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Use of Low Cost Adsorbents for the Adsorption of Heavy Metals from Waste Water: A Review

Mrs. Varada V. Khati
Department of Chemistry, Gramgeeta Mahavidyalaya, Chimur, Maharashtra, India
varadakhati@gmail.com

Abstract: *This review is exploring the possibilities of removing Heavy Metal ions using several low-cost adsorbents from water and wastewater. In the past, several traditional methods like precipitation, evaporation, electroplating and ion exchange were employed for removing Heavy Metal ions. These processes were associated with various limitations. The process using low-cost adsorbents can be considered as an eco-friendly process. Large amount of natural and agricultural waste are available in the environment which can be used in the process of adsorption. Adsorption is a one of the effective method for removal of heavy metals. Based on the superior characteristics, such as cost-effectiveness, effective removal of heavy meals, and availability, the adsorption is definitely an efficient for removing Heavy Metal ions from water and waste water. This review provides a brief consideration of the relevant literature which exists on the low-cost adsorption for removing various heavy metal ions from polluted water and wastewaters. In order to understand the overall adsorption process of low-cost adsorbents, this review also includes the various existing adsorption models like adsorption isotherm along with the impact of various factors like contact time, temperature, pH on the process of adsorption.*

Keywords: Adsorption, Adsorption Isotherm, Heavy Metal ions, Low-cost adsorbent

I. INTRODUCTION

Heavy metals are often found in excess levels in ecosystems and are extremely toxic living organisms. Among these trace metals, Cu^{2+}, Pb^{2+}, Hg^{2+}, Zn^{2+}, Cd^{2+}, Cr^{6+}, Ni^{2+}, and As^{3+} have been considered as pollutants in the contaminated water. Small amounts of these metals can greatly injure the human body, affecting the central brain, kidney, and liver. Central nervous system disorders can in turn lead to coma and death.

Adsorption is the alternative process, for ions removal due to the wide number of natural materials or agricultural wastes available are in abundance in our environment. Due to High adsorption capacities, cost effectiveness and their abundance availability in nature the adsorbent is economical for water contaminant removal.

The term “adsorption” refers as a mass transfer process by which a substance is transferred from the liquid phase to the surface of a solid and becomes bound by physical or chemical interactions. Some parameters considered during the adsorption process including the physical and chemical characteristics of adsorbent and adsorbate, the concentration of adsorbate, temperature, pH and also contact time [1]. Adsorption process is one of the easiest, safest and more effective methods for metal removal from industrial effluents [2, 3]. This process is already established as a simple operation and an easy-handling process. Extensive studies have been undertaken in recent years with the aims of finding alternative economic adsorbents for water treatment. Various types of natural materials or wastes have been utilized as adsorbents for the adsorption process due to their potential adsorption capacities; either used naturally or with some modifications. The removal of heavy metals using low cost adsorbent is found to be more promising in long terms as there are many materials available locally and abundantly.

Previous research shows that there is growing interest of searching for a variety of materials such as low cost adsorbents including cocoa shell[4], rice husk[5], modified sawdust of walnut[6], papaya wood[7], maize leaf[8] rice husk ash and neem bark[9], fly ash[10] and tea-industry waste [11]. The presence of metal ions in the Water is of major concern due to their toxicity to many life forms. Hence, the conversion of materials which are locally available as low cost adsorbents is recognized as a potential and economic application for wastewater treatment.

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Adsorption capacity of heavy metals ions using various adsorbents

Type of Adsorbent used	Pollutant Removed	Different parameters discussed	Removal Efficiency	Reference
Cottonseed Carbon	Pb(II) and Hg(II)	Agitation time, pH and carbon dosage	Effective removal	[12]
Natural adsorbents apricot and pistachio tree leaves	Cr(VI)	The Langmuir, Freundlich and Temkin isotherms	More than 97% removal Cr(VI) at pH 2.	[13]
Activated carbon from Glossocardia linearifolia stem	Iron(II)	Kinetics of batch adsorption	166.7mg adsorbed per gram of adsorbent	[14]
Maize corncob	Iron	dosage (1-6 g), pH (3-8), contact time (30-180 min), initial conc.(0.5-5 mg/L)	Max. Efficiency 75% at pH 5.5, contact time 120 min and 3g of adsorbent.	[15]
Saw dust	Cadmium	pH 6 to 9, Temperature	99% Removal	[16]
Activated alumina	Nickel (II)	pH	Good Result	[17]
Activated carbon	Mercury (Hg^{2+} ion)	pH, Initial Conc.	-	[18]
Moringa Oleifera	Fe, Zn, Cu	pH, Contact time.	Cu-99.94, Zn-95.38, Iron – 96% at pH 8,7,2.5	[19]
MnO_2 Modified Coconut shell charcoal	Fe^{2+}	Shaking time, partical size	Effective to remove below 0.3 ppm conc	[20]
Acanthaceae activated carbon	Fe^{3+}	Thermodynamic and Kinetic study	Good adsorbent	[21]
Sponge iron industry waste material such as dolochar	Cr(VI)	Contact time, adsorbent dose, adsorbate concentration, pH	(≈95%) was obtained at pH of 2	[22]
Activated carbon was prepared from paper mill sludge	Cr(VI)	Adsorbent dosage, pH, contact time, metal ion concentrations, and temperature	maximum equilibrium uptake23.18 mg g1 at optimum pH ¼ 4.0, contact time of 180 min, and temperature of 45C	[23]
Polypyrrole-Based Activated Carbon	Lead (II)	initial ion concentration, pH, contact time, and adsorbent dose,	equilibrium was attained within 4 h at the optimum pH of 5.5	[24]
Nano silica spheres synthesized on calcium carbonate templates	Lead (II)	Effect of temperature, Effect of initial sorbate concentration, Adsorption isotherm, Kinetics	adsorption efficiency was 99.6% and 87.4%,	[25]
Agrowaste-Based Mixed Biomass (Potato Peels and Banana Peels)	Lead (II)	Contact time, Adsorbent dose, Adsorbate Concentration, pH	Optimum conditions for the removal of lead pH = 5, concentration = 10 ppm, adsorbent dosage = 1.0 g, and contact time = 2 h.	[26]

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Pristine and Aminopropyl-Modified Blast Furnace Slag	Lead (II)	Contact time, Adsorbent dose, Adsorbate concentration, pH	optimal conditions, a removal rate of 99.98% and an adsorption capacity of 49.99 mg·g −1	[27]

When Egg shell and Pongamia pinnata also known as Karanja tree bark as adsorbents for the removal of iron from groundwater it was found that for adsorption, as the concentration of adsorbent increases, more and more surface area will be available, which expose more active sites for the adsorption of iron[28]. The adsorbent like Sugarcane baggasse, Coconut coir are having very good tendency for removal of total iron[29]. The adsorption properties of coconut shell are due to the presence of some functional groups, such as carboxylic, hydroxyl, and lactone, which have a high affinity for metal ions [30]

When Adsorption Studies for Arsenic Removal Using Activated Moringa oleifera leaves is carried out it was found that it is an effective and alternative biomass for removing As(V) from aqueous solution due to high bio-sorption capacity[31]. Removal of lead ions from aqueous solutions using powdered corn cobs is also effective [32]. The adsorptive capacity depends on the adsorbent utilized nature also on type of wastewaters under treatment [33].

Adsorption Isotherm - Several models have been used to describe the experimental data of adsorption isotherms. The Freundlich and Langmuir models are the most frequently employed models. Adsorption Isotherm Study shows Langmuir and Freundlich isotherm models were applied to relate the distribution of adsorbate ions between liquid phase and solid phase [33]. Freundlich isotherm is valid for a heterogeneous adsorbent surface with a non-uniform distribution of heat of adsorption over the surface[34] and also involves in the multilayer distribution of the adsorbate with interaction amongst adsorbed molecules while Langmuir is valid for homogeneous adsorbent surface suggests monolayer adsorption on a homogeneous surface with a finite number of adsorption sites and without any interaction between the adsorbed molecules

II. CONCLUSION

The discharge of wastewater containing heavy metals from different industrial processes in to the environment has been the great issue in today's world. Various techniques for removal of heavy metals from water and waste water are available in the literature. A detailed review of severing low-cost adsorbents is discussed in this paper, which reveals the efficiency and scope of using low-cost adsorbents for removing Heavy metal ions utilizing an adsorption procedure. The adsorptive capacity depends on the nature and amount of adsorbent and the metal ions and also on type of wastewaters under treatment and pH of the solutions. Further investigative works need to be performed in order to develop an improved understanding of the adsorption processes of low-cost adsorbents as an alternative to endorsing the use of non-conventional adsorbents on a large scale and also on recovery of adsorbent.

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