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Removal of Heavy Metals from Wastewater Using Low Cost Adsorbents: A Review

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***Abstract*—The adsorption process is being widely used by various researchers for the removal of heavy metals from waste streams and activated carbon has been frequently used as an adsorbent. Despite its extensive use in the water and wastewater treatment industries, activated carbon remains an expensive material. In recent years, the need for safe and economical methods for the elimination of heavy metals from contaminated waters has necessitated research interest towards the production of low cost alternatives to commercially available activated carbon. Therefore there is an urgent need that all possible sources of agro-based inexpensive adsorbents should be explored and their feasibility for the removal of heavy metals should be studied in detail. The objective of this study is to contribute in the search for less expensive adsorbents and their utilization possibilities for various agricultural waste by-products such as seaweed, algae, chitosan, egg shell and saw dust etc. for the elimination of heavy metals from wastewater.**

***Keywords*— Adsorption, Agro-based, Algae, Bioaccumulation, Chitosan, Egg shell, Seaweed.**

I. INTRODUCTION

Environmental pollution is currently one of the most important issues facing humanity. It was increased exponentially in the past few years and reached alarming levels in terms of its effects on living creatures. Toxic heavy metals are considered one of the pollutants that have direct effect on man and animals. Industrial wastewater containing lead, copper, cadmium and chromium, etc for example can contaminate groundwater resources and thus lead to a serious groundwater pollution problem [1]. Water of high quality is essential to human life and water of acceptable quality is essential for agriculture, industrial, domestic and commercial uses. All these activities are also responsible for polluting the water. Billions of gallons of waste from all these sources are thrown to freshwater bodies every day. The requirement for water is increasing while slowly all the water resources are becoming unfit for use due to improper waste disposal. The task of providing proper treatment facility for all polluting sources is difficult and also expensive, hence there is pressing demand for innovative technologies which are low cost, require low maintenance and are energy efficient. The adsorption technique is economically favorable and technically easy to separate as the requirement of the control system is minimum. In this article, the technical feasibility of various low-cost adsorbents for heavy metal removal from contaminated water has been reviewed [2]. Instead of using commercial activated carbon, researchers have worked on inexpensive materials, such as coconut shell, sawdust, mango leaves, chitosan, egg shell, and other adsorbents, which have high adsorption capacity and are locally available. The results of their removal performance are compared to that of activated carbon and are presented in this study. It is evident that low-cost adsorbents have demonstrated outstanding removal capabilities for certain metal ions as compared to activated carbon. The adsorption process is being widely used by various researchers for the removal of heavy metals from waste streams despite its extensive use in the water and wastewater treatment industries; activated carbon remains an expensive material. In recent years, the need for safe and economical methods for the elimination of heavy metals from contaminated waters has necessitated research interest towards the production of low cost alternatives to commercially available activated carbon. Therefore there is an urgent need that all possible sources of agro-based inexpensive adsorbents should be explored and their feasibility for the removal of heavy metals should be studied in detail.

II. EXPERIMENTAL

Sources of heavy metals

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb). Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food

chain. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater [3].

The effects of heavy metals

Many of the products, which we have used contain heavy metals in them. Heavy metals are in the foods we eat, water we drink, and the air we breathe. We need very little of only a few heavy metals including zinc, copper, cobalt, manganese, molybdenum, vanadium and strontium. These good heavy metals become toxic to us when the quantity is too high and it takes really very little to be too much. On top of that, we take in more than twenty heavy metals which are non-essential for our healthy functioning. How do they get into the body? Heavy metals enter your body through drinking, eating, inhaling, and skin and eye contact. Once in the body they do damage on the cellular level by causing dangerous free radicals production. The damage that they do is on the cellular level, and can cause cancer and many other diseases.

Low cost adsorbents

Definition

In general, an adsorbent can be assumed as “low-cost” if it requires a little bit processing, is abundant in nature, or is a by-product or a waste from an industry. Natural material or certain waste from industrial or agricultural operation is one of the resources for low cost adsorbents. Generally, these materials are locally and easily available in large quantities. Therefore, they are inexpensive and have little economic value [4].

Chitosan

Chitosan and its derivatives are examples of value-added materials. They are produced from chitin, which is a natural carbohydrate polymer found in the skeleton of crustaceans, such as crab, shrimp. Chitosan is a polymer obtained from deacetylation of chitin.

Preparation of chitosan

Shrimp shell waste materials were collected from Khulna, Bangladesh. Shrimp shells were scraped free of loose tissue, washed with cold water and dried in sun for 2 days. Chitin was extracted from shrimp shell. The process mainly involved the following steps:

Demineralizations of Shells

In this step, the shells were suspended in 4% HCl at room temperature in the ratio of 1 : 14 (w/v). After 36 hours, the shells were quite squashy and were rinsed with water to remove acid and calcium chloride.

Deproteinization of shells

The demineralized shells were then treated with 5% NaOH at 90°C for 24 hours with a solvent to solid ratio of 12 : 1 (v/w). The residue was then collected and washed to neutrality in running tap water then it was dried in sun and the product is chitin. The preparation of Chitosan is simply deacetylation of chitin. Removal of acetyl groups from the chitin was achieved by using 70% NaOH solution with a solid to solvent ratio of 1 : 14 (w/v) at room temperature for 72 hours. The mixture was stirred after some times for homogenous reaction. The resulting chitosans were washed to neutrality in running tap water and rinsed with distilled water. Then filtered and dried in sun [5].

Egg shell

Egg shell is largely-crystalline calcium carbonate. The calcium comes partly from the hen's bones and when necessary the hen can mobilize 10 percent of her bone for the purpose.

Egg shell preparation

Natural and boiled hen and duck egg shells were washed with tap water several times then air-dried and incubated in hot air oven at 40o C for 30 minutes (because protein component in egg shell can denature at high temperature; > 40o C). Consequently, egg shells were ground to a powder in a grinder, and sieved to obtain between 60-100 mesh (0.25-0.104 mm) size particles.

Adsorption process

Adsorption experiments were carried out in batch mode at ambient temperature. Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a molecular or atomic film (the adsorbate). Adsorption is operative in most natural physical, biological, and chemical systems, and is widely used in industrial applications such as activated charcoal, synthetic resins and water purification. Similar to surface tension, adsorption is a consequence of surface energy. Adsorption is usually described through isotherms, that is, functions which connect the amount of adsorbate on the adsorbent, with its pressure (if gas) or concentration (if liquid). [Ong pick sheen]. Describing process of adsorption, namely Freundlich isotherm, Langmuir isotherm, BET isotherm, etc. We will deal with Langmuir isotherm in more details:

Langmuir isotherm

In 1916, Irving Langmuir published an isotherm for gases adsorbed on solids, which retained his name. It is an empirical isotherm derived from a proposed kinetic mechanism. It is based on four hypotheses:

i. The surface of the adsorbent is uniform, that is, all the adsorption sites are equal.
ii. Adsorbed molecules do not interact.
iii. All adsorption occurs through the same mechanism.
iv. At the maximum adsorption, only a monolayer is formed: molecules of adsorbate do not deposit on other, already adsorbed, molecules of adsorbate, only on the free surface of the adsorbent [7].

III. RESULTS AND DISCUSSION

The present investigation shows that the low cost adsorbents like sawdust, egg shell and chitosan, seaweed, algae can be used as an effective adsorbent for the treatment of wastewaters containing metals like chromium (VI), iron (III), nickel (II) and mercury (II). Adsorption dynamics, isotherms, pH effect and adsorbent dosage on the removal of metals for all the adsorbates were examined. The effect of adsorbent dosage on the adsorption of metals showed that the percentage of metal removed increased with increase in adsorbent dosage due to increased adsorption surface area. For all the adsorbents studied adsorbent dosage of 1 g – 2 g/L was sufficient for adsorption of 90% of the initial metal concentration [8].

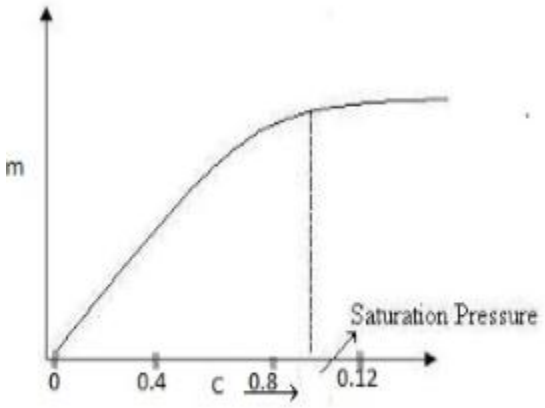

Fig. 1: Langmuir adsorption isotherm

IV. CONCLUSION

The analyses of the results indicate that egg shell, chitosan,etc. like 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 choosing the adsorbent amount precisely. The concentration of heavy metals has also an important effect on the treatment outcome. Chitosan, egg shell wastes are cheap material and thus it would be convenient to use it in industrial wastewater treatment plants.

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