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A physico-chemical analysis of water quality parameter of Tasik Dayang Bunting

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INTRODUCTION

Water quality is a general term that refers to a general description about the properties of a water body. Lakes that have a high water quality possess properties that make it a high valued resource to society and nature (Davis 2016). Water quality is also an important concern for both human use of lakes and other freshwaters as well as the ecological value of water bodies. Water quality is used in determining the state of aquatic environments and is an interesting point of study in determining both human impacts and natural processes in the environment.

A healthy aquatic ecosystem is depended on the physico-chemical and biological characteristics (Venkatesharaju *et al*. 2010). The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. Good quality of water resources depends on a large number of physico-chemical parameters and biological characteristics.

Lakes water quality is important for recreational purposes. Therefore, it is imperative that a good water quality is maintain for the economy of Langkawi. Thus, the lake water quality should be monitor from time to time. This chapter described our assessment of the water quality of a 'small' freshwater lake – Tasik Dayang Bunting or Lake of Pregnant Maiden, located on the Dayang Bunting Island, the second largest uninhabited island in Langkawi.

MATERIALS AND METHODS

Characteristic of study area

Tasik Dayang Bunting (TDB) or Lake of the Pregnant Maiden is the largest natural fresh water lake in the Langkawi Islands and is thought to be of doline origin (Leman *et al*. 2007). TDB is probably a unique freshwater lake in the world in that its water

is supplied mainly through rainfall water from numerous surface and ground water. The lake is situated on the Dayang Bunting island, the second largest uninhabited island in Langkawi. The Tasik Dayang Bunting Recreational Forest is located in the Dayang Bunting Island's Forest Reserve, which has forest type's coastal hills and the geology of the area is a karstic landscape developed in the marble of Chuping Formation and limestone of the Setul Formation (Leman *et al.* 2007). The detail of the lake and its configuration are shown in Table 2.1.

Table 2.1: Description of Tasik Dayang Bunting

No	Description	Details
1	Lake Surface area	0.28 km^2
2	Max Level	16 m
3	Normal Level	14 m
4	Min Level	11.31
5	Total Storage	3,128,250 m^3
6	Lake Perimeter	2.1 km

From the history perspective, actually the TDB formed from the doline which is a shallow depression formed when the limestone bedrock had been dissolved on its top and bottom surfaces by movement of water. The lake was formed when the cave chamber collapsed due to its inability to carry the load of the bedrock. This process left a doline, or hole which was eventually filled formed a lake.

The climate in this area is influenced by the northeast and southwest monsoons and mean annual rainfall from 1973-2013 (Fig. 2.1) is approximately 1853 mm/year.

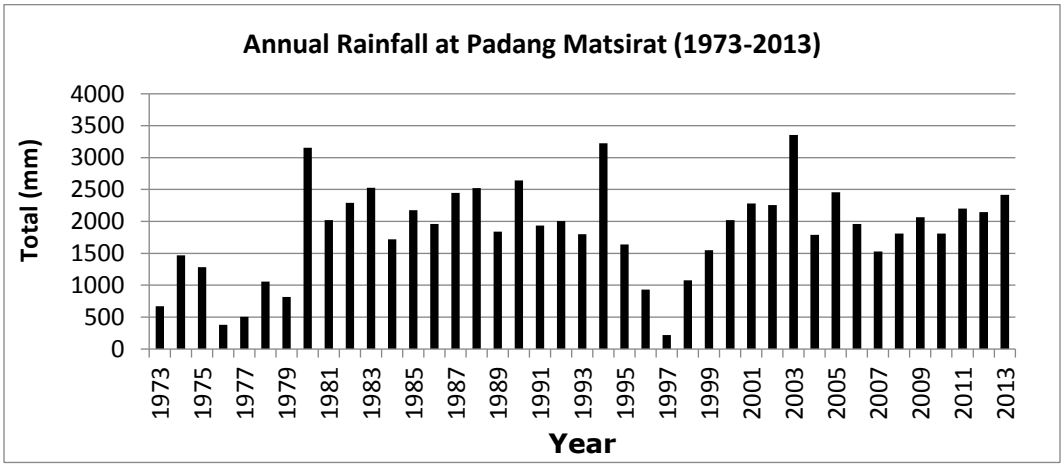

Figure 2.1: Annual rainfall data recorded in Padang Matsirat Station from 1973-2013.

Data Collection

The physico-chemical parameters involved in the evaluation of environmental water quality of Tasik Dayang Bunting consist of several basic water quality parameters such as temperature, turbidity, total suspended solid (TSS), conductivity, pH, dissolve oxygen (DO), total dissolved solid (TDS), salinity, nitrate (NO_3), nitrite (NO_2), ammonium (NH_4) and phosphate (PO_4). Measurements were conducted at three stations as shown in Figure 2.2.

Data collection involving in situ parameter measurements of water temperature, dissolved oxygen, pH, conductivity and turbidity at specific depth intervals was performed using multi-parameter probe in order to obtain vertical profile at each sampling station. Additionally, station 2 was selected for diurnal measurement of temperature and DO concentrations. Sampling were performed in April 2015 whilst diurnal measurement was undertaken in October 2015.

Secchi depths were recorded at all sampling stations using secchi disk. Water was collected based on surface, middle and bottom water in the lake using van Dorn sampler in duplicates, labelled and transferred to the laboratories in the ice-cooled container for further analysis. Water samples were collected at all locations near the surface of the water column for nutrient analysis and TSS determination.

The membrane filter was placed in a petri dish for drying in an oven at 103ºC to 105ºC and was left overnight. The membrane filter was cooled at room temperature before being weighed for it final weight. Drying, cooling, and weighing processes were repeated until a constant weight was obtained. TSS in the sample was analysed based on standard method (APHA 1992).

Filtered water samples were collected and were used later in the nutrient analysis (chemical parameter). Upon arrival at laboratory, water samples are analyzed for parameters such as nitrite nitrate, ammonia, phosphate, Sulfate, chlorophyll, oil and grease and selected heavy metal.

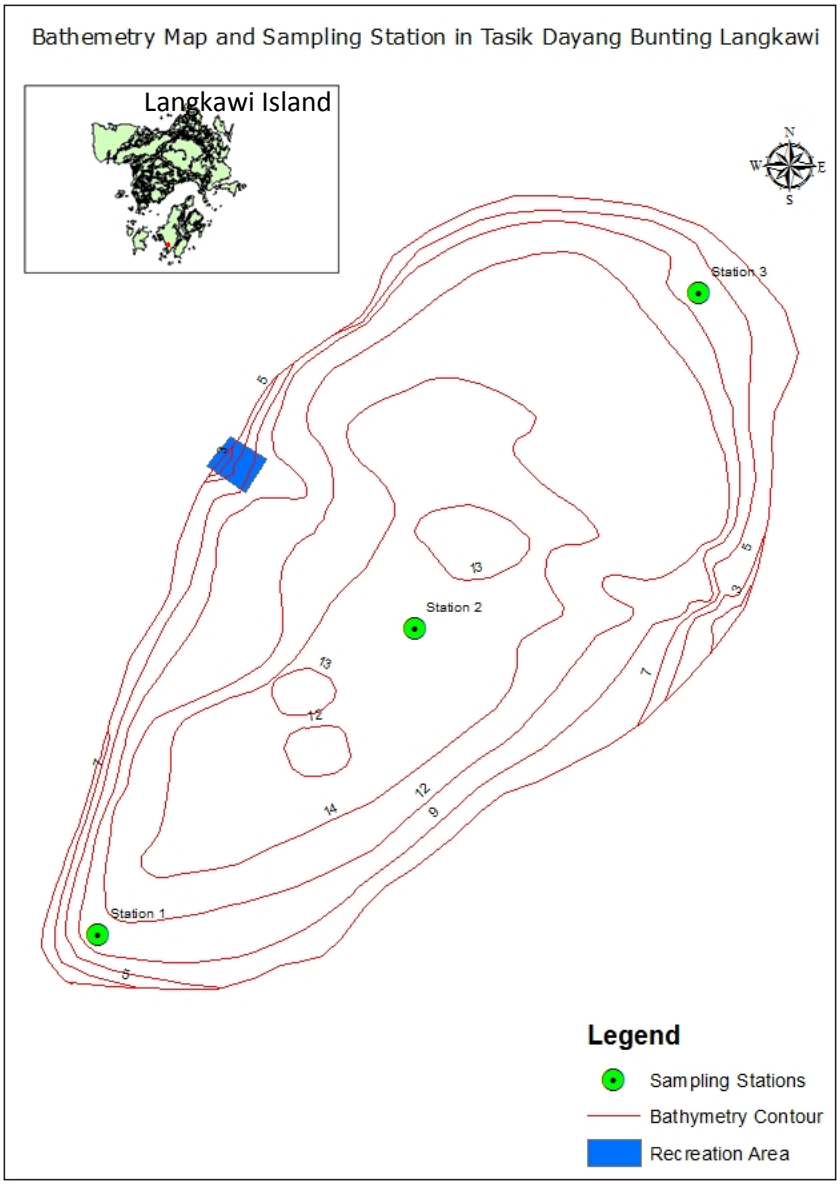

Figure 2.2: Depth profile and sampling station in TDB, Langkawi Island, Kedah.

For NH_4 analysis, a volume of 25 ml of each sample were poured into a container. Then 1 ml of phenol (C_6H_5OH) was added into the sample followed by 1 ml of sodium nitroprusside ($Na_2[Fe(CN)5NO]2H_2O$). After that, 2.5 ml of sodium hypochlorite (NaOCl) was added into the sample and left the sample for at least 45 minutes. The sample should be analysed by using UV-VIS spectrophotometer at 640 nm wavelength.

For NO_3 analysis, 50 ml of each sample were poured into a container. Then 1 ml of EDTA was added into each sample and each sample was inserted through the column. After that, 25 ml of the sample was collected from the column mouth and the sample was injected with 0.5 ml I-Nephtyl and 0.5 ml sulfanilmida. Sample was analysed by using UV-VIS spectrophotometer at 640 nm of wavelength.

For NO_2 analysis, a volume of 25 ml from each sample was poured into a container. Then 0.5 ml of sulfanilamide ($C_6H_8N_2O_2S$) and 0.5 ml of I-Nephtyl were added into each sample. After that, the samples were left at least for a half an hour to react completely. The sample should be analyzed by using UV-VIS spectrophotometer at 640 nm of wavelength.

For phosphate analysis, 10 ml of sulphuric acids (H_2SO_4), 1 ml of potassium antimonyl titrate ($C_4H_4O_7SbK$), 3 ml ammonium molybdate ($(NH_4)6Mo_7O_{24}4H_2O$), and 6 ml ascorbic acids ($C_6H_8O_6$) were added into each sample of water. Samples were analyzed by using UV-VIS spectrophotometer at 880 nm wavelength.

RESULT AND DISCUSSIONS

Understanding a lake physical, chemical and biology properties is essential to determining the lake's conditions and in making informed lake management decisions. The term water quality refers to the condition or state of a given parcel of water (Tebbutt 1977). These included seven physical parameters, fives chemical parameter, water clarity and biological measurement such as chlorophyll were determined in TDB. Measurement of these parameters in the TDB monitoring for determination of the lake's overall ecology and health. Table 2.2 summaries the mean value of the various physical parameters and six chemical parameters monitored at three selected stations in the lake during April 2015.

Table 2.2: Physical and chemical parameters of typical samples (April 2015)

Parameters[a]	Sampling site		
	Station A	Station B	Station C
Temperature (°C)	30.10	29.75	31.32
Conductivity (µg/cm)	1.68	1.83	1.64
Salinity	0.77	0.86	0.73
pH	7.58	7.61	8.04
DO (mg/L)	4.96	4.34	8.34
TDS (mg/L)	1.00	1.09	0.96
TSS (mg/L)	1.7	1.5	1.2
NO_2 (mg/L)	0.73	0.91	0.27
NO_3 (mg/L)	0.49	0.64	0.86
NH_4 (mg/L)	0.17	0.12	0.15
PO_4 (mg/L)	0.91	0.83	0.18
TP (µg/L)	1.83	1.47	1.94
TN (mg/L)	2.37	3.61	2.05

[a] mean of average from surface to bottom

Temperature

The measured temperature of water reflected the changes corresponding to the altitude of the sites and the sampling seasons. Temperature profile of water at the TDB was more stratified based on surface data. TDB is small and less exposed to physical and wind disturbances to make it more stratified for temperature data. In TDB, the highest temperature recorded at the surface of station C (31.4 °C) and the minimum temperature of 28.1 °C were recorded at Station B at a depth of 11 meter. Temporally, there existed a declining trend in temperature from the surface level to the bottom. The temperature started to decline at 7-meter level from surface (Fig. 2.3). Diurnal measurement of temperature at 1-meter depth indicated slight diurnal variation of ~1°C (Fig 2.4).

Temperature and oxygen are two of the principal water quality factors of lake hydro ecosystems. The change in lake water temperature and the temperature stratification dynamic can have an effect on lake biological and chemical processes. Dissolved oxygen (DO), nutrient cycling, biological productivity and fisheries are some water quality parameters severely controlled by temperature changes.

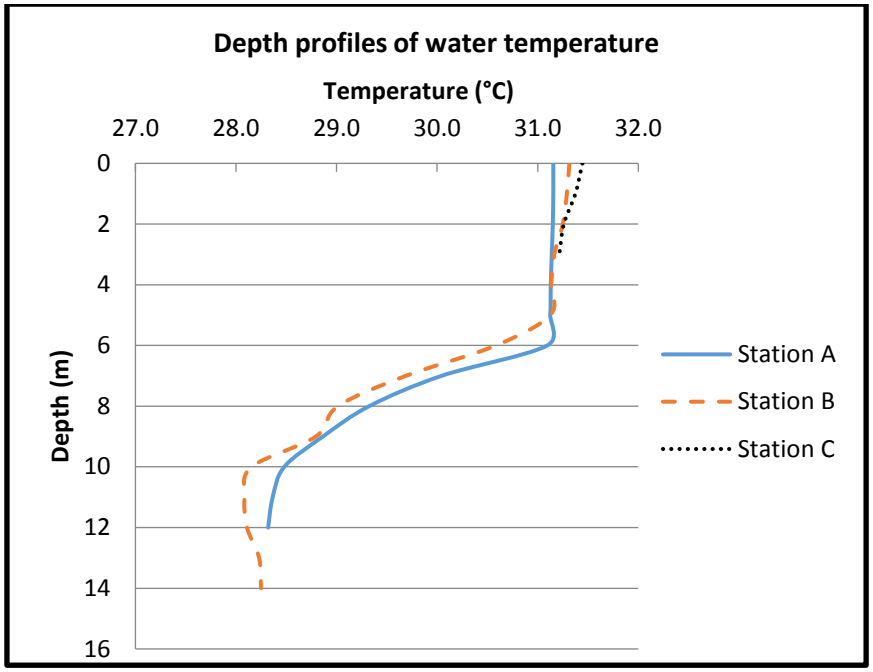

Figure 2.3: The depth profiles of water temperature recorded at three sampling locations.

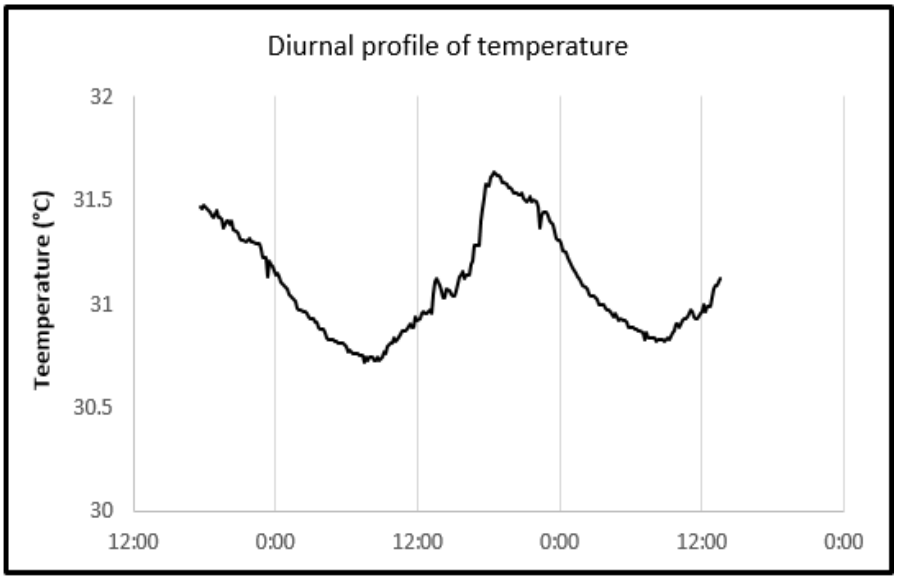

Figure 2.4: The diurnal profiles of water temperature recorded at one sampling location.

Dissolved Oxygen

The dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. The oxygen gets into the water by diffusion from the surrounding air, by aeration (rapid movement), and waste product of photosynthesis. When performing the dissolved oxygen test, only grab samples should be used, and the analysis should be performed immediately. Therefore, this is a field test that should be performed on site.

Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes required adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/L, aquatic life is put under stress. The oxygen levels that remain below 1-2 mg/L for a few hours can kill the fish. Fish and other aquatic animals depend on dissolved oxygen (the oxygen present in water) to live. In addition, dissolved oxygen is not using only for determining water quality solely, the value of DO in water bodies will act as indicator for what kind of fish will survive and to what extent the aquatic life may live in the water bodies. For example, certain fish need at least 0.008 kg/m^3 of DO to survive and below 0.004 kg/m^3, this type of fish will face mortality (Hamzah 2007). Figure 2.5 and 2.6 showed the data recorded in TDB based on DO concentration.

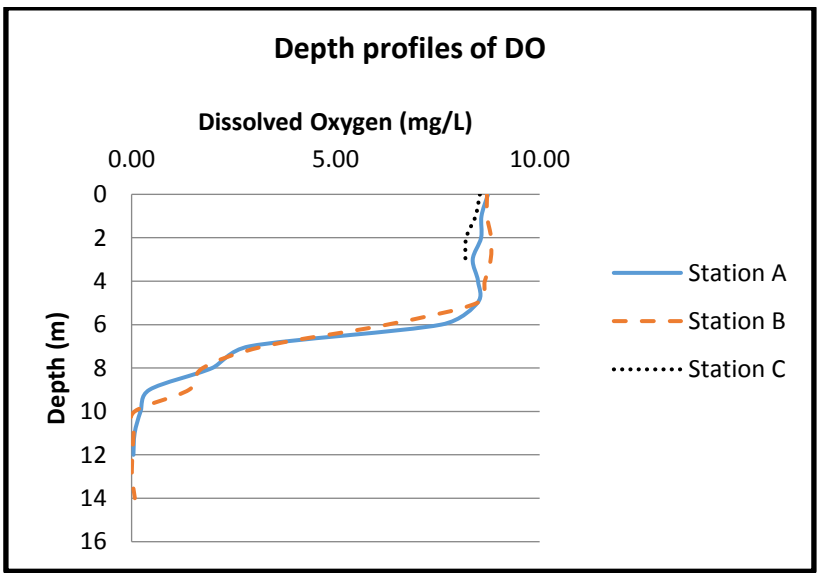

Figure 2.5: The depth profiles of dissolved oxygen recorded at three sampling locations in TDB.

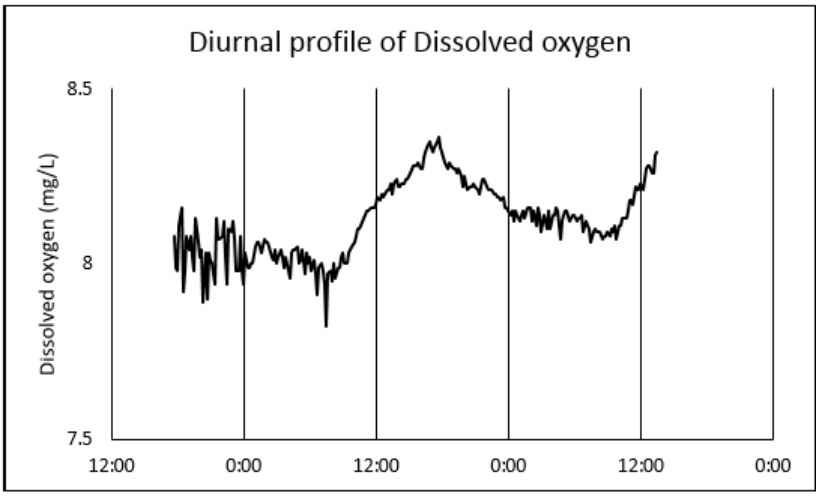

Figure 2.6: The diurnal profiles of dissolved oxygen recorded at one sampling location in TDB.

pH

Figure 2.7 illustrated the pH profile recorded in TDB in April 2015. The data showed a similar trend with temperature and dissolved oxygen showing a drastic change in values reflect reduction in DO starting from 6 to 7 meter depth. The normal data for pH is 7 for neutral. Water with a pH of 7 has equal amounts of natural separation of a tiny fraction of water molecules. In addition, the pH data in TDB is lower than 8.15 and higher than 7 for natural and the data is good for fish environment like a seepage lake.

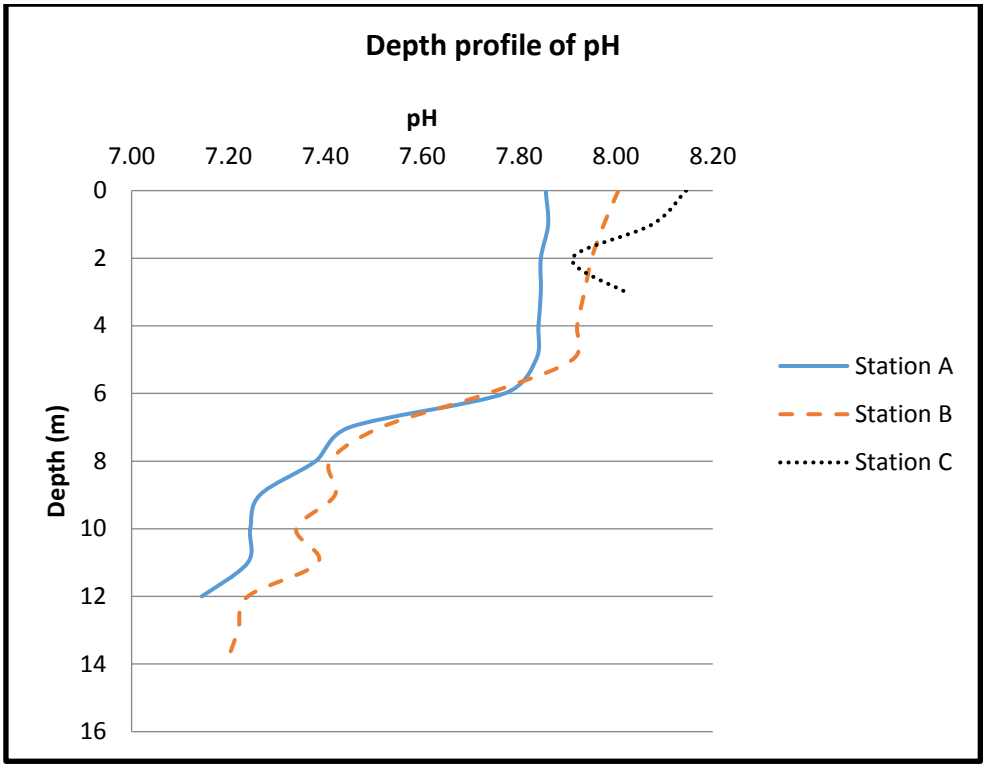

Figure 2.7: Depth profiles of pH at three sampling locations in TDB

Conductivity, salinity and total dissolved solids

Conductivity qualitatively reflects the status of inorganic pollution and is a measure of total dissolved solids and ionized species in the water. The lowest conductivity was recorded at station C at 2 meter depth with a value of 1.60 mS/cm, while the highest data was recorded at Station B at a depth of 14 meter with a value of 2.74 mS/cm (Figure 2.8).

The salinity found in this study ranged between 0.73-0.76 ppt. This salinity implied that there is a possible salt water intrusion into the lake (FRI 1993). The salinity in this study, however, is much lower compared to the findings in 1992 where mean salinity was around 2 ppt.

High levels of dissolved and suspended solids in water system increase the biological and chemical oxygen demand, which deplete the dissolved oxygen levels in aquatic system. The concentration of total dissolved solids at TDB range from 0.96 mg/L to 1.67 mg/L from three station and surface to bottom.

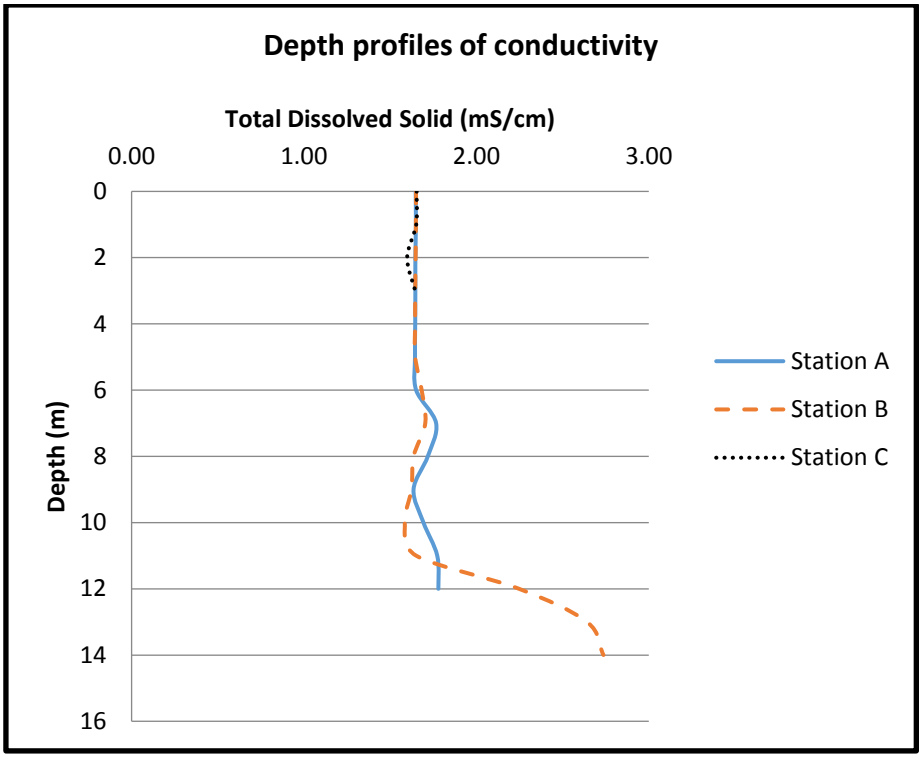

Figure 2.8: The depth profiles of conductivity at three sampling locations in TDB

Total suspended solids and nutrient

Based on three stations at TDB, the highest total suspended solids data recorded at station A Middle (AM) with value 2.2 mg/L, while the lowest data recorded at station A Bottom (AB), station C surface and Bottom with value 1.2 mg/L.

Phosphorus and nitrogen are important parameter to assess the water quality. Photosynthesis and respiration play an important role in the self-purification of natural lake. This disturbance of the stationary state between photosynthesis and respiration lead to chemical and biological changes reflecting pollution. High level of this nutrient (Phosphorus and total phosphorus) increase the growth of vegetation in the water systems, increase the oxygen demand and biological (chlorophyll). The nutrient also showed in Table 2.3 for nitrogen (nitrite, nitrate and ammonium) and phosphorus. Total phosphorus and soluble reactive phosphorus concentration in the TDB waters were low. The lowest concentration of phosphorus was observed at station B surface (BS) with value 0.49 mg/L while the highest level recorded at station B bottom (BB) with value 1.40 mg/L. Based on total phosphorus,

the highest data recoded at station A middle (AM) with value 2.0 mg/L while the lowest data recorded at station B middle (BM) with value 1.36 mg/L. TP is considered a better indicator of a lake's nutrient status because its levels remain more stable than soluble reactive phosphorus. Total phosphorus includes soluble phosphorus and the phosphorus in plant and animal fragments suspended in the lake.

Nitrogen is second only to phosphorus as an important nutrient for plant and algae growth. Nitrogen compounds often exceed 0.5 mg/L in rainfall, so that precipitation may be the main nitrogen source for Seepage Lake like TDB. In most cases, as we know the amount of nitrogen in lake water corresponds to local land use. Nitrogen may come from fertilizer and animal wastes on agricultural land, human waste from sewage treatment plant or septic system and lawn fertilizer used. Nitrogen exists in lakes in several forms. Analysis usually included nitrite, nitrate and ammonium. Total nitrogen is calculated by adding nitrite and nitrate to Kjeldal nitrogen. Organic nitrogen is often referred to as biomass nitrogen. All inorganic forms of nitrogen can be used by aquatic plant and algae.

Table 2.3: Total suspended solids and nutrient in TDB on April 2015

Sampling Site's	**Parameters (mg/L)**						
	TSS	**NO_2**	**NO_3**	**NH_4**	**PO_4**	**TN**	**TP**
Station AS	1.8	0.9213	0.3514	0.1980	1.1659	1.5329	1.7422
Station AM	2.2	0.6201	0.7036	0.1081	0.5240	2.1735	2.0087
Station AB	1.2	0.6587	0.4375	0.1917	1.0404	3.4150	1.7499
Station BS	1.0	0.8510	0.6711	0.1749	0.4853	3.8671	1.3734
Station BM	1.8	0.8836	0.8325	0.1267	0.6119	4.1535	1.3590
Station BB	1.8	0.9919	0.4213	0.0706	1.4039	2.7997	1.6877
Station CS	1.2	0.4005	0.7747	0.1738	0.1866	3.0926	1.9179
Station CB	1.2	0.1450	0.9399	0.1316	0.1836	1.0123	1.9618

Trophic State

Trophic state is another indicator of water quality. Lakes can be divided into three categories based on trophic state—oligotrophic, mesotrophic, and eutrophic. These categories reflect a lake's nutrient and clarity levels. Oligotrophic lakes are generally clear, deep and free of weeds or large algae blooms. Though beautiful, they are low in nutrients and do not supports large fish populations. However, oligotrophic lakes often develop a food chain capable of sustaining a very desirable fishery of large game fish. Eutrophic lakes are high in nutrients and support a large biomass (all the plants and animals living in a lake). They are usually either weedy or subject to frequent algae blooms, or both. Eutrophic lakes often support large fish populations, but are also susceptible to oxygen depletion. Small, shallow, eutrophic lakes are

especially vulnerable to winterkill which can reduce the number and variety of fish. Rough fish are commonly found in eutrophic lakes. Mesotrophic lakes lie between the oligotrophic and eutrophic stages. People can accelerate the eutrophication process by allowing nutrients from agriculture, lawn fertilizers, streets, septic systems, and urban storm drains to enter lakes.

Various methods have been adopted for the classification of lakes and to indicate their trophic status. This study used Carlson's Trophic State Index (TSI), also known as the Carlson Index, which was developed to compare SD depth, chlorophyll-*a* concentrations and TP concentrations (Carlson 1977), and to independently estimate algal biomass. Although chlorophyll-*a* is the most direct measure of algae biomass, Carlson (1977) used SD depth as the primary indicator.

Average Secchi depth transparency during sampling was 3.03 m, and TSI (SD) was 43.1, which is indicative of a mesotrophic status, caused by sediment and nutrient inputs to the reservoir (Table 2.4). This reading is about half of the measurement recorded in 1992 where mean secchi depth were 6.1 m (FRI 1993). Mesotrophic water, according to the Naumann (1932), classified mesotrophic water as water with moderate nutrient concentrations, and therefore more biological productivity, and the water may be lightly clouded by organic matter, sediment, suspended solids or algae. However, the trophic state of Pergau Lake also mesotrophic if it is based on TP (41.2) but trophic index based on chlorophyll-*a* (54.0). Naumann (1932) classification is extremely rich in nutrient concentrations, with high biological productivity. Water is also clouded by organic matter, sediment, suspended solids and algae, and some species may be eliminated.

Table 2.4: Trophic status based on indicator for three sites in the TDB

Stations	TSI (SD)	TSI (TP)	TSI (Chlorophyll-a)
Station A	44.3	19.4	50.7
Station B	43.1	10.4	53.9
Station C	43.7	9.1	52.0
Average	43.7	13.0	52.2
TSI	Mesotrophic	Oligotrophic-Mesotrophic	Eutrophic

Carlson's trophic state index (CTSI) = [TSI (TP) + TSI (CA) + TSI (SD)]/3

$$(CTSI) = 43.7 + 13.0 + 52.2/3$$
$$= 36.3 \text{ (Oligotrophic)}$$

According to Carlson (1977), a range of 40-50 is usually associated with the mesotrophic (moderate productivity); index values greater than 50 are associated

with eutrophic (highly productivity); values less than 40 are associated with oligotrophic (low productivity). Based on the mean CSTI obtained, the trophic state index is in the range of oligotrophic and this is consistent with earlier results (FRI 1993).

CONCLUSION

The water quality of TDB is still in a very good condition where the trophic index is classified as an oligotrophic lake. This conclusion is however restricted to a very limited data set. Future development for recreational uses of TDB should take into account the carrying capacity of the lake so as not to increase more stress on the lake environment.

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