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Effect of HNO_3 activated carbon on the decreasing basicity for cadmium ion sorption

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Abstract

Toxic metal pollution in water has long been a significant environmental issue, with previous incidents emphasizing its harmful effects and raising awareness about it toxicity. The adsorption of cadmium ion has been investigated using HNO_3 activated carbon from sesame stem to determine the effect of the decreasing basicity on adsorption of cadmium ion. Determination of metal ion in solution, effect of ionic strength on sorption capacity, effect of initial metal ion concentration on sorption capacity, effect of pH on sorption capacity, time on kinetic of absorption were investigated. From the results, the equilibrium absorption was attained after about 60 min for the HNO_3 activated carbon. The sorption capacity of 84.48 % for HNO_3-AC was observed. The removal efficiency of Cd^{2+} by HNO_3-AC increases with increasing presence of the adsorbate. However, as the Cd^{2+} concentration becomes exceedingly high, the removal efficiency decreases. Low removal capacity of cadmium ion was observed when the drops of HCl were added in an increase manner. The group of cheap biosorbent materials based on natural and waste biomasses constitutes the basis for a new cost-effective technology that can find its largest application in the removal of metal contaminated industrial effluents.

Keywords: Activated carbon; Adsorbent; Basicity; Cadmium

1. Introduction

Contamination of water by toxic heavy metal has been a major environmental problem since long. Some of the past episodes of heavy metal contamination in the aquatic environment have increased the awareness of the toxicity. To alleviate the problem of water pollution by heavy metals, several researches has led to the discovery of materials that are both efficient and cheap [1]. In view of these, interest has recently risen in the investigation of some unconventional methods and low-cost materials for sorption of heavy metal ions from wastewater [2]. Anthropogenic sources of Cd^{2+} in the environment are derived from copper and nickel smelting, fossil fuel combustion and the use of phosphate fertilizers. Cadmium is also present as a pollutant in non-ferrous metal smelters and the recycling of electronic waste. Furthermore, forest wide fires, gradual process of erosion, abrasion of rocks and soil are among reasons for the increase in Cd^{2+} concentrations in the living environment (atmosphere, soil and water) [3]. The absorption of Cd^{2+} takes place mainly through the respiratory tract and to a smaller extent via the gastro-intestinal tract, while skin absorption is relatively rare. When cadmium enters the body, it is transported into the bloodstream via erythrocytes and albumin and is then accumulated in the kidneys [4], liver and gut [5]. Cadmium may interfere with the activity of antioxidant enzymes, such as catalase, manganese superoxide dismutase and copper-zinc superoxide dismutase. Metallothionein is a zinc-concentrating protein that can act as a free-radical scavenger. Therefore, cells containing metallothioneins are resistant to cadmium toxicity while cells that cannot synthesize metallothioneins are sensitive to its intoxication [6]. Metallothionein expression determines the choice between apoptosis and necrosis in Cd-induced toxicity [7].

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2. Material and methods

The adsorption of Cadmium ion was carried out using Sesame stem, Beaker, Conical flask, Mortar and Pestle, Spatula, Separating funnel, Distilled water, Volumetric flask, Glass rod, Measuring cylinder, Filter paper, Petri dish, Weighing balance. All chemical reagent used to include Cadmium chloride, Sodium hydroxide, Nitric acid, Potassium hydroxide laboratory grade reagents.

2.1 Preparation of reagents

An initial stock solution of Cadmium (1000mgL^{-1}) was prepared by dissolving 2.0360g of cadmium chloride ($CdCl_2$) in 100 ml of deionizer water, diluted with water and make it up to 1L in a volumetric flask (1000 ppm AAS standard). Sodium Hydroxide: 20 g of NaOH was dissolved in 500 ml of deionizer water. Nitric Acid: 63 ml was dissolved in 500 ml of deionizer water.

2.2 Sampling and sample preparation

Sesame stem were collected from Wukari market Taraba State, Nigeria; the samples were dried under room temperature and cut into pieces in order to enhance carbonization, purification, chemical activation using the methods of Zhang *et al*., [8]. Sesame stem was carbonized in a specially constructed chamber, after cooling the charred products were grounded with the use of mortar and pestle to produce a fine powder. Chemical activation of the carbonized fine powder was done using different chemical reagents HNO_3, sample of the carbon was poured into two different beakers containing dilute sodium hydroxide and nitric acid. The content of the beaker was thoroughly mixed until a paste of each was formed. The pastes of the sample were transferred into a Petri dish and air dried for 24hr, subsequently washed with distilled water, then filtered and dried again.

2.3 Determination of metal ion in solution

The ion chosen for the study was cadmium chloride. A concentration of 200 ppm of the metal ion was prepared with distilled water from the above concentration, 50 ml of the solution of metal ion was taken into a beaker and 2 g activated carbon of sesame stem was added. This mixture was shaken vigorously for 1 hour using flask shaker machine. The mixture was later filtered and the residual metal ion concentration was determined using AAS.

2.4 Effect of ionic strength on sorption capacity

Useful information regarding salt effect was obtained by measuring sorption capacity of Sesame stem activated carbon in four various masses. Selected masses were adjusted with 0.1 g, 0.5 g, 1 g, and 2.0 g of NaCl in 200 ppm to obtain various desired concentration. 2.0 g activated carbon sesame stem was contacted to 50 ml of the prepared solution of NaCl for 12hours, a time sufficient for equilibrium to be attained [9]. After equilibrium concentration, the residual metal ion was determined. It was shaken for 1hour using flask shaker then the mixture was filtered and the residual metal ion concentration is determined using AAS.

2.5 Effect of initial metal ion concentration on sorption capacity

To investigate the initial metal ion concentration on sorption capacity, different sample consisting of 50 ml of the metal ion concentration from 10ppm, 20ppm, 40 ppm, 60 ppm, 100 ppm, but each containing 2g activated carbon sesame stem were prepared and shaken for 1hour until equilibrium was obtain. The synthetic wastewater was filtered and analyzed for residual metal ion concentration using AAS [10].

2.6 Effect of contact time on kinetic of sorption

To determine the kinetic of sorption, five different set of samples consisting of 2g activated carbon sesame stem and 50ml of metal ion solution was prepared as the sample underwent agitation with flask shaker. They were remove at a predetermined time interval from 1hrs, 2hrs 3hrs, 6hrs and 24hrs. The solution was filtered and analyzed for residual metal.

2.7 Effect of pH on sorption capacity

To determine the effect of pH, the pH of 50ml of 200ppm of the metal is taken using the pH meter. Another 50ml of 200ppm of the metals is taken and 2 drops of HCl is added while the pH is determining, this is repeated by adding 3drops of concentrated HCl and taking note of the pH. The above process is repeated by adding 2-3 drops of dilute NaOH to 50ml of 200ppm of respective metal, these was also repeated by adding 4-5 drops of dilute NaOH solution and taking note of the pH. Activated carbon sesame stem of about 2g was added to each solution mixture and shaken for one hour using a flash shaker. The solution is filtered and analyzed for residual metal ion concentration using AAS.

3. Results and discussion

3.1 Effect of sorption capacity of cadmium using HNO_3-AC

From Figure 1, it was observed that HNO_3 activated carbon shows a significant sorption of 84.48 % of the cadmium ions. Mikyitsabu *et al.,* [10] studied the sorption of sesame stem by KOH-AC, the result show that the equilibrium adsorption was attained after about 1 hour with adsorption capacities of 84.48 KOH-AC. Aghdas *et al.* [11] revealed the impregnation ratio of the activating agent which highly influenced the surface area and the porosity development during preparation. Mikyitsabu *et al.,* [10] found out that activated carbon prepared at low and intermediate impregnation ratios showed higher yields. This could be attributed to the decomposition of the polymeric structures of the activated carbons during the activation stage that release most elements different from carbon (N, H and O). Activating agent employed permits the dehydration,

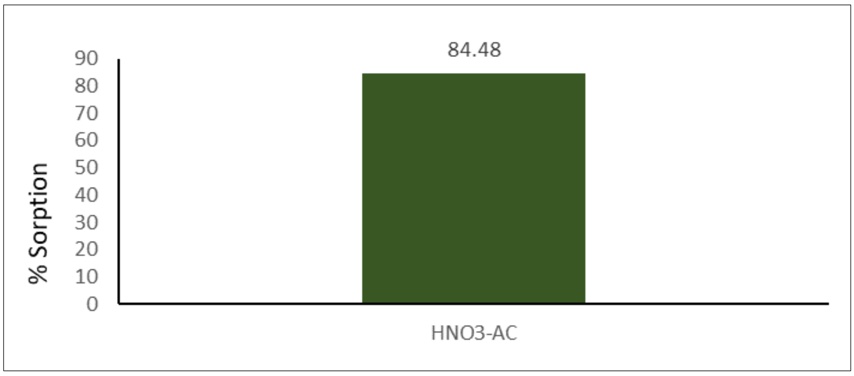

Figure 1 Effect of Sorption Capacity of cadmium using HNO_3-AC

3.2 Effect of basicity on contact time of HNO_3 AC in cadmium ion

Figure 2 shows the effect of basicity on contact time of HNO_3 AC on cadmium ion. Basically, the efficiency of adsorption strongly depends on the time of sorption. This was observed at time interval of 1hr, 2hrs 3hrs, 6hrs and 24hr. The results of the studies from Figure 2 shows that the equilibrium sorption was attained after about 60 min for the activated carbon with an increasing sorption capacity. A shape sorption was observed from 1 to 2 hours. A slit increase of sorption of the cadmium ion was observed also from 6 to 24 hours. A general observation was that before equilibrium, there is rise in the removal efficiency of Cd^{2+} by HNO_3-AC, with increasing contact time which is universally true for good adsorbents [12].

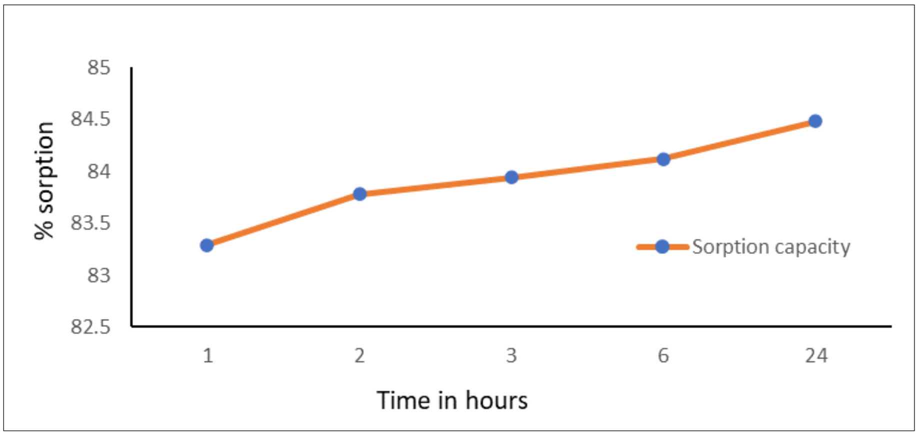

Figure 2 Effect of contact time in the sorption of cadmium using HNO_3-AC

3.3 Effect of metal ion concentration in the sorption of cadmium using HNO_3-AC

The effect of initial heavy metal concentration was studied within the range of 10ppm–100ppm. The result of this study as seen on Figure 3, indicates the removal efficiency of Cd^{2+} by HNO_3-AC increases with increasing presence of the adsorbate. This increase is due to the availability of adsorption sites on the activated carbon. However, as the Cd^{2+} concentration becomes exceedingly high, the removal efficiency increases. It may also be noted that the efficiency of adsorption was generally high (>80 %) with the chemically activated carbon. It is generally accepted that the mechanism for metal removal is related to the surface properties of activated carbons. The result shows the possibility of exhibiting varied pore sizes, large quantity of oxygen containing functionalities and total negative surface charge [13] which synergistically can provide active sites for adsorption of heavy metal salts. Improvement in the adsorption efficiency with the activated carbons (HNO_3-AC) as shown in Figure 3, can be linked to the improved surface properties resulting from chemical activation.

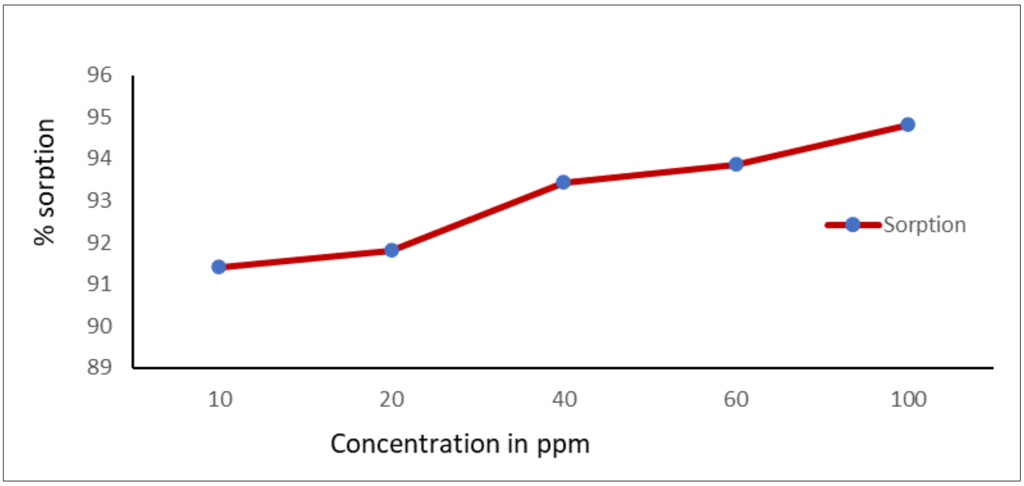

Figure 3 Effect of metal ion concentration in the sorption of cadmium using HNO_3-AC

3.4 Effect of pH on the sorption of cadmium using HNO_3-AC

Figure 4 shows the effect of pH on the sorption of cadmium ion using HNO_3-AC, the pH of the aqueous suspension of adsorbent is an important parameter that may control the adsorption of metals [14]. From the result, an increase in % sorption was observed. As the pH increases the sorption also increase. It can be seen also from Figure 4 the HNO_3-AC, slow removal capacity of cadmium ion was observed when the drops of NaOH solution was added in an increase manner from pH 3 to 6 as the basicity increases towards the pH of 7.

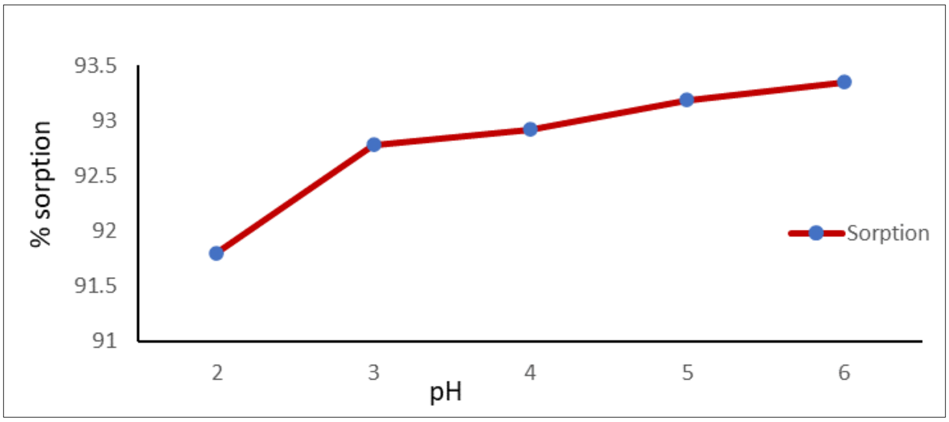

Figure 4 Effect of pH on the sorption of cadmium using HNO_3-AC

3.5 Effect of ionic strength on the sorption of cadmium using HNO_3-AC

Figure 5 shows the Effect of ionic strength on the sorption of cadmium using HNO_3-AC. It was observed that the sorption capacity of sesame stems activated carbon decrease with increase in ionic strength. Acid activated carbon shows minimal decrease at maximum amount of NaCl, this may be attributed to the fact that the sorption of metal ions decreases with an increase in halide. When the ionic strength can however be explained because of competition of Na^+ with other metal ion for electrostatic binding to the sesame stem.

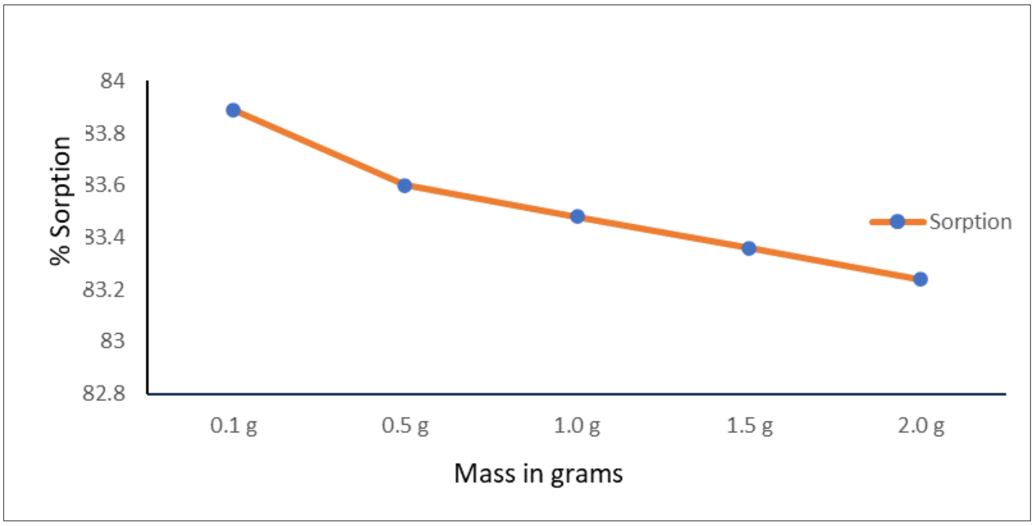

Figure 5 Effect of ionic strength on the sorption of cadmium using HNO_3-AC

4. Conclusion

Research over the past decade has provided a better understanding of metal biosorption by certain potential biosorbents. The group of cheap biosorbent materials based on natural and waste biomasses constitutes the basis for a new cost-effective technology that can find its largest application in the removal of metal contaminated industrial effluents. This research work has a role in transforming waste materials into valuable resources, which can help in safeguarding human health. The charts exhibited a rise in sorption as the different parameters increased, except for the influence of ionic strength, where all the Figure demonstrated a decline when NaCl concentration increased. This shows that Sesame stem is a good adsorbent. To attract more usage of bio sorbent technology, some strategies have to be developed where further processing of bio sorbent can be done to regenerate the biomass and then convert the recovered metal into usable form.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to disclosed.

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