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Distribution of organic contamination based on depth stratification in Maninjau Lake, Indonesia

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Abstract. The purpose of this study was to analyze the organic content of Lake Maninjau based on depth stratification and its organics carrying capacity. Sampling was carried out at the location of lake utilization, namely in the lake center, settlement, hydropower, endemic fisheries, and fish cage following Indonesian National Standard SNI 6989.57: 2008. The parameters measured were BOD₅, COD and environmental condition such as pH, DO and temperatures. Lake Maninjau generally is polluted, especially for organic pollutants characterized by the BOD₅ and COD values that did not meet the quality standard of Government regulations the Republic of Indonesia Number 82 the year 2001 class 2 according to its designation namely 21.87-47 mg BOD/L and 35.2-74 mg COD/L. Using one-way analysis of variance (ANOVA) at 0.05% level of significance both BOD₅ and COD has a strong correlation with depth of the lake, at hydropower and endemic fisheries. At the shallow lake depths, water is easy to mix so that the organic matter distributed vertically. Fish cage has the highest contribution to the contamination of organic matter in the lake.

1. Introduction

Lake Maninjau located in Agam district, West Sumatra, is one of the fifteen priority lakes in Indonesia that need to be saved regarding lake damage and utilization [1]. The decrease in water quality occurred since Lake Maninjau was used for developing aquaculture with the floating cage system in 1992 [2]. Based on the report of Agam District Government about the control and handling of sediment Lake Maninjau [3], there was a 392% increase of the fish cage for 15 years from 2001-2016 which reached 17,226 units. Lake Maninjau water quality in 2007 [4] still fulfilled class 1 water quality based on Government regulations of the Republic of Indonesia Number 82 the year 2001 for the parameters of TSS, COD, BOD₅, nitrite, and phosphate. The Decrease in water quality of Maninjau Lake occurred in the year 2013 [5] that the quality of Maninjau Lake did not meet the class 3 water quality standard classification for BOD₅ and COD parameters.

Organic matter has a crucial role in lake ecosystems. It derives from two sources that are autochthonous primary production within the system or from allochthonous organic carbon entering the system from the catchment [6]. It could be in dissolved or particulate forms and may be colored or colorless [7]. The entering of organics matter directly enhance the activity of the heterotrophic communities and indirectly reduces the autotrophic activity due to the decrease of sunlight [8]. Increased human activity and fish cage surrounding the lake can influence the aquatic ecosystems directly through organic matter and nutrients inputs. Furthermore, high concentrations of oxidizable



organic matter in anthropogenic effluents are a significant threat to the oxygen regime of surface waters [7]. Maninjau Lake has a reasonable depth (105 m average depth) located in a tropical climate and rich in sunlight. The extent of the lake is expected to affect the distribution of organic material flowing into the lake vertically or horizontally. This study aims to evaluate the level of the organic matter regarding BOD₅ and COD in various depth stratifications based on pollutant sources around the lake.

2. Materials and Method

2.1. Sampling Location

The study was conducted in February-May of 2018, three times sampling every two weeks. Sampling location was determined based on Indonesian National Standard (SNI) 6989.57: 2008 about surface water sampling method [9] which can be seen in figure 1.

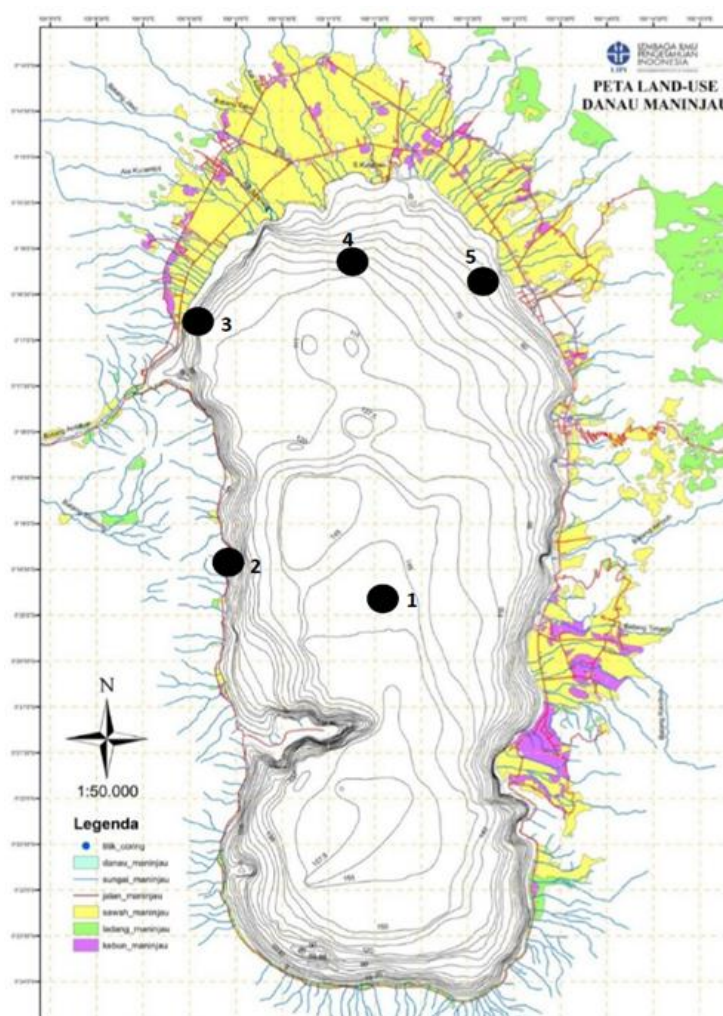


Figure 1. Map of Sampling Location. 1. Center of the lake (lat 00° 22'17" S, long 100° 11'22,3" E); 2. Settlement (lat 00° 18'59,9" S, long 100° 09'53,3" E); 3. Hydropower (lat 00°17'24,1" S, long 100°08'58,8" E); 4. Fish cage (lat 00°13'13,3" S, long 100°10'08,8 E); 5. Endemic Fish (lat 00°15'33,2" S, long 100°10'50,5" E).

Based on this standard 5 locations were established by considering lakes utilization and nearest the pollutant source, namely dense settlement, endemic fisheries, fish cage and

hydropower and the center of the lake. The preliminary study was carried out to determine the characteristics of Maninjau Lake and was taken in 4 locations, namely in the center of the lake, settlement, endemic fisheries, and fish cage locations, while the main sampling taken in all sites mentioned above. Parameters assessment was compared to Government regulations of the Republic of Indonesia Number 82 the year 2001.

2.2. Sampling and Parameters Analysis

Water sampling was taken by using a vertical water sampler by boat to get to the sampling location. Parameters analyzed were BOD, COD, temperature, DO, and pH. BOD and COD parameters were examined in the laboratory. The sample was put into a glass bottle with a volume of 1 L and tightly closed and placed in the cool box. Temperature, DO, and pH was measured directly using multiparameter EUTECH 1403157 after calibrated the instrument. BOD₅, COD, and TSS analysis referred to Standard Methods for The Examination of Water and Wastewater [10]. Lake water characteristics were compared to the quality standards by Government Regulation No. 82 of 2001 concerning Management of Water Quality and Water Pollution Control Class 2 for water recreation facilities, fisheries, irrigation, and stockbreeding [11]. One-way analysis of variance (ANOVA) was carried out to evaluate the significant differences among the sites for BOD₅, COD parameters to depths.

3. Results and Discussion

3.1. Water Characteristics

The characteristics of Maninjau Lake can be seen in table 1. The environmental parameters such as temperature, pH and DO still meet the standard. The temperature ranges from 28.1 to 32.8°C, indicates the tropical temperatures. This range is suitable for warm water fish culture, where a temperature range between 25 and 32°C is ideal for tropical fish culture [12]. The pH value ranged between 6.73 - 8.47, where this value indicates that the Lake Maninjau has a neutral to alkaline pH, while dissolved oxygen concentration (DO) ranges from 6.8 to 7.7 mg/L has fulfilled the standard.

Table 1. Water Characteristics of Lake Maninjau

Parameters	Level (ppm)				Quality standards (mg/L)*
	Center of the lake	Settlement	Fish cage	Endemic Fisheries	
Temperature (°C)	28.1	32.8	30.8	30.8	25-32
pH	6.73	7.8	8.2	8.47	6-9
DO	6.8	6.9	7.7	7.0	> 3
BOD ₅	47	31.06	35.2	21.87	3
COD	74	52.8	52.8	35.2	25
TDS	288	136	148	138	1000
TSS	850	582	516	462	50

*Government regulations the Republic of Indonesia Number 82 the year 2001 on Water Quality Management and Water Pollution Control; Quality standards Class 2

BOD₅, COD parameters in all locations did not meet the standard, i.e., 3 mg BOD₅/L and 25 mg COD/L. The BOD₅ values in the center of the lake, settlement, fish cage and endemic fisheries range from 21.87 to 47 mg/L, while the COD concentration in the range of 35.2-74 mg/L. Compared to Marganof's study in 2007, that was 4.52 mg/l and 10.98 mg/L, showed the quality has decreased [4]. High levels of the organic matter were mainly due to the dense settlements mostly in the downstream of the river which discharges to the lake and the increasing organic load from the aquacultures around the lake. It corroborated by Prima's study (2013) that in 2013 an increase of BOD and COD parameters 25.87 mg/L and 256 mg/L respectively, which did not meet the standard for class 3. It indicates in less than a decade, the BOD₅ and COD concentration in Lake Maninjau continued to increase and stated severely polluted by organic matter. According to Prima, increasing human activities around the lake, such as settlements, hotels, restaurants, and fish cage contributed to the high

organic matter. Physically, Lake Maninjau looks dark green. According to Li [13] green color due to excessive algae growth or algal blooms often lead to reduced water clarity and light penetration. Li revealed that nitrogen and phosphorus were essential nutrients for algae growth. Nevertheless, the excess input of nutrients results in the harmful proliferation of planktonic alga and disrupts the aquatic environment. Fish cage contributes to the high nutrient level in the lake which drives algal blooms [14], besides the addition of organic matter to the aquatic medium is also the trigger for eutrophication [15].

3.2. *BOD₅ and COD concentrations to a depth*

BOD₅ and COD level from each sampling location varied and all did not meet the standard as shown in figure 2. BOD₅ concentrations were found to be around 40.70-74.67 mg/L and COD 69.33-112 mg/L. The BOD₅ and COD concentrations increased with depth; it shows that more organic matter is decomposed in the bottom layer. Statistical analysis by One-way ANOVA on BOD₅ as a function of depth are statistically significant (0.000-0.048, $p < 0.05$), except at endemic fisheries with p-value 0.476. The same situation shown in COD, statistical analysis by ANOVA on COD as a function of depth is also statistically significant (0.011 to 0.027, $p < 0.05$), except at hydropower and endemic fisheries location (p-value 0.011 to 0.027). Hydropower and endemic fisheries have shallow depths, i.e., 2,5 m and 5 m. In shallow water, the BOD₅ concentration is almost the same in all depths. Water is mixed easily by wind and bring the sediments to the surface. In Lake Maninjau, there is a wind speed faster than 10.4 m/s, that can raise hypolimnetic water to the surface at the windward edge of the lake [16]. Variations in wind stress and general lake circulation primarily lead to vertical mixing, which agitates bottom sediments and particulates to the surface, the effect is expected to be more considerable for shallower environments [17]. In the center of the lake, both BOD₅ and COD concentrations are more stratified in the five depths. To a depth of 40 m the organic matter increase (40.70 to 56.89 mg BOD₅/L and 69.33 to 85.33 mg COD/L), then to a depth of 100 m, the value tends to be stable and towards the bottom of the lake the organic material increases again (67.56 mg BOD₅/L and 101,33 mg COD/L). In deep lake water, the decomposition of organic material and dissolution of its end products contribute their part to density and stratify the lake permanently [18]. At the bottom, the densest layer of a stratified lake, which is isolated from wind mixing and has rich organic sediments [19]. Pollutants from different origins and distant from primary sources can be transported at long distances and accumulated in sediments [20].

The highest BOD₅ and COD concentration come from the fish cage at 19 m depth, i.e., 71,11 mg/L and 106,67 mg/L respectively. The same COD concentration also obtained at of fish cage location at 2,5 m depth which is 106,67 mg/L. Higher BOD values indicate high organic contamination and nutrient loading so that its decomposition and mineralization depletes the oxygen content in the water, meanwhile higher COD value related with higher levels of inorganic material being discharged into the lake. Fish cage is the major contributor to the organic material in lakes, the accumulation of organic matter due to fish metabolism and residual fish feed resulting in increased organic compounds in the water. It also confirmed by Devi [12] that high values of BOD usually near the bottom of the cage aquaculture site where nutrients and organic matter from the fish, excess feed and waste accumulated, which resulted in high oxygen demand. Hydropower station located near the outflow of the lake, i.e., Batang Antokan River, which carries the organic accumulation from around the lake and there are also turbine stirrers for power plants that mixed the organic matter from the sediment. It showed one of the causes of the high organic matter found in Lake Maninjau is the presence of the aquaculture. However, the contribution of settlement waste is also quite high, which is represented by the BOD value of 42,48 – 63,31 mg/L and COD of 69,33 - 96 mg/L which increases both organic and inorganic materials in the lake.

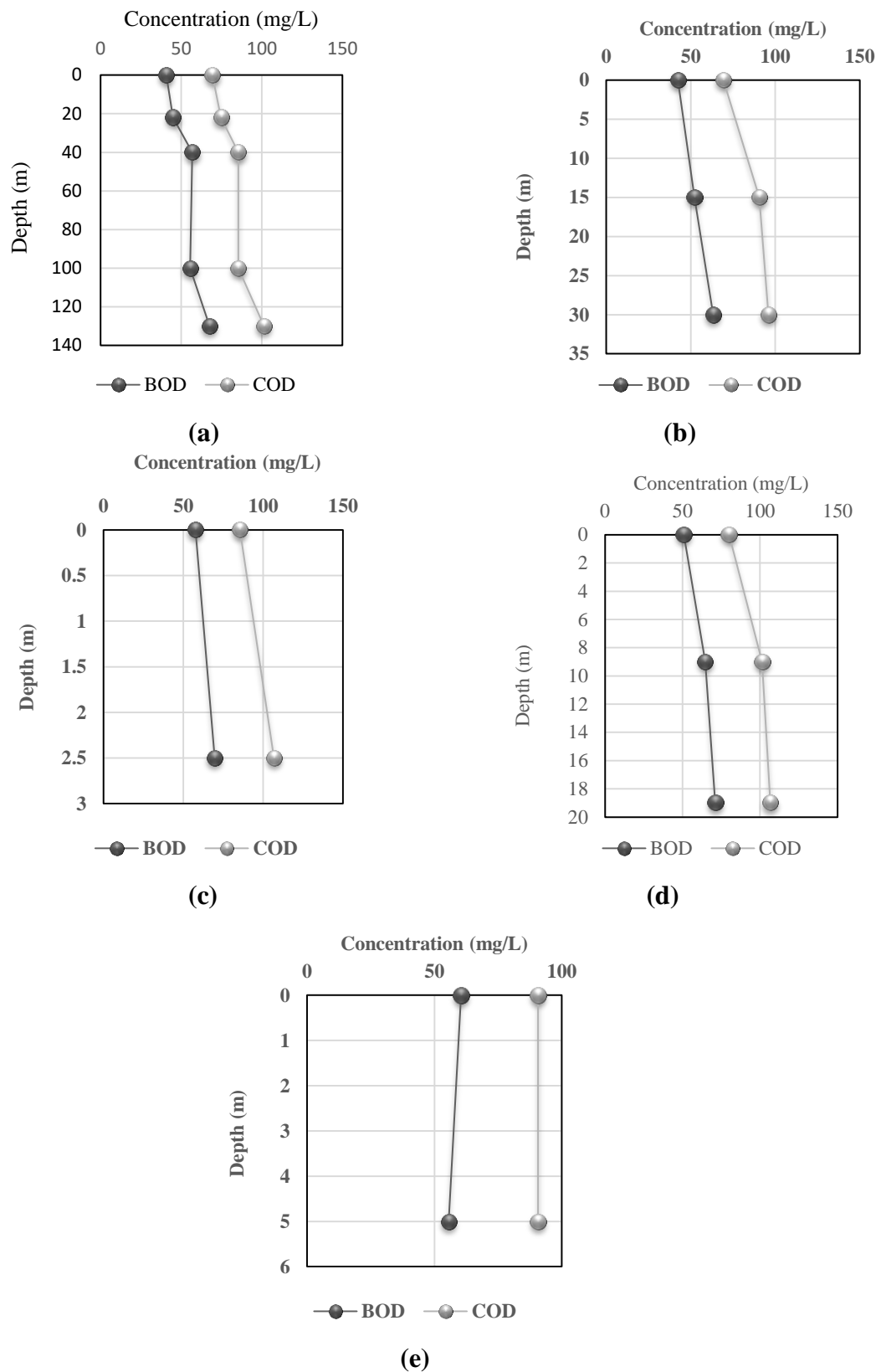


Figure 2. BOD and COD Concentration to Depth (a) Center of the lake, (b) Settlement, (b) Hydropower, (d) Fish cage, (e) Endemic Fisheries

Overall the material contamination is evenly distributed throughout the lake associated with the organic compounds in the center of the lake that has exceeded the standard. Pollution control efforts are needed through a reduction in the number of the fish cage as well as a requirement of domestic wastewater treatment before being discharged into the lake.

4. Conclusion

The water quality of Lake Maninjau regarding BOD and COD values does not meet the quality standards under the designation of Lake Maninjau. BOD values ranged from 21.87 to 47 mg/L, and COD concentration values ranged from 35.2 to 74 mg/L. Both BOD and COD influenced by depth in all location of the surrounding lake, except the endemic fish and hydropower which has a shallow depth. Both the BOD₅ and COD with depth has a strong correlation of the lake in all sampling locations, except hydropower and endemic fisheries. At shallow lake depths, water is easy to mix so that the organic matter is distributed evenly at all depths. Human activity around the lake, especially fish cage has the highest contribution to contamination of organic matter in the lake.

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