“REMOVAL OF HEAVY METALS USING COMBINATION OF ADSORBENTS - A CASE STUDY USING INDUSTRIAL WASTE WATER”

PROJECT REFERENCE NO. : 37S1399

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Keywords: Electroplating, Adsorption, Heavy metal, adsorption, water hyacinth, waste water.

Introduction:

In the past century there has been a rapid expansion in industries. Several industrial processes generate metal containing wastes. Heavy metal contamination has been a critical problem mainly because metal tend to persist and accumulate in the environment. Copper, nickel, mercury, lead, zinc, arsenic, chromium, cadmium etc. are such toxic metals which are being widely used. They are generated by the dental operation, electroplating, tanning, textile, paper and pulp industry. The effluents being generated by these industries are rich in heavy metals and should be treated before being discharged into the common waste water.

In many cases harmful substances enter the food chain and are concentrated in fish and other edible organisms. As they move from one ecological trophic level to another, metallic species start damaging the ecosystem. They also become difficult to track as they move up in trophic levels. They accumulate in living tissues throughout the food chain. Due to biomagnification, humans receive the maximum impact, since they are at the top of the food chain.
The current physico-chemical processes for heavy metal removal like precipitation, reduction, ion-exchange etc. are expensive and insufficient in treating large quantities. They also cause metal bearing sludge which is difficult to dispose off. Some of these traditional methods are also extremely expansive. One of the most commonly used techniques involves the process of adsorption, which is the physical adhesion of chemicals on to the surface of solid. Recently, efforts have been made to use cheap and readily available agricultural wastes such as coconut shells, orange peel, rice husk, peanut husk and saw dust as adsorbents to remove heavy metals from waste water.

**Objectives:**

This project focuses on treatment of industrial waste water containing heavy metals using different adsorbents like coconut shell, rice husk, water hyacinth, shrimp shells and crab shells in combination. The main objectives are:

1. Removal of heavy metals from waste water using different adsorbents in combination.
2. Removal of heavy metals from waste water using water hyacinth as the adsorbent.
3. Optimization of various adsorption parameters like time of contact, particle size and adsorbent dosage.
4. Plotting of adsorption isotherms.

**Material and Methods:**

The aim of this study was to use water hyacinth as an adsorbent in removing heavy metal content from industrial waste water and to use the other adsorbents in combination to see the effect of adsorption. The adsorbents used for this project were as follows:

**Rice Husk, Coconut Shell, Shrimp Shells, Crab Shells and Water Hyacinth**

The adsorbents were obtained from different sources. They were cleaned using tap water to eradicate possible strange materials present in it (dirt and sand). Washed sample material was sun dried for 2-5 days and then crushed using ball mill to reduce the size.

**Industrial waste water sample:** The waste water was collected from the effluent discharge point of an electroplating industry. It was carefully bottled in a plastic container and was immediately taken to a laboratory for analysis.
Fig 1 Flow diagram for pretreatment of adsorbents

The heavy metals present in the waste water sample were analyzed using atomic absorption spectrometer [Biotechnology center, Government of Karnataka]. It detected the concentration of Cr, Zn, Pb and Cd. The initial concentrations of the metal ions present in the waste water were

Zn-5246ppm, Cr-100.823ppm, Pb-0.236ppm, Cd-0.006ppm

**Adsorption Study:** The adsorbents were mixed in different proportions as shown in the table 1.

<table>
<thead>
<tr>
<th>Rice Husk (%)</th>
<th>Coconut Shell (%)</th>
<th>Shrimp Shells and Crab Shells (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>25</td>
<td>50</td>
<td>25</td>
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<tr>
<td>50</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

**Table 1 Combination of adsorbents in different proportions**

Adsorption experiment was done by measuring 100ml of waste water and poured into a 250ml conical flask. 2g of previously prepared adsorbent mixture of different proportions as shown in table 2 was added to the waste water. The conical flask containing the waste water
and adsorbents mixture was placed on a wrist shaker at a room temperature for a period of 200 minutes. The suspension was filtered. Atomic Adsorption Spectroscopy (AAS) was used to analyze the concentration of different metal ions present in the filtrate.

Contact time chosen were 40, 80, 120, 160 and 200 minutes. Different dosages of the adsorbent mixture taken were 2g, 3.5g and 5g. This was done to study the effect of adsorbent dosage. Particle size was varied from 100 to 250 microns (100, 150 and 250 microns).

**Results**

**Adsorption Isotherm:** To model the adsorption behaviour, Langmuir isotherm was studied and correlated with the experimental data. The data for the uptake of Zinc by the adsorbents has been determined in accordance with a linear form of Langmuir isotherm equation:

\[
(1/\text{Cs}) = (1/\text{C}_{\text{max}}.K_L)(1/\text{C}^*) + (1/\text{C}_{\text{max}})
\]

The slope of the graph is represented by \(1/\text{C}_{\text{max}}.K_L\), while \(1/\text{C}_{\text{max}}\) shows the intercept of the graph on Y Axis. The constant \(C_{\text{max}}\) refers to the adsorption capacity and constant \(K_L\) is an indicator for the molecular size of adsorbate.

Volume of the waste water sample taken – 100 ml, Weight of the adsorbent taken – 5g

\[
\text{Cs} = (\text{Amount of Zn adsorbed} / \text{Weight of adsorbent}) \times \text{Volume of solution} \quad \text{(mg/g)}
\]

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Initial concentration of Zn (ppm)</th>
<th>Equilibrium concentration of Zn (C*) (ppm)</th>
<th>Amount of Zn adsorbed (Cs) (mg/g)</th>
<th>1/Cs ( x 10^{-3})</th>
<th>1/C* ( x 10^{-4})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>5246</td>
<td>5245.76</td>
<td>262.288</td>
<td>3.812602</td>
<td>1.906301</td>
</tr>
<tr>
<td>2.</td>
<td>5246</td>
<td>5245.81</td>
<td>262.3405</td>
<td>3.81183</td>
<td>1.90628</td>
</tr>
<tr>
<td>3.</td>
<td>5246</td>
<td>5245.75</td>
<td>262.2875</td>
<td>3.81261</td>
<td>1.906305</td>
</tr>
<tr>
<td>4.</td>
<td>5246</td>
<td>5245.85</td>
<td>262.2925</td>
<td>3.81246</td>
<td>1.90626</td>
</tr>
</tbody>
</table>

**Table 2 Calculated values for the plotting of adsorption isotherm**
From the above graph we get the following value

\[
\text{Slope} = \frac{1}{C_{\text{max}}K} = 50
\]

\[
\text{Intercept} = \frac{1}{C_{\text{max}}} = 3.81212 \times 10^{-3} \text{ g/mg}
\]

**Effect of Adsorbent Dosage on Adsorption**

The amount of adsorbents taken was 2g, 3.5g and 5g into industrial waste water and the results are shown in Fig 3. As the dosage was increased, the amount of heavy metal removed also saw an increase.

![Fig 3 Concentration profile for Effect of Dosage of Absorbent](image)

**Conclusion**

- For composition 1, it was seen that for contact time of 40 minutes, adsorption dosage of 5g and for adsorbent particle size of 100 microns the adsorption was maximum.
- When composition 2 was considered it was found that for dosage of 3.5g, the adsorption was maximum and it decreased when the dosage was increased to 5g. This decrease might have been due to desorption.
- The amount of Zinc removed due to adsorption was maximum for composition 3 at contact time of 120 minutes and that for chromium was 40 minutes. The increase in contact time for Zinc maybe because of change in operating conditions which would have led to desorption.
According to the study made, Water Hyacinth proved to be an effective adsorbent in par with the others.

The adsorption capacity is best explained using Langmuir Isotherm.

In the micrometer scale, the variation in particle size had no major effect.

Scope for Future Work

More experiments can be carried out for various other combinations of adsorbents and their effect on contact time, particle size and dosage can further be investigated to choose the best combination.

Further work can be carried out on column studies and designs of adsorption towers to see its applicability in the removal of heavy metals using combination of different adsorbents as such.

The individual adsorbents could be further studied in order to get a clear understanding of their surface properties, porosity, structural properties etc to determine their full potential for use as an adsorbent.