Reed Bed System for the Improvement of Laguna Lake Waters

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ABSTRACT

Laguna lake is the biggest lake and considered one of the most important inland bodies of water in the Philippines due to its many uses. However, the lake has faced growing pressures (i.e., population expansion, urbanization, industrialization, deforestation, and land conversion) on its ecosystems over the past decades. These activities have led to the degradation of the lake's water quality and ecosystem. The Department of Environment and Natural Resources (DENR) provided a water quality standard for freshwater in determining trends and in the evaluation of stages of deterioration or enhancement in quality of water which include 1) Class AA (Public Water Supply Class I); 2) Class A (Public Water Supply Class II); 3) Class B (Recreational Water Class I); Class C (Propagation and growth of fish class); and Class D (Navigable Waters). The classification of Laguna Lake falls under Class C, which means it is suitable for fishery. With this, intervention for the improvement of the water in Laguna Lake is highly needed. This study aims to design and assess the effectiveness of the reed bed system for the improvement of Laguna Lake. Results show that using reed bed water treatment; the total coliform will meet the standards of DENR after three years of treatment, which can be used as a source of water for irrigation, recreational area, and propagation of fishes. The concentration of ammonia will meet the standards of DENR after two and a half years by using reed bed water treatment, and inorganic phosphate will meet the standards of DENR after three years by using reed bed water treatment.

Keywords: Water Quality Standard and Reed Bed System

I. Introduction

Laguna lake is the biggest lake and considered one of the most important inland bodies of water in the Philippines due to its many uses (LLDA, 2017). This lake supports the fisheries sector and provides a livelihood for more than 24,000 fisherfolks, used as a source of irrigation water for approximately 103,000 hectares (ha), used as a source of domestic water, and supports hydroelectric power generation. Also, the said lake is used for recreational purposes and serves as a waste sink for nearby industries for their solid and liquid wastes (WAVES, 2016). The water holding capacity of this lake is approximately 2.19 billion cubic meters despite being it shallow with an average depth of only 2.5 meters. The only outlet of Laguna Lake is the Napindan Channel, which is connected to Manila Bay through Pasig River. This linkage between Laguna Lake and Manila Bay resulted to seawater backflow. Seawater backflow has been a natural phenomenon and occurs whenever the water level in the lake is lower than in Manila Bay. This phenomenon has severe effects on the lake's water quality as it increases the salinity of the lake aside from the pollution problems from the multiplicity use of the lake resource (Santos-Borja, 1991) (LLDA 2017).

Moreover, based on the Laguna de Bay Basin Technical Report 2016, the lake has faced growing pressures (i.e. population expansion, urbanization, industrialization, deforestation, and land conversion) on its ecosystems over the past decades. These activities have led to the degradation of the lake's water quality and ecosystem. In connection with this, the Laguna Lake Development Authority (LLDA) spearheaded a study in partnership with the World Health Organization (WHO) from 1975 to 1977 entitled "Comprehensive Water Quality Management Program of Laguna Bay" which included benchmarking of essential water parameters and environment indicators. This program aims to evaluate the impacts of development activities (i.e. urbanization, industrialization) on the water quality of the lake. As of today, LLDA has been using this program to continuously monitor the water quality of Laguna Lake and its tributary rivers.

Furthermore, the Department of Environment and Natural Resources (DENR) provided a water quality standard for freshwater in determining trends and in the evaluation of stages of deterioration or enhancement in the quality of water. The said qualifications are the following: 1) Class AA (Public Water Supply Class I); 2) Class A (Public Water Supply Class II); 3) Class B (Recreational Water Class I); Class C (Propagation and growth of fish class); and Class D (Navigable Waters). The classification of Laguna Lake falls under Class C which means it is suitable for fishery (Santos-Borja, 1991) (LLDA, 2012) but in the study of Barril (1993) which assessed the ambient water quality of Laguna Lake with its classification as Class C showed that the lake's water quality did not meet the DENR Class C criteria during that year. In addition, the quarterly report of LLDA in the year 2016 has revealed that not all nine lake stations and its tributary rivers conformed with the class C criteria. This could be attributed to the development activities mentioned earlier and the wastes coming from households and nearby industries.

To prevent the variability in the quality of water of Laguna Lake, LLDA can adopt the Reed Bed Treatments for the improvement of Laguna Lake Waters. Reed bed is a particular type of constructed wetland which are designed to support the various physical and biological processes of natural wetlands (i.e., streams, pond, marsh), which is purifying water flowing through them (Halestrap, 2006).

The use of constructed wetlands such as reed beds to effectively treat wastewater as well as a various range of highly contaminated industrial and agricultural wastewater was not a new idea anymore. This has been widely used throughout Europe and America for many years (Tousignant et al., 1999) (Smeat et al., 2006). With this, this study aims to know if the use or introduction of reed bed to Laguna Lake will help in the improvement of the water quality of the lake. This study aims to design and assess the effectiveness of the reed bed system for the improvement of Laguna Lake.

II. Research Method

Research Design

The Reed Bed system is commonly used as a secondary wastewater system nowadays because it is an environmentally, economically, socially, and ethically viable solution towards the issue of waste and water management. This method will be introduced in this study, and test if it is an excellent way to improve the water quality of a place.

The design is a longitudinal experiment and must be monitored quarterly or monthly if possible to ensure that the system is properly maintained or not destroyed and to determine if it has a significant effect in improving the water quality of the experimented place. The researchers want to determine the water quality of the place by examining the changes in the amount of some water parameters such as coliform, ammonia, and inorganic phosphate. Also, the researchers want to determine how much time it will take to meet the excellent water quality standards.

This study also utilized secondary data analysis through descriptive statistics to determine the status of Laguna lake in terms of the concentration of Total Coliform, Ammonia, and Inorganic Phosphate.

Research Locale

The research will be conducted and implemented in Laguna de Bay, which is the largest lake in the Philippines located east of Metro Manila between the provinces of Laguna to the south and Rizal to the north. The lake has faced growing problems such as population expansion, urbanization, etc. which lead to the degradation of Laguna Lake's water quality. With this, some government agencies (i.e., LLDA) are tasked to protect and to find a way to restore Laguna Lake. Figure 1 shows the map of Laguna with the sampling stations of Laguna de Bay.

Figure 1. Map of the Philippines showing Laguna and Laguna Lake and its Stations (Source: LLDA, 2016)

Laguna de Bay has 21 major tributary river systems flowing into it aside from other relatively small rivers and streams (Smeal et al., 2006). Laguna de Bay also has nine sampling stations, and along the side of these stations is where the Reed Bed System will be applied.

Experiment Design and Procedure

The Reed Bed System will be applied alongside the sampling stations so that monitoring it and testing the water changes will be easier and more efficient. Figure 2 shows the position of the Reed Bed System in each station.

Figure 2. Position of Reed Bed System in Each Station

In this study, three types of soil/medium will be used that is gravelly soil, sandy loam, and black cracking clay. The gravel is used to have a higher rate of infiltration that will cause the wastewater to flow relatively quickly through the system, sandy loam to take longer time to treat wastewater and black cracking

clay to treat a small amount of wastewater at any given time (Smeal et al., 2006). Figure 3 shows the Reed Bed Design.

Figure 3: Reed Bed Design (Smeal et al., 2006)

The typical arrangement of soil is that at the bottom-most part is the grave soil, sandy soil at the middle, and black cracking clay at the top. The arrangement is for the inlet and outlet system. The inlet must be designed to allow the wastewater to flow evenly across various depths. Also, it is desirable to be placed on the grave soil to allow a high influx of wastewater and to help it flow horizontally in the Reed Bed. In the outlet system, it is good to have three different heights, from just below the surface, around the middle, and at the bottom of the bed. The outlet from just below is to allow maximum water in the reed bed, the outlet around the middle is to encourage the root growth of reed, and lastly, the outlet at the bottom of the bed is for drainage system (Smeal et al., 2006). The test of water will be conducted every month by using three water samples from every outlet of each reed bed. This experiment will use a system (software) that will control the flow of water in the inlet to avoid overflowing in the reed bed.

III. Results and Discussions

Total Coliform

Figure 4. Monthly Total Coliforms in each Station Year 2016 (Source: LLDA, 2016)

Figure 4 shows the monthly coliforms in each station of Laguna Lake. In January, the highest concentration of coliform is in station XVIII, which is 3,500 MPN/100 ml. Station XVII has the highest concentration in February and March, which are 1,486 and 918 MPN/100 ml, respectively. In April, May, June, and September, station II is the highest, which is 627, 945, 973, and 754 MPN/100 ml, respectively. Station V is the highest in July, August, October, November, and December, which are 793, 945, 478, 558, and 426 MPN/100 ml, respectively. In the graph, most of the stations have no clear trend for the reason that there is variability in the data from January to December.

The Department of Environment and Natural Resources (DENR) provided a water quality standard for freshwater which divided into five classes: Class AA (Public Water Supply Class I), Class A (Public Water Supply Class II), Class B (Recreational Water Class), Class C (Propagation and growth of fish class) and Class D (Navigable Water Class). The minimum standard for the concentration of Total Coliform for five classes is <1.1, <1.1, 100, 200, 400 MPN/100ml. Based on the graph, all of the stations did not meet the minimum standard for Class AA, Class A and Class B. In addition, most of the stations did not meet the minimum standard for Class C and D, and the decline of Total Coliform is not consistent. This shows that the water of Laguna lake cannot be used as a public water supply, recreational area, and fish propagation.

Figure 5. Total Coliform in each Month of 2016 in Laguna Lake. (Source: LLDA, 2016)

Figure 5 shows the total concentration of Total Coliform for every month in Laguna Lake. The month of January has the highest concentration of Total Coliform, which is 20,040 MPN/100ml, which followed by February and March, which are 6,211 and 4,472 MPN/100 ml. The month of December has the lowest concentration, which is 1,236 MPN/100 ml.

The minimum standard for the concentration of Total Coliform for five classes is <1.1, <1.1, 100, 200, 400 MPN/100ml. Based on the graph, the entire Laguna lake did not meet the minimum standard (Total Coliform) for Class AA, A, B, C and D. This shows that the water of Laguna lake cannot be used as public water supply, recreational area, fish propagation, and navigation.

Concentration of Ammonia

Figure 6. Monthly Total Ammonia in each Station Year 2016 (Source: LLDA, 2016)

Figure 6 shows the monthly total ammonia in each station of Laguna Lake. Station II has the highest concentration of ammonia in February, March, and November, which are 0.057, 0.264, and 0.32 mg/L, respectively. In May, June, and October, station V has the highest concentration of ammonia, which are 0.349, 0.336, and 0.236 mg/L, respectively. Station I has the highest concentration of ammonia in August and December, which are 0.313 and 0.77 mg/L, respectively. In December, there is a significant increase in the concentration of ammonia in station I. In the graph, most of the stations have no clear trend for the reason that there is variability in the data from February to December.

The freshwater quality minimum standard set by the DENR for the concentration of Ammonia for Class A, B, C, and D are 0.5, 0.5, 0.5, and 7.5 mg/L. The DENR has no data available for Class AA. Based on the data, each station met the minimum standard for all classes. Still, the over-all Laguna lake did not meet the minimum standard for Class A, B, and C. This shows that the water of Laguna lake cannot be used as a public water supply, recreational area, and fish propagation.

Figure 7. Total Concentration of Ammonia in each Month of 2016 in Laguna Lake. (Source: LLDA, 2016)

Figure 7 shows the total concentration of ammonia for every month in Laguna Lake. Months of August have the highest concentration of ammonia, which is 1.25 mg/L, which followed by May and October that have

a concentration of 1.034 and 0.972 mg/L, respectively. The month of January has the lowest concentration (0.241mg/L).

The freshwater quality minimum standard set by the DENR for the concentration of Ammonia for Class A, B, C, and D are 0.5, 0.5, 0.5, and 7.5 mg/L. The DENR has no data available for Class AA. Based on the data stated in Figure 7, Laguna lake did not meet the minimum standard for all classes. Still, the over-all of Laguna lake did not meet the minimum standard for Class A, B, and C. This shows that the water of Laguna lake cannot be used as a public water supply, recreational area, and fish propagation.

The concentration of Inorganic Phosphate

Figure 8. Monthly Total Inorganic Phosphate in each Station in the year 2016. (Source: LLDA, 2016)

Figure 8 shows the monthly inorganic phosphate in each station of Laguna Lake. Station V has the highest concentration of inorganic phosphate in February, March, May, June, August, November, and December, which are 0.135, 0.037, 0.164, 0.19, 0.306, 0.258 and 0.181 mg/L respectively. For April and October, the station I has the highest, which are 0.215 and 0.185 mg/L, respectively. Station II is the highest for July (0.179 mg/L), while station XVII is the highest for September, which is 0.61 mg/L.

The freshwater quality minimum standard set by the DENR for the concentration of inorganic phosphate for Class AA, A, B, C, and D is <0.003, 0.5, 0.5, 0.5, and 5. Based on the data, each station met the minimum standard for Class A only. Still, the over-all Laguna lake did not meet the minimum standard for Class A, B, and C. This shows that the water of Laguna lake cannot be used as a public water supply, recreational area, and fish propagation.

Figure 9. The total concentration of Inorganic Phosphate in each Month of 2016 in Laguna Lake. (Source: LLDA, 2016)

Figure 9 shows the total concentration of inorganic phosphate for every month in Laguna Lake. The month of November has the highest concentration of inorganic phosphate, which is 1.691 mg/L. It is followed by June and September, which is 1.123 and 1.099 mg/L. The month of March has the lowest concentration, which is 0.125 mg/L.

The freshwater quality minimum standard set by the DENR for the concentration of inorganic phosphate for Class AA, A, B, C, and D is <0.003, 0.5, 0.5, 0.5, and 5. Based on the data, the entire Laguna lake did not meet the minimum standard for Class AA, A, B, and C. This shows that the water of Laguna lake cannot be used as a public water supply, recreational area, and fish propagation.

Hypothetical Concentration of Total Coliform after Water Treatment using Reed bed

Figure 10. Hypothetical Result for Total Coliform after the use of Reed bed

Figure 10 shows the hypothetical result for Total Coliform after the water treatment using reed bed. The expected reduction of total coliform every month based on the designed capacity of reed bed is 10%. The current total coliform concentration in Laguna lake is approximately 2000 MPN/100ml which is cannot be used as source of potable water, recreational area and propagation of fishes based on the set standard of the Department of Environment and Natural Resources (DENR). By using reed bed, the concentration will reduce by 10% every month which will take three years in order the waters of Laguna lake to passed the standard of DENR. In this case, after three years the Laguna lake can be used as source of potable water, recreational area and propagation of fishes.

Expected Concentration of Ammonia after Water Treatment using Reed bed

Figure 11. Hypothetical Result for Ammonia after the use of Reed bed

Figure 11 shows the hypothetical result for Ammonia after the water treatment using a reed bed. The expected reduction of ammonia every month based on the designed capacity of the reed bed is 10%. The current concentration of ammonia in Laguna lake is approximately 0.87 mg/L, which cannot be used as a source of potable water, recreational area, and propagation of fishes based on the set standard of the Department of Environment and Natural Resources (DENR). By using a reed bed, the concentration will reduce by 10% every month, which will take two and a half years for the waters of Laguna lake to pass the standard of DENR. In this case, after two and a half years, the Laguna lake can be used as a source of potable water, recreational area, and propagation of fishes.

Expected Concentration of Inorganic Phosphate after Water Treatment using Reed bed

Figure 12. Hypothetical Result for Inorganic Phosphate after the use of Reed bed

Figure 12 shows the hypothetical result for inorganic phosphate after the water treatment using a reed bed. The expected reduction of inorganic phosphate every month based on the designed capacity of the reed bed is 10%. The current concentration of inorganic phosphate in Laguna lake is approximately 1.1 mg/L, which cannot be used as a source of potable water, recreational area, and propagation of fishes based on the set standard of the Department of Environment and Natural Resources (DENR). By using a reed bed, the concentration will reduce by 10% every month, which will take three years for the waters of Laguna lake to passed the standard of DENR. In this case, after three years, the Laguna lake can be used as a source of potable water, recreational area, and propagation of fishes.

IV. Conclusion

Based on the results presented, the researchers concluded the following:

- The current concentration of total coliform, ammonia and inorganic phosphate in Laguna Lake did not pass the standard set by the Department of Environment and Natural Resources (DENR) which cannot be used as a source of potable water, recreational area, and propagation of fishes;
- By using reed bed water treatment, the total coliform will meet the standards of DENR after three years of treatment which can be used as a source of water for irrigation, recreational area, and propagation of fishes;
- The concentration of ammonia will meet the standards of DENR after two and a half years by using reed bed water treatment; and
- Inorganic phosphate will meet the standards of DENR after three years by using reed bed water treatment.

V. Recommendations

Based on the results, the researchers highly recommended the following:

- The concerned institution/s should have proper monitoring of the reed bed water treatment;
- Application of reed bed water treatment in other areas with the same problem;
- The Local Government unit or other concerned institutions must provide some programs to maintain the excellent quality of water after the treatment using reed bed

References

- [1] Barril, C.R. (1993). Water quality assessment and management of Laguna de Bay: Concepts, Problems and Strategies. Environment and Resource Project. ISSN: 0117-3251
- [2] Department of Environment and Natural Resources (2017). Water Quality Guidelines and Effluent Standards and its Implementation in the Philippines.
- [3] Laguna Lake Development Authority (2016). Quarterly Water Quality Monitoring Report Laguna Lake and Tributary Rivers 2016.
- [4] Halestrap, L. (2006). Reed Beds & Constructed Wetlands: A brief introduction to a greener way to treat your sewage. The Centre for Alternative Technology, August 1998, updated 2006. Retrieved from www.cat.org.uk
- [5] Santos-Borja A.C. (1991). Water quality management of Laguna de Bay. Biotropica Special Publication. ISSN: 0125-975X.
- [6] Smeal, C., Truong, P., Biala, J., and Butler, A. (2016). Application of Vetiver Grass in Soil Based Reed Beds for Effluent Treatment at Gelita APA, Australia.
- [7] Tousignant, E.P., Fankhauser O., and Hurd S. (1999). Guidance Manual for the Design, Construction and Operations of Constructed Wetlands for Rural Applications in Ontario. Stantec Consulting Ltd R&TT, Alfred College (University of Guelph) South Nation Conservation
- [8] Wealth Accounting and the Valuation of Ecosystem Services (WAVES) Laguna de Bay Basin Technical Report 2016. Retrieved from www.wavespartnership.org