International Journal of Engineering & Technology, 7 (4.2) (2018) 26-29

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Adsorption of Cadmium from Aqueous Solutions Using Low cost Materials-A Review

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Abstract

With the onset of industrialization, a lot of anthropogenic sources of cadmium, including industrial emissions, application of fertilizers and sewage sludge to farm land has lead to the contamination of water bodies, and has increased cadmium uptake by agricultural crops, grown for human consumption. Cadmium when present, even at low concentrations may pose serious health as well as environmental hazards. The use of various materials has been widely investigated as a replacement of recent expensive methods for removing cadmium from water and wastewater. Plant based natural materials, agricultural products, nano materials and industrial wastes are efficiently used as low-cost adsorbents. Until now, most of the researchers have attempted to review the literature for multiple heavy metals. In the current review, an elaborate list of literature has been compiled to provide information on a wide range of natural as well as modified adsorbent materials for the removal of Cadmium from wastewater.

Keywords: *Adsorbent, agricultural products, cadmium, industrial wastes.*

1. Introduction

Effluents from many industrial activities are the sources of cadmium into the aqueous environment. Cadmium is an essential element for living organisms, but at increased concentrations it is injurious (Purkayastha *et al.*, 2014).Many conventional methods for the removal of Cadmium such as chemical precipitation (Khosravi and Alamdari 2009), floatation (Rubio *et al.*, 2002), ion exchange (Kang *et al.*, 2004), membrane separation techniques(Al-Rashdi *et al.*, 2013), electrodialysis (Mohammadi *et.,al* 2005), solvent extraction (Mauri *et al.*, 2001) etc; have certain limitations like generation of toxic sludge or other wastes, incomplete metal removal, high reagent and energy requirements. Most of these methods are often ineffective, have complexity in their processes or uneconomical when the concentration of cadmium is higher (10-100 ppm) than the permissible concentration. Adsorption has advantages over the other methods because of simple design with a sludge free environment, have high metal binding capacity, can work over a wide range of pH and can involve low investment in term of both initial cost and land required (Viraraghavan and Dronamraju, 1993).

2. Adsorbents

2.1. Plant Based Adsorbents

A wide range of plant based adsorbents are studied for decontaminating the cadmium containing industrial wastes. Batch experiments were conducted at a pH 6 with *polyalthia longifolia* Seeds as biosorbent (Rao and Rehman, 2012), the *sterculia lychnophera* seeds were eluted and easily digested with concentrated HNO_3 (Liu *et.,al* 2006), Loquat leaves, Loquat ash and *moringa oleifera* showed a good adsorption at pH 6 & pH 7 (Al-Dujaili *et al.*, 2012), (Reddy *et al.*, 2012), acacia leucocephala bark powder used as a sorbent gave an optimum adsorption at pH 5 (Munagapati *et al.*, 2010). Modified sawdust (cedrus deodar wood), *azolla filiculoides*, wheat bran and coirpith activated carbon are used either as raw or in modified forms (Memon *et al.*, 2007, Ganji *et al.*, 2005, Ozer and Pirinc 2006 and Kadirvelu *et al.*, 2003) were showed in table 1.

Table 1: Adsorption capacity (mg/g) of plant biomass based materials

Adsorbent	Adsorption capacity (mg/g)	References
Polyalthia longifolia Seeds (Seeds of Indian Mast Tree)	20.74	Rao and Rehman (2012)
Sterculia lychnophera seeds	17.5	Liu Y et al.(2006)
Loquat leaves (Eriobotrya japonica)	29.24	Al-Dujaili et al. (2012)
Loquat ash (Eriobotrya japonica)	21.32	Al-Dujaili et al. (2012)
Moringa oleifera (CAMOL)	171.37	Reddy et al. (2012)
Acacia leucocephala bark powder	167.7	Munagapati et al. (2010)
Modified Sawdust (cedrus deodar wood)	73.62	Memon et al. (2007)
Sawdust (Pinus sylvestris)	9.29	Taty-Costodes et al. (2003)
Juniper fibre	29.54	Min et al. (2004)
Azolla filiculoides (aquatic fern)	86	Ganji et al. (2005)

Palm Sheath(Petiolar felt-sheath)	10.08	Iqbal M et al.(2002)
Walnut sawdust	4.51	Bulut and Tez (2003)
Cassava tuber bark waste	26.3	Horsfall Jr. et al. (2006)
Cassava Waste(thioglycolic acid modified)	18.05	Abia A.A et al.(2003)
Cocoa Shell	4.94	Meunier et al.(2003)
Wheat bran	101	Ozer and Pirinc (2006)
Spent grain	17.3	Low et al. (2000)
Black oak bark	25.9	Masri *et al.*, 1974
Hardwickia binata bark	34	Deshkar *et al.*, 1990
Redwood bark	32	Masri *et al.*, 1974; Randall *et al.*, 1974a,b
Coirpith activated carbon	93.4	Kadirvelu et al. (2003)
Pomelo peel	21.83	M. Iqbal et al.(2009)
Mango peel	68.92	

2.1.1. Agricultural Products And By-Products

The biosorption properties sunflower stalk showed an adsorption of 70 mg/g (Jalali and Aboulghazi 2013), hazelnut husk carbon (61.35 mg/g) and Annona squamosa (71 mg/g) (Isaac and Sivakumar 2013). Studies reveal the various fruit peels like jack fruit peel (Inbaraj & Sulochana 2004), modified orange peel (Feng *et al.*, 2011) and mango peel (M. Iqbal *et al.*, 2009) showed good adsorption and were presented in table 2.

Table 2: Adsorption capacity (mg/g) of agricultural products and by-products

Adsorbent	Adsorption capacity (mg/g)	References
Corn stalk (acrylonitrile modified)	12.73	Zheng et al. (2010a, 2010b)
Corn stalk (raw)	3.39	Zheng et al. (2010a, 2010b)
Corncobs	8.89	Vaughan T et al.(2001)
Corn Starch	8.88	Zacaria R (2002)
Sunflower stalk	70	Jalali and Aboulghazi (2013)
Coffee Residues (Pyrolyzed)	39.5	Boonamuayvitaya V et al.(2004)
Blend coffee	2.0	M. Minamisawa et al. (2005)
Modified Orange peel (OPAA)	293.3	Feng et al. (2011)
Jack fruit Peel	52.08	Inbaraj & Sulochana (2004)
Peanut hulls	5.96	Brown P et al.(2000)
Peanut hulls pellets	6.0	Brown P et al.(2000)
Hazelnut husk carbon	61.35	Imamoglu et al. (2014)
Agave bagasee(raw)	14	Velazquez-Jimenez et al. (2013)
Agave sisalana (sisal fiber)	1.85	dos Santos et al. (2011)
Annona squamosa	71.0	Isaac and Sivakumar (2013)
Wheat straw	39.22	Farooq et al. (2011)
Wheat bran	0.70	Singh KK et al.(2006)
Walnut shell	1.5	Orhan and BuÈ yuÈ kguÈ ngoÈ r, 1993
Functionalized coconut fibers	0.2–5 mmol/g	D.A. de Sousa et al. (2010)
Coconut copra meal	4.99	Y.-S. Ho et al. (2006)
EDTA-modified groundnut husk	0.36 mmol/g	F.E. Okieimen et al. (1991)
Banana peel	35.52	J.R.Memon et al. (2008)

2.1.2. Industrial Wastes

Many industrial wastes are proved to have adsorption capacity towards heavy metal ions. Industrial by-products such as maize cope and husk (Igwe *et al.*, 2005), blast furnace slag (V.K. Gupta *et al.*, 1997), sugarcane baggasse (modified) (Junior *et al.*, 2006) and sugarcane baggasse carbon (Mohan and Singh, 2002) have maximum capacities in removing toxic cadmium ions from aqueous solutions were given in table 3.

Table 3: Adsorption capacity (mg/g) of industrial wastes

Adsorbent	Adsorption capacity (mg/g)	References
Black gram husk	19.56–49.97	A. Saeed et al.(2005)
Maize cope and husk	493.7	Igwe et al. (2005)
Blast furnace slag	18.72	V.K. Gupta et al.(1997)
Blast furnace sludge	6.74–10.15	A. Lopez-Delgado et al(1998)
Red mud	10.57	E. Lopez et al.(1998)
Rice husk(sodium hydroxide)	20.24	Kumar and Bandyopadhyay (2006)
Rice husk(Water washed)	8.58	Kumar and Bandyopadhyay (2006)
Rice husk(sodium bicarbonate)	16.18	Kumar and Bandyopadhyay (2006)
Rice husk(Epichlorohydrin)	11.12	Kumar and Bandyopadhyay (2006)
Waste slurry	15.73	S.M. Lee et al.(2001)
Lignin-Ablack liquor waste of paper & pulp industry	12.05	Demirbas A (2004)
Coffee husk	6.9	Oliveira et al. (2008)
Turkish tea waste	2.59–11.29	Cay S et al.(2004)
Tea wastes	11.3	Cay S et al.(2004)
Tea wastes(binary system)	2.59	Cay S et al.(2004)
Sugar beet Pulp	17.2	Zacaria R et al.(2002)
Sugarcane bagasse(Sodium bicarbonate)	189	Junior et al. (2006)
Sugarcane bagasse pith	24.7	Krishnan KA & Anirudhan TS (2003)
Sugarcane Bagasse carbon	38.03	Mohan and Singh (2002)
Grape bagasse	0.774 mmol/g	N.V. Farinella et. Al(2004)

3. Conclusions

Adsorption contributes significantly to the remediation of many heavy metals, dyes, organics, phenols etc. Studies conducted on natural materials were reviewed show that plant based biomass Moringa oleifera (171.37 mg/g), Acacia leucocephala bark powder (167.7mg/g), Wheat bran(101mg/g) were having maximum adsorption capacities. Maximum adsorption capacities of agricultural by-products reported were modified orange peel (293.3 mg/g), annona squamosa (71 mg/g), sunflower stalk (70 mg/g). Maize cope and husk (493.7 mg/g) and Sugarcane bagasse(Sodium bicarbonate)(189 mg/g) were having maximum adsorption under industrial wastes. This review concludes that adsorption is the best possible option for hassle free remediation of contaminated waters.

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