PAPER • OPEN ACCESS

Application of Water Hyacinth in Phytoremediation of Wastewater

To cite this article: N Kasmuri *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1135** 012008

View the article online for updates and enhancements.

You may also like

- Phytoremediation as a Sustainable Way for Land Rehabilitation of Heavy Metal Contamination
P Alvernia and T E B Soesilo
- Systematic Review of the Efficiency of Aquatic Plants in the Wastewater Treatment
Y. Palomino Seguil, L. Vilchez Garay, C. Matencios Cortez et al.
- N, P, O-codoped biochar from phytoremediation residues: a promising cathode material for Li–S batteries
Mei'e Zhong, Jingchun Sun, Xiaoqing Shu et al.

ECS
244th ECS Meeting
Gothenburg, Sweden • Oct 8 – 12, 2023
Early registration pricing ends September 11
Register and join us in advancing science!
Learn More & Register Now!

This content was downloaded from IP address 103.53.32.15 on 06/09/2023 at 02:01

Application of Water Hyacinth in Phytoremediation of Wastewater

N Kasmuri[1,2*], S A A Malik[2], Z Yaacob[1], M F Miskon[3] N H Ramli[4] and N Zaini[2]
[1]Pusat Asasi, Universiti Teknologi MARA, Cawangan Selangor, Kampus Dengkil 43800, Selangor, Malaysia
[2]School of Civil Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, 40450 Selangor, Malaysia
[3]Oceanography and Maritime Studies (INOCEM), Kulliyyah of Science, International Islamic University Malaysia, Bandar Indera Mahkota, 25200 Kuantan, Pahang Malaysia
[4]Fakulti Teknologi Kejuruteraan Kimia dan Proses, Universiti Malaysia, 26300 Kuantan, Pahang, Malaysia

E-mail: *norhafezahkasmuri@uitm.edu.my

Abstract. Wastewater is any water source that a human has used for domestic, agricultural, commercial, or industrial activity. Wastewater needs to be treated before being discharged into the environment to reduce contamination of water bodies. The wastewater treatment must follow the Environmental Quality (Sewage) Regulations, 2009. Rivers in Malaysia continue to suffer wastewater pollution from the inefficiency of treatment. Wastewater has been recognized as the significant cause of these issues. Many physical, chemical, and biological techniques have evolved for sewage treatment. It has been observed that biological procedures are advantageous, and one of these procedures that can be considered is phytoremediation. Thus, this study investigated the effectiveness of water hyacinths in treating wastewater, such as the effluent from the wastewater treatment plant, river, and pond in Pusat Asasi, UiTM Dengkil, Selangor, by phytoremediation. Different parameters of pH, suspended solids, phosphorus, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, chemical oxygen demand and biological oxygen demand have been assessed. The research has been conducted with experimental works of 14 days. The laboratory works showed a significant reduction in most parameters after two weeks of phytoremediation.

Keywords: Phytoremediation, water hyacinth, wastewater

1. Introduction

Wastewater is any water humans have used from domestic, agricultural, commercial, or industrial activity. Generally, wastewater contains organic and inorganic materials such as human waste, urea, detergents, food scraps and oil. Wastewater needs to be treated before it is discharged into the environment. Effluent discharged upstream needs to meet Standard A, while the effluent discharged downstream must follow Standard B set by the Environmental Quality (Sewage) Regulations 2009 [1].

[1] To whom any correspondence should be addressed.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

IOP Conf. Series: Earth and Environmental Science 1135 (2023) 012008 doi:10.1088/1755-1315/1135/1/012008

The wastewater treatment plant will reduce the pollutants in the wastewater to ensure it meets the required standards.

Wastewater treatment consists of pre-treatment, physical, biological, and chemical treatments. Pre-treatment techniques in a standard wastewater treatment system include screening, sedimentation, and skimming [2]. Screening involves eliminating huge and floating solid objects, which could cause clogging in subsequent treatment methods [2–4]. The floating solid materials are isolated using the grit chamber [5]. Grit chambers can be classified into three types based on size and characteristics: aeration grit chambers, vortex flow grit chambers, and horizontal flow grit chambers [2, 6].

Physical treatments are frequently done before biological or chemical treatments [2, 7]. Sedimentation tanks are installed to clean the wastewater thoroughly [2]. The sedimentation tank allows the sludge to settle before separating the heavier solid components from the water [3]. Gravitational force is used in sedimentation tanks to settle heavier particles [8].

Biological treatment relies on nematodes, bacteria, or other organisms to break down organic waste [2, 9]. The biological treatment has been done in the secondary stages of wastewater treatment plants in an aeration tank [2, 10]. This treatment is also used in the tertiary stages to remove substantial amounts of pollutants by biodegradation [2].

Furthermore, chemical treatment refers to using chemicals in a series of processes to aid the disinfection of wastewater [2, 11]. The dissolved pollutants in wastewater are forced to separate in chemical wastewater treatment technology by adding targeted chemicals [2, 10, 12].

Bioremediation has become a popular choice for enhancing wastewater effluent quality for tertiary treatment. This method can be the best management practice in the wastewater treatment plant [2]. Phytoremediation could regain soil quality and improve plant development, including mitigating soil pollution for long-term sustainability [2, 13, 14]. Phytoremediation is a viable technique for withdrawing contaminants in sewage and is acknowledged as a recommended sustainable remediation technology [15]. Phytoremediation is well-recognized environment-friendly technology which eliminates pollutants from sewage using plants [16–18]. The idea of phytoremediation is founded on utilizing microorganisms and plants in the same method to eliminate contaminants from the environment [19]. Phytoremediation has various benefits, which are inexpensive and long-lasting [18, 20]. Hence, phytoremediation could be a potential wastewater purification method [2, 19, 21]. *Eichhornia crassipes*, also called water hyacinths, have achieved great recognition as the aquatic plant that can potentially captivate contaminants from aquatic habitats with swift reproduction [19].

Moreover, rivers in Malaysia continue to endure heavy pollution from wastewater effluent that is not being treated properly [22]. This wastewater source has been recognized as the root cause [22]. The contamination due to the effluent from the ineffective treatment in wastewater treatment plants and the release of untreated effluent from squatters, restaurants, and wet markets have significantly contaminated the river water bodies. Water pollution affects human life by containing numerous microorganisms such as *E-coli* that can create many health issues like vomiting, severe abdominal pain, and diarrhoea. This issue also affects the ecosystems as these pollutants contain excessive nutrients such as nitrates and phosphate, which could impact the water bodies by eutrophication [22]. River water is used for drinking and is essential to the human population [23, 24]. Thus, it is crucial to implement the best management strategy to boost the security of the water.

The research study evaluated the effectiveness of using water hyacinth in the wastewater sample. The differences between the parameter such as biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammonia-nitrogen, pH, nitrite-nitrogen, nitrate-nitrogen, phosphorus, and dissolved oxygen (DO) are also evaluated.

2. Materials and Methods

The preparation for purified wastewater effluent samples, river, and detention pond in Pusat Asasi, UiTM Dengkil, Selangor, using water hyacinth (phytoremediation process) has been done. Laboratory works were conducted to determine the pH, total suspended solids, phosphorus, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, COD, and BOD in 14 days of incubation.

IOP Conf. Series: Earth and Environmental Science 1135 (2023) 012008 doi:10.1088/1755-1315/1135/1/012008

2.1. Preparation of Water Sample and Selected Plant
The water samples from the effluent of the wastewater treatment plant, river water and detention pond were collected in Pusat Asasi, UiTM Dengkil, Selangor, in July 2021 [25]. The water hyacinth has been prepared as the selected aquatic plant for phytoremediation in this study (refer to Figure 1).

Figure 1. Water hyacinth in water samples.

2.2. Laboratory Works for 14 Days with 2 Days Interval
The laboratory work started with the set-up of the apparatus. Three (3) containers with a 5.5 L volume were prepared to grow the water hyacinth. The containers are labelled according to the type of water sample. Five litres of water samples from each effluent wastewater, river and detention pond were poured into the container. The water hyacinth is intended to grow for 14 consecutive days (Figure 1). The samples' parameters are evaluated every two days at intervals until 14 days following [25]. In-situ testing for pH, dissolved oxygen for BOD and total suspended solids have been done using a digital probe (Hanna Instruments). Laboratory testing for phosphorus, nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen and COD was detected using DR 2800 Spectrophotometer [26]. *E-coli* and total *coliform* have been done using Colilert Test [25].

3. Results and Discussion
The results for different parameters include pH, total suspended solids, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphorus, COD, BOD, total coliform, and *E-coli* are evaluated in the graphs and tabulated in the tables accordingly.

3.1. pH
pH determination is crucial for the identification of water quality. It can be denoted that the optimal values of pH for microbial activities in the nitrification process can range from 6.6 to 8.0 [19]. As shown in Figure 2, the pH values for the water samples fluctuated during the two weeks of phytoremediation. Moreover, the pH values were significantly reduced on Day 10 for all water samples. The lowest pH value among the three water samples is 6.11 on Day 0 for the river water. Meanwhile, the highest pH value for the three types of water samples is 7.99 on Day 4, also the river water. According to [18], the pH of wastewater effluent was reduced when flowing through boxes of water hyacinths. The reduction of pH levels (referring to the lowest pH obtained was 6.11) may be caused by organic acids generated from organic materials adhered to the root of the plants and the release of carbon dioxide by microbial respiration [24]. It has been reported by [27] that the rate of pH reduction was higher in phytoremediation treatment with water hyacinth in an air circulation treatment system (aeration), which declined to 4.45, which contrasted to the treatment with water lettuce *(Pistia stratiotes*) that dropped to 6.24. Therefore, this demonstrates the effectiveness of water hyacinth over water lettuce.

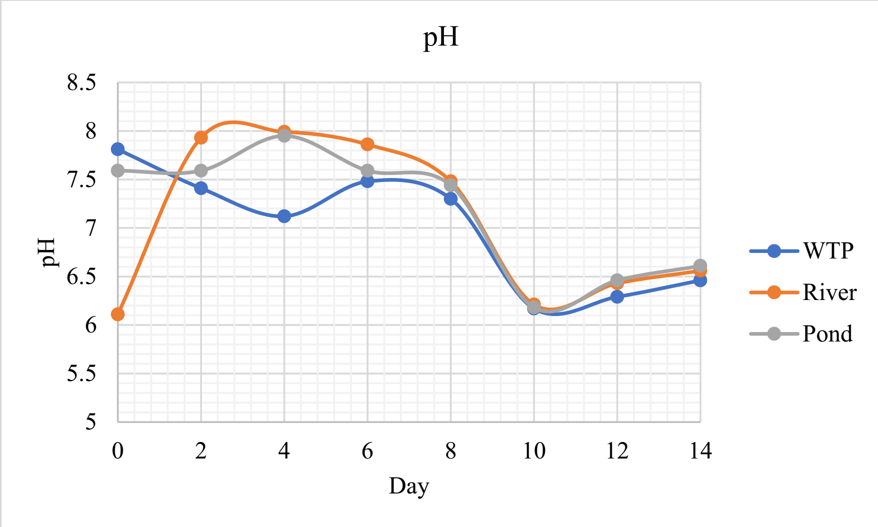

Figure 2. Results of pH against incubation period (Day).

3.2. Total Suspended Solids, TSS

Total suspended solids (TSS) are waterborne particles larger than 2 microns. TSS above a certain threshold raise water temperatures and reduce dissolved oxygen levels. Moreover, suspended particles absorb more heat from sunlight than water molecules. The TSS concentration for effluent samples decreased steadily during the 14 days of phytoremediation. It is shown in Figure 3 that the value of TSS for the detention pond sample reduced sharply from 24 mg/L on Day 0 to 1 mg/L on Day 14.

Furthermore, the initial value of TSS for the river water is the lowest among the three water samples. The removal efficiency of TSS for the pond water in Pusat Asasi, UiTM Dengkil is the highest, with 95.83%. Previous research by [28] found that water hyacinth had a greater treatment efficiency than water morning glory plant after 21 days. Total suspended solids ranged from 37.8% to 53.3%, whereas chemical oxygen demand ranged from 44.4% to 53.4%.

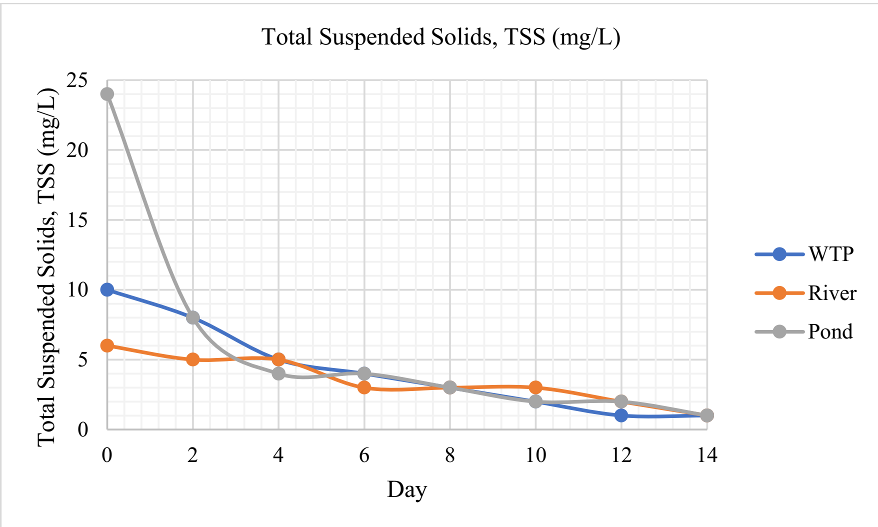

Figure 3. Total Suspended Solids against incubation period (Day).

3.3. Ammonia-nitrogen

The sum of un-ionized ammonia and ammonium is known as the level of ammonia-nitrogen. It is a water quality indicator and an important variable for evaluating the nitrogen cycle in aquatic ecosystems. Therefore, monitoring ammonia-nitrogen in aquatic ecosystems is crucial [29]. Ammonia-nitrogen was transformed into nitrite-nitrogen and nitrate-nitrogen through a two-stage nitrification process [30], first by aerobic ammonia-oxidizing bacteria and archaea and then by nitrite-oxidizing bacteria [31, 32]. Based on Figure 4, the ammonia-nitrogen concentration for the river water sample decreased significantly from 5.5 mg/L on Day 0 to 0.17 mg/L on Day 14. Next, the ammonia-nitrogen value for effluent samples reduced sharply from 1.75 mg/L to 0.33 mg/L on Day 2 of phytoremediation. The value of ammonia-nitrogen for the pond sample also experienced a sudden reduction on Day 2 of phytoremediation from 1.25 mg/L to 0.54 mg/L. Meanwhile, the removal efficiency of ammonia-nitrogen for wastewater samples in Pusat Asasi, UiTM Dengkil is 94.29%, followed by pond water (95.20%) and river sample (96.91%). Rainfall events may cause significant changes in physicochemical water parameters [33]. As a result, changes in the influent may significantly alter the microbial community composition affecting nitrogen removal. Ammonia-nitrogen was eliminated to a larger extent than other kinds of nitrogen. Ammonia-nitrogen levels dropped dramatically during 21 days of sampling [19]. It has been reported that a treatment system with aeration when using water hyacinth (96.12%) resulted in a significant reduction in ammonia-nitrogen compared when using *Pistia stratiotes* (91.82%) in the third week of the treatment process [27].

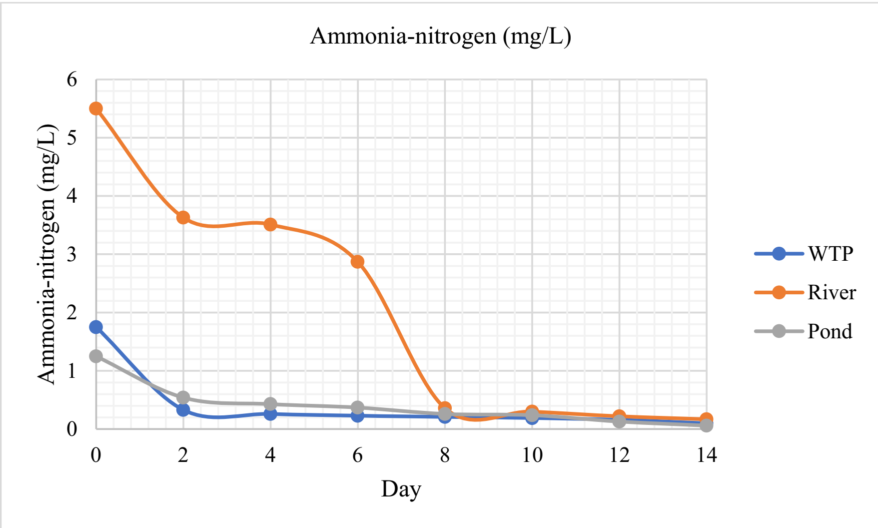

Figure 4. Ammonia-nitrogen against incubation period (Day).

3.4. Nitrite-nitrogen

As shown in Figure 5, the value of nitrite-nitrogen increased from 0.013 mg/L to 1.176 mg/L after 14 days of phytoremediation for the wastewater sample. Furthermore, the river water's nitrite-nitrogen concentration experienced a dramatic surge after Day 6 of phytoremediation. Next, the value in the pond sample soared sharply from 0.056 mg/L on Day 6 to 0.562 mg/L on Day 8. The removal efficiency of nitrite-nitrogen in river water is the highest, at 99.08%. After the extreme precipitation, nitrite-nitrogen concentrations in the influent and effluent of wastewater were much higher. The effluent nitrite-nitrogen concentrations were substantially lower than the influent at the start of the experiment, significantly greater after the precipitation, and then showed a declining trend and flattened. The increases in nitrate-nitrogen in the influent were similar to those in nitrite-nitrogen, which rose after the excessive precipitation [18]. The nitrite-nitrogen reduction in the pond and wastewater samples was due to the nitrification process as the nitrite-nitrogen was converted to nitrate-nitrogen [31].

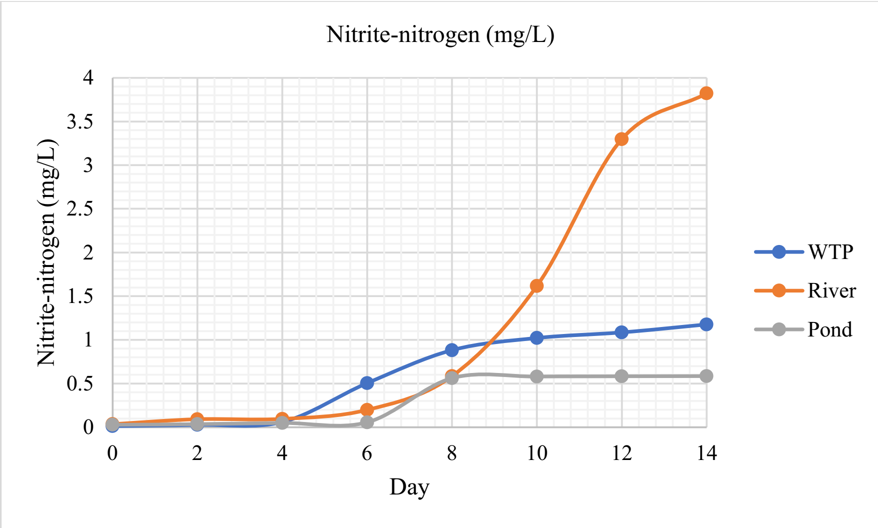

Figure 5. Nitrite-nitrogen against incubation period (Day).

3.5. Nitrate-nitrogen

Excess nitrate-nitrogen and nitrite-nitrogen in water are one of the causes of eutrophication. Eutrophication occurs when excessive nutrients enter water bodies, promoting too much plant growth [34]. This massive amount of plant growth ultimately depletes the oxygen supply in the water, resulting in the death of aquatic life. Therefore, it is crucial to determine nitrate-nitrogen and nitrite-nitrogen levels in the water body. In this study, nitrate-nitrogen concentration increased drastically during 14 days of phytoremediation for the river water sample. Meanwhile, the nitrate-nitrogen value for the wastewater sample rose steadily from 0.4 mg/L on Day 0 to 3.15 mg/L on Day 14.

Moreover, there was significant growth in the nitrate-nitrogen value for the pond water on Day 8 with 1.82 mg/L. The initial nitrate-nitrogen value for the pond water sample is the lowest of the three water sample types. Additionally, nitrate-nitrogen removal efficiency for effluent samples in Pusat Asasi, UiTM Dengkil, is substantial, with a value of 87.30%.

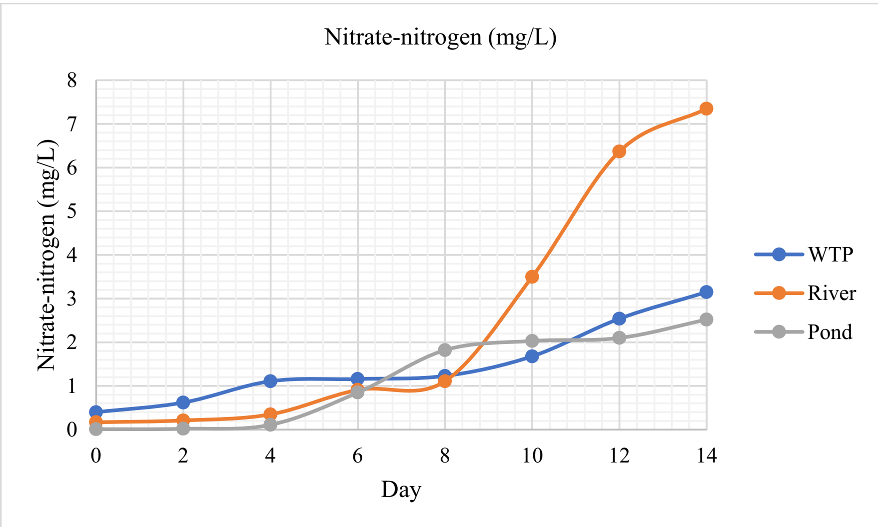

Figure 6. Nitrate-nitrogen against incubation period (Day).

3.6. Phosphorus

Phosphorus is an essential component for plant and animal growth and development. Eutrophication is caused by an excessive phosphorus concentration in the water [34]. Eutrophication happens when the environment becomes unusually rich in nutrients. It is necessary to keep phosphorus levels in water bodies under control to avoid potential cases of eutrophication. Figure 7 shows that phosphorus concentration reduced from 3.72 mg/L to 1.73 mg/L in two weeks of phytoremediation for the effluent sample. The phosphorus value for the river water decreased sharply from 2.19 mg/L to 0.77 mg/L on Day 4 of phytoremediation. Then, the value of phosphorus for the pond water sample fell significantly from 2.53 mg/L on Day 0 to 1.05 mg/L on Day 2. Next, the phosphorus removal efficiency for the pond water sample is 91.70%, followed by the river water sample with 89.95%. Kumar and Deswal (2020) [35] reported the phytoremediation capabilities of four floating aquatic plants for phosphorus removal from rice mill wastewater. They found that water hyacinth had a significantly higher removal efficiency than duckweed and *Salvinia* but a slightly lower than water lettuce. Furthermore, the free-floating water hyacinth proved more effective in removing phosphorus from fishpond effluents than the emergent macrophyte *Typha domingensis* [36].

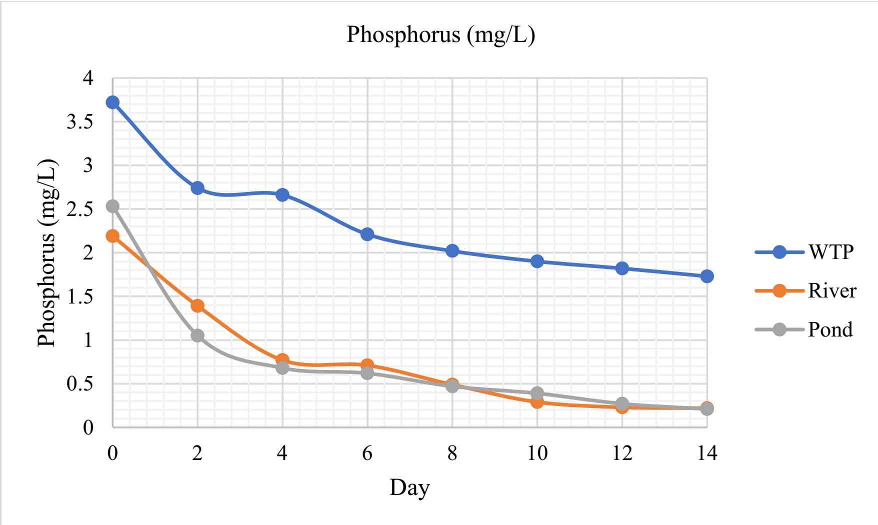

Figure 7. Phosphorus against incubation period (Day).

3.7. Chemical Oxygen Demand

The chemical oxygen demand (COD) measures the amount of oxygen required to oxidize organic matter in the wastewater into inorganic matter. As shown in Figure 8, the effluent sample shows a drastic reduction in the value of COD from 93 mg/L on Day 0 to 11 mg/L on Day 14. Moreover, the concentration of COD for the river sample dropped gradually from Day 0 to Day 8 of phytoremediation. The initial value of COD for the pond water sample is the smallest of the three water sample types. The removal efficiency of COD for wastewater samples in Pusat Asasi, UiTM Dengkil is at the maximum, at 88.17%. Munavalli and Saler (2009) [37] reported that water hyacinth efficiently decreased COD by 30% to 45%. Water hyacinth reduced COD by 95% in domestic wastewater [17]. Water hyacinth was reported to lessen 50% of chemical and biological oxygen demand in a hydraulic retention time of 20 days. Kumari and Tripathi (2014) [38] discovered that a mixed culture of water hyacinth and *Salvinia natans* could remove 84.5% of biochemical oxygen demand and 83.2% of chemical oxygen demand from municipal wastewater.

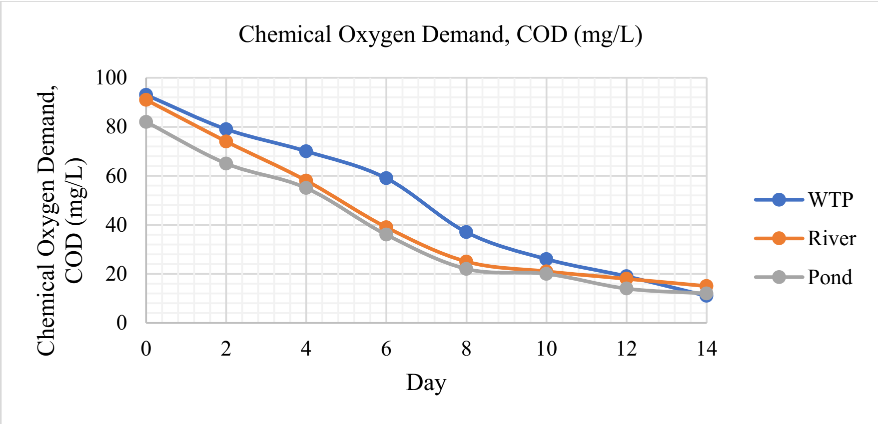

Figure 8: Chemical Oxygen Demand against incubation period (Day).

3.8. Biochemical Oxygen Demand

A biochemical oxygen demand (BOD) measures the number of oxygen microorganisms consume in decomposing organic matter in the water. BOD_5 measures the quantity of biodegradable organic matter in the water. This parameter is expressed as the milligrams of oxygen needed to break down the organic matter in a litre of water for five days. Figure 9 shows the value of BOD_5 for wastewater samples which dropped massively from 11.4 mg/L on Day 0 to 1.44 mg/L on Day 14. For the river water, the concentration of BOD_5 reduced significantly during the two weeks of phytoremediation. Then, the BOD_5 value for the pond water sample experienced a sharp decline on Day 4, with the value of 5.64 mg/L to 2.16 mg/L on Day 6. The removal efficiency of BOD_5 for pond water samples is 88.31%. According to Vymazal (2007) [39], the plant root system is a suitable medium for microbial development, providing an oxygen-rich environment in the rhizosphere for microbial decomposition of organic contaminants. It is the major cause of a significant decrease in biochemical and chemical oxygen demand in plant culture compared to other parameters [19].

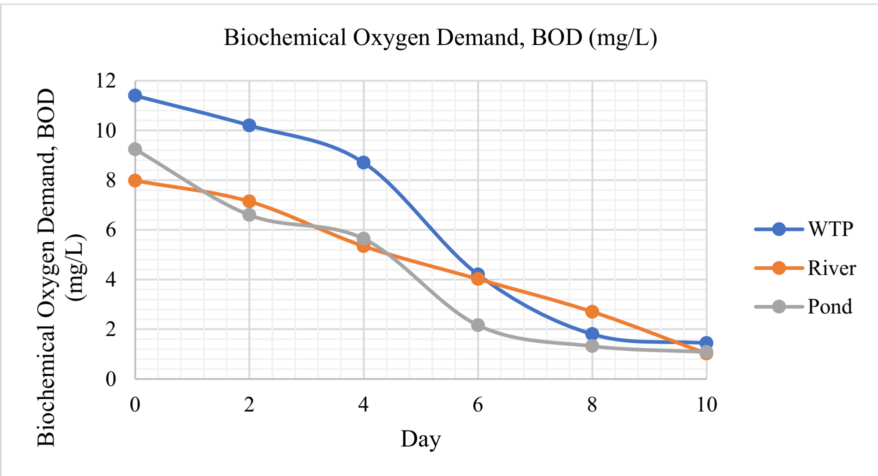

Figure 9. Biochemical Oxygen Demand against incubation period (Day).

3.9. Total Coliform Counts
Total coliform counts are a typical indicator of a water supply's sanitary quality. *E-coli* in water is a significant sign of sewage or animal waste pollution. The primary distinction between *E-coli* and *coliform* is that *E-coli* is a type of bacteria (a *faecal coliform*). In contrast, *coliform* is a bacterium that participates in lactose fermentation when cultured at 35 – 37 °C. As shown in Table 1, the total *coliform* counts are high for all three types of water samples during the two weeks of phytoremediation. Meanwhile, the *E-coli* counts significantly reduced from Day 0 to Day 14 of phytoremediation for all three water samples, as shown in Table 2.

Table 1. Total *Coliform* Counts.

Type of water sample	Total coliform (MPN)							
	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14
WTP	>2419.6	>2419.6	>2419.6	488.4	>2419.6	>2419.6	>2419.6	>2419.6
River	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6
Pond	920.8	>2419.6	>2419.6	980.4	>2419.6	>2419.6	>2419.6	>2419.6

Table 2. *E-coli* Counts.

Type of water sample	E-coli (MPN)							
	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14
WTP	>2419.6	770.1	5.2	2.0	4.1	1.0	1.0	1.0
River	387.3	<1	1.0	1.0	<1	1.0	<1	<1
Pond	30.7	1.0	3.0	<1	<1	<1	<1	<1

4. Conclusion
Data from this research study showed the changes for each type of water sample parameter before and after the phytoremediation process. The laboratory works conducted in this study exhibit a significant reduction in most parameters after 14 days of the phytoremediation process. Therefore, it is shown that water hyacinth effectively treats the water source, especially wastewater effluent. Furthermore, the tertiary treatment of biological processes by phytoremediation using aquatic plants is energy-saving, environmentally friendly, has a low maintenance cost, and has high pollutant removal efficiency. Therefore, the findings of this study potentially benefitted the key players involved in the purification of wastewater effluent.

5. References

[1] Suruhanjaya Perkhidmatan Air Negara (SPAN) 2008 Malaysian Sewerage Industry Guidelines vol 4 p 244
[2] Ahmed S F, Mofijur M, Nuzhat S, et al. 2021 Recent developments in physical, biological, chemical, and hybrid treatment techniques for removing emerging contaminants from wastewater *J. Hazard Mater.* **416** 125912
[3] Naidoo S and Olaniran A 2013 Treated Wastewater Effluent as a Source of Microbial Pollution of Surface Water Resources *Int. J. Environ. Res. Public Health* **11** 249–270
[4] Bhargava D A 2016 Physico-Chemical Waste Water Treatment Technologies: An Overview *Int. J. Sci. Res. Educ.* **4** 5308–5319
[5] Chauhan V, Kumar M and Patil A K 2020 Heat Transfer Enhancement in Pool Boiling of Distilled Water Using Gridded Metal Surface With Protrusions Over Microporous-Coated Surface *J. Heat Transfer* **142**
[6] Esfahani N, Mobarekeh M and Hoodaji M 2018 Effect of Grit Chamber Configuration on

Particle Removal: Using Response Surface Method *J. Membr. Sep. Technol.* **7** 12–16
[7] Mintenig S M, Int-Veen I, Löder M G J, et al. 2017 Identification of microplastic in effluents of wastewater treatment plants using focal plane array-based micro-Fourier-transform infrared imaging *Water Res.* **108** 365–372
[8] Pickering K T and Hiscott R N 2015 *Deep Marine Systems: Processes, Deposits Environments* John Wiley and Sons
[9] Mani S, Chowdhary P and Zainith S. Microbes mediated approaches for environmental waste management In: *Microorganisms for Sustainable Environment and Health* Elsevier p 17–36
[10] Samer M Biological and Chemical Wastewater Treatment Processes In: *Wastewater Treatment Engineering* InTech p 1–50
[11] Diamond J, Altenburger R, Coors A, et al. 2018 Use of prospective and retrospective risk assessment methods that simplify chemical mixtures associated with treated domestic wastewater discharges *Environ. Toxicol. Chem.* **37** 690–702
[12] Collivignarelli M, Abbà A, Benigna I, et al. 2018 Overview of the Main Disinfection Processes for Wastewater and Drinking Water Treatment Plants *Sustainability* **10** 21
[13] Dey P, Mishra A, Malik A, et al. 2020 Mechanistic insight to mycoremediation potential of a metal resistant fungal strain for removal of hazardous metals from multimetal pesticide matrix *Environ. Pollut.* **262** 114255
[14] Paz-Ferreiro J, Gascó G, Méndez A, et al. 2018 Soil Pollution and Remediation *Inter. J. Environ. Res. and Public Health* **15**
[15] Rezania S, Ponraj M, Talaiekhozani A, et al. 2015 Perspectives of phytoremediation using water hyacinth for removal of heavy metals, organic and inorganic pollutants in wastewater *J. Environ. Manage.* **163** 125–133
[16] Sood A, Uniyal PL, Prasanna R, et al. 2012 Phytoremediation potential of aquatic macrophyte, Azolla *Ambio.* **41** 122–137
[17] Rezania S, Taib S M, Md Din M F, et al. 2016 Comprehensive review on phytotechnology: Heavy metals removal by diverse aquatic plant species from wastewater *J. Hazard Mater.* **318** 587–599
[18] Qin H, Diao M, Zhang Z, et al. 2020 Responses of phytoremediation in urban wastewater with water hyacinths to extreme precipitation *J. Environ. Manage.* **271** 110948
[19] Rezania S, Md Din M F, Mat Taib S, et al. 2016 The Efficient Role of Aquatic Plant (Water Hyacinth) in Treating Domestic Wastewater in Continuous System *Int. J. Phytoremediation* **18** 679–685
[20] Batty L C and Dolan C 2013 The Potential Use of Phytoremediation for Sites With Mixed Organic and Inorganic Contamination *Crit. Rev. Environ. Sci. Technol.* **43** 217–259
[21] Roongtanakiat N, Tangruangkiat S and Meesat R 2007 Utilization of vetiver grass (*Vetiveria zizanioides*) for removal of heavy metals from industrial wastewaters *Science Asia* **33** 397–403
[22] Ariffin M and Sulaiman S N M Regulating Sewage Pollution of Malaysian Rivers and its Challenges. In: *Procedia Environmental Sciences* pp 168–173
[23] Munfarida I, Auvaria S W, Suprayogi D, et al. 2020 Application of Salvinia molesta for water pollution treatment using phytoremediation batch system In: *IOP Conference Series: Earth and Environmental Science*
[24] Wang X, Hu M, Xia Y, et al. 2012 Pyrosequencing analysis of bacterial diversity in 14 wastewater treatment systems in China *Appl. Environ. Microbiol.* **78** 7042–7047
[25] Baird R B, Eaton A D, Rice E W 2017 *Standard Methods for the Examination of Water and Wastewater* 23rd ed. American Water Works Association
[26] Hach. 2007 *DR 2800 Spectrophotometer*. 2nd ed. Germany
[27] Akinbile C O, Yusoff M S and Ahmad Zuki A Z 2012 Landfill leachate treatment using sub-surface flow constructed wetland by Cyperus haspan *Waste Manag.* **32** 1387–1393
[28] Loan N, Nguyen P and Anh N 2014 The role of aquatic plants and microorganisms in domestic wastewater treatment *Environ. Eng. Manag. J.* **13** 2031–2038
[29] Lin K, Zhu Y, Zhang Y, et al. 2019 Determination of ammonia nitrogen in natural waters: Recent

advances and applications *Trends Environ. Anal. Chem.* **24**
[30] Mehrani M J, Sobotka D, Kowal P, et al. 2020 The occurrence and role of *Nitrospira* in nitrogen removal systems *Bioresour. Technol.* **303**
[31] Koch H, Galushko A, Albertsen M, et al. 2014 Microbial metabolism: Growth of nitrite-oxidizing bacteria by aerobic hydrogen oxidation *Science (80-)* **345** 1052–1054
[32] Wang B, Wang Z, Wang S, et al. 2020 Recovering partial nitritation in a PN/A system during mainstream wastewater treatment by reviving AOB activity after thoroughly inhibiting AOB and NOB with free nitrous acid *Environ. Int.* **139** 105684
[33] Bouvy M, Nascimento S M, Molica R J R, et al. 2003 Limnological features in Tapacurá reservoir (northeast Brazil) during a severe drought *Hydrobiologia* **493** 115–130
[34] Daniel C, Hans P, Robert H, et al. 2009 Controlling Eutrophication: Nitrogen and Phosphorus. *Science (80-)* **323** 1014–1015
[35] Kumar S and Deswal S 2020 Phytoremediation capabilities of *Salvinia molesta*, water hyacinth, water lettuce, and duckweed to reduce phosphorus in rice mill wastewater *Int. J. Phytoremediation* **22** 1097–1109
[36] Osti J A S, Henares M N P and Camargo A F M 2018 The efficiency of free-floating and emergent aquatic macrophytes in constructed wetlands for the treatment of a fishpond effluent *Aquac. Res.* **49** 3468–3476
[37] Munavalli G and Saler P 2009 Treatment of dairy wastewater by water hyacinth *Water Sci. Technol.* **59** 713–722
[38] Kumari M and Tripathi B 2014 Effect of aeration and mixed culture of *Eichhornia crassipes* and *Salvinia natans* on removal of wastewater pollutants *Ecol. Eng.* **62** 48–53
[39] Vymazal J 2007 Removal of nutrients in various types of constructed wetlands *Sci. Total Environ.* **380** 48–65

Acknowledgments
The authors gratefully acknowledged Universiti Teknologi MARA, Shah Alam and IIUM-UMP-UiTM Sustainable Research Collaboration Grant (600-RMC/SRC/5/3 (051/2020)), provided by RMI for financially supporting this study and providing the resources. The authors also express their sincere gratitude to Pusat Asasi UiTM Dengkil and School of Civil Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam for their assistance throughout the research study.