conducted in Tasik Chini (0.03 to 5.25 mg/L) (Shuhaimi-Othman et al. 2007) and Batang Ai Reservoir (Ling et al. 2013). In the reservoir at 0.5 m depth, BOD was ranging between 2.29 mg/L to 3.80 mg/L (Figure 6). Station 6 showed the highest value of BOD that was significantly higher ( $p < 0.05$ ) followed by ST9, ST1, ST7, ST8, ST5, ST2, ST3 and ST4 has significantly lower BOD concentration. The  $BOD_5$  were significantly different ( $p < 0.05$ ) across all stations at three different depths. At 10 m depth, the range of  $BOD_5$  at all stations were 1.47 to 4.59 mg/L while at 20 m depth, the range was between 1.13 and 1.90 mg/L. Biodegradable matter found in the dam has also influenced the level of  $BOD_5$  recorded according to Ireosen et al. (2012). High  $BOD_5$  causes depletion in concentration of dissolved oxygen where it will become detrimental to the aquatic life (Ireosen et al. 2012). Low concentration of DO in the water body also a factor contributes to low  $BOD_5$  in the Murum Reservoir.

#### CHLOROPHYLL-A

The mean chlorophyll-a concentration in Murum Reservoir was  $6.76 \pm 4.59$  mg/L, with values ranging from 2.46 to 21.67 mg/L. The concentration of chlorophyll-a at 0.5 m were ranging from 3.27 to 20.83 mg/L as shown in Figure 7. Chlorophyll-a concentration was significantly higher at ST 9 and significantly lower at ST 4, at the depth 0.5 m ( $p < 0.05$ ). There were significant differences in concentration of chlorophyll-a at 0.5 m depth among the stations ( $p < 0.05$ ). At 10 m depth, concentration of chlorophyll-a were not significantly different ( $p > 0.05$ ) among ST1 and ST3 - ST8. The concentration of chlorophyll-a were significantly higher at ST1 ( $5.48 \pm 0.38$  mg/L) and significantly lower at ST8 ( $3.04 \pm 0.24$  mg/L),  $p < 0.05$ , at 10 m depth. At 20 m depth, there were significant difference ( $p < 0.05$ ) in

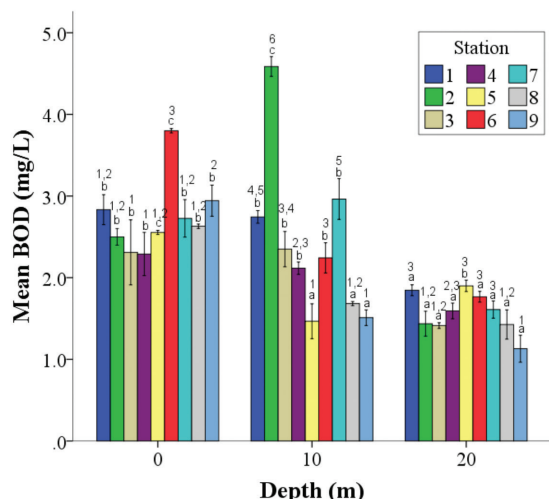


FIGURE 6. Mean BOD of the 9 stations in Murum Reservoir. Bars from the same group with same alphabet were not significantly different at 5% significant level among depths. Bars from the same group with same number were not significantly different at 5% significant level among stations at the same depths

concentration of chlorophyll-a among ST1 and ST4 with other stations while there were no significant differences ( $p > 0.05$ ) among ST2, ST3 and ST5 - ST9. Station 1 has significantly higher concentration of chlorophyll-a ( $12.66 \pm 0.18$  mg/L) while ST9 has significantly lower concentration of chlorophyll-a ( $2.60 \pm 0.04$  mg/L). Higher concentration of chlorophyll-a at subsurface area is common due to the accessibility of sunlight penetrate through thus enhance the growth of phytoplankton. Besides, stagnant water movement due to no rain could be another factor contributing to high concentration of chlorophyll-a in the water (Shuhaimi-Othman et al. 2007).

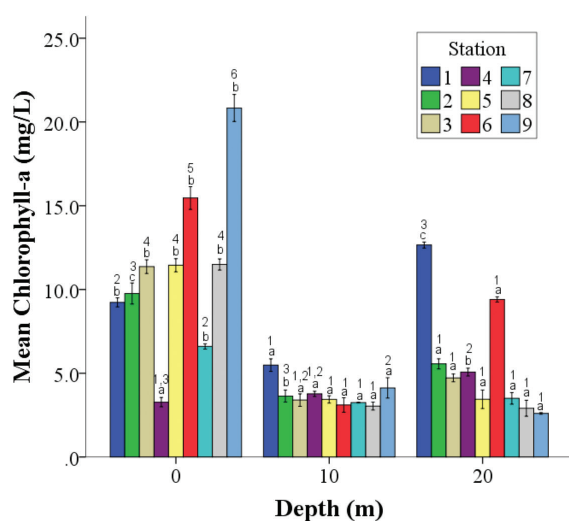


FIGURE 7. Mean chlorophyll-a of the 9 stations in Murum Reservoir. Bars from the same group with same alphabet were not significantly different at 5% significant level among depths. Bars from the same group with same number were not significantly different at 5% significant level among stations at the same depths

## CONCLUSION

On the basis of research, it can be concluded that the deterioration of water quality was observed at all sampling stations. The water temperature in Murum Reservoir were warmer at the subsurface and it decreased about  $8^{\circ}\text{C}$  as the depth increased to 20 m. After impoundment, the thermocline was observed at a very shallow depth of 4 m at Murum Reservoir suggesting that the reservoir is stratified. As the depth increased, pH decreased to acidic level at the depth of 10 and 20 m. However, the concentration of DO was evidenced to reduce drastically to anoxic level at 4 m depth. Concentration of TSS at 0.5 m in the reservoir was lower than at 10 and 20 m depths. Decaying and decomposition of submerged vegetation and other carbonaceous matters are factors that contributed to the acidic condition of water at greater depths. Besides, these factors also contribute to lower DO concentrations at the bottom of the reservoir. Impoundment on the Murum River has affected its water quality. Therefore, a continuous monitoring on water quality in Murum Reservoir would be necessary to adequately characterize the stratification of the reservoir.

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