Reservoir Management Analysis of Water Quality and Pollution Load in Jakarta

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Abstract. Jakarta as the Capital City of Indonesia has a high level of population growth. Hence, urban infrastructure movements have developed automatically. This implies some open spaces such as reservoirs are poorly managed. Reservoirs as one of blue open spaces (BOS) can function as a water catchment area to mitigate flooding during the rainy season, and drought during the dry season. Combating the reservoirs, the DKI Jakarta Government has taken action by revitalizing several untreated reservoirs. Therefore it is necessary to assess the water quality and pollution load on the reservoir. One of the supporting factors to maintain water quality and pollution load of the reservoir is to develop a robust reservoir management plan to revitalise their sustainable function. The reservoir management plan is based on the assessment of water quality and pollution load on three reservoirs in Jakarta. The formulation of reservoir management plan starts with evaluating the reservoir water quality using the Storet Method. The results of reservoir water quality based on physical parameters are in the range of class A (very good category) and B (Good Category), while based on chemical and biological parameters are in the range of class C (quite good category) and D (bad category). The results obtained from all parameters of reservoir water quality evaluation are in class D (bad category) for the three reservoirs. Further analysis was identifying the level of pollution by using the pollution index method. The result shows those three reservoirs are on heavily polluted level. Based on SWOT analysis for water quality and pollution load of the reservoir, the total score for both internal and external factors are 2.39 and 2.47, so it shows V quadrant that indicates hold and maintain strategy position and produce 8 alternatives as the result.

Keywords: Landscape management, pollution index, reservoir management, storet method.

1. Introduction
Transfer function of land from green or blue open space into building, which occurred in the urban area has increased every year. This is caused by many factors, one of which is the high demand for residents’ living area. Land acquisition for development sometimes do not pay attention to the function and designation of the land itself. As a result, the loss of area that support human life in many aspects could occurs, such as water supply [1]. Water demand can be fulfilled by building reservoirs or dams that can hold water. Implementation of development and management of the reservoirs and dams held as conservation of water resources [2].

The dam is building in the form of backfill soil, backfill stone, concrete, or masonry built in addition to hold and retain water, can also be constructed to withstand and accommodate mining waste that formed the reservoir [2]. Reservoir included within the scope of the Blue Open Space which has three functions of principal include the value of ecology, economic, social culture [3]. The sustainability of a landscape region can be measured from the provided landscape services or can be obtained from the structure, function, and dynamics of the natural
resources within it [4]. There are about 55 reservoirs which are located in Jakarta, 12 of them were revitalized in 2013 [5]. The study was conducted on three reservoirs: Ria-Rio reservoir, South Sunter reservoir, and Pluit reservoir. All three reservoirs have since included into the 12 reservoirs which had been revitalized. Selection of the reservoir is also based on the size of the area; all three of them were more than 5 ha. This analysis is motivated by the use of reservoir areas that have not been optimally used by the government and the community.

The objectives to be achieved through this research are:
1. Analyzing the quality of the water contained in the Ria-Rio reservoir, South Sunter reservoir, and Pluit reservoir,
2. Analyzing the pollution loads in the water in the Ria-Rio reservoir, South Sunter reservoir, and Pluit reservoir
3. Constructing the management plan based on the quality of water and the pollution loads.

2. Methods
2.1. Study sites and time
The study was conducted in the Ria-Rio reservoir, South Sunter reservoir, and Pluit reservoir (Figure 1). The study period was from January 2019 to April 2019.

2.2. Study Methods
The method that is used in this study consists of survey and interview. The stages of the research include the inventory phase, the analysis phase, and the output phase.

![Diagram](image-url)
2.2.1. Inventory

Field exploration was conducted to collect primary and secondary data using both the qualitative and quantitative approach. Primary data (existing conditions of the reservoirs) was obtained from the results of interviews with stakeholders. The resource persons are Ministry of Environment, PT. Jakarta Propertindo, and Pulomas Office Park. Secondary data (Physics, Chemical, and Biological parameters of water) were obtained from government agencies, Ministry of Environment.

2.2.2. Data Analysis

2.2.2.1. Analysis of Reservoir Water Quality

Analysis of the reservoir water quality refers to the Government Regulation No. 82 Year 2001 (Table 1) [6]. The parameters used are physical, chemical, and biological parameters, then they were analyzed by stored method. Determining the status of the water quality by storet method was done by the following steps:

1. collect the water quality data periodically (time series data).
2. look for maximum, minimum, and average values.
3. compare the measurement data of each water parameter with the quality standard values in Table 1.
4. if the measurement results are ≤ quality standard, then the parameter is given a value of 0 (zero), and
5. if the measurement results are > water quality standard, the parameters are given values according to Table 2.

The results of parameters that have been compared are added up and classified into four classes (Table 3).

| Table 1. Reservoir Water Quality Assessment Criteria |
|-----------------|-----------------|-----------------|
| Parameter | Unit | Class C |
| Temperature | °C | Deviasi 3 |
| Dissolved Solids | mg/l | 1000 |
| Suspended Solids | mg/l | 400 |
| pH | No unit | 6-9 |
| BOD | mg/l | 6 |
| COD | mg/l | 50 |
| Oil & Fat | µg/L | 1000 |
| Cadmium | mg/l | 0.01 |
| Phosphate | mg/l | 1 |
| Zinc | mg/l | 0.05 |
| Copper | mg/l | 0.02 |
| Lead | mg/l | 0.03 |

| Table 2. Values System for Determining the Status of Water |
|-----------------|-----------------|-----------------|-----------------|
| Total of Parameters | Score | Physics | Chemistry | Biology |
| < 10 | Max | -1 | -2 | -3 |
| | Min | -1 | -2 | -3 |
| | Average | -3 | -6 | -9 |
| ≥ 10 | Max | -2 | -4 | -6 |
| | Min | -2 | -4 | -6 |
| | Average | -6 | -12 | -18 |

| Table 3. Qualification of Water Quality Status [7] |
|-----------------|-----------------|
| Class | Category | Score |
| Class A | Very Good | 0 |
| Class B | Good | -1 until -10 |
| Class C | Quite Good | -11 until -20 |
| Class D | Bad | ≥ 30 |

After obtaining the total value and water class, the data was analyzed by Pearson analysis of correlation, to determine the relationship between parameters [8]. The formula for Pearson correlation is:

\[
rx\, y = \frac{N\Sigma xy - (x)(y)}{\sqrt{N\Sigma x^2 - (x)^2} \sqrt{N\Sigma y^2 - (y)^2}}
\]  

\[rx\, y = \text{Correlation Coefficient} \]  

\[N = \text{Number of Samples} \]

\[\Sigma x = \text{Total score for X variable} \]  

\[\Sigma y = \text{Total score for Y variable} \]
2.2.2.2. Analysis of Reservoir Pollution Loads
Pollution Index Method (IP) was used to determine the relative contamination level to water quality parameters that was allowed [9]. The IP method is based on two quality index. First is the average index, second is the maximum one. Category assessment of water quality as follows: fits with standard quality if the value of IP ≤ 1, lightly polluted when 1 < IP ≤ 5, moderately polluted when 5 < IP ≤ 10, and heavily polluted if value IP > 10 [7].

The first step in calculating IP is comparing Ci, which is the concentration of water quality parameters (i) with Lij, which is the concentration of quality standard parameters, the measurement results obtained.

\[ \frac{C_i}{L_{ij}} \text{ measurement results} = \frac{C_i}{L_{ij}} \]  

If the value of the measurement results < 1, it can be used. If the measured value is > 1, then the new value is determined by the following equation:

\[ \frac{C_i}{L_{ij}} \text{ new} = 1 + P \log \frac{C_i}{L_{ij}} \text{ measurement results} \]  

After the measurement results are obtained, then the average value is calculated as IR and the maximum value is determined as IM. Furthermore, IP formulations was obtained using the following method:

\[ \text{IP} = \sqrt{\left(\frac{IR}{2}\right)^2 + \left(\frac{IM}{2}\right)^2} \]  

2.2.3. Synthesis and Preparation of Recommendations
Synthesis is prepared by using analysis of Strength, Weakness, Opportunity and Threat (SWOT) by comparing between Internal Factors (IFE): Strengths and Weaknesses with External Factor (EFE): Opportunity and Threat. First step is identifying the factors through interview the person who understand the area completely. The interviewees are Ministry of Environment, PT. Jakarta Propertindo, and Pulomas Office Park. Second step is analyzed the factors by quantitative analysis which are carried out by giving the score based on the level of importance from scale 1-4 (1: not important, 2: less important, 3: important, 4: very important) [10]. After that, calculate the score to get the weight to provide the total score and then set the Internal-External Matrix (IE).

3. Results and Discussion
3.1 General Conditions
Special Capital District of Jakarta is the capital of the State of Indonesia, located on the island of Java. Based on Governor’s Decree Number 171 of 2007, the total area of DKI Jakarta Province is 7,639.83 km². Jakarta was crossed by 13 major rivers and 55 reservoirs are scattered in five areas of the city. In 2013, 12 dams of which had been revitalized so it returns to the main function/purpose of reservoirs building. The main problem that often occurs in several urban blue open spaces is the problem of waste management, especially household solid waste. Increased development is one of the causes of the reduction in blue open space that can support the lives of living creature. Blue open space has an important role in flood control by holding back the inflow and reducing the peak flow outflow so that the flow capacity in the downstream will be reduced [11].

3.2 Situational Analysis of Reservoir Environments
The main problem that often occur in reservoirs are garbage and facilities that are not optimal. Ria-Rio reservoir, South Sunter reservoir, and Pluit reservoir are artificial reservoirs, so that the water source only comes from rain cistern. Ria-Rio reservoir is located in East Jakarta with has area of 7.61 ha and depth of 2 m. This reservoir experiencing silting caused by soil erosion. South Sunter reservoir is located in North Jakarta with an area of 5.33 ha and depth of 2 m. Reservoir condition was maintained in 2018 so it can be used for the regional competition of
water skiing. Pluit reservoir is located in North Jakarta with an area of 63.31 ha and depth of 2.31 m. The condition of the reservoir experiences pollution and silting [5].

3.3 Analysis of Reservoir Water Quality

Quality of water reservoirs were analyzed using the physical, chemical, and biological parameters. The data which are used expanding from 2015 to 2018. The quality rating of the water in the reservoir is based on the standard of the raw quality of water class C, Regulation of Government No. 82 Year 2001, allotment of water can be used to breed fresh water fish, farming, and irrigate crops. The results of the assessment based on parameters found that the water quality in the three parts of the reservoir is in class D (bad category). The results of the calculation of total water quality in the three reservoirs can be seen in Table 4 and Figure 3.

### Table 4. Overall Water Quality Classification

| Information | Ria-Rio reservoir | South Sunter reservoir | Pluit reservoir |
|-------------|-------------------|------------------------|-----------------|
| Inlet       | -128 D            | -94 D                  | -112 D          |
| Midlet      | -108 D            | -106 D                 | -130 D          |
| Outlet      | -114 D            | -106 D                 | -112 D          |

![Figure 3. Water Quality Classification Chart](image)

The parameter assessment results are then correlated using Pearson correlation. The conclusion obtained is the significance value of chemical parameters < 0.05 which means it has a significant correlation to the poor quality of reservoir water. Physical and biological parameter value is > 0.05 which means no significant correlation. The results of correlation analysis can be seen in Table 5.
Table 5. Results of Correlation Analysis of Reservoir Water Quality Parameters

|                  | Whole   | Chemistry | Biology | Physics |
|------------------|---------|-----------|---------|---------|
| Whole Pearson Correlation | 1       | 0.934 **  | 0.542   | 0.142   |
| Sig. (2-tailed)   |         | 0.000     | 0.132   | 0.716   |
| N                | 9       | 9         | 9       | 9       |
| Chemistry Pearson Correlation | 0.934 ** | 1         | 0.282   | 0.104   |
| Sig. (2-tailed)   |         | 0.000     | 0.462   | 0.790   |
| N                | 9       | 9         | 9       | 9       |
| Biology Pearson Correlation | 0.542   | 0.282     | 1       | -0.426  |
| Sig. (2-tailed)   |         | 0.132     | 0.462   | 0.252   |
| N                | 9       | 9         | 9       | 9       |
| Physics Pearson Correlation | 0.142   | 0.104     | -0.426  | 1       |
| Sig. (2-tailed)   |         | 0.716     | 0.790   | 0.252   |
| N                | 9       | 9         | 9       | 9       |

**. Correlation is significant at the 0.01 level (2-tailed).

Based on the measurement results, physical parameters do not have a major influence on reservoir water quality. Data shows that biological parameters are found in the reservoir inlet. Chemical parameters are the most influential in lowering the quality of the water reservoir, that is, Biological Oxygen Demand (BOD) is the number of milligrams of oxygen required for the bacteria to oxidize dissolved organic chemicals contained in one liter of water \( [12] \). COD is a measure of the level of pollution by organic matter. Oil and fat are the main components of food that are also widely available in waste water \( [13] \). Based on the results of the test of correlation, it can be concluded that in order to improve the quality of the reservoir water, then the chemical parameters are the first one that must be corrected.

3.4 Pollution Loads Reservoir Water

Pollution index assessment was performed on each reservoir by using the data measurement from 2015 until 2018. The ratings refer to the Regulation of the Government No. 82 of 2001 in accordance with class C water quality standards. The result of the calculation shows that the environmental quality conditions were contaminated. Pollution index values can be seen in Table 6.

Table 6. Reservoir Pollution Index

| Year      | Ria-Kio reservoir | South Sunter reservoir | Pluit reservoir |
|-----------|-------------------|------------------------|----------------|
|           | Inlet  | Midlet | Outlet | Inlet  | Midlet | Outlet | Inlet  | Midlet | Outlet |
| 2015      | 5.39   | 3.24   | 4.81   | 3.85   | 3.50   | 3.38   | 11.86  | 5.18   | 4.85   |
| 2016      | 10.41  | 8.28   | 7.58   | 5.41   | 3.72   | 4.00   | 10.63  | 7.59   | 9.16   |
| 2017 (Period I) | 12.30  | 7.17   | 11.65  | 17.29  | 7.25   | 6.08   | 15.21  | 16.54  | 20.67  |
| 2017 (Period II) | 12.30  | 7.17   | 11.65  | 17.29  | 7.25   | 6.08   | 15.21  | 16.54  | 20.68  |
| 2018 (Period I) | 17.12  | 17.01  | 17.42  | 4.61   | 4.66   | 2.15   | 5.53   | 19.47  | 2.28   |
| 2018 (Period II) | 19.65  | 7.71   | 6.87   | 9.66   | 6.51   | 7.59   | 25.61  | 15.14  | 16.27  |
The measurement results show that the environmental conditions of the three reservoirs are heavily polluted. The results of the pollution index calculation in the Ria-Rio reservoir experience an increase every year (Figure 4). The highest pollution index occurred in 2018 (Period I). South Sunter reservoir index has increased every year, but in 2018 (Period I) the pollution index has decreased (Figure 5). The highest pollution index of South Sunter reservoirs occurred in 2017. Pluit reservoir in 2018 (Period I) experienced a decrease in the inlet and outlet (Figure 6). The highest pollution index in the Pluit reservoir occurred in 2018 (Period I).

Pollution that occurs in the three reservoirs can be caused by many things, one of them is the habit of the community that still discharges household waste into water bodies. The pollution index value is also influenced by sampling time. The dry season will have a high pollution index value because reservoir water will get worse due to slight rainwater dilution.

3.5 Strength, Weakness, Opportunity, Threat (SWOT) Analysis

Strength, Weakness, Opportunity, dan Threat (SWOT) analysis is done by identifying internal and external factors of the reservoir based on the results of discussions with the resource persons. The resource persons are Ministry of Environment, PT. Jakarta Propertindo, and Pulomas Office Park. Determination of these factors is done by direct observation and interviews. The stages carried out in this analysis include the identification of factors, factor assessments, the creation of an Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) matrix, as well as an alternative ranking of strategies.

3.5.1. Identification of Internal Factors

The strength factors are the strategic location of the reservoirs, good security and accessibility, the reservoir is also used as a gathering place. The reservoir also functions as a provider of

![Figure 4. Ria-Rio reservoir](image)

![Figure 5. South Sunter reservoir](image)

![Figure 6. Pluit reservoir](image)
water, but is still not widely used by the community. The weakness factors of the reservoirs show the means and infrastructure that is not well-managed, the lack of attraction point, the management that is still not evenly distributed, pollution of the environment caused by the public.

3.5.2. Identification of External Factors
The opportunity factor that exists and has the most influence on the sustainability of the reservoir is the amount of people's desire to visit. By bring up the leisure appeal, regions which can be developed, the cooperation with private sector, and increase of government income and become national assets are the other opportunities. Threats that are contained in reservoirs such as: a lack of awareness of the public in maintaining the environment, the emergence of traders around the reservoirs, and leading to competition with similar objects.

3.5.3. Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) Matrix
The results of the total score of internal factors and external factors are mapped on the internal-external matrix (IE). IE Matrix has nine quadrants to determine management strategies that is required. Based on the calculation score from from Ministry of Environment, PT. Jakarta Propertindo, and Pulomas Office Park, total IFE score is 2.39 and the total EFE score is 2.47.

The total value of each condition is mapped to the Internal - External (IE) Matrix (Figure 7). Based on the total score of IFE and EFE, it is known that the three reservoir conditions are in Quadrant V that indicates hold and maintain strategy position that focusing on maintaining and developing the current landscape.

Figure 7. External Internal Matrix

3.6 Alternative Strategy
The matrix creation was done by connecting mutual elements of SWOT. There are eight alternative strategies that are produced. The strategy is arranged based on the state of internal and external factors. The strategy of determining the ranking is based on the value of the analysis.

1. Development of zoning division of space to be more organized and in accordance with its function

   The division of zones in the region was required in order to be able to function as it should. The three reservoirs have many functions for the surrounding community, such as gathering, fishing, exercising, doing social activities and others. Activities that can be carried out in the reservoir must be balanced with the availability of zones for activities. This is necessary so that the environment around the reservoir can be maintained and has sustainability. The zoning division may begin with the area that may or not be used by public. Integrated vegetation planning can also be done in the area around the reservoir [14].
2. Increase the promotion of the reservoir as one of the travel objects
   The three reservoirs have the potential as a tourist attraction, where the South Sunter Reservoir held a fishing competition, this reservoir is also used as an area for water skiing. Having located in the middle of urban areas makes the reservoir within easy reach. Reservoir as a tourist attraction also will indirectly increase the country's income and the surrounding community. If the community is directly involved in reservoir development, public awareness of the reservoir's environmental cleanliness will also increase.

3. Empowering local communities towards the importance of reservoirs
   The low water quality and high pollution loads occur due to domestic waste originating from human activities. Event management which involve the community can improve the public awareness of the reservoirs' importance. Therefore, the active role of the community has a significant share in the sustainability of reservoir.

4. Waste Water Garden
   Waste Water Garden or WWG is domestic wastewater treatment using soft rooted plants as filter media [15]. The waste treatment process using WWG technique requires plants, microbes, sunlight and gravity to move waste water so that it can be reused. Illustration of the form of waste water garden can be seen in Figure 8 [16].

   ![Figure 8. Illustration of the form of waste water garden](image)

5. Improvement of facilities and infrastructure by the government and managers
   Improving and increasing the supporting infrastructure, such as building water rides, sports center, and other supporting facilities. Besides that, repairing damaged roads in the reservoir can facilitate access for visitors. In addition to increasing facilities support, improvements to the ones that already exist are very important in order to improve the quality and the cleanliness of the environment.

6. Increasing supervision that are conducted routinely and periodically
   Implementation of supervision efforts in the Ria-Rio reservoir, South Sunter reservoir, and Pluit reservoir are still not optimal enough. These people also dispose of household waste directly into the water body. The lack of supervision by government and managers happens because of several constraints, such as lack of manpower. In addition, the government or the manager has not been strict to impose sanctions/penalties on people who pollute or damage the environment around the reservoir.

7. Development of fisheries potential, history and education
   One of the biggest potential is in the field of fisheries, where every year there are stocking of fish seed by the Government of DKI Jakarta. Besides that, the three manmade reservoirs also has varying historical value. The environment around the reservoir can also provide appeal for visitors who come. One of the examples is to give the nametag on every tree and animal that is found around the reservoir.

8. Reservoir management plan by the government by giving rewards and punishment to the public
Make strategic management of the reservoir by the government and the manager by giving reward or punishment for the public and visitors. This system really needs contributions from the government and managers as the authority in reservoir management. In giving reward or punishment the government and the managers are not allowed to look at caste or degrees so that every individual has the same awareness of the reservoirs’ importance. This strategy can also reduce pollution in reservoirs by providing punishment for anyone who dumps waste into the reservoirs.

4. Conclusion
Based on the results of identification and calculation of water quality in reservoirs, it shows that the three reservoirs have class D water quality (poor category). Water quality in the three reservoirs is not in accordance with its designation, where the reservoir should be in class C, which is intended as a cultivation of freshwater fish, farming, dan to irrigate crops. Chemical parameters are parameters that have a major influence on the poor quality of reservoir water, especially in BOD, COD, oil & fat, and zinc.

The pollution load that occurs in all three reservoirs is at a heavily polluted level. Although there are years where the index of pollution of reservoirs located at the level of lightly to moderately polluted. Based on the monitoring results, the main source of pollution that occurs in the three reservoirs is domestic waste originating from community activities. Fecal coliform and total coliform become parameters that have a major influence on the contamination of reservoir water. Poor reservoir water quality and high levels of pollution in reservoirs can also be caused by sampling in the dry season. The dry season causes the reservoir water quality to decrease due to reduced dilution by rainwater.

Determine internal and external factors found in the three reservoirs. Then these factors produce IFE and EFE scores, it is known that the factors that influence reservoir sustainability are in Quadrant V (hold and maintain strategy) based on SWOT analysis. Based on this, the management strategies that can be implemented in all three reservoirs to be useful for the community was obtained. The resulting strategic management focus on the chemical parameters, because based on the analysis of the quality of water, chemical parameters are the one that provide the highest contribution in lowering the quality of the water.

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