Optimization of Adsorption of Heavy Metals onto Coconut Husk Adsorbent Using OFAT Methodology

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Abstract- In Nigeria, large quantity of coconut husk is generated in the rural areas as agriculture waste, and a critical question is to find alternative use of this waste into useful product such as adsorbent for the adsorption of heavy metals in industrial effluent. In this paper, optimization of adsorption of heavy metal onto the surface of activated and non-activated coconut husk using one-factor-at- a-time (OFAT) method was studied. The values of particle size, adsorbate concentration, contact time, adsorbent dose, process temperature and pH that optimizes adsorption capacity of the adsorbent was determined. For both activated and non-activated coconut husk, the particle size was varied from 250 µm to 1180 µm, while the concentration was varied from 0.1 mol/L to 0.5 mol/L. The temperature was varied from 25 ^oC to 65 ^oC while the contact time was varied from 10 to 50 minute. The adsorbent dose was varied from 2 g to 10 g, while the pH was varied from 6.0 to 7.3 respectively. The results indicated that optimal adsorption capacity of 0.522 mg/g and 0.1 mg/g were obtained for both non-activated and activated coconut husk at particle size of 820 µm, while the optimum adsorption capacity of 0.204 mg/g and 0.78 mg/g at concentration of 0.4 M were obtained respectively for both adsorbents. The results also indicate optimum adsorption capacity of 0.8 mg/g at pH of 8.4 for both adsorbent. Particle size, concentration, contact time, adsorbent dose, temperature, and pH were found to be suitable process parameters for optimization of adsorption of heavy metal onto to the surface of coconut husk.

Index Terms- Activated Carbon, Non-activated Carbon, Adsorbate, Adsorbent, Coconut Husk

1. INTRODUCTION

Activated carbon is defined as a carbonaceous material with a large internal surface area and highly developed porous structure resulting from the processing of raw materials under high temperature reactions. It is composed of 87% to 97% carbon but also contains other elements depending on the processing method used and raw material it is derived from. Activated carbon's porous structure allows it to adsorb materials from the liquid and gas phase. Its pore volume typically ranges from 0.20 to 0.60 cm^3/g, and has been found to be as large as 1 cm^3/g. Its surface area ranges typically from 800 to 1500 m^2/g but has been found to be in excess of 3,000 m^2/g (Bansal *etal.*, 2005). The surface area contains mostly micro pores with pore diameters smaller than 2 nm. These favorable properties make activated carbon a popular adsorbent for many applications (Gomez etal., 2009).

Ania etal., (2014) reported that sorption capacities were 0.86 and 1.781mg/g for activated and non-activated coconut husk respectively. Non-activated coconut husk presented the highest adsorption capacities for the Cr (VI) ion. Also Daud *etal*, (2004) reported that 89% of copper ion removal with coconut husk as the adsorbent can be achieved at 120-minute contact time. Sun *etal*, (2006) reported that coconut husk can be effectively used to remove methylene blue from solution. Important functional groups responsible for ion uptake include O-H, N-H, C-O and C=O groups (Sun *etal.*, 2006). Due to the disposal of heavy metals such as Chromium, Lead, and cupper, the pollution of water resources has been an increasing worldwide concern for the last few decades. The quality of water supply is affected due to discharge of toxic metals into water sources and is a serious pollution problem. In the industrialized world, the use of chromium in industries like electroplating, textile, leather tanning, metallurgical metal finishing, photography, dye manufacturing, ink and pigments, power generation, and chemical manufacturing etc., is extensive and hence it is not uncommon for the aqueous effluents from such industrial plants to have high amounts of chromium.

One-factor-at-a-time is optimization experiment which vary only one factor or variable at a time while keeping others variable fixed (Veronica, 1999). The advantage of the OFAT is that it can be used to determine whether there is curvature.

It is clear from various earlier researches work on production of adsorbent from cellulose materials such as coconut husk (Augustine etal., 2015; Okafor etal., 2012; and Ekpete etal., 2011) that adsorption capacity of adsorbent produced from these materials are function of particle size, adsorbate concentration, contact time, adsorbent dose, process temperature and pH. There exists a relationship between the adsorption capacity and these process parameters. These study was therefore to develop an optimization framework by using OFAT method in order to established the type of relationship that exist between these variables.

2. MATERIAL AND METHODS

2.1 Preparation of Non-Activated Coconut Husk

The coconut used in this work was gotten directly from a coconut tree in kabala west Kaduna. The coconut husk was removed by separating the outer covering shell from the main coconut shell and soaked in distilled water for one hour. The wet coconut husk was sun dried for 24 hour and latter dried in a dryer at 45 ^oC for one hours to form partial carbonized husk carbon (PCHC). Finally, the dried PCHC was oven-dried overnight at 45 ^0C and crushed into different particle size to formed coconut husk carbon (CHC). The CHC was then packed into a desiccator for utilization.

2.2. Preparation of Activated coconut husk

Activated coconut husk was prepared by treatment of the dried coconut husk with concentrated phosphoric acid and keeping it in an oven at 90^{o}c for 7 hours. The activated material was washed with distilled water to remove free acid and sun dried.

2.3 Preparation of Solution of Heavy Metal

The stock solution of 1000 ppm Cr (VI) was prepared by dissolving 19.4 g quantity of Potassium dichromate ($K_2Cr_2O_7$) in 500ml de-ionized water. Working solution of Cr (VI) standard was prepared by diluting the appropriate quantity of the above stock solution.

2.4 Determination of Adsorption Capacity

Batch experiment were carried out to determine the adsorption of metal ions onto to the adsorbent in a 500 Ml adsorption glass flask. The flask was shaken at a constant rate to allowed sufficient time for equilibrium. The pH of the solution in the flask was measured with a Graffin-pH meter. The flask was kept closed to avoid the fluctuation of pH. The effects of contact time, pH, adsorbent dosage, adsorbate concentration, particle size, and temperature were observed. The amount of metal adsorbed per unit mass is calculated using equation 1:

$$Q_e = \frac{(C_i - C_e)}{m} \qquad (1)$$

Where

C_i and C_e are the initial and equilibrium concentration (mg/L), m is the mass of the adsorbent (g).

3. RESULTS AND DISCUSSION

The effect of particle size, adsorbent dose, contact time, concentration, temperature, and pH on amount of metal adsorbed (adsorption capacity) were investigated. These variables were varied one at a time to identify the values of the adsorption process parameters that produced highest adsorption capacity. The results obtained are explained in what follows:

3.1 Effect of Adsorbent Dose on Adsorption Capacity

The effect of adsorbent dose on adsorption capacity for fixed particle size of 600 µm while other parameters are kept constant is shown in Figure 1 below. The result revealed that optimum adsorbent dose is 10g with optimum adsorption capacities of 0.763 mg/g and 0.57 mg/g for non-activated and activated coconut husk respectively. Ania etal., (2014) have reported adsorption capacities of 0.86 mg/g for activated coconut husk which is closed to the result obtained in this experiment. The minimum adsorption capacities of 0.01 mg/g and 0.05 mg/g were obtained for non-activated and activated at adsorbent dose of 2 g.

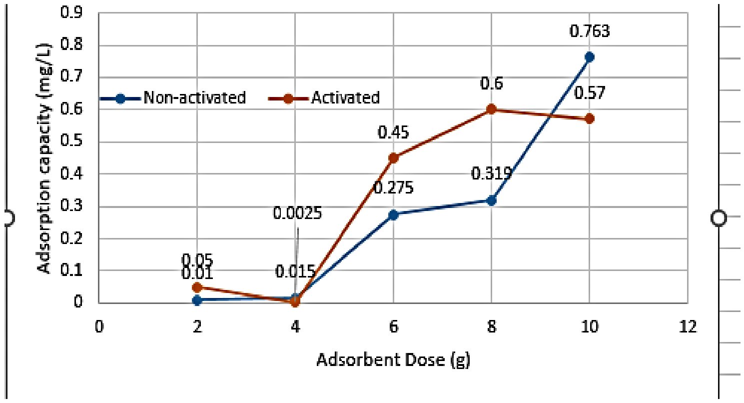

Figure1: Dose versus Adsorption capacity

3.2 Effect of Contact Time Adsorption Capacity

The effect of contact time on the adsorption capacity was investigated. The result obtained is shown in Figure 2. The result revealed that optimum contact time of 20 minute was established with optimum adsorption capacities of 0.58 mg/g and 0.016 mg/g for activated and non-activated coconut husk respectively. Contact time is one of the most effective factors in batch adsorption process (Hanit *etal.*, 2016). Adsorption rate rapidly increases initially, and the optimal removal was reached within 20 minute.

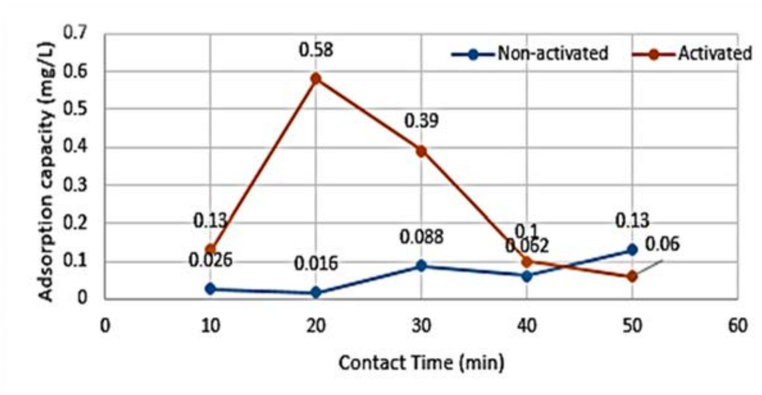

Figure 2: Effect of contact time on adsorption capacity

3.3 Effect of Adsorbate Concentration on Adsorption Capacity

Effect of adsorbate concentration on adsorption of the heavy metal onto coconut husk activated carbon was investigated at varied concentration while remaining parameters are kept constant. The result obtained is shown in Figure 3. Optimum adsorbate concentration of 0.4 mol/L was established with optimum adsorption capacities of 0.78 mg/g and 0.204 mg/g for activated and non-activated coconut husk respectively. The minimum adsorbate concentration was found to be 0.1 mol/L with minimum adsorption capacities of 0.024 mg/g and 0.38 mg/g for non-activated and activated carbon respectively.

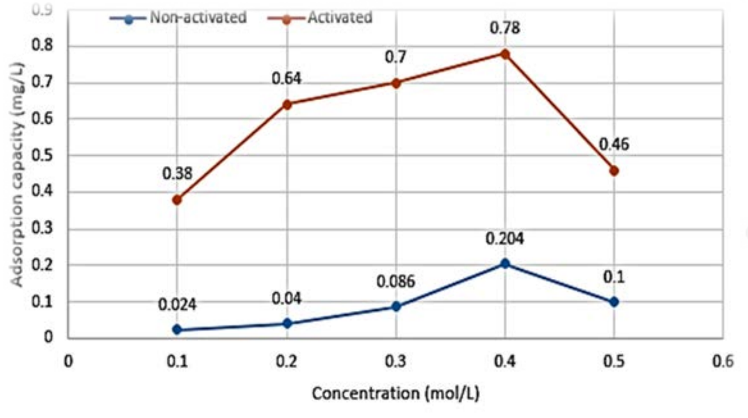

Figure 3: Adsorbate Conc. Versus Adsorption capacity

3.4 Effect of pH on Adsorption Capacity

Effect of pH on adsorption of the heavy metal onto coconut husk activated carbon was investigated at varied pH while remaining parameters are kept constant. During this study, results revealed that removal of metal ions was strongly depend on the pH of the solution as shown in Figure 4. Optimum pH value of 7.9 was established with optimum adsorption capacities of 0.96 mg/g and 0.68 mg/g for activated and non-activated coconut husk respectively. Minimum pH value of 6.8 with minimum adsorption capacities of 0.16 mg/g and 0.24 mg/g were obtained for activated and non-activated carbon respectively. This result revealed that adsorption capacity is higher in weak alkaline medium compared to acidic medium.

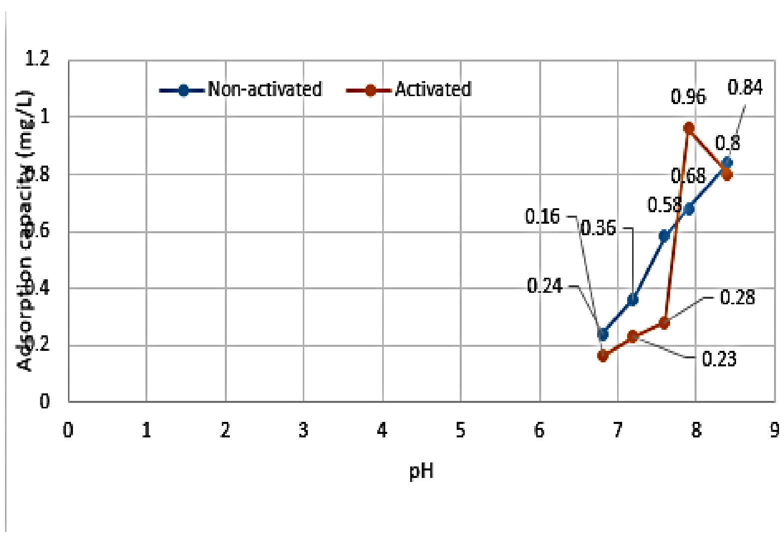

Figure 4: pH versus adsorption capacity

3.5 Effect of Temperature on Adsorption Capacity

Effect of process temperature on adsorption of the heavy metal onto coconut husk carbon was investigated at varied temperature while remaining parameters are kept constant. The result as shown in Figure 5 revealed that optimum temperature of 70 ^{o}C was established with optimum adsorption capacity of 0.83 mg/g and 0.13 mg/g for non-activated and activated carbon respectively. It shown from this result that the non-activated coconut husk adsorbed more heavy metal than the activated coconut husk. This result is supported by earlier result reported by Augustine and Zenebu, 2015.

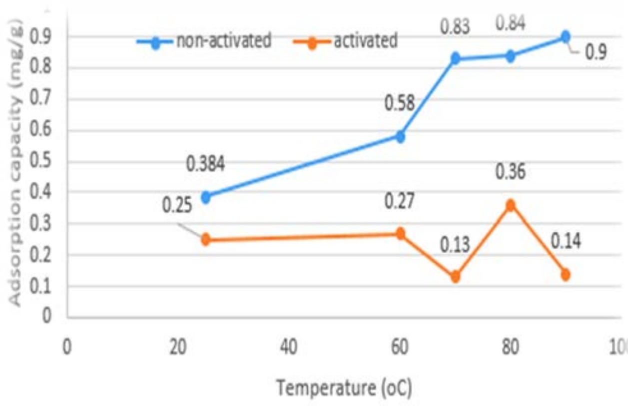

Figure 5: Temperature versus Adsorption capacity

3.6 **Effect of Particle size on Adsorption Capacity**

The effect of particle size on the adsorption capacity was investigated. The result obtained is shown in Figure 6. From the result, optimum particle size of 820 µm was established with optimum adsorption capacities of 0.522 mg/g and 0.1 mg/g for both non-activated and activated respectively. The result further revealed that non-activated coconut husk adsorption rate is higher than that of the activated coconut husk.

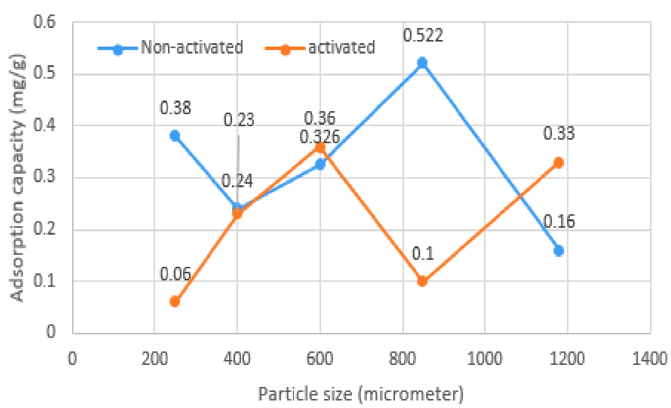

Figure 6: Particle size versus Adsorption capacity

4. CONCLUSION

This investigation has demonstrated the optimization of adsorption of heavy metals by coconut husk using OFAT method. The following conclusions were drawn from this study:

- The optimum adsorbent dose for adsorption of heavy metal by both non-activated and activated coconut husk using OFAT method is 10 grams.
- The optimum contact time for adsorption of heavy metal by both non-activated and activated coconut husk using OFAT method is 20 minutes.
- The optimum adsorbate concentration for adsorption of heavy metal by both non-activated and activated coconut husk using OFAT method is 0.4 mol/L.
- The optimum pH for adsorption of heavy metal by both non-activated and activated coconut husk using OFAT method is 7.9.
- The optimum temperature for adsorption of heavy metal by both non-activated and activated coconut husk using OFAT method is 70 oC.
- The optimum particle size for adsorption of heavy metal by both non-activated and activated coconut husk using OFAT method is 820 µm.

5. Recommendations

Factorial and design of experiment (DoE) methods of optimization should be carried out to determine optimum values of these parameters and relationship that exist between these parameters.

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