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Original Research Article

Implementing Constructed Nature Based System Solution as an Alternative for Water Treatment

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Abstract: Industrial wastes had contributed to environment pollution. In particular, wastewater had been increasing in any country around the world, from agricultural sectors to commercial sectors. Wastewater treatment had raised overhead costs on operational and maintenance. Many studies had been done on finding alternatives for wastewater treatment. In general, a variety of wastewater treatment processes are employed which includes primary treatment, secondary treatment and tertiary treatment. In this study, three designed systems of tertiary treatment had been observed to evaluate wastewater quality reduction. A designed system had been selected to identify the treatment efficiency using the same treatment concept of phytoremediation. There are three designs which are the large-scale design, medium-scale design and portable scale design. The differences among the designs are that the first large-scale design uses wastewater sources directed from a sewerage plant, while the second design with medium-scale uses groundwater water with nutrient loads from aquatic species. The third design with portable scale uses a customised aquarium method with conventional filtration. From the study, it was found that different solution design systems could perform treatments for different wastewater characteristics. The average range of treatment had been seen to reduce contaminated water quality between 10 to 60% on differences in water quality parameters. This identified that the constructed nature-based system (NBS) could possibly be performed as one of the wastewater treatments. Further study could be done for any sources of wastewater in future as an added value to the improvised existing design to improve surface water quality.

Keywords: wastewater; phytoremediation, treatment; efficiency; water quality

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1. Introduction

In Malaysia, about 95% of water source come from surface water. Data from Economic Outlook from Ministry of Finance, Malaysia (2020) shows that consistent and rapid growth of urban industries in Malaysia had resulted in great economic benefit but at the same time led to surface water contamination. Distribution of river water pollution by states in Peninsular Malaysia as reported yearly by the Department of Environment found that the majority of the states that contributed to consistent contamination were Selangor, Penang, Perak and Johor. As those states run the country's economic returns and at the same time possess dense population , it has also created domestic and industrial water consumption demands which require efficient and cost-effective sewerage systems that can be discharged back into the surface waters (Narimah & Mohammad Shanudin, 2018; Pivetz, 2001; Rahman & Hasegawa, 2011). These wastes in solid, liquid or gaseous forms could adversely affect the quality of the water. Organic water pollution load, sewage and animal wastes were the major contributors to water pollution followed by waste from the industries (Ramanjaneyulu, 2018; Raza *et al.*, 2020). In the case of pollution load, sewage contributed 385 tons per day in 1988 and increased to 698 tons per day in 1993, as reported by the Department of Environment: Malaysia Environmental Quality Report (1992–1995). Rivers, which are known to receive residential and commercial sewerage discharges, recorded some contamination (UN Water, 2017; Juhair *et al.*, 2011; Jackson *et al.*, 2012). Some of the heavy metals were found in rivers situated on the west coast of the Peninsular due to intensive economic activities (Ryan *et al.*, 2008). It is a requirement to treat sewerage at a low capital cost of investment using biological treatment compared to existing high cost sewerage treatment plants (Salt *et al.*, 1995). The development of conventional sewerage plants had been reported annually increased by years reported by National Water Services Commission (NWSC) in 2019. Thus, a nature-based (NBS) solution using the phytoremediation method had been studied as many countries around the world had observed certain species of plants could possibly treat sewerage effluent in the long-term run (Shahid *et al.*, 2020). Traditional treatments include excavation, transport to landfills, incineration, stabilisation, and verification.

Phytoremediation has been used for remediation in soil, sludge, sediment, surface water and groundwater for a diverse range of contaminants (Pivetz, 2001). Many studies had found that phytoremediation had remediated numerous chemicals including metals, radionuclides, pesticides and herbicides, excessive nutrients and organic pollutants (Raza, *et al.*, 2020). Cost saving and clean techniques are some of the advantages while many had already familiar with phytoremediation (Zain, *et al.*, 2013).

Contamination such as heavy metal poses a major threat to the drinking water supply and environmental health problems (Ryan, *et al.*, 2008). Some contamination could not be fully treated biologically but it could be possible only to be transformed from one state to another complexity. This study's objective is to determine the performance of phytoremediation method as an alternative water treatment in Lake NAHRIM.

2. Materials and Methods

Three study plots had been running for several study years and were used to monitor water treatment using phytoremediation in different sizes and content of plants. Study plot 1 (SP1) used a small land scale near premises with low sources of nutrients loading from various aquatic species as Figure 1. While, Study Plot 2 (SP2) used a portable unit similar to a market aquarium which had been customised with less plants and less aquatic species and standard aquarium filters as Figure 2. Study Plot 3 (SP3) used a large land scale with a sewerage treatment plant (STP) as Figure 3. However, the studies are still going on SP1 and SP2 with only physical observation recorded for overall study comparison for the selection of suitable methodologies towards scientific data collection.

Figure 1. SP1 located at nearby premises.

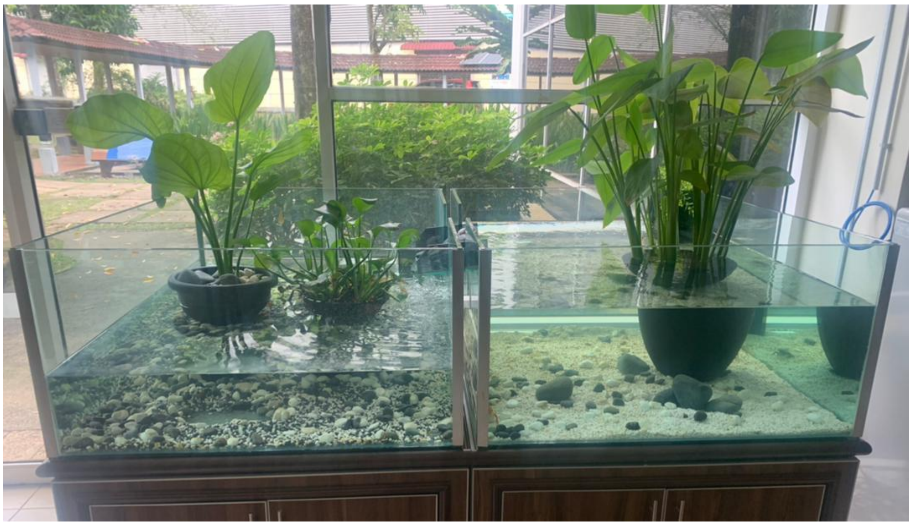

Figure 2. Study Plot 2 (SP2) using a portable unit with separate glasses compartment. Aquatic plants had been planted into the study plot.

Figure 3. Study Plot 3 (SP3) with the Supply of the Sewerage Treatment Plant.

As SP1 and SP2 are still under performance monitoring continuing in this study, further data discussed will be focused only on SP3. The data collection covers *in-situ* measurement and laboratory analyses collected. Each sampling point was spot sampling once in 2014 and later in 2020 with Standard Sampling Procedures (APHA 2005). Eight sampling points had been selected as shown in Figure 4, namely Tasik NAHRIM 1, Tasik NAHRIM 2, Tasik NAHRIM 3, Tasik NAHRIM 4, Tasik NAHRIM 5, Tasik NAHRIM 6, Tasik NAHRIM 7 and Tasik NAHRIM 8. The sampling points were sorted according to the flow of water where the upper of Tasik NAHRIM 7 is the upper side, while below Tasik NAHRIM 7 is the lower side, where lake water is discharged out to the nearby public drainage.

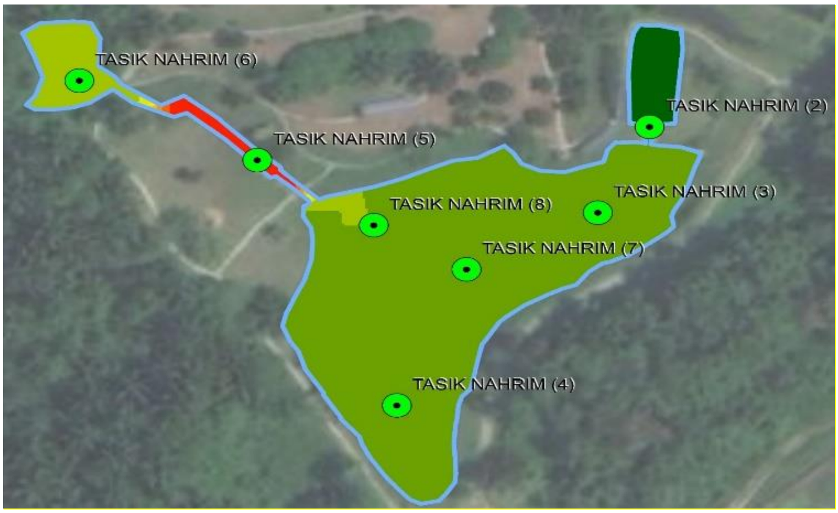

Figure 4. Sampling Point at Lake NAHRIM.

As Figure 4, two fixed point sources had been located on both left and right sides of the lakes. On the left side of Lake NAHRIM of Tasik NAHRIM 6, there are wastewater sources which came from the cafeteria. While at the right side of Lake NAHRIM of Tasik

NAHRIM 2, the wastewater sources came from the sewerage treatment plant located at Tasik NAHRIM 1.

Hence certain laboratory data will be limited covering up to certain parameters of Ammonia, Aluminium Barium, Boron, Calcium, Magnesium, Sodium, Zinc, Phosphate and Total Coliform Count, some data will be analysed using ArcGIS mapping. As the Study Plot 3 is in an open space, rainfall data had not been conducted by the study team due to the lack of funds in providing a rainfall monitoring station. Some aquatic species had been planted at Lake NAHRIM, such as *Cyperus alternifolus; Typha angustifolia; Scirpus grossus; Ipomoea aquatic; Pennisetum purpureum; Eleocharis dulcis; Eichhornia crassipes;* and *Chrysopogon zizaniodes*. As many studies had been done, these studies do not focus on the species' function in phytoremediation.

3. Results

Later studies confirmed similar parameters performance, significantly with additional parameters of Ammonia, Aluminium Barium, Boron, Calcium, Magnesium, Sodium, Zinc, Phosphate and Total Coliform Count. These new findings emphasised phytoremediation treatment is possible to be implemented at certain wastewater characteristics. In this study, very significant findings were found compared to the previous studies, that there was relativity among Total Coliform Count and Enterococcus with Chlorophyll A.

Both performed inversely after passing the NBS solution for a certain period. For instance, when the parameter Total Coliform Count was recorded at 2400 CFU/100 mL, Chlorophyll A was measured at 77.6 µg/L after passing the phytoremediation process, demonstrating a significant decrease from the initial 640,000 CFU/100 mL of Total Coliform Count whereas a significant increase was seen for Chlorophyll A which has an initial measurement of 6.9 µg/L prior to phytoremediation. After several years, spot sampling had been carried out to determine the load or level of contamination. As in Table 1, the selected parameters found that some sampling points at Lake NAHRIM have been loaded with contamination from 17% to 112%. Although the data do not show cleaner water quality all over the lakes, the finding shows that the lake had the potential to treat effluent minimally from the sewage treatment plant and cafeteria at the different sampling points. This will be further explained using ArcGIS.

Table 1. Lake NAHRIM Performance After Implementing Years, 2014.

Parameters	unit	2014	2020	Differences
Total Phosphate	mg/L	70.6	99.4	28.8 (41%)
Total Nitrogen	mg/L	58.1	86.6	28.5 (49%)
Total Faecal Coliform Count	CFU/100mL	84.4	99.8	15.4 (18%)
Total Escherichia Coliform Count	CFU/100mL	85.2	100.0	14.8 (17%)
Plumbum	mg/L	87.5	undetected	-
Ammoniacal Nitrogen	mg/L	47.0	99.93	52.9 (112%)

Using ArcGIS, some sampling points reflected improved water quality to be less contaminated at the end of the lakes. Selected 2020 data of Lake NAHRIM had been modelled using ArcGIS to overview the surface changes of each parameter sampled at selective sampling points taken. Figure 5 (a)–(d), are the ArcGIS modelling overviewing selected parameter performance at Study Plot 3.

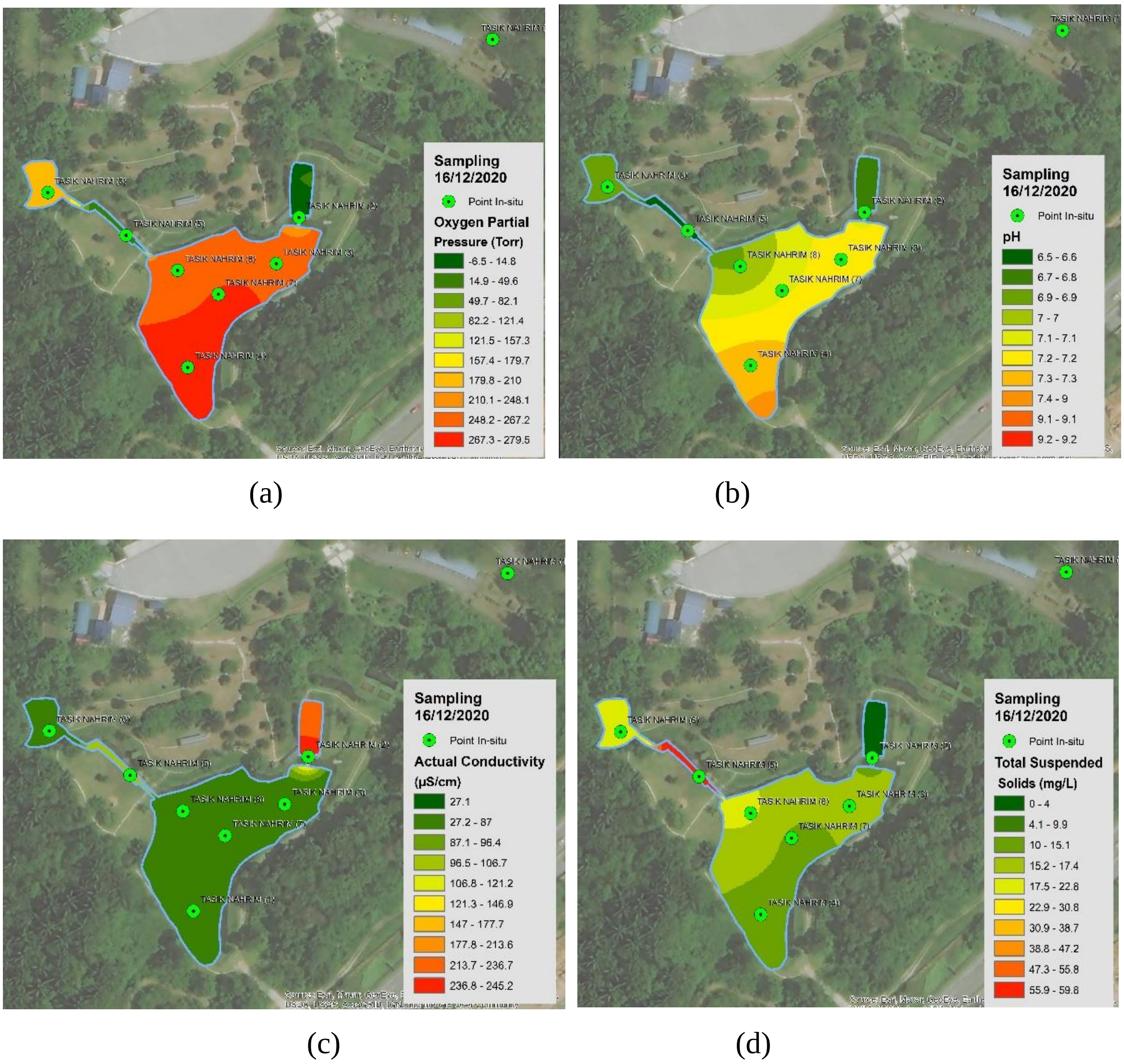

Figure 5. The condition of Lake NAHRIM according to selected parameter performances during 2020 monitoring of. **(a)** Oxygen; **(b)** pH; **(c)** Conductivity; and **(d)** Total Suspended Solid.

As seen in Figure 5(a), oxygen levels were seen to produce better levels at downstream of Lake NAHRIM. Data shows that the oxygen was between 267.3 to 279.5 Torr. These data have been verified by comparing with pH parameter as in Figure 5(b) and Total Suspended Solid as in Figure 5(d). Additionally, actual conductivity in Figure 5(c) shows that most of the Lake NAHRIM had been under the range of 27.1 to 106. 7 µS/cm after the incoming effluent as seen in red indicators between 238.8 to 246.2 µS/cm. Similar results of phytoremediation reaction could be seen in Figure 5(d) whereas discharge from the cafeteria was seen in red indicators between 17.5 to 59.8 mg/L of total suspended solid had been improving the water quality between 10.0 to 17.4mg/L.

4. Discussion

From the previous study in 2014, six parameters had been determined to give significant insights into the treatment of Lake NAHRIM to be cleaner which were, Total Nitrogen (N), Total Phosphate (P), Plumbum (Pb), Ammoniacal Nitrogen (NH3-N), Total Faecal Coliform Count and Total Escherichia Coliform Count. However, further parameters could possibly be counted to have a trend developed in classifying the Malaysia National Water Quality Standards for Malaysia (NWQI) and the National Lake Water Quality Criteria and Standards (NLWQS). As the world population is estimated to reach 10.9 billion in 2100, the increasing population growth and their living hood imply higher water consumption (UN, 2013). By improving the lake water quality, it would demonstrate the potential for lake water reclamation associated with sewerage sources.

From this study, SP3 shows that Lake NAHRIM is very suitably designed for implementing the constructed NBS solution as an alternative water treatment. Though the NBS requires a large land area, various species with different paths and lake depths, the aspect of maintenance compared to conventional treatment systems could be expected to be lessened. Further studies on the maintenance requirement are recommended to assure NBS cost effective approaches. As to the water flow, a solar pump based had been used to assure that the lake water flows downstream. This is similar to the Tasik Putrajaya which has 23 cells, which allows the phytoremediation process to take place for a certain period in order to treat the incoming water flows (Daud *et al.*, 2011). Though land has become the initial cost of NBS, the NBS still requires trimming or removal of plants to be carried out as part of its maintenance. Nevertheless, of this low maintenance cost, the NBS approach could be further studied to verify its overall operational cost-effectiveness as compared with the conventional design of sewage water treatment in the long-term run.

5. Conclusions

From the study, the sources of contaminated water were mostly with grey water and black water characteristic clusters from the sewage treatment plant and cafeteria effluent. Since the system was installed and operated in 2014, after six years, the system has been found to be relevant for a low incoming flow rate of grey water and black water during the pandemic. As Lakes NAHRIM is neighboured to MARDI for agricultural activities, the rainfall data could not be related to the influence of the lake's performance. Therefore, further studies related to weather conditions are recommended.

Although the virus parameter was not taken into the account, selective parameters of microbiological testing has successfully been highlighted to show microbial deterioration, therefore securing the water quality of Lake NAHRIM through the phytoremediation process. Further studies could be recommended to the extent of suitable aquatic plants at any of the hospital's sewerage treatment plant during the pandemic.

This study had found that phytoremediation could possibly extract certain heavy metal properties, microbiological elements, inorganic and non-metallic properties. Further studies could be carried out by selecting appropriate plants that could possibly be used to neutralise the activeness of coronavirus disease 2019 (COVID-19). As highlighted by Shahid *et al.* (2020), natural resources, such as by extracting licorice *(Glycyrrhiza glabra)*, has the possibility to deactivate components that could be used to neutralise or slow down the virus's activeness.

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Conflicts of Interest: The authors declare no conflict of interest.

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