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Biosorption of Zn(II) and Pb(II) Ions from Water and Waste Water Using by Low-Cost Bio sorbents: A Review

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ABSTRACT

Heavy metals are a unique group of naturally occurring compounds. Their continuous release leads to overconsumption and accumulation. As a result, people around the globe are exposed to adverse consequences of these heavy metals. Toxic heavy metals, which are of concern, are chromium (Cr), lead (Pb), zinc (Zn), arsenic (As), nickel (Ni), cobalt (Co), cadmium (Cd), mercury (Hg), and so on. Industrialization to a larger degree is responsible for the contamination of environment especially water where lakes and rivers are overwhelmed with a large number of toxic substances. Over the last few decades, many conventional treatment methods have been used for the removal of heavy metals from contaminated wastewaters. The commonly used methods include chemical precipitation, ultra-filtration, ion exchange, reverse osmosis, electro winning, and phytoremediation. Biosorption has emerged as an attractive option over conventional methods for the removal of heavy metal ions from effluents discharged from various industries which ultimately reach and pollute fresh water bodies. In view of the disadvantages associated with conventional methods for metal removal, there is a need for alternative, cost-effective technologies. In recent years, biosorption /bioaccumulation processes have been considered as novel, economic, efficient, and eco-friendly alternative treatment technologies for the removal of heavy metals from contaminated wastewaters generated from various industries.

Keywords: Bio-sorption, Bio-degradation, Bio-sorbent materials and heavy metals.

INTRODUCTION

Water plays an important role in the world economy. Majority (71%) of the Earth's surface is covered by water, but fresh water constitutes a miniscale fraction (3%) of the total. Heavy metals are a unique group of naturally occurring compounds. Their continuous release leads to overconsumption and accumulation. As a result, people around the globe are exposed to adverse consequences of these heavy metals. Toxic heavy metals, which are of concern, are chromium (Cr), lead (Pb), zinc (Zn), arsenic (As), copper (Cu), nickel (Ni), cobalt (Co), cadmium (Cd), mercury (Hg), and so on. Industrialization to a larger degree is responsible for the contamination of environment especially water where lakes and rivers are overwhelmed with a large number of toxic substances. Many industries (fertilizers, metallurgy, leather, aerospace, photography, mining, electroplating, pesticide, surface finishing, iron and steel, energy and fuel production, electrolysis, metal surface treating, electro-osmosis, and appliance manufacturing) discharge waste containing heavy metals either directly or indirectly into the water resources. Heavy metals are reaching hazardous levels when compared with the other toxic substances. As these metals tend to accumulate in the living organisms and lead to various diseases and disorders which ultimately threaten human life. They can cause ill health, even when present in the range of parts per billion (ppb).

Over the last few decades, many conventional treatment methods have been used for the removal of heavy metals from contaminated wastewaters. The commonly used methods include chemical precipitation, ultra-filtration, ion exchange, reverse osmosis, electro winning, and phytoremediation. (Azimi *et al.* 2016). Biosorption has emerged as an attractive option over conventional methods for the removal of heavy metal ions from effluents discharged from various industries which ultimately reach and pollute fresh water bodies (Monachese *et al.* 2012).

Biosorption can be defined as a simple metabolically passive physicochemical process involved in the binding of metals ions (biosorbate) to the surface of the biosorbent which is of biological origin. Biological removal includes the use of microorganisms, plant derived materials, agriculture or industrial wastes, biopolymers, and so on. It is a reversible rapid process involved in binding of ions onto the functional groups present on the surface of the biosorbent in aqueous solutions by means of various interactions rather than oxidation through aerobic or anaerobic metabolism. The advantages of this process include are simple operation, no additional nutrient requirement, low quantity of sludge generation, low operational cost, high efficiency, regeneration of biosorbent, and no increase in the chemical oxygen demand (COD) of water, which are otherwise the major limitations for most of the conventional techniques. Biosorption can remove contaminants even in dilute concentrations and has special relevance with respect to heavy metal removal owing to toxicity at ppb levels. Industrial and agriculture byproducts can be used as biosorbents for the process of biosorption. The first stage in biosorption is that biosorbent should be suspended in the solution containing the biosorbate (metal ions). After incubation for a particular time interval, equilibrium is attained. At this stage, the metal-enriched biosorbent would be separated (Chojnacka, 2010).

Generally the process of biosorption can be described as biological ion exchange with binding groups present on the surface of cell wall: carboxyl, sulfonate, phosphoryl, amido, amino, imidazole etc. The groups have distinguishable pKa (power of acidic constant) responsible for the binding properties of a given group. The factors which influence biosorption performance include the type of the biomass (and resulting the composition of cell wall), pH, temperature, presence of other competing ions (both cations and anions) (Michalak *et al.* 2013). on the surface of agriculture waste or adsorbents plays an vital role in binding of adsorbent metals to remove heavy metals from waste water (Sud *et al.* 2008). Agricultural wastes adsorbents has raised great interest in the field of environmental study and are characterized by affordability, availability, eco friendliness and high removal capacity (Kehinde *et al.* 2009). Many researchers have conducted experiment emphasizing on decreasing the pollutants in the polluted water. The main focus of their study is that how to treat the industrial waste water with the help of low cost adsorbent. Different kind of bio- products like Sugarcane bagasse (Mohan & Singh, 2002; Khan *et al.* 2001; Ayub *et al.* 1998; Ayub *et al.* 2001; Ayub *et al.* 2002), Rice husk (Srinivasan *et al.* 1988; Ajmal *et al.* 2003; Suemitsu *et al.* 1986; Khan *et al.* 2003), Sawdust (Ajmal *et al.* 1996; Ayub *et al.* 2001; Kadirvelu *et al.* 2003; Khan *et al.* 2003; Selvi *et al.* 2001; Tan *et al.* 1993), Oil palm shell (Khan *et al.* 2003), Coconut husk (Tan *et al.* 1993), Neem bark (Ayub *et al.* 2001),Wool, Pine needles, Olive cake, Almond shells, Charcoal, Cactus leaves (Dakiky *et al.* 2002), Hazelnut shells (Cimino *et al.* 2000; Demirbas, 2003; Dakiky *et al.* 2002), Banana and Orange peels (Annadurai *et al.* 2003), different Agro waste materials (Qaiser *et al.* 2007), Activated carbon (Marzal *et al.* 1996), Granulated blast-furnace slag (Dimitrova & Mehandgiew, 1998), Okra waste (Hashem, 2007), Marine algae (Holan & Volesky, 1994), Seaweed biosorbent (Lee &

Volesky, 1997), Olive pomace (Pagnanelli *et al.* ,2003), Olive residue (Gharaibeh *et al.* 1998), Sunflower stalks (Hashem *et al.* 2006), Peanut hulls (Hashem *et al.* 2005) etc. have been investigated for the heavy metals treatment.

Lead(II) is commonly present in effluents and sewages from industries such as paint, pesticides, battery, mine, and smelting. The various sources of Pb(II) contamination in the environment are depicted. Reports indicate that grown-ups engross 5–15% of lead(II) and nearly 5% of it is being retained and the existence of 0.5–0.8 µg per mL of lead(II) in the blood of living organisms leads to numerous health conditions. (Kaushal, 2017). The toxicity of lead(II) leads to widespread health disorders including pregnancy miscarriages in women, severe stomachache, hyper-tension, impaired blood synthesis, brain, and kidney damage. (Bayuo *et al.* 2019) Besides, lead(II) is a universal pollutant on earth, and aqueous media and its exposure cause feebleness in ankles, fingers, and wrists. (Jeyakumar and Chandrasekaran, 2014) Some of the toxic effects of Pb(II) on plants, animals, and humans.

Some metal ions are highly essential for proper functioning of human organs such as Zinc (Zn), Copper (Cu), Manganese (Mn), Magnesium (Mg) and cobalt (Co), (Zhang *et al.* 2014; Kozlowski *et al.* 2009), However the excess intake of these ions causes serious health issues to living organisms as they are highly toxic, carcinogenic and get bioaccumulated in food chain (Zhang *et al.* 2014; Kozlowski *et al.* 2009; Sebastian & Srinivas, 2015; Omraei *et al.* 2011). On surface and in ground water Zinc is one of the most common pollutants (Omraei *et al.* 2011). Liquid and solid contaminated with Zn are referred as hazardous wastes because of its non-biodegradability (A substance which can't be changed to a harmless end product or state by dint of bacteria and may therefore ruin the environment) and acute toxicity. According to WHO the satisfactory concentration of Zn ions in drinking water should be 5.0 mg/l, equivalent to 5ppm or 5000ppb.

Removal of Lead By using different by-products & By using chemically modified by-products

Contamination of water by lead is of great concern as it gets tightly attached to particles of sediments, oil and waste sludge. Lead can enter into our body through food chain resulting into a variety of harmful biological effects depending upon the duration of exposure and concentration. High Pb removal efficiency has been observed by various scientist using different agriculture wastes in their natural form viz. soybean hulls, peanut shells, rice straw, walnut shells (Johns *et al.* 1998); tree bark (Bankar & Dara,1985); black gram husk, waste tea leaves, flowers of Humulus lupulus, water hyacinth and Petioler felt sheath palm (Gardea- Torresdey *et al.* 2002; Kamble & Patil, 2001; Iqbal *et al.* 2002, 2005; Saeed *et al.* 2005; Ahluwalia & Goyal, 2005). Activated carbons produced from agricultural wastes, such as bagasse, walnut and hazelnut shells and shells of apricot stones with great removal efficiency and large surface area have been used to treat heavy metals ions (Wilson *et al.* 2006; Ozdemir *et al.* 2011; Kadirvelu *et al.* 2001; Dolas *et al.* 2011; Saka, 2012; Gajghate *et al.* 1991; Vaughan *et al.* 2001). In 1998, 65% Lead removal competency has been reported using bagasse fly ash (Gupta *et al.* 1998). Maple Saw dust, Pinus sylvestries and rubber wood saw dust have shown 85-90% proficiency for Lead removal (Taty-Costodes *et al.* 2003; Raji *et al.* 1997). For biosorption of Lead optimizes value of pH is ranging from 5-6 according to literature review. In 2009 an experiment was investigated for Pb(II) removal on Orange peels by Schiewer and Balaria (2009). They compared the removal efficiency of Orange peel and protonated Orange peel and more than 90% removal was observed using these biosorbents (Schiewer & Balaria, 2009). In 2004 Coconut-shell was investigated to treat Lead from aqueous solutions. It has been found that adsorption was dependent on pH and at pH 4.5 maximum removal was obtained. Adsorption equilibrium data fitted well to the Freundlich, Tempkin isotherm and Langmuir isotherm models. At pH 4.5, 26.50 mg/g removal efficiency has been observed with the Langmuir model (Sekar *et al.* 2004). Modified form of Apple residue with modifying agent phosphorous (V) oxychloride (Lee *et al.* 1999); rose petals with modifying agent NaOH (Karnitz *et al.* 2007); sugarcane modified with succinic anhydride (Tsui *et al.* 2006) and calcium treated sargassum (Nasir *et al.* 2007) have been utilized as excellent adsorbent for Lead removal.

Removal of ZINC By using different by-products & By using chemically modified by-products

Zinc is one of the most precious element or nutrient for biological function of body. It is believed that it contain antioxidant properties which protects our skin from aging effects. It is used as a catalyst during rubber manufacturing. As a pigment, Zinc is used in cosmetics, plastics, wallpaper, photocopier paper, printing inks etc. Zinc is the 23rd most abundant element on the Earth's crust but due to industrialization its concentrations are rising unnaturally in ecosystem particularly in drinking water resulting in severe health problems such as Teratogenesis (Process by which congenital malformation are produced in an embryos or fetus), carcinogenesis and Mutagenesis (Process causing changes in the gene structure). To overcome these affects caused by intake of excess amount of Zinc it becomes urgent to remove this metal from waste water using different by-products. Various attempts have been carried out for the eradication of Zn ion from industrial waste water by using different by-product. An experiment was conducted to study the sorption capacity of immobilized plant stem-bark (IMSB) to discharge Zn(II), Cd(II), Pb(II), Mn(II), Cr(II) and Fe(II) ions using different parameters such as contact time, ionic strength, temperature, pH and initial metal ion concentration. The result showed that the sorption capacity of Zn(II), Cd(II), Pb(II), Mn(II), Cr(II) and Fe(II) by IMSB were 91.60%, 85.08%, 97.85%, 65.20%, 78.46%, and 78.52% respectively (Osemeahon *et al.* 2015). The biomass of *Azadirachta indica* bark has been used to remove Zn(II) ions from aqueous solutions using different parameters such as contact time, initial metal ion concentration, pH, biosorbent dosage and average biosorbent size. At pH 6 maximum Zinc biosorption occurred and it has been noted that percentage biosorption increases with increase in the biosorbent dosage. Data obtained from the experiment were tested with the adsorption models like Freundlich, Langmuir and Redlich-Peterson isotherms. Langmuir isotherm best fitted on the experimental data with maximum biosorption capacity of 33.49 mg/g of Zinc ions on *A. indica* bark biomass (King *et al.* 2008). Aloe Vera leaves powder (AV), multi walled Carbon nanotube (MWCNTs) and activated Aloe Vera powder (AAV) as an adsorbents have been used for the treatment of Zn(II) from aqueous solutions using various parameters such as adsorbent dosage, pH and contact time.

CONCLUSION

Presently these days water pollution is a curse to mankind and it has become essential to develop alternate approach which is not so expensive but at the same time equally effective to treat the waste water to eliminate heavy metals. This study is an attempt in that direction and the outcome is quite encouraging In terms of efficiency of removal/eradication of heavy metals from waste water stream by making use of very inexpensive medium of adsorption. Industrial scale replication of such lab studies is worth considering as at macro level it not only save the national medical outlay against the treatment of those who are suffering of poisoning of heavy metals but it also saves the most precious human resource of the country which otherwise can be utilized effectively.

Conflicts of interest: The authors stated that no conflicts of interest.

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