Study of The Quality and Status of Water Quality on Reservoir Water Management Efforts Using a Dynamic System Approach (Case Study: Bozem Morokrembangan)

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Abstract. Morokrembangan bozem is one of the largest bozem in Surabaya with an area of ± 78.69 Ha which is designated as a flood controller in the city of Surabaya. However, the condition of Morokrembangan bozem experienced a decrease in water quality due to the inclusion of pollutant loads originating from waste discharges carried by the drainage channels entering Bozem Morokrembangan. The research can be useful for Surabaya Government to return the function of Morokrembangan bozem. The results showed that the water quality status of Morokrembangan bozem was moderately polluted with the highest pollution load coming from Kali Purwodadi with COD concentration of 28,283 mg / L, BOD₅ 7,491 mg / L, Ammonia 6,18 mg / L, and Total Phosphate concentration of 6.18 mg / L. The total pollution load that enters the Bozem comes from settlements averaging 99.87 Tons/year and industry averages 0.0028 Ton/year with a total waste load based on sub-dynamic simulation models an average of 26,923 Tons/year. Management efforts can be carried out using an optimistic scenario by building a communal WWTP in the Krembangan District that does not yet have a WWTP and implementing a 3R program to reduce solid waste (garbage), make efforts to manage environmentally friendly land, and increasing community participation.

1. Introduction
Morokrembangan bozem, which is located in the North Surabaya area, has a function as a flood controller in the city of Surabaya or accommodates river flow before heading out to sea. The condition of Morokrembangan bozem in the south is very smelly, cloudy, and black in color. This condition is caused by the deposition of solids originating from domestic wastewater throughout the bozem’s catchment area. From the water quality of Morokrembangan bozem, it can be obtained the status of the water quality using the Pollution Index (IP) method. This method can directly link the level of pollution with whether or not rivers can be used for certain uses and with certain parameter values (Awalunikmah, 2017). According to Sterman (2000), the dynamic system model approach can continuously illustrate the characteristics of a system and help in forming a flight simulator management, computer simulation model, and designing more effective policies. The reason for using this dynamic system is reinforced by the statement from Pruyl (2013) which explains that the concept of dynamic systems is not only used as based on the interaction between components through a comprehensive understanding, it can also be used as an alternative approach in making a decision.
2. Method
This study is using a dynamic systems approach to produce decisions on the management efforts of Morokrembangan bozem. In a dynamic system, there is a Causal Loop Diagram (CLD) depicting a cause-effect relationship that occurs in a system positively or negatively between variables so that it can be developed as a sub-model for efforts to manage the quality of the waters of Morokrembangan bozem. Based on the dynamic system sub-model, it can be obtained the pollution load that enters Morokrembangan bozem. Causal Loop Diagram of this study can be seen in Figure 1.

![Causal Loop Diagram](image)

Figure 1. Causal Loop Diagram of Bozem Morokrembangan.

3. Result and Discussion

3.1. Water Quality Bozem Morokrembangan

3.1.1. Temperature. According to Government Regulation No.82 of 2001 on class III water quality standard, the water temperature has a standard deviation of ± 3. This limit means that if the normal temperature of water in class III is 29°C, the criteria for class III water limits the water temperature to the range of 26°C - 32°C. From Figure 2, the temperature conditions of the Morokrembangan bozem waters range from 29°C - 30°C. So, it can be concluded that the water temperature of Morokrembangan bozem still meets the water temperature standards based on Class III, which is between 26°C - 32°C.

![Temperature Chart](image)

Figure 2. Temperature of Bozem Morokrembangan.
3.1.2. **pH.** Generally, rivers, lakes, and water bodies have a pH value of around 6 - 8.5, (Vigil, 2003). Based on class III water quality standards with a pH value range ranging from 6 - 9, it means that the pH concentration in Morokrembangan bozem ranging from 7.1 - 8.0 meets the quality standards. Low pH also affects dissolved oxygen (DO) levels in the water, low pH causes low dissolved oxygen, consequently, the water quality is not good. Based on the results of the analysis in Figure 3, it can be concluded that the pH of the water meets the standard of acidity (pH) in class III with a value between 7.1 - 8.0.

![Figure 3. pH quality of Bozem Morokrembangan.](image)

3.1.3. **Dissolved Oxygen (DO).** Dissolved oxygen is the main source of aquatic life that can come from the atmosphere and the photosynthetic process of aquatic plants. In Figure 4, it can be seen that the DO conditions in the waters do not meet the Class III water quality standard, namely 3 mg/ L according to the Environmental Government Regulation. The content of biodegradable organic compounds with high concentrations can cause low oxygen content in waters (Slamet, 2016). So, it can be concluded that the DO of Morokrembangan bozem water does not meet the Class III water quality standard.

![Figure 4. Dissolved oxygen quality of Bozem Morokrembangan.](image)
3.1.4. Chemical Oxygen Demand (COD). Based on Government Regulation No. 82 of 2001, the quality standard for class III COD water is 50 mg/L. The analysis results of the COD concentration based on Figure 5 show that the COD concentration fluctuates every day ranging from 49 mg/L - 242 mg/L. The increase in COD concentration in Morokrembangan bozem is due to domestic waste disposal which is very concentrated on the bottom of the Bozem due to sedimentation (Widyana, 2013). Thus, it can be concluded that the COD concentration does not meet the class III water quality standard.

![Figure 5. The chemical oxygen demand of Morokrembangan bozem.](image)

3.1.5. Biochemical Oxygen Demand (BOD5). Biochemical oxygen demand is the amount of oxygen required by aerobic microbes to break down organic matter. BOD5 only describes organic matter that can be biodegradable (Iriadi, 2015). Based on Government Regulation No. 82 of 2001, the quality standard for BOD class III is 6 mg/L. Figure 6 shows the range of BOD5 values in the Bozem ranging from 6.60 mg/L - 53.17 mg/L. The graphic image indicates that the level of pollution that occurs in Morokrembangan bozem is quite high because it exceeds the quality standard limit set in the Minister of Environment and Forestry Regulation No. the number of latrines leading directly into the bozem (Survey and Interview Results, 2020).

![Figure 6. Biological Oxygen Demand of Bozem Morokrembangan.](image)
3.1.6. Ammonia. Government Regulation No. 82 of 2001 stipulates the quality standard for ammonia at class III water quality standards, which is 0.02 mg/L. The results of the analysis in Figure 7 show that the ammonia concentration does not meet the class III water quality standard. This can be seen at the highest concentration of ammonia at point 2 which is Kali Purwodadi at 4.76 mg/L and point 1 which is Kali Greges at 4.72 mg/L followed by the concentration at point 5 is 4.23 mg/L, point 6 is 4.11 mg/L, point 7 is 4.08 mg/L, point 4 is 3.92 mg/L, point 8 is 3.89 mg/L and point 3 is 3.58 mg/L. The high concentration of NH\textsubscript{3} makes it possible for the channel to carry a lot of material including feces from households in the Morokrembangan bozem area which leads directly into the Bozem.

![Figure 7. Ammonia Concentration of Bozem Morokrembangan.](image)

3.1.7. Total Phosphate. According to the Environmental Government Regulation No. 82 of 2001, stipulates the water quality standard for class III, 1 mg/L. The PO\textsubscript{4}\textsuperscript{3-} concentration in Morokrembangan bozem fluctuated, at point 4 which is in East Kalianak has a high concentration of 1.68 mg/L and is followed by point 3 with a concentration of 1.64 mg/L. The concentration of total phosphate in Morokrembangan bozem fluctuated at another point with an average concentration at point 1 of 1.44 mg/L, point 2 of 1.56 mg/L, point 6 of 1.37 mg/L, point 7 amounted to 1.52 mg/L, and point 8 was 1.58 mg/L. Thus, it can be concluded that the total phosphate concentration of Morokrembangan bozem water has not met the Class III water quality standard. Morokrembangan bozem’s total phosphate content can be seen in Figure 8.

![Figure 8. Total Phosphate Concentration of Morokrembangan Bozem.](image)
3.2. Determination of Water Quality Status

Determination of water quality status is determined based on water quality data obtained from laboratory and field analysis. Determining the status of water quality using a different formula depending on the $P_{ij}$ price of each water quality parameter. IP is determined from the maximum resultant value and the average value of the per-parameter concentration ratio to the quality standard value. Analysis of the pollution index (IP) uses the following formula:

$$IP = \sqrt{\frac{\left(C_i / L_j\right)_M^2 + \left(C_i / L_j\right)_R^2}{2}}$$ (1)

The results of the analysis of the water quality status of Morokrembangan bozem based on this formula can be seen in Table 1.

| Sampling Points | IP Score |
|-----------------|----------|
| Day 1 | Status Day 2 | Status Day 3 | Status Day 4 | Status Day 5 | Status Day 6 | Status Day 7 | Status |
| 1 | 4.7 | lightly polluted | 6.4 | moderately polluted | 8.7 | moderately polluted | 8.8 | moderately polluted | 9.3 | moderately polluted | 8.7 | moderately polluted | 7.8 | moderately polluted |
| 2 | 7.7 | moderately polluted | 6.5 | moderately polluted | 9.4 | moderately polluted | 8.0 | moderately polluted | 6.9 | moderately polluted | 8.9 | moderately polluted | 7.9 | moderately polluted |
| 3 | 4.7 | lightly polluted | 6.7 | moderately polluted | 8.5 | moderately polluted | 8.6 | moderately polluted | 9.0 | moderately polluted | 8.5 | moderately polluted | 6.7 | moderately polluted |
| 4 | 7.3 | moderately polluted | 7.0 | moderately polluted | 8.9 | moderately polluted | 8.4 | moderately polluted | 9.1 | moderately polluted | 8.5 | moderately polluted | 8.0 | moderately polluted |
| 5 | 6.3 | moderately polluted | 5.6 | moderately polluted | 8.3 | moderately polluted | 9.0 | moderately polluted | 9.1 | moderately polluted | 7.9 | moderately polluted | 5.3 | moderately polluted |
| 6 | 7.0 | moderately polluted | 7.2 | moderately polluted | 8.8 | moderately polluted | 9.1 | moderately polluted | 9.0 | moderately polluted | 8.3 | moderately polluted | 6.8 | moderately polluted |
| 7 | 5.8 | moderately polluted | 5.9 | moderately polluted | 9.0 | moderately polluted | 8.8 | moderately polluted | 9.0 | moderately polluted | 8.5 | moderately polluted | 7.3 | moderately polluted |
| 8 | 6.3 | moderately polluted | 6.4 | moderately polluted | 8.7 | moderately polluted | 9.0 | moderately polluted | 8.4 | moderately polluted | 7.8 | moderately polluted | 6.8 | moderately polluted |

3.3. Morokrembangan Bozem Water Quality Sub Model

3.3.1. Sub Model of Bozem Inlet Pollution Load. Inlet pollution load sub-model is prepared based on the pollution parameters, namely BOD, COD, Ammonia, and Total Phosphate. Figure 9 describes the sub-model of the pollution load from the four inlets, namely Kali Greges, Kali Purwodadi, East Kalianak Channel, and Boezem Outlet. The total pollution load that enters Boezem Morokrembangan with the highest parameters COD of 143,863 tons/year, BOD5 of 23,808 tons/year, ammonia of 2,667 tons/year, and total phosphate of 1,762 tons/year.
3.3.2. Settlement Sub Model. The population around Morokrembangan bozem is used as the “Stock” variable, with the initial population simulated using data in 2011 of 124,797 people. The rate of population change is a variable "flow" with the population growth fraction being a "converter" variable with a figure of 0.000057 obtained from the average population growth in the 2011 - 2018 period. The total pollution load generated from residential waste disposal is in 2022 of 99,868 tons/year. The sub-model of residential pollution load using “flow” push is used to calculate the potential pollution load (PBP) of a settlement. Settlement PBP is calculated using the formula:

\[ \text{Domestic PBP} = \text{total population} \times \text{FE} \times \text{REK} \times \text{transfer of expenses} \quad (2) \]

Based on the results of the analysis of the greatest potential for contamination in COD parameters of 1,707 tons/year, BOD5 of 838 tons/year, ammonia of 5.6 tons/year, and total phosphate of 5.3 tons/year. The sub-model of potential residential pollution can be seen in Figure 10.

3.3.3. Industry Sub Model. The wood industry waste sub-model uses the total wood industry as a “stock” of 14 industries. The industrial growth rate is a variable of “flow” and the fraction of industrial growth is taken from the average industrial growth as a "converter" variable with a number of 0.0025. The amount of pollution caused by industrial waste disposal is 0.0028 tons/year. The potential industrial waste pollution load is calculated using the formula:

\[ \text{PBP Industry} = \text{Number of Industry} \times \text{FE} \times \text{REK} \times \text{TB} \quad (3) \]
The results of the analysis in Figure 11 show the greatest potential for COD contamination of 3.31 tons/year, BOD$_5$ of 2.21 tons/year, NH$_3$ of 0.20 ton/year, and total phosphate of 0.1 ton/year.

3.4. Morokrembangan Bozem Water Quality Sub Model

3.4.1. Management Efforts with Technical Aspect. Figure 12 shows the rate of increase in the total pollution load caused by the residential waste load in the simulation results of 99.84 tons/year. Then the increase in pollution load caused by industrial waste is produced by 0.0028 ton/year. At the end of the simulation, the total pollution load is obtained with an average concentration of 26,932 tons/year with an incoming pollution load flow of 91.55 tons/year.

3.4.2. Management Effort Scenarios. Based on Figure 13, it can be explained that the pessimistic scenario results in a decrease in the total pollution load of 26,932 tons/year. The simulation with the moderate scenario resulted in a decrease in the total pollution load of 140.52 tons/year due to the reduction of waste by WWTP by 30% and community participation by 45%. Meanwhile, the optimistic scenario produces a pollution load of 122.89 tons/year. This is due to the reduction of waste by IPAL.
by 30% with an increase in community participation by 70%. The results of the total pollution load from each scenario show that the lowest pollution load is the simulation in the optimistic scenario.

![Simulation Scenario](image)

**Figure 13.** Simulation of Pollution Load Scenarios.

3.4.3. **Management Efforts with Environmental Aspects.**

- The decrease in water quality. The decrease in the quality of Bozem waters is caused by community activities such as latrines which directly flow into the inlet channel or the bozem. Therefore, the effort that needs to be done is to provide IPAL facilities to reduce this waste so that it does not affect the Bozem aquatic environment. Furthermore, in reducing the environmental impact caused by industry, it is necessary to make management efforts related to environmental permits related to the disposal of industrial waste into waters so that the quality of wastewater is 20% tighter than the industrial BMAL.

- Eutrophication, the north side of the bozem has a high level of eutrophication due to the entry of waste originating from the south side of the bozem. This effort can be carried out structurally by building WWTP to reduce a load of nutrient compounds, dredging the bottom sediment of the bozem, and carrying out an environmental friendly land management. Meanwhile, the nonstructural effort is by increasing public awareness.

- Environmental health, pollution of the waters of Morokrembangan bozem has an impact on environmental health, one of which is garbage that has accumulated in Bozem waters which causes silting at the bottom of the bozem and causes odors to the surrounding area. Management efforts to improve environmental health at Morokrembangan bozem can be done by implementing the 3R program and increasing community participation and awareness to reduce waste.

4. **Conclusion / Recommendation**

Morokrembangan bozem has moderate pollution status due to the pollution load that enters the Bozem with a total pollution load of 26,923 tons/year with residential pollutant sources of 99.87 tons/year and sub-industrial pollutants of 0.0028 tons/year. In making efforts to manage Morokrembangan bozem, it is necessary to maximize efforts to dredge mud on the bottom of the bozem by providing dredging facilities, implementing the 3R program, and increasing community participation in supporting the management of Morokrembangan bozem.

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