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Potential of *Moringa oleifera* seeds and fuel wood ash as adsorbent of dye and organic matter in wastewater from batik producing enterprises

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Treatment of effluents from batik producing enterprises to removal dyes and other impurities is inevitable as these enterprises are becoming ubiquitous in many cities in Tanzania. Wastewater from batik production processes are discharged haphazardly without treatment. In this study, preliminary results on adsorption potential of defatted *Moringa oleifera* crude seed extract (DMOCSE) and fuel wood ash (FWA) for dye and chemical oxygen demand (COD) in batik processing wastewater (BPW) are presented. Batch and column adsorption studies were conducted using varied dye concentrations, adsorbents dosage, contact time and pH. 7% (w/v) DMOCSE at the dosage of 15 to 25 ml/L produced minimum residual dye in BPW with initial color ranging from 480 to 675 mgpt-Co/L. Optimum contact time for DMOCSE ranged from 1.5 to 2.5 h and pH 7.5 to 9.5 with 75.5 to 93% dye removal efficiency. FWA at optimum dosage of 25 g/l, contact time of 1.5 to 3 h and pH 8.5 to 11.5 removed 78.8 to 84% of dye. FWA and DMOCSE reduced 98 and 64% of COD. The FWA packed column with depth of 20 and 25 cm achieved 99% dye removal after 4 to 6 h of retention time. The findings reveal that DMOCSE and FWA have potential to treat BPW in both batch and column mode.

Key words: Dye-rich wastewater, impurities removal, natural adsorbent.

INTRODUCTION

Water pollution caused by discharging of untreated municipal and industrial wastewater, continues to be a great threat to both human beings survival and aquatic ecosystems existence especially in developing countries as it is reported by Ganapathy et al. (2018) and Majumdar and Sinha (2018). In textile industry, dyes are major wastewater pollutants, even in very low concentration. These enterprises consume large volumes of water and vast amounts of potentially hazardous substances and chemicals (Rahman et al., 2017). According to Scott (2015), the chemical substances present in textile industry wastewater, viz: dyes, bleaches, detergents and fixing

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Table 1. Research materials used, data type and where they were obtained.

Type of material used	Type of data	Source	Location
Dye-rich wastewater samples	Dye removal indicator parameters: colour, pH, COD and heavy metals	Muungano Arts Association	Dar es Salaam, Tanzania
Defatted *M. oleifera* seed powder	Adsorbent capacity	Kariakoo market	
Fuel wood ash	Adsorbent capacity	Households	

agents, produce billions of tonnes of fabric, which in return discharge great amounts of wastewater that result to high levels of environmental pollution. The effluents from batik dyes, textile, are heavily colored due to the presence of residual dyes which are very difficult to treat, as they are recalcitrant organic molecules, resistant to aerobic digestion, and are stable to light, heat, and oxidizing agents (Shalla et al., 2018; Sun and Yang, 2003).

Wastewater treatment is conducted to remove unwanted substances contained in it. Although many treatment methods such as catalytic oxidation, adsorption using synthetic adsorbents, membrane separation process, biological treatment, and fenton reaction are available; they require high investment and technical skills to operate (Ghasemi et al., 2010; Sheng and Ming, 1997; Valdes et al., 2010; Xiu and Zhang, 2009; Ferrari et al., 2010). Also, performance of these methods is limited due to synthetic origin and complex structure present in dyes (Kavithayeni et al., 2019).

Natural materials for wastewater treatment are derived from plants, microorganisms and animals derivatives for example lime, bottom ash, and chitosan (crustacean origin). *Moringa oleifera* commonly known as drumstick or horseradish tree is a tropical, fast growing and drought tolerating plant belonging to the family Moringaceae. It is a non-toxic natural organic polymer which contains active, biodegradable, non-toxic, water-soluble, basic, cationic polypeptides which act as natural adsorbents and coagulants for water and wastewater treatment (Villaseñor-Basulto et al., 2018; Gassenschmidt et al., 1995; Ghebremichael, 2004). Adsorption has been shown to be an effective and attractive method for the treatment of industrial wastewaters containing colored dyes, heavy metals and other inorganic and organic impurities (Wasti and Awan, 2018).

Currently, adsorption processes have been explored because of their low cost, eco-friendly and easy access (Fil et al., 2014). Fuel wood ash, residue material from charcoal combustion, is commonly found in households in Tanzania. The ash material is soft, non-toxic, cheap material that can be used to remove dye from dye-rich effluents discharged from textile and batik industries (Willett, 2015; Khan et al., 2009). The main objective of this study was to conduct preliminary investigations on the potential of *Moringa* seed extract and fuel wood ash, for dye and organic matter removal from batik processing enterprises over a varied range of parameters affecting the sorption process, prior to conducting further kinetic study of the sorption process. The study focuses on the wastewater discharged from the batik production. The batik producing enterprises collectively known as Muungano Arts Association is a local batik producing business in which the population of low and middle income people who are engaged in batik production is increasing very rapidly. However, the increase of batik production generates large volumes of dye-rich wastewater which are discharged haphazardly into water bodies without being treated and hence have created diverse health and other ecological problems.

MATERIALS AND METHODS

The materials used included wastewater, coagulant and adsorbent, while the methods included data collection techniques and analysis as detailed subsequently.

Research material

The research material used in this research included dye-rich wastewater samples. Other materials included defatted *M. oleifera* seeds powder and fuel wood ash. These materials were all locally available in Dar es Salaam, Tanzania shown in Table 1.

Dye-rich wastewater samples

Dye rich wastewater samples from Muungano Arts Association which deals with batik production was selected because it encompasses local and middle batik producing businesses which involves increasingly large populations from low and middle income people engaged in batik production. Therefore, Muungano Arts Association represents low and middle income businesses which generate and discharge untreated dye-rich wastewater into the environment.

A total of 20 dye-rich wastewater samples were collected from 5 different batik producers. The wastewater from batik production was taken from batch reactor with the capacity of 200 L. The sampled dye-rich wastewaters were collected and stored in 20 L clean plastic buckets. Four (4) samples were sampled from each reactor five (5) times. The average values of five (5) samples from each batik production enterprise were presented. Samples were collected from the same production point at an interval of atleast seven (7) days for three months period. All samples were transported to the

Table 2. Amount of adsorbents used to treat dye-rich wastewater.

Material used	Amount of material used to prepare coagulant dose in 100 ml	Dosage of coagulant applied to treat 1000 ml of wastewater (g)				
		5 ml	10 ml	15 ml	20 ml	25 ml
Coagulant (DMOCSE)	5 g	0.25	0.5	0.75	1	1.25
	7 g	0.35	0.7	1.05	1.4	1.75
	10 g	0.5	1	1.5	2	2.5
Adsorbent (FWA)		5	10	15	20	25

Environmental Laboratory at the School of Environmental Science and Technology, Ardhi University for further analytical procedure.

Defatted *M. oleifera* seed powder

M. oleifera seeds used in this study were purchased from Kariakoo market in Dar es Salaam. The seeds were ground into fine powder using mortar and pestle. The seed powder was then defatted by exposure to direct sunlight for 8 h for two consequent days until the oil separated from the seed powder and absorbed into absorbent sheets. The defatted seed powder was then ground again to obtain a homogeneous fine powder.

DMOCSE was prepared by suspending 5, 7 and 10 g in 100 ml distilled water followed by extracting active agent using magnetic stirrer for 15 min at room temperature (25 ± 2°C) to extract coagulating components and the suspensions were filtered through a muslin material to obtain 5, 7 and 10% (w/v) DMOCSE. Varied dosages of DMOCSE (5, 10, 15, 20, and 25 ml per 1000 ml of wastewater) were used for adsorption studies of dye and organic matter in the wastewater as shown in Table 2.

Fuel wood ash

Fuel wood ash (FWA) was collected from households and sifted using a fine strainer of 0.4 mm in diameter. The fines fuel wood ash was then used as adsorbent in column system to treat the dye-rich wastewater in Tanzania. The dosage of FWA used as adsorbent through coagulation experiments were 5, 10, 15, 20 and 25 g per 1000 ml of BPW.

Experimental setup

The adsorption study was conducted at lab scale in batch and column mode. In the batch mode, a Jar tester (Model, Phipps and Bird – PB-700TM) apparatus was used in which various dosages of DMOCSE and FWA were separately mixed with 1000 ml of wastewater sample at a flash mix speed of 150 rpm for 3 min followed by slow mixing at 30 rpm for 25 min. Operating conditions varied include adsorbent dosage, concentration of dye in wastewater, contact time and pH. The treated wastewater samples were allowed to settle from 1 to 3 h thereafter 1 to 3 ml of the treated sample were collected at the depth of about 3 cm for different analytical procedures.

For adsorption investigations in column mode, four flexible polyvinyl chloride (PVC) pipes (columns) with same diameter and different depths were used. The dimensions of the columns included (i) 10 cm/0.3 m, (ii) 15 cm/0.3 m, (iii) 20 cm/0.4 m, and (iv) 25 cm/0.4 m. The four experimental columns with varied depth were packed with FWA while the other four were packed with defatted *M. oleifera* seed powder (DMOSP) and mounted on a bench. About 1000 ml of batik processing wastewater (BPW) was allowed to flow through the column with retention time ranging from 1 h to 6 h for each column size thereafter samples were collected for analysis.

Analytical methods

All analytical methods were carried out following the Standard Methods of Water and Wastewater Examinations (APHA/AWWA/WEF, 1998). Raw and treated wastewater quality parameters analyzed included color (mgpt-Co/L for apparent color), chemical oxygen demand (mgO_2/L), pH and heavy metals. Color was analyzed by Platinum-Cobalt Standard Method using a portable spectrophotometer (DR 2010; Hach Co., Loveland, CO). Blanks and calibration checks were run to ensure that the analytical methods were accurate and reliable. The pH was measured using a digital Hach pH meter, model Sension156. The pH of BPW was adjusted using 0.1 N solutions of NaOH and HCl. The COD was measured with the Hach spectrophotometer (Model, 21D) after 2 h of digestion in a Hach tube digester at 150°C. Heavy metals including copper, zinc, chromium, cadmium and lead were analyzed using an atomic Absorption Hydride System (HC 3000) from GBS Scientific Equipment (Arlington Heights, IL). The detection limit of this method is 0.5 ppb. The percentage removal efficiency (percent adsorption) was calculated according to Equation 1, where Ci and Ce are the initial and equilibrium values of the color, COD and pH wastewater quality parameters.

$$Removal\ efficiency = \frac{Ci - Ce}{Ci} \times 100 \quad (1)$$

RESULTS AND DISCUSSION

Characteristics of batik wastewater

Physico-chemical characteristics of batik processing wastewater (BPW) are presented in Table 3. The results showed that dye-rich wastewater from batik SMEs processes is basic in nature with pH ranging from 9.2 to 12 which is above the Tanzania standards set for wastewater/effluent discharge (TZS 860:2006). The color of wastewater ranged from 480 mg/L to 675 mgpt-Co/L which is also above the Tanzanian standards (TZS 860:2006) of 300 mgpt-Co/L. Similarly, the COD of the

Table 3. Selected physical and chemical parameters of batik processing wastewater.

Parameter	Unit	Range	Average	Tanzanian standards (TZS 860:2006)
pH	-	9.22-12.01	10.9	6.5-8.5
Color	mgpt-Co/L	480-675	550	300
COD	mg/L	1550-2105	1900	60
Cu	mg/L	<0.01	<0.01	0.1
Zn	mg/L	<0.01	<0.01	0.1
Cr	mg/L	<0.01	<0.01	0.1
Cd	mg/L	<0.01	<0.01	0.1
Pb	mg/L	<0.01	<0.01	0.1

wastewater ranged from 1550 to 2105 mg/L which is above the standards, Tanzanian standard which is 60 mg/L. The nature of chemicals used during dyeing of the fabrics including dyes, caustic soda and hydro-sulphate, causes a rise in the wastewater pH, color and COD. Currently, dye-rich wastewater from batik enterprises in Tanzania does not receive any kind of pre-treatment before discharge. The direct discharge of dye-rich wastewater from batik production without treatment pollutes the environment and therefore, treatment of such wastewater is inevitable. These findings are in good agreement with those reported by Yaseen and Scholz (2019) in which, the minimum and maximum pH, color and COD in textile effluent were 5.5 and 11.8, 50 and 2,500 mg/L and 150 and 30,000, respectively. The slight differences in the observed physical and chemical parameter between textile effluent and BPW could be due the nature of the dyes used and the series of processes involved during fabric dyeing. Moreover, all heavy metals analyzed in BPW were <0.01 mg/L while those in textile effluent were <10 mg/L. The observed difference in the level of heavy metals in textile effluent and BPW could be due to the differences in the detection limit of the methods used in heavy metal analysis.

Batch adsorption studies

Adsorption of dye by DMOCSE

Dye-rich wastewater from batik production enterprises was treated using locally available natural materials namely, *M. oleifera* and fuel wood ash in a column reactor. The results for dye removal efficiencies of DMOCSE at different dosages and initial concentrations of dyes in wastewater after 1 h of settling time are presented in Figure 1. The results revealed that dye removal efficiency increased with an increase in initial concentration of dye in the BPW which was accompanied by the corresponding increase in the dosage of the DMOCSE. The observed increase in the dye removal with the increase of initial dye concentration may be due to ample dye adsorption sites at adsorbent (Poots et al., 1976). Moreover, the results have shown that the dosage of 20 and 25 from 7% DMOCSE showed the best performance in dye removal compared to 5 and 10% extracts. These were optimum dosages which produced minimum residual color after 1 h of contact time. The removal efficiency of dye from wastewater with initial color of 480, 575, 620 and 675 mgpt-Co/L at the dosage of 20 and 25 ml/l from 7% DMOCSE were 64.4 and 70%, 86.3 and 87.5%, 89 and 92%, as well as 85.2 and 87%, respectively. These dosages were used in subsequent adsorption studies. The probable mechanism for removal of dye materials in the wastewater treated by proteins rich CSE of *M. oleifera* could be adsorption and neutralization of charges, adsorption and bridging and enmeshment in the precipitate (Ganapathy et al., 2018; Gregory and Duan, 2001; Huang and Shiu, 1996).

Effect of contact times on dye adsorption

Figure 2 shows the effect of contact times on dye removal which were evaluated using the established minimum dosages of 20 ml/l of 7% DMOCSE as optimum dose for dye removal from wastewater with different dye concentrations. The length of contact times varied from 1 to 3 h. The results showed that dye removal increased with increase in contact time and the initial wastewater dye concentration, although maximum dye removal was achieved between 2 and 2.5 h. The residual dye concentration in the treated wastewater with initial dye concentration of 480, 575, 620 and 675 mgpt-Co/L after 2 and 2.5 h of contact times were 106.6 and 67, 72.8 and 54, 63.5 and 43, and 90.3 and 77.8 mgpt-Co/L which are equivalent to removal efficiencies of 78 and 86%, 87 and 91%, 90 and 93%, and 87 and 88%, respectively. The dye concentration in the treated water complied with the Tanzania standards for colored wastewater discharge in the receiving water bodies. The length of contact times of flocculated water enhanced the adsorption process and settlement of dye stuff along with other suspended

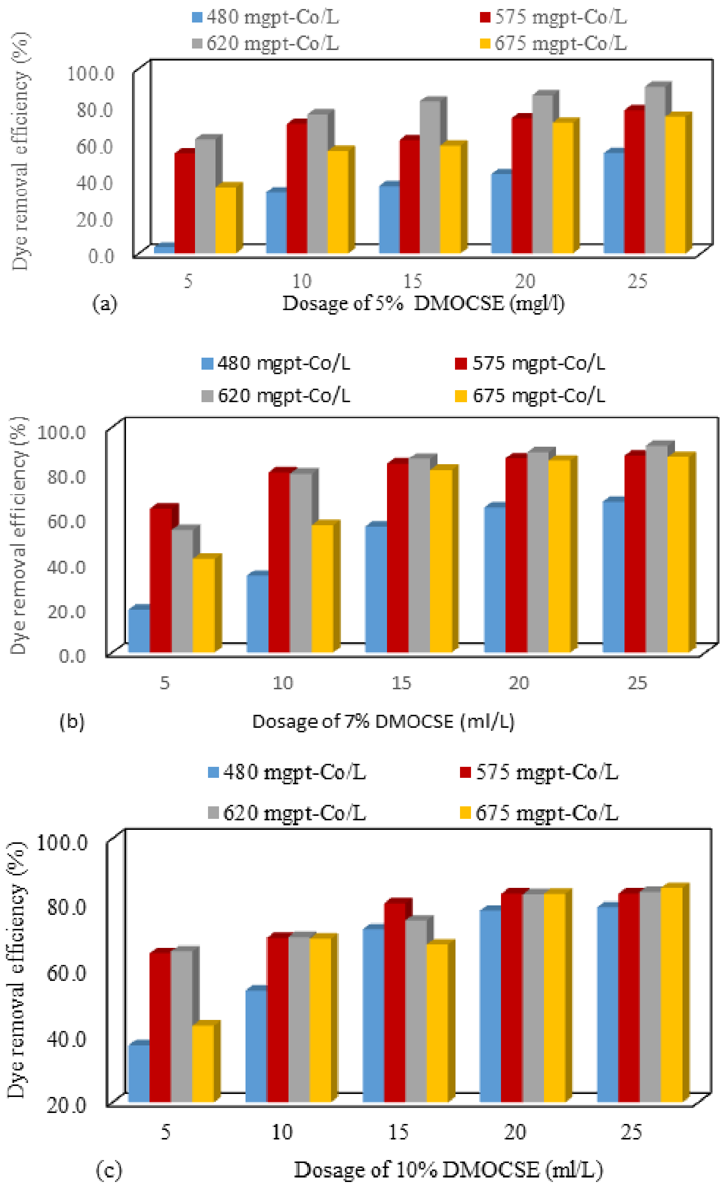

Figure 1. Dye removal efficiencies of DMOCSE at varied dosages of 5% (a), 7% (b) and 10% (c) and varied initial dye concentrations.

particles. Contact time beyond 2.5 h did not have significant added advantage on dye adsorption capacity of DMOCSE. The removal efficiency was negligible beyond 2.5 h of contact time. According to Poots et al. (1976), the 2.5 h of contact time phenomenon could have been due to large number of surface sites available for adsorption at the initial stages and after an interval of time, the remaining surface sites were uneasily occupied due to repulsion between the solute molecules of the solid and bulk phases. These results are very closely similar to those reported by other researchers working with crude extract of *M. oleifera* seed on dye removal from textile effluents in which, the optimum contact time observed was 2 h which reduced up 95% of the dye stuff (Gupta et al., 2005). However, more studies are warranted to ascertain the adsorption equilibrium models of DMOCSE which will provide the understanding of the sorption mechanism, surface properties and affinity of adsorbent.

Effect of pH on dye adsorption by DMOCSE

The effect of pH on dye removal by DMOCSE at the dosage of 20 ml/l in BPW with initial dye concentration of

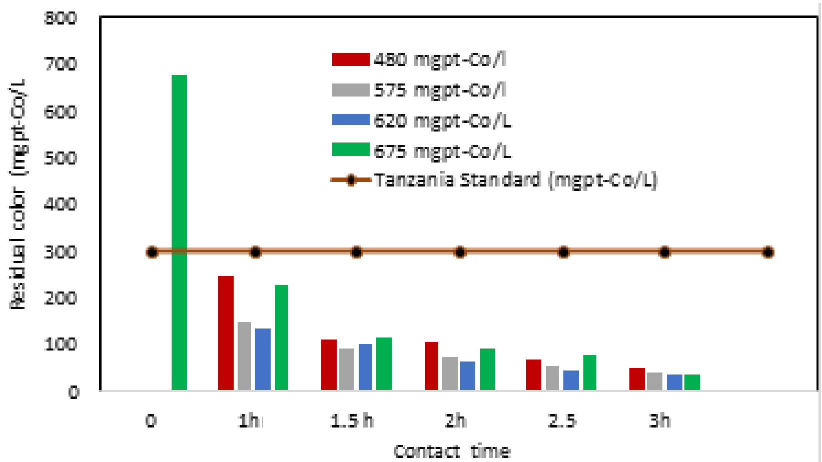

Figure 2. Effect of contact time on dye removal from wastewater with varied initial dye concentration.

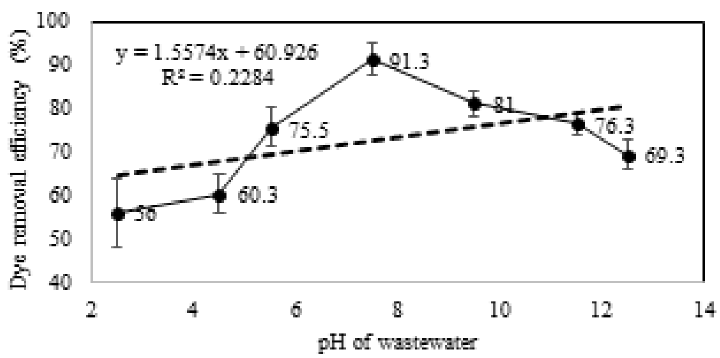

Figure 3. Effect of pH on dye removal using 7% DMOCSE at the dosage of 20 ml/L, initial dye concentration of 480 mgpt-Co/L and 2 h contact time. Drop lines are standard deviations of dye removal based on three analyses

675 mgpt-Co/L and contact time of 2 h is as shown in Figure 3. *M. oleifera* crude seed extract contains carboxylic, fiber carbonaceous, and amino functional groups, which may be dissociated at different pH values and consequently take part in the adsorption process. Therefore, pH may influence the adsorption of dye components onto DMOCSE (Akhtar et al., 2007a). The results shown in Figure 3 revealed that DMOCSE has a wide pH range for bio-sorption. The removal of dye was high at pH levels ranging from slightly acidic condition (pH=6.5) to alkaline values (pH=9.5) at which the color removal ranged from 75.5 to 91.3%. However, maximum dye removal occurred at pH 7.5 (91.3% dye removal). Similar results for improved dye removal efficiency at pH 7.5 were observed in BPW with initial dye concentration of 480 mgpt-Co/L. The performance was generally poor at very low and very high pH values and also there was a weak positive correlation between the pH level and dye removal efficiency of the adsorbent (R^2= 0.23). This condition may be attributed to the limited amount of hydrogen ions at these pH values which were to enhance the uptake and adsorption of dye on the bio-sorbent. Higher pH and very low pH suppress the adsorption capacity of the adsorbents (Bhatti et al., 2007). Vieira et al. (2010) obtained similar results in which the optimal pH for absorption of *Moringa* seed ranged from 5 to 8 which reduced up to 95% of the dye in daily industry wastewater. Ghebremichael et al. (2004) observed that *M. oleifera* seed contains cationic peptides of relatively low molecular weight (6 kDa) and pH value of 10. This could be among the reasons for the reduced removal efficiencies of DMOCSE in BPW at pH above 10 at which the solubility of the *Moringa* seed proteins decreases since high adsorption capacity is obtained at low pH (Yaseen and

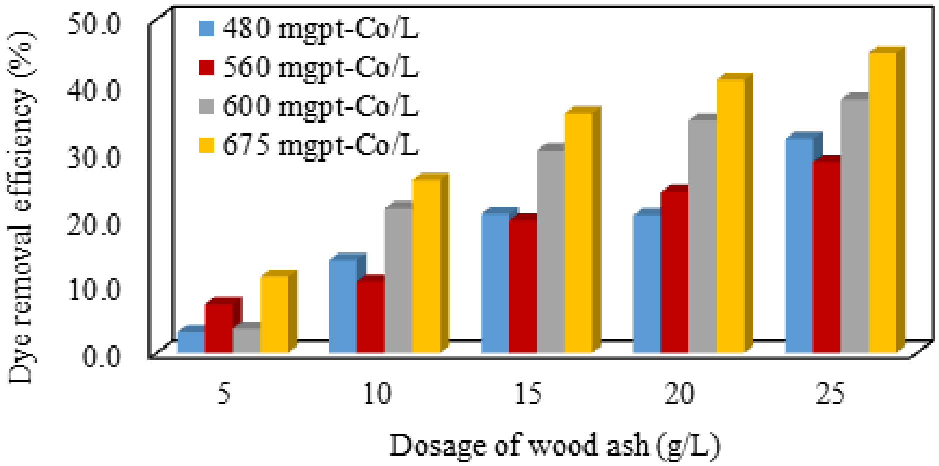

Figure 4. Effect of FWA dosage on dye removal in wastewater with varied dye concentrations.

Schotz, 2019b). Analogous to this study, Kyzas et al. (2018) also observed higher uptake (78 to 91%) of basic dye onto low-cost natural textile fibers at pH 12 with the large increase occurring between pH 6 and 8 signifying that some change in the nature of the process was occurring.

Effect of FWA on dye adsorption

Figure 4 presents the performance of FWA at varied dosage (5 to 25 g/L) on dye adsorption in BPW with different initial dye concentration and 1 h of contact time. As for case of DMOCSE, the removal efficiency increased with increase of initial dye concentration which was also associated with an increase in adsorbent dosages. Dye removal efficiencies for the BPW with initial dye concentration of 480, 560, 600 and 675 mgpt-Co/L ranged from 3.1 to 11.4%, 14 to 25.9%, 20.8 to 35.9%, 20.6 to 40.9% and 32.1 to 44.9% at the dosages of 5, 10, 15, 20, and 25 g/L, respectively. The highest removal efficiencies were achieved at the dosage of 25 g/L (Figure 3). The residual dye concentrations in the treated wastewater using FWA ranged between 326 and 400 mgpt-Co/L which do not comply with Tanzania standard set at 300 mgpt-Co/L. It is evident that the FWA performs poor as adsorbent compared to DMOCSE which its removal efficiency for wastewater with varied dye concentration ranged between 86 and 91%. These results are contrary to those reported by Khan et al. (2009) on removal of dye from textile wastewater by fly ash in which the uptake of dyestuff was observed to be rapid in the initial stages of the contact time and became slow near the equilibrium and in between these two phases of the uptake, the rate of adsorption was found to be nearly constant. These differences could be attributed to difference in chemical composition of the two adsorbents, the main FWA composition being silica while fly ash contains silica and alumina which might have influenced the instant adsorption of the dye.

Effect of contact time

Figure 5 shows dye removal by FWA in wastewater with low (480 mgpt-Co/L) and high initial dye (675 mgpt-Co/L) concentration at varied contact time and the established optimum FWA dosage of 25 g/L. The results showed that longer contact time for FWA is necessary for maximum dye adsorption in BPW with high initial dye concentration. The residual dye concentration after 1 and 3 h of contact time ranged between 458.6 and 287.6 mgpt-Co/L which correspond to the removal efficiencies of 20.3 and 50%, respectively. On the other hand, wastewater with low initial dye concentration showed maximum dye removal after 1.5 h of contact time and there was no significant additional dye removal at longer contact times. The residual dye in the effluent after 1.5 and 3 h of contact time were 240.2 and 195 mgpt-Co/L with removal efficiency of 50 and 59%, respectively. It is evident from these results that FWA is not a suitable adsorbent for wastewaters with high dye concentration. However, this study has established that optimum contact time of FWA for dye adsorption in BPW should range between 1.5 and 3 h in which the dye concentration in the treated BPW complies with the Tanzania standards (300 mgpt-Co/L) for discharge of colored effluents into water bodies or environment at large.

Effect of pH on dye removal by FWA

Figure 6 shows dye removal efficiency of FWA in BPW

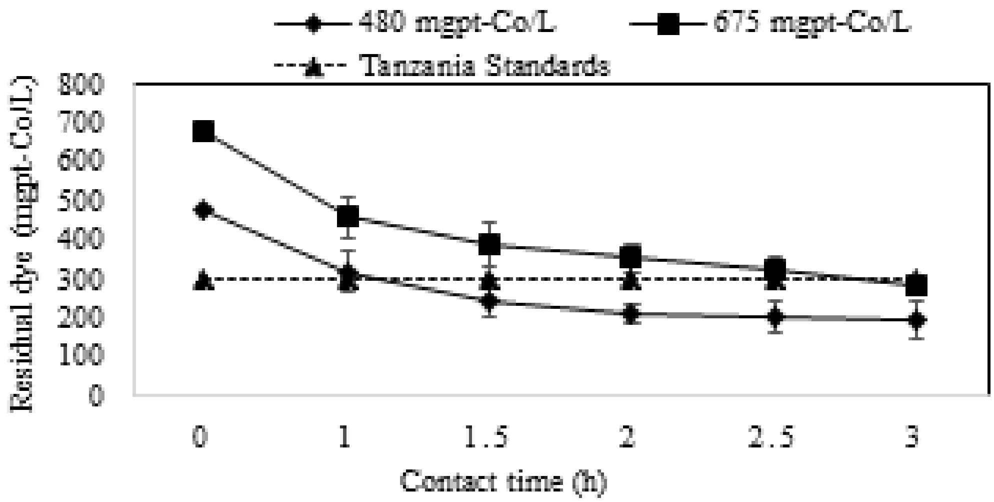

Figure 5. Effect of contact time on dye removal from BPW with lowest and highest initial dye concentration. Drop lines are standard deviations of dye removal based on three analyses.

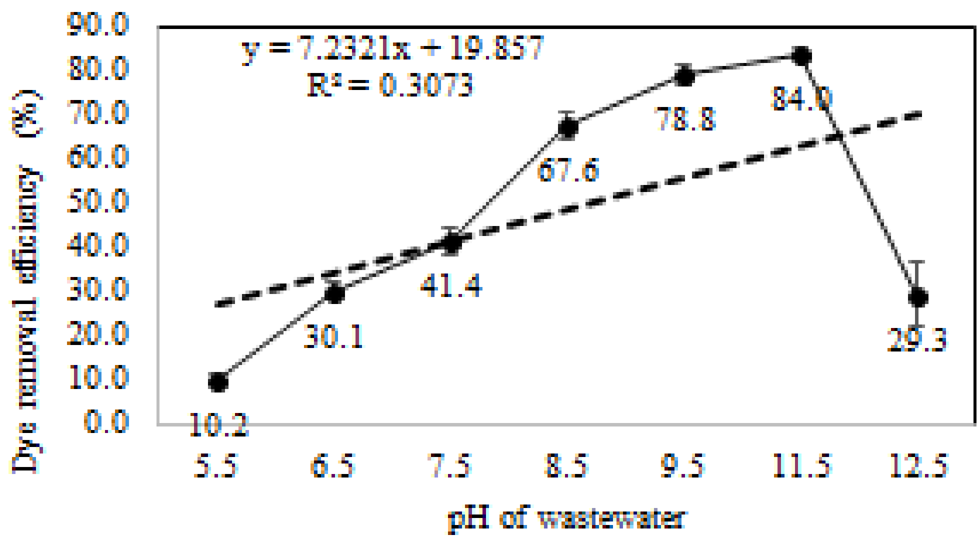

Figure 6. Effect of pH on dye removal using FWA. Drop lines are standard deviations of dye removal based on three analyses.

with initial dye concentration of 675 mgpt-Co/L, 3 h of contact time and different pH levels of wastewater. It was observed that there was a weak positive correlation between the pH of BPW and the removal efficiency of dye (R^2 =3.1). Also, unlike DMOCSE the FWA is effective on dye removal at alkaline conditions between pH 8.5 and 11.5 in which the removal efficiency achieved were from 78.8 to 84%, respectively. This may be attributed by the alkaline nature of FWA and the favorable alkaline conditions of the BPW, hence facilitating higher dye sorption compared to acidic conditions that may have increased possibilities of neutralization thus influencing dye adsorption (Gupta et al., 2005). The observed optimum pH range (pH 8.5 and 11.5) for FWA adsorption and the normal pH range of BPW suggests that it will not be necessary to regulate the pH of BPW for the large scale adsorption of dye which will avoid cost implications associated with the pH adjustments.

Effect of DMOCSE and FWA on COD removal

Chemical oxygen demand is a measurement of the oxygen required to oxidize soluble and particulate organic matter

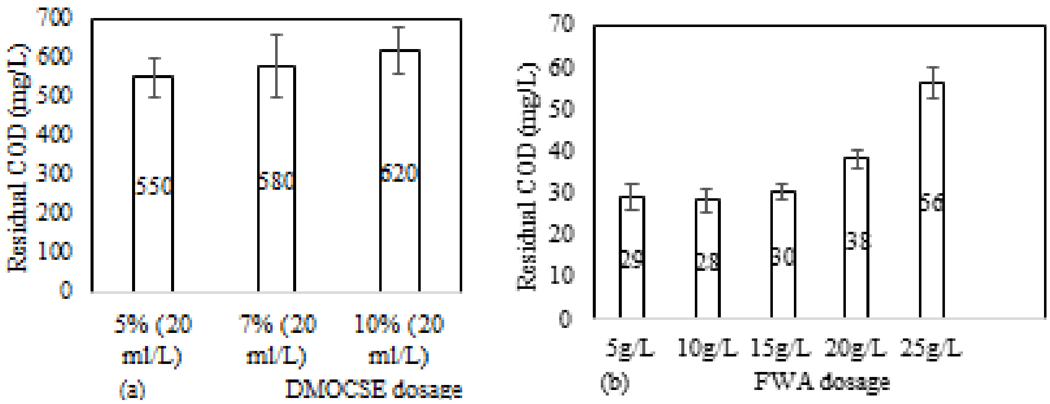

Figure 7. Effect of FWA and DMOCSE on removal of COD in BPW.

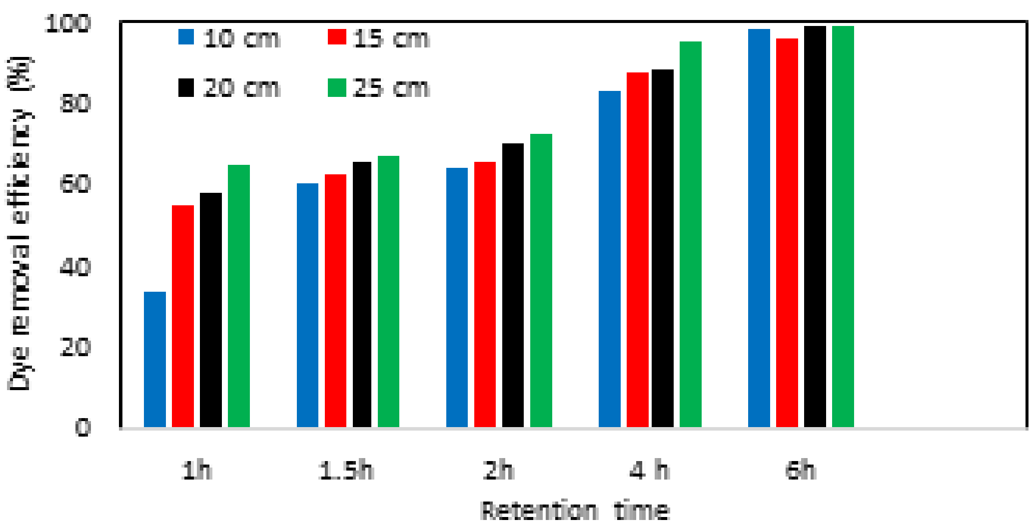

Figure 8. Effect of FWA adsorption column height and retention time on dye removal.

in water. The results on the effect of FWA and DMOCSE on COD removal are shown in Figure 7a and b, respectively. It was revealed that FWA applied at different dosages reduced COD in wastewater with initial COD of 1550 mg/L up to 98% with the residual COD ranging from 28 to 56 mg/L which comply with the Tanzania standard of 60 mg/l. The non-reactivity property of FWA with the dye was among the probable reasons for the decrease in the COD in the treated BPW. On contrary, DMOCSE reduced COD up to 64% with the residual COD ranging from 550 to 620 mg/L. The COD removal efficiency of DMOCSE is quite similar to those reported by Vieira et al. (2010) who observed that 50% of COD in the dairy industry wastewater were reduced at pH 8. The DMOCSE performed better than the *Moringa* seed extract used in dairy industrial wastewater treatment most likely due to defatting of the seed powder which reduced oil and fat globules which interferes with the dye adsorption process by DMOCSE. According to Ghebremichael et al. (2006) the (COD) of *M. oleifera* crude extract samples was 12000 mg/L after purification of coagulant proteins from the crude seed extract up to 96% of the COD that was present originally in the crude extract was removed. Purification of coagulant proteins for BPW treatment could be costly for most batik producers and hence crude extracts could still be suitable under controlled conditions for treatment of BPW.

Dye adsorption using columns

Figure 8 presents the results on adsorption capacity of FWA for wastewater with initial dye concentration of 675 mgpt-Co/L in columns with different depth and contact time. Dye removal efficiency of FWA increased with increase in the depth of the FWA packed column and the retention time of BPW in the media. This was due to maximum adsorption of the dye materials as the BPW passed through the ash media for longer time although other unknown removal mechanisms could have been involved. The FWA media achieved removal efficiency that ranged from 82.9 (115 mgpt-Co/L) to 98.9% (7.4 mgpt-Co/L) in all column depth, that is, 10, 15, 20 and 25 cm. However, longer retention time from 4 to 6 h was required for maximum adsorption of the dye onto the FWA media. On the contrary, DMOCSE performed very poorly in COD removal through columns (results not shown) due to nature of the CSE being a heterogeneous mixture of organic matter which could have leached out through the DMOCSE media hence increasing the COD in the treated effluent. This shows that DMOCSE are suitable adsorbents in batch approach.

CONCLUSION AND RECOMMENDATIONS

The following are conclusions from adsorption potential studies of defatted *Moringa* crude seed extracts (DMOCSE) and fuel wood ash (FWA) on removal of dye and COD in batik processing wastewater (BPW) conducted in batch and column mode with different initial dye concentration, contact and retention time, dosage of adsorbents and pH:

(1) DMOCSE performed best using 7% (w/v) at dosages ranging from 15 to 25 ml and contact time ranging from 2 to 2.5 h in which the dye removal efficiency ranged from 75.5 to 93%. DMOCSE has a wide pH range (5.5-9.5).
(2) The effective dosage for dye removal by FWA in BPW with different dye concentration was 25 g/l, optimum contact time for low and high dye concentration were 1.5 and 3 h, respectively; while the optimum pH ranged from pH 8.5 and 11.5 in which the removal efficiency achieved ranged from 78.8 to 84%.
(3) Residual COD values using FWA as adsorbent ranged from 28 to 56 mg/L and up to 98% COD removal was achieved. On the contrary, DMOCSE reduced up to 64% COD with the residual COD ranging from 550 to 620 mg/L.
(4) FWA showed to be the most effective adsorbent using columns with the height between 20 and 25 cm in which dye removal efficiencies of up to 99% was achieved revealing that FWA are effective adsorbents in column set up compared to batch mode and the converse is true for DMOCSE.
(5) These results reveal potential natural adsorbents which are locally available in Tanzania which can be applied by batik production enterprises to treat the dye-rich wastewaters prior to disposal to the environment. The use of *M. oleifera* seed extract and FWA for dye-rich wastewater treatment at batik production sites will improve environmental management, It will also reduce health risks from direct contamination with untreated dye-rich with dye-rich wastewater which is disposed randomly. prior to treatment of dye-rich wastewater will therefore improve the social-economic.

This study recommends adoption of these materials for treatment of BPW although further studies are warranted to ascertain the adsorption equilibrium models of DMOCSE and FWA which will provide understanding of the sorption mechanism, surface properties and affinity of adsorbent and come up with concrete recommendations about the suitability of these adsorbent for future field applications.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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