Constructed floating wetland with mooring system technology to improve water quality in Gedebage Reservoir, Bandung

Y M Hidayat\textsuperscript{1}, W Herwindo\textsuperscript{1} and S Bachri\textsuperscript{1}

\textsuperscript{1} Research Center For Water Resources, Ministry of Public Work and Housing, Jl. Ir H. Juanda No. 193, Bandung 40135

yuliya96119@gmail.com

Abstract. Gedebage Reservoir is built as retention ponds, in the future it will be developed into an integrated religious tourism area, so that the quality of water reservoir must suitable for tourism. Constructed floating wetland with mooring system, besides being used as water quality improvement technology, it will also add aesthetic value. The purpose of this study was to identify the possibility of applying the constructed floating wetland in the Gedebage Reservoir area. This study uses secondary data to determine the design parameters and characteristics of water sources, design parameters are used for location recommendations, while the characteristics of water sources are to determine the accuracy of the technology used. The result shows that the placement of a floating wetland technology with mooring system in Gedebage reservoir has meets the requirements of design parameters than in a biological filter channel. The characteristics of the Gedebage Reservoir water source that have not met requirements consist of several parameters, namely: Ammonia, Chlorine, Mn, DO, Sulfide, Detergent, Oil and Fat, Cd, Pb, DO, BOD, COD, Fecal Coliform and Total Coliform. Whereas, based on the ratio of BOD5 / COD in the dry season that ranged from 0.25 indicating that the water had been toxin, so that it would disrupt the development of biofilms, so in addition to wetland, a pre-treatment was needed before entering the reservoir.

1. Introduction

Gedebage reservoir is located in Gedebage Sub-district, Bandung, basically used to cope the flood of Cinambo River in Citarum Watershed. With the reservoir, flood-prone locations will have clearly boundary, so that the water level, discharge, and volume of water that must be removed can be controlled. The land used as a reservoir is limited by the embankment so that water from outside cannot supply. The reservoir is expected to reduce the impact of flooding that often occurs in Gedebage.

Besides reducing the impact of flooding, the Gedebage Reservoir area will be developed into integrated Religious Tourism with the construction of the Al-Jabbar Mosque and the landscaping surrounding area. The development of the reservoir as a tourism area cause the water quality must support to these activities, so that the water quality in reservoir should refer to water criteria for tourism.

The Gedebage reservoir is supplied by Cinambo River which is contaminated as a result of activities in upstream, both from domestic waste, agricultural, and industry. Contaminated water such as nutrients eq. excessive nitrogen and phosphorus, and other organic materials cause the low value of dissolved oxygen (DO), combined with high levels of BOD, COD, and fecal coliforms bacteria also the disruption of the lives of aquatic ecosystems. In order to prevent the degradation of water quality...
in the reservoir, it is necessary to do an integrated watershed management. It is also a special concern of the Government to overcome the pollution and damage of the Citarum Watershed which is confirmed through Presidential Regulation 15 of 2018 concerning the Acceleration of Citarum Watershed Pollution and Damage Control [1]. Referring to the regulation Citarum as the longest river in West Java and the dirtiest in the world should be solve whole problem in 7 years.

In supporting for the Presidential Regulation above and to improve water quality, it is necessary to improve water quality in Gedebage Reservoir because it is located in the Citarum Watershed through a technological approach.

Constructed floating wetland with mooring system is a technological innovation produced by the Research Center of Water Resources which will be applied to control water pollution that supply into Gedebage Reservoir. This innovation technology is developed into two technologies namely floating wetland technology and biocord technology.

Floating Wetland is the development of constructed wetlands which is placed flood and quiet stream [2], and as a buffer on the waterfront [3], consisting of plant vegetation grown above media with floating structures above the water surface [4]. In the floating wetland system, the plant stem is above the water surface, the roots grow downward in the water column through growing media, so the plants take nutrients directly from the water column [5].

Biocord is a technological innovation from Bishop Water to increase surface area so that biofilms are formed faster. The results of previous studies, biocords can reduce Suspended Solid by 87.2%, COD, NH3-N, TN, and TP respectively at 19.4-34.4%, 55.2-74.0%, 46.2-55.9%, and 13.1-18.5% [6]. Biocords are developed as mooring system as part of floating wetlands.

Based on the description above, the purpose of this study was to identify the possibility of applying a floating wetland in the Gedebage Reservoir area.

2. Methodology
The study was conducted from August 2018 - April 2019. The research location was located in Gedebage Reservoir, Gedebage Sub-District, Bandung. This study attempts to analyze the possibility of a constructed floating wetland technology with mooring system applied. The data in this research were obtained from secondary data in Citarum River Basin Organization (RBO) and Environmental Services Agency in Bandung.

2.1. Research data
Data related to the location study consisted of: site plan for the Gedebage Reservoir construction, cross section, detailed design which contains topographic analysis, geology, hydrology, storage capacity and simulation pattern. Data for water resources characteristics consist of water quality measurement in Cinambo River.

2.2. Location
Location assessment criteria are based on analysis of the wetland design parameters. These parameters consist of water depth, Hydraulic Retention Time (HRT), and Surface Coverage and Hydraulic Loading Rate. Some references that can be used are as follows:

- Water depth [7-11]
- Hydraulic retention time [8,12,13]
- Surface Coverage [7-10, 14]
- Hydraulic Loading Rate [7, 8, 10, 15]

2.3. Analysis of water quality characteristics
The water quality criteria is refer to Governmental Regulation 81 of 2001 for Class II. Assumptions are made because the future of Gedebage Reservoir will be used as an integrated religious attraction along with the presence of the West Java Grand Mosque.
2.4. Technology selection analysis
The choice of technology is based on the location that has been obtained with conformity to the design parameters and water quality characteristics to be achieved. This analysis determines the treatment of constructed floating wetlands with mooring system in a single treatment or combination with pre-treatment.

3. Results and discussion

3.1. Study

3.1.1. Constructed floating wetland with mooring system placed on channels for biological filters.
Study have been carried out on the detailed design of Reservoir Construction (Figure 1), according to the request of Citarum RBO carried out on the channel originally intended for biological filters. The biological filter is a winding channel of 200 - 250 m, width 5 m, which is made with soil excavation where the left and right sides of the channel are for plants commonly used for constructed wetland. The construction of this biological filter is expected that the water before reaching the reservoir has a longer contact time, so that there will be an improvement in water quality when it reaches the reservoir, adding that the emergent plant in both channels will improve the quality of the channel. This floating wetland technology will replace the biological filter originally planned.

![Figure 1. Gedebage Reservoir Planning Concept](image)

Based on the position of the channel level contour in Gedebage Reservoir, the channel depth is still possible, based on water depth on the channel about 1 m. The water depth in the constructed floating wetland is determined based on the maximum length of the root of the plant used [7-10]. The water depth referenced is a minimum of 0.8 m [11], with the aim that the plant roots do not reach the lower zone. If the roots reach the bottom of the root zone will stick and began to take root in the soil or sediment that settles so feared when there are fluctuations in the water then floating wetland will be drawn down and sink [15].

The contact time between pollutant and floating wetland needs to be maximized for optimal processing results [12]. The calculation results show Hydraulic Retention time (HLR) on the channel around 12,500 seconds or 0.14 days. This time is too short, so to increase HRT can be by deepening the channel. However, to deepen the channel is not possible with conditions in the field. The results of
previous studies showed that the higher the value of HRT, the greater the efficiency of TP, but not for TN [13]. Other studies recommend maximum HRT for floating wetland is 15 days [8]. Floating Wetland efficiency processing decrease in surface coverage of more than 50% [7-10], but according to other studies 5% surface coverage has been able to process significant nutrients in time (HRT) 15 days with phosphate pollutant concentration of 1 mg/l and Nitrate 3 mg/l [14]. Surface coverage greater than 5% is required when HRT is less than 15 days so surface coverage is recommended between 5-50%, because if it is too high it is feared to cause anoxic conditions in the water body [15]. The surface coverage of 50% on the channel is still possible, because the HRT results are less than 15 days.

Floating wetlands processing efficiency is inside Hydraulic Loading rate (HLR) 0.1 - 0.3 m³/m² [15], based on charts that are processed from various types of research [7, 8, 10]. Calculations show the HLR in a biological filter channel 1 m³/m², a larger HLR indicates that processing with a floating wetland is less effective.

The placement of a floating wetland in a biological filter channel does not meet the design parameter requirements, because of the 4 parameters, the HLR does not meet the requirements, HRT is too short and does not allow it to expand or deepen the channel.

3.1.2. The constructed floating wetland in reservoir Gedebage. Construction of the Gedebage Reservoir as of December 2018 has been completed, at the end of January 2019 impounding has been carried out. After the implementation of the development it turned out that something had changed in the concept of planning, namely the channel for biological filters did not become built. The reservoir that has been built has an area of 7.2 hectares, based on the detailed design data, Gedebage Reservoir has a reservoir volume of 263,524.00 m³. The calculation results show Hydraulic Retention time (HRT) on the channel around 1, 5, 25 days if rounded 15 days. The time is good enough for a maximum HRT for floating wetland.

Surface coverage of 5% is able to process nutrients that are significant in time (HRT) of 15 days with pollutant concentrations of phosphate is 1 mg/l and nitrate 3 mg/l [14], so as to surface coverage of wetland floating alone, simply by 5% because the HRT has been 15 days. The addition of mooring system, which can expand the surface so that the biofilm attachment occurs faster, is assumed to be able to reduce the area so that surface coverage can be reduced from 5%.

The calculation shows that the HLR in the Gedebage Reservoir is 36.6 m³/m², the HLR is greater than the Hydraulic Loading rate (HLR) of 0.1 - 0.3 m³/m² reference [15], based on the graphs processed from various types of research [7, 8, 10]. Although this value is greater than the reference HLR, it is still possible, because there is no further research on the effect of HLR on FTW processing efficiency [15]. Reference 0, 1 - 0.3 m³/m² is only based on a regression of the other HLR values that have been done [7, 8, 10].

Placement of a floating wetland at Gedebage Reservoir still meets design parameter requirements, so the application of floating wetlands is more precisely placed in Gedebage Reservoir.

3.2. Water quality characteristics

The results of the quality analysis obtained from secondary data from several stake holders can be seen in Table 1. Specific quality of the Cinambo River originating from the Environmental Services Agency was taken from one data from the highest data series (dry season conditions), and data taken from the downstream near the Gedebage Reservoir, from the upstream-middle-downstream data series.

Data from the Citarum RBO taken in the rainy season. Analysis of the planner consultant data shows that the water quality of the Cinambo River still meets the Class II in Governmental Regulation 81 of 2001 water criteria, but for DO, BOD, COD, Fecal Coliform and Total Coliform parameters still do not meet. The results of the analysis of the data on the detailed design show that several parameters that have met the requirements include: Cd, Pb, DO, BOD and COD. The results of the analysis of data from the Environmental Services Agency show that parameters that did not meet the requirements included: Ammonia, Chlorine, Mn, DO, sulfide, detergent, Oil and Fat, BOD, and COD.
Table 1. Water quality of the Cinambo River

| Parameter                        | Unit     | Criteria Clas II (Gov. Reg. 81 of 2001) | Data of Environmental Service Agency | Data of Citarum RBO | Data of DED | Sample Number |
|----------------------------------|----------|----------------------------------------|--------------------------------------|---------------------|-------------|---------------|
|                                  |          |                                        |                                      |                     |             | I            | II           | III          | IV          |
| Temperature                      | °C       |                                        |                                      |                     |             | 27.5         | 28.1         | 28           | 27.5        |
| TDS                              | mg/L     | 1,000                                  |                                      | 510                 | 345          | 387          | 525          | 488          | 447         |
| TSS                              | mg/L     |                                        |                                      |                     |             | 43           | 27           | 17           | 28          |
| DHL                              | mhos/cm  | 2,250                                  |                                      | 1,018               | <0.05797     | <0.05797     | <0.05797     | <0.05797     | <0.05797     |
| Hg                                | mg/L     | 0.001                                  |                                      | <0.0004             | -            | -            | -            | -            | -           |
| Ammonia                          | mg/L     | 0.02                                   |                                      | 0.0136              | -            | -            | -            | -            | -           |
| As                                | mg/L     | 0.05                                   |                                      | <0.0021             | -            | -            | -            | -            | -           |
| Ba                                | mg/L     | 1                                      |                                      | <0.01741            | -            | -            | -            | -            | -           |
| Fe                                | mg/L     | 5                                      |                                      | 0.4652              | <0.021       | -            | -            | -            | -           |
| Boron                            | mg/L     | 1                                      |                                      | <0.00726            | 0.392        | 0.07232      | 0.14681      | 0.11408      | 0.09661     |
| Cd                                | mg/L     | 0.01                                   |                                      | <0.00928            | <0.032       | 0.05118      | 0.07066      | 0.07075      | 0.04317     |
| Chloride                         | mg/L     | 600                                    |                                      | 86.43               | 52.2         | -            | -            | -            | -           |
| Chlorin                          | mg/L     | 0.003                                  |                                      | 0.05                | -            | -            | -            | -            | -           |
| Cobalt                           | mg/L     | 0.2                                    |                                      | <0.0033             | -            | 0.00747      | 0.0114       | 0.01059      | 0.00623     |
| Chromium Heksavalen              | mg/L     | 0.05                                   |                                      | 0.0136              | <0.0012      | <0.0154      | <0.0154      | <0.0154      | <0.0154     |
| Mn                                | mg/L     | 0.5                                    |                                      | 0.57199             | 0.21         | -            | -            | -            | -           |
| Ni                                | mg/L     | 0.5                                    |                                      | <0.01485            | -            | -            | -            | -            | -           |
| Nitrate                          | mg/L     | 129,530                                |                                      | 4.5911              | 5.7765       | 6.1042       | 7.4485       | -            | -           |
| Nitrite                          | mg/L     | 0.06                                   |                                      | 0.0901              | 0.003        | -            | -            | -            | -           |
| DO                                | mg/L     | >3                                     |                                      | 2.65                | 1.2          | 2.6          | 1.5          | 3.2          | 2.5         |
| Total Phosphate                  | mg/L     | 0.2                                    |                                      | 0.0402              | 0.198        | 0.1442       | 0.0747       | -            | -           |
| pH                               |          | 6.0-9.0                                |                                      | 7.445              | 7.6          | 7.3          | 7.33         | 7.28         | 7.02        |
| Selenium                         | mg/L     | 0.01                                   |                                      | <0.0013             | -            | <0.01797     | <0.01797     | <0.01797     | <0.01797     |
| Zn                                | mg/L     | 0.02                                   |                                      | <0.01894            | 0.006        | <0.01852     | <0.01852     | <0.01852     | <0.01852     |
| Cyanide                          | mg/L     | 0.02                                   |                                      | <0.005              | <0.003       | -            | -            | -            | -           |
| Sulfate                          | mg/L     | 400                                    |                                      | 280.62              | 12.4         | -            | -            | -            | -           |
| H₂S                              | mg/L     | 0.002                                  |                                      | 0.0181              | -            | -            | -            | -            | -           |
| Cu                                | mg/L     | 0.02                                   |                                      | <0.00819            | <0.013       | <0.00527     | 0.0062       | 0.00957      | 0.00618     |
| Pb                                | mg/L     | 0.03                                   |                                      | <0.01039            | <0.025       | 0.06717      | 0.08193      | 0.08039      | 0.06294     |
| Mercury                          | mg/L     | 0.001                                  |                                      | <0.01320            | <0.01320     | <0.01320     | <0.01320     | <0.01320     | <0.01320     |
| Detergent                        | mg/L     | 0.2                                    |                                      | 21.195              | 0.793        | -            | -            | -            | -           |
| Phenol                           | mg/L     | 0.001                                  |                                      | 0.0014              | 0.024        | -            | -            | -            | -           |
| Oil and Fat                      | mg/L     | nihil                                   |                                      | 4.00                | <0.1         | -            | -            | -            | -           |
| BOD₅                              | mg/L     | 6                                      |                                      | 179.14              | 23           | 12.88        | 62.99        | 9.63         | 18.58       |
| COD                              | mg/L     | 10                                     |                                      | 476.43              | 93           | 22.2155      | 115.91      | 18.1731      | 37.1688     |

Fluctuating water quality at any time depends on the input of wastewater entering at that time, from the analysis can be concluded that the water of the Cinambo River as a source of water for the Gedebage Reservoir has not met the requirements of several parameters including: Ammonia, Chlorine, Mn, DO, Sulfide, Detergent, Oil and Fat, Cd, Pb, DO, BOD, COD, Fecal Coliform and Total Coliform. The high value of detergents and oils and fats shows high concentration of pollutant. The presence of elements Mn, Cd and Pb indicates that the Cinambo River water has been contaminated with industrial waste. Levels of Mn are slightly above requirements, levels of Cd ranging from 5 to 7 x exceed the standardized criteria, while Pb levels range from 2.1 - 2.7 above the required criteria.

3.3. Technology selection

Analysis of data from the report on the collection of detailed design shows that BOD5 / COD ratios ranged from 0.50 - 0.58, indicating that it is still possible to process using wetlands. Analysis of the data showed that BOD5 / COD ratios ranged from 0, 38 , indicating that it is still possible to process wetlands, because in biofilms it can still live under these conditions, even though the BOD5 / COD
ratio has dropped. The BOD5 / COD ratio can still be accommodated by biofilms because the ratio is still in the rainy season range. But the results of the analysis of the data from Environmental Services Agency carried out during the dry season shows that ratio BOD5 / COD ranged between 0.25 indicates that the water has toxins, it will disrupt the development of biofilms, so in addition to the required pre-wetland treatment before entering reservoir.

4. Conclusion

Based on the analysis of secondary data that has been carried out, it can be concluded that the location of the Constructed Floating Wetland which is placed in Gedebage Reservoir is more suitable compared to the placement in the biological filter channel. Cimambo River as water supply for Gedebage Reservoir has not meet the requirements of several parameters including: Ammonia, Chlorine, Mn, DO, Sulfide, Detergent, Oil and Fat, Cd, Pb, DO, BOD, COD, Fecal Coliform and Total Coliform. Ratio of BOD5 / COD in the dry season ranges from 0.25 indicates that the water has toxins, so it will disrupt the development of biofilms, so in addition to wetland will require pre-treatment in advance before entering the reservoir.

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