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Adsorptive Capacity of Water Hyacinth on Heavy Metals

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Abstract:
The adsorptive capacity of activated water hyacinth (AWH) on lead (Pb^{++}) and iron (Fe^{++}) was studied. The zinc chloride activated carbons were characterized under pH and iodine number, moisture content, particle size, specific gravity, bulk density, porosity and volume of void. Batch adsorption studies were also carried out under varying experimental conditions of pH of the solutions, contact time of the carbons and metal ions, and initial concentration of Pb^{++} and Fe^{++} solutions. The results showed that the highest percentage removal of 99.85 occurred at pH = 8 by AWH on Fe^{++} and the lowest % removal of 3.03 on the same metal and iodine number of 620mg/g. Although a pH of 7.0 is recommended because of treatment of consumables.
On the effect of contact time, it was found that the equilibrium time for the sorption was at 60mins with the percentage removal of 99.59 by AWH on Fe. On the effect of initial concentration, the results showed that the adsorption of Fe increases with the initial concentration, while that of Pb^{++} decreases with the increase in initial concentration. The Langmuir and Freundlich isotherm gave values of 0.692 and 0.771 correlation coefficients respectively for lead, which indicate poor modeling ability of the AWH and entirely inadequate for modeling that of iron.

Keywords: *Water hyacinth, heavy metals, activated carbon, adsorption, capacity*

1. Introduction

Heavy metals are metals or metalloids of environmental concern. This means that they are metals of relatively high density and toxic or poisonous even at low concentrations. Their presence in humans can cause severe problems such as: cancer of the lungs, anemia, neurotic disorder, liver and kidney damage, circulatory and nervous damage. (en.wikipedia.org/wiki/Heavy – Metal). Hence, there is an urgent need to remove heavy metals from our drinking source and also removal from waste water that comes from industrial processes before discharge.

Cost has been a major factor in any process, and man is constantly seeking better ways of achieving his purpose at cheaper cost. Most of the adsorbent for years has been quite costly to manufacture and replenish for regular industrial need, while some lack the availability (abundance) required by man.

Water hyacinth (Eichhornia Crassipes), a free – floating aquatic plant having the ability to double its population in two weeks has been proven by many researchers to be a good adsorbent and in turn a cheap source of material to measure up with industrial demand.

Most of the works on water hyacinth has been their application in removal of heavy metals and other hydrocarbons for example, Kanawade and Graikwad (2011), worked on the removal of methylene blue from effluent by using activated carbon and water hyacinth as adsorbent. This was a comparative study to show that water hyacinth could be used as an alternative to activated carbon.

Buasri and others (2012) reported that water hyacinth could be a low cost absorbent for heavy metals and also is efficient in removal of CU (II) and Zn (II) ions from aqueous environment. Inengite, Abasi and Johnny (2014), showed that water hyacinth shoot has the ability to biosorp methylene blue dye. "Water hyacinth as a biosorbent: A review" was carried out by Mahamadi (2011). He unlocked the various forms in which the plant could be used in heavy metal removal; some of which are: Raw and dried water hyacinth roots in metal removal. Adsorption of phenol from aqueous solution by water hyacinth ash was studied by uddin, Islam and Abedin (2007). They reported that factors such as pH, concentration of phenol affected the adsorption.

Having known to some extent that water hyacinth can be used as a biosorbent for heavy metals and other pollutant, however, in this work, "adsorption capacity of water hyacinth on heavy metals" we seek to reaffirm that of a truth, that water hyacinth has the capacity to adsorb heavy metals by using different activating agent and different heavy metallic ions, such as iron and lead. Hence this defines the objective of this work.

2. Materials and Method

The water hyacinth was collected from the Swani River beside Swani Market of Yenegoa in Bayelsa State. The collected water hyacinth was washed thoroughly with clean water several times to remove dirties. They were cut into smaller bits and air – dried for 168 hours. The dried water hyacinth was carbonized in a muffle furnace at $300^{O}C$ for an hour, which thereafter was impregnated with zinc chloride of suitable concentration and heated again at $450^{O}C$ for 1:30mins in a muffle furnace (Carbolite, LMF 4. Sheffield, England) at plant anatomy laboratory Ofrima, University of Port Harcourt (UNIPORT).

2.1. Determination of PH of the Activated Carbons

- Apparatus; Activated carbons, distilled water, beaker and pH meter. The pH was determined by weighing 1g of activated water hyacinth into a beaker and 100ml of de-ionized water was also measured into the beaker. The solution was stirred for 5mins and allowed to stabilize. An electrode was inserted into the beaker containing the solution and the reading was also taken. The Activated carbon was washed several times and processes repeated until a stabilized pH reading was taken.

2.2. Determination of the Iodine Numbers of the Activated Carbon

- Apparatus: Burette, measuring cylinder, standard flask, conical flask, Weighing Balance, Mechanical Shaker, Filter Paper, Funnel.
- Reagent: Sodium thiosulphate, (standard thiosulphate titrate, iodine solution, starch indicator, 20% H_2 SO_4.

A known concentration of Iodine solution was prepared; also a known molarity of Sodium thiosulphate was prepared too. 1g of the activated carbon was weighed in a conical flask and 50m1 of iodine solution was added. The sample was agitated with a mechanical shaker for 1hr and then filtered; the filtrate was titrated against standard sodium thiosulphate solution to the end point using starch indicator. The end point was read when the blue colored solutions changed to colorless solution.

2.3. Batch Adsorption Process

The batch adsorption process of the metal ions were carried out under the condition of the effect of pH of the solution to the adsorption, the effect of contact time of the metal ions on the activated carbons, and the initial concentrations of the metal solutions.

2.4. Chemicals

The stock solutions of l000mg/l of Lead (II) chloride and Iron (II) chloride were prepared by dissolving 1 .0g of analytical reagent grade of the metallic salts in 1L of de-ionized water. The test solutions of desired concentrations were then prepared by diluting the stock solution. A 0.1M of HCL and KOH used to adjust the pH to the required value were also prepared.

2.5. Determination of the Effect of Ph on the Adsorption of PB^{++} and Fe^{++} By AWH

The effect of pH on the amount of Iron (II) chloride and Lead (II) nitrate removal was analyzed over the pH range of 2 to 8. In this study, 50ml of the metal solutions of 100mg/I was taken in stopper plastic conical flask and are agitated with 1.0g of activated water hyacinth using a mechanical shaker (Stuart flask shaker, Industrial chemistry research Laboratory) at room temperature. Agitations were made for 2hrs. 30mins at constant oscillations of 300 osc/min. The samples were allowed to settle down before filtering, and the left out concentrations of the filtrate/solution were analyzed using Atomic Absorption spectrophotometer (Buck Scientific Atomic Absorption/Emission Spectrophotometer 205).

2.6. Determination of the Effect of Contact Time

The effect of contact time of activated water hyacinth on the amount of removal of heavy metal solutions of Iron (II) chloride and lead (II) nitrate were also obtained by contacting 100ml of the solutions of initial concentration of 70mg/1 with 1 .5g of the adsorbents at constant pH and room temperature. The samples were agitated for the time of 30mins, 1hour, 1.30mins, and 2hours respectively in plastic conical flask at a constant oscillation of 300osc/min. Then, the samples were allowed to settle down after which it was filtered and the left out concentration of the solutions was analyzed as before.

2.7. Determination of the Effect of Adsorption Equilibrium of PB^{++} and Fe^{++} on Awh

Equilibrium studies were carried out by contacting 1.0g of activated water hyacinth with 100ml of lead solution of different initial concentrations (40,60,80,100mg/L) and also 100ml of iron solution of different concentrations (10,20,30,40 mg/L) respectively in 150ml plastic conical flask. The samples were then shaken at a constant oscillation of 300 osc/min for 2.30mins. After equilibrium, the concentrations were analyzed as before.

3. Results and Discussion

S/N	PARAMETERS	AWH
1	PH	7.67
2	Iodine number (mg/g)	620
3	Particle size (un sieve)	0.375
4	Bulk density (g/cm^3)	0.127
5	Volume of void	58.14
6	Porosity (n)	0.91
7	Specific gravity	0.78
8	Moisture content %	54.09

Table 1: Summary of results from characterization carbons

The properties of activated carbons are a function of the material from which the activated carbon is made of. As it can be seen from the Table 1 above that the specific gravity of water hyacinth is less than 1.0 confirms its floatation in water.

3.1. The Effect of P^H on the Adsorption of Fe^{2+} and Pb^{2+} by AWH

The effect of ph on the adsorption of Fe2+ and Pb2+ was carried out at the Ph solution range of 2-8 and the percentage of the metal ions adsorbed is shown below.

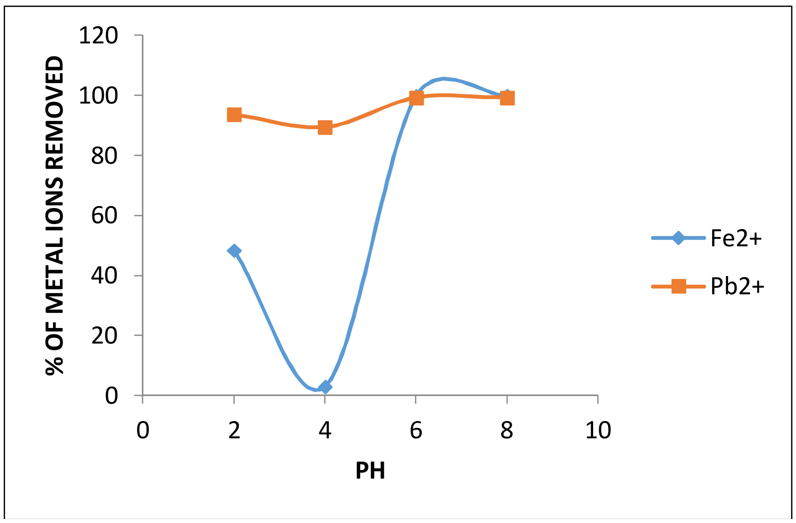

Figure 1: Effect of PH on percentage removal of iron and lead

This shows that the removal of metals from aqueous solution by AWH is PH dependent. This is because that pH affects the surface charge of the adsorbents degree of ionization. This influence of pH on the adsorption of metals ions was highest at pH = 8 for the both metals by the samples. It is generally believed to be that this effect is due to the exchange of hydrogen atoms in the substrate by metals ions (Okieirnen and others, 1988). It is thought that the presence of a relatively high concentration of H^+ in the medium would influence this exchange from the substrate as decreasing solution pH increases H^+ concentration in the solution which will coordinate with OH^- groups to form OH^+_2 and thereby reducing the number of negative sites on the adsorbent causing the repulsion of metal ions (Ofomaja and others, 2005). On the other hand, increasing pH reduces the amount of H^+ in and promotes ionization OH^- groups. Again, as can seen in Figure 1, that the uptake capacity of AWH on Fe^{++} is higher than that on Pb^{++}, this differential sorption of different ions may be attributed to the differences in their ionic sizes. The smaller the ionic size, the greater its affinity to reactive sizes (Horsfall Jnr and others, 2003). We recommend that PH = 7 should be prefect because of consumable produce.

3.2. The Effect of Contact Time on the PB^{++} and Fe^{++} by AWH

The adsorption data for the uptake of metals versus contact time at initial concentration of 70mg/1 is presented in Figure 2. The result showed that the time required for the adsorption of metals onto AWH was almost l20mins (2hrs). However, for subsequent experiments, the samples were left for 150mins to ensure equilibrium.

These results also indicated that up to 96 - 99% of the metals ions uptake by the adsorbents occurred in between the first phase of 30mins and l hr after in which it is found to decrease at 90mins and tend to remain constant at l20mins. The higher sorption rate at the initial period (30 - 60rnins) may be due to an increased number of vacant sites on the adsorbent available at the initial stage; as a result, there exist increase concentration gradients between adsorbents in solution and adsorbate on adsorbent surface (Uddin and others, 2007). It is also believed that at 90 and 120mins, is where the adsorption equilibrium is attained, where sorption and desorption is tending to be equal.

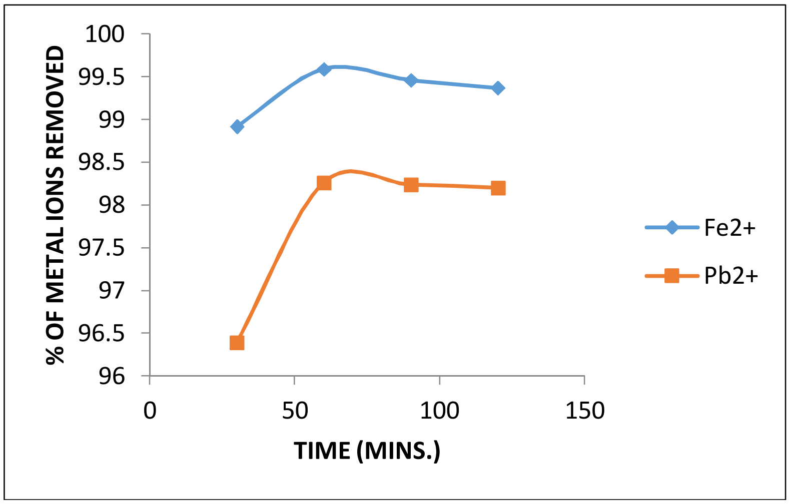

Figure 2: Effects of contact time on the percentage removal of Iron and Lead

3.3. The Effect of Initial Concentration of the Metal Ions

The effect of initial concentrations of the metal ions were determined and the data obtained were plotted as shown in Figure 3 and 4

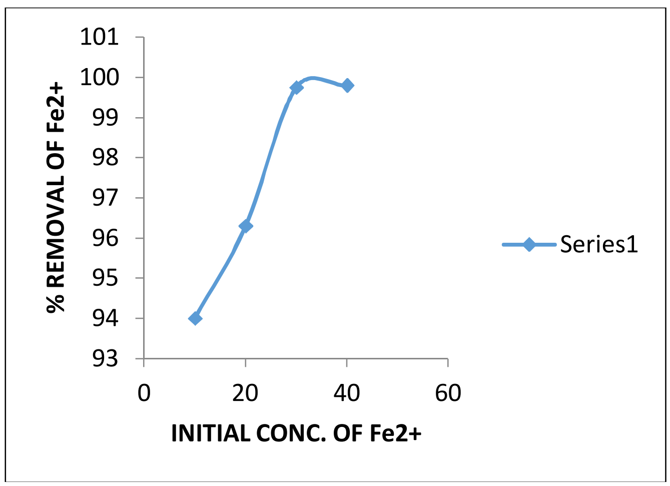

Figure 3: Effects of initial concentration of Iron

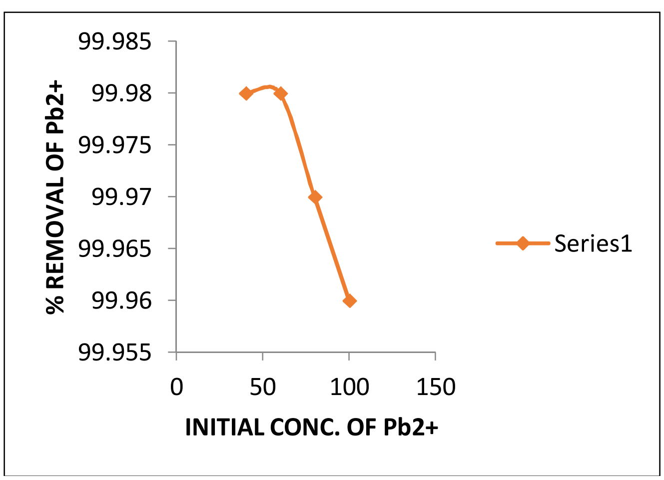

Figure 4: Effects of initial concentration of Lead

From (Figure 3 & 4), it can be seen that the percentage of removal of Fe^{++} increases as the concentration of the solution increases with the highest percentage removal of 99.80% at the concentration of 40mg/1. This shows that at high concentration of Fe^{++} the carbon has more affinity with the Fe solution and that the active sites is more active when the concentration is high than when it is at low concentration, which may be due to its low ionization sizes. However, the percentage removal of Pb^{++} decreases with increase in concentration, as can be seen that the highest percentage removal of 99.98% at 40mg/1 and 60mg/1. This shows that the active site of the carbon takes up the available ion faster at low concentrations and as the concentration increases the binding site gradually become saturated.

3.4. The Effect of Adsorption Equilibrium

Equilibrium study on adsorption provides information on the capacity of the adsorbent. An adsorption isotherm is characterized by certain constant values, which express the surface properties and affinity of the adsorbent and can also be used to compare the adsorptive capacities of the pollutants.

The Figures 4.5 -4.8 shows the Langmuir and Freundlich plots for Pb^{++} and Fe^{++} adsorbed by AWH.

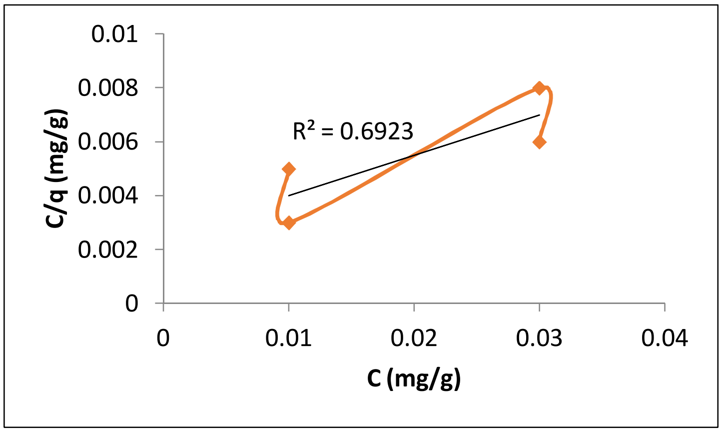

Figure 5: Langmuir isotherm for lead

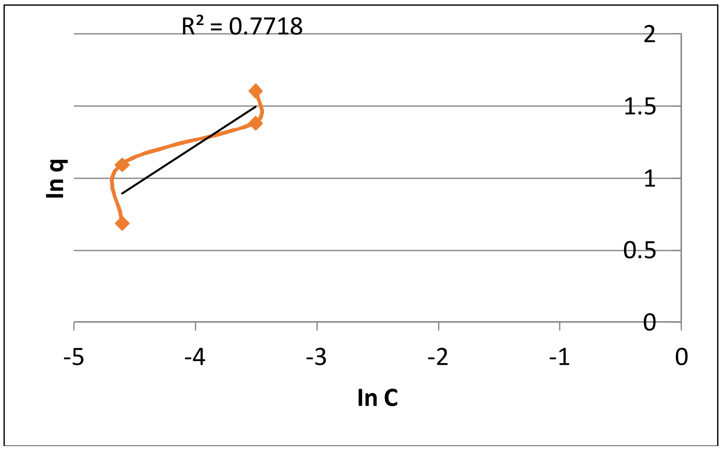

Figure 6: Freundlich isotherm for lead

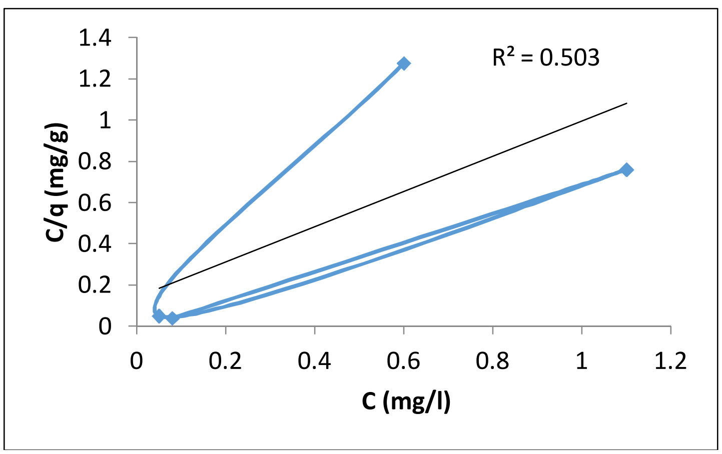

Figure 7: Langmuir isotherm for Iron

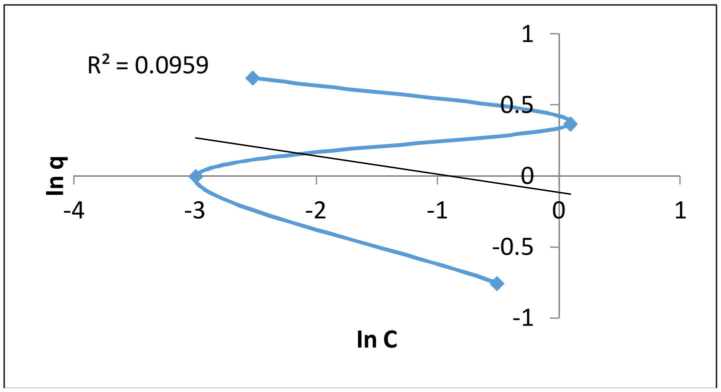

Figure 8: Freundlich isotherm for Iron

From the figures above, the Langmuir and the Freundlich model was not fitted for the modeling of AWH on any of the metals, though Freundlich model has a close range of correlation coefficient of 0.771 for the lead on AWH. It was also observed that the maximum sorption capacity (q_{max}) of the carbons for the metals was found to be 6.67mg/g on the sorption of lead by AWH. (Table 2)

AWH		
Constants	**Iron**	**Lead**
a	3.47	6.67
b	0.66	-27.26
R^2	0.062	0.6923

Table 2: Langmuir Constants

AWH		
constants	**Iron**	**Lead**
n	0.963	1.82
K_f	0.126	30.57
R^2	0.2046	0.7709

Table 3: Freundlich Constants and Correlation

5. Summary and Conclusion

The main objectives of drinking water treatment are to produce high quality water that has aesthetic appeal, safe for human consumption and is also economical in production. For this reason, activated carbon has been a source for drinking water purifications, hence the need for a PH of 7.0

In this research work, activated carbons for removal of heavy metals were produced from water hyacinth; some of the properties of activated carbon that enhances adsorption were determined under pH, iodine number, moisture content, particle sizes and bulk density. The results showed that water hyacinth has a pH of 7.67, iodine number of 620mg/g, and particle size of 0.14mm. And moisture content of 54.09%. A batch adsorption experiment was also carried out, the results shows that the adsorption is pH dependent, the percentage adsorption of both metals (Lead & Iron) are higher at higher PH. AWH adsorbing 99.85% of iron at pH = 8 and 99.20% for lead. Under the condition of contact time, the adsorbent has a higher adsorption at 60mins of contact at which AWH adsorbed 99.59% of iron and 98.26% for lead. Langmuir and Freundlich model was also applied and the results show that the Langmuir and Freundlich cannot be used for modeling the adsorption.

6. Conclusion

Based on the results of this study, the following conditions can be drawn;

- That the use of AWH as an alternative, inexpensive adsorbent could, drastically reduce the cost of wastewater treatment.
- That the use of AWH as adsorbents could equally reduce the environmental problem that may be created by water hyacinth and palm.

Therefore, it is now recommended that government should encourage this kind of research works by recommending it to the users of the activated carbon since it has the capacity to be adapted in industrial scale. This will help boost the economy of the country as a domestic product and a major way of adopting the integrated waste management method of recovering resources from waste.

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