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Effect of Process Parameters on the Single Adsorption of Zinc and Nickel ions Using Activated Carbon from Waste Nigerian Bamboo

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Abstract— **The study focused on the effect of process parameters on the single adsorption of Zinc and Nickel ions using activated carbon from waste Nigerian bamboo. The bamboo was cut into sizes, washed, dried and carbonized at 300oC-500oC. The carbonized bamboo was then activated at 800oC using nitric acid. The effect of process parameters such as particle size, carbon dosage, initial concentration of adsorbate on the single adsorption of Zinc and Nickel ions in aqueous solution was also investigated and were found to significantly affect the adsorption capacity of Zinc and Nickel ions in solution using activated carbon from waste Nigerian bamboo. For optimum adsorption of Zinc and Nickel ions in solution, particle size of Nigerian bamboo activated carbon less than 150 μm should be used for batch operations. The amount of Nickel ions adsorbed at equilibrium within initial adsorbate concentration of 28mg/L - 223mg/L was 28mg/g - 170mg/g, while The amount of Zinc ions adsorbed at equilibrium within initial concentration of 28mg/L - 227mg/L was 26mg/g - 185mg/g for carbon dosage of 10g/L . The results obtained showed that Nigerian Bamboo is highly effective in the single adsorption of Zinc and Nickel ions in solution.**

Index Terms— **Nigerian Bamboo, Activated Carbon, process parameters, Zinc ions, Nickel ions, single adsorption.**

I. INTRODUCTION

Heavy metals enter water supply by industrial and consumer waste which are released into streams, lakes, rivers and ground water. Nickel can be combined with other metals like iron, copper, chromium, and Zinc has an alloy. These alloys are used in making metal coins and jewelry, the Nickel alloy can further be used in the industry for making items such as valves and heat exchangers. Food is the major source of exposure to Nickel. Exposure to Nickel can be by breathing in air, drinking water, or smoking tobacco containing Nickel. Skin contact with soil, bath or shower water, or metals containing Nickel, as well as, metals plated with Nickel can also result in exposure. Stainless steel and coins contain Nickel. Some jewelry is plated with Nickel or made from Nickel alloys [1]. Nickel toxicity has been reported to cause pulmonary fibrosis and inhibit many enzymatic functions. Cancers of the lung and nasal sinus have resulted when workers breathed dust containing high levels of Nickel compounds while working in Nickel refineries or Nickel processing plants.

Several studies have been carried out on single metal adsorption of Zinc and Nickel. Malamis and Katsou [2] carried out a review of Zinc and Nickel adsorption on natural and modified zeolite, bentonite and vermiculite and Examine the effect of process parameters on the adsorption. The process parameters under investigation was: the initial metal concentration, ionic strength, solution pH, adsorbent type, grain size and concentration, temperature, agitation speed, presence of competing ions in the solution and type of adsorbate. The system's performance was evaluated with respect to the overall metal removal and the adsorption capacity. High removal of Zinc from water was also achieved using acid treated Carbon Nanofibers by Muataz [3]. Results of the study showed that, 97 % of Zinc was removed by using COOH-CNFs a Carbon Nanofibers at pH 7, 150 rpm, and 2 hours. Process optimization of the removal of Zn (II) by activated carbon prepared from rice husk using chemical activation was also reported by Ahmad et al [4] . Umesh et al., [5] also studied the removal of Nickel (II) from aqueous solution by adsorption on agricultural waste biomass using a response surface methodological approach. Effect of adsorbent dose, pH and agitation speed on Nickel removal from aqueous medium using an agricultural waste biomass was studied and these parameters were found to affect the adsorption of Nickel ions.

Bamboo is abundant in the rainforest region of the west and Eastern Nigeria. The work of Ademiluyi and David-West [6] on the effect of chemical activation on the adsorption of heavy metals using activated carbons from waste materials also revealed that waste bamboo activated with HNO3 can effectively be used to remove metal ions from waste streams and in different metal recovery processes than activated carbon from Palm kernel and coconut shell.

In the design of batch adsorbers the particle size of carbon , carbon dosage and the amount of adsorbate adsorbed are very important parameters considered and hence the aim of this research was to study the effect of process parameters on the single batch adsorption of Zinc and Nickel ions in aqueous solution using activated carbon from waste Nigerian bamboo.

II. MATERIALS AND METHODS

A. Materials

The following materials and apparatus were used for this work: waste Nigerian based bamboo from a construction site on campus. Nitric acid was used as activating agents, A pyrolytic reactor was used for carbonization with condenser. Other materials used are heating mantle, desiccators, crucibles, funnels, and filter papers. Two electronic weighing balance, Ohaus top loading balance (+0.01) was used to

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weigh the bamboo before pyrolysis, while a more sensitive electronic analytical weighing balance (+0.001, Adams AFP 360L) was used for other analysis, retort stand, thermocouple with temperature sensor, spatula, crusher, sieves, measuring cylinders, petri dish, and metallic salt containing Nickel and Zinc ions.

B. Carbonization

2kg of waste Nigerian bamboo was cut into small sizes, washed, and dried. They were carbonized differently in a pyrolytic reactor at about 300–500°C for about two hours after which the charred products were allowed to cool to room temperature. The charred material was crushed and sieved.

C. Chemical Activation

The carbonized waste bamboo were weighed separately and poured in different beakers containing known quantity of trioxonitrate (v) acid. The best concentrations of the Nitric acid used for activation were already determined before this study. The content of the beakers was thoroughly mixed until a paste was formed. The paste of the sample were then transferred to crucibles and were placed in a Muffle furnace and heated at 800°C for two hours. The activated sample were then cooled at room temperature, washed with distilled water to a pH of 6-7, and dried in an oven at 105°C for three hours. The final products were sieved, kept in an air tight polyethylene bags, ready for use.

Fig 1 Pieces of Nigerian waste bamboo and activated carbon produced.

D. Adsorption of Zinc and Nickel ions in Aqueous Solution on Activated Carbons

Stock solution of Zinc and Nickel solution was prepared by dissolving 1g of metallic salt containing Zinc and Nickel II ions separately into 1 liter of distilled water. 1g of activated carbon was measured and poured into 100ml of the Zinc salt solution inside the flask to give a dosage of 10g/L. The adsorption was carried out at a neutral pH and at room temperature of 30oC. The above procedure was done for 30 minutes , till equilibrium was reached and was repeated for different concentration of Nickel ions in solution. The adsorption of Zinc and Nickel ions in aqueous solution on bamboo activated carbon was carried out by studying the effect of various physicochemical parameters such as particle size, carbon dosage, initial concentration of the adsorbate on the adsorption process.

The amount of Zinc and Nickel ions in solution (i.e., Zn^{2+}) was determined using conductometric method from the filtrate after adsorption using waste Nigerian based bamboo. As described in the work of Banjonglaiad et al. [7], at low concentrations, conductivity is linearly related to the different metal ion concentrations so that if just one metal is present its concentration is readily established through calibration. Hence a calibration curve of Zinc ions and Nickel ions concentration versus conductivity was first prepared for each metal ions in solution before the adsorption process.

The amount of Zinc ions adsorbed at equilibrium, Q eq (mg/g) was determined using equation

$$Q_e = \frac{(C_o - C_e)V}{m} \quad (1)$$

and the percent Zinc ion adsorbed (%) was computed as follows [8] :

$$\text{Percent adsorption (\%)} = \frac{(C_o - C)}{C_o} \times 100 \quad (2)$$

where Co and Ce are the initial and equilibrium concentrations (mg/L), V volume of solution, m the weight of activated carbon (g) and C the solution concentration at the end of adsorption

III. RESULTS AND DISCUSSION

A. Effect of particle size on the batch Adsorption of Zinc (II) ions and Nickel ions in aqueous solution using activated bamboo carbon

Fig. 2 shows the effect of particle size of activated carbon produced from waste Nigerian bamboo on the batch adsorption of Zinc ions in aqueous solution . The adsorption of Zinc ions increased with reduction in particle size. The shape reduction also revealed that the adsorption of Zinc is particle size dependent. The particle size of activated bamboo carbon has significant effect on the adsorption of Zinc ions in aqueous solution for batch process. A strong linear relation was observed between percentage (%) Zinc ion adsorbed and the particle size of activated carbon, Pearson correlation = -0.972, p = 0.006 (2-sided), using SPPS 20. Fig 2 also shows that smaller particle size of activated carbon (≤ 150 µm) adsorbed the highest amount of Zinc ion within 30 minutes of adsorption, hence for effective adsorption of Zinc ions in aqueous solution using Nigerian bamboo activated carbon, the particle size of the carbon should be within 75 – 150µm for effective adsorption for batch processes.

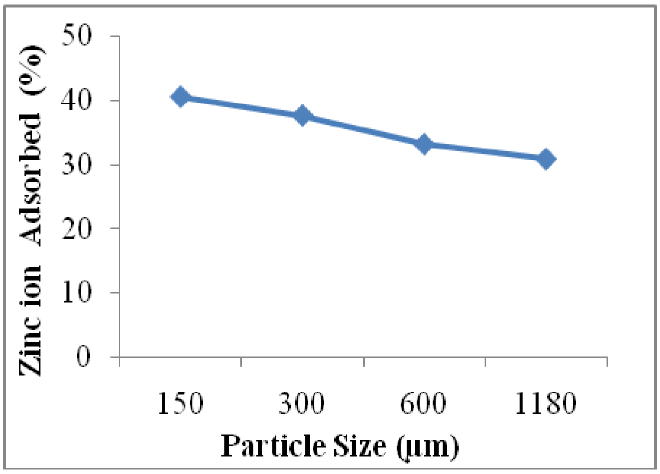

Figure 2: Effect of Particle Size on the Adsorption of Zinc (II) ion using activated from waste Nigerian Bamboo Carbon.

The effect of particle size on the batch adsorption of Nickel (II) ion by Nigerian bamboo carbon is presented in Fig 3. The amount of Nickel ion adsorbed linearly increase with reduction in particle size of carbon. A linear relationship was also observed between the amount of Nickel ion adsorbed as reported earlier for Zinc ions and the particle size of Nigerian bamboo activated carbon with a Pearson correlation of -0.965, p = 0.035 (2-sided), using SPPS 20. Although the percentage Zinc ion (40.6%) adsorbed within 30mins of adsorption was high than the percentage of Nickel ion (18.2%) adsorbed at the same time by Nigerian Bamboo. These results revealed that the adsorption of Nickel and Zinc using Nigerian Bamboo was strongly dependent on particle size of the carbon and carbon particle size <150 µm is recommended for batch operations.

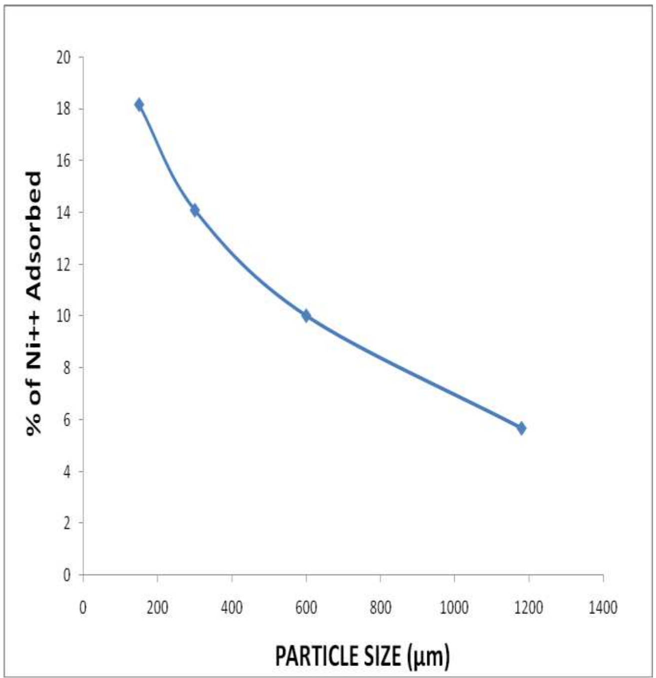

Figure 3 Effect of Particle size on the batch Adsorption of Nickel (II) ion by waste Nigerian Bamboo Carbon

B. Effect of Carbon Dosage on the Batch Adsorption of Zinc ions in Aqueous Solution

Fig 4 shows the effect of carbon dosage on the adsorption of Zinc ion using Nigerian Bamboo Carbon. 100 ml of stock solution of Zinc ions in aqueous solution were adsorbed into different carbon dosage of activated bamboo ranging from 0.1g – 1g . There was significant increase in the adsorption of Zinc ions in solution as carbon dosage increased within adsorption time of 30min. A strong linear relation was observed between % Zinc ion adsorbed and the carbon dosage of activated carbon, Pearson correlation using SPPS 20 = 0.995, p = 0.000 (2-sided). Mehmet [9] reported similar findings during the removal of heavy metal adsorption by modified oak sawdust. Increasing the adsorbent dosage further, it was found that the optimum uptake of Zinc ions requires about 3.2g of activated carbon from bamboo to adsorb 100% Zinc ions in aqueous stock Zinc II solution within adsorption time of 30mins in a batch process.

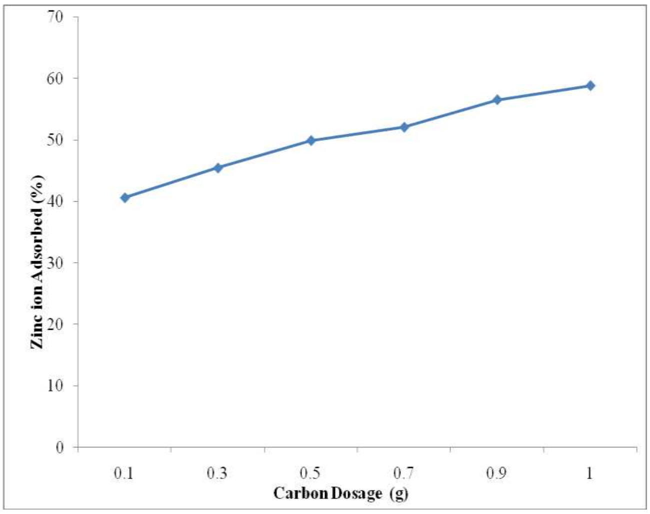

Figure 4: Effect of Carbon dosage on the Adsorption of Zinc(II) ions using Nigerian Bamboo Carbon.

Fig. 5 shows that effect of carbon dosage on the adsorption of Nickel (II) ions using Nigerian bamboo carbon. Nickel ions adsorption increase steadily with increase in carbon dosage. The increase in the amount of Nickel ions adsorbed was attributed to the rapid increase in surface area and number of available active sites. A strong linear relation was observed between % Nickel ion adsorbed and the carbon dosage of activated carbon, Pearson correlation using SPPS 20 = 0.985, p = 0.000 (2-sided).

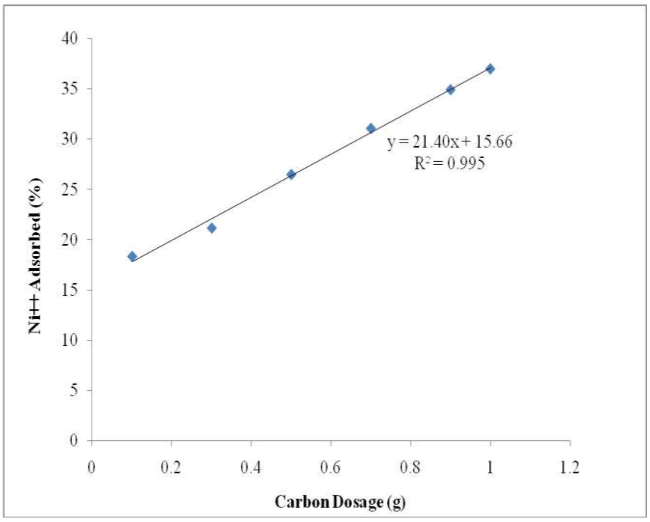

Figure5:Effect of Variation of Carbon dosage on the Adsorption of Nickel (II) ions by Bamboo Carbon

C Effect of initial concentration on the adsorption of Zn2+ ions using activated carbon from waste Nigerian bamboo

The effect of initial concentration of Zn2+ ion was studied by varying the concentration levels. The influx of concentration of metal ion under investigation on the amount of Zinc ion adsorbed is shown in Fig. 6 below. The initial concentration of Zinc ions in solution ranged from 28mg/L - 227mg/L and the percentage Zinc ions removed was 94% - 61% respectively while the amount of Zinc ions adsorbed at equilibrium Qe within this range of concentration was 26mg/g - 185mg/g. The adsorption of Zinc ion on Nigerian Bamboo carbon was dependent on the initial concentration of adsorbate because a strong linear relation was also observed between percentage (%) Zinc ion adsorbed and the initial concentration of adsorbate used for the adsorption with a Pearson correlation = -0.992, p = 0.001 (2-sided) using SPPS 20.

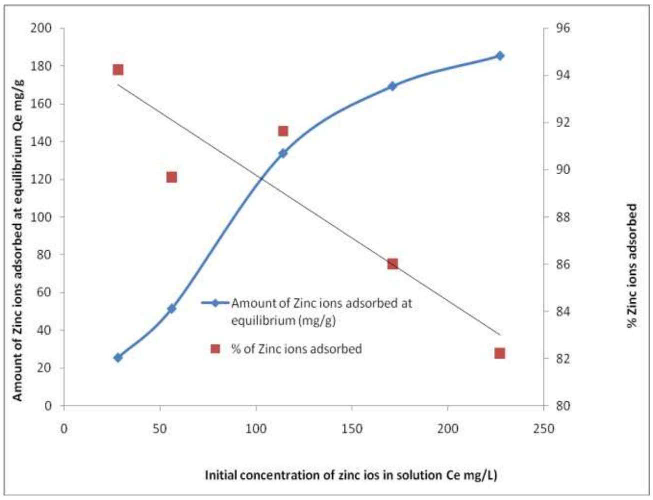

Fig 6 Effect of initial concentration on the adsorption of Zn2+ ions using activated carbon from waste Nigerian bamboo

The effect of initial concentration on adsorption of Nickel ions in solution using activated carbon from bamboo is presented in Fig 7 . the percentage of Nickel ions adsorbed decreased as the concentration of Nickel ions increased in solution. But the amount of Nickel ions adsorbed per gram of carbon increased steadily with the concentration of Nickel ions in solution. The initial concentration of Nickel ions in solution ranged from 28mg/L - 223mg/L and the percentage Nickel ions removed was 100% - 67% respectively while the amount of Nickel ions adsorbed at equilibrium within this range of concentration was 28 mg/g - 170mg/g.

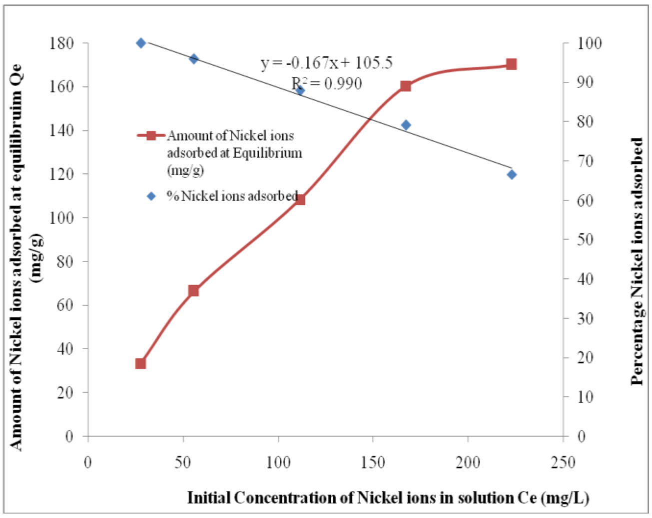

Fig 7 Effect of Initial Concentration on adsorption of Nickel ions in solution using activated carbon from waste Nigerian bamboo

The results presented in Fig 6 and 7 shows that Nigerian Bamboo is highly effective in the single adsorption of Zinc and Nickel ions in solution. Comparing the amount of Nickel ions adsorbed using Nigerian Bamboo activated carbon and the work of Malihe et al., [10] shows that only 4.82 mg/ g of Nickel ions was adsorbed using a biosorbent Aspergillus niger . But at same initial concentration of 30.00 mg L−1 Nickel (II) ions in solution , 37.68mg/g of Nickel ions was adsorbed using Nigerian bamboo activated carbon.

Also the adsorption capacity Zn (II) ions on calcinated Chinese loess was found to be as high as 113.6 mg g−1 from the work of Xiaowu et al., [11] while activated carbon from Nigerian Bamboo adsorbed up to 185mg/g of Zinc ions in solution.

IV. CONCLUSION

Effect of process parameters on the single adsorption of Zinc and Nickel ions using activated carbon from waste Nigerian bamboo was investigated. The adsorption of Zinc and Nickel ions using waste Nigerian bamboo revealed that the adsorption was strongly dependent on the particle size, carbon dosage, initial concentration of adsorbate . For optimum adsorption of Zinc and Nickel ions in solution. Particle size of activated carbon from waste Nigerian Bamboo less than 150 um should be used . The amount of Nickel ions adsorbed at equilibrium within this range of concentration initial concentration of 28mg/L - 223mg/L was 28 mg/g - 170mg/g. while The amount of Zinc ions adsorbed at equilibrium within this range of concentration initial concentration of 28mg/L - 227mg/L was 26mg/g - 185mg/g. The results obtained showed that Nigerian Bamboo is highly effective in the single adsorption of Zinc and Nickel ions in solution.

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