Case study: Vertical distributions of both temperature and dissolved oxygen in Lake Diatas - Indonesia

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Abstract. Lake Diatas is one of the largest lakes in West Sumatra with a variety of uses that are vulnerable to contamination that could endanger lake organisms. Therefore, the objective of the present study is to describe the vertical distributions of both temperature and dissolved oxygen (DO) in Lake Diatas as an indication of lake quality. The samples of lake water were taken at five points, namely in the middle of the lake, Teluk Kinari, Muara Danau, Gurun Datar and in Tanduk Kecil. Frequency of taking was once a month in October, November and December 2019. Variation in depth for temperature and DO observations was based on the methods of surface-water sampling (SNI 6989.57: 2008). The present study results show that the temperature range at various points with respect to lake depth variation was 20.1 to 25.9 °C with a standard deviation of 1.15 °C, while DO was in the range of 6.2 to 7.9 mg/l. These conditions still met the quality standards of lake water (Governor Regulation No. 24 Year 2010 Class II) where the temperature deviation must be less than 3 °C, and the minimum DO is 4 mg/l. By using statistical method of the two-way ANOVA, it is found that the temperature was significantly different from the time of sampling with a P-value <0.05, but the temperature did not differ significantly based on depth. The sampling time and depth of collection differed significantly for DO at 2 points close to the agricultural land. It can be concluded that the temperature and DO in Lake Diatas were still good because the oxygen content was still sufficient to ensure the survival of lake organisms. In addition, there was no indication of thermal stratification in the lake.

1. Introduction
Temperature is one of the factors that plays a role in controlling aquatic ecosystems related to dissolved oxygen (DO) levels. DO is an important factor in aquatic ecosystems, especially in the process of respiration for most aquatic organisms. Oxygen solubility decreases with increasing temperature. This means that warmer surface waters require less DO to achieve 100% air saturation than deeper and cooler water [1]. In water, oxygen plays a role in breaking down chemical components into simpler components. The main source of oxygen in a waters comes from the process of free air diffusion and photosynthesis of organisms that live in waters so that DO levels are relatively higher in the upper layers of lake waters [2]. Governor Regulation No. 24 of 2010 Class II concerning lake-water quality-standards [3] requires that the temperature deviation in lake waters is <3 °C, and the minimum DO is 4 mg/dl.
The temperature in lake waters is influenced by radiation and the position of the sun, geographical location, season, cloud conditions, wind gusts, evaporation, weather, water depth and human activity around the waters. Water temperature has an important role because it affects the metabolic activity of aquatic organisms. It can be seen that temperature changes greatly affect the physical, chemical and biological processes in aquatic ecosystems [4]. Some of the thermal properties of the waters such as heat capacity and heat of evaporation cause a decrease in temperature changes in the waters, so that variations in water temperature are smaller when compared to variations in air temperature. The decrease in temperature due to the increasing depth of lake waters will form a layer that affects the chemical and physical processes that occur in the lake [5]. This is known as thermal stratification. Vertically stratified lakes are grouped into three. The first stratification is called epilimnion, which is the upper layer of lake waters. The second stratification is metalimnion which is often called thermocline, which is located under the epilimnion. Every additional 1 m depth in this layer an increase in temperature around 1 °C. The third stratification is called hypolimnion, which is under metalimnion. The difference in depth in this layer only results in a relatively small temperature difference. The lakes in the tropics have a high temperature range, which is between 20 and 30 °C and show a slight decrease in temperature as the depth increases [2]. Even so, stratification is still possible.

Lake Diatas is one of the largest lakes in West Sumatra. Administratively, it is located in two sub-districts namely Lembah Gumanti Sub-district and Danau Kembar Sub-district. Astronomically, it is located at 01° 4' 26.85" South Latitude and 100° 45' 17.37" East Longitude with an altitude of 1,531 meters above sea level. Lake Diatas is a tectonic lake formed by a decrease in soil level due to shifts or faults. A research conducted by De Maisonneuve shows that most of the water in the Lake Diatas comes from high rainfall, and a small part comes from several small tributaries that enter the lake. The lake has a minor outlet through Batang Gumanti river in the east. The area of the lake is about 12.3 km², the depth at the flat bottom is 35 m, and the maximum depth is 55 m. The retention time of the lake is estimated at 20 years under steady state conditions [6]. Near the lake, there is an agricultural land with a sloping topography to the lake, thus allowing the flow of water from agricultural activities containing fertilizers and pesticides into the lake. Near the lake there is also a residential area. The lake is also used as a tourist area and a small portion for fish cages. The lake waters is deep enough with various uses has the potential to reduce the quality of the waters. For this reason, it is necessary to examine the vertical distribution of both temperature and dissolved oxygen in Lake Diatas. Both of these distributions are important things that need to be considered in lake management. The purpose of this study is to describe the vertical distributions of both temperature and DO over variations in water depth in Lake Diatas as an indication of lake quality.

2. Methodology

Location of the present study was conducted in Lake Diatas, Solok District, West Sumatra in October, November and December 2019. The sampling points were determined based on the results of the field survey by taking into account the activities around the lake in the form of settlements and agriculture, the flow of water entering and exiting the lake, as well as the deepest point of the lake. Determination of the depth of sampling is based on SNI 6989.57: 2008 concerning methods for sampling surface-water [7]. Based on the SNI, points that have a depth of less than 10 m, samples can be taken at 2 elevations, namely on the surface and at the bottom. Whereas for a point whose depth is 10 to 30 m, samples are taken at 3 elevations namely surface, middle and bottom. Description of the sampling points for the present study can be seen in Figure 1 and Table 1.

In the present study, the trip to the sampling point was by boat. Then, the samples were taken using a vertical water sampler. The samples taken were immediately put into a ± 1 L container. A DO meter with the brand EUTECH 1403157 equipped with a temperature detector was used to measure DO and temperature of the samples.

Both temperature and DO are then compared with Governor Regulation No 24 Year 2010 Class II concerning the standards of lake-water quality. Temperature and DO correlations are determined by
bivariate tests using Pearson product-moment correlation. While the multivariate test uses a two-way ANOVA test to see differences in the mean temperature and DO for each depth and time of sampling.

Figure 1. Sampling points at Lake Diatas as a study area [9]
3. Results and discussion

These five sampling points were considered to represent and describe the characteristics of Lake Diatas as a whole. The parameters measured to describe the environmental conditions of Lake Diatas were temperature and dissolved oxygen. Figure 2 shows the vertical range of temperature distribution in the lake waters ranging between 20.1 and 25.9 °C. From the calculation results, the standard deviation of Lake Diatas temperature was 1.15 °C. This temperature meets the deviation regulation, which is < 3 °C. The vertical distribution of the temperature shows that there was no indication of thermal stratification in Lake Diatas during the measurement. Thermal stratification did not occur meaning the waters of Lake Diatas tend to be mixed [5]. This was consistent with the results of Lewis's study [8] who reported that in tropical lakes, thermal stratification of lakes is estimated to be rare. This is closely related to the vertical mixing that often occurs in tropical lakes. However, stratification may occur at certain time intervals.

Overall, the vertical distribution of DO concentrations in the lake ranged between 6.2 and 7.9 mg/l. At first glance, there will be a slight decrease in DO content as water gets deeper at all sampling points. However DO still meets the requirements because it was above the minimum requirement which is equal to 4 mg/l. The DO content obtained in this study was higher than that obtained in the study of Samuel et al in 2016 [10]. Samuel et al obtained DO content in Lake Diatas ranging between 5.9 and 6.34 mg/l. However, Samuel et al did not display DO distribution vertically but only horizontally for several points. The high DO value indicated that Lake Diatas could be said to still have good water quality to support the life of aquatic organisms in the lake.

Although based on statistics, DO also did not show a significant difference, but in Figure 3, it can be seen that a decrease in DO with increasing depth at all sampling points except samples taken in October at Teluk Kinari. From Table 2 it can be seen that the sampling depth and time differed significantly only at two points, namely Gurun Datar and Tanduk Kecil Points, which were the points affected by agricultural activities. From Figure 4 can be seen that around this area had been overgrown by water hyacinth which generally grows in waters with high levels of Nitrate and Phosphate, which causes DO at the bottom of the waters lower than the surface [12]. The presence of Nitrate and

Table 1. Description of the sampling points

| No | Sampling Points     | Longitude  | Sampling Depth (meters) | Description                                                                 |
|----|--------------------|------------|-------------------------|-----------------------------------------------------------------------------|
| 1  | Middle of the lake | 100° 45' 52.95" E 1° 4' 51.68" S | 0                        | The middle of the lake is the deepest point of the lake. This sampling point has a depth of 47 meters measured from the surface of the lake. |
| 2  | Teluk Kinari       | 100° 44' 55.94" E 1° 4' 56.59" S | 0                        | Teluk Kinari is near an irrigation channel. This point has a depth of 18 meters |
| 3  | Muara Danau       | 100° 46' 17" E 1° 4' 44" S | 0                        | Muara Danau is located near the Batang Gumanti upstream. This sample point is also near Villa Danau Diatas and the Umum Mosque which is frequently visited by many tourists. This point has a depth of 10.5 meters. |
| 4  | Gurun Datar        | 100° 43' 48.300" E 1° 3' 55.962" S | 0                        | Gurun datur is close to agriculture and housing activities. This point has a depth of 13 meters |
| 5  | Tanduk Kecil       | 100° 44' 19.194" E 1° 4' 5.172" S | 0                        | Tanduk Kecil is close to the protected forest, but has now been converted into an agricultural area. This point has a depth of 13 meters. |
Phosphate is closely related to agricultural activities, because these two compounds are contained in fertilizer used by farmers. This can cause a significant difference in DO at the sampling points of Gurun Datar dan Tanduk Kecil. While significant differences in DO based on the time of sampling, might be caused by different pollution loads at the time the sample is taken.

The relationship between temperature and DO can be seen in Figures 5 and 6. In this study, the result of the coefficient of Pearson product-moment correlation between temperature and DO is R = -0.14024, and the R² value of the linear regression is 0.0197. These results indicate the correlation between temperature and DO in the lake was very weak. Besides temperature, DO in lake waters is also influenced by pressure, salinity, and the activity of aquatic organisms [2].

The two-way ANOVA method is used to see significant differences in temperature and DO values obtained based on the depth and time of sampling. This test was also carried out by other studies, such as the Araujo study [11], which examined the influence of seasons and spatial variations in water quality in tropical lakes. In Table 2, it is found that the vertical temperature distribution did not show a significant difference, but the sampling time showed a significant difference. The temperature of tropical lake waters can be influenced by radiation and the position of the sun, geographical location,
season, cloud conditions, wind gusts, evaporation, weather, water depth and human activities around the waters [4].

Figure 3. Vertical distribution of DO in the lake.

Table 2. The significance of the difference in sampling time on both temperature and DO in the lake

| No | Sampling Points      | P-value of Temperature against | P-value of DO against |
|----|----------------------|--------------------------------|-----------------------|
|    |                      | Depth Sampling Time            | Depth Sampling Time   |
| 1  | Middle of the lake   | 0.357 0.026 *                  | 0.125 0.809           |
| 2  | Teluk Kinari         | 0.574 0.004 *                  | 0.506 0.032           |
| 3  | Muara Danau          | 0.319 0.047 *                  | 0.217 0.784           |
| 4  | Gurun Datar          | 0.552 0.027 *                  | 0.011 0.020 *         |
| 5  | Tanduk Kecil         | 0.744 0.049 *                  | 0.015 0.043 *         |

Note: * Significantly different of $P$-value<0.05
Figure 4. Water hyacinth that grows in Lake Diatas in Gurun Datar (left) and in Tanduk Kecil (right)

Figure 5. Relationship between temperature and DO in October, November and December

4. Conclusions
From the study results, it can be concluded that the vertical distribution of the temperature (towards depth) in Lake Diatas was not significantly different so it did not indicate the occurrence of thermal stratification, but rather indicated that lake waters mixing at least during sampling. Temperature and dissolved oxygen (DO) at each depth at each sampling point met the Regulation of the Governor No. 24 of 2010 Class II concerning the quality standards of lake waters. The variation in sampling depth and sampling time differed significantly with DO at the 2 sampling points near the agricultural area.
5. Recommendations

For further research, it is advisable to look at the vertical distribution of both temperature and DO in the lake with smaller ranges in order to ascertain thermal stratification. In addition, it is better to study the relationship of temperature and DO in Lake Diatas for a longer period of time, so that the results obtained can be more accurate.

![Figure 6. Relationship between temperature and DO for all samples](image-url)

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