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# Adsorption studies on *Parthenium hysterophorous* weed: Removal and recovery of Cd(II) from wastewater

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**Abstract**

The efficiency of parthenium weed as an adsorbent for removing Cd(II) from water has been studied. Parthenium is found to exhibit substantial adsorption capacity over a wide range of initial Cd(II) ions concentration. Effect of time, temperature, pH and concentration on the adsorption of Cd(II) was investigated by batch process. Pseudo-first-order and Pseudo-second-order models were evaluated. The kinetics data for the adsorption process obeyed second-order rate equation. The equilibrium data could be described well by the Langmuir and Freundlich isotherms. Thermodynamic parameters such as $\Delta H^\circ$, $\Delta S^\circ$ and $\Delta G^\circ$ were calculated. The adsorption process was found to be endothermic and spontaneous. The maximum adsorption of Cd(II) ions (99.7%) in the pH range 3–4 indicated that material could be effectively utilized for the removal of Cd(II) ions from wastewater. The desorption studies showed 82% recovery of Cd(II) when 0.1 M HCl solution was used as effluent.


*Keywords:* Parthenium; Adsorption kinetics; Adsorption dynamics; Langmuir isotherm; Freundlich isotherm; Breakthrough capacity

## 1. Introduction

Heavy metals are essential in small amounts for the normal development of animals and plants but most of them are toxic at higher concentrations. Heavy metals are generally introduced into the environment through natural phenomena and human activities [1]. The contamination of the existing water resources is increasing day by day with increasing industrialisation. The disposal of wastewater containing heavy metals is always a challenging task for environmentalists. Various methods available for the removal of heavy metals and organic pollutants from industrial wastewater are precipitation, ion exchange, electrochemical reduction, evaporation and reverse osmosis but these methods involve large liquid surface area and long detention period [2]. Adsorption on activated carbon is the promising processes considered during the past few decades for the removal of trace pollutants but it is costly and requires high cost to regenerate. Therefore there is a need for the development of low cost and easily available materials, which can adsorb heavy metals.

The ability of agricultural waste materials to adsorb traces of heavy metal ions has received considerable attention. Several materials in this category have been successfully used for the removal of heavy metal ions from industrial wastewater in our laboratory [3–7]. The main advantage of such adsorbents is that they do not need an expensive regeneration step since they can be discarded after use because of their low cost.

Cadmium has been classified as a toxic heavy metal that can cause serious damage to kidney and bones. It also causes high blood pressure, skeletal deformity and muscular cramps [8]. The World Health Organization has recommended a maximum permissible limit of $0.005\,\text{mg}\,\text{l}^{-1}$ Cadmium in drinking water. Numerous low cost adsorbents [9–12] have already been explored for the removal of cadmium ions from aqueous solutions.

In the present study, the sorption behavior of cadmium ions on parthenium was examined. *Parthenium hysterophorous* is popularly known as Congress weed, Star weed, Carrot weed, Gajar ghas or Ramphool is the most feared weed species [13]. It is one of the 10 worst weeds in the world. Parthenium is herbaceous annual or ephemeral plants, reaching a height of 2 m and flowering within 4–6 weeks of germination. The adverse effects of parthenium on humans as well as on animals have been well

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documented. It is known to cause asthmas, bronchitis, dermatitis and hay fever in man and livestock. The chemical analysis has indicated that all the plant parts including pollen contain toxins. The major component of these toxins being parthenin and other phenolic acids such as caffeic acid, vanillic acid, anisic acid, chlorogenic acid, parahydroxy benzoic acid, and para anisic acid are lethal to humans and animals. This weed is generally uprooted and destroyed by burning in air without any use.

We have explored the adsorption properties of this natural material, which can be utilized for the removal of Cd(II) ions from water. The dead biomass of parthenium in powder form may also be utilized to sequester Cd(II) ions in the soil. This technique may help to some extent in reducing the uptake of Cd(II) ions by agricultural crops.

## 2. Materials and methods

### 2.1. Preparation of adsorbent

Parthenium plants were collected from the university campus. They were washed with water to remove dust and dirt, etc., dried in an open-air oven at 60–70 °C. The dried mass was then crushed and sieved. The particles of mesh size 100–150 BSS were collected and kept in sealed bottles for study.

### 2.2. Adsorbate solution

Stock solution of cadmium was prepared (1000 mg $l^{-1}$) by dissolving the desired quantity of Cd $(NO_3)_2 \cdot H_2O$ (A.R. grade) in double distilled water.

### 2.3. Adsorption studies

Batch process was employed for adsorption studies. A 0.5 g adsorbent was placed in a conical flask having 50 ml Cd(II) solution and the mixture was shaken in a shaker incubator at 100 rpm. The mixture was then filtered at predetermined time interval and the final concentration of metal ions was determined in the filtrate by Atomic Absorption Spectrophotometer (GBC 902). Amount of Cd(II) adsorbed was then calculated by subtracting final concentration from initial concentration. Adsorption studies were carried out by varying the adsorbate concentration (10–100 mg $l^{-1}$), the agitation time (5–60 min), adsorbent amount (0.1–1.0 g) and adsorption temperature (20, 30 and 40 °C). A series of experiments with pH of the initial Cd(II) solution varying between 2 and 10 (by adding 0.1 M HCl and 0.1 M NaOH solutions) were also carried out using 0.5 g adsorbent at 20 °C. Adsorption isotherms were studied by varying the initial Cd(II) concentration from 10 to 100 mg $l^{-1}$ while weight of adsorbent in each experiment was kept constant (0.5 g). Each experiment was repeated three times and results were reported as average of them.

### 2.4. Desorption studies

Batch process was used for desorption studies with varying amount of adsorbent (0.25–1.0 g). The desired amount of adsorbent was taken in a conical flask and treated with 50 ml of Cd(II) solution (50 mg $l^{-1}$). After adsorption the solution was filtered and adsorbent was washed several times with distilled water to remove any excess of Cd(II). It was then treated with 50 ml of 0.1 M HCl solution. The amount of Cd(II) desorbed was then determined as usual. The same procedure was repeated with different adsorbent doses. Attempts were also made to desorb Cd(II) with 0.1 M NaCl in the same way.

### 2.5. Breakthrough capacity

A 0.5 g of adsorbent was taken in a glass column (0.6 cm i.d.) with glass wool support. One litre of Cd solution of 50 mg $l^{-1}$ strength was then passed through the column with a flow rate of 1 ml $min^{-1}$. The effluent was collected in 40 ml fractions and Cd(II) was then determined in each fraction by atomic absorption spectrophotometer.

## 3. Results and discussions

### 3.1. Effect of concentration

Parthenium is an effective adsorbent over a wide range of initial Cd(II) concentration. When the initial Cd(II) concentration was increased from 10 to 100 mg $l^{-1}$, the adsorption remains maximum (99.5%) and decreases to 97% only when initial concentration is further increased to 150 mg $l^{-1}$ (Fig. 1). The adsorbent can be utilized effectively for the removal of Cd(II) from water at lower as well as higher initial concentration of cadmium.

### 3.2. Effect of contact time

The effect of contact time on the adsorption of Cd(II) at 50 mg $l^{-1}$ initial Cd(II) concentration is shown in Fig. 2. The rate of adsorption is very fast initially and maximum removal of Cd(II) occurs within 20 min. The adsorption rate then decreases

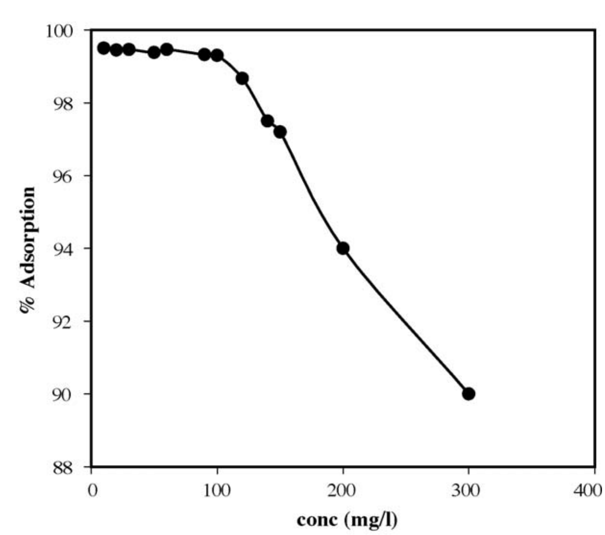


Fig. 1. Effect of initial Cd(II) concentration. Conditions: adsorbent = 0.5 g, temperature = 20 °C, pH 4.