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Removal of lead from aqueous solution using low cost adsorbents: A Review

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Abstract
Heavy metals like lead, mercury, zinc, copper, nickel etc. present in waste water and industrial effluent is major concern of environmental pollution. Lead is highly toxic to human's body systems causing mental deficiency, brain damage, anemia as well as behavioural problems. According to Environmental Protection Agency (EPA) the permissible level of lead (II) in drinking water is 0.05 mg/L^{-1}. Contamination of water by toxic metal is a worldwide problem. Adsorption is an effective purification and separation technique used in industry especially in water and waste water treatments. Many methods and materials are used in heavy metal removal from water. These methods have several disadvantages and advantages.

Keywords: Lead, Aqueous solution, Low cost adsorbents, Adsorption.

Introduction
Environmental contamination by toxic metals is a serious problem worldwide due to their incremental accumulation in the food chain and continued persistence in the ecosystem. The heavy metals lead, mercury, copper, cadmium, zinc, nickel, chromium is among the most common pollutants found in industrial effluents. Even at low concentrations, these metals can be toxic to organisms, including humans [1]. The higher concentration of lead will cause severe damage to the nervous system and affects the function of brain cells [2]. For example Pb is highly toxic to humans; causing mental deficiency, brain damage, anemia, as well as behavioural problems [3] the greater Environmental awareness in both the public and regulatory sphere in recent years has necessitated greater treatment of industrial effluent [4]. Strict environmental protection legislation and public environmental concerns lead the search for novel techniques to remove heavy metals from industrial waste water [5]. The industrial activity is the major source of lead contamination in water [6] there are several techniques to remove heavy metals from waste water [7]. Lead is one of the industrial pollutants. Possibly enter to the ecosystem through soil, air, and water [8]. Activated carbon is one of the most popular adsorbents for the removal of metal ions from aqueous solutions [9]. Adsorption is an effective purification and separation technique used in industry especially in water and wastewater treatments [10]. Lead can cause central nervous system damage. Lead can also damage the kidney, liver and reproductive system [11]. In children, lead causes a decrease in intelligent quotient (IQ) score, retardation of physical growth, hearing impairment, impaired learning, as well as decreased attention and classroom performance [12]. The heavy metals are of special concern because they pose a significant danger to human health [13]. Dissolved and liberated metals in the environments [14] tend to accumulate in living bodies through the food chain and direct uptake [15] many naturally occurring materials have been investigated for assessing their suitability in controlling water pollution [16] water pollution due to heavy metals such as cadmium and lead are serious global problems [17] many methods have been developed to address these stringent environmental regulation which necessitate removal of heavy metal compounds from wastewater [18]. The permissible level of lead (II) in drinking water is 0.05mg/L^{-1} as given by the environmental protection Agency (EPA).meanwhile the level of lead (II) permitted by bureau of Indian Standards (BIS) is 0.1

mg/L^{-1} [19]. Hence proper treatment of industrial wastewater that is releasing lead into the aquatic and land systems is very important [20]. Increasing level of heavy metals in natural water bodies poses a serious threat to all living species including humans [21]. Amongst the present day's environmental issues, water scarcity and water pollution rank equal to climate change [22] so their removals from industrial waste waters remain an important challenge [23] many techniques tried out to remove heavy metals from wastewater [24]. The numbers of applications of metals for commercial uses continue to grow with the developments in modern science and technology [25] various biological treatments, both aerobic and anaerobic can be used for heavy metal removal [26]. Lead is widely used in storage battery, hot-dip galvanizing, ceramic glazing [27] due to rapid development and industrialization in many countries the level of industrial pollution have been steadily rising [28] while Pb(II) can bio accumulate through the food chain [29] the Royal society of Canada (1986) reported that human exposure to lead has harmful effects [30]. Therefore a very low concentration of lead in water is very toxic [31] heavy metals have been used in a variety of ways for many centuries for the past three centuries the production of heavy metals such as lead, copper, and zinc has increased exponentially [32]. According to the United Nations Organization reports there are 1.1 billion people still do not have access to safe supply of drinking water [33]. Lead has a high degree of accumulation upon continued exposure and a slow rate of removal when exposure ceases [34] waste water is a very complex mixture of different species with a variety of different physicochemical properties [35].

Health Impact of Lead Exposure

Impact of lead exposure in humans has been known to cause wide variety of health problems such as

- Various forms of blood disorders and Anemia.
- Rapid deterioration of brain and the nervous system.
- Reduced fertility both in men women
- Failure of the kidney and
- Alzheimer disease

In 2000, the allowable level of lead in drinking water was reduced from 0.6 ppm to 0.05 ppm. However, no level of lead is considered to be actually safe today [36].

Advantages of Adsorption Process and Adsorbents

Adsorption is an effective purification and separation technique used in industry especially in water and waste water treatments. A number of methods for toxic metal removal from waste water have been used. But most have several disadvantages such as continuous input of chemicals, high cost, toxic sludge generation or incomplete metal removal but the adsorption process has been found advantageous such as low cost of adsorbent, easy availability, utilization of industrial biological and domestic waste as adsorbents, low operational cost, ease of operation compared to other processes. reuse of adsorbent after regeneration, capacity of removing heavy metal ions over wide range of pH and to a much lower level, ability to remove complex form of metals that is generally not possible by other methods, environmentally friendly cost effective and technically feasible. Adsorption process is the best process for removal of metals from waste water because it is simple, time saving and inexpensive involving no sophisticated apparatus. A definite need exists for low cost adsorbents which exhibit superior adsorption capacities and local availability [37].

Various Conventional Methods of Heavy Metal Removal

Electro dialysis

Electro dialysis (ED) is a membrane process during which ions are transported through semi permeable membrane under the influence of an electric potential. The membranes are cat ion or anion selective, which basically means that either positive ions or negative ions will flow through. Cation selective membranes are polyelectrolytes with negatively charged matter, which rejects negatively charged ions and allows positively charged ions to flow through [38].

- **Reverse Osmosis**

It is a process in which heavy metals are separated by a semi permeable membrane at a pressure greater than the osmotic pressure caused by the dissolved solids in waste water. The disadvantage of this method is that it is expensive [39].

Chemical Precipitation

Precipitation of metals is achieved by the addition of coagulants such as alum, lime iron salts and other organic polymers. The large amount of sludge containing toxic compounds produced during the process is the main disadvantage [39].

- **Ion – exchange**

In this process metal ions from dilute solutions are exchanged with ions held by electrostatic forces on the exchange resin. The disadvantages include – high cost and partial removal of certain ions [39].

Ultra filtration

They are pressure driven membrane operations that use porous membranes for the removal of heavy metals. The main disadvantage of this process is the generation of sludge [39].

- **Coagulation / Flocculation**

Coagulation and Flocculation are an essential part of drinking water treatment as well as waste water treatment. Coagulation is the chemical reaction which occurs when a chemical or coagulant is added to the water. The coagulant encourages the colloidal material in the water to join together into small aggregates called “flocs”. Suspended matter is then attracted to these flocs. Flocculation is a slow gentle mixing of the water to encourage the flocs to form and grow to a size which will easily settle out [38].

Relevant Literature

Adlan M.N. *et al*., 2005, the Investigated was conducted to determine the removal efficiency of heavy metals (Ni, Cd, Pb, and Zn) and colour from waste water using cheap available materials in Malaysia such as charcoal, coconut shell carbon and a mixture of these carbons with limestone. It was found results that a mixture of activated carbon and limestone had removed 92% of heavy metals and 85% of colour from synthetic waste water at a wide range of pH. When activated carbon was only used, 85% of heavy metals and 99% of colour were removed. For a mixture of charcoal with limestone, the removal efficiencies for heavy metals and colour were at 65% and 35% respectively [40].

O. Yavuz. *et al*., 2006, the removal of toxic cadmium (II) and lead (II) from aqueous solutions was study using calcite, which is inexpensive and widespread over the globe, as the effective inorganic adsorbent. The maximum adsorption capacities was found to be at 18.52 mg/g cd and 19.92 mg/g pb for natural calcite at 25 ^{0}C, respectively [41].

Omar W. and Itawi H.A., 2007, the investigated of adsorption potential of the kaolinite clay for the removal of lead ions from aqueous solutions was tested. The measured adsorption isotherms at the different temperatures 298.15K, 308.15K and 318.15K were found to be perfectly fit to the Langmuir isotherm equation [42].

Saleemi A.R. *et al*., 2009, The biosorption of lead (II) and chromium (VI) on groundnut hull was studied. The maximum biosorption capacity of lead (II) and chromium(VI) was found to be 31.54 ± 0.63 and 30.21 ± 0.74 mg g^{-1}, respectively. The optimum pH for lead(II) and chromium(VI) removal was 5± 0.1 and 2 ± 0.1, respectively [43].

Adelaja O.A. *et al*., 2011, investigated of adsorption of Pb^{2+} onto ground moringa oleifera pods was studied under various conditions such as, pH, contact time, adsorbent dosage, and concentration of adsorbate. It was found to be maximum percent adsorption obtained after contacting the Pb^{2+} aqueous solution with ground moringa pods for 180 mins was 48.4% at pH 7. The study revealed that moringa pods are not a very good biosorbent for the removal of Pb^{2+} from waste water at pH [44].

Acharya J and Kumar U., 2011, A new adsorbent material for removing lead ions from aqueous solutions had been study. Studied that the sorption of Pb(II) from aqueous solution on chemically pretreated rice husk. Equilibrium time was found to be 60 min. The activation energy for the sorption of Pb(II), was found to be 20.02 kJ/mol indicating chemisorptions (45).

T.O. *et al*., 2012, investigate that Blighia sapida pod was utilized as a low cost adsorbent to remove Pb(II), Cd(II) and co(II) ions from aqueous solutions. It was found that maximum pH for pb(II), cd(II) and co(II) ions removal from aqueous solution occurred at 6 [46].

Liu J. *et al*., 2012, investigated on Sesame leaf, an agricultural solid waste, was used as low cost adsorbent for removal of Pb(II) from aqueous solution in batch mode. The adsorption capacity of the biosorbent was found to be 279.86 mg g-1, which was higher or comparable to the adsorption capacity of various adsorbents reported in the literature [47].

Adeyemi AF *et al*., 2012, investigated at the removal of $Pb^{2+}$and Cd^{2+} ions from waste water using palm kernel shell charcoal. The influence of several operating parameters such as the effects of adsorbent dose, time of contact of adsorbate with adsorbent, and agitation speed were investigated. The optimum found that the PKSC dose for cadmium and lead ions was 2.0 g/25ml of solution and the optimum shaking time were 45 and 50 min for cadmium and lead ions respectively [48].

Nwabanne J. T. and Igbokwe P. K., 2012, investigated on adsorption of lead(II) from waste water effluent using indigenous cellulose based waste biomass, such as nipa palm nut (NPN), palmyra palm nut (PPN), oil palm empty fruit bunch (EFB), oil palm fibre (OPF), and oil palm shell (OPS), as potential raw materials for the preparation of activated carbons was studied. The optimum pH was obtained at pH 6 for all the adsorbents. It was found of adsorption studied showed that activated carbons produced from OPS and NPN are the most efficient adsorbents for the removal of Pb2+ from aqueous solutions [49].

Singh D.K. *et al*., 2013, Investigated carbonization of raw biomass directs an attractive approach for improvement of lead(II) uptake from aqueous solutions. The maximum adsorption capacity was found of PSC for Pb(II) was 68.4 mg/g which is relatively large compared to most of the biomass adsorbents as reported. Desorption experiments were carried out using HCl solution and the recovery of Pb(II) from PSC was found 98.5% using 0.2 M HCl [50].

Trivedi N.*et al*., 2013, the investigated on performance of low cost adsorbent such as Neem leaves powder in the removal of cadmium (II) and lead(II) ion from aqueous solution is performed. It was found that the metal uptake capacity (amount of removal) of Cadmium (II) and lead(II) ion decreased, but the adsorption capacity (percentage of removal) increased with the decrease in the concentration of Cadmium (II) and lead (II) in the initial sample solution [51].

Seniunait J.*et al*., 2014, investigated that water contamination is an actual problem around the world. The main source of contaminated water is the industry. It was also found that coffee grounds are great adsorbent for heavy metal removal from aqueous solutions. Using the > 200 >m fraction of coffee grounds for copper removal the treatment efficiency is 85.9% when the metal concentration is 0.5 mg/l, while the lead is 87.2% [52].

Singh D.*et al*., 2014, studied batch experiments under different experimental conditions have been performed to evaluate the adsorption characteristics of red mud [53].

Pandey R. *et al*., 2014, Cucumissativus peel (CSP), was studied as a new adsorbent for Pb(II) removal from aqueous solution under several varying conditions such as pH, adsorbent dosage, and contact time. Maximum metal sorption was found to occur at initial pH 5.0. The adsorption capacity of CSP was found to be 28.25 mg/g for initial Pb(II) concentration of 25 mg/l at 25 ^{0}C [54].

Conclusion

Heavy metal pollution of waste water is one of the most important environmental problems throughout the world. Heavy metal may enter the human body through food, water, air or absorption through the skin when they come in contact with humans in agriculture and in manufacturing, pharmaceutical, industrial or residential settings. Heavy metals are dangerous to human body. Various conventional methods for heavy metal removal such as Electrodialysis, reverse osmosis, chemical precipitation, ultra-filtration, coagulation/flocculation, ion exchange etc. a Review of various processes and low cost Adsorbents used for the removal of lead from waste water. Various Parameters like contact time, pH, initial concentration have Significant effect on the heavy metal removal.

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