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PERFORMANCE EVALUATION OF Cr (VI) REMOVAL BY USING ACTIVATED CARBON AND WATER HYACINTH

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ABSTRACT

In the present investigation, the scope of commercially available powdered activated carbon (adsorbent) and water hyacinth (absorbent) as alternative cost-effective and efficient treatment methodologies have been warranted for a simulated aqueous environment. The present sorption studies were carried out in the batch reactors under control conditions such as contact time, pH, initial adsorbent concentration and adsorbent dosage. While water hyacinth as an absorption media indicated economic viability, isotherm analysis indicated adsorption by activated carbon as an excellent alternative and reliable technique for Cr (VI) removal.

Key words: Adsorption, Absorption, Hyacinth, Chromium, Environment, Isotherm.

INTRODUCTION

One of the most serious environmental problems faced by mankind is the toxic heavy metal contamination in surface waters resources. With the rapid pace of industrialization, hexavalent chromium has begun to pose a persistent concern in sustainable environmental management. Elevated levels of this heavy metal is found in effluents from a variety of sources such as electroplating industries, chrome tanneries, dye manufacturing, ink and pigment units, textiles, pickling industry etc.[1] The most important use of chromium is however in the production of steel where it is added to steel in the form of an alloy with iron known as Ferrochrome[2].

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Discharge of the untreated wastes from these manufacturing firms contributes chromium to water supplies in hexavalent and trivalent forms. While there is no evidence to indicate that trivalent form is detrimental to human health, hexavalent chromium poisoning is known to cause skin disorder and liver damage[3]. The permissible limit for hexavalent chromium, for discharge into municipal sewer and inland surface water are 2.0 and 0.1 mg/L, respectively[4].

Chromium bearing effluent treatment has been reported by methods such as precipitation, ion exchange, electrochemical reduction, reverse osmosis and adsorption. Amidst this, the most widely employed technique is Chemical precipitation. This technique however generates enormous quantity of metal hydroxide sludge[5]. Consequently it has undermined the overall effectiveness of the technique due to treatment and disposal problems associated with metal hydroxide sludge, thereby necessitating alternatives.

In the current context, performance evaluation of adsorption using activated carbon and absorption using water hyacinth, as alternative cost-effective and efficient treatment methodologies have been warranted for the removal of hexavalent chromium. The process of adsorption results in ions present in one phase tending to condense and concentrate on surface of another[6]. Among the adsorbents, powdered activated carbon (Fig. 1) has a very high metal adsorption capacity[7].

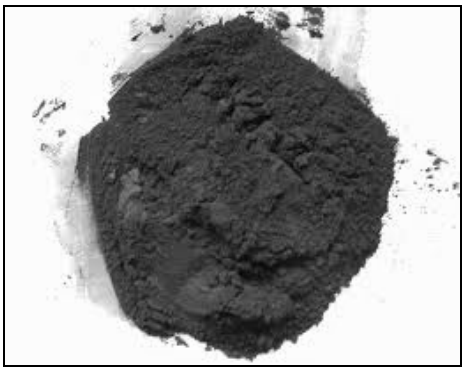

Fig. 1: Powdered Activated Carbon

Fig. 2: Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) (Fig. 2) is a perennial, fresh water aquatic vascular plant and the eighth fastest growing weed in the world. Water hyacinth grows in tropical regions in non-saline waters such as ponds, pools, lakes and reservoir luxuriantly at temperature 28-30^{o}C[8]. As Water hyacinth has extremely high growth rate and is abundantly found, it has been subjected in the present study to determine its ability to absorb and concentrate hexavalent chromium.

Methodology

The adsorption studies envisaged commercially available Powdered Activated Carbon [PAC] of size 20 µ being used in a controlled Batch scale laboratory setup. The removal efficiency was based on variation of contact time, pH, adsorbent dosage and initial concentration of adsorbate on removal process. The validity of Freundlich and Langmuir isotherm models concluded the adsorption study.

The biosorption studies by water hyacinth also involved batch studies conducted for a detention period of 10 days. The weeds having length around 0.28-0.35 m and approximately 500 g in weight were collected from Dalvayi Lake and allowed to regain its normal growth under controlled laboratory conditions for a week. Distilled water was added in order to compensate for water loss through plant transpiration, sampling and evaporation. The health and vigor of the plants were observed over the incubation period of this experiment. Initial and dry weight of the plant was assessed to find the moisture content. After study period, all the plant as a whole was taken out, dried at 110^{o}C in hot air oven and weighed. From the differential concentrations of chromium before and after treatment, the amount of chromium uptake was ascertained and expressed as mg/gm of dry water hyacinth plant tissues[9].

Chemical quantitative and qualitative analysis for the conjoint research was referred from Standard Methods[10].

The sorption experiments were investigated for varying initial concentrations ranging from 5, 10, 15, 20, 25 upto 100 mg/L and the uptake of chromium from the simulated sample were withdrawn at intervals of 1, 5, 10, 15, 20, 25, 30 and 60 minutes. The withdrawn samples were then filtered through Whatmann filter paper no. 42 and the filtrate was analyzed for residual concentration by s-diphenyl carbazide method, using visible spectrophotometer.

RESULTS AND DISCUSSION

Absorption studies

The uptake process-absorption or ‘biosorption’, in the current context involves transportation of metal ions across the cell membrane to be used in a building of new biomass or stored in vacuoles.

As can be observed from Fig. 3, the uptake process or removal efficiency was generally found to decrease with increase in the strength of chromium concentration. Above

20 mg/L, the removal efficiency was found to gradually decline as water hyacinth plants had started wilting due to chromium toxicity. Hence, at higher concentrations of Cr (VI), the plant growth was inhibited. However, Irrespective of the initial concentration, uptake of chromium generally was observed to increase with each passing day of incubation period, however beyond 9th day, the removal rate was found to either saturate or decline. On the 10th day, the maximum removal efficiency achieved was 80.16%, 68.88%, 53.25%, 38.89% and 24.84% for solution strengths 5, 10, 15, 20 and 25 mg/L, respectively. The initial pH of 6-7 which was maintained in the initial solutions was found to vary considerably according to the exposure time, on the downside.

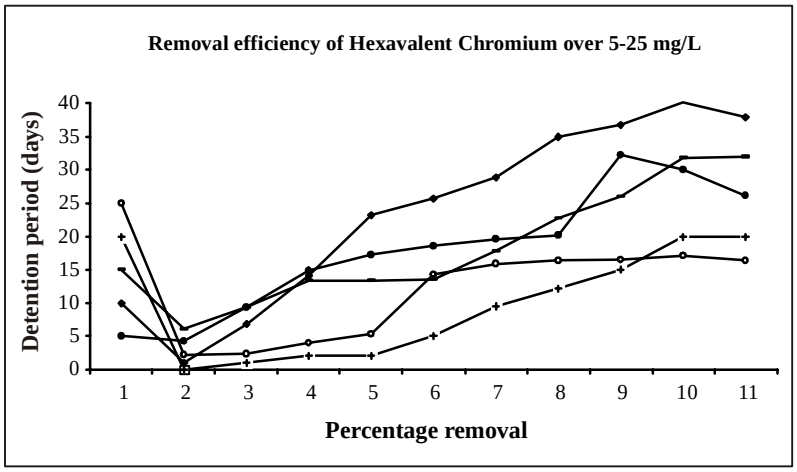

Fig. 3: Rate of effect of initial concentration on removal efficiency

Adsorption studies

Chromium adsorption by PAC for an initial chromium concentration of 10 mg/L as a function of stirring time for varying dosages of activated carbon [1-30 g] was carried out initially at neutral pH. From the Fig. 3, general observation envisaged the rate of uptake of chromium to be rapid in the early stages i.e., within 20 minutes and then further on to have reduced. As a result, the current experiment was restricted to only an hour.

Chromium adsorption by activated carbon as a function of activated carbon dosage (Fig. 4) at neutral pH also depicted a pattern where the rate of adsorption increased with increased dosage. The percentage removal increased up to 99.38% for dosage of 30 g/L, while it was a paltry 27.50% for a dosage of 1 g/L. Based on economics and rate of removal efficiency, an optimum dosage of PAC as 10 g/L was considered further on. Also as the rate

of adsorption and desorption was found to be insignificant after 30 minutes, all further experimental setups envisaged half an hour interval only.

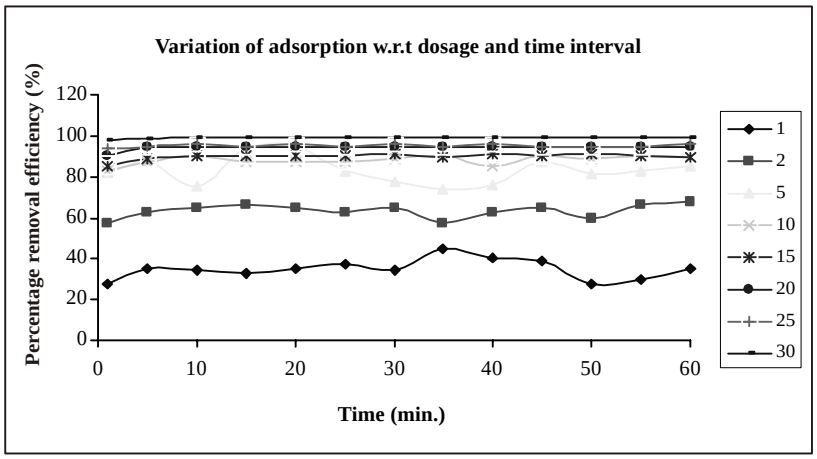

Fig. 4: Variation of adsorption w.r.t contact time and PAC dosage

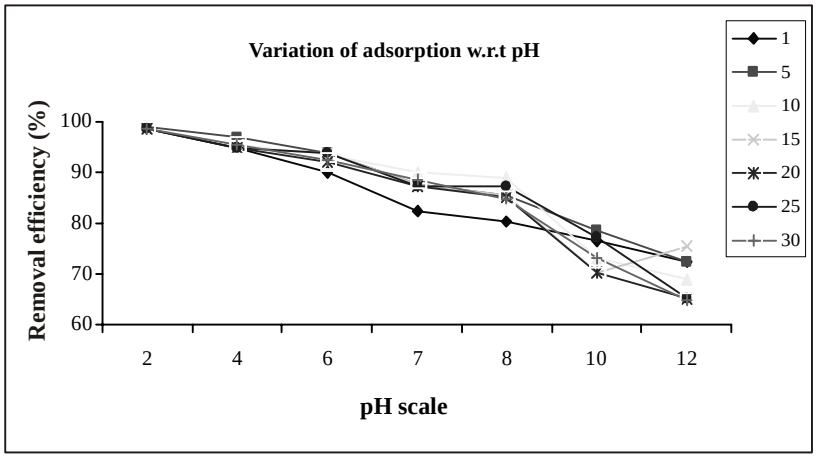

Fig. 5: Variation of adsorption w.r.t pH

Further studies as a function of pH for detention time of 1-30 minutes, activated carbon dosage of 10 g/L and initial chromium concentration of 10 mg/L revealed the percentage removal to be boosted from 65 to 99% when the pH was reduced from 12 to 2. Hence all further experiments envisaged a reduced pH scale of 2. The same has been indicated in Fig. 5. The effect of initial concentration of chromium on the sorption potential of the activated carbon was investigated over a wide range of chromium concentration

(10-100 mg/L). From the plot of percentage removal and amount adsorbed per unit weight of activated carbon at various initial chromium concentrations (Fig. 6 and 7), it's evident that the removal efficiency decreased with increased initial concentration. Removal efficiency was found to drop from 50.30 to 98.75% over the experimental range. When the initial concentration was increased from 10 to 100 mg/L, the amount adsorbed also increased from 0.99 to 5.03 mg/g, respectively.

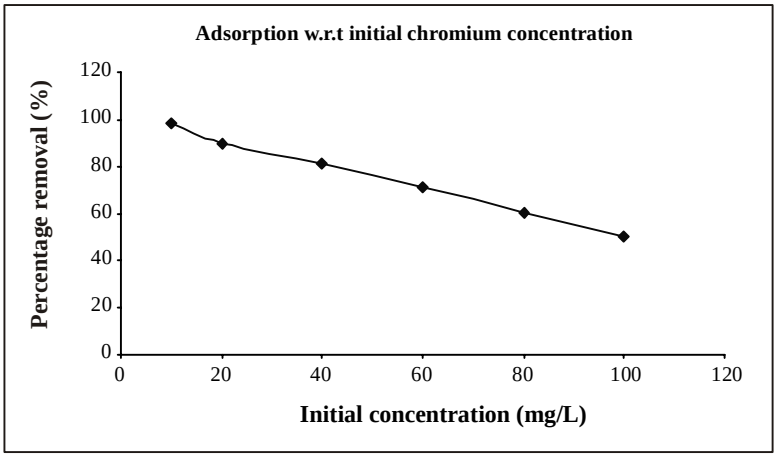

Fig. 6: Effect of initial concentration on the removal process

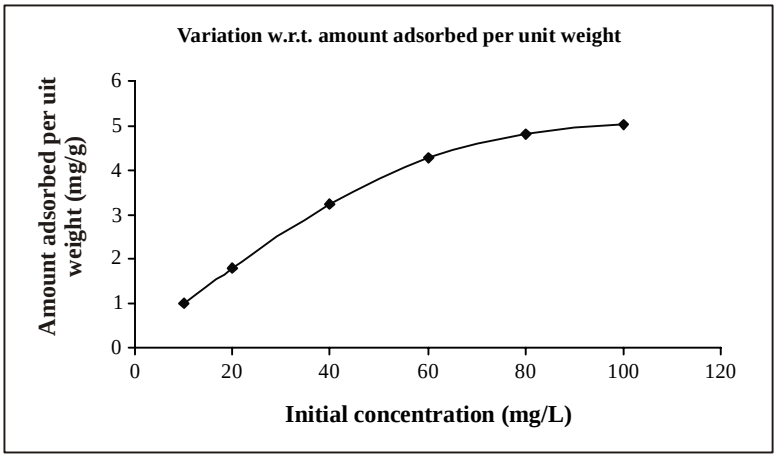

Fig. 7: Variation of initial concentration with amount adsorbed/unit weight of adsorbent

Isotherm study

For the present study, the Langmuir and Freundlich isotherm models were analysed for validity. As can be deduced from the plot of 1/Qe vs 1/Ce (Fig. 8), the adsorption process closely followed the Langmuir isotherm model as the R^2 value was found to be 0.9943, thereby indicating a strong linear relationship. This clearly confirmed monolayer adsorption. Unlike the Langmuir model, the Freundlich isotherm model advocates a multilayer sorption with a heterogeneous energetic distribution of active sites accompanied by interaction between sorbed molecules. Though the plot of log (Qe) vs log (Ce) (Fig. 9) indicated good adsorption, the R^2 value was found to be 0.9616, which was lower than that for Langmuir Isotherm. Hence, it may be deduced that the Freundlich model faltered in describing the relation between the amount of hexavalent chromium adsorbed and its equilibrium concentration in the solution.

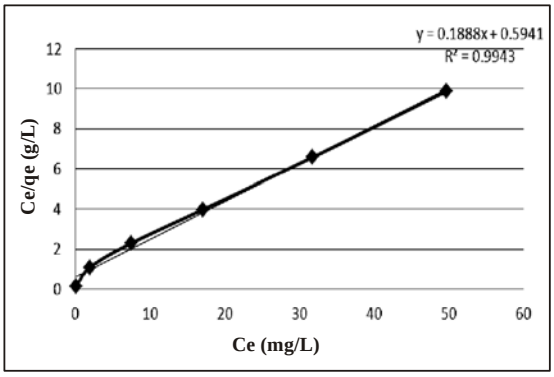

Fig. 8: Langmuir isotherm plot

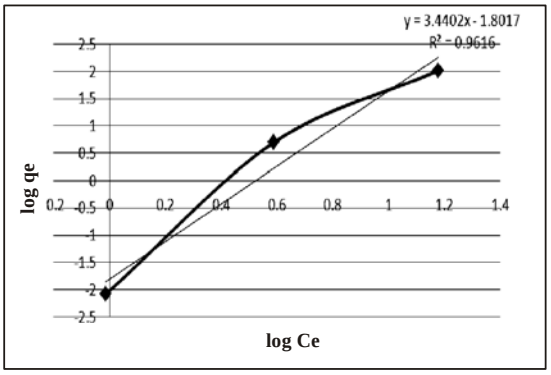

Fig. 9: Freundlich isotherm plot

CONCLUSION

Using batch reactors, the removal efficiency of commercially obtained powdered activated carbon as an adsorbent and water hyacinth as an absorbent was monitored for the removal of hexavalent chromium. The findings confirmed that both the removal processes were highly dependent on the dosage of removal media. Initially the rate of percentage removal was greater, and then reduced as contact time elapsed. While for bio-absorption studies, pH was maintained constant, it was varied for adsorption analysis and subsequently the removal was found to posses an inverse relationship. While water hyacinth as an absorption media confirmed the removal efficiency to be best for strength less than 20 mg/L, the isotherm studies confirmed monolayer adsorption. As a concluding note the present study affirmed that both activated carbon and water hyacinth were sufficiently efficient in removing Cr (VI).

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