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Research Article

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Adsorption of Cadmium from Aqueous Solution using Agricultural Wastes Based Activated Carbon

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Abstract Adsorption of heavy metal is a new technology for treatment of wastewater containing different types of selected heavy metals. Adsorbents were made out of sugarcane bagasse, guinea corn shaft, rice husk and corn cobs, available as agricultural wastes at controlled pH and contact time. The ability of the activated carbon prepared from these selected agricultural wastes to remove metal ion from aqueous solution has been carried out as a function of contact time, pH and concentration. An amount of 1g of the adsorbent each for sugarcane bagasse, guinea corn shaft, rice husk, and corn cobs was used to derive % adsorptions are 45%, 84%, 62% and 76% respectively. Results showed that pH 5 was the minimum content for the adsorption of cadmium ion (Cd^{2+}) at ambient temperature. Therefore, it is concluded that activated carbon prepared from these selected agricultural wastes have the potential of removing cadmium ion (Cd^{2+}) under experimental condition. The percentage adsorption in order of increase is sugarcane bagasse < rice husk < corn cobs < guinea corn shaft.

Keywords Adsorption, Cadmium, Concentration, Contact time, pH

Introduction

Adsorption is a process whereby a solid is used for removing a soluble substance from water. In this process active carbon is a solid, activated carbon is produced specifically so as to achieve a very big internal surface between 500 – 1500m^2/g [1]. This big internal surface makes activated carbon ideal for adsorption. If in a solid substance, the molecules or ions in the surface of the crystal do not have all their faces satisfied by union with other particles, they tends to satisfy their residual forces by attracting into and retaining on their surfaces gases or dissolved substances with which they come in contact. The substance thus attracted to the surface is called the "absorbate" while the substance to which it is attracted is called "adsorbent".

Cadmium is highly toxic non-essential metal which accumulates in kidney dysfunction [2]. Cadmium epidemiological studies have revealed that it may contribute to some forms of cancer in humans and low exposures may result in kidney damage [3]. Cadmium is widely distributed in the environment as a result of the use of galvanizing, pigments, stabilizers, thermoplastics, batteries and alloys. Moreover, the absence of the direct control from environmental protection agencies on above industries has increased the size of the problem. Cadmium is responsible for serious damage to the health of humans. "Tai – Tai", a disease characterized by excruciating pain in the bone [4]. The harmful effects of cadmium include a number of acute and chronic disorders, such as renal damage, emphysema, hypertension and testicular entrophy [5]. Cadmium toxicity contributes to a large number of health conditions, including the major killer disease such as heart disease, cancer and diabetes, Cadmium concentration in the kidney, liver and various other organs is considered more toxic than either lead or mercury. It is toxic at level one tenth that of lead, mercury, aluminum or nickel [6].

Adsorption is the user friendly technique for the removal of heavy metal. This process seems to be the most versatile and effective method for removal of heavy metal. This process is being widely used by various researchers for the removal of heavy metals like cadmium from waste streams. It has been established that a serious health hazard result from dissolved heavy metals escaping into the environment. They tend to accumulate through the food chain in living tissues multiplying their effects in human body. Different methods have been used to remove heavy metals from wastewater such as chemical precipitation, adsorption with new adsorbents, membrane filtration, eletrodialysis, photocatalysis. Among them adsorption was found to be the most commonly used method for eliminating these contaminants, especially at low concentrations.

Methodology

The selected agricultural wastes include rice husk, corn cobs, sugarcane bagasse and guinea corn shaft. They were dried, grinded and stored. 1000mg/l cadmium solution as stock solution was prepared. The parameters that were studied are: contact time, pH and concentration of adsorbent. The cadmium content was analyzed using atomic absorption spectrophotometer (AAS).

Equipment and Chemicals Used

The equipment/apparatus and chemical reagents used for this research work are listed in the tables below:

List of Apparatus Used

Materials	Sources
Measuring cylinder	Pyrex glass
Separating funnel	Pyrex glass
Breakers	Pyrex glass
Volumetric flask	Pyrex glass
Stirring rod	
Fitter paper	Whatman No.42
Spatula	Stainless steel
Wash bottle	
Knife	Stainless steel
Wash glass	Pyrex glass
Wooden mortar and pestle	
Sieve (0.5mm)	Tyler 28 mesh
Micropipette	Pyrex glass

List of Reagents Used

Materials	Sources
Cadmium sulfate salt	BHD England
Aqueous ammonium chloride	BHD England
Conc. Hydrochloric acid	BHD England
De – ionize water	Laboratory
Conc. Nitric acid	BHD England
Conc. Hydrogen fluoride	BHD England
Conc. Tetraoxosulphate (iv) acid	BHD England

List of Equipment Used

Materials	Sources
pH meter	Pcstestr 35, Singapore
Digital weighing balance	Vibra AJ – 3200E, Japan
Shaker	Stuart (SSLl)
Oven	Carbonate 5336RB Ax 30, England.
Blender	5B, 242, 220v/240v, 50/60H2, 200w Sayona, China
Furnace	Carbolite RWF 1200/RWF, England
Hot plate	Fisher scientific FB 68921
Bunsen burner	
Atomic absorption spectrophotometer (AAS)	Varian spectr AA 220.

Sampling

The agricultural wastes collected are rice husk, corn cobs, sugarcane Bagasse and guinea corn shaft. The rice husk was collected from a rice mill in Abakalili, Ebonyi state and guinea corn shaft was obtained from a rice mill at Dawanu market, Kano State, while the corn cobs and sugarcane baggases were gotten from Mokwa axis of Niger state.

Sample Preparation

The various agricultural wastes were washed thoroughly. The water content of the sugarcane Bagasse was extracted by pounding and pressing to remove the water content. The rice husk, sugarcane Bagasse, guinea corn shaft and corn cobs were later dried under the sun for 8hrs. The samples were then ground to fine particle powder of 0.5mm.

Ground Sugar cane baggase

Ground Guinea corn shaft

Ground Rice husk

Ground Corn cob

Carbonization process

Wet activated carbon

Absorption process

Treatment of Sample with Chemicals/Carbonization

The finely ground samples were mixed with an aqueous solution of ammonium chloride (NH_4Cl) in a beaker separately and was boiled in a hot plate for 3hrs. The boiled samples were dried in an oven for 6hrs at a temperature of 100^oC.

The dried samples were then carbonized in mini – furnace (carbolite RWF, 1200) at the temperature of between 450 – 500^oC for 45 minutes separately. The samples were washed with de – ionized water to remove the acid.The activated carbon obtained for each of the samples was left in an oven over – night at the temperature of 100^oC.

Preparation of Stock Solution of Cadmium Ion

In the preparation of the stock solution of cadmium ion (Cd^{2+}). A mass of 4.14g was weighted from salt of $3CdSO_4.8H_2O$ using a digital weighing machine. The weighed mass of the salt was transferred into 1000ml volumetric flask and added up with de – ionized water to the required mark. This gave a stock solution of 1000ppm cadmium ion (Cd^{2+}).

Adsorption Process

A given mass of 1.0g of the active carbon of the samples were weighted separately into each beaker containing 100ml of cadmium ion (Cd^{2+}) solution. The adsorption process was carried out to study the concentration absorbed at constant contact time of 30 minutes at various pH of 4.0, 4.5, 5.0. 5.5 and 6.0.

Also at a constant pH4 for various contact time at 30, 40, 30, 50, 60, and 70 minutes.

Before mixing the adsorbent, the pH of each test solution was adjusted to the required value with Hydrochloric acid solution.

Filtrate Solution

The solution mixture of the different adsorbent of cadmium ion (Cd^{2+}) concentration were mechanically agitated and was filtered using the filter paper (Whatman No. 42) to remove the adsorbent from the solution mixture.

The various filtrate solution of the cadmium ion (Cd^{2+}) was stored in different beaker and labeled.

Digestion Process (Extraction)

Digestion involved the use of chemical and heat to breakdown substances into component that can be analyzed.

20ml of the sample was measured in a beaker, then conc. $HClO_4$, conc. HNO_3 and conc. HF was added in the ratio of (1.3:1) to the sample under a fume hood. It was then covered with a watch glass. It was placed on the hot plate to evaporate it near dryness until a dense white fume appear, finally it was heated strongly (medium to high heat) for half a minute.

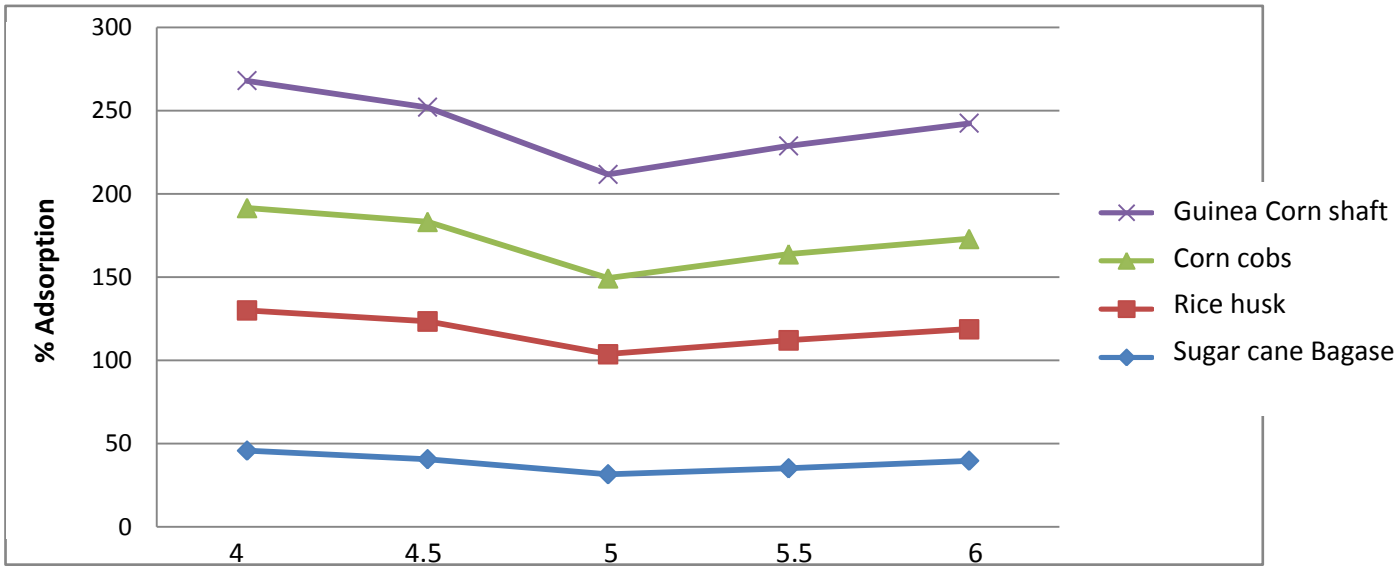
It was allowed to cool then the solution was filtered into a 100ml pyrex volumetric flask. The 100ml volumetric flask was then made up with distilled water to the mark. It was then filter with filter paper.

The filtrate extract and the standard solution were aspirated into the air – acetylene flame of Varian 220 (fast sequential) atomic absorption spectrometer for the Cd ion metal concentration.

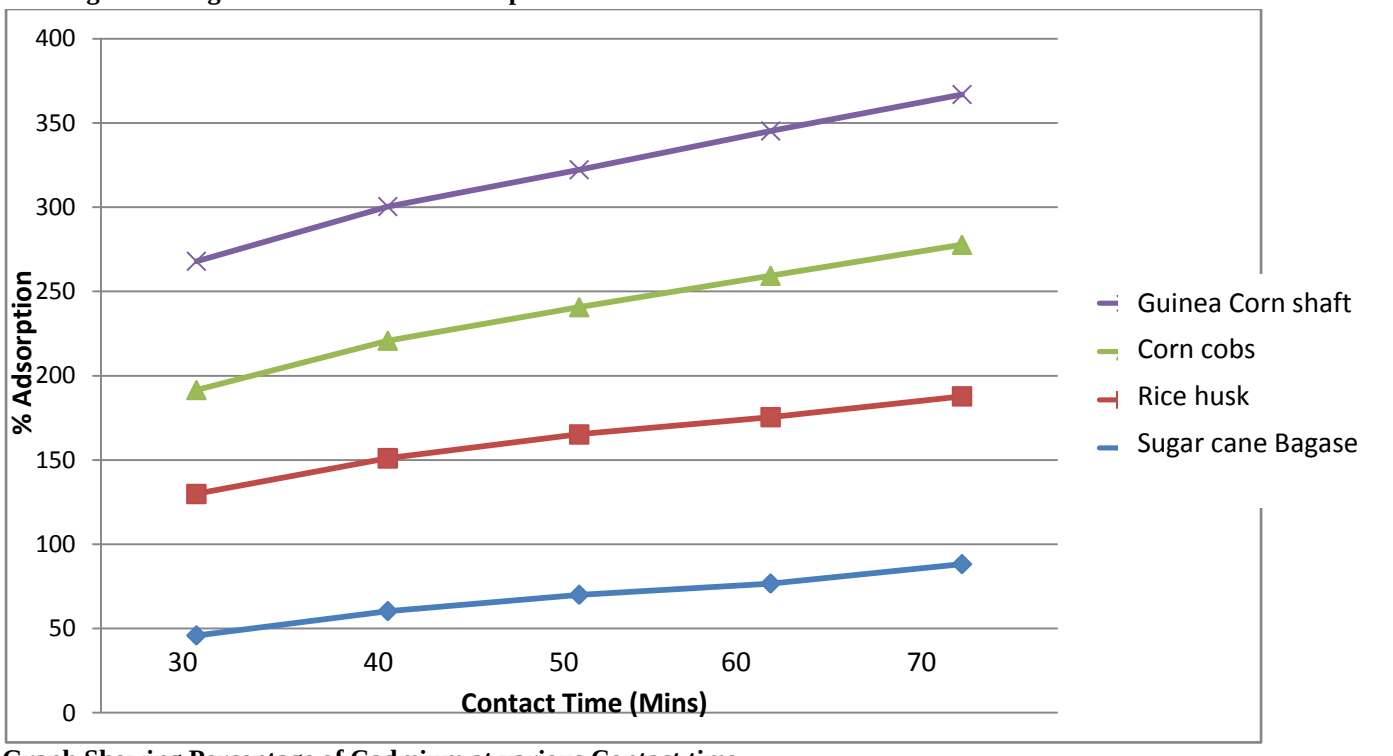
Result and Discussion

The results of this analysis are presented in the figures and tables below:

Result of Analysis



Showing Percentage of Cadmium at various pH.



Graph Showing Percentage of Cadmium at various Contact time.

The Result of Percentage of Cd at Various pH with Contact Time of 30 minutes

pH@ Contact Time of 30mins	Sugarcane Bagasse	Guinea Corn Shaft	Rice Husk	Corn Cobs
pH values	% absorbed	% absorbed	% absorbed	% absorbed
4.0	45.79	84.14	61.57	76.38
4.5	40.64	82.68	59.85	68.74
5.0	31.57	72.14	45.57	62.38
5.5	35.15	76.89	51.68	65.03
6.0	39.73	78.93	54.26	69.39

The Result of Percentage of Cd at Various Contact Time with Constant pH 4

Contact Time of @pH4	Sugarcane Bagasse	Guinea Corn Shaft	Rice Husk	Corn Cobs
Contact Time (min)	% absorbed	% absorbed	% absorbed	% absorbed
30	45.79	84.14	61.57	76.38
40	60.26	90.80	69.76	79.56
50	69.95	95.27	75.51	81.40
60	76.63	98.81	83.93	85.79
70	88.14	99.57	90.08	89.02

Discussion of Results

The adsorption of cadmium ion (Cd^{2+}) at various pH with contact time of 30 minutes are showed in figure above. The absorption of cadmium ion (Cd^{2+}) decrease until it got to pHs 5 where it starts to increase which indicates that pH 5 is the minimum content for the adsorption of cadmium ion (Cd^{2+}) at ambient temperature.

Also for pH 4 at various contact time as contained in figure above indicates that as the % adsorbed increases slightly. This may be due to blockage of the pores as adsorption process progresses.

However, Guinea Corn shaft has the highest percentage adsorbed at all the pH considered in this work, while sugar cane bagasse has the least. The order of increasing is given as: Guinea Corn shaft > Corn Cobs > Rice Husk > Sugar cane Bagasse. In the case of percentage of Cadmium adsorbed of various contact time at pH 4 also indicate that the order of increasing as per the four sample follow the same trend as above Guinea Corn shaft > Corn Cobs > Rice Husk > Sugar cane Bagasse.

Conclusion

It can be concluded from the research work that the activated carbon made from sugarcane bagasse, Guinea corn shaft, Rice husk and Corn cobs could be used to remove cadmium ion (Cd^{2+}) from aqueous solution with guinea corn shaft as the highest removal of cadmium ion and sugar cane bagasse as the least.

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