Characteristics of Pergau Reservoir Water Quality Profile

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Abstract. Water quality profile of Pergau Reservoir or also known as Sultan Ismail Petra Hydroelectric Reservoir has been conducted from 28th October to 3rd November 2019 during Pergau scientific expedition 2019. Three (3) lentic sampling stations (P1, P2 and P3) were selected with eleven (11) water parameters such as water temperature, pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), total dissolved solid (TDS), dissolved oxygen (DO), turbidity, ammonical-nitrogen, oil and grease (O&G), and total coliform were analyzed for water quality status of Pergau Lake. Stratification profile of DO, pH and water temperature were recorded by 10m depth at all lentic stations. Generally DO, temperature and pH reading at the surface lentic sampling stations ranging between 7.11 to 9.21 mg/L, 27 to 27.5 °C and 7.50 to 8.72, respectively. Anoxic layer was detected at depth of 9 m at P1 whereas 3 m at P2 and P3. Profiling of DO, pH and water temperature shown decreased pattern when the water depth increased. Others parameters such as COD at the subsurface were ranged from 1.3 to 1.4 mg/L, TSS reading recorded ranged from 4.00 to 6.80 mg/L, ammonical-nitrogen ranged from 0.05 to 0.07 mg/L whereas BODs were ranged from 1.3 to 1.4 mg/L. The Department of Environment – Water Quality Index (DOE-WQI) classification was used to assess the water quality status of the selected sampling locations. The results showed that all locations fall under Class I ranged between 92.66 to 94.55% and in summary the area can be classified as clean and suitable for sensitive aquatic organisms.

1. Introduction
Lake is one of important water resources in Malaysia where lake water body (usually freshwater) enclosed with considerable size, surrounded by land with no direct access to sea except with a river or stream that feeds or drains the lake [12]. Lake may occur within a river basin as natural or man-made lakes [17]. Lakes also act as habitat of variety biological life and freshwater fish sector [16]. Pergau in Kelantan is one of the man-made lake that function as reservoir [16]. Kenyir Lake in Terengganu, Batang Ai and Bakun in Sarawak, Temengor in Perak also Pedu and Muda Lake in Kedah were some of the man-made lakes that function as reservoir [12].

Lake water quality can be influenced by external inputs entering the lake or reservoir from the watershed as well as the in-lake ecosystem, nutrients cycling and internal loading. External inputs can be organic and inorganic pollutant depends on the human activities within lake catchment areas such
as point source; discharge from domestic and municipal wastewater, agricultural effluent and non-point source; includes urban/stormwater runoff, agricultural runoff and construction site runoff. These sources may causes deterioration of water quality of lake. Excess nutrient such as phosphorus and nitrogen into the lake or reservoir will led to eutrophication. Eutrophication is a condition where water body become uncontrollably rich in aquatic plants; such as algae and aquatic macrophytes (water weeds) [18]. This phenomena will directly induce disturbances to the balance of organisms present in the water and to the quality of water. Despite with high in storage capacity and lake status in Malaysia, there are still functioning as water supply sources after being used as irrigation and hydropower energy.

The preliminary desk top study on the current status of eutrophication of lakes in Malaysia indicated that more than 60% out of 90 lakes reviewed, is experiencing eutrophication [16, 22]. The classification of lakes is based on the trophic state index (TSI) which defines the biological productivity of a lake. Based on the TSI of the 90 lakes and reservoirs listed, 34 lakes (39%) are mesotrophic whilst 56 lakes (62%) are categorised as eutrophic [22]. Detail studies on a few major lakes in Malaysia show different level of degradation. Deterioration of water quality and water quantity was reported in the three biggest natural lakes in Malaysia; the Bera Lake [7], Chini Lake [15] and Loagan Bunut Lake [1]. Addition with man-made reservoirs were included reported; two biggest man-made reservoirs are Kenyir and Temengor which were built for hydropower generation while for small and medium man-made reservoirs such as Bukit Merah, Pedu, Muda and Ahning, which are located in the northern Peninsular Malaysia, were built essentially for irrigation of rice crops besides domestic used [2].

Pergau Reservoir is a man-made lake which is located 100 km from the Jeli city which is well known for its own nature beauty and biodiversity. It encompasses a 4.3 km$^2$ of lake which flows with seven other rivers, producing high productivity and rich diversity of fish population. These river and water bodies play important roles for hydropower and flood mitigation. Pergau Hydroelectric Power Station are operated since 2003 till present. Pergau Reservoir was also known as eco-tourism destination and was temporarily shut down since 2016 by Royal State due to illegal fishing activities and logging at upstream. These activities are affecting the abundance of fish and water quality. It is reported Pergau Reservoir were categorised as Moderate with TSI value range between 37.4 to 47.4 [4]. Previous study [13], was mainly focus at surface water column, hence, this study aim to understand the water quality profile of Pergau Reservoir by 10 m depth. The outcomes of this study eventually will understand the physical characteristic and startification water column of Pergau Reservoir.

2. Material and Method

2.1 Study area

Water quality sampling were conducted between 28th October 2019 to 3rd November 2019 at Pergau Reservoir, Kelantan. There were three (3) water quality-sampling stations of the Pergau Reservoir as indicated in Table 1 and Figure 1.

| Station | Latitude (N)      | Longitude (E)      |
|---------|------------------|--------------------|
| P1      | 5°36′56.50″      | 101°41′6.30″       |
| P2      | 5°37′18.30″      | 101°41′51.50″      |
| P3      | 5°37′45.50″      | 101°41′12.40″      |

Table 1. Georeference of the selected sampling locations
2.2 Sampling method and analysis
There are eleven (11) water parameters analyzed for each sampling locations such as water temperature, pH, BOD, COD, TSS, TDS, DO, turbidity, ammonical-nitrogen, O&G and total coliform. The water quality is divided into two measurements: in-situ and ex-situ. The surface water collected was in five (5) different type of bottles for ex-situ test for physico-chemical parameters; BOD test, O&G, TSS, total coliform and a bottle for the other test; ammoniacal nitrogen and COD. After the collection, the samples were preserved into ice boxes and proceed for analysed using Hach DR/2000 5 portable water analysis kit in the laboratory according to APHA 1992 and HACH 2003 procedures.
Three water quality parameters (temperature, pH and DO) were measured via in-situ using calibrated multiprobe meters YSI Professional Plus handheld from the water surface to 10 m depth with 1 m interval. All these parameters later will be analysed using WQI to determine its water quality status.

3. Result and Discussion

3.1 Water Quality Assessment
Table 2 shows the results of the water quality characteristics calculated using Water Quality Index (WQI) and National Water Quality Standards for Malaysia (NWQS) in Pergau Reservoir. The WQI introduced by Department of Environment (DOE) is being practiced in Malaysia for about 33 years and serve as the basis for the assessment of environment water quality, while NWQS classifies the beneficial uses of watercourse based on WQI. Overall, DOE-WQI for Pergau Reservoir at all sampling locations are categorised as Clean and within Class I. Hence, this reservoir is suitable for sensitive aquatic species conservation.

| Parameter   | P1     | P2     | P3     |
|-------------|--------|--------|--------|
| Temp (°C)   | 27.0   | 27.5   | 27.5   |
| pH          | 7.50   | 7.57   | 8.72   |
| DO (mg/L)   | 7.11   | 6.85   | 9.21   |
| Turbidity   | 3.74   | 3.76   | 3.26   |
| O&G         | 0.4    | 2.2    | 7.4    |

*Figure 1. Sampling locations in Pergau Reservoir*
### Water Quality Profile

Three water quality parameters; pH, DO and temperature were measured *in-situ* (during sampling) and recorded for develop the lake profiling. Stratification usually occurred due to temperature differences within the water body which created separate layers of water [6]. These layers are separated by clines, known as thermoclines (temperature divides) or chemoclines (chemistry gradients). Chemoclines can be based on oxygen, salinity, or other chemical factors that do not cross the cline, such as carbon dioxide. Due to CO$_2$’s influence on the pH of water, stratification can cause pH levels to differ across a cline.

#### 3.2 pH

The range of pH value during the sampling was 7.50 to 8.72, with a mean of 7.93±0.69. The mean pH value of the Pergau Reservoir is indicated as slightly alkaline. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0 [21]. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life. The pH value was ideal when compared to the NWQS and classified as Class I.

![Figure 2. pH profile in Pergau Reservoir](image)

Highest pH recorded was at P3 at 0.2 m (8.72), whereas the lowest pH recorded at P3 at 2 m (6.2) (Figure 2). Water surface were shown the highest range of pH (7.50 to 8.72), compared to the previous observations in 2017 (6.31 to 6.71) [13] which are slightly acidic. As in Figure 2, pH recorded was lower at greater depths. The lowest values are usually near the lake bottom where decomposition of organic matter creates more acidic conditions. The higher pH measurements are

| Parameter          | P1      | P2      | P3      |
|--------------------|---------|---------|---------|
| **TSS (g/L)**      | 4.0     | 6.8     | 6.6     |
| **TDS (g/L)**      | 20.41   | 43.77   | 20.24   |
| **BOD$_3$ (mg/L)** | 1.4     | 1.3     | 1.4     |
| **COD (mg/L)**     | 16      | 3       | 8       |
| **NH3-N (mg/L)**   | 0.1     | 0.1     | 0.1     |
| **E. coli** (cfu/100ml) | 5430   | 822     | 4840    |
| **WQI**            | 92.80   | 94.55   | 92.66   |
| **Class**          | I       | I       | I       |
| **WQ Status**      | C       | C       | C       |
| **Secchi Disk(m)** | 1.2     | 0.8     | 0.76    |
found within a few meters of the surface and usually indicate a zone of vigorous photosynthesis by algae. Differences in pH levels between water strata are due to increased CO$_2$ from respiration and decomposition below the thermocline. This significant drop comes from the saturated CO$_2$ that is stored up in the lower strata of the lake.

### 3.2.2 Temperature

According to the temperature profile measured at P1, temperature at the surface was the lowest (27 °C) and the temperature decreased as depth increased (Figure 3). Vertical water temperature profile shows that water temperature decreased with depth in the transitional and lacustrine zones [19]. High temperature value recorded on the 0.2 m depth (27°C to 27.5°C) and reduced (24.2 to 25.5°C) at 10 m depth which eventually created clinograde curve. There is a drastic drop from 8 m to 10 m depth, indicating that thermocline occurred at 8 m for P1 sampling station, whereas for P2 and P3 the thermocline occurred at 3 m and 2 m depth respectively. Thermocline phenomena happened when there are drastic changes from temperature and metalimnion layer created above or below which temperature changes more rapidly with depth. The result shows there are two main water column occurred in Pergau Reservoir; epilimnion layer within range of 0.2 m depth to 2 m depth with a warmer and typically has a higher pH and higher dissolved oxygen concentration vice versa with hypolimnion layer (5 m to 10 m).

Thermal stratification is a common phenomenon in most deep lakes and reservoirs. In the tropics, the long hot months tend to intensify reservoir thermal stratification since the differences in water density due to temperature differences are greater at a higher temperature[10]. Temperature stratification for Muda Reservoir was albeit weak compared to Pedu reservoir; where the highest value recorded was 30.1 °C and the lowest was 25.7 °C [3]. In 2007, Fatimah had determined that Kenyir reservoir seems to have relatively stable thermal stratification due to high temperature differences (5 to 8 °C) in dry season between epilimnion and hypolimnion and 3 °C during wet season. However in the wet season, temperature of Kenyir reservoir could be decreased as the winds become stronger, and the dissolved oxygen may penetrate until the bottom of the reservoir (30 to 40 m) [10]. In more turbid tropical reservoirs, the thermocline depth can be much shallower. For example in the Murum reservoir, the lacustrine zone started at a depth of less than 1 to 7 m, separating the epilimnion (28.6 to 29.7°C) and the hypolimnion (∼23.2 °C) in just 4 to 6 m thick [19].

![Figure 3. Temperature profile in Pergau Reservoir](image-url)
3.2.3 Dissolved Oxygen (DO)

The DO profile is based on a pattern in the lacustrine zone. Most of oxygen enters the water from the atmosphere, mainly from the mixing action of winds and waves [8]. Figure 4 shows the highest DO of Pergau Reservoir was observed at P3 station. The range of water surface DO value recorded at all sampling location was in range of 6.85 to 9.21 mg/L (7.72 ± 1.29). Dissolved oxygen is an important element involved in chemical and biological reactions in the aquatic environment [11]. The availability of dissolved oxygen in water is essential for life in a lake. Aquatic plants and algae also produce oxygen as a by-product of photosynthesis. The DO value was ideal when compared to the NWQS and classified as Class I.

Figure 4 shows that at P1, DO was constant (~7.00 mg/L) up to 9 m depth. Above the 9 m depth, the anoxic layer occurred where the DO dropped drastically to 0.03 mg/L. Whereas anoxic layer been detected at depth of 3 m at P2 and P3. Anoxic layer for the Temengor Reservoir was recorded in range of 8 to 25 m depth [5] whereas, at the Kenyir was about 8 to 15 m depth [10]. The data recorded were showed a DO profile of Pergau Reservoir and clinograde oxygen curve created as the result of an excess of oxygen consuming processes in the lake. The epilimnion layer remains in contact with the atmosphere, while in contrast, the hypolimnion; without contact with the atmosphere. The DO stratification may gradually lose oxygen in greater depth due to redox processes, including the aerobic oxidation of organic matter. Compared to the Temengor Reservoir limnology study [5], the epilimnion and hypolimnion layer of the lake was recorded at the surface to 6 m depth and 25 to 30 m depth respectively. Meanwhile, the Pedu Reservoir recorded the highest DO value at 5.28 mg/L and lowest at 2.51 mg/L. As for Muda reservoir, the highest and lowest DO was at 3.88 mg/L and 1.60 mg/L respectively. The DO stratification was also observed to be almost anoxic at 10 m depth in the Muda reservoir [3]. In Kenyir Reservoir, the epilimnetic layer is determined thinner in hot dry months (2 to 7m) compared to the wet season (14 to 15m) [10]. Despite limited aerobic conditions with the availability of oxygen between 10 to 15 m layers above the metalimnion, Kenyir reservoir is known to have highly diverse commercial fish stock value. Kenyir reservoir is popular with sport-fishing and intensive cage aquaculture activities. Such activities provide a nutrient rich environment that encourage localised eutrophication within the lake. Infection of fish species were also reported [14] in Kenyir reservoir. However, the DO in the Bakun reservoir, had been shown to drop sharply from about 4 m depth and by 6 m depth, it was anoxic. Researchers recently observed similar hypoxic conditions below the Bakun Dam in Malaysia with less than 5 mg/L recorded for more than 150 km downstream [20].

Figure 4. Dissolved oxygen (DO) profile in Pergau Reservoir
4. Conclusion
This study shows that the temperature for all stations in the reservoir were high at the subsurface (0.2 m) with values of above 27 °C and dropped to 3.3 °C as the depth increased to 10 m. In addition, the thermocline occurred within the range of 2 to 8 m depth and the DO was in Class I for the top layer (2 to 9 m). For BOD, all stations was in Class I with the range between 1.3 to 1.4 mg/L. Overall the water quality of Pergau Reservoir indicates an excellent condition and is suitable for sensitive aquatic organism. Since this study were conducted during the scientific expedition, we would like to recommend further study of water quality monitoring for seasonal changes in Pergau Reservoir.

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