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RESEARCH ARTICLE

A Preliminary Study of the Physico-Chemical Parameters and Potential Pollutant Sources in Urban Lake Rawa Besar, Depok, Indonesia

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Abstract Lake Rawa Besar is an urban lake surrounded by dense settlements and commercial areas that are currently experiencing physical and ecological pressures due to uncontrolled land-use change around the lake. Therefore, this preliminary study aimed to investigate the sustainable management of the lake in order to create a recreational destination area. It was carried out by ascertaining the lake water quality status through the analysis of the physical and chemical parameters and identifying the potential pollutant sources due to land use and human activities. The physical parameters include TDS, TSS, Turbidity, while the chemical parameters include Nitrate-N, Total Phosphate-P, and BOD. Furthermore, field surveys on 30 water samples were conducted once at noon and statistical analysis was used to ascertain the correlation between the physical and chemical parameters. Finally, Geographic Information System (GIS) tools were used to investigate the spatial distribution of the Physico-chemical parameters and the potential pollutant sources. The results showed that based on the six parameters of the water quality status, the lake was lightly polluted. It also showed that three parameters such as Turbidity, BOD, and TSS exceed the permissible limit with 93.3, 66.7, 43.7% of the total samples, respectively. Additionally, a strong correlation existed between BOD and Turbidity with r=0.95, while a medium correlation existed between Nitrate-N and Phosphate-P with r=0.40. The spatial distribution of the concentration of the physico-chemical parameters generally had a varied pattern, however, Turbidity and BOD had a similar pattern, especially in the bank areas. Finally, domestic and organic wastes were indicated as pollutant sources, which increased eutrophication in the lake.

1. Introduction

Lake Rawa Besar is the second largest lake in Depok, West Java, Indonesia, and has an area of 17 ha. Furthermore, it has an ecologically important role as a catchment area and the main sources of its water are rainfall, domestic wastewater, and groundwater (Depok City Environmental Agency, 2006). It is also located in the city centre which is close to economic, governmental, and transportation activities. Therefore, from 1999 to 2003 the area of settlement and trade around the lake increased up to 64 and 12%, respectively (Susilowati, 2004). Consequently, the initial lake area of 25 hectares decreased to 17 hectares due to the number of uncontrolled squatter settlements in its banks (Depok City Environmental Agency, 2006).

The previous studies of Lake Rawa Besar showed that the water quality was declining due to the increase in settlements and commercial areas. In 2003, the concentration values of several parameters such as ammonia, phenol, lead (Pb), BOD, COD, and the presence of coli bacteria exceeded the environmental quality standards (Susilowati, 2004), and the macrozoobenthic community experienced extinction (Retnawati, 2003). Furthermore, Ayu (2009) revealed that the macrozoobenthic community in the lake was decreasing and might lead to the death of aquatic organisms. Thus, the pressure on the ecological conditions was increasing, while the sustainability of the lake was decreasing. This condition has the potential to cause the destruction of the lake (Saraswati et al., 2003).

Lake Rawa Besar is an urban lake surrounded by an urbanized area of more than 2 ha (Persson, 2012; Williams et al., 2004). By characteristics, the lake is shallow, artificial, and hypertrophic (Birch & McCaskie, 1999; Henny & Meutia, 2014; Norris & Laws, 2017), therefore, is prone to physical and ecological degradation, which could cause a deterioration in water quality (Sutjiningsih, 2017; Henny & Meutia, 2014). Several recent studies have shown that the water quality of urban lakes is severely damaged due to the increase in human activities, particularly in developing countries such as in the Beira Lake, Sri Lanka (Weerasinghe & Handapangoda, 2019), in Tasik Taman Idaman Lake, Malaysia (Hossain & Mahmud, 2019), and in Dianchi Lake, China (Yang et al., 2020).

The main cause of the decline in the quality of the lake was the lack of attention and management by the public, especially the government. Therefore, strong institutional coordination involving all stakeholders is urgently needed in order to have the power to impose lake management policies (Listiani, 2005). For this reason, this preliminary study is conducted to investigate the water quality status of Lake Rawa Besar according to the Indonesian Government Regulation No. 82/2001 Class II (State Secretary of the

Indonesian Republic, 2001). It also aims to map the spatial distribution of physical and chemical parameters, and identify potential pollutant sources due to land use and human activities. This study hopes to enable the development of the lake into a recreational destination in order to promote economic growth and health benefits to the humans and animals that depend on its quality (Betiku et al., 2021).

2. Methods

Study Area

This study was carried out in Lake Rawa Besar and its catchment area located in Depok Jaya Urban Village, Pancoran Mas Sub-District, Depok, West Java. It is also located at coordinates 106.816 East Longitude and 6.39 South Latitude as shown in Figure 1. The surface elevation of the study area is around 86-90 meters above sea level with a slope of 0-2%, while the lake has an area of 170,000 m^2 with a length of about 1.2 km, a width of between 300-700 meters, and a depth of 1-2 meters (Depok City Environmental Agency, 2006). However, the area of the lake experienced a shrinkage due to the slum settlement of at least 25,000 m^2 in area.

In the western part of the lake, there was a well-ordered settlement named Perumnas I, while in the eastern part, there were disordered settlements with slum conditions that did not have legal land ownership. This illegal settlement has been occupied by residents with non-permanent livelihoods, such as market labourers, porters, and street vendors with relatively low incomes. However, residents living in well-ordered settlements have a higher income but are still categorized in the middle-income level.

The study area included the water body of Lake Rawa Besar and its catchment area with the eastern boundary named Jalan Kampung Lio, the northern boundary named Jalan Arif Rahman Hakim, the Western boundary named Jalan Nusantara Raya, and the Southern boundary named Jalan Dewi Sartika. Furthermore, the determination of the catchment area was based on topographic aspects in the form of surface elevation and the direction of water sewer flow. Finally, the total area of the study area was 4,830,000 m^2 or 48.3 ha.

Figure 1. Location of Lake Rawa Besar in Depok, West Jawa, Indonesia

Field Sampling

Water sampling was carried out on August 14, 2018, in the dry season at noon due to low rainfall. It was conducted using a small boat to collect water samples from different locations in the lake. The sample locations were thirty in number and were evenly determined by dividing the lake body into ten segments. Three samples were then obtained from each segment, due to the elongated shape of the lake (Figure 2). The determined sampling locations represented the characteristics of each location, such as close to well-ordered settlements, disordered settlements, slum settlements, vegetated lands, and potentially polluted areas due to human activities. The water samples were put into dark glass bottles of size 300 ml, then stored in a cooler box for less than six hours and delivered to the laboratory. Once the samples arrived at the laboratory, they were stored in a cooler at 4° C.

The parameters tested include the Physico-chemical parameters such as Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Turbidity represents physical parameters. Meanwhile, Nitrate as N (Nitrate-N), Total Phosphate as P (Total Phosphate-P), and Biochemical Oxygen Demand (BOD) were the chemical parameters. These parameters are the main parameters in analyzing the quality of non-consumption water from natural waters such as lakes and rivers. This is because they could indicate the general condition of the lake ecosystem and the factors affecting its water quality.

Sample Analysis

All samples were processed within 14 working days by a nationally accredited laboratory, PT. Anugerah Analisis Sempurna (AAS) (www.aaslaboratory.com) in Cibinong, West Java, Indonesia, with a test contract number of AAS.LHP.IX.2018.1575. Moreover, the measurement method for each parameter was carried out according to the instructions of the Indonesian National Standard (SNI), while also referring to international standards, also known as

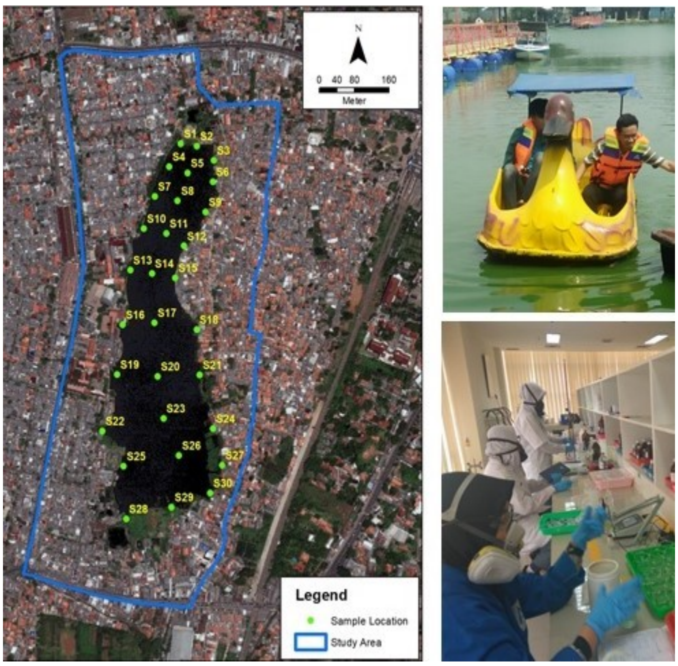

Figure 2. Distribution of sample locations and sampling processes

Standard Methods for Examination of Water and Wastewater (Clesceri et al., 1998). The explanation for each parameter is as follows:

- TDS is a dissolved material with a diameter of <10-6 mm in the form of chemical compounds and inorganic materials in the form of ions that could be found in the waters (Effendi, 2003). It was measured through a gravimetric method by filtering water samples using a porous membrane filter of 2.0 µm or smaller and heated at a temperature of 180° C for not less than 1 hour. Finally, the unit of TDS is mg/L;
- TSS is a suspended material with a diameter of >1 µm consisting of mud, fine sand, and microorganisms, and is mainly caused by soil erosion carried to the water body (Effendi, 2003). It was measured through a gravimetric method, using filter paper with a pore size of 0.45 µm and heated at 103 to 105° C, and the unit is mg/L;
- Turbidity describes the optical properties of water which are determined by the amount of light absorbed and emitted by the ingredients in the water. It is caused by suspended and dissolved organic and inorganic materials (e.g. silt and fine sand), including inorganic and organic materials in the form of palms and microorganisms (Effendi, 2003). Turbidity was measured using the nephelometric method, where the light source was pointed at the samples and the intensity of the light reflected by the materials causing turbidity was measured through a formazine polymer suspension as standard (Effendi, 2003), and the unit is NTU (Nephelometric Turbidity Unit);
- Nitrate (N) is the main form of nitrogen in natural waters and is the main nutrient for the growth of plants and algae (Effendi, 2003). It was measured through a spectrophotometric method using cadmium reduction column with a measurement range of 0.01 mg to 1.0 mg NO_3^--N/L with a path length of 1 cm or more, at a 545 nm wavelength, and the unit is mg/L;
- Total Phosphate describes the total amount of phosphorus, both particulate and dissolved, and inorganic or organic (Effendi, 2003). Total Phosphate- P was measured using a spectrophotometer method with ascorbic acid in water samples at a range of 0.01 to 1.0 mg P/L and at a wavelength of 880 nm, while the unit is mg/L;
- BOD depicts the levels of organic matter from dead plants and animals or from domestic and industrial wastes that could be biologically decomposed (Effendi, 2003). It was measured using a solution of glucose-glutamic acid as a standard control material at a temperature of 20° C ± 1° C for 5 days, and the unit is mg/L.

Water Quality Status

The water quality status was ascertained using the pollution index (PI) in accordance with Ministry of Environment Decree No.115/2003 (Ministry of Environment Republic Indonesia, 2003). Moreover, this method has been widely used for case studies in Indonesia, for example, by Effendi et al. (2015), Barokah et al. (2017), and Sari et al. (2020). The formula as follows:

$$PI_j = \sqrt{\frac{(C_i/L_{ij})_M^2 + (C_i/L_{ij})_R^2}{2}} \quad \text{.....................(1)}$$

where,

PI_j : Pollution Index
C_i : Concentrations of water quality parameters
L_{ij} : Standard of water quality parameters of Class II
$(C_i/L_{ij})_M$: Maximum value C_i/L_{ij}
$(C_i/L_{ij})_R$: Average value Ci/L_{ij}

The Pollution Index results are then evaluated based on the Pollution Index criteria as follows:

$0 \leq PIj \leq 1{,}0$: Good condition (according to the permissible limit)
$1{,}0 \leq Plj \leq 5{,}0$: lightly polluted
$5{,}0 \leq Plj \leq 10$: moderately polluted
$Plj \geq 10$: heavily polluted

Statistical Analysis for Correlation Calculation

The statistical analysis was carried out to ascertain the relationship between parameters. Furthermore, the data were tested for normality using the Kolmogorov-Smirnov and Liliefor tests, which showed that some parameters were normally distributed such as TDS, TSS, Turbidity, and BOD, thus were analyzed with parametric methods such as Pearson correlation. While, Nitrate-P and Total Phosphate-P were not normally distributed, thus were analyzed with non-parametric methods such as Rank Spearman correlation.

Data Mapping and Interpolation

The mapping of the Physico-chemical parameters was carried out using ArcGIS software, through the following procedure. First, the table data of the survey results for each sample location were converted into GIS format (.shp). Second, interpolation was carried out using the Spline model to predict the concentrations for the location that did not have data points. It was used due to the lowest RMSE compared to Kriging, IDW, and Natural Neighbor (Kazemi et.al., 2017; Yan & Kahawita, 2006) to produce a spatial distribution of the Physico-chemical parameters. The shapefile data was then converted into raster format with a pixel size of 1 m^2, where each pixel contained coordinates and parametric concentrations. Third, the results of the interpolation were clipped according to the lake boundary. Finally, contour, label, and colour intervals were selected to display better data.

Land-use Mapping and Potentially Pollutant Sources Identification

Land-use mapping and identification of pollutant sources were carried out to show the influence of human activities on the distribution of the physicochemical parameter. Moreover, Land-use and building data were obtained by digitizing high-resolution satellite images from Google Earth in 2018 with a scale of 1:5000.

The classifications of residential land-use were made in detail such as well-ordered, disordered, and slum settlements. Moreover, the classification was determined by the pattern of buildings. The potentially polluting human activities were then identified by tracking inlet sewers entering the lake and the activities of the following, food factories, landfills, chicken coops, fish cages, and others.

3. Result and Discussion

The Spatial Distribution and Water Quality Status

The concentration of each parameter was identified through the laboratory test (Appendix). Furthermore, a simple statistical analysis was used to show the magnitude of concentration such as minimum, maximum, average, and standard deviation. Then, the comparison of concentration between measuring results and the threshold that refers to the clean water standard under Class II (recreation objectives) set by the Indonesian Government Regulation No. 82/2001 (State Secretary of the Indonesian Republic, 2001) was conducted, as shown in Table 1.

The results of the simple statistic of the physical parameters could be explained as follow. TDS concentrations across all samples ranged from 105 to 132.7 mg/L, which were still below the permissible limit of 1000 mg/L. However, the concentrations tended to increase in the middle of the lake, where the water was deeper, while in the southeast part, the concentrations were reduced.

TSS concentrations ranged from 14.3 to 97.4 mg/L, and a total of 13 samples (43%) showed that its concentrations exceed the permissible limit of 5 mg/L. Furthermore, the TSS value was dispersed extensively in the middle to the southeastern part of the lake.

Turbidity concentrations ranged from 12.7 to 207 NTU, and most samples (83%) showed that its concentrations exceed the permissible limit of 25 NTU. Furthermore, spatially, the concentrations increased in the banks of the lake, however, decreased in the middle region and in the northern area (Fig. 3 and 4). Therefore the results of the simple statistic of the chemical parameters as follow. Nitrate-N concentrations ranged from 0.23 to 1.20 mg/L, however, all water samples showed that its concentration was still below the permissible limit of 10 mg/L. Spatially, the concentrations were increasing towards the north and south bank of the lake, including in the middle.

The Total Phosphate-P concentrations ranged from 0.014 to 0.118 mg/L. However, all samples showed that its concentrations were still below the permissible limit of 0.2 mg/L and evenly dispersed throughout the lake's waters. There were only two samples where its concentrations were above 0.1 mg/L. They include samples S13 and S28, which were located on the banks of the mid-western part of the lake, including the south-western part.

BOD concentrations ranged from 1.83 to 5.97 mg/L and out of the 30 samples, 20 (66.7%) showed that the concentrations exceed the permissible limit of 2 mg/L. Moreover, the concentrations were evenly distributed in the lake's waters, except in a small part of the northern area (Fig. 3 and 4).

Based on the physical and chemical parameters, the water quality status could be determined. Moreover, the concentration values used for each parameter to ascertain the water quality status of the whole of the lake in the calculation was an average value of the 30 sample locations. The results in Table 2 showed that the value of PI is 2.99. This means that the water quality of Lake Rawa Besar is lightly polluted. Finally, the turbidity parameter is the parameter that most influenced the poor quality of the water, followed by the BOD and TSS parameters.

Previous research by Tallar & Suen (2015) examined the water quality of Lake Rawa Besar. Moreover, based on the

Table 1. The concentration of the parameter of Lake Rawa Besar and the thresholds of clean water standards

Value element	TDS (mg/L)	TSS (mg/ L)	Turbidity (NTU)	Nitrate-N (mg/L)	Total Phosphate-P (mg/L)	BOD (mg/L)
Minimum	105.0	14.3	12.7	0.23	0.014	1.83
Maximum	132.7	97.4	207.0	1.20	0.118	5.97
Average	121.9	51.1	102.0	0.67	0.020	3.75
St. dev	6.3	23.5	50.2	0.22	0.025	1.35
Thresholds for permissible limit of clean water (Class II)	1000	50	25	10	0.2	3
Number of samples over the permissible limit	0	13	28	0	0	20
Percentage of samples over the permissible limit	0 %	43.3 %	93.3 %	0 %	0 %	66.7 %

Source: Data processing, 2018

Table 2. Calculation of Pollution Index based on the mean value of each parameter

Parameter	Unit	L_{ij}	Mean Value	Ci/L_{ij}
TDS	mg/L	1000	121.9	0.12
TSS	mg/L	50	51.1	1.02
Turbidity	NTU	25	102	4.08
Nitrate-N	mg/L	10	0.67	0.07
Total Phosphate-P	mg/L	0.2	0.02	0.10
BOD	mg/L	3	3.75	1.25
		Total		6.64
		Average		1.11
		Max.		4.08
		PI		2.99

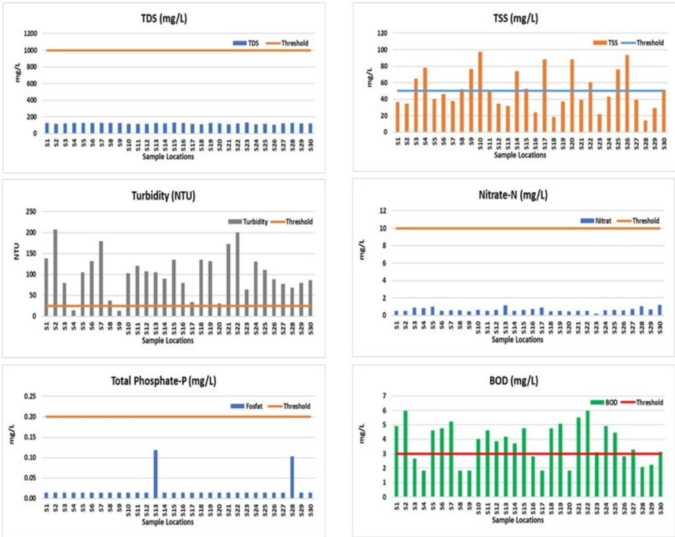

Figure 3. Graph of Physico-chemical parameters concentration

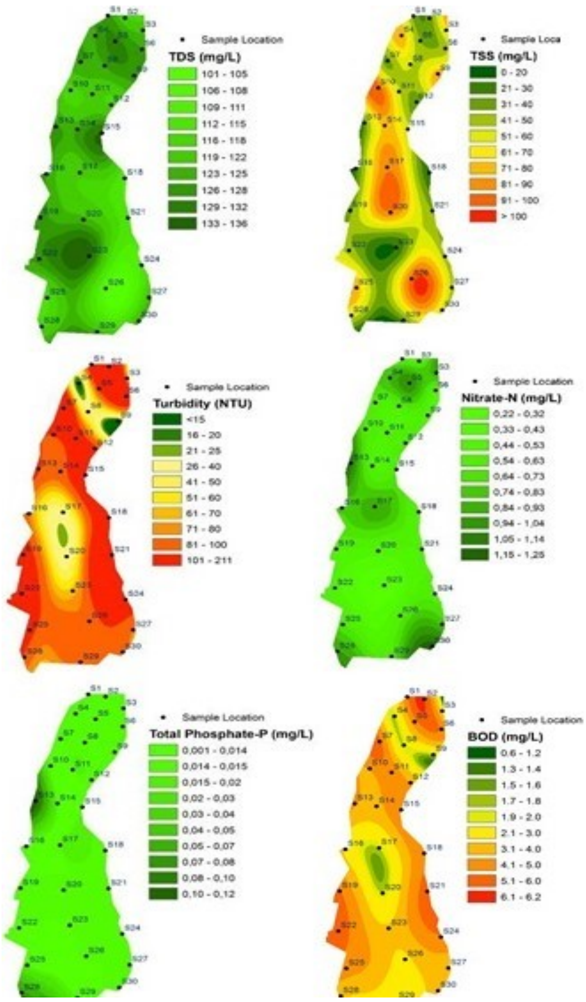

Figure 4. Maps of the spatial distribution of Physico-chemical parameters

four methods used such as STORET, the National Sanitation Foundation (NSF), River Pollution Index (RPI), and Malaysian Development and Environment (MDE) in 2009, 2010, and 2011 data, it was stated that the status of water quality of the lake generally fluctuated, as in 2009 it was polluted, 2010, it was good, and 2011, it was polluted. Thus, the water quality was quite dynamic, in line with the dynamics of community activities and consistency in the management of the lake carried out by the local government.

Identifying the Potential Pollutant Sources

The normality test was conducted for all parameters using Kolmogorov-Smirnov and Liliefors with Asym. Sig. (2-tailed) 0.05. The results showed that TDS, TSS, Turbidity, and BOD parameters were normally distributed, while Nitrate-N and Total Phosphate-P were not normally distributed. The parametric method, Pearson was used to analyze the correlation between any two of the normally distributed parameters, while the non-parametric method, Rank Spearman was used in analyzing the correlation between any two of the non-normally distributed parameters (Table 3).

The results showed that not all parameter couples correlated with a statistical significance of 0.05. Furthermore, only four-parameter couples had a correlation, such as Turbidity-TSS ($r = -0.36$), Turbidity-BOD ($r = 0.95$), Total Phosphate-TSS ($r = -0.37$), and Total Phosphate-Nitrate ($r = 0.40$). The correlation between Turbidity and TSS in this research was weak (negative). This shows that the correlation was not always strong (positive) as stated by Daphne et al. (2011), Hannouche et al. (2011), Nasrabadi et al. (2016); and Rügner et al. (2013). However, the correlation between Turbidity and BOD parameter was strong (positive) and linear ($r = 0.95$) as shown in Figure 5. This shows that the Turbidity concentration of the lake was strongly influenced by the presence of organic materials in the waters and not from land erosion.

The correlation between nutrient parameters as indicated by a moderate positive correlation between the concentration of Nitrate-N and Total Phosphate-P of $r = 0.40$ was in line with the study by Liu et al. (2018). Moreover, the Nitrate-N concentration of 0.67 mg/L which exceeded the threshold of 0.2 mg/L shows that eutrophication occurred. The lake water could be categorized as oligotrophic, with low fertility levels, as the average concentration of Total Phosphate was 0.02 mg/L. Moreover, the ratio of Nitrate-N to Total Phosphate-P was greater than 16: 1, meaning that phosphorus was a limiting factor for the eutrophication of average Nitrate-N (Effendi, 2003). The eutrophication that occurred in the study area was categorized as artificial and was caused by industrial and domestic activities. It caused excessive growth of the lower species of plants such as algae and cyanobacteria, both called phytoplankton. The method of investigating the phytoplankton in the freshwater was by measuring the amount of chlorophyll-a.

Phu (2014) and Xu & Xu (2014) studied the relationship between Chlorophyll-a with BOD concentration in a lake and the result showed a high linear correlation. Thus, the findings such as the green colour of lake Rawa Besar and the high concentration of BOD and Turbidity could indicate that the water pollution was from household and home industry wastes disposed of by the community, resulting in fairly high eutrophication.This study showed findings different from those of previous studies, as it showed the absence of a strong correlation between Turbidity and TSS and the presence of a strong positive correlation between Turbidity and BOD. These may indicate that the turbidity level of the waters in the lake was not affected by the erosion process from the surrounding areas.

The lake's catchment area was mostly in the form of built-up lands, such as settlements, commercial areas, and school zones, therefore, the amount of soil erosion due to rainfall was small, which is in contrast to natural lakes, where sediment concentration (TSS) is strongly influenced by soil

Table 3. Correlation between sediment and nutrient parameters

Parameters	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	Nitrate-N (mg/L)	BOD (mg/L)	Total Phosphate-P (mg/L)
Turbidity	1					
TDS	-0.21*	1				
TSS	-0.36[a]*	-0.28*	1			
Nitrate	-0.26**	0.06**	-0.03**	1		
BOD	0.95[a]*	-0.16*	-0.31*	-0.29**	1	
Phosphate	-0.11**	0.29**	-0.37[a]**	0.40[a]**	-0.12**	1

Source: Data processing (2018)

Note: [a] statistically significant (Sig.=0.05); * Pearson Correlation; ** Spearman Correlation (Non Normal Distribution)

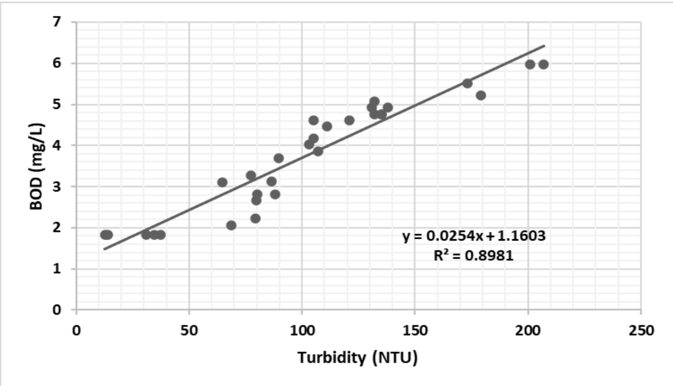

Figure 5. Scatter plots and correlation between Turbidity and BOD

erosion due to rain (Mir et al., 2016). The existence of settlements producing household wastewater was a major cause of high BOD concentrations which lead to water turbidity (Khatri & Tyagi, 2015). Furthermore, the high BOD concentration may be caused by the high amount of chlorophyll A in the lake's waters (Phu, 2014).

Figure 6 shows the land use data, most of which are dominated by built land in the form of well-ordered settlements (38.4%), disordered dense settlements (42.5%), slum settlements (5.2%), school zones (10.4%), traditional market areas (2.9%), and only a small portion of vegetated lands and wetlands (3.5%), as shown in Table 4. The well-ordered settlements were spread in the northwestern and southwestern parts of the lake. While the disordered dense settlements were evenly distributed in the eastern part. The slum settlements were concentrated in the southwestern part of the lake, while the school zones were in the mid-western part. Finally, the vegetation and wetlands were scattered in the southern part of the lake, while the traditional market areas were in the southern part, about 100 meters from the lake.

Based on the results of the field survey on the physical condition of the lake and the activities of the surrounding residents, it was found that most of the lake's banks were concreted, except in the southern part which was still covered by vegetation. This condition would slow down the rate of erosion in the lake's banks, both caused by splashing and pounding of the lake's water.

At least 37 inlets in the form of small sewers due to the surrounding land use were identified in the lake banks. Furthermore, a total of 31 small sewers were sourced from

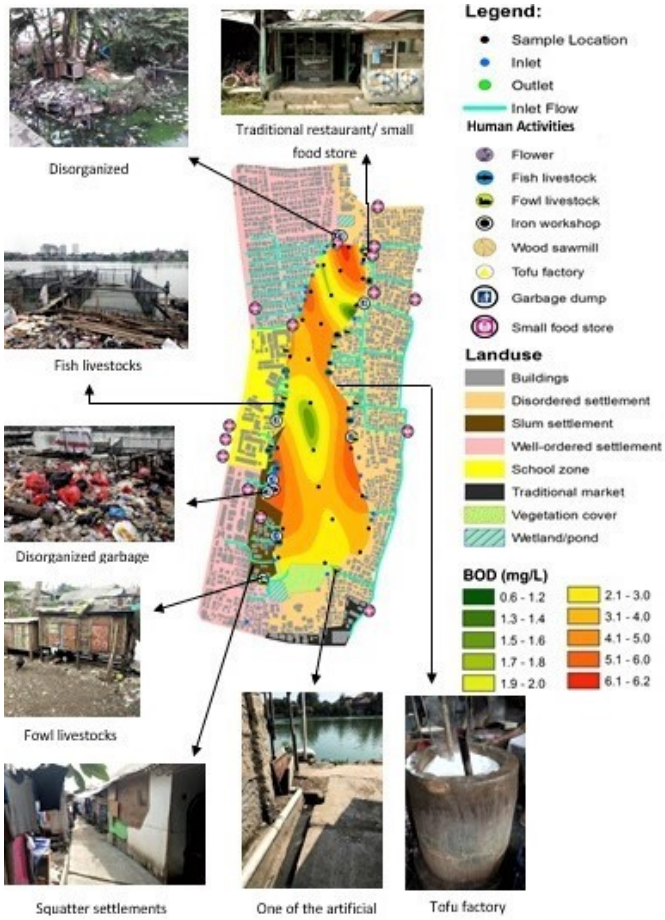

Figure 6. Potentially polluting human activities in the Lake Rawa Besar corridor

residential areas. When observed during the day, there was no water flowing continuously into the lake through the small sewers nor was there a river body streaming into the lake.

Based on the results of interviews with the local community leaders around the lake, it was found out that some residents dumped their household wastes into the lake through the small sewers. In addition, there were 29 locations with potentially polluting human activities of the lake's water. Also, as many as 18 locations of potentially polluting human activities were found in the disordered dense settlements, consisting of four fish cages, seven chicken coops, one iron workshop, two wood sawmills, one tofu factory, two landfills, and one food stall, as shown in Table 4.

The results of the laboratory tests showed that of the six parameters, three had concentrations that exceed the threshold for standard clean water. This means that the lake had experienced pollution or a decrease in quality when viewed from the concentrations of turbidity, TSS, and BOD. Furthermore, a strong correlation between turbidity and BOD was also shown by the spatial distribution patterns of the two parameters which were similar.

Figure 6. shows the distribution of locations suspected to be potential pollutants of the lake. Moreover, high turbidity and BOD concentrations in the sample locations of S2 and S21 may be caused by the existence of disorganized garbage. This is because organic materials in the garbage may enter the lake, especially when raining. In addition to these two locations, high concentrations of turbidity and BOD were also found in locations adjacent to fowl and fish livestock, as seen in the sample locations of S3, S18, S19, and S22. The existence of a traditional restaurant and a tofu factory near the sample locations of S1, S10, and S15 may also have contributed organic matters from leftover food or pulp dumped into the lake.

A high distribution of TSS concentrations (> 50 mg/L) was present in the middle to the south-eastern part of the lake, which may be due to the vegetated lands. Vegetated lands indicate the presence of a soil layer on the surface. Therefore, the potential for erosion was quite large, and caused by both rain and the behaviour of the lake's water. In addition, the presence of 37 small sewers as inlets into the lake played a role in bringing several sediments and organic materials from the settlements in the lake's catchment area. At the locations of S13 and S28, the eutrophication process occurred with the emergence of water hyacinth and algae plants (Matisoff et al., 2017). This was indicated by higher phosphate concentrations compared to other locations. Finally, rain contributed to the amount of sediment and nutrient which moved from land to the lake (Norris & Laws, 2017).

This research analyzed the factor influencing water quality in Lake Rawa Besar using the current data and information, particularly the land use data. However, the author's statement was in line with the previous study by Susilowati (2004) which showed the relationship between water quality and land-use change from 1999 to 2003. The results showed that the changes of uncontrolled land use in the Lake's area were shown by the increasing land used for settlements and trade. The Lake's area in 2003 was mostly used for settlements (64%), while the rest was for trade (12%), uncultivated gardens (4%), environmental roads (12%), and public facilities (8%). Moreover, one of the edges was fully built with permanent houses and had a paved road environment.

The effect of the land-use changes on the water quality is clearly shown in Table 5 that DO concentration decreased due to the increase of settlement and trading areas from 1999 to 2003. Thus, although this research lacks the updated long-term water quality data, Table 5 could convince the audience of the land use impact on the water quality in the lake.

The results of the laboratory tests showed that of the six parameters, three had concentrations that exceed the threshold for standard clean water. This means that the lake had experienced pollution or a decrease in quality when viewed from the concentrations of turbidity, TSS, and BOD. Furthermore, a strong correlation between turbidity and BOD was also shown by the spatial distribution patterns of the two parameters which were similar.

Table 4. Area of each type of land use around Lake Rawa Besar

Landuse type	Area (m^2)	Percentage (%)	Number of inlet sources to the lake	Type and number potentially polluting human activities
Traditional Market	10,034.9	2.9	0	
School Zone	35,450.0	10.4	4	2 fish livestock 4 fowl livestock
Slum settlement	17,552.2	5.2	11	1 water flower 1 fish livestock 1 fowl livestock
Disordered settlement	144,780.3	42.5	11	4 fish livestock 7 fowl livestock 1 iron workshop 2 wood sawmills 1 tofu factory 2 disorganized garbages 1 traditional restaurant
well-ordered settlement	130,619.5	38.4	9	1 disorganized garbage 1 traditional restaurant
Vegetation cover	8,339.3	2.4	2	
Wetland/pond	3,649.1	1.1	-	
Total	350,425.3	100.0		

Source: Data proceeded using Quickbird imagery in 2017

Figure 6 shows the distribution of locations suspected to be potential pollutants of the lake. Moreover, high turbidity and BOD concentrations in the sample locations of S2 and S21 may be caused by the existence of disorganized garbage. This is because organic materials in the garbage may enter the lake, especially when raining. In addition to these two locations, high concentrations of turbidity and BOD were also found in locations adjacent to fowl and fish livestock, as seen in the sample locations of S3, S18, S19, and S22. The existence of a traditional restaurant and a tofu factory near the sample locations of S1, S10, and S15 may also have contributed organic matters from leftover food or pulp dumped into the lake.

A high distribution of TSS concentrations (> 50 mg/L) was present in the middle to the south-eastern part of the lake, which may be due to the vegetated lands. Vegetated lands indicate the presence of a soil layer on the surface. Therefore, the potential for erosion was quite large, and caused by both rain and the behaviour of the lake's water. In addition, the presence of 37 small sewers as inlets into the lake played a role in bringing several sediments and organic materials from the settlements in the lake's catchment area. At the locations of S13 and S28, the eutrophication process occurred with the emergence of water hyacinth and algae plants (Matisoff et al., 2017). This was indicated by higher phosphate concentrations compared to other locations. Finally, rain contributed to the amount of sediment and nutrient which moved from land to the lake (Norris & Laws, 2017).

This research analyzed the factor influencing water quality in Lake Rawa Besar using the current data and information, particularly the land use data. However, the author's statement was in line with the previous study by Susilowati (2004) which showed the relationship between water quality and land-use change from 1999 to 2003. The results showed that the changes of uncontrolled land use in the Lake's area were shown by the increasing land used for settlements and trade. The Lake's area in 2003 was mostly used for settlements (64%), while the rest was for trade (12%), uncultivated gardens (4%), environmental roads (12%), and public facilities (8%). Moreover, one of the edges was fully built with permanent houses and had a paved road environment.

The effect of the land-use changes on the water quality is clearly shown in Table 5 that DO concentration decreased due to the increase of settlement and trading areas from 1999 to 2003. Thus, although this research lacks the updated long-term water quality data, Table 5 could convince the audience of the land use impact on the water quality in the lake.

Table. 5. The effect of land use changes on the water quality

Year	Area of Settlements (ha)	Area of Trading (ha)	DO (mg/L)	pH	Ammonia (mg/L)
1999	35.04	7.21	9.71	7.35	0.022
2000	35.62	8.18	8.42	8.12	0.032
2001	35.92	8.76	9.39	7.84	0.028
2002	36.21	9.34	7.45	8.36	0.032
2003	36.79	9.93	4.5	8.53	0.035

4. Conclusion

This study investigated the water quality status according to Indonesian Government Regulation Number 82/2001 on Class II (recreational objective), mapped the spatial distribution of physical and chemical parameters, and identified potential pollutant sources in Lake Rawa Besar. Based on the laboratory tests on 30 water samples and the application of the Pollution Index method, the water quality status was categorized as lightly polluted. The spatial distribution of the concentration of the physico-chemical parameters generally has a varied pattern, however, Turbidity and BOD had a similar pattern since they both increased in the bank areas. The strong correlation between Turbidity and BOD parameters, including the weak correlation between Turbidity and TSS parameters, and the fairly high eutrophication showed that the domestic and organic wastes sourced from settlements and traditional trade surrounding the lake were indicated as the pollutant sources. These conclusions have been strengthened by the results of previous studies related to water quality assessment and the influencing factors. Therefore, the results are very useful for policymakers as the first step in efforts to manage the lake's ecology in a sustainable manner, especially in preparing the lake as a new recreational destination.

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