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Phytoremediation Efficiency of Water Hyacinth for Batik Textile Effluent Treatment

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ABSTRACT

The present study focused on the phytoremediation efficiency of water hyacinth for the batik effluent treatment. Three operating factors were investigated such as retention times (0 to 28 days), batik effluent strength (20, 30 and 60%), and number of water hyacinth clumps (8, 10 and 12 clumps). The water hyacinth efficiencies was monitored through the measurement of dry weight, color, chemical oxygen demand (COD), total suspended solid (TSS), and pH. The highest efficiency of color and COD in the batik effluent treatment were achieved at day 7 with 83% (61 mg/L) and 89% (147 ADMI) removals, respectively. Both wastewater parameters were removed to below the Standard A for COD and Standard B for color. Meanwhile for TSS, the removal decreased as the batik effluent strength increased, where the highest removal (92%) was achieved at day 28 with 8 number of plant clumps. The pH was observed in range of 6 to 7. The results indicated that water hyacinth would be the best option for the low cost batik effluent treatment.

Keywords: Batik effluent, water hyacinth, phytoremediation, color removal, COD removal

INTRODUCTION

Fresh water is one of the most important needs in human life besides food and shelter. The sources of fresh water consist of surface water and underground water. However, with Malaysia rapidly becoming an industrial-based country, many rivers have become polluted since wastewater or effluent is kept being discharged into the rivers. The industrial effluent discharged without proper treatment into water body often contains non-biodegradable substances and which likely accumulate in the soil, aquatic environment and in the organ of plants (Gandhi et al. 2013). One of the industries that should be put into list of concern is the batik textile industry which operates at small medium scale. This is due to the fact that this industry does not only generate massive amount of effluent but the generated effluent contains a mixture of chemicals such as dyes and waxes that comes from bleaching, washing, dyeing and printing process in the production (Nemerow 1971). The chemicals washout from batik textile industry into the water body was expected and can cause deterioration of the water quality.

Since the discovery of synthetic dyes, it was recorded that the annual production of dye to date was 800,000 tons of 10,000 different synthetic dyes (Kumar et al. 2018). The figures itself shows that synthetic dyes have vast in application not only in the production of textile but also in pulp and paper manufacturing, plastics and leather treatment (Buthelezi et al. 2012). Moreover, according to Buthelezi et al. (2012), there are more than 8,000 chemical products involving the dyeing process recorded in Colour Index that includes variation in structure of dyes like acidic, basic, reactive, disperse, azo, diazo, anthraquinone-based and metal-complex dye hence, making the treatment of wastewater containing dye very difficult and challenging. The dyes containing wastewater are often characterized as high in chemical oxygen demand (COD), high in color, high variations of pH and toxic to microbial consortia that lead to interference to photosynthetic activity, temperature and microbial activities in the environment (Kumar et al. 2018).

Batik is reported as one of the oldest cottage textile industries in Malaysia and Indonesia. In Malaysia, there are over 1000 batik small scale factories located throughout Terengganu and Kelantan on the east coast of Malaysia (Rashidi et al. 2013). Meanwhile, the batik industries in Indonesia are located in 38 regions of Java Island. The most scatted locations are in Pekalongan, Solo, Lasem, Tegal, and Banyumas. Most of the batik industries are home-based and small-scale industries with no effluent treatment plant due. The main problem of the batik industry is the effluent discharge during the process of soaking, boiling, and rinsing without proper treatment. This effluent contains a huge amount of water and chemicals such as dyes, waxes, as well as fixing agents like silicate, resulting in a high pH, total suspended solids (TSS), chemical oxygen demand (COD), and color (Khalik et al. 2015; Birgani et al. 2016; Mukimin et al. 2018). For these reasons, the treatment of batik effluent is essential to conserve environment, especially water bodies.

In order to curb the problem regarding the dyes-based effluent, many treatment technologies – either via physical, chemical and biological treatments such as bioremediation (El-Kassas & Mohamed 2014), catalytic oxidation (Malik et al. 2018; Asgari et al. 2019), membrane filtration (Rashidi et al. 2012; Tavangar et al. 2019), sorption process (Wibowo et al. 2017; Sharma et al. 2019) and coagulation/flocculation (Pavas et al. 2018; Dotto et al. 2019) process – were studied. However, the application of the phytoremediation technology gained more attention in treating the dye-based effluent such as the batik effluent, because this type of technology is new and interesting for exploration; additionally, it is characterized by eco-friendliness and cost effectiveness compared to the physicochemical and other biological methods (Khandare & Govondwar 2015; Tan & Morad 2016). This technology is suitable for application in the treatment industrial effluent, and can also be applied on contaminated soil and groundwater due to its low-tech and low-cost.

Therefore, the objectives of this study were to determine the tolerance of water hyacinth towards the difference strength of the batik effluent and to determine the performance of water hyacinth as a phytoremediation agent in treating the batik effluent. The performance of the water hyacinth was monitored and evaluated through the removal of chemical oxygen demand (COD), color, total suspended solid (TSS) and pH.

MATERIALS AND METHODS

Water hyacinth

Water hyacinth was collected in a lake located in Bukit Mahkota, Selangor, Malaysia. The plant was collected at appropriate size of clumps and leaves. Prior to the experiment, the plant was regrown under a greenhouse condition in Universiti Kebangsaan Malaysia.

Experimental setup

An aquarium with the dimensions of 37×27×10 cm (Figure 1) was used as phytoremediation reactor in this study. It was made of plastic. The batik effluent was placed inside the reactors and operated in batch mode system. Then, the water hyacinth was put on the surface of the batik effluent inside the reactor. As shown in Table 1, three variables were, investigated namely hydraulic retention time (HRT) (0, 4, 7, 14, 21 and 28 days), number of plant clumps (8, 10 and 12), and batik effluent strength (20%, 30%, 60%). The samples was taken at each HRT and kept at 4°C prior to the water quality analysis (COD, color, TSS and pH). Table 1 shows the design of experiment in this study.

Water Quality Analysis

The water quality analysis was conducted before and after the water treatment to determine the effectiveness of phytoremediation. The water quality parameters were pH, COD, color, and total suspended solid (TSS).

pH

The pH values was measured using a pH meter (Metrohm 827 pH Lab, Switzerland). The pH was measured by dipping the electrode into a container that contained the batik effluent sample.

Chemical oxygen demand

The measurement of COD was conducted using a spectrophotometer (HACH DR3900, USA). In order to analyse COD, high range (20–1,500 mg/L) COD reagent were digested with 2 mL of the batik effluent sample in a digestion reactor (HACH DRB200, USA) at 150 °C for 2 hours according to Method 8000 (HACH 2010).

Color

The color of the textile wastewater sample was measured by using a spectrophotometer (HACH DR 3900,USA) which can be found in Environmental Laboratory FKAB,. In order to analyse the color of the wastewater sample, the wavelength of 455 nm was used.

Total suspended solid

For total suspended solid analysis, 0.45 µm cellulose nitrate membrane filter (Whatman™, UK) was dried at 105°C for an hour and allowed to cool in dessicator for 15 minutes. The initial weight of the filter paper after dried was recorded. Next, 20 ml of wastewater sample was filtered using the vacuum pump. The filter paper that contained suspended solid was dried in the oven for another 1 hour at 105°C and the final weight was recorded. The total suspended solids present in the batik effluent wastewater sample was calculated using equation (1).

$$\text{Total suspended solids (mg/L)} = \frac{[\text{final weight (mg)} - \text{initial wight (mg)}]}{\text{volume of the sample (L)}} \tag{1}$$

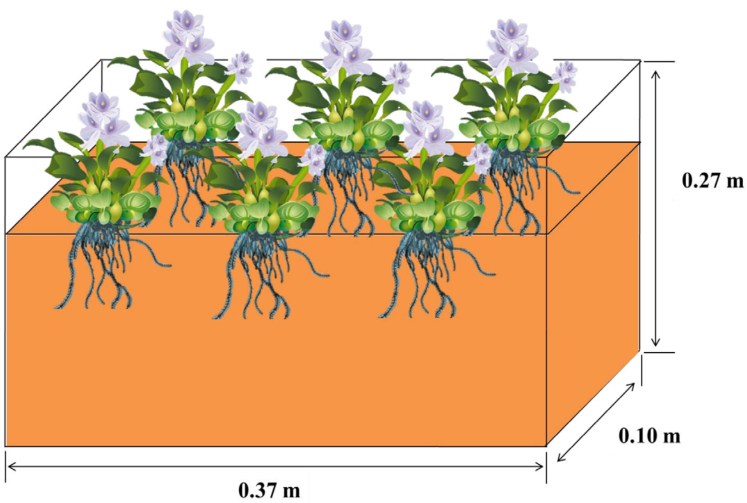

Figure 1. Schematic of floating phytoremediation using water hyacinth in treating batik effluent

Table 1. Experimental design of phytotoxicity test

Number of clumps			Batik effluent strength (%)	Hydraulic retention time (Days)
8 clumps	10 clumps	12 clumps	0	0, 4, 7, 14, 21 and 28
			20	
			30	
			60	

Statistical analysis

The statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software version 21 (USA). A function of multivariate one-way analysis of variance (MANOVA) was used with the level of confidence set below than 0.05 ($p < 0.05$).

RESULTS AND DISCUSSIONS

Characteristic of the batik textile effluent

The characteristic of the batik effluent was determined for three types of samples; 1) after printing, 2) after washing, and 3) mix effluent after printing and washing. As summarized in Table 2, the batik effluent contained high concentration of COD and BOD5 ranging between 248–2198, and 148.5–399 mg/L, respectively, but low NH_4^+-N concentration in range of 1.18–3.60 mg/L. As dyes are a main components in the batik industry, the level of color was from 87 to 1469 ADMI with turbidity in range of 13.1 to 18.7 NTU. The batik effluent did not contain high concentration of TSS (4–72 mg/L). The pH was measured in range of 6.55 to 7.9. On the basis of the characterization, batik effluent from printing process can be considered as high strength batik effluent due to high contamination. However, in this study, the mix batik effluent was used. The batik effluent was higher than the standard limit regulated by Department of Environment (DOE), Malaysia.

Water hyacinth growth monitoring

The photo of growth and health of water hyacinth with the time (day 0 and 28) and batik effluent strength were shown in Table 3. The higher the batik effluent strength, the more water hyacinth plant growth decreased. The water hyacinth plant growth in a tap water showed a good condition at the end of 28 days. From the table, it can be seen that the best growth of water hyacinth was for 20% batik effluent strength. For the batik effluent strength of 30%, 95% of the plants died (with 8 plants), 75% (with 10 plants) and 60% (with 12 plants). In addition, the plants died entirely for the batik effluent strength of 60%.

Figure 2 shows the weight of water hyacinth at day 0 and end of 28 days. Initially, the weight of a water hyacinth was constant at 40 g for each tank containing different batik effluent strength. It can be seen that the weight of the plant for control increased to 70, 90, and 60 g for 8, 10 and 12 plants, respectively. As the plant was exposed to the batik effluent strength of 20%, the weight of water hyacinth was consistent at the end of 28 days. However, the water hyacinth weight started to decrease to below 35 g when the exposed to batik effluent strength of 30 and 60%. This relate to the Table 3 where most of the plant died 30 and 60% batik effluent strength.

Removal of chemical ogygen demand (COD)

The COD levels in the batik effluent were measured throught the exposure time of 28 days, as shown in Figure 3. The initial COD concentration for the batik effluent strength of 20, 30 and 60% were 200, 320 and 450 mg/L, respectively. The COD started to decrease after day 4 exposure, and the removal significantly occurred at day 7 onwards for all numbers of water hyacith, but only in the case of exposure with 20% and 30% batik effluent strength. As can be seen in Figure 3, after day 7, the removal rate was slightly slower until day 28. This could be related to the growth of water hyacith where some of the plants died, especially for 60% batik effluent

Table 2. Characteristics for batik effluent

Parameter	Printing process	Washing process	Mix	Standard A	Standard B
pH	6.55	7.9	7.15	5.5–9.0	6.0–9.0
NH_4^+-N (mg/L)	3.6	1.18	2.75	10	20
COD (mg/L)	2198	248	533	80	200
TSS (mg/L)	51	4	72	50	100
Turbidity (NTU)	13.1	18.7	17.4	<5	<5
BOD_5 (mg/L)	399	148.5	204	20	50
Colour (ADMI)	1469	87	885	100	250

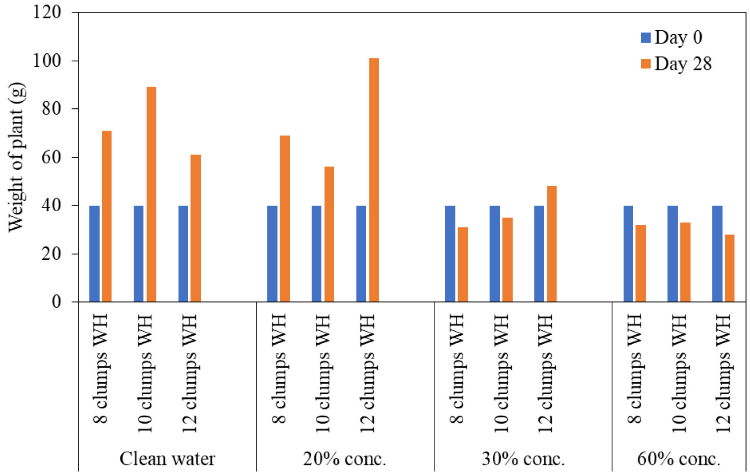

Figure 2. Dry weight of water hyacinth plant before and after treatment

Table 3. Physical observation of water hyacinth throughout 28 days exposure

Batik effluent	Day 0	Day 28
Control		
20%		
30%		
60%		

strenght. With number of 8, 10 and 12 plants for 20% batik effluent, the COD removal achieved the Standard A limits (< 80 mg/L). However, for the 30 and 60% batik effluent, the removal only achieved the Standard B limits (200 mg/L). As summarized in Table 4, one-way analysis of variance (ANOVA) shows that there was no significant difference of COD removal as increased the number of water hyacinth ($p > 0.05$). In addition, an increase in the batik effluent strength, significantly reduced the COD removal for all plant numbers. In the research by Tambunan et

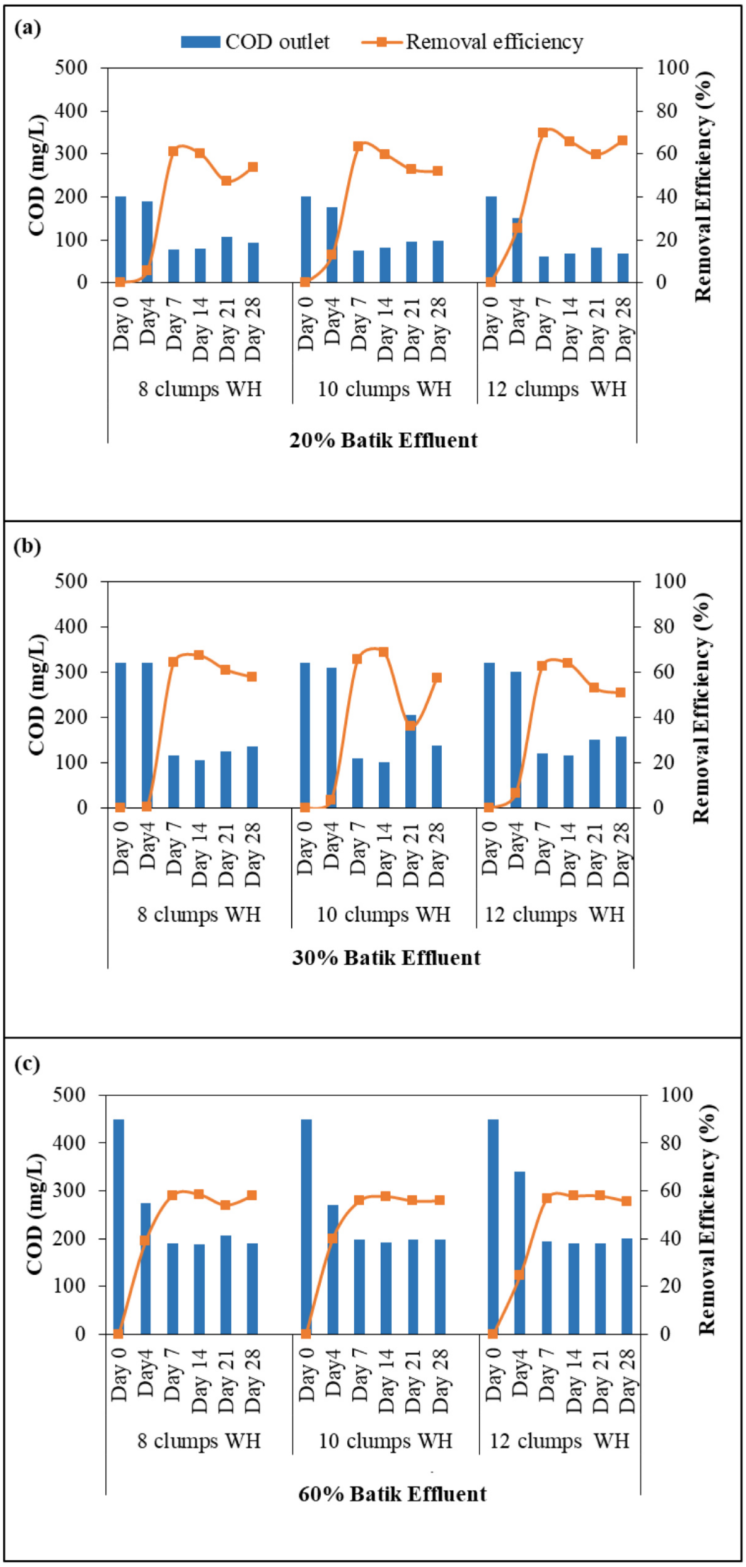

Figure 3. Removal of COD in difference batik effluent strength for (a) 20 % batik effluent, (b) 30 % batik effluent and (c) 60 % batik effluentRemoval of color

al. (2018) using vetiver *Chrysopogon zizanioides* (L), increased the batik effluent strength from 50 to 75 and 100%, the COD removals did not show a propotional pattern where the removal decreased from 89.1% (50%) to 60.9% (75%) and increased to 88.7% in 100% batik effluent. The batik effluent with a strenght of 20% and COD concentration of 771 mg/L was also separately treated using *Scirpus grossus* and *Iris pseudacorus*. The highest removals were achieved at day 11 with removal of 83 (*S. grossus*) and 82% (*I. pseudacorus)* (Tangahu et al. 2019). Another study by Mahajan et al. (2019) using *Chara vulgaris* found that with a textile wastewater strength of 10% and COD concentration of 216 mg/L, the removal of COD was 78% achieved within 5 days retention time.

The removal of color throughout 28 days was shown in Figure 4. At first week of exposure (day 7), removal occurred for all batik effluent strength and fresh plant numbers. However, the removal percentages declined from day 14 to 28. This could result from the death of plants which could not perform well in absorbing color. At day 0, the level of color for 20, 30 and 60% batik effluent strength were 495, 525 and 610 ADMI, respectively. On day 7, the color removals in 20% batik effluent were 77% for 8 and 10 plants, and to 83% for 12 plants. However, the removal decreased as the batik effluent strength increased to 30 and 60%. At the end of 28 days exposure with 20% batik effluent strength, the color was removed up to 43% (8 plants), 41% (10 plants), and 53% (12 plants). Under 30% batik effluent strength, the color removals

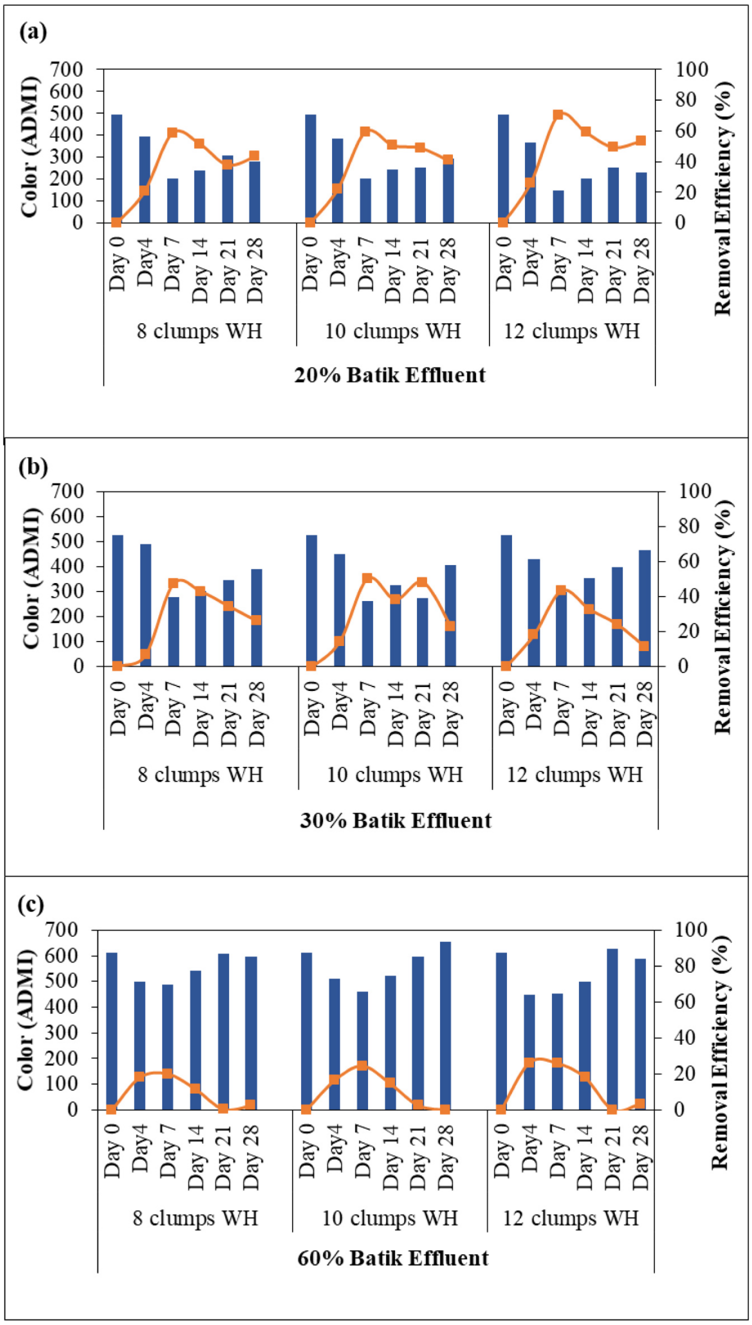

Figure 4. Removal of color in difference batik effluent strength for (a) 20 % batik effluent, (b) 30 % batik effluent and (c) 60 % batik effluent

were only 26, 23, and 115 for 8, 10, and 12 plants of water hyacinth, respectively. Meanwhile, due to the total death of water hyacinth at the end of 28 days, there was no removal of color for all plant numbers exposure with 60% batik effluent strength. Thus, the best color removal below the Standard B limits (< 200 mg/L) was achieved with 12 number of water hyacinth plants at day 7.

Removal of total suspended solid

The initial TSS concentration in the 20, 30 and 60% batik effluent were 36, 52 and 62 mg/L, respectively. As shown in Figure 5, the TSS in the all batik effluent strengths were removed as retention times increased up to 28 days. There was no significant effect of water hyacinth numbers on the

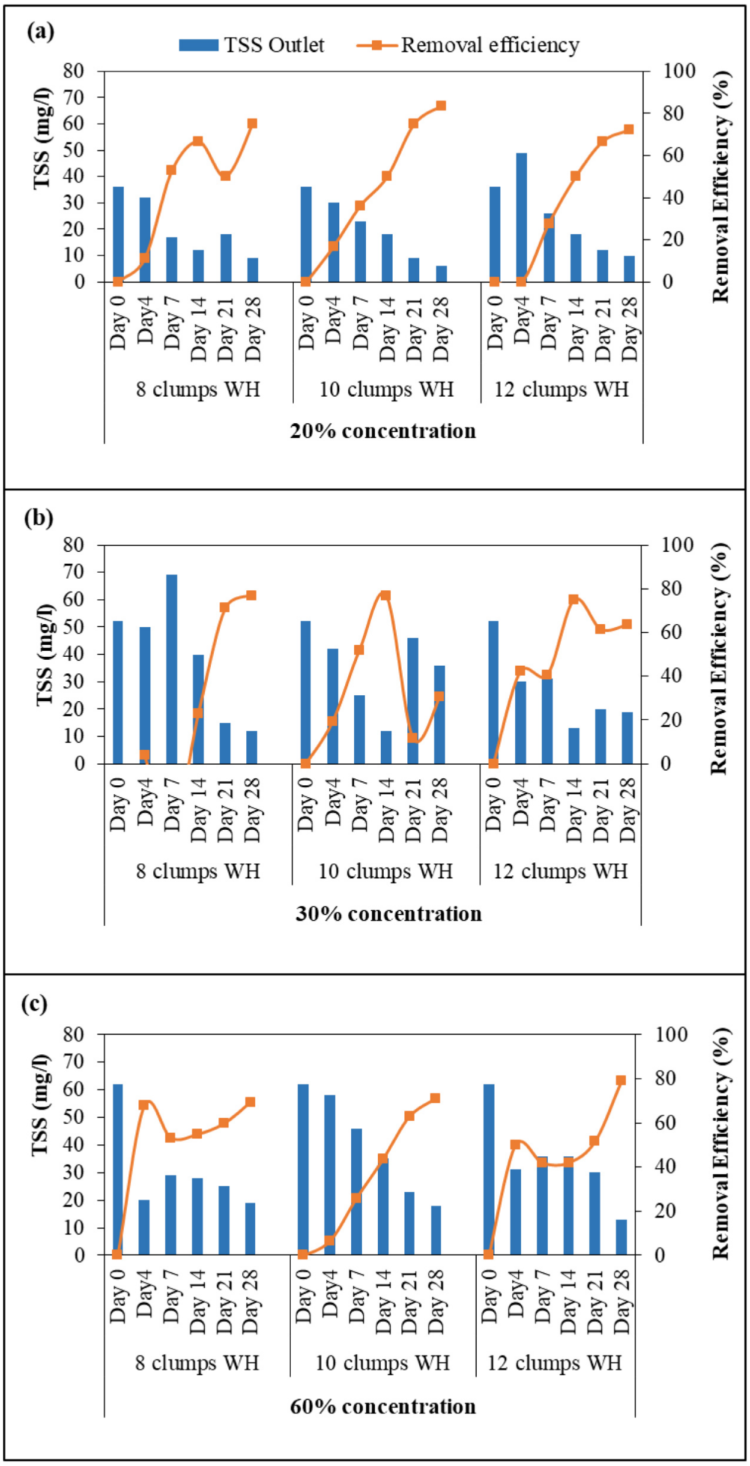

Figure 5. Removal of TSS in difference batik effluent strength for (a) 20 % batik effluent, (b) 30 % batik effluent and (c) 60 % batik effluent

TSS removal as this plant was a hydroponic plant type and the physical filtration of TSS did not occur efficiently only thorough the water hyacinth roots. At the end of 28 days, the removals of color in 20% batik effluent were 88, 92 and 86% for 8, 10 and 12 plants, respectively. However, as the batik effluent strength increased to 30 and 60%, the TSS removal decreased drastically. At the batik effluent strength of 30%, there was no removal with 8 plants, but there were 50 and 70% for the 10 and 12 water hyacinth plants. Meanwhile, the worst TSS removal was observed at 605 batik effluent where the removal were only 32, 26, and 33% for 8, 10 and 12 plants, respectively.

pH monitoring

Over the 28 days exposure, pH was also monitored for all conditions, as shown in Figure 6. Throughout, the pH was observed in range of 6.8 to 8.1. As can be seen in the figure, the pH of 30 and 60% batik effluent increased after day 14 due

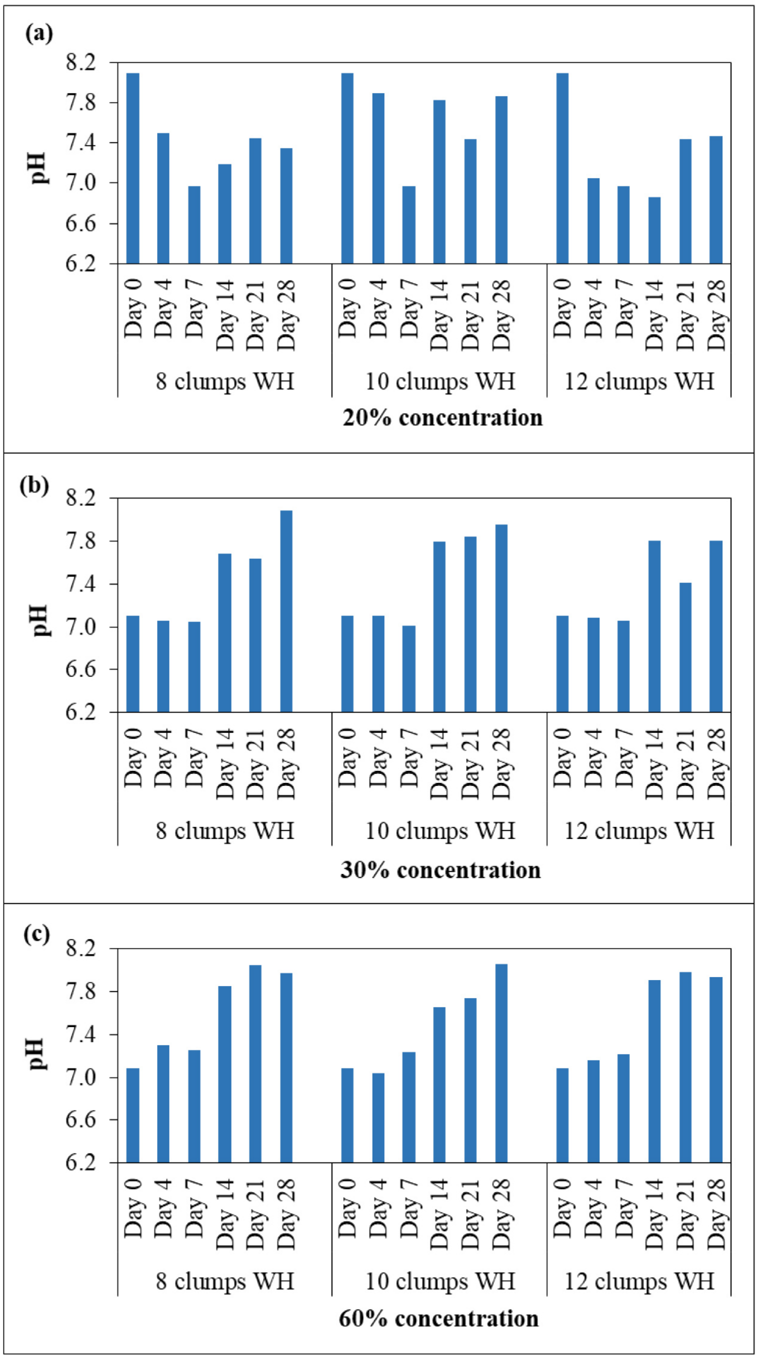

Figure 6. Variation of pH for (a) 20 % batik effluent, (b) 30 % batik effluent and (c) 60 % batik effluent

Table 4. Technologies comparison for the batik/textile effluent treatment

Treatment technology	Retention time (day)	COD removal (%)	Color removal (%)	References
Solar Photocatalytic Process	10 h	-	86.9	Khalik et al. (2015)
Acidification	15 min	78–95	-	Birgani et al. (2016)
Zero Valent Iron	10 min	-	95.9	Sajab et al. (2019)
Ultra-membrane filtration	-	92	60	Sharifah (2018)
Adsorption	60 min	-	100	Amran (2018)
Phycoremediation	96 hours	-	80	Kassim et al. (2018)
Phycoremediation	15 days	69.9	75.7	El-Kassas & Mohamed (2014)
Phytoremediation	7 days	83	89	This study (2019)

to the death of water hyacinth plants. However, for the 20% batik effluent, the pH varied for the three numbers of plants.

Comparison with other technologies

A few technologies for the batik effluent treatment have been investigated, as summarized in Table 4. Chemical treatment such as solar photocatalytic, zero valent iron, ultrafiltration and adsorption were popular technologies for the batik effluent treatment due to quick reaction and high efficiency. However, some of the chemical technologies (acidification and zero valent iron) generate other by-product, which required additional treatment process. In addition, the chemical treatment such as adsorption, ultrafiltration and solar photocatalytic requires high cost for the operation and maintenance. As can been seen in Table 4, the zero valent iron method could remove 95.9% of color within 10 min compared to the adsorption and solar photocatalytic which remove 100% and 86.9% of color within 1 and 10 hour, respectively. On the other hand, treatment of batik effluent through Phycoremediation using immobilized *Chlorella* sp. had resulted in 80% color removal within 96 hours. For the COD removal, the acidification process could remove 78 to 95%, while ultrafiltration removed 92%.

CONCLUSIONS

In conclusion, water hyacinth has a great potential as a low cost phytoremediation material for the effluent of batik industry treatment. The plant tolerated up to 60% the batik effluent strength within 28 days exposure where it could well growth in 20% batik effluent strength. The performance of water hyacinth as a phytoremediation agent showed that it could threat the batik effluent to below the standard limits for COD and color within 7 days retention time. Increased number of water hyacinth clumps resulted in insignificant improvement of the treatment performance.

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REFERENCES

1. Amran, N.A. 2018. Column study for the removal of colour from batik printing effluent using wastewater sludge carbon. Universiti Teknologi Petronas.
2. Asgari, G., Faradmal, J., Nasab, H.Z. & Ehsani, H. 2019. Catalytic ozonation of industrial textile wastewater using modified C-doped MgO eggshell membrane powder. Advanced Powder Technology 30: 1297–1311.
3. Birgani, P.M., Ranjbar, N., Abdullah, R.C., Wong, K.T., Lee, G., Ibrahim, S., Park, C., Yoon, Y. & Jang, M. An efficient and economical treatment for batik textile wastewater containing high levels of silicate and organic pollutants using a sequential process of acidification, magnesium oxide, and palm shell-based activated carbon application. Journal of Environmental Management 184: 229–239.
4. Buthelezi S.P., Olaniran A.O. & Pillay B. 2012. Textile dye removal from wastewater effluents using bioflocculants produced by indigenous bacterial isolates. Molecules 17: 14260–14274
5. Dotto, J., Fagundes-Klen, M.R., Veit, M.T., Palácio, S.M. & Bergamasco, R. 2019. Performance of

different coagulants in the coagulation/flocculation process of textile wastewater. Journal of Cleaner Production 208: 656–665

6. El-Kassas, H.Y & Mohamed, L.A. 2014. Bioremediation of the textile waste effluent by Chlorella vulgaris. The Egyptian Journal of Aquatic Research 40: 301–308
7. Gandhi N., Sirisha D., & Sekhar K.B.C. 2013. Phytoremediation of chromium and fluoride in in industrial wastewater by using aquatic plant ipmoea. Science of the Total Environment. 12: 1–4.
8. Kassim, M.A., Latif, N.A.F.A. & Hashim, N.H.F. 2018. Decolorization and total nitrogen removal from batik effluent using alginate immobilized freshwater microalgae Chlorella sp. Journal of Applied Biology & Biotechnology 6: 26–34.
9. Khalik, W.F., Ho, L.N., Ong, S.A., Wong, Y.S., Yusoff, N.A. & Ridwan. F. 2015. Decolorization and mineralization of batik wastewater through solar photocatalytic process. Sains Malaysiana 44: 607–612.
10. Khandare R.V. & Govindwar S.P. 2015. Phytoremediation of textile dyes and effluents: Current scenario and future prospects. Biotechnology Advances: 33(8): 1697–1714.
11. Kumar P.S., Varjani S.J. & Suganya S. 2018. Treatment of dye wastewater using an ultrasonic aided nanoparticle staked activated carbon: Kinetic and isotherm modeling. Bioresource Technology. 250: 716–722.
12. Mahajan, P., Kaushal, J., Upmanyu, A. & Bhatti, J. 2019. Assessment of Phytoremediation Potential of Chara vulgaris to Treat Toxic Pollutants of Textile Effluent. Journal of Toxicology, Article ID 8351272, https://doi.org/10.1155/2019/8351272.
13. Malik, S.N., Ghosh, P.C., Vaidya, A.N. & Mudliar, S.N. 2018. Catalytic ozone pretreatment of complex textile effluent using Fe2+ and zero valent iron nanoparticles. Journal of Hazardous Materials 357: 363–375.
14. Mukimin, A., Vistanty, H., Zen, N., Purwanto, A. & Wicaksono, K.A. 2018. Performance of bioequalization-electrocatalytic integrated method for pollutants removal of hand-drawn batik wastewater. Journal of Water Process Engineering. Journal of Water Process Engineering 21: 77–83
15. Nemerow N.L. 1971. Liquid waste of industry, theories, practices and treatment. Addition-Wesley Publishing Company 66: 12–20.
16. Pavas, E.G., Dobrosz-Gómez, I. & Gómez-García, M.A. 2018. Optimization of sequential chemical coagulation – electro-oxidation process for the treatment of an industrial textile wastewater. Journal of Water Process Engineering 22: 73–79
17. Rashidi, H.R., Nik Sulaiman, N.M. & Hashim, N.A. 2012. Batik industry synthetic wastewater treatment using nanofiltration membrane. Procedia Engineering 44: 2010–2012
18. Rashidi, H.R., Sulaiman, N.M., Hashim, N.A. & Che Hassan, C.R. 2013. Synthetic batik wastewater pretreatment progress by using physical treatment. Advance Materials Research 627: 394–398.
19. Sajab, M.S., Ismail, N.N.N., Santanaraj, J., Mohammad, A.W., Hassan, H.A., Chia, C.H., Zakaria, S. & Noor, A. M. 2019. Insight observation into rapid discoloration of batik textile effluent by in situ formations of zero valent iron. Sains Malaysiana 48: 393–399.
20. Sharifah, A. 2018. Development of integrated kenaf core cellulose nanofiltration flatsheet membrane for batik wastewater. IPSis Biannual Publication, 13 (13). Institute of Graduate Studies, UiTM, Shah Alam.
21. Sharma, A., Syed, Z., Brighu, U., Gupta, A.B. & Ram, C. 2019. Adsorption of textile wastewater on alkali-activated sand. Journal of Cleaner Production, 220: 23–32
22. Tambunan, J.A.M., Effendi, H. & Krisanti, M. 2018. Phytoremediating batik wastewater using vetiver Chrysopogon zizanioides (L). Polish Journal of Environmental Studies 27: 1281–1288.
23. Tan K.A., Morad N. & Ooi J.Q. 2016. Phytoremediation of methylene blue and methyl orange using Eichhornia crassipes. International Journal of Environmental Science and Development 7: 724–728.
24. Tangahu, B.V., Ningsih, D.A., Kurniawan, S.B. & Imron, M.F. 2019 Study of BOD and COD removal in batik wastewater using Scirpus grossus and Iris pseudacorus with intermittent exposure system. Journal of Ecological Engineering 20: 130–134.
25. Tavangar, T., Jalali, K., Shahmirzadi, M.A.A. & Karimi, M. 2019. Toward real textile wastewater treatment: Membrane fouling control and effective fractionation of dyes/inorganic salts using a hybrid electrocoagulation – Nanofiltration process. Separation and Purification Technology 216: 115–125
26. Wibowo, S.E., Rokhmat, M., Rahman, D.Y., Murniati, R., Khairurrijal & Abdullah, M. 2017. Batik Wastewater treatment using TiO2 nanoparticles coated on the surface of plastic sheet. Procedia Engineering 170: 78–83.