ENHANCEMENT OF CHROMIUM REMOVAL FROM WATER BY BIO-ADSORPTION USING EDTA-TREATED RICE STRAW

Magdy M. Niazy[*]

Soil, Water and Environ. Res. Inst., Agric. Res. Cent. (ARC), Giza, Egypt

ABSTRACT

Using factorial experiments, rice straw of 1g or 2g weight was immersed into 100 ml of water solution of different concentrations of Cr (25, 50 and 75 mg Crl), in a form of Cr-chloride 'CrCl$_3$. 6H$_2$O'. The contact and shaking time intervals were 60, 90 and 120 minutes and the solution pH values were 5, 7 and 9. One experiment was conducted for each of the 1g and 2g non- ethylenediamine tetra acetic acid (EDTA)-treated straw and one experiment for each of the 1g and 2g EDTA-treated straw. In terms of the amount of Cr removed from solutions, it increased as the initial concentration increased. In terms (%) removal from the initial concentration, the removed portions decreased as the initial concentration increased. Treating the straw with EDTA and increasing the time of contact enhanced the removal. High removals occurred with the neutral or alkaline pH. Lowest (%) removal was 24% for the treatment of 1g non-EDTA straw of the 75 mg Crl solution of pH 5 and the shortest contact time of 60 min. Highest (%) removal of 100% was obtained by the treatment of 2g EDTA straw in the 25 mg Crl of either pH 7 or 9 and longest contact time of 120 min.

Key words: Adsorption, chromium, rice straw, contact time, pH, EDTA-modified.

INTRODUCTION

Rapid industrialization in Egypt has created pollution problems of uncontrolled disposal of the wastewater which is potentially dangerous since it contains such as Chromium (Cr). Cr is a transition metal contaminant that exists in nature primarily as the soluble highly toxic Cr (VI) anion and the less soluble, less toxic Cr (III). Its compounds have widespread industrial use such as steel production, wood preservation, leather tanning, metal corrosion inhibition, paints and pigments, metal plating, and other applications. It is a contaminant in certain waters, soils, and sediments, occurring primarily as Cr (III) or Cr (VI); the latter being carcinogenic and mutagenic (Priester *et al*., 2006). Leather and its tanning are the fifth largest industry in Egypt using 125 to 130 million cubic meters per year (Mahmoud, 2009). Leather industry in Egypt is most important representing 5% of the total industrial production with 300 leather factories employing 250 thousand workers located in the old Cairo (Marina *et al*., 2012). On the other hand workers in the cement industry have high exposure levels to Cr VI and one third of the leather workers have severe skin and chest manifestations and one fifth of the cement workers have nasal manifestations (Elhosary *et al*., 2014). Use of low-cost sorbents such as some agricultural wastes in sorbing heavy metals from waste waters represents environmentally friendly practice (Deans and Dixon, 1992).

The basic components of the agricultural waste materials include hemi cellulose, lignin, lipids, proteins, simple sugars, water, hydrocarbons and starch, containing a variety of functional groups (Bhatnagar and Sillanpää, 2010). Cellulitic agricultural materials have high capacity for absorbing pollutants (Bhatnagar and Jain, 2005). Agricultural wastes are a rich source for activated carbon production due to their low ash content and reasonable hardness (Ahmedna *et al*., 2000). These materials are used in their natural form or after some physical or chemical modification. Pretreatments are practiced using different kinds of modifying agents such

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*Corresponding author: Tel. : +201093458689

E-mail address: amagdy16@gmail.com

treatment with base alkaline sodium hydroxide, calcium hydroxide, sodium carbonate or acidic solutions of hydrochloric, nitric, sulphuric, tartaric, and citric acids or organic compounds such as ethylenediamine, formaldehyde, epichlorohydrin, methanol or the oxidizing agent of hydrogen peroxide (Aydin *et al.*, 2004). The choice of the absorbing materials is based on their easy availability, their source natural (*e.g.* wood, peat, coal, lignite), byproducts (*e.g.* slag, sludge, fly ash, bagasse flyash, red mud), and synthic products (Ahmaruzzaman, 2008 ; Gupta *et al.*, 2009). Organic wastes are major sources of problems in the world representing annual 25 million Mg of agro-residues, of which 12 million Mg are used for heating or for industrial purposes (Allam *et al.*, 2011). In Egypt, rice straw is a main agricultural waste which represents 4 million Mg annually produced every autumn. It is traditionally disposed of, by burning in situ, causing harmful environmental implications (Yakout and Elsherif, 2010).

The objective of the current study was to assess the practicality of using rice straw to absorb/adsorb Cr in water of different cocentrations of Cr using ethylenediamine tetra acetic acid (EDTA) treatment of the straw.

MATERIALS AND METHODS

Experiments were conducted to evaluate the ability of rice straw as an absorbent of Cr from Cr solutions of different concentrations and different time duration and different pH of the solutions. The design of each experiment was a randomized complete block design, factorial, with 3 factors. The factors were as follows: (1) Cr concentration in the contact solution, (2) Time duration of contact between straw and solution and (3) the pH of the solution. Cr concentrations (in a form of Cr chloride 'CrCl$_3$.6H$_2$O') were 25, 50 and 75 mgl^{-1}. Time of duration intervals were 60, 90 and 120 min. The pH values were 5, 7 and 9. Therefore the different treatment combinations were 27 (3 concentrations X 3 time durations X 3 pHs) .Treatments were done in 3 replicates.

The rice straw was either EDTA-treated or non-EDTA-treated. Treatment with EDTA was done as described by Abia *et al.* (2005). A 30g weight of straw was washed with de-ionized

water several times then dried at 50°C. For EDTA treatment, 17g weight of the dried straw refluxed in 300 mL solution of pyridine and 56.7 g of EDTA for 3 hr., at 70°C. After cooling, an amount of 300 ml deionized water was added and finally the straw was dried for 50°C for 12 hr.

Execution of each experiment was done as follows (Jimoh *et al.*, 2011): the straw sample was soaked in 100 ml of Cr solution of the specified concentration and pH, then shaken for the specified contact time. At end of shaking time, the concentration of Cr in the solution sample was digested by perchloric, nitric and sulfuric acid mixture (1:5:0.5) (Stewart, 1989)

Cr in solution samples were determined using an atomic absorption spectrophotometer (AA – Scan I Thermo Jarrell Ash, USA).

. The portion of Cr removed from the contact solution was calculated as follows (Argun *et al.*, 2007):

Cr removal (%) ={(Cr$_i$ –Cr$_f$) ÷ Cr$_i$ } x 100

Where Cr$_i$ is the initial Cr concentration of the contact solution and Cr$_f$ is the concentration at end of the contact time interval. Such removal indicates the extent of efficiency of the straw as an absorbent of Cr from the solution.

One experiment was done for each of the followings (1) non-EDTA-treated straw and (2) EDTA- treated straw, (3) using straw weight of 1 g and (4) using straw weight of 2 g to be submerged in 100 ml of Cr-containing water solutions.

RESULTS AND DISCUSSION

There were positive responses due to treatments. The main effects (1) Cr concentration of the contact solution, (2) pH of the solution and (3) the initial concentration of solution are shown in Table 1.

Main Effect of Contact Time

Increased contact time was associated with increased removal of Cr from the contact solution. The increased removal was progressive ranging from about 31 to 46% for the 1g non-EDTA sample upon increasing the contact time from 60 to 120 min. The EDTA-treated sample

Table 1. Final concentration (F.conc.) of Cr in solution contacting rice straw (mgl⁻¹) and (%) Cr removal from initial solution as affected by contact time, solution pH and initial Cr concentration using EDTA-treated and non-treated rice straw absorbent (1 g and 2 g) straw samples (main effects)

T pH	1 g rice straw				2 g rice straw			
	Non-EDTA-treated		EDTA-treated		Non-EDTA-treated		EDTA-treated	
	F.conc.	Removal (%)	F.conc.	Removal (%)	F.conc.	Removal (%)	F.conc.	Removal (%)
Contact time (min)								
60	34.73	31.31	20.42	61.55	27.28	46.89	8.11	84.90
90	31.97	32.50	15.47	70.77	22.67	56.18	4.76	91.51
120	29.26	43.30	11.92	78.06	16.97	67.70	2.67	96.29
LSD 5%	0.57	0.63	0.57	0.57	0.57	0.57	1.01	0.57
LSD 1%	0.75	0.84	0.75	0.75	0.75	0.75	1.35	0.75
pH								
5	34.55	31.73	20.98	60.86	25.58	50.08	7.81	85.46
7	31.90	37.47	14.80	72.17	22.41	57.12	4.36	92.62
9	29.51	37.91	12.02	77.36	18.93	63.58	3.37	94.61
LSD 5%	0.57	0.63	0.57	0.57	0.57	0.57	1.01	0.57
LSD 1%	0.75	0.84	0.75	0.75	0.75	0.75	1.35	0.75
Cr concentration (mg l⁻¹)								
25	14.60	41.50	5.62	77.48	9.31	62.73	1.87	94.16
50	31.04	36.94	14.77	69.45	21.33	56.32	4.25	91.09
75	50.32	28.67	27.41	63.45	36.28	51.72	9.42	87.44
LSD 5%	0.57	0.63	0.57	0.57	0.57	0.57	1.01	0.57
LSD 1%	0.75	0.84	0.75	0.75	0.75	0.75	1.35	0.75

Notes: Straw samples were immersed in 100 ml of solution and shaken for the specified time.

showed greater removal ranging from 62 to 78% reflecting the considerable effect of EDTA on increasing the removal of Cr. Results of the 2g sample showed much greater removal of Cr from the initial solution with comparable removals 47 to 67% for the non-EDTA-treated and 85 to 96% for the EDTA-treated straw. This shows that the more time allowed for contact of straw allows the straw to retain more Cr from the solution, and that the EDTA facilitates chelating of Cr from the solution.

These also indicate that increases amount of straw allows retaining increases amounts of Cr. These results are in agreement with those of Babel and Kurniawan (2004) who removed Cr from waste water using coconut shell charcoal and commercial activated carbon.

Main Effect of pH

Increased pH from 5 to 7 caused a marked increase in (%) removal of Cr. Average removals were 32 and 37% at above-mentioned

pH values, respectively for the non-EDTA-treated straw of 1g sample. Comparable removals for the EDTA-treated straw were much higher giving 61 and 72%, respectively. The removal was greater with the 2g sample: 50 and 57%, respectively for the non-EDTA-treated straw and 85 and 93%, respectively for the EDTA-treated straw. The increase of removal at pH 9 was slightly greater than that given by the pH 7 indicating that the pH 7 is most appropriate for increasing Cr removal from the solution.

Chromium removal was shown by Dakiky *et al.* (2002), Kalavathy and Miranda (2010) and Sharma *et al.* (2006) to increase by increased pH. On the other hand, Ahluwalia and Goyal (2007) noted that heavy metal removal decreased upon decreasing the pH of the solution from 6 to 2 and that in the pH range of 2.5 to 5, binding of heavy metal cations was determined primarily by dissociation of the weak acidic groups. Kratochvil and Volesky (1998) reported that at low pH the hydrogen and hydronium ions are high and compete with metal ions for the binding sites causing low metal uptake by plant, while at high pH of 5 to 7, the competing hydrogen ions are low in number.

Abia *et al.* (2005) and Wan *et al.* (2006) used rice straw modified by EDTA caused and obtained increases the adsorbed metal ion concentration, ions adsorbed increased as the initial concentration increased. The EDTA treatment enhanced the adsorption capacity of maize husk due to the chelating ability of EDTA.

Main Effect of Initial Cr Concentrations in the Contacting Solution

Although increased concentration of the solution was associated with increased removal of the amount of Cr removed from the solution, the removal in terms of portion of the initial concentration decreased. For example regarding the non-EDTA-treated 1g sample, the final Cr concentration averaged 15 mgl^{-1} for the initial solution of 25 mgl^{-1}, increasing progressively reaching a highest level of 50 mgl^{-1} for the solution of the highest initial concentration of mgl^{-1} averaged. But in terms of (%) removal the portions of removal decreased with the increase

in initial concentration. The parallel progressive decrease of (%) removal averaged 42, 37 and 29% for the low, medium and high concentration solutions, respectively. Although the progressive decrease in the (%) removal Cr was not exactly parallel to the progressive increase in the final concentration of Cr, it was very much near the exact parallel. This is predictable since the extent of decrease in the final solution was not considerable enough to allow such status. The pattern of response with regard to the EDTA-treated 1g straw was rather similar to that of the non-EDTA-treated one, but the positive effect of EDTA was very much considerable in decreasing the final concentration of Cr. The 2g samples showed higher removal of Cr reaching an overall average of 87 to 94 reflecting the high efficiency of the greater amount of straw in removing Cr from waste waters. Coupal and Lalancette (1976) reported high removal of heavy metals using peat materials.

Interaction Effect of Contact Time and pH of Solution

The increase of (%) removal of Cr was progressive with the increase of the contact time of particularly with pH 7 or 9 (Table 2). For example the average (%) Cr removal for the solution soaking the 1g non-EDTA-treated straw was about 31, 32 and 43% for the 60, 90 and 120-min contact intervals, respectively. The increased pattern was more marked under conditions of the pH 7; being 32, 37 and 43% for the same time intervals, respectively. The pattern of response regarding the EDTA-treated straw was rather similar to the non-EDTA-treated but with considerable magnitudes. Average (%) removal for solution of the 1g EDTA-treated straw was 47, 56 and 68, respectively indicating similar trend of the time of contact but with greater magnitude, and reflecting the considerable positive effect of EDTA treatment in removing Cr from the water. The removal under pH 9 was most marked, being 54, 65 and 71%, respectively. Results for the 2g straw weight show more positive effects in view of the higher amount of the straw absorbent. Aydin *et al.* (2004) demonstrated the high efficiency of low-cost cellulitic materials in absorbing heavy metals from waters.

Table 2. Final concentration of Cr in solution contacting rice straw (mgl⁻¹) and (%) Cr removal from initial solution as affected by contact time, solution pH and initial Cr concentration using EDTA-treated and non-treated rice straw of 1g and 2g samples (interaction effect of contact time 'T' and pH) *

pH \ T	1 g rice straw						2 g rice straw					
	Non-EDTA-treated			EDTA-treated			Non-EDTA-treated			EDTA-treated		
	60	90	120	60	90	120	60	90	120	60	90	120
Cr concentration in final solution (mgL⁻¹) following 60 to 90 min contact time												
5	36.87	34.75	32.02	31.46	26.54	18.76	25.86	20.83	16.26	10.73	7.86	4.67
7	34.54	31.82	29.34	27.15	23.13	16.96	19.04	14.40	10.97	7.23	3.95	1.27
9	32.79	29.33	26.41	23.24	18.35	15.20	16.36	11.17	8.54	6.38	2.18	1.00
LSD at	0.05	0.01		0.05	0.01		0.05	0.01		0.05	0.01	
For: T x pH				0.98	1.30		0.98					
(%) removal of Cr (removed from the initial solution)												
5	26.69	30.90	37.59	38.29	47.90	64.06	51.55	60.85	70.18	79.49	85.38	91.52
7	31.82	37.42	43.16	47.46	56.09	67.80	63.97	72.77	79.78	86.58	92.78	98.49
9	35.42	29.01	49.16	54.92	64.56	71.26	69.14	78.70	84.23	88.63	96.36	98.86
LSD at	0.05	0.01		0.05	0.01		0.05	0.01		0.05	0.01	
For: T x pH	1.09	1.45		0.98	1.30		0.98	1.30		0.98	1.30	

*See footnotes of Table 1

Interaction Effect of Contact Time and Cr of the Initial Solution

In terms of mg Cr l⁻¹, the removal was greater as the initial concentration of Cr was higher (Table 3). The Cr concentration in the final solution soaking the non-EDTA 1g straw averaged about 15, 32 and 50 mg Cr l⁻¹ for treatments of initial solution of 25, 50 and 75 Cr l⁻¹, indicating a removal of 10, 18 and 25 mg Cr l⁻¹ from such solutions, respectively. The amount of removal was much greater where the contact time was longest (13, 22 and 28 mg Cr l⁻¹, respectively for the 120-min time) and much smaller where the contact time was shortest (9, 16 and 11 mg Cr l⁻¹, respectively for the 60-min contact time). However in terms of (%) removal it was the low initial concentration which showed greater portion of removal. Such results demonstrate the expected response of low versus high initial concentration of pollutes in waste waters. The EDTA and the higher weight of straw raised the efficiency of removal. A highest removal of 99% was given by the 2g EDTA straw where the initial Cr concentration was lowest, i.e., for the 25 mg Cr l⁻¹ solution.

Interaction Effect of Cr and pH of the Initial Solution

The increase in Cr concentration in final solution which was associated with the increase in Cr concentration of the initial solution occurred under all conditions of pH, particularly pH 9 (Table 4). For example the average Cr in solution soaking the 1g non-EDTA-treated straw was about 15, 31 and 50 mg l⁻¹ in solutions of Cr of 25, 50 and 75 mg l⁻¹, respectively indicate removals of 10, 19 and 25 mg l⁻¹ (i.e., 40, 38 and 33%) from the respective solutions. Where the pH was 9 the comparable removals were more, being 12, 22 and 28 mg l⁻¹ (i.e. 48, 44 and 37%), respectively. Thus in terms of (%) Cr removal relating initial status, the pattern was not exactly

Table 3. Final concentration of Cr in solution contacting rice straw (mgl⁻¹) and % Cr removal from initial solution as affected by contact time, solution pH and initial Cr concentration using EDTA-treated and non-treated rice straw of 1g and 2g straw samples (interaction effect of contact time 'T' and initial solution Cr concentration)*

T \ Cr	1 g rice straw						2 g rice straw					
	Non-EDTA-treated			EDTA-treated			Non-EDTA-treated			EDTA-treated		
	60	90	120	60	90	120	60	90	120	60	90	120
Cr concentration in final solution (mgl⁻¹) following 60 to 90 min contact time												
25	16.20	15.07	12.52	12.02	9.44	6.48	7.50	5.60	3.77	2.69	1.46	0.56
50	33.96	31.31	27.85	25.97	21.96	16.07	19.10	14.64	10.58	7.11	3.64	1.56
75	54.04	49.52	47.40	43.86	36.61	28.36	34.65	26.17	21.42	14.54	8.90	4.83
LSD at	0.05	0.01		0.05	0.01		0.05	0.01		0.05	0.01	
Foe: T x Cr	2.94	3.91		2.94	3.91		2.94	3.91		5.27	7.02	
(%) removal of Cr (removed from the initial solution)												
25	34.90	39.81	49.80	51.87	62.27	74.07	70.01	77.51	84.93	89.26	94.65	98.57
50	31.08	36.42	43.30	47.05	55.06	66.87	60.81	69.70	77.84	84.78	91.73	96.77
75	27.95	21.10	36.80	41.75	51.22	62.18	53.84	65.11	71.41	80.65	88.14	93.53
LSD at	0.05	0.01		0.05	0.01		0.05	0.01		0.05	0.01	
For: T x Cr	3.26	4.35		2.94	3.91		2.94	3.91		2.94	3.91	

*See footnotes of Table 1

Table 4. Final concentration of Cr in solution contacting rice straw (mg l⁻¹) and (%) Cr removal from initial solution as affected by contact time, solution pH and initial Cr concentration using EDTA-treated and non-treated rice straw of 1g and 2g straw samples (interaction effect of and initial solution Cr concentration 'Cr' and its pH)*

Cr \ pH	1g rice straw						2g rice straw					
	Non-EDTA-treated			EDTA-treated			Non-EDTA-treated			EDTA-treated		
	25	50	75	25	50	75	25	50	75	25	50	75
Final Cr concentration (mg l⁻¹) in contact solutions of initial 25 to 75 mg Cr l⁻¹												
5	16.04	33.80	53.80	11.22	24.83	40.70	7.32	19.47	36.16	2.62	6.75	13.89
7	14.38	30.92	50.40	9.01	21.28	36.94	5.31	13.66	25.44	1.23	3.32	7.91
9	13.37	28.40	46.76	7.71	17.88	31.19	4.23	11.19	20.65	0.86	2.24	6.46
LSD at	0.05	0.01		0.05	0.01		0.05	0.01		0.05	0.01	
For: Cr x pH	0.98	1.30		0.98	1.30		0.98	1.30		1.76	2.34	
(%) removal of Cr (removed from the initial solution)												
5	35.51	31.40	28.27	55.13	49.34	45.77	70.71	60.07	51.80	89.44	85.50	81.45
7	42.43	37.17	32.80	63.97	56.41	50.97	78.77	71.69	66.06	95.55	92.81	89.48
9	46.57	42.24	24.78	69.10	63.22	58.41	82.97	76.59	72.51	97.48	94.97	91.39
LSD at	0.05	0.01		0.05	0.01		0.05	0.01		0.05	0.01	
For: Cr x pH	1.09	1.45		0.98	1.30		0.98	1.30		0.98		

*See footnotes of Table 1

in line with that of the concentration since differences among the initial concentrations were big. The response regarding the EDTA-treated straw more than for the non-EDTA-treated and much greater where the straw weight was 2 g. The most effective removals was 97% caused by the treatment of initial concentration of 75 mg l⁻¹ soaking 2g EDTA-treated straw.

Conclusion

Rice straw proved a very highly efficient material for Cr removal from waters, particularly with treatment by EDTA which increased its efficiency by about 50%. The more duration of the contact time between the waste water and the straw, the greater is the removal. The less the initial concentration of the metal in the water, the more effective is the removal. Using greater amount of straw increases the efficiency. Where the pH of the solution was 7 or the removal was rather high. The results of the complete combination treatments are shown in Table 5. The complete removal of 100% occurred in the 2g EDTA-treated straw having the following combinations: initial Cr of 25 or 50 mg l⁻¹, contact time of 120 min and at pH 7 or 9. Hence, rice straw, particularly treated with EDTA is an efficient friendly adsorbent of heavy metals in waste waters. Therefore for removing Cr from waste waters, a very effective low-cost method is merge rice straw treated with EDTA into such water for a long time and at a wide ratio of straw: water.

Table 5. **Final concentration of Cr (f.Cr) in solution contacting rice straw (mgl⁻¹) and (%) Cr removal from initial solution as affected by contact time 'T', solution pH and initial Cr concentration (Cr) using EDTA-treated and non-treated rice straw:**

a: Results of all treatment combinations for the 1g straw weight

Cr	Non-EDTA-treated straw					
	f.Cr	Removal (%)	f.Cr	Removal (%)	f.Cr	Removal (%)
	Contact time (min) 'T'					
mg l⁻¹	60		90		120	
	pH 5					
25	17.50	29.20	16.62	33.54	14.00	43.80
50	36.33	27.35	34.83	30.34	31.25	37.50
75	57.11	23.86	53.14	29.15	51.15	31.80
	pH 7					
25	16.00	35.90	14.60	41.60	12.55	49.80
50	34.25	31.50	31.10	37.80	28.40	43.20
75	53.70	28.40	50.10	33.20	47.40	36.80
	pH 9					
25	15.10	39.60	14.00	44.30	11.00	55.80
50	32.30	35.40	29.00	42.13	24.90	50.20
75	51.30	31.60	45.33	0.90	43.65	41.80
Cr	EDTA-treated straw					
	f.Cr	Removal (%)	f.Cr	Removal (%)	f.Cr	Removal (%)
	Contact time (min)					
mg l⁻¹	60		90		120	
	pH 5					
25	9.22	63.12	7.58	69.70	5.17	79.32
50	24.90	50.23	19.73	60.54	14.79	70.43
75	43.79	41.62	35.52	52.65	29.16	61.12
	pH 7					
25	7.16	71.37	5.21	79.18	3.56	85.76
50	18.12	63.76	14.18	71.65	9.68	80.65
75	32.16	57.12	24.15	67.81	20.00	73.25
	pH 9					
25	6.12	75.55	4.00	83.65	2.58	89.71
50	15.29	69.43	11.00	77.90	8.28	83.45
75	28.00	62.78	18.85	74.87	15.10	79.87

b: Results of all treatment combinations for the 2g straw weight

Cr		Non-EDTA-treated straw					
		f.Cr	Removal (%)	f.Cr	Removal (%)	f.Cr	Removal (%)
		Contact time (min) 'T'					
mg l⁻¹		60		90		120	
		pH 5					
25		14.25	43.00	12.10	51.60	7.30	70.80
50		30.80	38.40	25.84	48.33	18.85	62.30
75		49.65	33.80	42.00	44.10	30.45	59.40
		pH 7					
25		11.80	52.80	8.68	65.30	6.55	73.80
50		26.20	47.60	22.90	54.14	15.75	68.50
75		43.78	42.30	38.13	49.17	28.90	61.43
		pH 9					
25		10.00	59.80	7.53	69.90	5.60	77.60
50		21.90	56.15	18.15	63.70	14.60	70.80
75		38.15	49.14	29.70	60.40	25.73	65.70
Cr		EDTA-treated straw					
	f.Cr	Removal (%)		f.Cr	Removal (%)	f.Cr Removal (%)	
		Contact time(min)					
mg l⁻¹		60		90		120	
		pH 5					
25		4.14	83.45	2.71	89.17	1.00	95.70
50		10.23	79.54	6.68	86.65	4.35	91.30
75		18.15	75.80	14.52	80.65	9.00	87.90
		pH 7					
25		2.35	90.65	1.00	96.00	0.00	100.00
50		6.68	86.64	3.60	92.80	0.00	100.00
75		13.00	82.77	7.59	89.88	3.15	95.80
		pH 9					
25		1.59	93.67	0.50	98.77	0.00	100.00
50		5.42	89.17	1.63	96.74	0.00	100.00
75		12.46	83.39	4.59	93.89	2.33	96.90

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تعزيز إزالة الكروم من المياه بواسطة الإدمصاص باستخدام قش الأرز المعامل بالفرسين

مجدى محمد نيازي

معهد بحوث الأراضي والمياه والبيئة – مركز البحوث الزراعية – الجيزة – مصر

تم إجراء تجربة باستخدام مواد من الطبيعة (مخلفات زراعية) للتخلص من عنصر الكروم في المياه الملوثة بهذا العنصر وقد استخدم لذلك قش الأرز غير المعامل والمعامل بالفرسين وتم تقييم معاملات تركيز الكروميوم في محلول الإزالة والذي كان بتركيزات ٢٥ ، ٥٠ و ٧٥ ملليجرام/لتر ولمدد تلامس ورج هي ٦٠ ، ٩٠ و ١٢٠ دقيقة ودرجات الحموضة pH هي ٥ ، ٧ و ٩ (كان وزن القش ١ أو ٢ جم تم غمرها في ١٠٠ ملليلتر محلول Cr)، وأظهرت النتائج زيادة كمية الأيونات المزالة مع زيادة تركيز محلول Cr لكن نسبة الأيونات المزالة الي التركيز الأصلي كانت أعلى كلما كان تركيز Cr في محلول التلامس منخفضاً، كانت الإزالة عالية في حالة القش المعامل بالـ EDTA وكانت عالية أيضا في حالة استخدام ٢ جم عن استخدام ١ جم وبمقارنة نتائج كافة المعاملات تراوحت نسبة الإزالة من ٢٤% (لمعاملة محلول أعلى تركيز ودرجة حموضة pH 5 وأقصر مدة تلامس مع الرج في ١ جم قش غير معامل بـ EDTA) إلى ١٠٠% (لمعاملة محلول أقل تركيز "أو التركيز المتوسط" ودرجة حموضة ٧ أو ٩ مع أعلى مدة تلامس مع الرج في ٢ جم قش معامل بـ EDTA).