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Research Article

Tea Wastes as a Sorbent for Removal of Heavy Metals from wastewater

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Abstract

Waste water contamination is ever increasing problem which the whole world is now facing. Industrialization and globalization has led to production and disposal of large amount of heavy metals in the environment. The tremendous increase in use of heavy metals over the past decades has inevitably resulted in an increase flux of metallic substances in the aquatic environment. Heavy metals are major pollutants in marine, ground, industrial and even treated wastewaters. Mining activities, agricultural runoff, domestic and industrial effluents are mainly responsible for the increase of the metals released into the environment. Tea waste has been utilized in agricultural field to enhance the production under heavy metal stress. After water, tea is the most widely consumed beverage in the world With great production and consumption large quantities of tea wastes(From the Caff,Cafeteria,or tea –processing factory) are usually discarded into the environment without any treatment. The main objectives of the review is to determine the effectiveness and feasibility of some low cost agricultural waste material (Tea waste, coconut husk and coconut shell) in the process of heavy metals removal from waste water

Keywords: *Heavy metals, Tea waste, Industrialization, Waste water contamination.*

Introduction

Waste water contamination is ever increasing problem which the whole world is now facing. Waste water comprises liquid waste discharged by domestic residence, commercial properties, industry and agriculture waste. Industrial waste constitutes the major source of metal pollution in natural water. Toxic heavy metals (Cd, Zn, Pb and Ni) are major pollutant of waste water which is very hazardous. Various methods are used for the removal of these heavy metal like chemical oxidation and reductions, ion exchange, Electrodialysis, Electro precipitation, liquid extraction, ultrafiltration *etc*. which are very costly as well as not completely remove the metal. Biosorption is potentially an attractive technology for treatment of waste water for retaining heavy metal form dilute solution. Biosorption has been suggested as cheaper, more effective and minimization of chemical and biological sluge.There are many natural bisorbent are present in our environment which have the capacity to remove heavy metal from waste water. Tea (*Camellia sinensis)* is the most widely consumed beverage in the world. The global production in 2007 was 3.60 million tonnes .With such a great production and consumption, a large quantity of tea waste are discarded into the environment. Now a days tea waste is gaining a much attention by researcher because it is very suitable biosorbent in removing heavy metals like Iron (II), Cr (VI), Lead and Nickel.

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Heavy metals pollution

Industrialization and globalization has led to production and disposal of large amount of heavy metals in the environment. The tremendous increase in use of heavy metals over the past decades has inevitably resulted in an increase flux of metallic substances in the aquatic environment. Contamination of soil with heavy metals is one of the great problems of modern societies. Large number of people has been exposed to the health hazards caused by heavy metals presence in drinking water, surface water, ground water and animal tissue. The toxic effects of heavy metals are made more serious because of their non-biodegradable nature which makes heavy metals pollution a serious environmental problem. Some of these heavy metal are also known to attack the active sites of enzymes in the body therefore inhibiting the enzymes. (Olayinka *et al.*,2007). Mining activities, agricultural runoff, domestic and industrial effluents are mainly responsible for the increase of the metals released into the environment. Effluents from industrial processes such as electroplating, mining, nuclear power operation, battery manufacturing, dye and pigments have been identified to contain high level of heavy metals. Such metals include Cr (II), Cr (VI), Zn, Cd, Cu, Ni, Hg and Pb (Blais *et al*., 2000). Most of the heavy metals salts are soluble in water and form aqueous solution and consequently cannot be separated by ordinary physical means of separation (Alkpokpodion *et al*., 2010).

Effects of Heavy Metals on Human Health

Table 1 Heavy metals effect on human health

Pollutants	Major sources	Effect on human health	Permissible level (mg/l)
Arsenic	Pesticides, fungicides, metal smelters	Bronchitis, dermatitis, poisoning	0.02
Cadmium	Welding, electroplating, pesticide fertilizer, Cd and Ni batteries, nuclear fission plant	Renal dysfunction, Lung disease, Lung cancer, Bone defects (Osteomalacia, Osteoporosis), increased blood pressure , kidney damage, bronchitis, gastrointestinal disorder, bone marrow, cancer	0.06
Lead	Paint, pesticide, smoking, automobile emission, mining, burning of coal	Mental retardation in children, developmental delay, fatal infant encephalopathy, congenital paralysis, sensor neural deafness and, acute or chronic damage to the nervous system, epilepticus, liver, kidney, gastrointestinal damage	0.1
Manganese	Welding, fuel addition, ferromanganese production	Inhalation or contact causes damage to central nervous system	0.26
Mercury	Pesticides, batteries, paper industry	Tremors, gingivitis, minor psychological changes, acrodynia characterized by pink hands and feet, spontaneous abortion, damage to nervous system, protoplasm Poisoning	0.01
Zinc	Refineries, brass manufacture, metal Plating, plumbing	Zinc fumes have corrosive effect on skin, cause damage to nervous membrane	15
Chromium	Mines, mineral sources	Damage to the nervous system, fatigue, irritability	0.05
Copper	Mining, pesticide production, chemical industry, metal piping	Anemia, liver and kidney damage, stomach and intestinal irritation	0.1

(Source-Reena *et al.,* 2011)

Table 2 Performance characteristics of various heavy metal removal /recovery technologies

Technology	pH change	Metal selectivity	Influence of Suspended solids	Tolerance of organic molecules	Working level for appropriate metal (mg/I)
Adsorption, e.g. Granulated Activated carbon	Limited tolerance	Moderate	Fouled	Can be poisoned	<10
Electro chemical	Tolerant	Moderate	Can be engineered to tolerate	Can be accommodated	>10
Ion exchange	Limited tolerance	Chelate - resins can be selective	Fouled	Can be poisoned	<100
Membrane	Limited tolerance	Moderate	Fouled	Intolerant	>10
Precipitation					
(a) Hydroxide	Tolerant	Non-selective	Tolerant	Tolerant	>10
(b) Sulphide	Limited tolerance	Limited selective pH dependent	Tolerant	Tolerant	>10
Solvent extraction	Some systems pH tolerant	Metal selective extractants available	Fouled	Intolerant	>100

(Source-Ramachandran *et al*.,2005)

The heavy metals which are hazardous to humans include lead, mercury, cadmium, arsenic, copper, zinc and chromium. These metals are found naturally in the soil in trace amounts which pose few problems (Table 1).When concentrated in particular area, they pose a serious danger to human health.

Techniques used for removal of heavy metal

Many physio-chemical methods have been proposed for removal of heavy metals from industrial effluents are chemical precipitation, membrane separation, liquid extraction,flotation,hydroxide and sulphide precipitation,crystallization,ultrafiltration ,evaporation, solvent extraction ,ion exchange ,reverse osmosis,elctrodialysis and adsorption with activated carbon(Foster and wittman,1983).Chemical precipitation, reverse osmosis and other methods become inefficient when contaminants are present in trace concentration .

Adsorption

All these methods have been found to be expensive and may not be suitable for developing countries like India. Therefore there is need to look into alternatives to investigate a low-cost method which is effective and economic. Adsorption technique is good proposition for high strength and low volume of wastewater. Adsorption is an effective purification and separation technique used in industry especially in water and wastewater treatment (Al-Asheh *et al*., 2000). Adsorption has advantage over other methods. The design is simple, highly efficient; it is sludge free and can involve low investment in terms of both the initial costs and land.

Activated carbon has been recognized as a highly effective adsorbent for the treatment of heavy metals in wastewater, but is readily soluble under extreme pH conditions (Huang and Blankenship,1989). Activated carbon is most widely used adsorbent, as it has good capacity for adsorption of carcinogenic metals. However, high cost of activated carbon and 10-15% loss during the regeneration has deterrents in the utilization of activated carbon in the developing countries (Ho *et al*., 2005).

Low cost adsorbent

Increasing research interest in using alternative low-cost adsorbents. Many such materials have been investigated, including microbial biomass, peat, compost, leaf mould, palm press fibres, coal, sugarcane bagasse, straw, wool fibres and by products of rice mill, soybean and cottonseed hulls(Marshall and Champagne,1993,1995), tea waste, *Azadirachta indica* (Neem) leaf powder, pomegranate peel, olive bagasse and hazelnut(Hadmohammadi,2011). Coal and straw, are inexpensive but ineffective. Peat moss has been found as very effective in adsorbing heavy metals. Muhammad *et al*. 1998 used slow sand filters to remove heavy metals (Cu, Cd, Cr, Pb). Quek *et al*. 1998 used the sago processing waste, which is both a waste and a pollutant, to adsorb lead and copper ions from solution. Mahavi *et al*. 2005 used tea waste as an adsorbent for the removal of heavy metals (Cd, Pb, Ni) from industrial waste. About 94-100% removal of lead, 86% for Ni and 77% for Cd were achieved using tea waste.

Hence the use of agricultural residues or industrial bi-product having biological activities have been received with considerable attention (Hasar *et al*., 2000). By-products of soybean and cottonseed hulls, rice straw and sugarcane bagasse were evaluated as metal ion adsorbents in aqueous solution (Marshall and Champagne, 1995). Agricultural by-product and biological material have been found to be useful for metal sorption.Carrilho and Gilbert (2000) studied biomaterial from marine algae in removing Al, Cd, Co, Cr, Fe, Ni and Zn. Filamentous fungi have been found to possess a high potential of accumulating Cu, Ni, Co and uranium in aqueous solution (Siegel *et al*., 1990). The feasibility of using chitosan coated oil palm shell charcoal to remove heavy metals has been described by Nomanbhay and Palanisamy in 2005. It has been concluded that major mechanism of heavy metal by algae and peat moss is by ion exchange.

Mangifera indica (Mango) seed and seed shell powders were studied for their possible application in the removal of Cu (II) from waste water. It was found that seed shell of Mango had higher sorption capacity than that of seed powder for Cu (II). The presence of Ca (II), Mg (II) and K (I) decreased the percent adsorption of Cu (II) on these adsorbents (Ajmal *et al.*, 1998). Agricultural materials such as coconut husk which is also an abundant agricultural waste in India (Tan *et al*, 1985), Rice husk (Munah and Zein, 1997), almond husk (Hasar and Cuci, 2000) and a host of other agricultural bi-product have been reported for the removal of toxic metals from aqueous solution. These wastes are considered to be good metal scavengers from solution and waste water as they contain certain functional groups. These functional groups are associated with protein, polysaccharides, lignin and cellulose as major constituents. Metal uptake is believed to occur through sorption process involving carboxylic and phenolic functional groups which result in formation of surface complexation mechanism between metal ions and lignocellulosic adsorbents (Khalid *et al*., 2000, Pagnanelli *et al*., 2003b).

Adsorption by tea waste

In India, yearly production of tea is approximately 857000 tonnes which is 27.4% of total world production (Wasewar, 2010). The amount of dry tea produced from 100kg green tea leaves is 22 kg on average and approximately 18 kg tea is packed for the market. The other 4kg of dry tea material is wasted(Wasewar,2010).With such a great production and consumption large quantities of tea wastes(From the Caff,Cafeteria,or tea –processing factory) are usually discarded into the environment without any treatment.Furthermore,additional amount of tea leaves enters the environment by defoliation and pruning annually. These tea wastes could cause environmental hygiene problems during their degradation process and contaminate water environment by releasing organic matter.

Tea waste has been utilized in agricultural field to enhance the production under heavy metal stress. Azmat and Akhter in 2010 grow *Vigna radiata* under chromium stress with tea waste as suitable adsorbent is mixed with soil which can protect plant from the phytotoxicity of Cr^{3+} by altering various metabolic processes.Tea leaf waste alone and in different combination with wheat straw were used for the mycelial growth of *Pleurotus flabellatus* and *P. Sapidus* in petriplates at national centre for mushroom research and training solan India by Upadhyay *et al*., 1996. Tea waste is a cheap material so it's utilizing in industrial wastewater plants would be convenient .Meanwhile it is possible to increase the treatment efficiency by pre-treatment with some chemical such as acids, bases and detergents (Ajmal *et al*., 1998). It is suggested that for industrial application of waste tea powder to be effective in waste water treatment. After water ,tea is the most widely consumed beverage in the world, as attested by the over 3,500,000 tons of tea leaves produced annually (FAO,2009).Tea beverages are typically available as green, black or Oolong tea depending on the way of manufacturing (Ho *et al*.,2005).Like other biomass residues ,tea waste represent an unused resource and pose increasing disposal problem (Arvanitoyannis and Varzakas,2008).For theses reason ,strategies are being investigated to evaluate their possible use as an energy source or in other value –added application. The cell wall of waste tea consist of cellulose ,lignin, carbohydrate which have hydroxyl groups in their structures (Aikpokpodian *et al*.,2010).One third of total dry matter in tea leaves should have good potential as metal scavengers from solution and waste water because they contain functional groups. The responsible functional groups is lignin, tannin or other phenolic compounds are mainly carboxylate,aromatic carboxylate,phenolic hydroxyl and oxyl groups and could be a good sorbent for contamination. Mahvi *et al*. 2005 showed that tea waste like the most other natural absorbents can be used in the treatment process of heavy metals and the treatment efficiency may be as high as 100% by precise choosing of adsorbent amount. He also mention that Tea waste is a cheap material so its utilizing in industrial waste water treatment plants would be convenient and it is possible to increase the treatment efficiency by pre-treatment with some chemical such as acids, base and detergents (Ajmal *et al*.,1998). Shaikh *et al*. 2011 concluded that adsorbent prepared from tea waste has good potential for the arsenic removal. It was noticed that arsenic adsorption onto tea waste adsorbent is highly dependent on pH.The optimum arsenic removal was noted as 92.5% at pH 7.

Fig.1 Effect of tea wastage on Mung bean plants in Cr contaminated soil. (Source- Rafia Azmat 2011).

Alkpokpodion *et al*., 2010 study revealed that tea waste powder is an effective adsorbent for the adsorption of Ni (II) ions from aqueous solution. The uptake of nickel ions by the biomass was increased by increasing metal ion concentration but decreased adsorption of the total initial metal concentration. Dave *et al*. 2012 concluded on their study that adsorbents prepared from tea waste and coconut husk could be used for the removal of chromium (VI) from aqueous solution. Both tea waste and coconut husk are found to be a good low cost alternative to be used for the removal of Cr ions from wastewater (Fig 1).

Disposal of Tea Factory waste (TFW) after Adsorption

Disposal of the exhausted adsorbent loaded with heavy metal ions creates another environmental problem such as acid rains can wash out the adsorbed heavy metal ions (Cay *et al.*, 2011).TFW has a calorific value of about 21.69 MJ/kg (Wasewar *et al*.,2008a).It can be utilized for making blended fuel briquettes which could be used as a fuel in the furnaces. The bottom ash obtained after its combustion can be blended with the cementitious mixtures. Setting and leaching tests on cementitious mixtures have shown that the bottom ash can be incorporated into the cementitious matrices to a great extent (75% of total solid) without the risks of an unacceptable delay of cement setting and an excessive heavy metals leach ability from solidified products (Mangialardi ET *al.*,2003). In many parts of the world where tea waste is available at low or no cost, regeneration is not required and the metal laden biomass can be disposed by incineration (Tunali *et al.*, 2006).

Conclusion

Now a day it is important to prevent water pollution due to heavy metals. Research is now focused to develop a suitable technology either to prevent heavy metal pollution or to reduce it to low level. Prevention of heavy metal to water bodies can be possible only by reducing their direct discharge into the water stream. The most widely used conventional methods for removing heavy metals have many disadvantage such as high capital and operational cost, not suitable for small –scale industries and inadequate efficiency.

Adsorption is one of the promising processes for the removal of heavy metals from wastewater. The process of adsorption is suitable at very low concentration i.e. 1mg/l. Activated carbon is used by many industries as an adsorbent of Pb,Cd and other heavy metals but the cost is major draw of this adsorbent. Therefore increasing the use of low cost adsorbent for the removal of heavy metals like agricultural waste like coconut husk, rice husk, almond husk etc, biomaterial from marine algae, mango seed shell powder. In the recent year focus has been on the tea waste. In India total production as well as consumption is high so tea waste produced in very huge quantities. Disposal of this waste is major problem because is causes water pollution. Tea waste is a good option as it is a low cost adsorbent for removal of metals. Many studies shows their efficiency which is nearly 100%.Tea waste is found to be good adsorbent for metals like Ni, Cr, Cr, Cu, Pb etc. The accumulation of heavy metals in plants has been a serious environmental concern because their uptake by plants from contaminated soils is the principal processes by which heavy metals enter the food chain and then to men and animals and are relatively toxic at levels slightly above than those required for maintaining normal metabolic activities of body (Hapke, 1991; Chakraborty et al., 2004)

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