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# An Assessment on Removal of Chromium from Water Using Activated Carbon Prepared from Coconut Shell

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**Abstract**

Heavy metals can be removed from water by activated carbon produced from coconut shells used as an adsorbent. This produced activated carbon has good adsorption capacity. This study presents an assessment of the potential of coconut shell in removing heavy metal ions from water. At first, we made a 2 mg/L Chromium (VI) solution as a water sample of heavy metal ions. Then we added different doses of activated carbon, which acts as an adsorbent made from burned coconut shell. Agitating them for different contact times in the rotary shaker intermittently. After the desired period, the mixture was filtered by Whatman No.44 filter paper and a syringe filter. The concentration of the filtrate of Chromium (VI) solution was measured by an Atomic Absorption Spectrophotometer machine. Secondly, 1.2 g/L of the activated carbon being the optimum adsorbent from the previous experiment, was added and agitated at 80 rpm for one hour. The pH was adjusted from 2-6 using HCI. The Whatman filter paper was used to filter the mixture and the filtrate analysed to determine the concentrations of Chromium (VI) ions. Finally, it was observed that the removal percentage varies between 50% and 74%. Increased adsorbent doses up to 1.2 g/L & agitating time in a rotary shaker increases the removal efficiency. In addition, that, at pH 6, maximum removal was observed (74%) using optimum adsorbent dosage & highest agitating time.

***Keywords:*** *Coconut shell; Activated carbon; Chromium (VI) solution; Batch Experiments; Contact time.*

## 1 Introduction

The Earth's crust is made up of heavy metals. They cannot be changed or destroyed. They get into our bodies through food, water, and air in a small amount. There are a lot of environmental problems now because there are so many heavy metals in the groundwater and the surface water. Many health problems can be caused by industries that do not properly treat their wastewater before dumping it into surface water bodies (Aravind et al., 2017). Cadmium (Cd) causes kidney damage, renal disorder, and is a human carcinogen, while copper (Cu) causes liver damage and insomnia, and nickel (Ni) causes dermatitis and nausea.

Chromium is one of the most prevalent metal pollutants found in the environment, primarily from businesses such as leather tanning, metal plating and alloying, and wood preservation (Amuda and Ibrahim, 2006). Chrome-based liquid and solid forms produced by the leather industry include chromium sludge, chrome-tanned leather shavings, and chrome leather trims. Chromium is commonly found in the environment as Cr (III) or Cr (VI). The chemical, biological, and environmental aspects of these two oxidation states differ. Cr (III) is an insoluble micronutrient that is needed for animal and human glucose, lipid, and protein metabolism. In contrast, Cr (VI) is mobile, poisonous, and mutagenic for most species. Cr (VI) is used in film, photography, galvanometric and electrical processes, metal cleaning, plating, leather, and mining (Ray, 2016). These industrial processes produce toxic waste in large amount. Cr (VI) is often found in soil and ground water due to its widespread in industrial use. It shortens seed sprouting of plants and retards photosynthesis and enzyme actions of algae.

## 2 Literature Review

There are numerous approaches for removing heavy metals from wastewater. Chemical precipitation, chemical oxidation, ion exchange, and membrane separation are examples of traditional heavy metal contamination treatment procedures (Kong et al., 2014). Among other techniques available, adsorption is one of the easiest and most cost- effective methods of water treatment. The treatment becomes even more cost-effective if absorbents can be prepared from renewable and cheap sources like agro-waste. Activated carbon produced from coconut shells can be used to remove heavy metals.

Activated carbons are extremely versatile adsorbents and have major industrial significance. They have high specific porosity and hence enhanced surface area. Thus, they are used in a wide range of applications, particularly those concerned with the removal of species by adsorption from the liquid or gas phase. Activated carbons can be composed of non-graphitic, non-graphitizable carbons with a highly ordered microstructure (Díaz and Gullón, 2006). Adsorption procedures that make use of activated carbon are favoured among the several types of chemical and physical methods that have been created for the treatment of effluents. This is because these processes are simple to implement and are highly effective. However, commercial activated carbon is both costly and non-renewable, which restricts its application in practical situations. This is especially true for situations involving large-scale settings. To overcome these drawbacks, production of activated carbon from cheap and renewable precursors, which are agricultural by-products and wastes like coconut husks and coconut shells, has been investigated.

Coconut shells are excellent materials to produce activated carbon due to their high carbon content and hardness (Ademola et al., 2015). Coconut shell is composed of carbonaceous materials like lignin, cellulose, and hemicellulose. The activated carbons that are made from coconut shells have a more compact and microporous structure than their counterparts that are made from coal. This is because the coconut shell precursor has a naturally porous structure, in contrast to the coal predecessor, which does not. This micro porosity itself makes it a very efficient adsorbent (Sun et al., 2017).

## 3.0 Research Objectives and Overview

The objective of this study was to prepare activated carbon from coconut shell and assess removal of Chromium (VI) ion from water using the activated carbon. The specific objectives were:

- To prepare activated carbon from coconut shell.
- To determine effect of adsorbent dosage in removing Chromium (VI) from water.
- To determine effect of contact time in removing Chromium (VI) from water.
- To determine effect of pH in removing Chromium (VI) from water.
- To determine the optimum values in removing Chromium (VI) from water.

## 4 Materials and Methods

The main objective of this research work was to evaluate the parameters in removing Chromium (VI) from water using activated carbon prepared from coconut shell. The overall methodology of this study is:

- Preparation of Activated carbon from coconut shell.
- Preparation of stock solution.
- Mixing of sample with activated carbon.
- Shaking of the sampling tubes for 5,15,30,60 minutes.
- Determination of concentration of Cr (VI) using AAS machine.
- Adjusting pH from 2-6 using HCI.
- Using optimum condition, again concentration of Cr (VI) is measured.

### 4.1 Activated Carbon Preparation:

In this study, activated carbon was prepared from coconut shell. The method used in this study was adopted from a number of similar studies (Dabrowski et al., 2005). The details of these steps are described below:

- Collection of coconut.
- Burning of coconut shell at $350^{o}$C.
- Oven drying at $105^{0}$C.
- Grinding of oven-dried shell.

#### 4.1.1 Collection of Coconut shell

Coconuts were purchased from a local store. The coconut shell was then physically removed, and the coconut shell was sliced into small pieces for burning.

#### 4.1.2 Burning of Coconut shell

The shell was folded with a double layer of aluminium foil to achieve thorough deoxygenation once it had been prepared for the burning purpose. Carbonization took place at $350^0$C for 30 minutes after being placed in an oven. The carbonized sample was then washed with distilled water.

#### 4.1.3 Oven-drying of shell at 105ºC

The sample was ready for oven-drying once it had been completely carbonized. The sample was placed in the oven dryer and remained there for 360 minutes at 105ºC.

#### 4.1.4 Grinding of oven-dried shell

Grinding was done after the carbonized sample was oven dried. To prepare activated carbon in the form of fine powder, the sample was grounded in a grinder.

### 4.2 Preparation of the Stock Solution

In this phase, we evaluated the removal of Cr (VI) by activated carbon. Cr (VI) stock solution was prepared by dissolving reagent Potassium Chromate ($K_2CrO_4$) in water.

Molecular weight of Potassium Chromate is 194.1903 gm, and the substance was 95% pure. Doing calculation, for making 1000 mg/L Cr (VI) stock solution, we need 3.9318 gm of the salt in 1L water. This stock solution was used to achieve desired Cr (VI) concentration in our batch experiments.

### 4.3 Batch Experiments

Batch experiments were carried out for assessing the removal of Cr (VI) from water by the activated carbon prepared from Coconut shell. The batch experiments were carried out in 50 ml tubes. The initial concentration of Cr (VI) in each tube was fixed at 2 mg/L. The dosage of activated carbon was varied from 0.5 to 1.4 g/L. Seven experiments were carried out with seven doses of activated carbon: (0.5, 0.6, 0.8, 1.0, 1.2, 1.3, 1.4 ) g/L. The batch experiments were designated as Exp.1, Exp.2, Exp.3, Exp.4, Exp.5, Exp.6 and Exp.7.After addition of required amount of Cr (VI) stock solution and activated carbon, the tubes were placed in a rotary shaker for shaking/mixing at 80 rpm. The shaking time varied from 5 to 60 minutes (5, 15, 30 and 60 minutes). After the desired shaking time, the contents of the tube were allowed to settle for 15 minutes. It was then filtered through a Whatman filter paper. The filtrate was then analysed for total Cr (VI) in an AAS (Shimadzu AA 6800) at pH= 2 adjusting HCL.

Secondly, over a pH range of 2-6, the effect of pH on adsorption on Cr (VI) ions was studied. For this study, 1.2 g/L of the activated carbon being the optimum adsorbent from the previous experiment, was added and agitated at 80 rpm for one hour. The pH was adjusted from 2-6 using HCI. The Whatman filter paper was used to filter the mixture, again the contents of the tube were allowed to settle for 15 minutes, and the filtrate was analysed an AAS (Shimadzu AA 6800) to determine the concentrations of Cr (VI) solution.

## 5 Results and Discussions

Table 1 presents the data from batch experiments carried out to assess the effect of Activated Carbon produced from Coconut Shell (and effect of mixing time) on removal of Cr (VI) from water. It should be noted that while performing these batch experiments, the Activated Carbon (adsorbent) was mixed in a specified volume of water, and specific volumes of this water containing the Activated Carbon was added to the 50 ml test tubes to achieve adsorbent concentrations varying from 0.5 to 1.4 g/L. We have designated these experiments as Expt.1 through Expt. 7.

Table 1. clearly shows the strong effects of adsorbent dose and equilibration/mixing time on the removal of Cr (VI) from water at 80 rpm shaking speed at pH= 2. For different doses of activated carbon, removal of Cr (VI) (present at an initial concentration of 2.0 mg/L) varied from about 29% (for Expt. 1) to 68% (for Expt. 5). Table 1.also shows that for a particular adsorbent dose, removal of Cr (VI) increases with increasing equilibration/mixing time. For example, for Expt. 7, removal of Cr (VI) (initial concentration 2.0 mg/L) varied from about 58% for 5 minutes of mixing time to about 66% for 60 minutes of equilibration time.

Table 1. Cr (VI) Concentration in filtered samples from batch experiments for different equilibration times (5, 15, 30, 60 min) at pH=2

| Dosage of Activated Carbon (g /L) | Experiment ID | Initial Conc. (mg/L) | Conc. after 5 minutes (mg/L) | Conc. after 15 minutes (mg/L) | Conc. after 30 minutes (mg/L) | Conc. after 60 minutes (mg/L) |
|---|---|---|---|---|---|---|
| 0.5 | Exp. 1 | 2.00 | 1.430 | 1.400 | 1.307 | 1.276 |
| 0.6 | Exp. 2 | 2.00 | 1.310 | 1.297 | 1.221 | 1.133 |
| 0.8 | Exp. 3 | 2.00 | 1.150 | 1.083 | 1.002 | 0.998 |
| 1.0 | Exp. 4 | 2.00 | 0.956 | 0.926 | 0.897 | 0.767 |
| 1.2 | Exp. 5 | 2.00 | 0.798 | 0.738 | 0.653 | 0.639 |
| 1.3 | Exp. 6 | 2.00 | 0.821 | 0.783 | 0.732 | 0.665 |
| 1.4 | Exp. 7 | 2.00 | 0.835 | 0.793 | 0.756 | 0.683 |

Among of these experiments, we had found highest removal of Cr (VI) in case of Exp. 5 (dosage of Activated Carbon 1.2 g/L) which is about 68%. Figure 1. is showing removal percentage of Cr (VI) increases with increasing equilibration/mixing time for Exp. 5. The increase in equilibration/mixing time resulting to increase in percentage of Cr (VI) removal, was due to the fact that, increase in equilibration/mixing time enhanced the metal ions diffusion to the surface of the adsorbent; and caused reduction in the film boundary layer around the adsorbent. In all aspects, it is noticeable that highest removal of Chromium is found at highest agitating time (60 minutes).

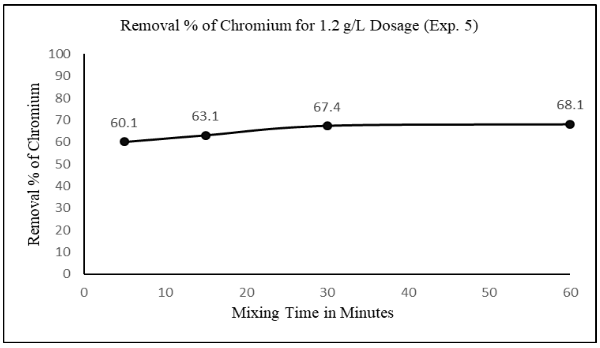


Figure 1. Removal % of Chromium with mixing time for Exp. 5 at pH=2

Figure 2. is showing removal % of Chromium with different dosages of activated carbon at 60 minutes equilibration time at 80 rpm shaking speed. At first hand, removal percentage increases with increasing activated carbon dosage & in the same way highest removal is found for 1.2 g/L activated carbon dosage. But after that removal percentage slightly reduces (from 68% to 66%). In most of the carbonaceous materials, there are a certain degree of porosity and internal surface area. After activation, these internal surface areas become extended and increase the adsorption capacity of activated carbon. Higher doses of activated carbon create higher surface area and increases adsorption capacity. Hence removal % of chromium initially increases with activated carbon dosages because initially higher adsorbent dosages of activated carbon create more surface area acting large adsorption sites for Chromium.

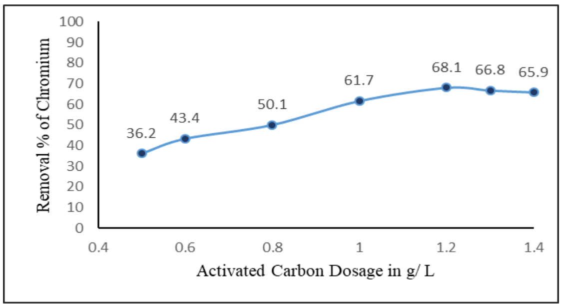


Figure 2. Removal % of Chromium with different adsorbent dosages at pH=2

After which further increase in adsorbent dosage, brought no increase in adsorption rather slightly reduces removal %, which was because of overlapping of adsorption sites due to overcrowding of adsorbent particles. Hence 1.2 g/L was chosen as the optimum adsorbent dosage for removal of Cr (VI) and corresponding highest removal % of chromium stands at 68.1%.

Table 2. Cr (VI) Concentration in filtered samples for Exp. 5 for different pH values at 60 min equilibration time at 80 rpm shaking speed

| **Dosage of Activated Carbon (g /L)** | **Experiment ID** | **Initial Conc. (mg/L)** | **Conc. at pH 2 (mg/L)** | **Conc. at pH 3 (mg/L)** | **Conc. at pH 4 (mg/L)** | **Conc. at pH 5 (mg/L)** | **Conc. at pH 6 (mg/L)** |
|---|---|---|---|---|---|---|---|
| 1.2 | Exp. 5 | 2.00 | 0.639 | 0.603 | 0.578 | 0.552 | 0.529 |

The effect of pH was studied from a range of 2 to 6 under the precise conditions (at optimum contact time of 60 min, 80 rpm shaking speed, with 1.2 g/L of the adsorbents used. From Table 2, with activated carbon from coconut shell used as adsorbent, it was observed that with increase in the pH (2-6) of the wastewater, the percentage removal of chromium increased up to the pH 6 as shown above. At pH 6, maximum removal was obtained, and it was about 74%. The increase in percentage removal of chromium may be explained by the fact that at higher pH the adsorbent surface is deprotonated and negatively charge; hence attraction between the positively metal cations occurred. The removal % of chromium with pH is shown below in Figure 3.

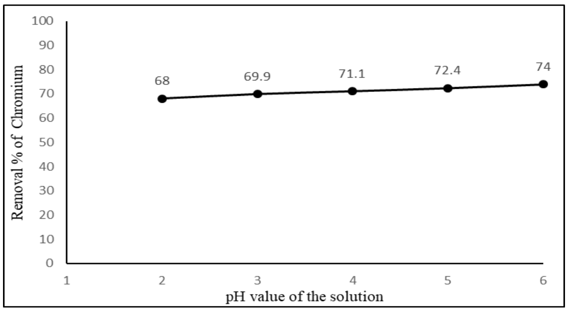


Figure 3. Effect of pH on the adsorption of Chromium (VI) by activated carbon from coconut shell (Time = 60 min, agitation speed =80 rpm, adsorbent dosage 1.2 g/L).

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**6 Conclusion:**

The major conclusions from the study area as follows:

- Activated Carbon prepared from Coconut shell was found to be effective in removal Cr (VI) from water. For the experimental conditions employed in this study (initial Cr 2.0 mg/L and mixing time of up to 60 minutes), the highest removal achieved was 74%.

- Highest removal of Cr (VI) is found at 1.2 g/L activated carbon dosage for 60 minutes equilibration time at pH=6 and 80 rpm shaking speed. So, it can be considered optimum dose for this experimental condition.

- Mixing or equilibration time has a significant effect on the removal of Cr (VI) by Activated Carbon. For any adsorbent dose, removal of Cr (VI) increased significantly with increasing mixing time.

- The percentage removal of chromium increased with increasing the pH up to 6 for highest equilibration time (60 minutes) and optimum dosage condition (1.2 g/L).

- Since Coconut shell is easily available in Bangladesh, activated carbon produced from Coconut shell could be a cost-effective adsorbent for the removal of Cr and possibly other heavy metals from water.

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