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Application of Treatment System Using Lepironiaarticulata and Scirpusgrossus for Drinking Water from Tasikchini, Pahang

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Abstract

Abstract—Lake Water from TasikChini is getting more polluted due to human activities like logging, mining, agriculture and tourism around it. The lake water acts as a source of food and water, and medium of transportation for the indigenous people near the lakeside which explain the need for lake water treatment for their sake. There are many types of treatment for polluted water. Phytoremediation is one ofgreen technologies for polluted water which uses plant and increasingly receiving attention as it is a cost-effective treatment and less destructive compared to others. In this study, phytoremediation in a constructed wetland system is used to treat and produce clean potable water. The whole treatment system consists of 5 tanksplanted with two types of plant species. Tank 1 and 2 were planted with Scirpusgrossusand Lepironiaarticulata, respectively. Tank 3 and 4 were connected in series and consist of S. grossus and L.articulata, respectively while Tank 5 is a control tank with no plants. Tank 1 and 2 managed to remove 99.4% and 100% of colour and COD respectively. The highest removal of ammonia and BOD was recorded inTank 3/4 with 100% and 96%, respectively. The treated water is then compared to Malaysia National Water Quality Standard (NWQS) for drinking water purposes. Tank that produced treated water closest to the standard is Tank 3/4, giving evidence that combination of phytoremediation from two different plants is efficient and can be used for lake water treatment.

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I. Introduction

Nowadays, millions of wastewater from sewage, agriculture and other industries which are usually not treated accordingly are released into water bodies like sea, river and lake and eventually pollute those bodies [1]. The water bodies have become a medium for spreading or distributing the pollutants caused or produced by human activities. Despite these water bodies keep on flowing every second, the pollutant content in water bodies keep on increasing everyday which finally accumulate in them. One of the polluted water bodies in Malaysia is TasikChini, the second largest freshwater lake in Malaysia which is linked to Pahang River byChini River [5]. In 2009, TasikChini has been awarded as the first biosphere reserve in Malaysia by United Nations Educational, Scientific and Cultural Organization (UNESCO)[4] which later promote this lake as a tourism spot. The large area of TasikChini which is approximately around 69.22 km^2[6] is reported to be rich in diversity as it has around 288 species of flora, 21 species of aquatic plants, 92 species of birds and 144 species of freshwater fishes [7].TasikChini is inhabited by indigenous people mostly from Jakun tribe. As a result, it serves as food source, water supply and transportation medium for the indigenous people there.

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Due to the multipurpose function of TasikChini, it gives more reason to preserve this national heritage so that the local people can continuously gain as many benefits as they can from the lake and the status of biosphere reserve from UNESCO can be maintained. Nevertheless, the quality of the lake water decreases in the past two decades due to human activities including logging, mining, agriculture and tourism. Uncontrolled logging activities destroyed the habitat of animal and caused soil erosion resulting in flooding during monsoon season. Due to high demand of iron from China, an abandoned iron mine near the river bank is reactivated which lead to heavy metalcontamination in the lake [9]. Agricultural activities surrounding the lake like palm oil plantation uses fertilizer containing high content of nitrogen and phosphorus. This causes TasikChini to be rich in nutrients and more fertile as all those nutrients are washed into the lake during heavy rains and have caused eutrophication.

The National Service Camp and tourism resort built near the lake deteriorate the quality of the lake water by increasing the bacteria content in the lake. According to [10], the lake was contaminated with high level of Escherichia coli (E. coli), Salmonella and other coliform bacteria which exposed the indigenous people nearby to health issues like rashes, diarrhea, vomiting and fever due to improper sewage disposal. The construction of small dam at the downstream of the lake worsen the situation as it caused the water to become stagnant or blocked sink which lead to nutrient increment, blooming of algae and later on the death of aquatic life [8]. Although the lake is very contaminated, but the indigenous people have no choice other than to use it for daily activities Hence, the water from TasikChini needs to be treated so that it will continue to benefit the indigenous people living at the lakeside. The treated water will also help to prevent health problem from rises. Therefore, this research was conducted to treat the polluted lake water for the benefit of indigenous people in TasikChini.

Current conventional treatment for polluted water body and wastewater like coagulation-flocculation, membrane process, adsorption, foam flotation, aerated lagoons, aerobic activated sludge, trickling filter, reverse osmosis, ion exchange, and ozone treatment are used to reduce the contaminants content in the water [41], [11],[13], [12]. However, these types of treatment are found not effective in removing pollutants as they require higher cost of operation, fail to give optimum solution and may introduce secondary contamination [13],[17].

Phytoremediation is a process of treatment that uses plants to clean up, degrade, extract or remove contaminants or pollutants from contaminated soils, sediments and water [14], [15],[16]. This new biological treatment is getting attractive in water treatment field due to its advantages like cost-efficient compared to conventional technologies, environmental friendly (uses solar energy only), can be applied in situ over large area, less hazardous, aesthetically pleasing, effective in reducing wide range of contaminants [18],[13], [19], [17]. Furthermore, it provides habitats for animals and restore the ecosystem that are destroyed by human activities [26]. However, effectiveness of phytoremediation depends on several factors like type of plants species used, rhizosphere microorganism (root zone), medium properties, characteristic and concentration of contaminants, plant growth and survival, addition of chelating agents, climate change and bacteria-plant interaction [13], [27],[17], [28].

Phytoremediation has several mechanisms of treatment such as phytoextraction, phytovolatilization, phytostabilization, phytodegradation, rhizodegradation, rhizofiltration, and hydraulic control [29],[30], [32], [31], [33]. The plants that are used in phytoremediation must have the ability of accumulating heavy metal and known as hyperaccumulators[34]. There are many hyperaccumulators that have been found by other researchers around the world. Table 1 shows the

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phytoremediation studies that have been conducted and its removal efficiency in various field.

Based on Table 1, it has been proven that phytoremediation can be used to treat wide range of contaminants from different source of waste. Since TasikChini is polluted with mining product that consist of heavy metals like arsenic (As), lead (Pb), chromium (Cr), aluminum (Al), cadmium (Cd), iron (Fe) and manganese (Mn), the species of plants used are Scirpus grossus and Lepironia articul at a which are the native plants in the lake to reduce shock from climate change in the process of adapting to local condition [35].Besides that, both plant species are abundantly available around the lake. S. grossus is a perennial tropical aquatic plant that has fibrous roots, triangle and solid stem with high growth rate and exceeds 2 m long for leaves. S. grossusis often found growing in large colonies in water in tropical and temperate regions and its common name in Malaysia is Rumputmenderong [36], [26]. L. articulata is usually known as grey sedge which has cylindrical hollow shoots [17] and pine-cone like at the tip of the stem. According to [39], the common name for this plant in Malaysia is Purundanau. Both plant species has been proven efficient in removing wide range of contaminants by other researchers as listed in Table 1.

Table 1 Application of phytoremediation and its efficiency in different field

Type of effluent/ wastewater	Type of plant used	Removal efficiency	References
Low level nuclear waste	Vetiveriaz izanoides	Sr-90 (94%) Cs-137(61%)	[20]
Polluted river water	Eichhorni acrassipes Loliumpe renne	Ammonia nitrogen (48.6%) COD (20%) TP (63.3%)	[21]
Agriculture (Wheat)	Salix viminalis	Cadmium (27%)	[22]
Iron industry	Phragmati skarka Veteveria nigritana	Lead (15.4%) Magnesium (79.7%) Chromium (97.9%)	[23]
Diesel	Lepironia articulata	TSS (86.3%) PAH removal (96%)	[38]
Mining	Eichhorni acrassipes	Cadmium (90%) BOD (50%) COD (34%) TDS (19%)	[24]
Pulp and paper mill effluent	Scirpusgr ossus	Colour (50.28%) COD (100%)	[37]
Sewage sludge	Helianthu s annuus	Cadmium (84%) Manganese (91%) Copper (85%) Lead (89%) Zinc (84%)	[25]

Constructed wetland (CW) is a technique of phytoremediation that uses the interaction between plants, substrates and microorganisms to treat wastewater [40]. It is reported as a low-cost process for the treatment of municipal, industrial, stormwater and agricultural wastewaters containing heavy metals [23]. Furthermore, CW is also considered as aesthetically pleasing treatment as it can reduce or eliminate the odors from wastewater and it has low maintenance expenses [42]. [43] Reported that CW managed to remove 75-86% of total suspended solid (TSS), total ammonia nitrogen (TAN) and biological oxygen demand (BOD). [23] Reported that vegetated submerged bed CW had removed 15.4%, 79.7% and 97.9% of Pb, Mn and Cr respectively. A study by [48] also reported that CW had efficiently removed chemical oxygen demand (COD), nitrogen and phosphorus but the performance of the wetlands were also affected with seasonal change. Since Malaysia is not affected with the seasonal change, phytoremediation process in a CW system seems like a potential and affordable solution for the treatment of TasikChini lake water as its efficiency has been proven by many.

Therefore, this research was conducted to treat the polluted water from TasikChini in a water treatment system known as CW that uses phytoremediation process and to compare the treated water with the Malaysia National Water Quality Standard (NWQS) for drinking water purpose in order to ensure it meets the regulation standard and is suitable for drinking for the sake of indigenous people and provide them a solution for their current water problem.

II. MATERIALS AND METHOD

A. Location and wastewater source

The study area wasTasikChini which is located in Pekan Pahang with the coordinate of 3.433°N, 102.9167°S. It is made up of 12 open water bodies known as “laut” (Gumum, PulauBalai, Cendahan, TanjungJerangking, GentingTeratai, Mempitih, Kenawar, Serodong, Melai, BatuBusuk, Labuh, Jemberau) by local people [3], [2]. All the tests are conducted in a laboratory at PusatPenyelidikanTasikChini (PPTC), UniversitiKebangsaan Malaysia (UKM) near to the lake. The polluted lake water from TasikChiniwas used as the wastewater source in this experiment.

B. Plant propagation

S. grossusand L. articulatawere collected from the lakeside with the radius of 200 m from the jetty and boat house of PPTC. There were 5 fiber tanks with the dimension of 1 m x 1 m x 1 m. They were planted in fiber tanks for two months to propagate the new healthy plants and to allow acclimatization of new plants to the current condition. After the new plants started to grow, they were divided equally in 4 tanks where one fiber tank consisted of 30 new plants with the same height and age.

C. Design of constructed wetlands

The CW is formed with layer of medium consisting of sand and gravel based on research conducted by [44].There are two different sizes of gravel (big and small). The big gravel has diameter of 30-35 mm while the small gravel has the diameter of 10-15 mm. Difference in sizes of gravel was chosen based on research conducted by [38] which was able to remove TSS. The layer of medium from the bottom was big gravel, followed by sand (1-3 mm in diameter) in the middle and small gravel at the top level. By using the ratio of 3:3:1, big gravel, sand and small gravel has the depth of 15 cm: 15: cm: 5 cm respectively (Fig.1(a) and 1(b)). The CW system consists of 5 fiber tanks labeled as Tank 1, Tank 2, Tank 3, Tank 4 and Tank 5. Tank 1 consisted of S. grossus species only,and Tank 2 withL. articulataspecies only. Tank 3 and 4 were connected in series and consisted of S. grossus and L. articulata, respectively as shown in Fig. 2. Tank 5 acted as control tank with no plants. This arrangement is made to evaluate the performance of each species of the plants and the combination of both plant species. The on-site of the whole system can be referred in Fig. 3.

D. Experimental set up and sampling

The CW was a free surface flow system (FSF) type as this type is widely used and preferred because of low construction cost and it provide habitats for the animal [26]. The system was also designed to operate in a continuous mode to ensure the treated water is produced consistently and sufficient for domestic usage of indigenous people. The new plants were exposed to the polluted lake water for 45 days. The volumetric flowrate (Q) of influent that entered the system is 20 L/min with hydraulic retention time (HRT) of 3 days. The sampling was six times along the duration scheduled on day 0, 3, 10, 20, 35 and 45.

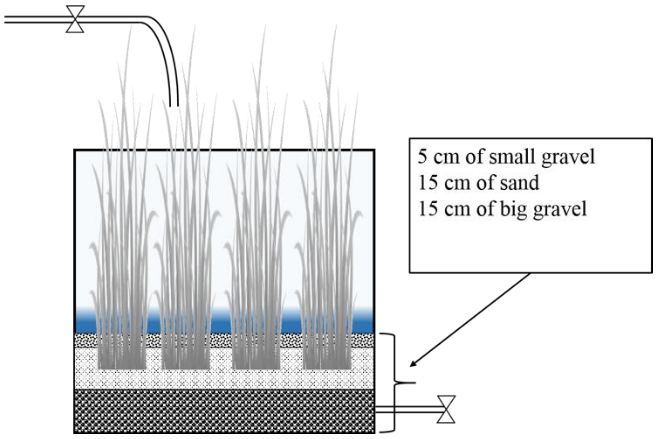

Fig.1(a) Layer of medium with S. grossus

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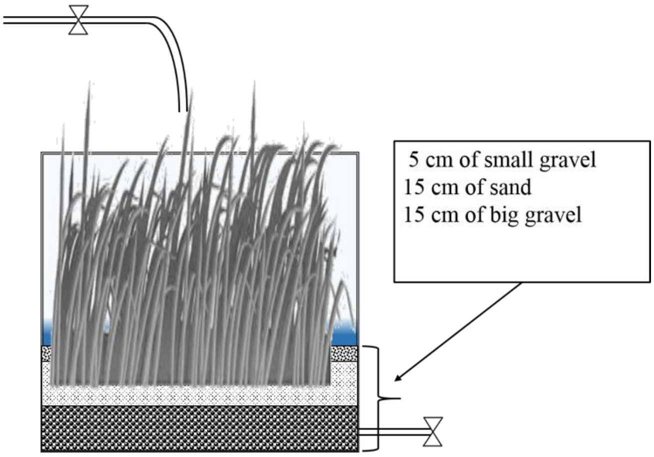

Fig. 1(b) Layer of medium with L. articulata

E. Analysisof water quality

The treated samples were collected in triplicates to increase the accuracy of the results. These samples were tested for water quality parameters(TSS, colour, dissolved oxygen (DO), nitrate, ammonia, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total coliform, fecal coliform and heavy metal (Cr, Cd, Pb, Fe)) to monitor the performance of phytoremediation in CW system. Colour, nitrate and ammonia were tested using machine HACH DR2800 (U.S.) while BOD and DO wereanalysed using DO meter. For heavy metals parameter, the samples were determined using Inductively Coupled Plasma-Optical Emission Spectrophotometry (ICP-OES). These parameterswere then compared to Malaysia NWQS for drinking water purposes in order to check whether the treated water is safe for human consumption through this treatment.

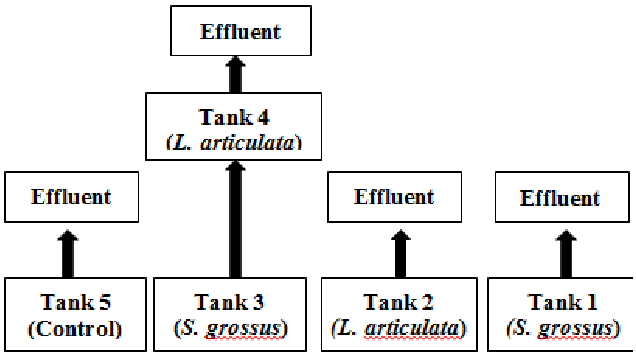

Fig. 2 Block diagram for the whole CW system

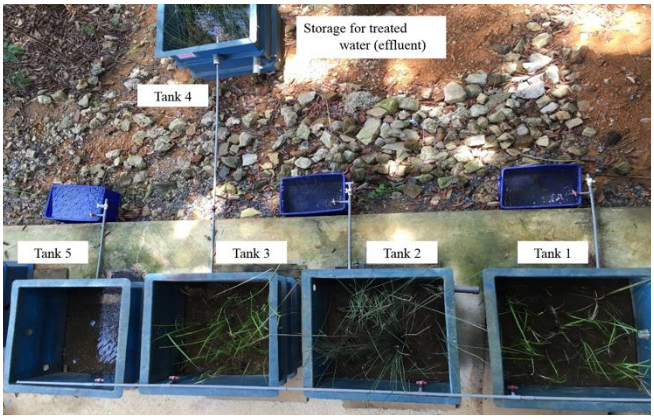

Fig. 3 On-site treatment system

II. Results and Discussion

A. Performance of constructed wetland through phytoremediation process

i. TSS

Fig. 4 shows the concentration of TSS for each tank for the whole 45 days. The initial amount of TSS in the influent was 8.846 mg/L. Tank 1 managed to remove 94.6% of TSS from the influent which in the end become 0.474 mg/L while Tank 2 removed 89.5% of TSS. The combination of Tank 3 and 4 was capable to remove 94.1% of TSS. Tank 5 which acted as control could remove 92.7% of TSS although there were no plants. The highest removal of TSS came from Tank 1 followed by Tank 3/4, tank 5 and tank 2. According to a study conducted by [44], L.articulatawas proven better as it could tolerate higher concentration of Fe and Al mixture compared to S. grossus. This is also proven by another researcher, [17] whom reported that L. articulatashows high resistance towards diesel contamination around 39.2 mL/L compared to S. grossus(5mL/L). However, in this experiment, Tank 1 (S. grossusonly) achievethe highest TSS removal compared to Tank 2 (L. articulataonly) after 45 days although the TSS value by Tank 2 has decreased significantly on day 10. This may be due to the presence of dead insects in Tank 2 is more than Tank 1 which increased the TSS amount. High removal of TSS from Tank 5 without plants was still obtainedsince the medium layer of CWhas acted as filtering system. This shows that medium layer in CW without plant can remove TSS as it provides space for the interaction between pollutants and microbes besides from filtering purposes.

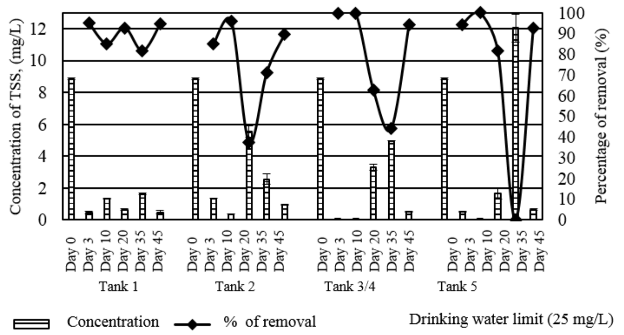

Fig. 4 Concentration of TSS for each tank for 45 days

ii. Colour

Fig. 5 depicts the amount of colour removal for each tank for 45 days of exposure. Originally, the amount of colour in the influent was 54 total colour unit (TCU). After 45 days, Tank 1 and 2 managed to reduce colour to a value of 0.333 TCU which equivalent to 99.4% removal, while Tank 3/4 managed to remove 100% colour from the influent. Tank 5 managed to reduce colour to 11 TCU which equivalent to 79.6% of removal. The order of colour removal from highest to lowest areTank 3/4, Tank 1 and Tank 2 at the same removal rate and Tank 5. This shows the effectiveness of phytoremediation as all tanks that have plants managed to reduce a substantial amount of colour compared to the control tank (Tank 5) without plants.

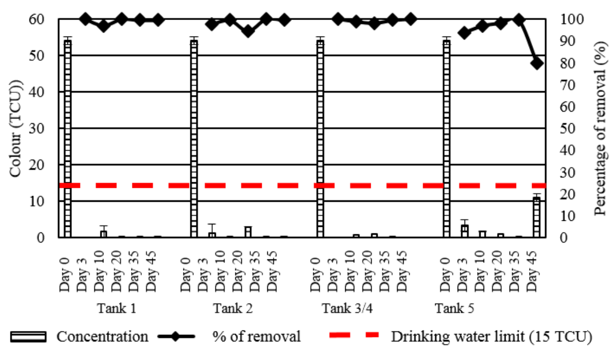

Fig. 5 Concentration of colour for each tank for 45 days

[33] Reported that the greatest removal of colour in coffee effluent was by CW with plants (83%), whereas CW without plant managed to gradually reduce colour from the coffee effluent from time to time. This prove that phytoremediation in a CW is better that CW alone without plants in removing colour in wastewater. Tank 1 and 2 (S. grossus and L. articulatarespectively in each tank)reduced the amount of colour almost the same as Tank 3/4 (S. grossus followed by L. articulata) with the two stages of phytoremediation, indicating that one stage phytoremediation is already enough to remove colour from TasikChini lake water as the concentration is not too high.

iii. Nitrate

Concentration of nitrate along the exposure is illustrated in Fig. 6. It can be observed that nitrate content increased for all tanks. The initial amount of nitrate concentration in the influent was 0.04mg/L. From the initial amount of nitrate in the lake water, Tank 1, 2, 3/4 and 5 became 0.149mg/L, 0.083 mg/L, 0.08 mg/L and 0.083 mg/L respectively. The order of nitrate increment from highest to lowest are Tank 2 and tank 5 with same increment, followed by Tank 1 and Tank 3/4.The highest amount of nitrate increment from Tank 2 and 5 correlates with the result of TSS removal which indicate the two lowest removal of TSS is also by Tank 2 and 5.Tank 1, 2 and 3/4 increased in nitrate concentration because CW with plants is known to be a habitat provider for the animal [26] and this can also lead to addition of nitrate. However, the reason why tank 5 (control tank) still had increment in its nitrate content is because CW without plant still provide habitat for small animals like mosquitoes, spiders and ants mostly from the insect family since there is source of water in tank. When these animals are dead in the tank, they decomposed naturally and increase the nitrate content causing nitrate increment in every tank.

A research conducted by [45] reported that hydromacrophyte like S. grossus has potential in reducing nitrate content up until 90% after 6 days of treatment for water body that is rich in nutrient like nitrate and phosphate. However for this study, the amount of nitrate reduced by Tank 1 (S. grossusonly) in 10 days from day 35 to day 45 is

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only 70%. The small amount of nitrate removal in this study is because of the low nitrate content availability in the water compared to the previous research that uses water that is rich in nutrient.

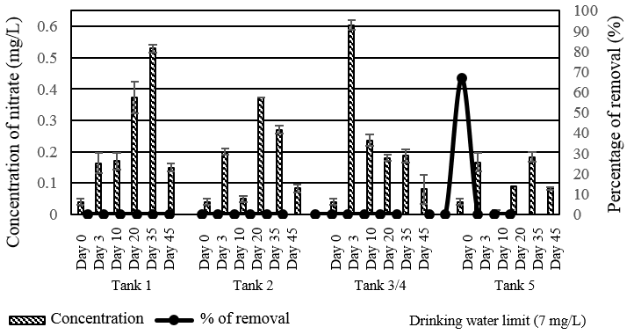

Fig. 6 Concentration of nitrate for each tank for 45 days

iv. Ammonia

Fig. 7 indicates the concentration of ammonia for each tank along the 45 days of experiment. Initially, the concentration of ammonia in TasikChini lake water was 0.237 mg/L. After 45 days of exposure, tank 1 and 2 managed to remove 98.6% of ammonia content from the influent while tank 5 managed to remove 97.2% of ammonia content. Tank 3/4 has succeeded in removing 100% of ammonia from the influent after 45 days. From the results, it can be said that all tanks containing plants (Tank 1, 2 and 3/4)has removed ammonia slightly higher than the control tank (Tank 5). A study by [47] reported that most studies have shown that CW system with plants has higher treatment efficiency compared to unplanted system. This can be explained by the addition of oxygen supply to the rhizosphere zone through plant roots which can enhance the microbial degradation of the pollutant.

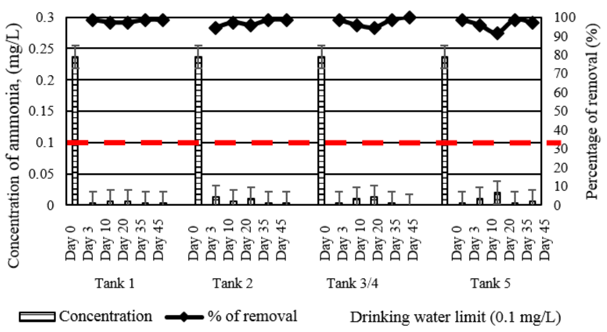

Fig. 7 Concentration of ammonia for each tank for 45 days

v. COD

From Fig. 8, it can be seen that all tanks have succeeded in removing almost all organic pollutant (COD) in the influent. Tank 1 and 2 has removed COD content completely from the influent while Tank 3/4 and 5 has removed 89.5% and 94.7% of COD, respectively. The difference in COD removal between planted tanks (Tank 1 and 2) and the control tank (Tank 5) is insignificant. In fact, Tank 5 managed to reduce the amount of COD more than by Tank 3/4. [50] reported that high removal rates of COD from the water contaminated with diesel were also due to CW substrate or medium or filtration bed which is by physical filtration and sedimentation process. Other researcher reported in their study that COD removal mechanism in CW is by microbial activity of aerobic and anaerobic bacteria [48]. This explains whythe control tank (Tank 5) was capable in removing COD significantly as the filtration bed of CW and microorganismalso presented in this tank.

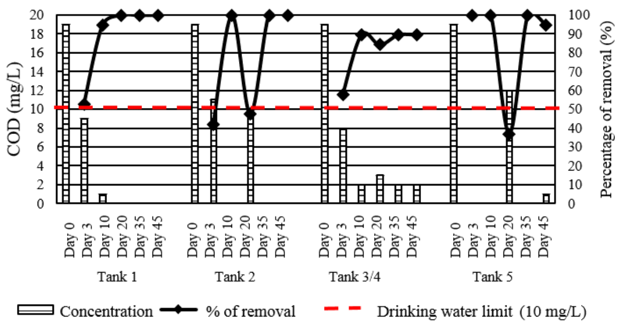

Fig. 8 Concentration of COD for each tank for 45 days

The removal of COD from Tank 3/4 was lower than Tank 1 and Tank 2 although it has two level of phytoremediation treatment. [33]whom conducted two stages of phytoremediation reported that the two-stage phytoremediation could remove 95% of COD content from the coffee effluent where the initial amount of COD was 13,000 mg/L. The efficiency of two stages phytoremediation treatment could not be seen in this study since the available COD content in the lake water (19 mg/L) was already low. However, it still needed treatment as the COD value is still above the standard limits. From here, it can be concluded that

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phytoremediation by single plant species is already enough and efficient in removing 100% of COD from the lake water.

IV. BOD

Fig. 9 below demonstrates the BOD concentration for each tank along the exposure days.The highest removal of BOD was by Tank 3/4 followed byTank 1, Tank 2 and Tank 5 with the removals of 96%, 91.8%, 89.95 and 87.5%, respectively. All tanks containing plants (Tank 1, 2 and 3/4) has removed slightly higher amount of BOD compared to Tank 5 without plants. The reason why Tank 5 still managed to remove 87.5% of BOD content was due to the microbial activity in the unplanted wetland that break down the pollutants or the layer medium of the wetland itself that filter the pollutant as they went through the medium [48], [26].

[49]statedthat plants can transfer oxygen to the rhizosphere zone which will enhance the biodegradationof pollutants by microbes. The interaction between plant and microorganism shows that phytoremediation processhas assisted removing BOD content compared to tank 5 which has lowest BOD removal. The percentage of BOD removal does not differ much (5%) between Tank 1 that has single species of plant and Tank 3/4 that has two species of plants. As mentioned earlier, the effectiveness of two stages phytoremediation could not be seen in this study due to the initial amount of BOD whichwas originally too low.

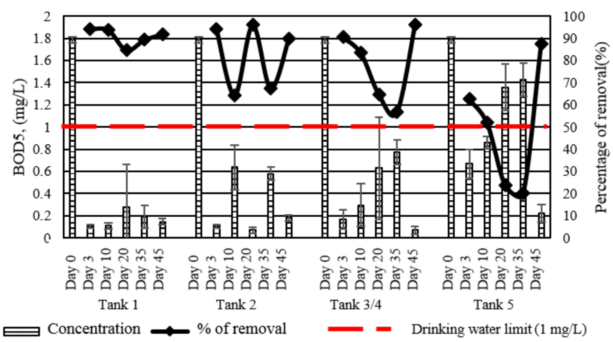

Fig. 9 Concentration of BOD for each tank for 45 days

vii. Fecal coliform

Fig. 10 shows the amount of fecal coliform for each tank for the whole 45 days. The result shows that highest removal of fecal coliform is by Tank 2 (99.2%) followed by Tank 3/4 and 5 at the same amount (98.4%) and Tank 1 with 92.1% of removal. In a previous research by [46], it was reported that removal of coliform by CW system is carried out by macrophytes where the coliform number is decreased by stimulating the preying microorganism in the rhizosphere and secreting the inhibiting metabolites. CW without plants (Tank 5) can also remove almost all the fecal coliform. This may be due to layer of filtration bed in all tanks that helps to filter or trap the coliform in between the layer. The highest fecal coliform removal is by Tank 2 showing that L. articulatais more efficient is reducing the amount of fecal coliform.

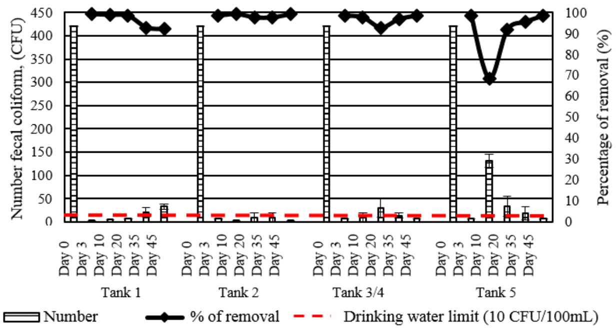

Fig. 10 Amount of fecal coliform for each tank for 45 days

viii. Total coliform

Fig. 11 illustrates the removal performance of total coliform for each tank in 45 days. The highest removal of total coliform is by Tank 5 followed by Tank 3/4, Tank 2 and Tank 1 with removals of 97.1%, 93.5%, 90.8% and 90.6%, respectively. It can be seen that the removal does not have significant difference and almost the same for all tanks. This is due to similarities that all the tanks were equipped with layer of filtration bed that has played an important role in removing total coliform. This is supported with a researchby [51] who highlighted that average removal in unvegetated bed was higher compared to vegetated bed which is due to the entrapment and attachment by filtration bed.

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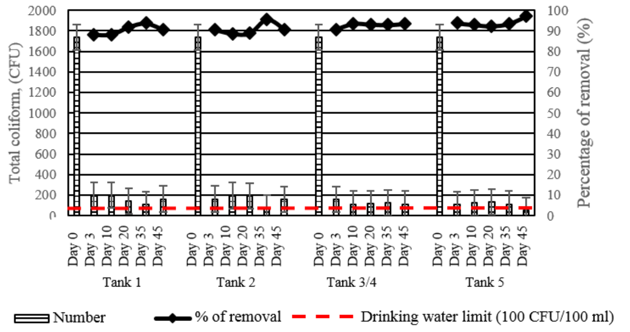

Fig. 11 Amount of total coliform for each tank for 45 days

xi. Heavy metal concentration

Heavy metal that was studied in this experiment are Cd, Cr, Fe and Pb.For Cd. From Fig. 12, the concentration of Cd for Tank 1 increased to a higher amount at 35 days which is from 0.599 mg/L to 0.888 mg/L which then was removed completely by Tank 1. Tank 2, 3/4 and 5 show no increment of Cd along the 45 days. Based on this study, it is observed that increment in Cd concentration for Tank 1 is may be due to the unhomogenized influent. All the tanks removed Cd completely by the end of experiment which shows the important role of metal-resistant microorganism that existed in filtration bed of all CW tanks which help in reduction of metal concentration like Cd.For chromium, there is no significant change on the concentration for all tanks as the influent has too little amount of Cr (Fig. 13).

Fe concentration in each tank is shown in Fig. 14. Based on the results, it can be concluded that Tank 1, 2 and 3/4 has an improvement in reducing Fe from the initial amount of 0.41 mg/L, 0.4 mg/L and 0.39 mg/L, respectively. The removal of Fe concentration by all the planted tanks has proven the effectiveness of phytoremediation in CW.

Fig. 15 shows the concentration of Pb throughout the experiment. According to [23], vegetated submerged bed CW has removed 15.4% of Pb. This has proven to be true as all the planted tanks (Tank 1, 2 and 3/4) managed to reduced amount of Pb significantly and completely. However, the removal of Pb is also being done by unplanted tank (Tank 5) leading to a conclusion that removal of Pb for all the tanks can also be due to filtration bed.

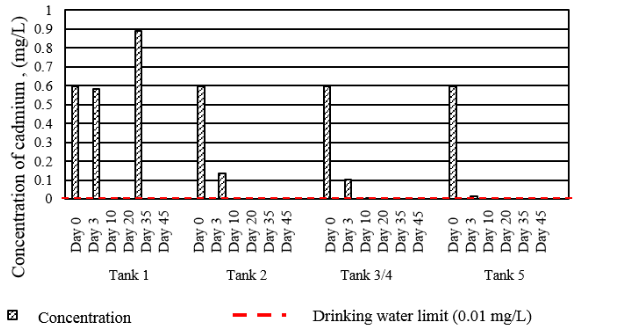

Fig. 12 Concentration of Cd for each tank for 45 days

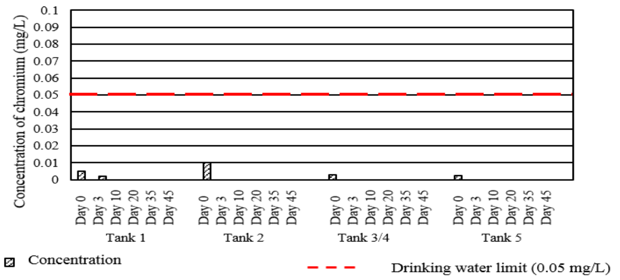

Fig. 13 Concentration of Cr for each tank for 45 days

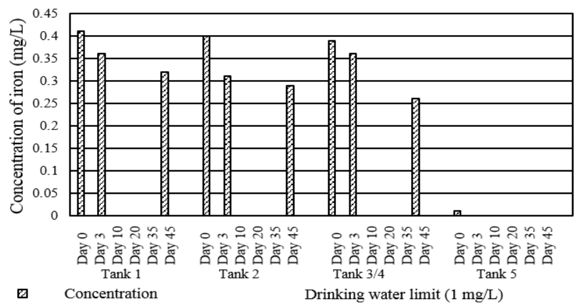

Fig. 14 Concentration of Fe for each tank for 45 days

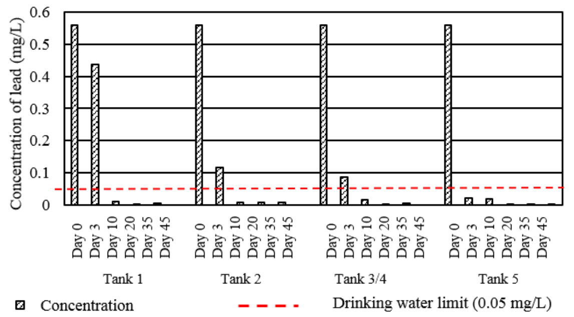

Fig. 15 Concentration of Pbfor each tank for 45 days

B. Comparison of the treated water with drinking water standard

Finally, the treated lake water qualitywas

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compared with the standard drinking water of Class I, set by Malaysia NWQS, which requires no treatment and it can be consumed directly. Furthermore, Class I is also set for conservation of natural environment like TasikChini.Based on Table 2, parameters that exceeded the acceptance limit for drinking water standard by Malaysia NWQS were total coliform and fecal coliform. For total coliform, all tanks except Tank 5 exceeded the allowable limit with the value of 163.3 CFU/100mL, 160 CFU/100 mL and 113.3 CFU/100 mL, respectively. In term of fecal coliform, the tanks that succeeded the maximum limit standard set by Malaysia NWQS for drinking water were Tank 1 with the amount of 33.33 CFU/100mL. The other 3 tanks were below the maximum limit allowed. Exposure to the excess amount of total coliform and fecal coliform will cause rashes, allergies, severe diarrhea and abdominal cramps which can result in fatal [10].

The other parameters (COD, BOD, nitrate, TSS, colour, ammonia and heavy metals concentration (Fe, Cr, Cd and Pb)) were lower than the standard limit set for drinking water for all tanksindicating remarkable performance achieved by the constructed wetlands. Tank 3/4 with combination of both S. grossusand L. articulataor tank with two stages of phytoremediation has successfully treated the lake water closest to the Malaysia NWQS standard for drinking water.The removal of total coliform can be enhanced by increasing the exposure time of the experiment as the amount keep on decreasing from day to day.

III. CONCLUSIONS

The main objective of this study is to treat the lake water from TasikChini through phytoremediation in a constructed wetland and to compare the treated water with Malaysia NWQS standard for drinking water. From the findings, it can be concluded that highest removal of TSS is by Tank 1 (94.6%). Tank 1 and 2 has the highest removal of colour and COD which were 99.4% and 100% respectively. Tank 2 has removed the highest amount of fecal coliform (99.2%). Ammonia and BOD were reduced by 100% and 96% respectively, by Tank 3/4. The treated water has been compared with Malaysia NWQS for drinking water standard based on Class I and the tank that has treated TasikChini lake water closest to the standard is Tank 3/4, proving that the combination of phytoremediation from two plants is more efficient and can be used for lake water treatment.

Table 2 Final concentration of tested parameter in each tank

Type of tank / Parameter	Final concentration of tested parameter in each tank				MalaysiaNWQS drinking water standard
	Tank 1	Tank 2	Tank 3/4	Tank 5	
TSS (mg/L)	0.474	0.931	0.518	0.639	25
Colour (TCU)	0.333	0.333	0.337	11	15
Nitrate (mg/L)	0.149	0.083	0.08	0.083	7
Ammonia (mg/L)	0.003	0.003	0	0.007	0.1
COD (mg/L)	0	0	2	1	10
BOD (mg/L)	0.147	0.18	0.07	0.223	1
Cd(mg/L)	0	0	0	0	0.01
Cr(mg/L)	0	0	0	0	0.05
Fe(mg/L)	0.32	0.29	0.26	0	1
Pb(mg/L)	0.005	0.007	0.004	0.002	0.05
Total coliform (CFU/100ml)	163.33	160	113.33	50	100in 100 ml
Fecal coliform (CFU/100ml)	33.33	3.33	6.67	6.67	10 in 100 ml

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