Effects of Process Variables On The Adsorption of Heavy Metals From Coal Effluent Using Cowbone-Derived Granules

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Abstract- This research work was centered on the Effects of Process Variables on the Adsorption of Heavy Metals on Cowbone Granules. Carbonization of the cowbone sample was achieved at a controlled temperature of 500°C, while a granular size of 500µm of the carbonized cowbone was generated by means of micro sieves. Acid activation was achieved through hydrochloric acid impregnation at different molarities of 0.2, 0.5 and 1.0g/mol for respective samples of cowbone adsorbent (A_1, A_2, A_3), at varying dosages of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0g. In each experiment, 20ml of the coal effluent of known total contaminant concentration was treated with 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0g respectively, for similar variation of adsorbent dosages and contact times of 5, 10,15,20, 25, 30 and 35minutes. The concentration values were found to decrease with increase in time,while the adsorption efficiency was observed to be best (97.38 %) within the adsorption times of 20 to 25 minutes, and adsorbance was found to increase in the direction of increasing dosage. Large amount of contaminants was also found to be adsorbed in the first 20 minutes of contact time. This initial fast rate of adsorption was attributed to the availability of several binding sites for solute uptake. Generally, adsorption of heavy metals from coal effluent, using cowbone-derived adsorbent was found to be largely dependent on process variables, such as Concentration, Dosage and Contact Time.

Indexed Terms- Effect, Process Variables, Adsorption, Heavy Metals Cowbone Granules

I. INTRODUCTION

Effluents are highly undesirable and unsafe to use. Wastewater contains solid particles with a wide variety of shapes, sizes densities and composition. Specific properties of these particles affect their behaviour in liquid phases- and thus the removal capabilities. Many chemical and microbiological contaminants found in wastewater are coagulated and adsorbed on or incorporated in the solid particles. Thus, essential for purification and recycling of both wastewater and industrial effluents is the removal of solid particles (Gumus, 2012*).*

Nigeria at the moment has established industries like petroleum refinery, soaps and detergents, food and beverages, breweries, textiles and apparels, building materials, timber products, wood and leather works, metal works, chemicals and plastics, clay, coal mining and other industries.

All these industries produce various effluents that are discharged into the environment.Most large cities in Nigeria e.g. Lagos, Port harcourt, Ibadan, Kano, etc, are feeling the pinch of pollution from industrial effluents. It is needless to talk of tons of effluents disposed indiscriminately into the lagoon, rivers and streams. It has been realized that discharges of untreated or incompletely treated wastes containing algal nutrients, non-biodegradable organics, heavy metals and other toxicants will hasten the deterioration of receiving water bodies.There has been growing awareness of the need for effective treatment of various effluents before discharging into a public water body (Sahu *et al*, 2009; Ocholi, 2012).

On a global scale, environmental pollution by food or related industries via effluent discharge has become a threat to plants and animals, and may ultimately threaten the quality of human life. In 1956, cases of minimata disease were reported in Japan (Aidan *et al*., 2012). The disease affects the brain, causing insanity and leading to death, as a result of pollution of water

by industrial effluents containing methyl-mercury. Also, the Itai-Itai disease caused by cadmium poisoning originated in a prefecture factory in Japan. This disease damages the joints, softens the bones and causes the body to shrink and the affected person may die very painfully. Within one time and the other, heavy metals have constituted into undue nuisance to our water resources in varying dimensions. There have been, in the past, cases of outbreak of mercury poisoning in Iraq and Nigeria when a number of people ate bread made from wheat which had been treated with alkyl- mercury as a fungicide (Ab Aziz *et al.*, 2016). However, unit operations, such as adsorption, could be employed to handle surface removal of heavy metals from effluent wastes, for possible essential reuse.

This work, thus, focuses of the effect of process variables (Concentration of heavy metals, Adsorbent Dosage and Contact time) on the adsorption of heavy metals (Cu, Zn, Fe, Pb, Cr) from coal effluent, using cowbone-derived adsorbent.

II.   MATERIALS AND METHODS

2.1 Raw Materials Collection and Adsorbent Preparation

The wastewater sample (coal effluent) was collected with sterile 10 litres container from the effluent holding pond of the Coal Mining Industry, Akwukwe-Enugu, located at the South-Eastern part of Nigeria, while the cow bone was collected from an abatoir, in Minna central market, Niger State.

The cowbone was thoroughly washed with water, and then cut into smaller pieces and was subjected to carbonization process at a charring temperature of $500^{o}C$, in a muffle furnace for two hours, as guided by Gayatri and Ahmaruzzaman (2010). A ceramic mortar set was used to grind the adsorbent sample. The carbonized cow bone was then seived to a particle size of 500µm. The carbonized cow bone was impregnated with hydrochloric acid for 24-hours for the purpose of activation, at the acid strength of 0.2M, 0.5M and 1.0M, after which it was dried in an oven at $104^{o}C$ for 2hours (El Shafey, 2007).

2.2 Adsorption Experiments

Batch adsorption experiments were carried out at $25^{o}C$. In each experiment, 20ml of the coal effluent of known total contaminant concentration was treated with 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0g respectively, for similar variation of adsorbent dosages (of 0.5 – 3.0g) and contact time from 5, 10,15,20, 25, 30 and 35 minutes.

Samples of the activated cow bone carbon were labeled as A_1 for 0.2 M (HCl), A_2 for 0.5 M (HCl) and A_3 for 1.0 M (Hcl), showing the different Molarities of the acid used. For each sample, the indicated weight of the activated carbon were weighed and poured into the tube of the centrifuge, with 20ml of the effluent. Each tube was labeled and placed inside the holes made for them in the centrifuge, and were revolved at 1500rpm at the variable contact stipulated times. The supernatant solution was collected from the centrifuge by decantation. The resulting supernatant solution was poured into the cuvette of the Ultraviolet Spectrophotometer (UVS) set at 610nm (wave length) and the rate of absorbance measured at room temperature. The read value of the absorbance from the top digital display of the UVS gives the final concentration of the effluent sample. The sediments in the tube comprise the used activated carbon and the adsorbate, which was filtered and kept for reactivation and further use. This experiment was repeated for A_2 and A_3 activated carbons with coal effluent.

The concentration of dissolved contaminant (Cu, Zn, Fe, Pb, Cr) adsorbed, C was evaluated as follows:
$$C = C_o\text{-}C_t \qquad (1)$$

Where, Co=Initial concentration of coal effluent before treatment

Ct=Final concentration of coal effluent at time, t

III.   RESULTS AND DISCUSSION

The results of the batch adsorption experiments at different concentrations, times and adsorbent dosages for A_1, A_2 and A_3 are, respectively, presented in figures 1, 2 and 3. Similarly, the results of Adsorption Efficiency, with respect to time at various dosages are presented in figures 4 to 6.
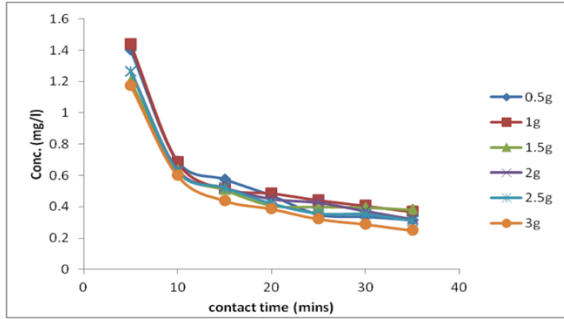
Fig 1: Concentration of pollutants in the effluent versus contact time at varying dosages for A_1
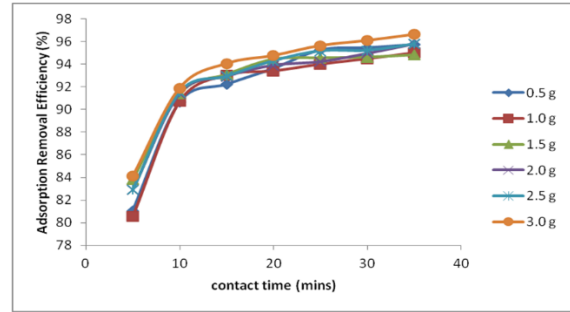

Fig 2: Concentration of pollutants in the effluent versus contact time at varying dosages for A_2

Fig 3: Concentration of pollutants in the effluent versus contact time at varying dosages for A_3

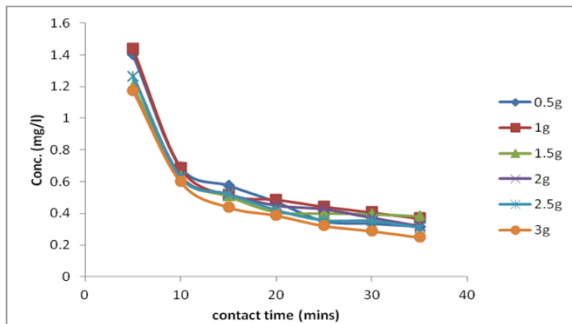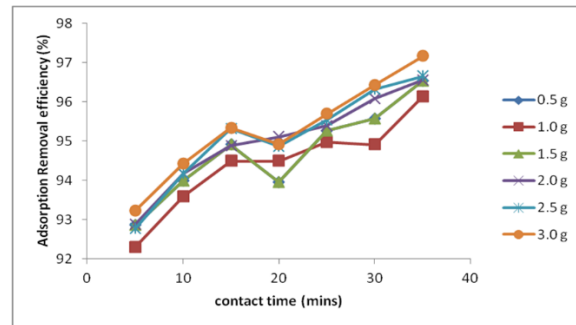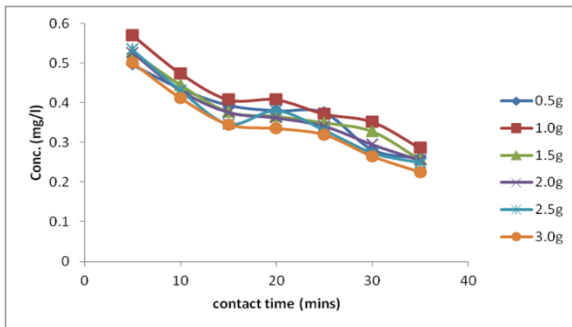Fig 4: Adsorption Efficiency versus Contact Time, at Varying Dosage for A_1.

Fig 5: Adsorption Efficiency versus Contact Time, at Varying Dosage for A_2.
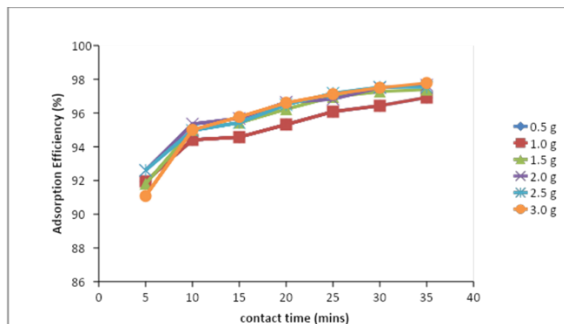

Fig 6: Adsorption Efficiency versus Contact Time, at Varying Dosage for A_3.

The concentration values decreased with increase in time, as observable in figures 1 to 3. It could also be observed that the adsorption efficiency of 97.38 % was attained within 20 to 25 minutes of contact time (figure 4.6). Large amount of contaminants was found to be adsorbed in the first 20 minutes of contact time.

This initial fast rate of adsorption may be a consequence of the availability of several binding sites for solute uptake (Offurum *et al*, 2011). The large amount of heavy metal removal in the first few minutes of contact time between solute and adsorbent may be due to increased surface area resulting from the influence of thermal pretreatment and improved (special) surface reactivity from the influence of chemical pretreatment. Similar observation of large removal in less than 20 minutes was reported by Parton and Menkiti (2007). This is also in agreement with the works of Ngah and Hanafiah (2008), which reveals that rapid solute removal and immediate attainment of equilibrium signifies the efficiency of an adsorbent for wastewater treatment. In a batch adsorption process, agitation which is associated with energy and cost is a function of solute-sorbent

residence time. A smaller residence time will require less agitation period than a larger residence time and this entails comparative energy/cost savings advantage.

CONCLUSION

The effect of process variables that was undertaken in this study duly showed that the modification of cowbone with hydrogen chloride acid has the tendency of increasing the surface area and porosity of the cowbone-derived adsorbent. Also, adsorption capacity of the activated cowbone (and removal efficiency of the heavy metals from the coal effluent sample) are highly dependent on the process variables, such as concentration of effluent, adsorbent dosage and contact time.

Generally, the batch adsorption study has demonstrated the applicability of cowbone activated carbon in adsorption of heavy metals from coal effluent, and was also found to be good. Thus, the use of cowbone-derived activated carbon for the removal of surface pollutants is recommended for large scale application.

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