Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 5, p. 315-321, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Removal of strontium and cadmium from industrial wastewater using castor been and jojoba wastes

E.A. Kotb[1], A.M. Algharib[2]

[1]*Soils and Water Dept. Res., N.R.C., Atomic Energy Authority, Abou-Zaabal, 13759, Egypt*

[2]*Environment and Bio-agriculture Dept., Fac. Agric., Al-Azhar Univ., Cairo, 11884, Egypt*

Article published on November 19, 2014

Key words: Castor bean, Jojoba, Industrial wastewater, Strontium.

Abstract

Four agricultural wastes: 1) castor bean leaves (CBL), 2) castor bean capsules (CBC), 3) jojoba leaves (JL), and 4) jojoba capsules (JC), were used as adsorbents for the adsorption of Strontium (Sr) from Abu Zaabal industrial wastewater. Three different dosages (0, 0.5, and 1g /100ml wastewater) were used for each at different contact times (1h., 2h., 3h, and 24h). The data showed that: 1) the concentration of Sr in Abu Zaabal industrial wastewater was high (9.8 mg/L), 2) the concentration of Sr has declined overtime and with the use of high dosage of bio-sorbents, 3) the maximum Sr (II) adsorption percentage was observed by using jojoba capsules wastes at 1% dosage and at 24 hours contact time (48.1%).While the lowest percentages were recorded by using castor leaves at 0.5% for 1 and 3 hours of contact time (1.6 and 1.2%). The data also showed that jojoba leaves at concentration 1% recorded the highest adsorption percentage (78%) for Cd. Castor bean and jojoba wastes were found to be attractive low cost materials for the treatment of industrial wastewater to remove Sr and Cd.

***Corresponding Author:** A.M. Algharib ✉ aelghareb@gmail.com

Introduction

Castor bean (*Ricinus communis* L.) is cultivated on commercial scale in more than 31 countries (Algharib and Kotb, 2013). On the other hand, India, China, and Mozambique are the major castor bean growing countries by contributing about 98% of the world's production (FAO, 2012). Castor is an important industrial oilseed crop (Sarwar *et al.*, 2010). Jojoba (*Simmondsia chinensis*) is another oilseed crop. The seeds contain a characteristic liquid wax of economic importance in industry (Mohammed *et al.*, 2008). Jojoba and castor bean are most important industrial plants that best suits the nature of the desert, especially Egypt (Algharib and Kotb, 2013). Water shortages, deterioration of water quality, and environmental constraints, have led to an increased interest of treated wastewater in many parts of the world (Jeannie *et al.*, 2011). Toxic heavy metal ions get introduced to wastewater through various industrial activities (Celik and Demirbas, 2005). Heavy metals are not biodegradable and tend to be accumulated in living tissues, causing various diseases and disorders; therefore, they must be removed before discharge to natural resources (Ozer and Pirincci, 2006). The radio-nuclides such as Strontium-90 (Sr) are key drivers of liquid waste classification at light water reactors (Denton *et al.*, 2009). Sr is often found in nuclear test sites and other locations associated with nuclear tests and waste storage (Kasimsteva, 2010). On the other hand, strontium has a variety of commercial uses such as optical materials and produces the red flame color of pyrotechnic devices such as fireworks and signal flares (Ahmadpour *et al.*, 2010). Removal of Sr is critical for waste treatment and environmental remediation (Denton *et al.*, 2009).The toxic doses of strontium have negative effects on human health (Tautkus *et al.*, 2007). Because Sr is an analogue of calcium; therefore it can replace cations of Ca^{2+} in human body and accumulate in bone tissue (Kasimsteva, 2010). Also, it is easily integrates into components of biosphere, migrates in the biological chain, gains access to human organism with vegetative and animal strain food or fish and can lead to serious problems such as curiosity (Tautkus *et al.*, 2007). On the other hand, the exposure to Sr may result in reduction of blood cell counts, in humans who received injections of radioactive strontium as a part of cancer treatment (Public Health Service, 2007). So it is very important to have tools to reduce human exposure to this constituent (Kasimsteva, 2010). Also, due to the long life of strontium (half-life 29 years) (Denton *et al.*, 2009), and bio-toxicity of it, separation and recovery of this ion from waste solutions needs special attention (Ahmadpour *et al.*, 2010). There are many physical-chemical processes for the removal of radioactive ions from wastewater streams such as: chemical precipitation and flocculation (Rout *et al.*, 2006), phosphate precipitation (Volkovich *et al.*, 2003), Cu or Ni ferrocyanide precipitation (Haas 1993), immobilization method (Elkamash *et al.*, 2006), and adsorption (Omar *et al.*, 2009). Among these, adsorption is one of the most effective and economic methods. On the other hand, the adsorption process by using the activated carbon is expensive and uneconomical from the operational cost aspect. So, the alternative adsorbents include agricultural wastes are used (Mandal, 2014). On the other hand, technologies for removing strontium have been an active field of research (Denton *et al.*, 2009). Thus, the goal of this study was to use new adsorbents derived from agricultural wastes of castor bean and jojoba for rapid removal of Sr ion from industrial wastewater.

Materials and methods

The experiment was carried out in the laboratory of Agriculture, Department of Soils and Water Research, Nuclear Research Centre, Atomic Energy Authority, Egypt.

Sorbent materials

Green leaves and dry capsules of castor bean and jojoba were collected from trees, and washed with distilled H_2O, and then air dried (Fig 1). The dried samples were milled and then passed through a 0.6 mm sieve (No. 3).

(A) (B)

Fig. 1. Dry capsules of castor bean (a) and jojoba (b).

Wastewater samples

Adequate samples of industrial wastewater were obtained from Abu Zaabal industrial area, Qalyubia Governorate, Egypt. The samples were transferred to laboratory in closed bottles and then filtered to remove any suspended materials. The filtered wastewater was analyzed for E.C., pH, cations and anions and heavy metals according to Page et al. (1982). Adequate amounts of filtered samples were kept in the fridge for sorption experiments.

Experimental work

To achieve the aim of this study, laboratory experiment was conducted to study the effect of three factors: 1) sorbent type, 2) sorbent dosage, and 3) contact time, on heavy metals removal of Abu Zaabal industrial area wastewater. Four types of bio-sorbents were used: 1) castor bean leaves (CL), 2) castor bean capsules (CC), 3) jojoba leaves (JL), and 4) jojoba capsules (JC), at three different dosages (0, 0.5, and 1g /100ml water), and at different contact times (1, 2, 3 and 24 h.).

Batch sorption procedure

Batch sorption treatment was carried out with ratios 0, 0.5, and 1%. The suspensions in all sorption assays were stirred at room temperature for 1, 2, 3, and 24 hours and then filtered through Wattman filters to remove any suspended adsorbent. Initial and final concentrations of testing heavy metals were determined by atomic absorption spectroscopy (AAS). The adsorption percentage (Ad) was determined by:

$$Ad\% = [(Co - Ca)/Co] * 100$$

Where; Co=Initial concentration of solution, Ca= Concentration of the solution after adsorption (Kehinde *et al.*, 2009).

Statistical analysis

The results were expressed as means of triplicate determinations with standard deviation (±S. D.).

Results and discussion

The presence of heavy metals in industrial waste water represents a significant environmental hazard, and one of the most difficult contamination problems to solve. The wastewater samples were collected from Abu Zaabal industrial area characterize by the high concentration of cations, anions, and heavy metals (Cd, Cu, Fe, Sr, Pb, and Zn) (Table 1). The data also showed that the concentration of strontium (Sr) in Abu Zaabal industrial wastewater was high (9.8 mg/L). This could be attributed to a lot of factories in Abu Zaabal industrial area. Sr has a variety of commercial uses such as optical materials and produces the red flame color of pyrotechnic devices such as fireworks and signal flares (Ahmadpour et al., 2010).

Effect of sorbent type on strontium Sr (II) ion removal

The feasibility of using a new adsorbent derived from wastes of castor bean and jojoba for the rapid removal of strontium ion from aqueous solutions was studied. Data in Table 2 show the effect of sorbent types (castor bean and jojoba leaves, castor bean and jojoba capsules) on the adsorption percentage of Sr (II) ion in Abu Zaabal industrial wastewater. The obtained data indicated that, at 0.5% bio-sorbent dosage, castor capsules, followed by jojoba capsules recorded the highest adsorption percentage (28.4, 24.2%) respectively at 24 hours contact time. On the other hand, castor and jojoba leaves recorded the lowest adsorption percentage (1.2 and 5.7%) at 3 hours contact time. Furthermore, at 1% bio-sorbent dosage, jojoba capsules recorded the maximum adsorption percentage (48.1%) at 24 hours contact time, while the lowest adsorption percentage was observed by using castor leaves (9%) at 1 hour contact time. This could be attributed to the functional groups on the surface of castor and jojoba capsules. The high adsorption efficiency and readily available adsorbing sites (functional groups) depend on the adsorbent surface (Ahmadpour et al., 2010). The role of cell structure, cell wall, micropores and macropores was evaluated in terms of the potential of these bio-sorbents for metal sequestration (Igwe and Abia, 2006).

Effect of bio-sorbent concentration on strontium Sr (II) removal

Sr (II) removal is concentration dependent (Ahmadpour *et al.*, 2010). It was observed that, the amount of bio-sorbent employed was found to influence the efficiency of the adsorption process. The removal efficiency of Sr (II) was enhanced by increasing the adsorbent/adsorbate ratio in all bio-sorbents (Table 2). It was found that the castor leaves at 0.5% dosage recorded 1.6, 2.8, 1.2, and 18.5% respectively. However, at 1% dosage the adsorption percentages were 9, 17.5, 18.2, and 35.2%.

Table 1. Chemical characteristics of the tested industrial waste water.

		mg/L							
pH	EC	Cations				Anions			
		Ca	Mg	Na	K	CO_3^{-2}	HCO_3^-	SO_4^{-2}	Cl
7.2	2.2	64	74	250	37	-	550	339	175

mg/L					
Zn	Cd	Fe	Pb	Cu	Sr
5.3	0.40	19.50	1.24	0.77	9.80

Similar results were also obtained in castor capsules and jojoba wastes (leaves and capsules). Increasing the amount of the sorbent and keeping sorbate concentration fixed makes a large number of sites available for a fixed concentration of sorbate hence the increase in extent of adsorption (Oladoja *et al.*, 2008). The results are in agreement with those reported by Ahmadpour *et al.* (2010), who found that the removal efficiency of Sr (II) was enhanced by increasing the adsorbent/adsorbate ratio, especially at the period of 30 s. At higher initial concentrations, the ratio of available adsorption sites to strontium ions is less and the binding sites saturate more rapidly.

Effect of contact time on strontium Sr (II) ion removal

Although biosorption is promising, its mechanism is not well elucidated (Igwe and Abia, 2006). Table 2 shows the effect of operating time on the adsorption of Sr (II). In general all adsorbents gave better adsorption percentage than the control as the contact time increased. The 1hour contact time recorded the lowest percentage; while the 24 hours contact time recorded the best results. The experimental data also indicated that Sr (II) ion adsorption increases rapidly during lately contact times and the process achieves almost 48.1% of adsorption. The mechanism for Sr removal form wastewater by absorption techniques was studied (Weber and Morris, 1963), it was surmised that the mechanism involved four steps: migration of Sr from solution to the surface of the sorbent, diffusion through the boundary layer to the surface of the sorbent, adsorption at a site, and intra particle diffusion into the interior of the sorbent. The slowest of these four steps has been considered as the rate limiting step for any adsorption process.

Table 2. Effect of bio-sorbent type, concentrations, and contact times on adsorption percentage (Ad %) of Sr (ppm) from *Abu Zaabal industrial area* wastewater.

Plant	Bio-sorbents	Con.	0%			0.5%				1%			
		Contact times	M		SD	M		SD	Ad	M		SD	Ad
Castor Bean	Leaves	1hr.	0.994	±	0.08	0.978	±	0.07	1.6	0.904	±	0.03	9.0
		2hr.	0.979	±	0.09	0.951	±	0.02	2.8	0.808	±	0.03	17.5
		3hr.	0.917	±	0.02	0.906	±	0.00	1.2	0.750	±	0.01	18.2
		24hr.	0.695	±	0.002	0.566	±	0.033	18.5	0.451	±	0.022	35.2
	Capsules	1hr.	1.049	±	0.02	0.871	±	0.00	17.0	0.803	±	0.01	23.4
		2hr.	0.979	±	0.03	0.834	±	0.03	14.8	0.756	±	0.02	22.8
		3hr.	0.952	±	0.02	0.798	±	0.02	16.2	0.735	±	0.01	22.8
		24hr.	0.501	±	0.013	0.359	±	0.007	28.4	0.341	±	0.016	32.5
Jojoba	Leaves	1hr.	0.784	±	0.02	0.690	±	0.03	12.0	0.663	±	0.01	15.4
		2hr.	0.772	±	0.02	0.682	±	0.02	11.6	0.619	±	0.01	19.8
		3hr.	0.710	±	0.01	0.669	±	0.03	5.7	0.613	±	0.01	13.6
		24hr.	0.745	±	0.003	0.648	±	0.001	13.0	0.490	±	0.001	34.1
	Capsules	1hr.	0.858	±	0.06	0.733	±	0.12	14.6	0.696	±	0.02	18.9
		2hr.	0.769	±	0.03	0.675	±	0.01	12.2	0.618	±	0.02	19.6
		3hr.	0.756	±	0.03	0.632	±	0.01	16.4	0.557	±	0.02	26.3
		24hr.	0.767	±	0.004	0.581	±	0.007	24.2	0.399	±	0.043	48.1

*The data represent mean ± SD of three replicates, **M= Mean, SD=Standard deviation, Ad= Adsorption percentage, hr. =hour.

Effect of bio-sorbent concentrations on adsorption percentage (Ad %) of heavy metals from Abu Zaabal industrial area wastewater at 24h contact times

The removal of heavy metals from our environment especially wastewater is now shifting from the use of conventional adsorbents to the use of biosorbents (Igwe and Abia, 2006). The present investigation shows that the low cost adsorbents like castor bean and jojoba wastes can be used as an effective adsorbent for the treatment of wastewaters containing metals like Cd and Sr. Data in Table 3 show that Zn, Cu, and Pb concentrations (ppm) increased with increase castor bean and jojoba wastes dosage after the 24 hours contact time. However Sr decreased with increase both wastes dosage. On the other hand, Cd increased with increase castor bean wastes dosage, and decreased with increase jojoba wastes dosage. The data also showed that jojoba capsules at concentration 1% recorded the highest adsorption percentage (48.1%) for Sr ions, however, jojoba leaves at concentration 1% showed the highest adsorption percentage (78%) for Cd. This is could be due to increased adsorption surface area (Renge *et al.*2012).

Conclusion

The effect of various bio-sorbents on the removal of Strontium from industrial wastewater was investigated. The following conclusions can be drawn from the present study: 1) Efficient and rapid adsorption takes place within only 24h. contact time, 2) Batch adsorption studies also showed that approximately 48.1% of the Sr ions were removed by using jojoba capsules as bio-sorbents at 1% concentration, and at 24 hours contact time, 3) Approximately 78% of the Cd ions were removed by using jojoba leaves as bio-sorbents at 1% concentration, and at 24 hours contact time.

Table 3. Effect of bio-sorbent concentrations on adsorption percentage (Ad %) of some heavy metals from *Abu Zaabal industrial area* wastewater at 24h contact times.

Plant	Bio-sorbents	Con. %	Sr (ppm)			Cd(ppm)			Zn(ppm)			Cu(ppm)			Pb(ppm)		
			M	SD	Ad%	M	SD	Ad%	M	SD	Ad%	M	SD	Ad%	M	SD	Ad%
Castor bean	Leaves	0	0.695	0.002	0	0.023	0.001	0.0	0.015	0.001	0.0	0.752	0.005	0.0	1.735	0.049	0.0
		0. 5	0.566	0.033	18.5	0.033	0.003	-46.7	0.146	0.017	-906.9	0.899	0.032	-19.4	2.390	0.099	-37.8
		1	0.451	0.022	35.2	0.046	0.000	-104.4	0.229	0.024	-1479.3	1.041	0.018	-38.3	3.155	0.007	-81.8
	Capsules	0	0.501	0.013	0	0.055	0.003	0.0	0.027	0.004	0.0	0.915	0.021	0.0	2.585	0.219	0.0
		0. 5	0.359	0.007	28.4	0.064	0.003	-16.4	0.223	0.006	-724.1	1.050	0.016	-14.8	6.420	0.358	-148.4
		1	0.341	0.016	32.5	0.085	0.004	-53.6	0.306	0.006	-1034.6	1.129	0.035	-23.5	7.153	0.225	-176.7
Jojoba	Leaves	0	0.745	0.003	0	0.050	0.000	0.0	0.026	0.004	0.0	1.666	0.018	0.0	0.055	0.007	0.0
		0. 5	0.648	0.001	13.0	0.020	0.000	60.0	0.089	0.000	-249.0	1.890	0.000	-13.4	0.060	0.000	-9.1
		1	0.490	0.001	34.1	0.011	0.000	78.0	0.086	0.000	-237.3	1.691	0.000	-1.5	0.420	0.000	-663.6
	Capsules	0	0.767	0.004	0	0.012	0.002	0.0	0.028	0.011	0.0	1.752	0.006	0.0	0.185	0.078	0.0
		0. 5	0.581	0.007	24.2	0.011	0.001	8.7	0.084	0.030	-205.5	1.798	0.004	-2.6	0.560	0.057	-202.7
		1	0.399	0.043	48.1	0.008	0.009	34.8	0.107	0.050	-287.3	1.8045	0.005	-3.0	0.595	0.049	-221.6

*The data represent mean ± SD of three replicates, **M= Mean, SD=Standard deviation, Ad= Adsorption percentage.

Acknowledgments

The authors are grateful to Mr. Nabil El Mogy, The Egyptian Natural Oil Co. (NATOIL), for his help, and providing us with jojoba raw materials.

References

Ahmadpour A, Zabihi M, Tahmasbi M, Rohani T. 2010. Effect of adsorbents and chemical treatments on the removal of strontium from aqueous solutions. Journal of Hazardous Materials, **182**,552–556.

Algharib AM, Kotb EA .2013. Biodiversity of castor bean in Egypt for the potential possibility of using as a bioenergy crop. The 3rd International Conference on: Neglected and Underutilized Species (NUS): for a Food-Secure Africa Accra, Ghana, 25-27 September 2013.

Celik A, Demirbas A. 2005. Removal of heavy metal ions from aqueous solutions via adsorption onto modified lignin from pulping wastes. Energy Sources, **27,** 1167– 1177.

Denton MS, **Manos MJ**, **Kanatzidis MG.** 2009. Highly Selective Removal of Cesium and Strontium Utilizing a New Class of Inorganic Ion Specific Media – 9267. WM2009 Conference, March 2009, Phoenix, AZ

Elkamash AM, **Elnaggar MR**, **Eldessouky MI.** 2006. Immobilization of cesium and strontium radionuclides in zeolite-cementblends, Journal of Hazardous Materials, **136**, 310–316.

FAO. 2012. Food and Agriculture Organization of United Nations. (http/faostat.fao.org).

Haas PA. 1993. A review of information on ferrocyanide solids for removal of cesium from solution, Separation Science and Technology, **28**, 2479–2506.

Igwe JC, **Abia AA.** 2006. A bio separation process for removing heavy metals from wastewater using bio sorbents. African Journal of Biotechnology, **5 (12),** 1167-1179.

Jeannie S, Avner V, Erika W. 2011. Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. Climatic Change **104**, 599–627

Kasimtseva NK. 2010. Removal of arsenic and strontium from aqueous solution using iron oxide coated zeolitized tuff; Master these, University of Nevada, Las Vegas.

Mandal NK. 2014. Performance of Low-Cost Bio Adsorbents for the Removal of Metal Ions – A Review. International Journal of Science and Research, **3(1),** 177-180

Mohammed AM, **Aly EA**, **Amer W**, **Al-Zayadneh AE.** 2008. Growth regulators influence the fatty acid profiles of in vitro induced jojoba somatic embryos. Plant Cell, Tissue and Organ Culture **93**, 107-114

Oladoja NA, **Aboluwoye CO**, **Oladimeji YB**, **Ashogbon AO**, **Otemuyiwa IO.** 2008.Studies on castor seed shell as a sorbent in basic dye contaminated wastewater remediation. Desalination, **227,** 190–203.

Omar H, **Arida H**, **Daifullah A.** 2009. Adsorption of 60 Co radio nuclides from aqueous solution by raw and modified bentonite, Applied Clay Science, **44,** 21–26.

Ozer A, Pirincci HB. 2006. The adsorption of Cd (II) ions on sulphuric acid-treated wheat bran. Journal of Hazardous Materials, **137**,849–855.

Polyakova IV, **Synzynys BI.** 2009.Stable strontium and fluorine in groundwater north Kaluga region: Possible biological effects and risk assessment for health. Bulletin of Moscow Society of Naturalists.

Renge VC, **Khedkar SV**, **Pande SV.** 2012. Removal of heavy metals from wastewater using low cost adsorbents: a review. Scientific Reviews & Chemical Communications, **2 (4),** 580-584.

Rout TK, **Sengupta DK**, **Kaur G**, **Kumar S.** 2006. Enhanced removal of dissolved metal ions in radioactive effluents by flocculation, International Journal of Mineral Processing, **80**, 215–222.

Sarwar G, **Ahmed HM**, **Hussain J.** 2010. Evaluation of Castor bean (*R. Communis* L.) Mutants for Genetic Parameters and Cluster Analysis. Journal of Agricultural Research.**48(3),** 289-302.

Tautkus S, **Uzdaviniene D**, **Pakutinskiene I**, **Kazlauskas R**, **Zalieckiene E.** 2007. Determination of strontium in milk by flame atomic absorption spectrometry. Polish Journal of Environmental Studies, **16(5),** 771-775.

Volkovich VA, **Griffiths TR**, **Thied RC.** 2003. Treatment of molten salt wastes by phosphate precipitation: removal of fission product elements after pyrochemical reprocessing of spent nuclear fuels in chloride melts, Journal of Nuclear Materials, **323**, 49–56.

Weber WJ, **Morris JC.** 1963. Kinetics of adsorption on carbon from solution, Journal of the Sanitary Engineering Division, **89**, 31–59.