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Textile Wastewater Treatment by Combination of Chemical and Phytoremediation Processes

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ABSTRACT: In the present investigation, coagulation-flocculation and fenton process in conjunction with phytoremediation by water hyacinth (*Eicchornia crassipes*) were applied to treat the most frequently occurred contaminants in textile wastewater. The mean values of EC, TDS, turbidity, pH, DO, BOD, COD and TOC in the raw effluents were 2300 μSCm^{-1}, 1260 mgL^{-1}, 48.28 FTU, 10.5, 1.2 mgL^{-1}, 265 mgL^{-1}, 522 mgL^{-1} and 12.8 mgL^{-1}, respectively whereas the average concentration of Cr, Pb, Mg, Cu, Ni and Zn was 0.86, 1.21, 10.97, 0.47, 2.85 and 0.52 mg/L, correspondingly which evidently indicated that the effluents were highly contaminated compared to Bangladeshi standard. The results demonstrated that the values of EC, TDS, turbidity, pH, BOD, COD and TOC reduced significantly compared to raw effluents by both coagulation-flocculation and fenton processes and meet the standards set by BDS-ECR except BOD and DO. After being treated the COD value reduced to 70 mg/L (86.56%) and 188 mg/L (63.985%) from its initial concentration by coagulation-flocculation and fenton process, respectively on the other hand TOC removal efficiency by coagulation- flocculation process was 97.8125%, significantly greater than fenton methods where removal efficiency was 63.9%. However, the BOD removal efficiency by both treatment processes was ~50% which was not satisfactory compared to local standard. Interestingly, the concentration of DO increased substantially by both coagulation-flocculation (1.2 to 4.4 mg/L) and fenton process (1.2 to 3.85 mg/L). In case of trace elements removal, the combination of coagulation-flocculation-water hyacinth and fenton-water hyacinth show promising results where the removal efficiency of coagulation-flocculation-water hyacinth and fenton-water hyacinth was 24%-76% and 17%-76.36%, respectively. Therefore, it can be concluded that coagulation-flocculation-water hyacinth combination is better than fenton-water hyacinth combination in terms of trace metals removal. Textile effluents treatment and management is considered as one of the most significant issues in Bangladesh herein based on the this study, combination of chemical and phytoremediation technologies could be a promising sustainable low cost alternative for Bangladesh’s textile industrial sector.

Keywords: Textile effluents, Water quality, *Eicchornia crassipes*, Fenton methods, Coagulation-flocculation, Bangladesh.

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INTRODUCTION

Growing number of industrial activities create undesirable ecological and global health impact due to the use of huge amount of chemical and harmful heavy metals (Qureshi et al. 2016; Kabir et al. 2017). The effluents from textile dyeing industries are highly colored coupled with high chemical oxygen demand and biochemical oxygen demand and suspended solids and discharge of such effluents not only affect the esthetic value of the receiving stream but also contaminates the environment with heavy metals (Gong et al. 2018). Arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb) and mercury (Hg) are carcinogenic and show toxicity even at trace amount (Kabir et al. 2020). Moreover, the presence of different dyes in water reduces light penetration, prevents the photosynthesis of aqueous flora (Tkaczyk et al. 2020).The complex aromatic structure and synthetic origin of the dyes make them stable to heat, oxidizing agents, photodegradation, and biodegradation (Oliveira and Airoldi 2014). Different physico-chemical methods have been applied including photo degradation (Daneshvar et al. 2003), chemical oxidation membrane processes, adsorption (Dasgupta et al. 2015), coagulation-flocculation (Dotto et al. 2019) and advanced oxidation processes, such as ozonation (Oturan et al. 2014), fenton treatments (Ilhan et al. 2019) ,electro-Fenton methods, photo-fenton oxidation processes (Tarkwa et al. 2019), and photo-electrocatalytic reaction (Sapkal et al. 2012) for complete degradation of the toxic textile wastewater components. The most conventional way of removing the contaminants in textile dyeing industries is the physicochemical treatment (Castro et al. 2018). This method involves the coagulation-flocculation process which uses up various coagulants such as alum, lime etc. When in solution, chemical coagulants are capable of dissociating polyelectrolytes which neutralize the negatively charged dye molecules to form particle-polymer-particle complexes. These contaminants precipitates in the form of chemical sludge when the treated water is further added with flocculants. The oxidation system based on the fenton’s reagent (hydrogen peroxide in the presence of a ferrous salt) has been applied for the treatment of both organic and inorganic substances. The process is based on the construction of reactive oxidizing species and able to efficiently remove the color and COD of the effluent water (Sozen et al. 2020).

Heavy metal is not biodegradable (Kabir et al. 2018) and the conventional treatment methods such as coagulation–flocculation, adsorption, reverse osmosis and ion exchange are not very efficient and comparatively expensive for heavy metal removal or recovery. So, it is necessary to develop and design alternative effective, cheaper, and eco-friendly cumulative heavy metal bioaccumulation applications and wastewater treatment practices (Aggoun and Benmaamar 2019). Phytoremediation is a technique of using plants (Macrophytes) and algae for the recovery of polluted land, soil, and wastewater. Several aquatic plants including free-floating water lettuce (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*), duckweed (*Lemna minor*), and *Salvinia natans*, submerged *Myriophyllum spicatum* and *Ceratophyllum demersum* and emergent *Typha angustifolia* have been investigated for their heavy metal phytoremediation capacities (Kumar et al. 2019). Among the free-floating species, the water hyacinth (*Eichhornia crassipes*) appears to be a promising candidate for pollutant removal owing to its rapid growth rate and extensive root system (Kumar et al. 2019). The ready-made garment (RMG) industry occupies a unique position in Bangladesh’s (BD) economy. It is the largest exporting industry in Bangladesh, having experienced phenomenal growth in last few decades (Hasan et al. 2016). The sector creates about 4.2 million employment opportunities and contributes significantly to national GDP (Gross Domestic Product) being the world's second largest exporter of clothing after China (Islam et al. 2013). Bangladesh textile industries currently have an annual export value of nearly 28 billion USD. It is expected that the annual RMG export value will be about 50 billion USD by 2021. However, effluents from textile industries is a major source of environmental pollution in Bangladesh. It is estimated that by 2021, BD textile industries will produce around 2.9 million metric tons of fabric, which will generate about 349 million m^3 of wastewater. Considering conventional key performance indicator (KPI), 349 million m^3 of wastewater will contain about 1,469,641 metric ton of TDS, 49,442 metric ton of TSS, 175,252 metric ton of BOD and 519,342 metric ton of COD (Hossain et al., 2016). Considering, the above facts and figures; severe pollution scenarios caused by textile dyeing industries in Bangladesh especially the deteriorated water bodies all over the country. The present study was planned to treat the textile effluents by coagulation-flocculation and fenton treatment processes. Moreover, phytoremediation in combination with these processes has been integrated by water hyacinth (*Eichhornia crassipes*) to increase the heavy metal uptake efficiency in treated effluents after coagulation-flocculation process and fenton treatment process for enhancing the overall treatment facilities of textile dyeing released wastewater in Bangladesh.

MATERIALS AND METHODS

The raw effluent samples were collected in plastic jars of 10 liters of capacity from renowned textile dyeing and printing industries ltd. located at Savar Upazilla in Dhaka, Bangladesh. The plastic sample jars were washed with 20% HNO_3 solution, thence rinsed thoroughly with de-ionized water and finally labeled and transported to the laboratory and stored in the Refrigerator at 4ºC temperature for further treatment. And all the experiment and analysis were performed at the department of Environmental Sciences in Jahangirnagar University.

The physical parameters such as Color, Temperature (°C), EC (µS/cm) and TDS (mg/l) were measured with portable photometer (Model: HI96727, HANNA instrument), thermometer, electrical conductivity meter (HI 8033) and Total Dissolved Solid Meter (HANNA, HI 8734). Chemical parameters such as pH was measured with pH Meter (HM-30P, pH Meter), DO (mg/L) was measured with DO Meter (970 DO_2 Meter, Jenway, UK), TOC (mg/L) was measured with Total Organic Carbon Analyzer (TOC-L CPN E200), BOD (mg/L) was determined by 5-days incubation (20 ℃) method and COD (mg/L) was determined by gravimetric method (Kazi et al. 2009) and titrimetric method. The digested effluent samples were analyzed by Atomic Absorption Spectrophotometer to determine heavy metals (Cu, Cr, Ni, Mg, Zn and Pb).

10mL HNO_3 was added to one-gram (1gm) of ground sample (root, shoot, leaves) and kept it overnight in room temperature and heated at different temperatures (120-180 ºC respectively up to dryness. Then 70% $HClO_4$ was added at different temperatures and finally 100 ml of solution was made with distilled water. Then heavy metal was determined by Atomic Absorption Spectrophotometer (AAS) after the filtration of sample water with Whatman, 0.45 µm Glass Microfiber Filter paper. All the reagents of analytical grade were obtained from Merck. Standard solutions were prepared by appropriate dilution of stock standards with deionized water. All other reagents were purchased from Hach Company.

Quality control and quality assurance have been incorporated into the analysis. The analytical performance was standardized by treating spiked samples. The accuracy and precision were also validated in accordance with the European Commission guidelines (EC 2011). The precision was articulated as Relative Standard Deviation (RSD). Accuracy was identified by analyzing the samples with known concentrations and comparing the measured values with actual spiked values. For the recovery experiments, free samples of the metal were spiked, in three replicates, after being homogenized by the addition of appropriate volumes of standards of Cu, Cr, Ni, Mg, Zn and Pb at three different levels (0.125, 0.50, 1.0, and 5.0 mg/L).

Table 1. Performance characteristics of the analytical methods, employed for metallic residues analysis at three spiking levels.

Spiked Levels (mg/L)	% Recovery (n=3) (Repeatability / %RSD) of trace metals					
	Cr	**Pb**	**Cu**	**Ni**	**Zn**	**Mg**
0.5000	87.4326 (1.80)	92.32 (3.71)	90.34 (6.03)	94.74 (4.52)	92.79 (3.63)	89.52 (2.56)
1.0000	97.52 (2.82)	88.90 (4.56)	107.51 (2.73)	98.61 (1.98)	97.91 (2.91)	96.73 (3.87)
5.0000	103.78 (5.50)	98.92 (6.12)	98.67 (0.29)	95.51 (5.62)	107.73 (3.54)	99.72 (2.91)

n*= number of replicates, values are average of triplicate analysis

Control samples were processed along with spiked ones. Average percent recoveries ranged between 87.43% and 103.78% for Chromium (Cr), with its precisions being within 1.8-5.50%. For Lead (Pb), this changed to 92.32-98.92%, with the precisions ranging from 3.71% to 6.12%. As for Cupper (Cu), average recoveries were between 90.34% and 98.67% and its precisions ranged from 6.03% to 0.29%, which changed in case of Nickel (Ni) to 94.74%-95.51% for average recovery and to 1.98%-5.62% for the metal's precisions. Average recoveries and precisions of Zinc (Zn) were within 92.79%-107.73% and 2.91%-3.63%, respectively. As for Magnesium (Mg), the average recoveries ranged between 89.52% and 99.72%, while the precisions were from 2.91% to 2.56%. The QC and QA data are provided in Table 1.

Chemical coagulation was conducted by jar test method. For this test a beaker was taken which contained 1 liter of raw sample. Then 1g of $FeSO_4$ and 1g of $Ca(OH)_2$ were added for the chemical coagulation-flocculation treatment. Later, those chemicals were mixed rapidly (in 200 rpm) with the effluent for five minutes. Thence polymer was added for flocculation and mixed slowly (in 30 rpm) with the effluent for fifteen minutes and kept the mixture for thirty minutes for settling down. After that filtration was done using sand filter. Thence filtrated effluent was collected and its physico-chemical parameters were measured.

Fenton process is considered as one of the advanced oxidation processes. Hydroxyl ($OH^{\cdot}$) radical is produced in this system as a byproduct of reaction between hydrogen peroxide (H_2O_2) and ferrous sulphate ($FeSO_4$). The hydroxyl ($OH^{\cdot}$) radical acts as a strong oxidant capable of oxidizing various organic compounds. For this process pH of the raw effluent was adjusted in pH-2 by adding hydrochloric acid. Then sample was taken in a beaker of 500 ml and iron catalyst ($FeSO_4$) of ten milliliters (10 ml of $FeSO_4$ in ppm) was added to the sample. After that 3 ml (30% concentrated) of hydrogen peroxide (H_2O_2) was added slowly again. Later the effluent and chemicals were mixed up for five minutes (5 mins) and kept the mixture for thirty minutes (30 mins) for settling down. After that filtration was done using sand filter. Thence filtrated effluent was collected and its physico-chemical parameters (BOD, COD, TOC, EC, TDS, pH, DO and Temperature) were measured.

In this research Water hyacinth (*Eicchornia crassipes*) plants were stocked in a little pond located at Jahangirnagar University, Savar, Dhaka where Water hyacinth was used as aquatic macrophytes for removal of heavy metals (Cu, Cr, Ni, Mg, Zn and Pb) from three types of effluents. Firstly, in raw effluent, secondly, in effluent treated by coagulation-flocculation treatment and finally in effluent treated by Fenton treatment process. These effluents were taken separately in the tubs of 12-liter capacity each. Nearly equal weights of Water hyacinths (300 gm fresh weight) were transferred to the tubs containing three types of effluents labeled as experimental plants. Equal weights of Water hyacinths were transferred to another set of tubs containing natural water and were labeled as control. The experimental and control tubs were kept in a greenhouse for 6-7 days. After that the experimental plants were collected and dried at 70ºC in oven for 48 hours (root, shoot, leaves separately). Then the dried sample were grounded for digestion.

RESULTS AND DISCUSSION

The average effluent temperature of textile dyeing and printing industries ltd. was above 40°C which is higher than the set limit by the ECR 1997, Bangladesh. The average temperature of the textile effluents was higher than the average value of 41.675 ℃ reported by Roy et al. (2010) in Bangladesh. High temperature decreases the solubility of gases in water that ultimately articulates high BOD and COD. BOD and COD values were measured in the range of 138 to 181 mg/L and 448 to 520 mg/L respectively which are higher than the standard of (DoE 2008). The pH value of the effluent was alkaline (10.5) in nature and alkaline pH of textile effluent is associated with the process of bleaching and is extremely undesirable in water ecology (Chhikara et al. 2013). This alkalinity has effects on the buffering capacity of the water systems and needs to be monitored in all cases. Again textile effluents were obtained highly colored because 10-15% of the dyes are usually lost in the effluents of textile units (Roy et al. 2010). The most significant measure of water quality is the dissolved oxygen (DO). DO value of the sample water was found 1.2 mg/L which is lower than the standard (DoE 2008). The DO content could be lower due to intrusion of excessive organic load in the water which leads to oxygen depletion (Mohabansi et al. 2011).

Table 2. Concentration of physico-chemical and trace elements in raw effluent.

Physico-chemical parameters	Wastewater samples	Effluents quality standard (ECR-1997)
Color	Dark deep green	Transparent
Temperature (º C)	45	40
EC (µs/cm)	2300	1200
TDS (mg/L)	1260	2100
Turbidity (FTU)	48.28	5
pH	10.5	6-9
DO (mg/L)	1.2	>5
BOD (mg/L)	265	50
COD (mg/L)	522	200
TOC (mg/L)	12.8	-
Cr (mg/L)	0.8611	0.50
Pb (mg/L)	1.2171	0.50
Mg (mg/L)	10.9761	-
Cu (mg/L)	0.4738	0.50
Ni (mg/L)	2.8528	1.0
Zn (mg/L)	0.5238	0.50

Heavy metals concentration of raw effluent was found both lower and higher than the standard values set by (ECR 1997). Metals result from metal complex dyes, dye stripping agents, oxidizing agents, and finishers in textile effluent (Zeiner et al. 2007). The measured concentration of Cr was 0.8611 mg/L which was lower than the standard value (1 mg/L). In this study Pb concentration was found above normal limits. Cu is a vital substance to human nutrition as a factor of metallo-enzymes in which it performs as an electron donor or acceptor (Deepali and Gangwar 2010). However, in high concentrations it may cause anemia, liver and kidney damage, stomach, and intentional irritation (Imtiazuddin et al. 2014). Cu is toxic to aquatic plants at concentrations below 1 mg/L where as a concentration close to this level may be toxic to some fishes. Cu concentration was found below normal limit. The most adverse health effects from exposure to Ni include lung fibrosis, cardiovascular and kidney diseases, and cancer of the respiratory tract. In this study the measured concentrations of Ni were above the permissible limit of wastewater discharge standards according to (DoE 2008) and Zn was resulted as 0.5238 mg/L which was lower than the permissible limit.

The raw effluent collected from textile was alkaline in nature and the pH value was >10. The measured pH value was higher than the standards of DoE 2008 and ECR 1997. After the treatment the pH value of the sample was found decreased to 6.85 which followed the standard value. The COD level was initially 522 mg/L which indicated dissolved organic matter containing non-biodegradable matter existing in it. After being treated the COD value reduced to 70 mg/L that means 86.56% reduction, which indicated a significant reduction state. It was found that at different doses COD removal efficiency was found to be 62% and 64% (Seval et al. 2006). High value of Total Dissolved Solids reduces the light penetration into water and ultimately decreases the photosynthesis. The decrease in photosynthetic rate reduces the DO level of wastewater which results in decreased purification of wastewater by microorganisms. Prior to the treatment DO level was very low as 1.2 mg/L. While treated, this level increased to 4.4 mg/L. TDS reduces water clarity and cloudy water engages more heat and blocks light penetrations. Therefore, intensified turbidity increases water temperature and prevents photosynthesis. Posterior to the treatment the TDS value also decreased to 400 mg/L whereas the initial value was 1260 mg/L. In raw effluent the value of EC was 2300 µs/cm. After being treated it changed to 1010 µs/cm. Initially value of the TOC was 12.8 mg/L. While treated, this value changed to 0.28 mg/L which showed the improvement with 97.8125% reduction, it was found that TOC removal efficiency is 94.2% by coagulation-flocculation process (Cristina et al. 2016). However, BOD removal was not significant by coagulation-flocculation process which was ~50% (265 mg/L to 132.01 mg/L)

Table 3. Treatment of physico-chemical coagulation-flocculation methods.

Physico-chemical parameters	Pre-treatment effluents quality	Post-treatment effluents quality
pH	10.5	6.85
COD (mg/L)	522	70
BOD (mg/L)	265	132.01
DO (mg/L)	1.2	4.4
TDS (mg/L)	1260	400
EC (µs/cm)	2300	1010
TOC (mg/L)	12.8	0.28

After the Fenton treatment process a significant reduction was observed in pH value (5.80) which is near to Bangladesh standard value. High COD levels imply toxic state and the presence of biologically resilient organic substances. Initially the COD value was 522 mg/L. After the Fenton treatment process this value reduced to 188 mg/L (63.985%), it also found that COD removal efficiency is 78% at pH-3 (Seval et al. 2006). It was found that the value was almost very near to the standard value 200 mg/L set by (ECR, 1997). The BOD reduced from 265 mg/L to 131.50 mg/L which was ~49%. Total Organic Carbon (TOC) is an important parameter of industrial effluent, the presence of which indicates unhealthy condition for water. It was noticed that after the Fenton treatment process TOC value reduced satisfactorily by 84.296875% (2.01 mg/L) at pH-2. The lower DO content could be due to intrusion of high organic load in the water which leads to oxygen depletion (Mohabansi et al. 2011). In this study the DO value was found 1.2 mg/L which increased to 3.85 when it was treated. EC of effluent was found 2300 µS/cm which was higher than standard value (1200 µS/cm) set by (DoE, 2008). High EC indicates a large amount of ionic substances like sodium, potassium, iron etc. in textile effluent (Roy et al. 2010). Water with high EC affects the soil structure, permeability and irrigation. After Fenton treatment process the EC reduced to 1360 µs/cm which was near about the standard value set by (ECR 1997). High TSS and TDS detected could be recognized to the high color and they might be major sources of the heavy metals. Increased heavy metals concentration in river sediments could grow suspended solid concentration (Kambole 2003). This study found the value of TDS (after Fenton treatment) satisfactory at pH-2 which was 520 mg/L.

Table 4. Status of physico-chemical parameters after fenton process

Physico-chemical parameters	Pre-treatment effluents quality	Post-treatment effluents quality
pH	10.5	5.80
COD (mg/L)	522	188
BOD (mg/L)	265	131.5
DO (mg/L)	1.2	3.85
TDS (mg/L)	1260	520
EC (µs/cm)	2300	1360
TOC (mg/L)	12.8	2.01

Aquatic macrophytes have abundant potential to accumulate heavy metals inside their plant bodies. These plants can accumulate heavy metals up to 100,000 times greater than the amount in the associated water. In a study by Roy et al. (2010) of water hyacinth farming in a plastic bowl containing textile industry effluent the sample analysis has shown 70–90% removal of heavy metals like iron, lead, copper and chromium. Mahmood et al. (2005) reported that the water hyacinth plant could be able to eliminate metal ions like chromium, zinc and copper from the textile effluent a maximum of 94.78% reduction in chromium, 96.88% in zinc and 94.44% decrease in copper. Metals found from treated effluent were 24% less than the metals in raw effluent (100%). In this treatment the levels of Chromium (Cr), Lead (Pb), Magnesium (Mg), Cupper (Cu), Nickel (Ni) and Zinc (Zn) were found with notable reduction rate. From the remaining (76%) heavy metals, water hyacinth accumulated 9.62%, 23.56% and 44.83% by leaves, shoot and root respectively where after this phytoremediation process, maximum 78.01% heavy metal removal efficiency was found.

Water hyacinth can accumulate great amount of metals due to rapidly adaptation to different aquatic physicochemical conditions (Liao and Chang 2004). Recently, Rezania et al. (2015) studied that the water hyacinth is accomplished of assimilating large quantities of pollutants (heavy metals) and nutrients, which makes it effective in wastewater treatment. Hasan et al. (2007), found that this plant can tolerate high concentrations of heavy metal and can endure in extreme conditions too.

As acknowledged by Kay et al. (1984) the metal accumulations within plant tissues of water hyacinth was in the order leaves < stems < roots. Metals found from treated effluent were 17% less than the metals in raw effluent (100%). In this treatment Chromium (Cr), Lead (Pb), Magnesium (Mg), Cupper (Cu), Nickel (Ni) and Zinc (Zn) were found reduced. From the remaining (83%) heavy metals, water hyacinth accumulated 7.83%, 25.73% and 42.80% by leaves, shoot and root respectively. After this phytoremediation process, maximum 76.36% heavy metal removal efficiency was noticed.

Table 5. Heavy metal removal after coagulation-flocculation process

Heavy metals (mg/L)	Control group	Raw effluent (100%)	After Coagulation process	Phytoremediation		
				Leaves (9.62% of 76%)	Shoot (23.56% of 76%)	Root (44.83% of 76%)
Cr	BDL	0.8611	0.6544	0.063	0.1542	0.2934
Pb	BDL	1.2171	0.925	0.089	0.2179	0.4147
Mg	BDL	10.9761	8.3418	0.8025	1.9653	3.7396
Cu	BDL	0.4738	0.3601	0.0346	0.0848	0.1614
Ni	BDL	2.8528	2.1677	0.2085	0.5107	0.9718
Zn	BDL	0.5238	0.3981	0.0383	0.0938	0.1785

BDL*=Bellow Detection Limit

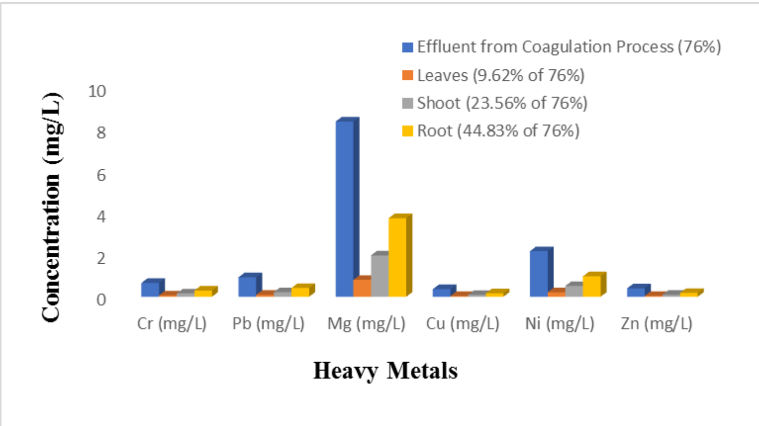

Fig. 1. Heavy metal removal efficiency after coagulation-flocculation

Table 6. Heavy metals removal after fenton process

Heavy Metals (mg/L)	Control group	Raw effluent (100%)	After Fenton Process	Phytoremediation		
				Leaves (7.83% of 83%)	Shoot (25.73% of 83%)	Root (42.80% of 83%)
Cr	BDL	0.8611	0.7147	0.056	0.1839	0.3059
Pb	BDL	1.2171	1.0102	0.0791	0.2599	0.4324
Mg	BDL	10.9761	9.1102	0.7133	2.3441	3.8992
Cu	BDL	0.4738	0.3933	0.0308	0.1012	0.1683
Ni	BDL	2.8528	2.3678	0.1854	0.6092	1.0134
Zn	BDL	0.5238	0.4348	0.034	0.1119	0.1861

BDL*=Bellow Detection Limit

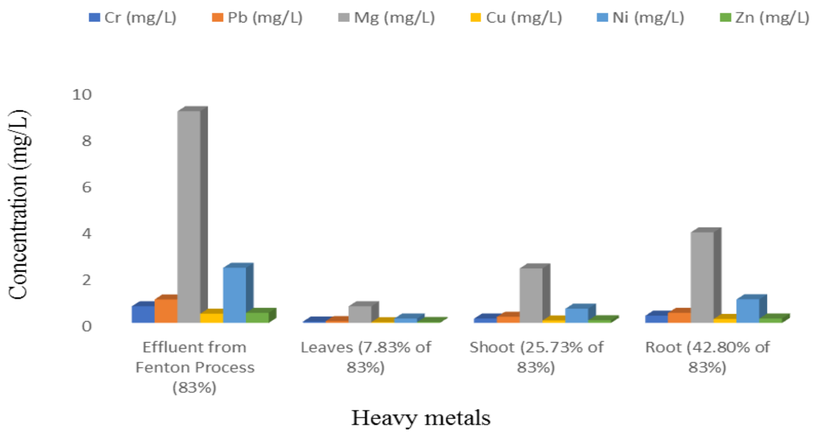

Fig. 2. Heavy metal removal efficiency after Fenton process

A comparative study was performed to assess the textile wastewater treatment efficacy by coagulation-flocculation and fenton process (Table 7). After being treated the COD value reduced to 70 mg/L (86.56%) and 188 mg/L (63.985%) by coagulation-flocculation and fenton process, respectively. Moreover, TOC removal efficiency by coagulation- flocculation process is 0.28 mg/L (97.8125%) significantly better than another one. However, Gilpavas et al. (2017) reported that TOC removal efficiency by fenton Process (80 mg/L) was significantly higher than the coagulation- Flocculation process (151 mg/L). Here, the value of TOC in raw sample was 290 mg/L before applying any treatment process (Gilpavas et al. 2017). In the coagulation- Flocculation treatment, concentrations of chromium (Cr), lead (Pb), magnesium (Mg), cupper (Cu), nickel (Ni) and zinc (Zn) were found with prominent reduction compared with the Fenton Process. Therefore, it is evident that coagulation-flocculation has the potential of being applied as an effective treatment process than the fenton process.

Table 7. Comparison of textile wastewater treatment efficacy by coagulation-flocculation, fenton and phytoremediation processes.

Parameters	Raw effluent	Effluent after coagulation/ flocculation processes	Effluent after advanced oxidative process (Fenton)	References
pH	10.3	6.9	7.0	Favero et al. 2018
COD (mg O_2/L)	2072.97	322.06	151.80	
DO	-	-	-	
EC	-	-	-	
TOC	-	--		
pH	9.96	6	5.31	Gilpavas et al.2017
COD (mg O_2/L)	865	450	225	
DO	-	-	-	
EC	-	-	-	
TOC (mg C/L)	290	151	80	
pH	12.0	6	-	Sabur et al. 2012
COD (mg O_2/L)	1638	161	-	
DO	-	-	-	
EC	-	-	-	
TOC (mg C/L)	-	-	-	
pH	10.5	6.85	5.80	Present study
COD (mg O_2/L)	522	70	188	
DO (mg/L)	1.2	4.4	3.85	
EC (µs/cm)	2300	1010	1360	
TOC (mg C/L)	12.8	0.28	2.01	
Cr(mg/L)	0.8611	0.6544	0.7147	
Pb(mg/L)	1.2171	0.925	1.0102	
Mg(mg/L)	10.9761	8.3418	9.1102	
Cu(mg/L)	0.4738	0.3601	0.3933	
Ni(mg/L)	2.8528	2.1677	2.3678	
Zn(mg/L)	0.5238	0.3981	0.4348	

CONCLUSION

Textile effluents characterization and treatment by applying coagulation-flocculation and fenton processes along with the use of water hyacinth for phytoremediation of heavy metals were the major goals of this study. Excellent removal efficiency of this combined processes for different parameters such as heavy metals, EC, TDS, pH, DO, COD and TOC from the untreated textile effluent was found. In both treatment processes the values of TOC, COD, TDS, EC and pH were reduced to a significant level. The heavy metal remediation by water hyacinth was also found very effective. The effluents quality was improved acceptably from the untreated samples. The heavy metal removal efficiency by phytoremediation process in both treated effluents (coagulation-flocculation and fenton processes) was also appreciable. In general, both the processes are manifested as fruitful, cost effective and easily operative. Physico-chemical processes along with phytoremediation by water hyacinth can be a good option for textile wastewater treatment in industrial scale for Bangladesh.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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