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Removal of Cadmium from Electroplating Industrial Waste Water using Natural Adsorbents

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Abstract - *Removal of heavy metal ions has received considerable attention due to the toxicological effects of these ions on ecosystem, human health and agriculture. Commercially activated carbon is widely used as an adsorbent for removal of heavy metal ions from industrial wastes though its cost is a restricting factor. The present study explores the effectiveness of activated carbon obtained from sources other than wood, such as groundnut shell, Indian beech and Onion skin for removal of cadmium ions from aqueous waste. Adsorption studies were carried out for removal of cadmium ions on activated carbon obtained. Adsorption studies were carried out at various pH values and for a range of initial concentrations of cadmium. Utilization of groundnut shell, Indian beech and Onion skin serves dual purpose of simultaneous waste eradication as well as cost effective pollution treatment process.*

Keywords: **Cadmium, Groundnut shell, Indian beech, Onion skin, adsorbent**

1. INTRODUCTION

Rapid industrialization has led to increased disposal of heavy metals into the environment. The tremendous increase in the use of heavy metals over the past few decades have inevitably resulted in an increased flux of metallic substance in the aquatic environment. The metals are special because of their persistency in the environment. At least 20 metals are classified as toxic, and half of these are emitted into the environment in quantities that pose risks to human health. Various treatment techniques available for the removal of cadmium from waste water include precipitation, coagulation and flocculation, ion exchange and reverse osmosis. Most of these methods having high investment and expensive chemicals. Adsorption is the most effectively used technique for removal of heavy metals. These ions are toxic in nature and hazardous to human health. Minimization of hazardous associated with drinking water has played important role in the development of various technologies for waste water purification namely, adsorption, filtration, etc.., most of these methods are used for removal of heavy metals. Adsorption of heavy metal ions on activated carbon adsorbent is effective.

2. OBJECTIVE

- To treat the electroplating industrial waste water.
- To know the optimum dosage required for maximum removal of cadmium by varying dosage.
- To know the optimum pH, temperature, speed of maximum removal.
- To use the low cost waste material like groundnut shell, Indian beech, Onion skin as adsorbents.
- To removal of heavy toxic materials.

3. BACKGROUND

3.1 Electroplating industry:

Electroplating units most widely scattered in urban areas. The electroplating industry waste water is one of the major industries which generate a large portion of waste water containing heavy metals. As effort has been made in the present study to evaluate potentials of groundnut shell, Indian beech for the elimination of cadmium from the synthetic factory and electroplating waste water are used as samples.

3.2 Flow diagram of manufacturing process of electroplating of Tin:

Source: [1] Frank Woodard, "Industrial waste treatment handbook", Butterworth-Heinemann publications new Delhi.

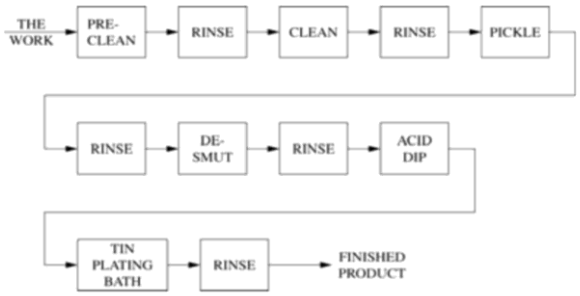

Figure 3.2 Electroplating of Tin manufacturing process

3.3 Effects of industrial waste water on natural water bodies and humans:

Untreated or inadequately treated heavy metal contaminated waste water effluents cause a variety of health

and environmental impacts, when released into receiving water bodies. In aquatic ecosystems, heavy metals greatly depress the number of living organisms. Heavy metals have negative effect on the growth of aquatic organisms and can cause serious upsets in biological wastewater treatment plants. The presence of heavy metal pollutants serve as great threats to soil and plants growing on such soils, with the consumption of such plants by animals and humans due to their entry into the food chain through biomagnifications and bioaccumulation, leading to severe detrimental effects. It is reported that the intake of toxic metals in vegetables and corn products accumulate in the kidney, leading to dysfunction. Some reports have linked skeletal damage (osteoporosis) in humans due to heavy metals. [2]

3.4 Characteristics of industrial waste water:

Source: [2] M.N.Rao,A.K.Datta, "Industrial wastewater treatment",third edition, oxford & IBH publishing Co Pvt.Ltd.

Parameters	Range	Standard
pH	2.2-3.8	6.5-8.5
Temperature	18-26	<40
TSS	675-1495	20
TDS	316-571	500
COD	371-571	250
BOD	64-102	30
Oil & grease	17-23	10
Sulphate	248-390	500
Phosphate	0.6-3.5	5
Chromium	21-47	0.05
Copper	8-21	0.5
Zinc	100-200	5
Nickel	72-243	2
Lead	10	0.2
Cadmium	12	1

Table 3.4 Characteristics of industrial waste water

All values are expressed in terms of mg/l except pH and temperature (^{0}c).

3.5 Details of Heavy metals:

a) Heavy metals: chromium, copper, zinc, nickel, cadmium, cobalt, arsenic, selenium, lead etc.., are heavy metals.

b) Sources of heavy metals: Common sources of heavy metals are mining and industrial wastes, vehicle emissions, lead-acid batteries, volcanic activity, forest fire etc.., volcanic eruptions produce hazardous impacts to the environment, climate and health of exposed individuals. Apart from the deterioration of social and chemical conditions and the gases (carbon dioxide, sulphur dioxide, carbon monoxide, hydrogen sulphide) released during eruptions, various organic compounds and heavy metals, such as mercury, lead and gold are also released. Cadmium is a toxic heavy metal that has been linked with cancers of the lung, pancreas, breast, prostate, endometrium, and urinary bladder. Cigarette smoking, in particular, provides exposure to high levels of cadmium, believed to be due to contaminated soil. Recently, cadmium has also been identified in e-cigarettes.

c) Uses of heavy metals: Electroplated cadmium is a robust and versatile metallic coating. Cadmium is a soft white metal that, when plated onto steel, cast iron, malleable iron, copper, and powdered metal, functions as a "sacrificial coating," corroding before the substrate material. To enhance the corrosion protection of cadmium plating, chromate conversion coatings can be applied over the plated metal. Chromium plating is a technique of electroplating a thin layer of chromium onto a metal object. The chromed layer can be decorative, provide corrosion resistance, ease cleaning procedures, or increase surface hardness. Sometimes, a less expensive imitator of chrome may be used for aesthetic purposes.

d) Effects of cadmium on Human health: Natural as well as anthropogenic sources of cadmium, including industrial emissions and the application of fertilizer and sewage sludge to farm land, may lead to contamination of soils, and to increased cadmium uptake by crops and vegetables, grown for human consumption. The uptake process of soil cadmium by plants is enhanced at low pH. Cigarette smoking is a major source of cadmium exposure. Biological monitoring of cadmium in the general population has shown that cigarette smoking may cause significant increases in blood cadmium levels, the concentrations in smokers being on average 4–5 times higher than those in non-smokers. Heavy metals are natural components of the earth crust that cannot be degradable, they are only toxic when they are not metabolized and synthesized by the body and when accumulated in the soft tissue of the body. As an example, lead is considered the number

one health threat to children, whose effects can last a lifetime. Some of such effects include child's growth, damage the nervous system, and cause learning disabilities, but also it is now linked to crime and anti-social behavior in children. A long term exposure to cadmium in humans may lead to renal dysfunction; while high exposure levels could cause obstructive lung disease, cadmium pneumonitis, bone defects, osteomalacia, osteoporosis and spontaneous fractures, increased blood pressure and myocardic dysfunctions.

4. MATERILAS AND EQUIPEMENTS

4.1 Groundnut shell (scientific name: Arachis hypogaea): Groundnut shell that has been considered as agricultural waste, which sometimes poses environmental threat can now be considered as a precursor for the production of activated carbon (A.C) as an adsorbent to adsorb metals in raw water, thereby we can convert waste to wealth. Utilization of groundnut shells serves dual purpose of simultaneous waste eradication as well as cost effective pollution treatment process. Being an oil seed crop, it contains 40% to 49% oil. In addition to protein, groundnut is good sources of calcium, phosphorous, iron, zinc and boron.

Fig 4.1 Groundnut shells

4.2 Indian Beech (scientific name: pongamia pinnata): It is commonly used and applied for heavy metal ions removal from water samples and aqueous solutions. In addition, adsorption process is well recognized as one of the most efficient methods for removal of heavy metal ions from their matrices. Adsorption is attractive due to its merits of efficiency, economy and simple operation. Activated carbon is commonly used as an adsorbent for water treatment because it has porous structure and large surface area.

Fig 4.2 Indian beech (Pongamia Pinnata)

4.3 Onion skin

Red onion skin is used in this study was collected from local paying guests of vasantha vallaba nagar,bengaluru. The onion skins were washed and sundried for 10 days.

Figure 4.3 Onion skin

4.4 Spectrophotometer

Spectrophotometer is an instrument that measures the amount of photons (the intensity of light) absorbed after it passes through sample solution. With the spectrophotometer, the amount of a known substance (concentrations) can also be determined by measuring the intensity of light detected.

Working: A lamp provides the source of light. The beam of light strike the diffraction grating, which works like a prism and separates the light into its component wavelengths. The grating is rotated as that only a specific wavelength of light reaches the exit slit.

Uses: Instrument used to measure the intensity of wavelength in a spectrum of light compared with the intensity of light from a standard source.

Figure 4.4 Spectrophotometer

4.5 Magnetic stirrer

A magnetic stirrer or magnetic mixer is a laboratory device that employs a rotating magnetic field to cause a stir bar immersed in liquid to spin very quickly, thus stirring it. The rotating field may be created either by rotating magnet or a set of stationary electromagnets, placed beneath the vessel with the liquid.

Working: A stir bar is the magnetic bar placed within the liquid provides the stirring action. The stir bar's motion is driven by another by another rotating magnet or assembly of electromagnets in the stirrer device, beneath the vessel containing the liquid. Stir bars are typically coated in Teflon, or less often in glass.

Uses: The magnetic stirrer has several applications and is actively used in many different industries. The main task it performs is to either stir or mix fluid samples. This is very useful in the food industry and chemical industry; besides which it is used in several other industries like biotechnology.

Figure 4.5 Magnetic stirrer

4.6 pH meter

A pH meter is a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as pH. The pH meter measures the difference in electrical potential between a pH electrode and reference electrode and so the pH meter is sometimes referred to as a potentiometric pH meter. The difference in electrical potential relates to the acidity or pH of the solution. The pH meter is used in many applications ranging from laboratory experimentation to quality control.

Figure 4.6 pH meter

5. METHODOLOGY

5.1 Preparation of adsorbents:

- Groundnut shell, Indian beech and onion skin have been used as adsorbents for removal of cadmium from the electroplating waste water.
- The groundnut shell, Indian beech and Onion skin were cut into small pieces, washed several times with distilled water.
- Then dried in oven at 100^0c for period of 24 hours.
- The adsorbents were dipped in 1N NaOH for a period of 10 hrs, washed several times with distilled water to remove liginin content and then dried.
- The adsorbents were again washed separately with double distilled water and dipped in 1N H_2SO_4 for 10 hrs to remove traces of alkalinity.
- The acid treated adsorbents are washed thoroughly with double distilled water there after the materials are dried in sun.
- The adsorbents were ground & sieved to a particle size of 150,600micrometer & stored in desiccators.

5.2 Preparation of solution:

The stock solution of cadmium was prepared by dissolving 2.74g of cadmium nitrate ($Cd(NO_3)_2.4H_2O$) in 1,000ml of double distilled water. All working solution of different concentrations was prepared by diluting the stock solution with distilled water.

5.3 Contact time:

The contact time was studied by shaking the adsorbent with the 50ml aqueous solution of cadmium different concentrations, at their neutral pH and at room temperature.

5.4 Adsorption dosage:

The effect of adsorption dose was studied by agitating 50ml of Cd solution at different concentration with different dose of adsorbents for a time greater than their equilibrium time at their neutral pH.

5.5 PH study:

The effect of pH on removal of cadmium was studied by using 50ml of cadmium solution of desired concentration adjusted to a desired initial pH value mixed with known concentration of carbon and agitated for a time greater than equilibrium time. The pH of Cd solution was adjusted using dilute solution NaOH.

6. RESULTS AND DISCUSSION

Following are the final result parameters of the cadmium removal by absorbents i.e. groundnut shell, Indian Beech (pongamia pinnata) and Onion skin.

Table 6.1 Initial characteristics of cadmium solution prepared

SL.NO	PARAMETER	VALUE FOR			UNIT
		Groun-dnut shell	Pongam-ia pinnata	Onio-n skin	
1	pH	5.69	5.80	5.69	-
2	Adsorption	0.971	0.97	0.97	ms/cm
3	Transmittance	10.6	10.6	10.6	%
4	Colour	Whitis-h	Whitish	Whiti-sh	-

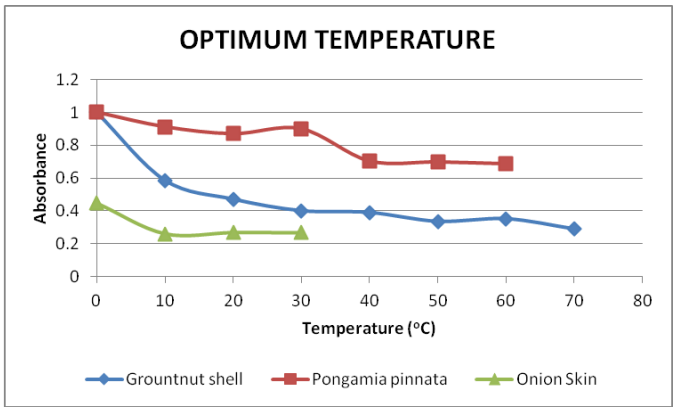

Figure 6.2 Optimum temperature

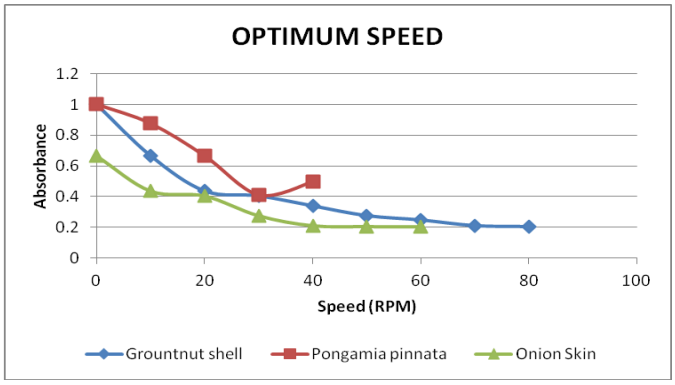

Figure 6.3 Optimum Speed

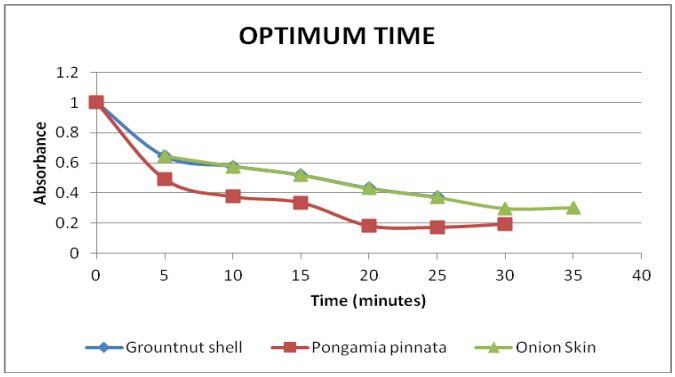

Figure 6.4 Optimum time

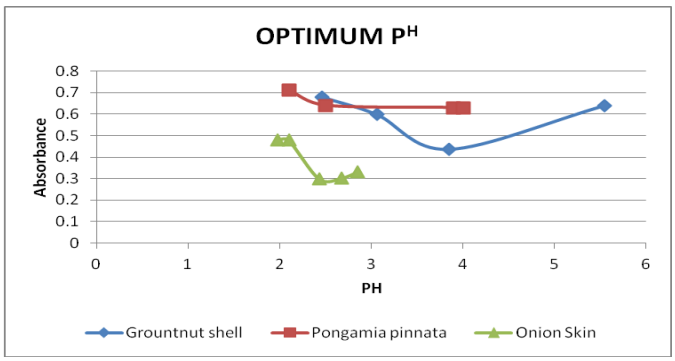

Figure 6.5 Optimum pH

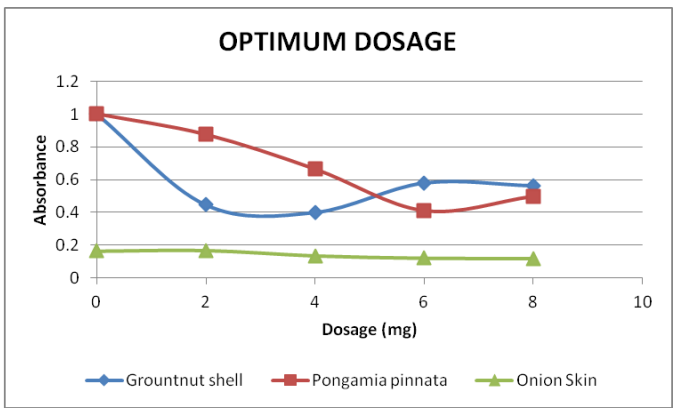

Figure 6.6 Optimum Dosage

Table 6.7 Final characteristics of cadmium solution

SL.NO	PARAMETER	VALUE FOR			UNIT
		Groun-dnut shell	Pongam-ia pinnata	Onio-n skin	
1	pH	2.2	3.9	2.1	-
2	Adsorption	0.285	0.195	.238	ms/cm
3	Transmittance	52	63	10.64 2.3	%
4	Colour	Partiall-y clear	Partially clear	Partially clear	-

Table 6.8 Optimum values

OPTIMUM VALUES	GROUNDNUT SHELL	PONGAMIA PINNATA	ONION SKIN
Temperature	60 ^{0}C	40 ^{0}C	30 ^{0}C
Speed	80 rpm	50 rpm	50 rpm
Time	25 minutes	20 minutes	30 minutes
Dosage	6 mg	6 mg	6 mg
pH	2.2	3.9	2.1

3. CONCLUSIONS

- The results shows that the optimum values at which the two adsorbents can be used effectively.
- The removal efficiency by groundnut shell was 70.64%.
- The removal efficiency by pongamia pinnata was 79.9%.
- The removal efficiency by Onion skin was 75.45%.
- By comparing the three adsorbents, pongamia pinnata is more effective in removal of cadmium.
- The optimum value of temperature, speed, time, dosage at which 'cadmium' removed are 40^{o}C, 50rpm, 20 minutes, 6 mg respectively.
- The usage of pongamia pinnata was found to be economical and efficient adsorbent for removal of electroplating metals from industries effluents.

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