OPTIMIZATION OF EXPERIMENTAL FACTORS FOR HEXAVALENT CHROMIUM REMOVAL BY DEAD BIOMASS OF WATER HYACINTH

Sunil Kumar* and Rajesh Dhankhar

Department of Environmental Sciences, Maharshi Dayanand University, Rohtak-124001,
Haryana, India

*E-mail: sunilevs@yahoo.com

ABSTRACT

The purpose of this work was to use the dead biomass of water hyacinth, *Eichhornia crassipes* (Mart.) solms for hexavalent chromium adsorption from synthetic solution in batch process and surface morphological characterization of adsorbent by FTIR and SEM. Two sizes (0.3 mm and 1.0 mm) were prepared from dead biomass. The various experimental factors like pH, contact time, temperature, shaking rate, initial concentration, and dosage of adsorbent on the removal of metal were examined in the batch process. 100 % removal was achieved by both sizes at 1.0 pH, when initial concentration, contact time, adsorbent dose, temperature, and shaking speed were 20ppm, 1 hour, 1.0 g/100 ml, 25 °c, and 150 rpm, respectively. It was observed that the percent Cr (VI) removal decline with increasing pH. Similarly, complete removal has been obtained by 0.8 g and 1.0 g doses of 0.3 mm and 1.0 mm sizes at optimum pH, while other factors are the same as during the pH study. The study also identified the optimum contact time, initial concentration, temperature, and shaking time. The unloaded and Cr (VI) loaded FT-IR spectra showed a significant shift of absorption peaks. The SEM analysis showed that adsorbent tubes appear to be prominently swollen after Cr (VI) adsorption as it enters the fibers of the adsorbent. This study concluded that the dead biomass of water hyacinth can be effectively used as an absorbent for wastewater treatment.

Keywords: Water Hyacinth, Adsorbent, Chromium (VI), Dead Biomass, Wastewater.

© RASĀYAN. All rights reserved

INTRODUCTION

Industrial development activities in recent past such as mining operations, metal plating facilities, tanneries, batteries, fertilizer industries, paper industries, and pesticides, etc., increased by many folds in developing countries, these industries directly or indirectly are accumulating the heavy metals in wastewaters.¹ Heavy metals ions are not degraded by micro-organism unlike organic pollutants, they start to buildup in living organisms and many of them have the potential to create carcinogenic toxicity. The toxic heavy metals namely mercury, cadmium, lead, zinc, copper, nickel, and chromium are required special attention in wastewaters of industries.²

The chromium in the aquatic environment exists as Cr (III) and Cr (VI). In general, Cr (VI) is highly hazardous to the organism in comparison to Cr (III).³ The toxic effects of hexavalent chromium are included, human physiological effects, skin irritation, lung carcinoma, food chain accumulation, and causes several other health problems.⁴ The ion exchange, filtration, chemical precipitation, chemical oxidation and reduction, electrochemical treatment, and bio-reduction are usual methods for removing wastewater heavy metal ions.^{5,6,7} But, these conventional processes of treatment have many drawbacks, including requirements of high energy, insufficient metal elimination, high cost of removal, and production of toxic sludge⁸. Due to these treatment problems, a developing country like India required alternative low-cost technology development for the treatment of Cr(VI) and other toxic chemicals from industrial effluents.^{9,10} The country like India has poor wastewater treatment facilities and due to the release of untreated effluents most of the water sources have eutrophic, producing an excess of macrophytic plants. These plant wastes have no or very low economic use and inexpensive.

The species *Eichhornia crassipes* (Mart.) solms (water hyacinth) found in the tropical areas between 40°N and 40°S, it is a member of the pickerelweed family (Pontederiaceae) and abundantly available. This

Rasayan J. Chem., 13(4), 2376-2384(2020)

<http://dx.doi.org/10.31788/RJC.2020.1345949>

species is a native of central South American countries and Brazil, now shows its presence in streams, wetlands, and swamps of the world including India.¹¹ It occupies all the space in the water body very rapidly due to its quick growth with high densities (over 60 kg m^{-2}). This property of water hyacinth creates bad effects on economic development, aquatic environment, human health and interfere with navigation, recreation, irrigation, and power generation.¹² Its production on dry basis is 50 tons/hectare/year.¹³ Various researchers are working on the utilization of water hyacinth for useful applications because this is an unwanted/weed for water bodies and responsible for many problems. From the last few decades dried biomass of water hyacinth has been actively researched for the elimination of metals from industrial effluents as a low-cost bioadsorbent. The dead water hyacinth roots have been efficiently used for sorption of uranium, copper as well as basic dyes.^{14,15} Al Rmali et al.¹⁶ demonstrated that powder produced from dried roots of water hyacinth efficiently removes more than 93% of arsenite As(III) and 95% of arsenate As(V) from a solution containing $200 \mu\text{g As/l}$ within 60 min. Keeping in view of water hyacinth waste problem, adsorbent of *Eichhornia crassipes* collected from Bhindawas wetland, was prepared and the study on removal of Chromium (VI) was conducted. Two different sizes were prepared, upto 0.3 mm and from 0.3 mm to 1.0 mm. Surface morphology characterizations were determined with the help of Fourier transform infrared (FTIR) and Scanning electron microscopy (SEM).

EXPERIMENTAL

Preparation of Adsorbents

The collection of water hyacinth (*Eichhornia sp.*) has been done from Bhindawas wetland. The freshwater and distilled water were used to wash the collected water hyacinth plants in the laboratory. The knife was used to cut the plants in the pieces. Initially, plant material was dried under sunlight. Further moisture was removed by drying the plant material in a hot air oven at 110°C for 24 hrs. The powder of plant material was obtained with the help of a grinder. The color of powder adsorbent was removed by washing with the 1% formaldehyde solution. The washed adsorbent was dried at a temperature range of $120\text{--}140^\circ\text{C}$ in an oven for a period of 12 hrs. To obtain particle sizes of upto 0.3 mm and upto 1.0 mm the dried material was grounded and sieved through a standard sieve.

Characterization of Adsorbent

The adsorbent characterization was evaluated by using the standard procedure as given in Allen.¹⁷

Cr (VI) Solution Preparation and Determination

The analytical grade Potassium Dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) was taken for Cr (VI) solution preparation in the batch experiment. The stock solution (1000 ppm) was prepared by mixing 2.829 g of Potassium Dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) into one liter of double-distilled water. The stock solution was diluted by 50 times to prepare the 20 ppm chromium working solution. 0.25% 1, 5-Diphenylcarbazide solution was used to develop violet color in treated samples, and intensity was determined at 540 nm. Chromium (VI) concentration was measured by a standard curve, prepared in the range of 0.2 to 1.4 ppm.

Cr (VI) Removal Studies

The 250 ml conical flasks were used to carry out batch experiments. The 100 ml synthetic solution of chromium was utilized for the optimization of experiments. The batch experiments were carried out by using a mechanical shaker.

The pH, adsorbent dose, agitation time, agitation speed, and temperature were optimized with a synthetic solution of chromium in the batch process. The pH was varying from 1 to 7 to examine the effect of pH, time was kept 1 hr, while chromium (VI) concentration, dose, temperature, and agitation speed were 20 ppm, 1.0 g/100 ml, 25°C , and 150 rpm, respectively. The dose was varying from 0.1 to 1.0 gm to assess the effect of adsorbent dose, while other conditions were 20 ppm chromium concentration, 150 rpm agitation speed, temperature 25°C and 1 hour agitation time. To assess the effect of agitation time, the study was carried by varying time from 15 to 135 minutes at the interval of 15 minutes while, dose, pH, agitation speed, and temperature were kept 0.3 g/100 ml, 1, 150 rpm, and 25°C . The influence of concentration, shaking rate, and temperature were evaluated by taking the concentration from 10 to 100 mg/l, agitation speed from 50 to 300 rpm, and 20 to 100°C at optimized pH, dose and agitation time. The solution containing conical flasks was removed after a desirable agitation period. The adsorbent was

settled down after proving two minutes, thereafter Whatman filter paper No. 42 was used to filter solutions. The chromium concentration in the filtrate was measured by spectrophotometer using the diphenylcarbazide method as given in the Standard Method of Water and Waste Water Analysis.¹⁸ The following equation used to determine the adsorption percentage-

$$\text{Adsorption (\%)} = \frac{(C_i - C_{eq})}{C_i} \times 100$$

The initial and the final concentrations of the chromium (VI) are denoted by C_i and C_{eq} .

The solid adsorbed chromium (VI) amount was computed as follows:

The per unit weight of the solid adsorbed amount of chromium (VI) at equilibrium (mg/g)

$$q_e \text{ (mg/g)} = \frac{(C_i - C_{eq}) * V}{M}$$

Where the volume of solution given by V; the mass of adsorbent given by M (gm)

Fourier Transform Infrared (FTIR) Analysis

The Fourier transform infrared spectrometer (Shimadzu, Japan) was used to produce infrared spectra of the raw and chromium-loaded biosorbent. The translucent sample disks for the FTIR study was prepared by 1mg of powdered adsorbent encapsulated in 200 mg of KBr pellet. The functional groups involved in the adsorption of metals were determined by the infrared spectral analysis. The spectral locations of infrared energy adsorption by chemical bonds at specific wavelengths determine the basic structure of compounds. The plot of FTIR was compared with reference spectra for the identification of the material.

SEM Photomicrograph

The surface physical morphology of the raw and chromium loaded adsorbent was determined by scanning electron microscopy (SEM) technique. The samples were sputter-coated with a thin layer of platinum for charge dissipation. The argon atmosphere was used to operate the sputter coater. The SEM images were got after transferring the sample in the SEM specimen chamber. The raw and chromium-loaded photomicrographs of SEM at various magnifications determine the surface nature of the adsorbent.

RESULTS AND DISCUSSION

Keeping in view of the abundance of *Eichhornia crassipes* in Bhindawas wetland adsorption study was done, so that the unwanted *Eichhornia crassipes* weed can be utilized for some useful purpose. The adsorbent of *Eichhornia crassipes* was utilized to eliminate the hexavalent chromium from the aqueous solution. Raw *Eichhornia crassipes* (REC) adsorbent was prepared in two sizes upto 0.3 mm and 0.3mm to 1.0 mm. These adsorbents mark as 0.3mm and 1.0mm in the study.

Characterization of Adsorbents

The characterization of adsorbents has been given in Table-1. Raw *Eichhornia crassipes* (REC) was found slightly basic. The electrical conductivity of REC was 225 μ mho/cm for both sizes. Bulk density was found 0.101 g/cm³ for both sizes. The particle density of REC was noted as 0.145 g/cm³ and 0.141 g/cm³ for 0.3mm and 1.0mm adsorbent sizes, respectively. The adsorbent solubility in water was recorded at 6.4% and 6.2% for REC adsorbent of 0.3mm and 1.0mm sizes, respectively. Similarly, the solubility in acid was 8.3% and 7.8% recorded for 0.3mm and 1.0mm. The moisture content of adsorbent REC was recorded 3.25% for 0.3mm size and 2.9% for 1.0mm size. The porosity of REC was 30.3% for 0.3mm size and 28.3 was for 1.0mm size.

Adsorption Study of *Eichhornia crassipes*

Hexavalent chromium removed by REC was carried out and the influence of various parameters namely pH, adsorption dose, agitation time, initial Cr (VI) concentration, rotation per minute (rpm) of the shaker, and temperature in batch on Cr (VI) removal was studied. All experiments were carried out in the batch process.

Effect of pH

The influence of pH on Cr (VI) reduction by REC is shown in Table-2. The pH effect on Cr (VI) removal was evaluated by using 20 ppm initial Cr (VI) concentration with 1g/100ml of adsorbent dose for 0.3mm

and 1.0mm sizes, where pH was varied from 1 to 7. The 0.1N HCl and 0.1N NaOH solutions were used to adjust the pH.

Table-1: Characterization of Adsorbents prepared from *Eichhornia crassipes*

Parameters	Raw <i>Eichhornia crassipes</i> (REC)	
	0.3mm	1.0mm
pH	6.75	6.75
EC $\mu\text{mho/cm}$	225	225
Bulk density g/cm^3	0.101	0.101
Particle density g/cm^3	0.145	0.141
Solubility in Water (%)	6.4	6.2
Solubility in Acid (%)	8.3	7.8
Moisture Content (%)	3.25	2.9
Porosity(%)	30.3	28.3

The percent of Cr (VI) removal by 0.3mm and 1.0mm sizes were 100% at pH 1.0. The results revealed that Cr (VI) removal decline with increasing pH. The removal percentages of Cr (VI) at 2 pH for 0.3mm and 1.0mm were 71% and 69.3%, respectively. The removals by adsorbents per unit mass were 1.42 mg/g and 1.386 mg/g at 2 pH, respectively. The ionic state of functional groups along with the metal chemistry in solution is the deciding factor for the influence of the pH on metal removal.¹⁹

Table-2: Effect of pH on Cr (VI) Removal by Raw *Eichhornia crassipes* (REC)

pH	REC (0.3mm)		REC (1.0mm)	
	% Removal	Removal in mg/g	% Removal	Removal in mg/g
1	100	2.0	100	2.0
2	71	1.42	69.3	1.386
3	52.7	1.054	49.5	0.989
4	51.1	1.022	48.5	0.969
5	49.8	0.996	47.1	0.943
6	48.8	0.977	45.8	0.916
7	46.2	0.924	44.1	0.883

Initial Cr (VI) – 20 ppm, Dose – 1.0 g/100 ml, Time – 1hour, Temperature – 25°C, RPM – 150

The functional groups with positive charge present on the bioadsorbent surface bind to negatively charged chromium species (chromate/dichromate) at pH 1.0 because the positive charge is carried by many functional groups at this pH. The main species that present at acidic pH were $\text{Cr}_2\text{O}_7^{2-}$, HCrO_4^- , $\text{Cr}_3\text{O}_{10}^{2-}$ and $\text{Cr}_4\text{O}_{13}^{2-}$ in solution,²⁰ while above pH 7, only CrO_4^{2-} was dominated. Moreover at lower pH $\text{Cr}_3\text{O}_{10}^{2-}$ and $\text{Cr}_4\text{O}_{13}^{2-}$ species are formed. Thus at lower pH more polymerized Cr oxide species are formed. Similarly, the uptake of Cr (VI) under acidic conditions by adsorbent becomes highly protonated and favorable.²¹ Furthermore, competition between OH^- and chromate ions (CrO_4^{2-}) at basic pH reduces the adsorption because OH^- was the main species at higher pH.

Effect of Adsorbent Dose

The Cr (VI) removal at various dosages from 0.1 to 1.0 g of REC (0.3mm&1.0mm) has been given in Table-3. The experiment was performed at 20 ppm initial Cr (VI) concentration, 1 hour agitation time, pH 1.0, temperature 25 °C, and 150 rpm agitation rate.

It was found from the outcome that removal of Cr (VI) by 0.3mm and 1.0 mm adsorbents were increased from 72.2% to 100% at 0.1g to 0.8 gm dosages and 71.5% to 100% at 0.1 g to 1.0 g for REC. The 80.7 % and 78.5% removal of Cr (VI) for 0.3mm and 1.0mm took place at 0.3 g, where per unit mass removal was 5.38 mg/g and 5.23 mg/g, which is a significant amount of removal. So for further study 0.3 g of REC/ 100 ml dosage was taken for both sizes. The number of particles per unit weight increased when increased in adsorption dose, which provides more binding sites with more surface area for adsorption. Typical saturation in terms of %age removal has been observed after certain adsorbent doses. It could be due to an increased competition level between the adsorbent particles for the binding of metal substances.²² The study revealed that a slightly higher removal rate was observed in 0.3 mm than 1.0mm size. The surface area of the adsorbent decreases with increasing particle size. Furthermore, the migration

time of the metal ions into inner pores increased with increasing particle size, which results in longer equilibrium time with lower sorption capacity.¹⁶

Table-3: Effect of Dose on Cr (VI) Removal by Raw *Eichhornia crassipes*(REC)

Dose (g/100ml)	REC (0.3mm)		REC (1.0mm)	
	% Removal	Removal in mg/g	% Removal	Removal in mg/g
0.1	72.2	14.43	71.5	14.3
0.2	75.9	7.59	75.1	7.5
0.3	80.7	5.38	78.5	5.23
0.4	97.4	4.86	94	4.7
0.5	97.7	3.9	96.6	3.86
0.6	98.1	3.27	97.3	3.24
0.7	99.5	2.84	98.9	2.82
0.8	100	2.5	99.2	2.48
0.9	--	--	99.6	2.21
1.0	--	--	100	2.0

Initial Cr(VI) – 20 ppm, pH – 1, Time – 1hour, Temperature – 25 °C, RPM – 150

Effect of Adsorbent Time

The variation of Cr (VI) reduction from synthetic solution by REC absorbent sizes of 0.3mm and 1.0mm concerning agitation time exhibits in Table-4. The experiment was performed at 20 ppm initial Cr (VI) concentration, a dose of absorbent was 0.3g/100ml, pH was 1, the temperature was 25 °C, agitation at 150 rpm, while contact time was varied from 15 minutes to 135 minutes.

It has been highlighted from the outcome that Cr (VI) reduction by REC sizes of 0.3 mm and 1.0 mm increased from 64.5% to 93.6% and 63.7% to 92.7%, respectively at 15 minutes to 120 minutes of contact time. The removal per unit mass was increased from 4.29 mg/g to 6.23 mg/g for 0.3mm and 4.24 mg/g to 6.18 mg/g for 1.0 mm. It was also noted that a significant amount of Cr (VI) removal took place at 60 minutes, so further experiments were conducted by taking 60 minutes as an agitation time.

The outcome of the study showed that initially, the reduction rate was high, but after the lapse of time, it was slower. Higher removal in the starting time could be due to more adsorption sites availability, higher metal concentration gradient, electrostatic affinity and ion-exchange at an earlier stage. It was also noted that the removal of metal ions increase with the increasing agitation time to some extent. Further agitation time increase did not increase the uptake of metal ion on the adsorbent.

Table-4: Effect of Time on Cr (VI) Removal by Raw *Eichhornia crassipes* (REC)

Time (Min)	REC (0.3mm)		REC (1.0mm)	
	% Removal	Removal in mg/g	% Removal	Removal in mg/g
15	64.5	4.29	63.7	4.24
30	69.6	4.64	67.8	4.52
45	76	5.06	74.6	4.97
60	80.7	5.38	78.5	5.23
75	84	5.59	82.3	5.48
90	90.8	6.05	90	5.99
105	91.8	6.12	91.3	6.08
120	93.6	6.23	92.5	6.16
135	93.6	6.23	92.7	6.18

Initial Cr (VI) – 20 ppm, pH – 1, Dose – 0.3 g/100 ml, Temperature – 25 °C, RPM – 150

A similar outcome has been reported by several other authors for the adsorption of metals on *Eichhornia crassipes* adsorbent.^{16,19,23} Equilibrium time depends upon the initial metal concentration and affinity of metal binding. The equilibrium time reported by Mohanty *et al.*¹⁹ for 10 mg/l initial concentration of Cr (VI) was 360 min on *Eichhornia crassipes* adsorbent. Where in the current investigation equilibrium time was 135 min for 20 mg/l Cr (VI) concentration. The equilibrium time required by the adsorbent of *Eichhornia crassipes* used in the current work is lower in comparison to others reported equilibrium time in literature. The equilibrium time is considered an important aspect of economical water and wastewater

treatment applications. The rapid (or instantaneous) biosorption phenomenon is advantageous in-process application because smaller size treatment equipment is required in case of shorter contact time adsorbent.

Effect of Initial Cr (VI) Concentration

The experiment was conducted at various Cr (VI) concentrations i.e. 10-100 ppm. The dosage of adsorbent was kept 0.3 g/100 ml, pH was 1.0, temperature 25 °C, rpm was 150 at the contact time of 1 hour. The removal results have been presented in Table-5.

The elimination of Cr (VI) concentration was found a maximum of 100 % and 99.1% at 10 ppm initial Cr (VI) concentration by 0.3mm and 1.0mm REC adsorbent. Removal by per unit mass was maximum 15.26 mg/g for 0.3 mm and 14.09 mg/g for 1.0mm at 100ppm. It could be due to the more metal ions was available to adsorbed per unit mass at higher concentration adsorbate. A greater concentration gradient was formed during higher metal concentration and the quicker the Cr(VI) ions transferred on the surface of REC from a liquid solution. The percentage of removal was decreased with increasing Cr (VI) concentration. The minimum percent reduction of Cr(VI) was recorded 45.7 for 0.3mm and 42.3 % for 1.0mm size at 100 ppm. The limited numbers of active sites were occupied and saturated quickly at a higher metal concentration in comparison to lower concentrations. The outcome suggested that Cr (VI) elimination by REC was extremely concentration-dependent.

Table-5: Effect of Initial Concentration on Cr (VI) Removal by Raw *Eichhornia crassipes* (REC)

Initial Conc. (ppm)	REC (0.3mm)		REC (1.0mm)	
	% Removal	Removal in mg/g	% Removal	Removal in mg/g
10	100	3.33	99.1	3.30
20	80.7	5.38	78.5	5.23
30	87	8.7	82.2	8.22
40	89.2	11.89	84.9	11.31
50	69.7	11.61	68.3	11.38
60	50.5	10.09	48.3	12.99
70	42.8	9.99	41.5	9.68
80	41.7	11.12	38.6	10.30
90	45.8	13.74	40.1	12.04
100	45.7	15.26	42.3	14.09

Time – 1 hour, pH – 1, Dose – 0.3 g/100 ml, Temperature – 25 °C, RPM – 150

Effect of Shaking Rate

The experiment was conducted at various shaking rates i.e. 50-300 rpm. The dosage was taken as 0.3 g/100 ml, pH was 1.0, and the temperature was 25 °C, at the contact time of 1 hour. The outcomes have been presented in Table-6.

The reduction of Cr (VI) amount was increased from 72.9 to 97.8% for 0.3mm and 72% to 97.3% for 1.0mm size when the agitation rate increased from 50 rpm to 300 rpm. This could be due to the diffusion coefficient of the metal ion in the solution was increased, which led to increased mass transfer flux with increasing shaking rate.

Effect of Temperature

The effect of temperature on the removal of Cr (VI) by REC was assessed by experimenting with temperatures range of 20 to 100 °C (interval 20 °C), pH 1.0, Cr (VI) concentrations of 20ppm, adsorbent dosage 0.3 g/100ml and contact time 1 hour. Maximum removal was 94 % for 0.3mm and 90.2% for 1.0 mm adsorbent size at 100°C. The removal efficiency minimum at 40°C temperature (Table-7). This might be contributed by the deteriorating of hydrogen bonds and intermolecular bonding at this temperature, resulting in the poorer activation of sites and physical interaction between REC adsorbent and Cr (VI).²⁴ It was noted that adsorption and uptake of Cr (VI) increased with increasing temperature from 60 to 100°C. The inclined in adsorption with increasing temperature suggests the adsorption process was endothermic. A similar investigation using the different adsorbent system also reported the endothermic nature of the adsorption process.²⁵ The higher temperature decline the thickness of the boundary layer of adsorbent

with decreasing the mass transfer resistance, resulting in more number of active surface sites available for adsorption.²⁶

Infrared Spectroscopic Studies (FTIR)

The untreated sample of REC and Cr (VI) loaded sample was analyzed by Fourier transform infrared spectroscopy (FTIR) and the transmissions percentage for different wave numbers is depicted in Fig.-1. The spectra of REC sample confirmed the occurrence of several functional groups on the adsorbent surface, the adsorption of chromium ions facilitated by these functional groups. The bonded hydroxyl group and NH stretch are shown by a broad absorption peak around 3388 cm^{-1} . The peak noted at 1640 cm^{-1} can be indicative of C=O stretch and 1429 cm^{-1} (mainly NO_2 antisym stretch) can be recognized to the NO_2 in aromatic nitro compounds. It was clear that the CH_2OH in primary alcohols gave rise to one band: C-O stretch at 1056 cm^{-1} , where 1247 cm^{-1} gave rise AR-O in alkyl ethers to another band of C-O. The COO group in carboxylic acid with Antisym stretch was observed at 1375 cm^{-1} . The CH_2 stretching was also noted by the spectrum band at about 896 cm^{-1} . The native and chromium-loaded biomass showed the significant shifting of absorption peaks in FT-IR spectra. The carboxylic acids and other compounds having “benzyl” hydrogen to benzoic acids and primary and secondary alcohols related to ketones were oxidized by Cr (VI) and it reduces to trivalent form.²⁷

SEM Analysis

This study also investigates the morphology of *Raw Eichhornia crassipes* (REC) and Cr (VI) loaded adsorbent using the scanning electron microscope. The SEM pictures of the REC and Cr (VI) loaded REC are shown in Fig.-2. The raw powdered REC shows the tubular structures and irregular symmetry in the SEM image. The Cr (VI) loaded SEM image shows the swollen tubes due to the entering of chromium in fibers of the REC adsorbent. The SEM results indicated that functional groups available inside the REC adsorbent wall adsorbed the Cr (VI).

Fig.-1: Comparison of FTIR Spectrum of *Raw Eichhornia crassipes* (REC) Adsorbent without and with Cr (VI) loaded

Table-6: Effect of Shaking Rate (rpm) on Cr (VI) Removal by *Raw Eichhornia crassipes*

RPM	REC (0.3mm)		REC (1.0mm)	
	% Removal	Removal in mg/g	% Removal	Removal in mg/g
50	72.9	4.86	72	4.8
100	83.8	5.58	77.5	5.16
150	85.4	5.69	78.5	5.23
200	93.8	6.25	91.4	6.09
250	95.8	6.38	95.1	6.34
300	97.8	6.52	97.3	6.49

Time – 1 hour, pH – 1, Dose – 0.3 g/100 ml, Temperature – 25 °C, Initial Cr (VI) – 20 ppm

Table-7: Effect of Temperature on Cr (VI) Removal by Raw *Eichhornia crassipes* (REC)

Temp.	REC (0.3mm)		REC (1.0mm)	
	% Removal	mg/g Removal	% Removal	mg/g Removal
20	80.7	5.38	78.5	5.24
40	72.5	4.83	64.6	4.31
60	79.6	5.31	72.9	4.86
80	86.7	5.77	85.9	5.73
100	94	6.26	90.2	6.01

Time – 1 hour, pH – 1, Dose – 0.3 g/100 ml, Initial Cr (VI) – 20 ppm

Fig.-2: SEM Image of Raw *Eichhornia crassipes* before (A) and after (B) Cr (VI) loaded

CONCLUSION

The main problem associated with eutrophic water is weed infestation, 70% of the waterlogged area of many wetlands is covered with the *Eichhornia crassipes*. For many decades, researchers are involved to find out the useful application of *Eichhornia crassipes*. The current study was also an attempt to utilize this unwanted aquatic weed for the treatment of wastewater by preparing adsorbent from dead biomass. Two different particle sizes were prepared, upto 0.3mm and upto 1.0mm. A decrease in adsorbent size slightly improves the removal efficiency, which indicates the surface area increases with the reduction of particle size. 100 % removal was achieved at pH 1 by using 1 gm/100ml of adsorbent dose at 1 hour shaking time. The removal of metals improved with increasing contact time till the equilibrium was reached. The chromium (VI) reduction was declined with increasing adsorbate concentration, while the amount of adsorbate uptake (q) per unit weight of the adsorbent was increased. The removal of chromium (VI) initially decreased with increased temperature, but after 60°C gradually increased in the removal percentage. Chromium (VI) removal increasing with increased shaking speed. The present investigation shows that weed-like *Eichhornia crassipes* can be used in the treatment of wastewaters as an effective adsorbent.

ACKNOWLEDGEMENT

The authors are thankful for the department of Genetic and the department of Chemistry, M.D.U Rohtak to provide facilities for FTIR and SEM studies.

REFERENCES

1. E. A. Ofudjel, I. A. Adeogun, M. A. Idowu, S. O. Kareem and N. A. Ndukwe, *Journal of Analytical Science and Technology*, **11**, 7(2020), DOI:10.1186/s40543-020-0206-0
2. Ş. Parlayici and E. Pehlivan, *Journal of Analytical Science and Technology*, **10**, 15(2019), DOI:10.1186/s40543-019-0175-3
3. J. Bayuol, K. B. Pelig-Bal and M. A. Abukar, *Applied Water Science*, **9**, 107(2019), DOI:10.1007/s13201-019-0987-8

4. L. Khezami and R. Capart, *Journal of Hazardous Materials*, **123**, 223(2005), DOI:10.1016/j.jhazmat.2005.04.012
5. A. Singh, S. Kumar, V. Panghal, S. S. Arya and S. Kumar, *Rasayan Journal of Chemistry*, **12** (4), 1956 (2019), DOI:10.31788/RJC.2019.1245401
6. S.Sultan and S. Hasnain, *Bioresource Technology*, **98**, 340(2007), DOI:10.1016/j.biortech.2005.12.025
7. B. Mukhopadhyay, J. Sundquist and R.J Schmitz, *Journal of Environment Management*, **82**, 66(2007), DOI:10.1016/j.jenvman.2005.12.005
8. B. Volesky and Z.R. Holan, *Biotechnology Progress*, **11**, 235(1995), DOI:10.1021/bp00033a001
9. V. Panchal, A. Ghosh, P. C. Tomar and S. S. Chapadgaonkar, *Rasayan Journal of Chemistry*, **13** (2), 949(2020), DOI:10.31788/RJC.2020.1325404
10. R. E. K. Billah, Y. Elyamani, Y. Rakhila, M. Agunaou and A. Soufiane, *Rasayan Journal of Chemistry*, **12**(1), 347(2019), DOI:10.31788/RJC.2019.1215078
11. T.D. Center, 1994, Biological control of weeds: water hyacinth and water lettuce, in: D. Rosen, F.D. Bennett and J.L. Capinera (Eds), *Pest management in the subtropics, biological control—a Florida perspective*, UK: Intercept Ltd, pp. 481.
12. P. Epstein, *Lancet*, **351**, 577(1998), DOI:10.1016/s0140-6736(05)78570-6
13. A. Malik, *Environment International*, **33**, 122(2007), DOI:10.1016/j.envint.2006.08.004
14. K.S. Low, C.K. Lee and C.H Tai, *Journal of Environmental Science and Health A*, **29**, 171(1994), DOI:10.1080/10934529409376028
15. S. Shawky, M. A. Geleel and A. Aly, *Journal of Radioanalytical and Nuclear Chemistry*, **265**, 81(2005), DOI:10.1007/s10967-005-0790-x
16. S.W. Al Rmalli, C.F. Harrington, M. Ayub and P.I. Haris, *Journal of Environmental Monitoring*, **7**, 279(2005), DOI:10.1039/b500932d
17. S.A. Allen, *Chemical analysis of ecological materials*, Blackwell, London, (1989), APHA, *Standard methods for the examination of waters and wastewaters*. APHA- AWWA-WEF, Washington, DC, 1998
18. K.Mohanty, M. Jha, B.C.Meikap and M.N. Biswas, *Chemical Engineering Journal*, **117**, 71(2006), DOI:10.1016/j.cej.2005.11.018
19. C. Raji and T.S. Anirudhan, *Water Research*, **32**(12), 3772(1998), DOI:10.1016/S0043-1354(98)00150-X
20. K. Selvi, S. Pattabhi and K. Kadirvelu, *Bioresource Technology*, **80**, 87(2001), DOI:10.1016/s 0960-8524(01)00068-2
21. M.D. Converti, M.L. Borgi, G.Ferraiola and Zilline, *Chemical and Biochemical Engineering*, **16**, 195(1992)
22. S. Saraswat and J.P.N Rai, *International Journal of Mineral Processing*, **94**, 203(2010), DOI:10.1016/j.minpro.2010.02.006
23. E. Lorenc-Grabowska and G. Gryglewicz, *Dyes and Pigments*, **74**, 34(2007), DOI:10.1016/j.dyepig.2006.01.027
24. Z. Aksu, U. Acikel, E. Kabasakal and S. Tezer, *Water Research*, **36**, 3063(2002) DOI:10.1016/s0043-1354(01)00530-9
25. V.K. Gupta, and A. Rastogy, *Journal of Hazardous Materials*, **163**, 39(2009), DOI:10.1016/j.jhazmat.2008.06.104
26. R. Elangovan, L. Philip and K. Chandraraj, *Journal of Hazardous Materials*, **152**, 100(2008), DOI:10.1016 / jhazmat.2007.06.067

[RJC-5949/2020]