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Removal of Zn (II) from Aqueous Solution Using Agro-based Adsorbents

Achla Kaushal[1] & Prof. S.K.Singh[2]
[1]Faculty in Chemical Engineering Department, Guru Nanak Dev Institute of Technology, Rohini, Delhi, India.
[2]Professor, Department of Environmental Technology, Delhi Technological University, Delhi, India

Abstract: *Of the 20 metals recognized as heavy metals found on earth, 11 have been classified as toxic. They are hazardous due to their mobility in aquatic ecosystems and their toxicity to higher forms of life. Zinc is an essential element and is required for a healthy body. But when consumed in excess, it is harmful for the body. It comes to water bodies from mining and manufacturing processes. Literature has shown that agro based adsorbents exhibit good potential in terms of good adsorption capacity and % removal to remove heavy metals including zinc from waste water. In the present study, removal of heavy metals by adsorption was carried out by adsorbents prepared from mango, bel and ashoka tree leaves. They showed a good potential in removing zinc ions from the aqueous solutions.*

1. Introduction

It is a common practice in India since ancient times to use leaves of a few trees in religious functions, for example, mango, banana, bel, ashok, peepal etc. This is because they possess ability to absorb excess carbon dioxide and hence purify the polluted air. Owing to its purifying nature, have been used to study their potential for waste water treatment. Studies have shown that agricultural waste possess a good adsorption capacity and % removal in a very low cost [1,2,3,4]. Agricultural waste consists of peels, seeds, stones of fruits and vegetables, wood, bark, leaves, roots and sawdust of trees. They have been classified as low cost adsorbents for their ease of availability, processing and regeneration [5]. Banana peels, mango leaves, onion skins, apricot stones, peepal leaves, neem leaves etc. have been investigated for their ability to remove heavy metal ions and they have shown excellent results in the given cost of operation [6,7,8]. Keeping in mind the success of agricultural waste in waste water treatment, the present study was conducted with mango, bel and ashok tree leaves to study their ability to remove zinc ions from aqueous solution

Zinc is a heavy metal, but is essential for a healthy body [9]. But it is harmful when consumed in excess with contaminated water. It comes to water bodies from mining and industrial effluents such as automobile industry, rubber, paints, pigments and iron and steels, plastics, cosmetics, photocopier paper, wall paper, printing inks, pharmaceuticals and metal industries containing high amounts of zinc. Safe dosage of zinc for human body is at about 100 mg/day. Ingestion of greater than 225 mg of zinc causes toxicity. Excessive absorption of zinc can suppress copper and iron absorption and cause nausea, burning sensations, pain, cramps, watery or bloody diarrhoea, shortness of breath, low blood pressure etc. Hence removal is zinc from polluted water is must [10,11,12,13].

2. Materials and methods

2.1. Preparation of Adsorbent

Mango, bel and ashok tree leaves were collected from Rohini, Delhi, India. Leaves were Sun dried for 5 days, oven dried at 200 ^{o}C for six hours in hot air oven separately. Dried leaves were powdered in a grinder and washed several times with distilled water till all the coloured impurities removed, again dried in hot air oven at 200 ^{o}C for 8 hours. The powdered leaves were sieved (Indian Standard Sieve) and various fractions of adsorbent was separately stored in air tight containers.

2.2. Preparation of stock solution

Stock solution was prepared by dissolving Zinc metal chips in a few drops of concentrated HCl and then diluting it to a solution of 1000 ml with distilled water. Solutions of required concentrations were prepared by further diluting the stock solution with distilled water. pH of the solutions was adjusted with the help of 0.1N HCl and 0.1N NaOH solutions.

2.3. Batch Adsorption Studies

Batch experiments were carried out to study the adsorption of zinc ions on mango, bel and ashok tree leaves at 20 ^{o}C. Aqueous solutions in the concentration range of 10 to 100 ppm with adsorbent dose of 2 to 20 g/L in the pH range from 2 to 8 were agitated at 200 rpm at 22 ^{0}C for 2 hours. The mixture was then filtered and analyzed for zinc ion concentration with the help of AAS using air-acetylene flame. The amount of metal ions adsorbed on the surfaces of adsorbents was calculated from the difference between the initial and final concentrations of the solutions. Percentage removal of zinc from the solution after the batch adsorption was calculated as

% Removal = $[(C_i - C_o)/C_i]*100$ (Eq. 1)

Where C_o represents the final zinc ion concentration and C_i represents the initial zinc ion concentration in the solution in mg/g.

The equilibrium adsorption capacity (mg/g) is calculated as

$q_e = [(C_i - C_e)V]/m$ (Eq.2)

Where V is the volume of the solution in litres and m is the mass of the adsorbent (g) used [14].

3. Results and Discussions

3.1. Effect of pH

Adsorption of zinc on mango tree leaves was investigated in the pH range between 3 and 8. The effect of initial pH on % removal of zinc ions is shown in Fig. 1.

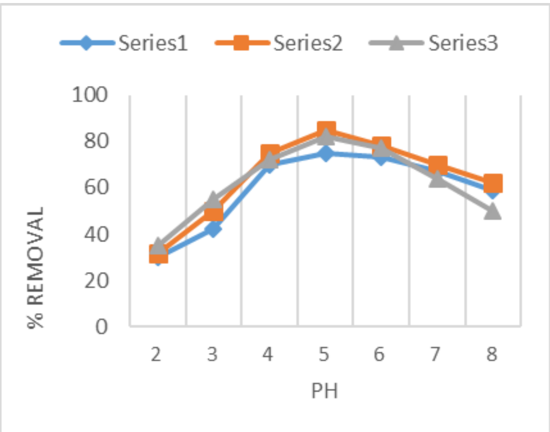

Fig 1: Effect of pH on % removal of zinc ions

Series 1,2 and 3 represent % removal of zinc ions by mango, bel and ashok tree leaves respectively with pH.

Chart suggests that the maximum zinc ion removal was obtained at pH 5. A maximum amount of 75%, 85% and 82% zinc metal ions were removed at pH 5 by mango, bel and ashok tree leaves respectively at 22^{o}C. % removal is sufficiently high between pH 4 to 6, but drops sharply at low pH values and gradually at higher pH values. % removal is lowest at pH 3. % removal increased with increase in pH due to negative charges at active sites on the surface [15].

3.2. Effect of initial zinc ion concentration in the solution

The amount of zinc removed by adsorption on to adsorbent surfaces depended largely on the initial metal ion concentration, as shown in the fig 2. % removal decreased with increase in metal ion concentration. Lower initial concentrations results in higher % removal due large number of available binding sites. As the total number of active sites on the adsorbent surfaces are occupied by the heavy metal ions with the course of time, % removal start to decrease.

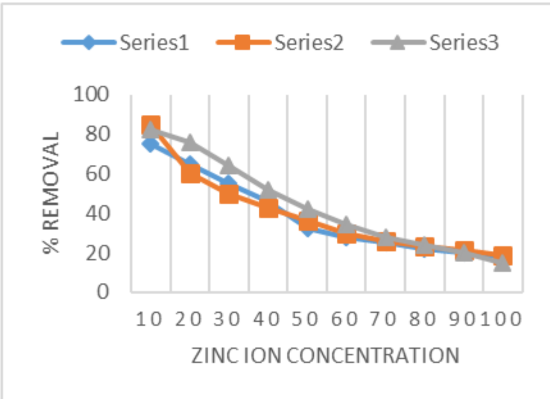

Fig 2: Effect of initial zinc ion concentration in the solution on % removal

Series 1,2 and 3 represent the % removal by mango, bel and ashok leaves powder respectively w.r.t. initial zinc ion concentration in the solution.

3.3. Effect of adsorbent dose

As shown in Fig. 3, the amount of zinc adsorbed increased as the amount of adsorbent increased from 2 to 20 g/L, as shown in. This is because the surface area available for adsorption increases to a large extent with increase in adsorbent dose, hence increasing the availability of active sites for the metal ion to adsorb. As the adsorbent dose is increased, the time taken for adsorption also decreases as the metal ions come in contact with freely available active sites, thus increasing the efficiency of the process.

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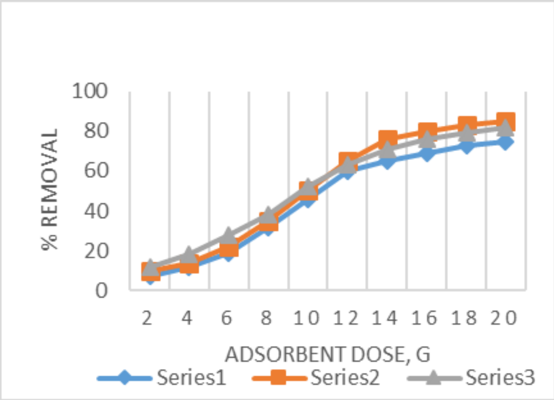


Fig 3: % removal of zinc from aqueous solution w.r.t. adsorbent dose

Series 1,2 and 3 represent the % removal by mango, bel and ashok leaves powder respectively w.r.t. adsorbent dose.

3.4. Effect of Contact Time

Fig.4 shows that the % removal of zinc ions increased with time till the equilibrium was reached. Equilibrium was reached in 60 minutes for mango tree leaves and 80 minutes each in case of both bel and ashok tree leaves, after which the concentration of zinc ions in the solution became constant. The adsorption of zinc ions was rapid in the beginning, but became gradual with time.

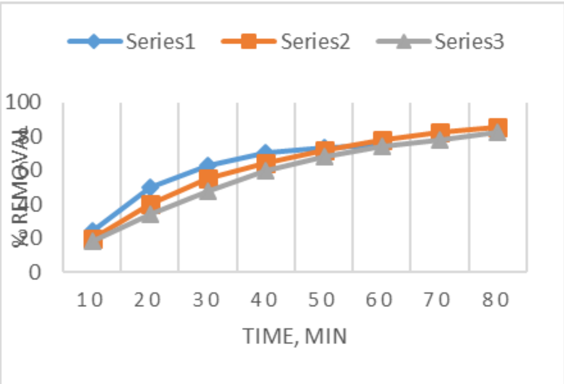


Fig 4: Effect of contact time on % removal of zinc ions from aqueous solutions.

Series 1,2 and 3 represent the % removal by mango, bel and ashok leaves powder respectively w.r.t. contact time.

3.5. Adsorption isotherms

The equilibrium data was tested with the help of adsorption isotherms, Langmuir, Freundlich and Temkin isotherms as shown in fig. 5.1, 5.2 and 5.3.

Fig 5.1: Langmuir isotherm

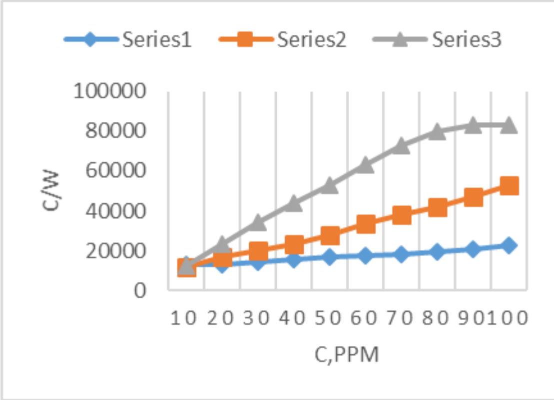


Fig 5.2: Freundlich isotherm

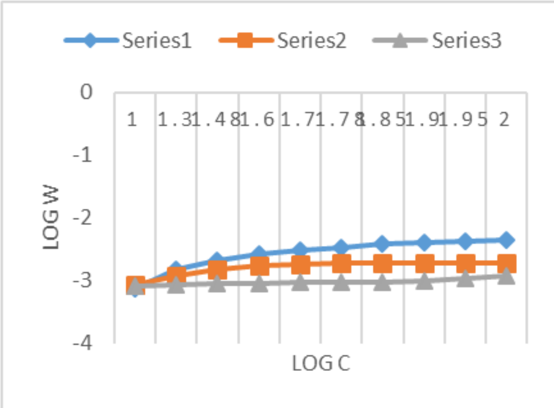
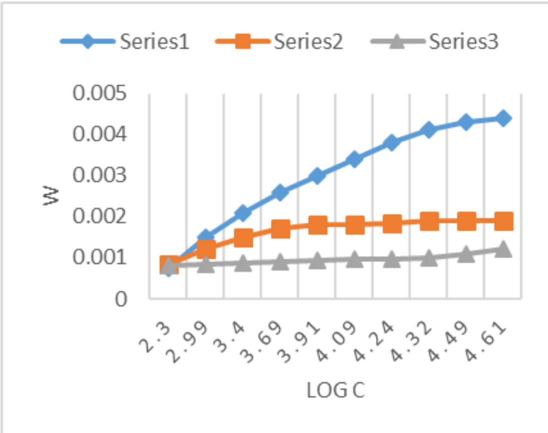


Fig 5.3: Temkin isotherm



Series 1,2 and 3 represent the % removal by mango, bel and ashok leaves powder respectively w.r.t. contact time.

The data fitted well into all the three isotherms. The K values of Langmuir isotherm obtained were .0085, .035 and .078 respectively for mango, bel and ashok tree leaves as adsorbents. Slope of Freundlich isotherm is 0.725, 0.33 and .0117 respectively for mango, bel and ashok tree leaves as adsorbents. The Temkin isotherm constant B_T is 50.23, 1304.12 and 159.68 respectively for mango, bel and ashok tree leaves as adsorbents. Since both the K value and the slope were less than 1 and the isotherms gave a straight line, the results represented a good fit of the equilibrium data. The Karl Pearson correlation coefficient (r^2) obtained were .998, .953 and .880 for Langmuir, Freundlich and Temkin isotherms respectively representing a good relation between isotherm variables.

4. Conclusions

The agricultural adsorbents, mango, bel and ashok tree leaves have shown a good potential towards removal of zinc, a heavy metal ion harmful for life when consumed in excess amount, from aqueous solution. The maximum % removal of the zinc metal ion obtained was 75%, 85% and 82% by mango, bel and ashok tree leaves as adsorbents even at very low temperature i.e. 20^{o}C. The Langmuir, Freundlich and Temkin isotherms were obtained linear indicating a good fit of the equilibrium data. Further, the K value of the Langmuir isotherm and the slope of Freundlich isotherm indicate the strongly favourable isotherms. It is concluded that the adsorbent can be recommended for treatment of industrial waste water, as it can be a good solution to treat contaminated water when used at optimum conditions given its low cost and ready availability.

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