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Removal of Chromium Ions (VI) from Industrial Waste Water using a Novel Bioadsorbent (Coral tree seeds)

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Abstract—*As we know, pollution serves to be as one of the most imminent and hazardous threat to mankind affecting on a global scale. Research has been conducted in numerous ways to minimize the amount of pollution. One of the important form of pollution is the increase of heavy metal pollution which is slow and interminable, as these metal ions (zinc, cadmium, lead, chromium) are also non bio-degradable. Also, the exposure of these heavy metals to mankind would bring harmful health issues. However, to counter the threat of heavy metal pollution, the technique of biosorption has proven to be more economical, effective and environmental friendly. In these current studies, we have chosen coral seeds as the bioadsorbant to facilitate the biosorption process for the removal of chromium ions. Adsorption studies were performed by batch experiments and the parameters such as contact time, temperature, concentration, dosage, pH and agitation speed were altered. It was found out that coral tree seeds served as a worthy bioadsorbant in the biosorbtion process to remove the heavy metal chromium ions and that it could be used for the removal of heavy metals in wastewater. Waste water containing the heavy metal chromium was collected from a tanning industry in Vellore, Tamil Nadu. After treating the effluent with the bioadsorbant, it was found to remove 92% of chromium from the waste water. Also, Adsorbtion isotherm and kinetic studies were performed and were found that the equilibrium adsorption data were satisfactorily fitted in the order: Langmuir > Temkin > Freundlich, in the case of chromium ions. Also, the kinetic data correlated well with the second order kinetic model for the biosorbtion studies of chromium using coral tree seeds as the bioadsorbant.*

Keywords: Chromium, isotherms, kinetics, coral seed, bioadsorbant.

I. INTRODUCTION

The earth's surface comprises of 70% water which is the most valuable natural resource. Life on earth would cease to exist without this invaluable compound, water. Although this fact is widely recognized, pollution of water resources is a common problem being faced today. Lakes, rivers and oceans are being polluted with many toxic man made contaminants, among which heavy metals play an important and hazardous role in the pollution of water (Shankar *et. al.*, 2005).

Pollution interacts naturally with biological systems. It is currently uncontrolled, seeping into any biological entity within the range of exposure. The most problematic contaminants include heavy metals, pesticides and other organic compounds which can be toxic to wildlife and humans in small concentration. There are existing methods for remediation, but they are expensive or ineffective. However, an extensive body of research has found that a wide variety of commonly discarded waste including eggshells, bones, peat, fungi, seaweed, yeast and carrot peels can efficiently remove toxic heavy metal ions from contaminated water. Ions from metals like mercury can react in the environment to form harmful compounds like methyl mercury, a compound known to be toxic in humans.

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In addition, adsorbing biomass, or bioadsorbents, can also remove other harmful metals like: arsenic, lead, cadmium, cobalt, chromium and uranium. The discharge of heavy metals into aquatic ecosystems has become a matter of concern in India over the last few decades. These pollutants are introduced into the aquatic systems significantly as a result of various industrial operations. Industrialization in India gained a momentum with initiation of five year developmental plan in the early 50's. The pollutants of concern include lead, chromium, mercury, uranium, selenium, zinc, arsenic, cadmium, gold, silver, copper and nickel. These toxic materials may be derived from mining operations, refining ores, sludge disposal, fly ash from incinerators, the processing of radioactive materials, metal plating, or the manufacture of electrical equipment, paints, alloys, batteries, pesticides or preservatives. Heavy metals such as zinc, lead and chromium have a number of applications in basic engineering works, paper and pulp industries, leather tanning, organ chemicals, petrochemicals fertilizers, etc. Major lead pollution is through automobiles and battery manufacturers. For zinc and chromium the major application is in fertilizer and leather tanning respectively (Amarasinghe, 2007). Over the few decades, several methods have been devised for the treatment and removal of heavy metals.

By far the greatest demand for metal sequestration comes from the need of immobilizing the metals 'mobilized' by and partially lost through human technological activities. It has been established beyond any doubt that dissolved particularly heavy metals escaping into the environment pose a serious health hazard. They accumulate in living tissues throughout the food chain which has humans at its top. The danger multiplies. There is a need for controlling the heavy metal emissions into the environment. Some of the environmental factors include, stricter regulations with regard to the metal discharges are being enforced particularly for industrialized countries, and toxicology of heavy metals confirms their dangerous impacts and the currently practiced technologies for removal of heavy metals from industrial effluents appear to be inadequate and expensive.

Biosorption is a physiochemical process that occurs naturally in certain biomass which allows it to passively concentrate and bind contaminants onto its cellular structure. Though using biomass in environmental cleanup has been in practice for a while, scientists and engineers are hoping this phenomenon will provide an economical alternative for removing toxic heavy metals from industrial wastewater and aid in environmental remediation. Biosorption can also be said as a metabolically passive process, meaning it does not require energy, and the amount of contaminants a sorbent can remove is dependent on kinetic equilibrium and the composition of the sorbents cellular surface. Contaminants are adsorbed onto the cellular structure.

Biosorption promises to fulfill the requirements. Biosorption uses biomass raw materials which are either abundant (seaweeds) or wastes from other industrial operations (fermentation wastes). The metal-sorbing performance of certain types of biomass can be more or less selective for heavy metals. That depends on the type of biomass, the mixture in the solution, the type of biomass separation, the chemical-physical environment. It is important to note that concentration of a specific metal could be achieved either during the sorption uptake by manipulating the properties of a bioadsorbent, or upon desorption during the regeneration cycle of the bioadsorbent. Biosorption process of metal removal is capable of a performance comparable to its closest commercially used competitors, namely the ion exchange treatment. Effluent qualities in the order of only ppm (mg/L) of residual metal(s) can be achieved. While commercial ion exchange resins are rather costly, the price tag of bioadsorbents can be an order of magnitude cheaper. The main attraction of biosorption is its cost effectiveness.

Agricultural by-products have been widely studied for metal removal from water. Peat, wood, pine bark, banana pith, soybean and cotton hulls, rice bran, saw dust, wool, orange peel have been demonstrated to remove heavy metals from waste water .The plant biomass is inexhaustible, cheap and non-hazardous material, which are specifically selective for heavy metals and can be easily disposed by incineration (Ozer and Ozer, 2004; Bailey *et. al.*, 1999; Ho, 2000).

The agricultural wastes such as banana bunch, tea waste and maize cob were used as bioadsorbents in the present study for the removal of heavy metals from waste water. The advantages of biosorption process include high efficiency at low metal concentration, operation success rate over a wide range of pH and temperature, easy recovery and the biosorption processes are reduced comparatively to other physio-chemical processes. Therefore, there is a need to look into alternatives to investigate a low-cost method which is effective and economic. For high strength and low volumes of waste water, heavy metal removal biosorbtion technique is a good proposition (Asheh *et. al.*, 2000).

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The novel bioadsorbant used here are the coral tree seeds. The scientific name of the coral tree name is known as *Erythrina* Indica. *Erythrina* is a genus of flowering plants in the pea family, Fabaceae. It contains about 130 species. The coral tree is highly known for its medicinal value. However, no further research has been done on the coral tree seeds with regard to biosorbtion. The coral trees are usually found along the coastal and inland districts in deciduous forests. In has been known that the coral tree seeds were used in ancient times to purify water.

Figure 1: Coral tree seeds

II. MATERIALS AND METHODS

A. Preparation of bioadsorbent:

The novel adsorbant was collected and washed with double distilled water. The novel adsorbant was then dried in the hot air oven at 100 °C for 24 hrs. The outer shell of the novel adsorbant was removed and crushed. The adsorbant was oven dried for 12h at 100°C. The crushed powder was put into a mechanical sieve to separate the particles based on their size. The separated samples were weighed and sealed with the polythene bags for the analysis of adsorption studies.

B. Stock solution preparation:

2.83g of potassium dichromate was weighed and transferred to a 1000 ml standard flask. Distilled water was added to the standard flask to dissolve the salt and water is further added up to the mark to obtain a solution of potassium dichromate. Adsorbate solutions for further studies were prepared by diluting the stock solution to the desired concentrations. The freshly diluted solutions were used for each biosorption studies. The metal solution was prepared in sterilized glassware.

C. Experimental procedure and conditions:

Initially, the bioadsorbant was submitted for SEM (scanning electron microscope) analysis and FTIR (Fourier transform infrared spectroscopy) analysis. Batch biosorption experiments were conducted in 250 ml conical flasks containing heavy metal ion solution and the required amount of distilled water to which the bioadsorbant was added. All the experiments were carried out at room temperature. At the end of the biosorption, samples were collected and filtered with the wattmann no.4 filter paper. The solution after filtration process was collected and analyzed to measure the chromium ion concentration present in that solution. The concentrations of the metal ions before and after sorption were determined using atomic absorption spectrophotometer by monitoring the absorbance for the metal ion used. Similarly, batch biosorption experiments were conducted and studied varying the different parameters such as concentration, agitation speed, time, pH, particle size and contact time. Further, adsorbtion isotherm studies and adsorbtion kinetic studies were done.

III. RESULTS

A. SEM Image:

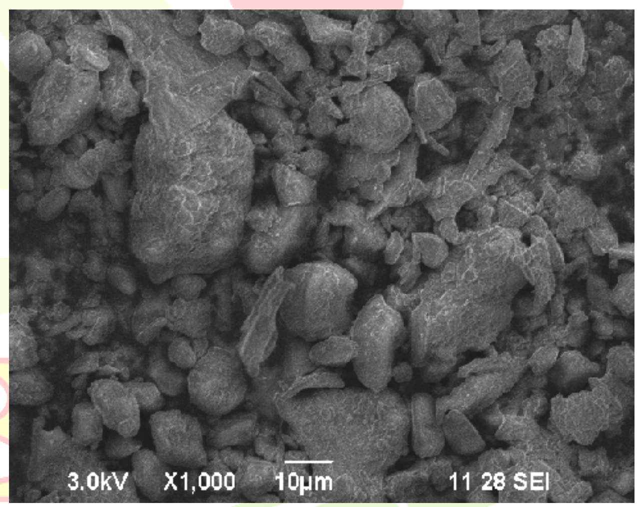

Figure 2: SEM image

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Ash content	1.8%
Thermal conductivity	0.605
Viscosity	0.89
Denisty	0.99

B. FTIR analysis:

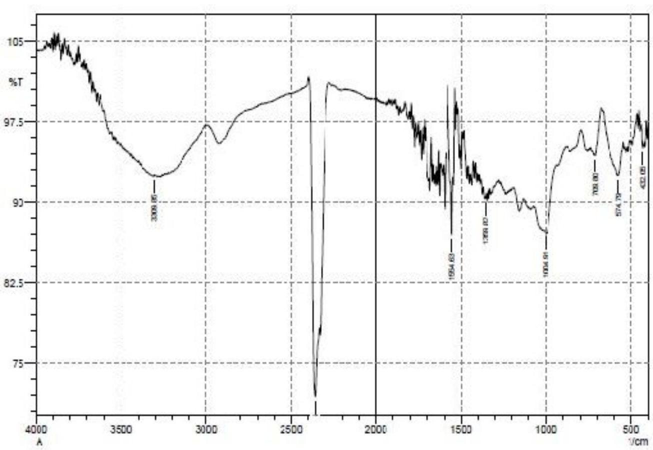

Figure 3: FTIR graph

The above FTIR analysis showed the presence amine group, OH, and C-O which play an important role in the binding of chromium (VI) ions (figure 3).

C. *Physical properties of the bioadsorbant:*

Table 1: Physical properties

D. Effect of various parameters:

Analysis was done for obtaining the optimum values of the various parameters such as bioadsorbant dosage, concentration, particle size, agitation speed, pH and contact time. The optimum concentration was 30 ppm (Figure 4). The dosage of the adsorbent was optimum at 2g (Figure 5). The optimum contact time is 120 minutes (Figure 6). The agitation speed was 300 rpm (Figure 7). The optimum mesh size was found to be 240# (Figure 8). The optimum pH was found to be 6 (Figure 9).

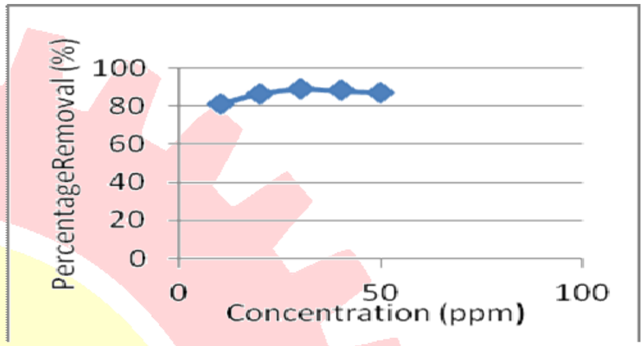

Figure 4: Effect of concentration

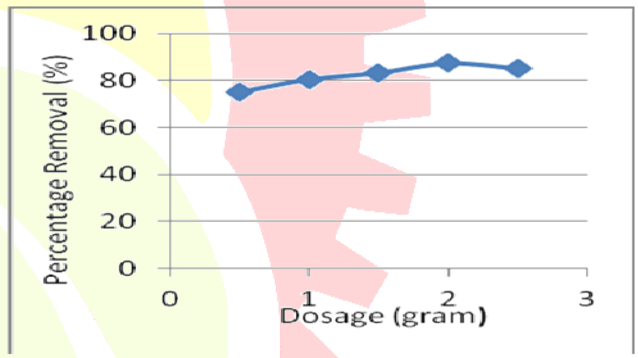

Figure 5: Effect of bioadsorbent dosage.

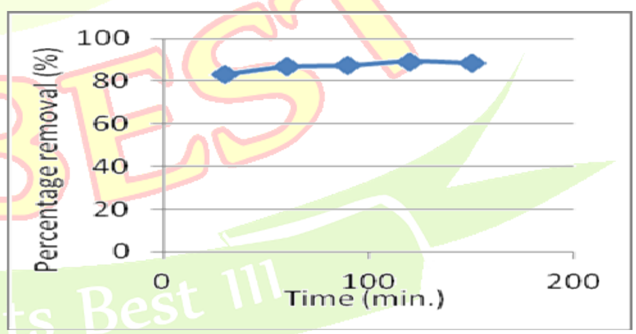

Figure 6: Effect of contact time

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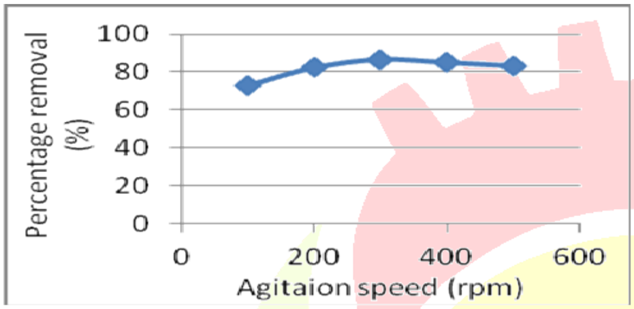

Figure 7: Effect of agitation speed

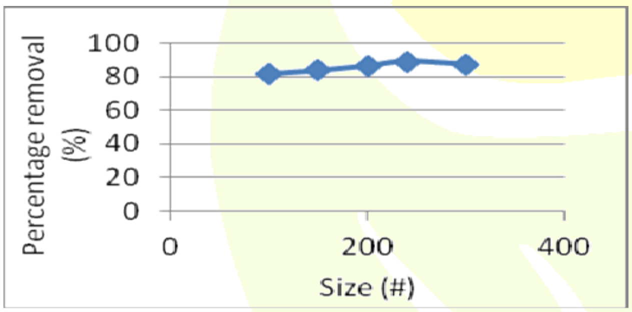

Figure 8: Effect of particle

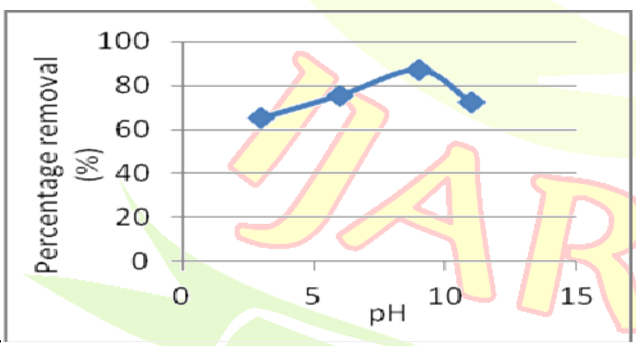

Figure 9: Effect of pH.

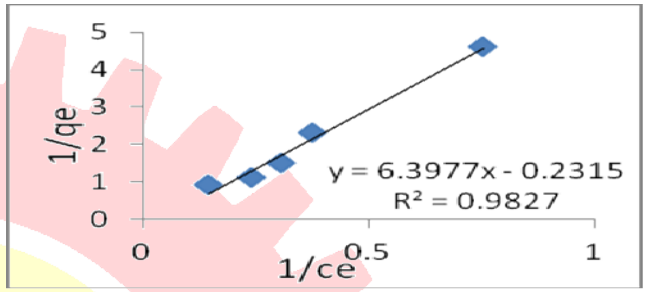

Figure 10: Langumir isotherm

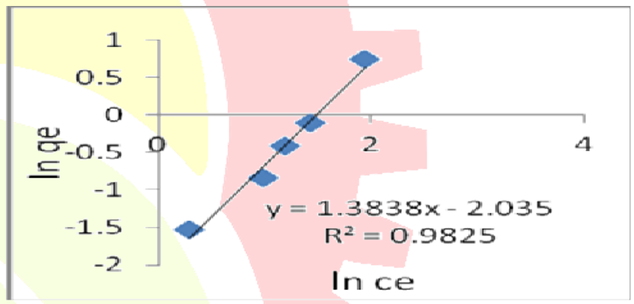

Figure 11: Freundlich isotherm

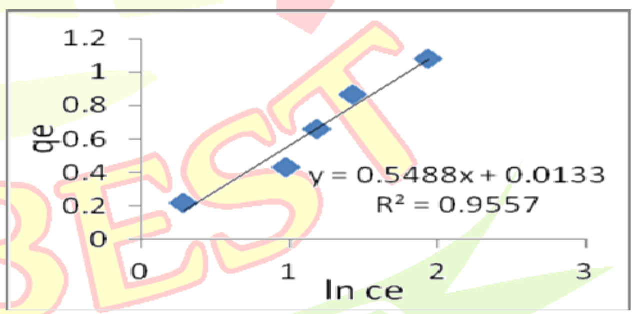

Figure 12: Temkin Isotherm

E. Adsorption isotherm studies:

Adsorbtion isotherm studioes were conducted and the equilibrium sorption data satisfactorily fitted in the order: Langmuir > Freundlich > Temkin, in the case of chromium ions.

F. Adsorbtion kinetic studies:

Adsorbtion kinetic studies were also done. The kinetic data correlated well with the second order kinetic model for the biosorbtion studies of chromium using coral tree seeds as the bioadsorbant.

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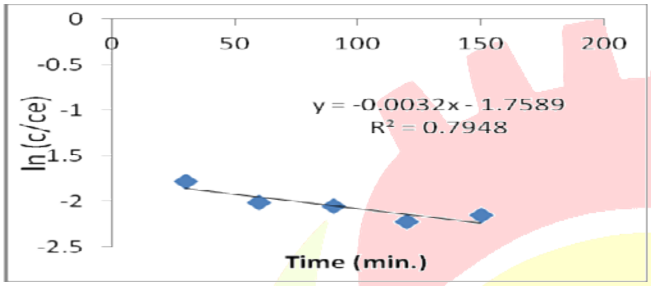

Figure 13: First order Kinetics

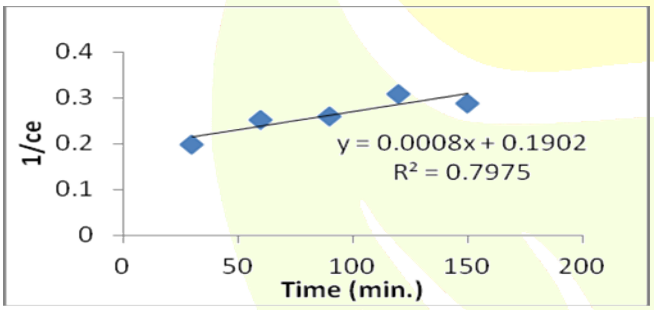

Figure 14: Second order kinetics

IV. Discussion

The present study shows that coral seeds serve as an effective bioadsorbant for the removal of chromium ions from aqueous solutions. The biosorption process is a function of the adsorbent and adsorbent concentrations, dosage, time, rpm, particle size, pH and temperature. Waste water containing the heavy metal chromium was collected from a tanning industry in Vellore, Tamil Nadu. After treating the industrial effluent with the bioadsorbant, it was found to remove 92% of chromium from the waste water. The equilibrium sorption data are satisfactorily fitted in the order: Langmuir > Freundlich > Temkin, in the case of chromium ions. Also, the kinetic data correlated well with the second order kinetic model for the biosorbtion studies of chromium using coral tree seeds as the bioadsorbant.

The economic feasibility of low cost adsorbents was also estimated in the present study. It was found that coral tree seeds were cheap and readily available in abundance locally. Coral tree seeds are also found to be one of the most economical bioadsorbents among all the other developed low cost adsorbents. The result is not only important for the industries but also to the planet Earth in general due to the resultant social and environmental benefits.

V. Conclusion

The intensification of industrial activity and environmental stress greatly contributes to the significant rise of heavy metal pollution in water resources making threats on terrestrial and aquatic life. The toxicity of metal pollution is slow and interminable, as these metal ions are non bio-degradable. The most appropriate solution for controlling the biogeochemistry of metal contaminants is the biosorption technique, to produce high quality treated effluents from polluted wastewater. Coral tree seeds were used as an effective bioadsorbant for the removal of chromium ions from aqueous media. Adsorption studies were performed by batch experiments as a function of process parameters such as bioadsorbant dosage, concentration, particle size, agitation speed, pH and contact time. The equilibrium bioadsorption data are satisfactorily fitted in the order: Langmuir > Freundlich > Temkin, in the case of chromium ions. The kinetic data correlated well with the second order kinetic model for the biosorbtion studies of chromium using coral tree seeds as the bioadsorbant. It was concluded that the bioadsorbent prepared from coral tree seeds to be a favorable bioadsorbent and easily available to remove the heavy metal chromium and can be used for the treatment of heavy metals in wastewater.

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