Performance Evaluation of Avacado Pear Seed Activated Carbon on Iron Removal from Tap Water in Bayelsa State, Nigeria

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***Abstract* - The optimum performance of activated carbon prepared from Avocado Pear seed for the removal of iron from tap water without chemical pretreatment was investigated. Avacado Pear seed chars activated with phosphoric, nitric and sulphuric acids of varying concentrations were used in batch adsorption test with tap water of 0.2mg/l iron content. Iron removal efficiency was explained in relation to iodine number and carbon yield. Carbon yield showed linearity with acid concentration for the three different acids used but no linearity was observed with iron removal efficiency. Char activated with sulphuric acid showed linearity between iron removal efficiency and iodine number while phosphoric and nitric acid activated carbons did not show similar linearity. Chars activated with phosphoric acid gave the highest carbon yield while those of sulphuric acids gave the highest iodine numbers. Optimum iron removal was observed at similar concentration of 0.2M for all acid type used in this work. The iodine numbers and iron removal efficiencies of sulphuric, phosphoric and nitric acids at optimum concentration were 1713 and 94%; 1256 and 100%; and 1218 and 93% respectively. The outstanding performance of phosphoric acid activated char was attributed to high carbon yield and iron-phosphorus complexation. The results of this work concluded that iron removal efficiency from tap water is a function of both micropore content and surface functional groups hence, iodine number alone may not be a good indicator for activated carbon performance of iron removal efficiency.**

***Key words*- Iron removal efficiency; Tap water; Avocado pear seed; Activated carbon; Activating acids**

I. INTRODUCTION

In Nigeria, water supply is more of an individual responsibility than a government responsibility. Most government owned public water utilities are non-functional and so water supply has gradually shifted from government to individual household responsibility. In the urban cities of Nigeria, the main water source is groundwater. Compared to surface water, groundwater requires minimal treatment to produce potable water because of the natural filtration that takes place during the formation of groundwater. However, groundwater quality is often influenced by minerals within the underlying geologic formations that are soluble in water.

Iron is a soluble mineral that is abundantly available in the earth's crust. It makes up at least 5 percent of the earth's crust. It dissolves in rainwater that infiltrates the soil and underlying geologic formations, seeping into groundwater. Iron is mainly present in water in two forms: either as soluble ferrous iron or insoluble ferric iron. Water containing ferrous iron is clear and colourless because the iron is completely dissolved. When exposed to air in the pressure tank or atmosphere, the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of iron that does not dissolve in water. Also Iron can combine with different naturally-occurring organic acids or tannis to form organic iron. High content of iron in water gives water a disagreeable metallic taste.

There are hardly any recorded effects of iron on human health, thus, the World Health Organization (WHO) classified iron as a secondary or aesthetics element which means iron affects only taste, colour and smell of water. According to the WHO's report, the maximum allowable concentration of iron in water is 0.1mg/L [1] while the Nigerian Drinking Water Standard for iron is 0.3mg/L [2] but this would leave reddish brown stains on tableware, laundry and fixtures that is very hard to remove. Also for piped systems, a much lower concentration of iron as 0.05-0.1mg/l could cause colour and turbidity of water.

Coloured turbid water is often the type of water found in most parts of Bayelsa state of the Niger Delta Region of Nigeria. Most water storage tanks and fixtures are seen stained with rusty particles. This is an indication that the iron content in the groundwater is high and that water must be treated with special iron removal technologies. The WHO's current recommended filtration technologies for the removal of iron from water including, manganese greensand, anthra/sand or iron-man sand, electromedia, and ceramic filters require chemical pretreatment of the water to oxidize iron. This pretreatment increases treatment cost and also requires specified knowledge on the type of chemicals and their mode of applications.

Activated carbon (AC) is a porous carbonaceous adsorbent that is commonly used in the water industry for the removal of organic and inorganic contaminants, soluble and insoluble contaminants as well as toxic and non-toxic contaminants from surface water, groundwater and wastewater [3-7]. Its common use is attributed to its high adsorptive capacity, intrinsic physiochemical properties as well as its availability and affordability. The availability and affordability of activated carbon is dependent on the precursor [8-9], while the physiochemical characteristics are dependent on the precursor and the type of chemicals used for the activation [10-15].

Activated carbon can be prepared from virtually all carbonaceous materials especially from amorphous carbonaceous materials. The most available and affordable carbonaceous materials are agricultural wastes. The use of agricultural waste as precursors of activated carbon also meets the 11th sustainable development goal of the United Nations agenda 2030 which makes it even more viable, economically and environmentally. Thus, a diversity of agricultural waste such as woods, palm kernel and coconut husk has been tested for their suitability as adsorbent in the removal of contaminants from water [16-17, 6]. The suitability of non-edible bioseeds as precursors for activated carbon has also been investigated. Avocado pear *(Persea americana)* seed char was activated using various acids and their iodine numbers and carbon yield percentages were reported [18]. Following the preparation of the activated carbon with avocado pear seed, this work further investigated the optimum performance of the avocado pear seed activated carbon in the removal of iron without any chemical pretreatment of the raw water.

II. MATERIALS AND METHOD

A. Preparation of Activated carbon with avocado pear seed as precursor

The activated carbon used for the adsorption of iron in this research was prepared in the Chemical Engineering Laboratory of Akwa Ibom State University, Ikot Akpaden, Nigeria. Three different types of acids namely phosphoric, nitric and sulphuric acids were used as activating agents. The activating acids were applied at varying concentrations of 0.05M, 0.1M, 0.2M, 0.3M and 0.4M. Description of the method of preparation of activated carbon and properties of prepared activated carbons including bulk density, percentage yield, ash content, and iodine number were determined and reported in our previous work [18]. The activated carbons prepared from the various activation agents at the different concentrations used in this experiment were labelled as shown below.

Table I: Labelling of activated carbon with respect to the activating agent and concentration

Concentration	Nitric acid	Phosphoric acid	Sulphuric acid
0.05	N-05	P-05	S-05
0.1	N-1	P-1	S-1
0.2	N-2	P-2	S-2
0.3	N-3	P-3	S-3
0.4	N-4	P-4	S-4

B. Batch Adsorption Experiment

Batch adsorption experiment was carried out in the Biochemistry Laboratory of the Federal University Otuoke, Bayelsa state, Nigeria as raw groundwater was obtained from same laboratory. Experiment for Iron removal from tap water was carried out by gently stirring 2g of activated carbon with 500ml of tap water sample of 0.2mg/l of iron. A magnetic stirrer was used to gently stir the solution for 10minutes and filtered using Whatman 1micron filter. Iron content and pH of raw and treated tap water were determined using UV-visible spectrophotometer of 190-1030nm wavelength and pH meter respectively.

III. RESULTS AND DISCUSSIONS

A. Iron Removal by Physiosorption of Activated Carbon

Chemical activation by acids affects carbon properties such as carbon yield and iodine number. Iodine number is a measure of the porosity of the activated carbon. The pore spaces created during the activation process are responsible for the large surface area of activated carbon. It is within the pores (micropores, mesopores or macropores) that adsorption largely takes place. Hence high iodine number is an indication of high porosity and high physiosorption capacity.

1) *Activated carbons of sulphuric acid:* Relating iron removal efficiency with pore volume for sulphuric acid activated carbons (S-05, S-1, S-2, S-3 and S-4), iron removal efficiency showed direct linear relation with iodine number. As sulphuric acid concentration increased from 0.05M to 0.2M, iodine number and iron removal increased, but with further increase in concentration from 0.2M to 0.4M a decline in both iodine number and iron removal efficiency was observed (See Fig. 1). Carbon yield did not show any direct linear relationship with iron removal, but it was observed that carbon yield increased with sulphuric acid concentration (Fig. 2). These results indicated that increase sulphuric acid concentration lowered the degree of pyrocatalytic degradation. During the pyrocatalytic degradation the organic substances were converted into volatile gases and liquid, leaving solid carbonaceous residue with high micropore volume. The volume of micropores increased with carbon yield until 0.2M beyond which a collapse in the micropore walls began to occur despite the increase in carbon yield. The collapsed micropore walls formed mesopores and macropores that lowered iodine number and hence iron removal efficiency with 0.3M and 0.4M of sulphuric acid.

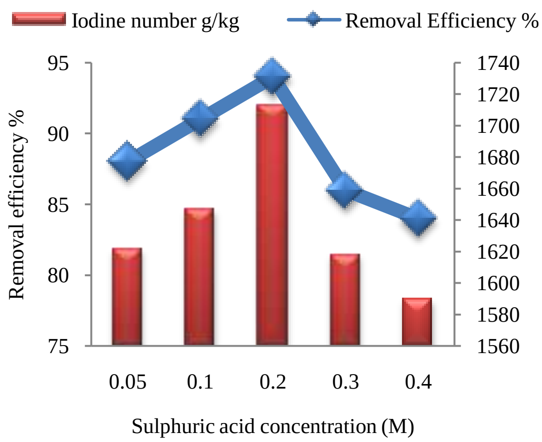

Fig. 1: Effect of Sulphuric acid concentration on porosity of activated carbon and iron removal

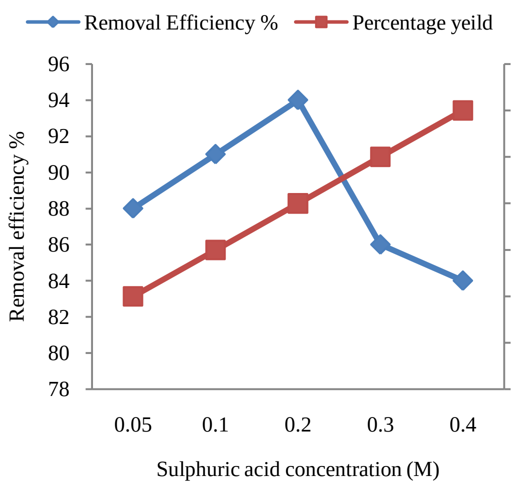

Fig. 2: Effect of Sulphuric acid concentration on carbon yield of activated carbon and iron removal

2) *Activated carbons of Phosphoric acid:* Increase in phosphoric acid concentration resulted in decrease in both iodine number and carbon yield with a sharp decline in carbon yield from 0.2M to 0.3M (see Figures 3 and 4). Contrary to expectation, phosphoric acid activated carbons did not show linear relation between iron removal efficiency and iodine number (see Figure 3). P-05 with the highest iodine number showed the least iron removal while P-1 and P-2 with similar iodine number showed varying iron removal efficiencies. It was observed that iron removal increased from 0.05M to 0.2M phosphoric acid concentration and then declined from 0.3M to 0.4M phosphoric acid concentration. The relation between iodine number, carbon yield and iron removal efficiencies indicated that with phosphoric acid, pyrocatalytic degradation which lead to the collapse of micropore walls became intense with increased acid concentration and that iron removal efficiency did not only occur by physiosorption.

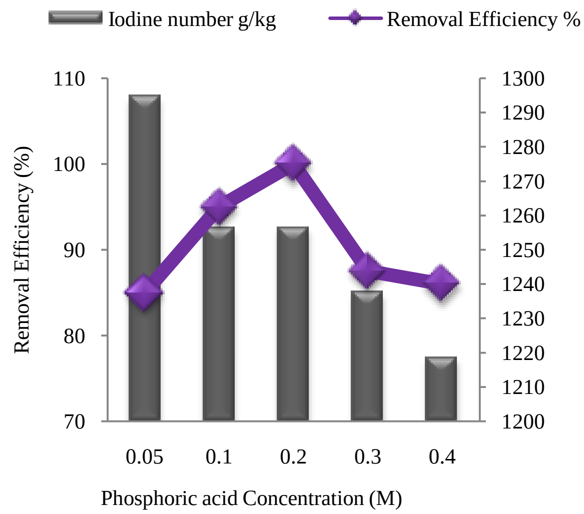

Fig. 3: Effect of phosphoric acid concentration on porosity of activated carbon and iron removal efficiency

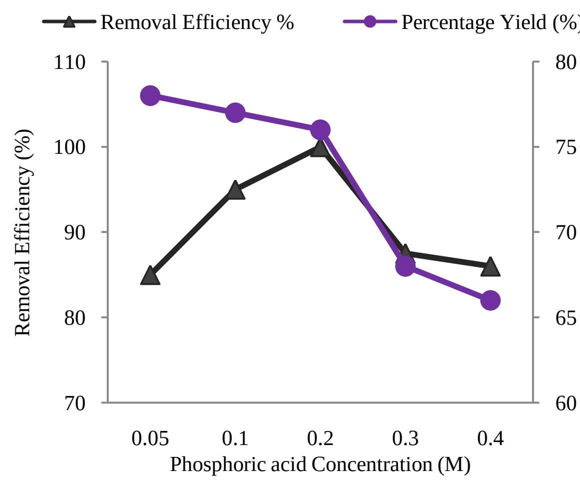

Fig. 4 Effect of Phosphoric acid concentration on carbon yield of activated carbon and iron removal

3) *Activated carbons of nitric acid:* Similar to the phosphoric acid group of activated carbons, the carbon yield of the nitric acid activated carbons decreased with acid concentration, but the iodine number of these activated carbons did not show linear relation with acid concentration (Figs. 5 and 6). The iron removal efficiency was observed to increase from 0.05M to 0.2M (N-05 to N-2) and then a decline in iron removal set in at 0.3M (N-3). The decline was not maintained as a sharp increase was observed for 0.4M (N-4). Highest iodine number was obtained for N-05 (0.05M) but N-05 did not give the highest nor least iron removal efficiency. This suggests that with nitric acid, iron removal was better achieved by chemisorptions due to specific functional groups formed on the carbon surfaces.

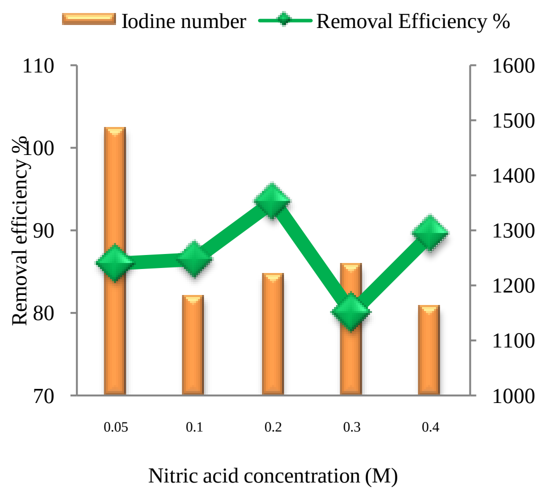

Fig. 5: Effect of Nitric acid concentration on porosity of activated carbon and iron removal efficiency

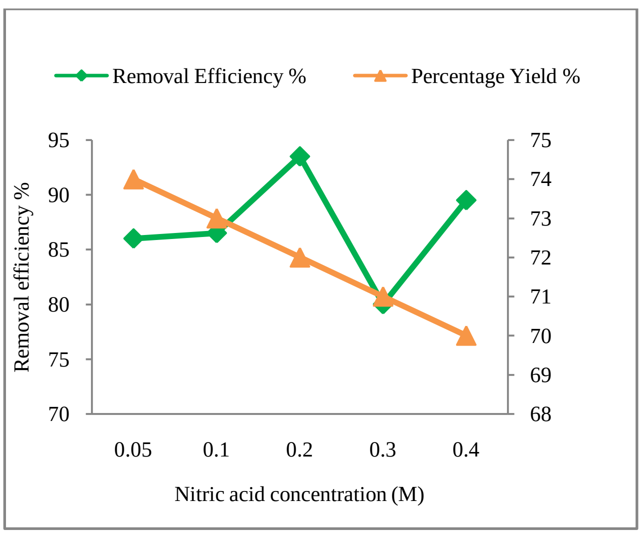

Figure 6: Effect of Nitric acid concentration on carbon yield of activated carbon and iron removal efficiency

B. Iron Removal by Chemisorption of Activated Carbon

Chemical activation develops oxygenated surface complexes on activated carbon surfaces that enhances specific chemisorption on the surface of the activated carbon. One common complexation in waste water treatment is iron-phosphate complexation. In this work the excellent iron removal efficiency of the phosphoric acid activated carbons as shown in Fig. 7 was attributed to the iron-phosphate complexation. It was inferred that the oxygenated phosphate species concentration must have increased with carbon yield and hence phosphoric acid concentration. However, iron removal efficiency for P-3 and P-4 did not increase with acid because of the volume of mesopores and macropores that must have formed with the possible collapse of micropore walls. This is similar to the report of [14]. The optimum iron removal which occurred at similar acid concentration of 0.2M for all acid type used in this work further suggests that iron removal may have occurred not only by physiosorption as the iodine numbers and the iron removal efficiency at optimum concentrations varied significantly as shown in Fig. 8.

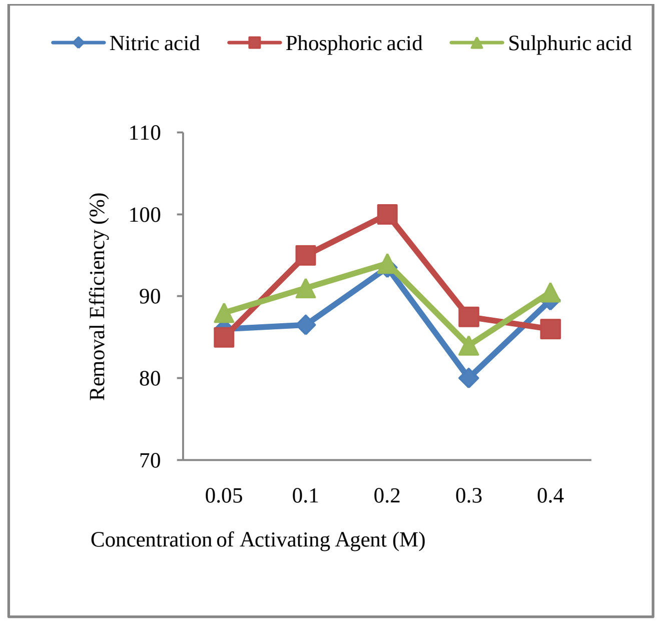

Fig. 7: Effect of acid type on concentration on iron removal efficiency

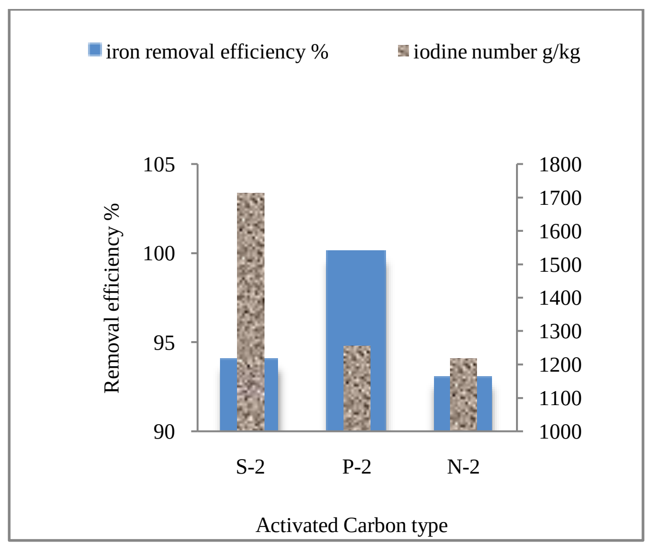

Fig. 8: Relationship between iron removal and iodine number at optimum concentration of acid

IV. CONCLUSION

Avacado Pear seed is a good precursor for the preparation of activated carbon for iron removal from tap water. High removal efficiency of 80% and above is possible when sulphuric, phosphoric or nitric acid is used as activating agent on Avacado Pear seed. Optimum acid concentration is similar for all three acid types. Phosphoric acid is a better activating agent due to iron-phosphorus complexation as additional iron removal process.

REFERENCES

[1]. **World Health Organization** (WHO 2011), Guidelines for drinking-water quality, 4th edition

[2]. **Standard Organization of Nigeria** (SON 2015), Nigerian Standard for Drinking water Quality

[3]. **Ijaola, O.O., Ogedengbe, K. and Sangodoyin, A.Y** (2013), On the efficacy of activated carbon derived from Bamboo in the Adsorption of water contaminants, *Intl. Journal of Engr. Interventions,* 2(4), 29-34

[4]. **Zeng, X., Xia, J. Wang, Z. and Li, W** (2014) Removal of iron and manganese in steel industry drainage by biological activated carbon, *Desalination and Water Treatment.* (2014), 1-8

[5]. **Van der Hoek, J.P., Hofman, J., and Graveland, A** (1999), The use of biological activated carbon filtration for the removal of natural organic matter and organic micropollutants from water. *Water Science Technology,* 40, 257-264.

[6]. **Ademiluyi, F. T., Amadi, S. A. and Amakama, N. J** (2009), Adsorption and treatment of organic contaminants using activated carbon from waste Nigerian Bamboo. *Journal of Applied Science and Environmental Management,* 13 (3) 39-47.

[7]. **Zamora, R.M.R., Schouwenaars, R., Moreno, A.D. and Buitrón G** (2000), Production of activated carbon from petroleum coke and its application in water treatment for the removal of metals and phenol. *Water Science and Technology*, 42, (5-6) 119–126.

[8]. **Kadirvelu, K., Kavipriya, M., Karthika, C., Radhika, M., Vennilamani, N., and Pattabhi, S.** (2003), Utilization of various agricultural wastes for activated carbon preparation and application for the removal of dyes and metal ions from aqueous solutions. *BioresTechnol,* 98, 32-129.

[9]. **Wang, J., Wu, F., Wang, M., Qiu, N., Liang, Y., Fang, S. and Jang, X.** (2010), Preparation of activated carbon from a renewable agricultural residue of pruning mulberry shoot. *African J. of Biotechnology*, 9(19), 2762-2767

[10]. **Ademiluyi, F.T. and David-West, E.O.** (2012), Effect of Chemical Activation on the Adsorption of Heavy Metals Using Activated Carbons from Waste Materials. *Journal of International Scholarly Research Network,* 1-6

[11]. **Xiao, J.J., Zhi-Ming, Y. and Wu, Y.** (2012), Preparation of activated carbon from lignin obtained by straw pulping by KOH and K_2CO_3 Chemical activation.*Cellulose Chemistry and Technol*, (46) 1-2,79–85.

[12]. **Awoyale, A.A., Eloka-Eboka, A.C. and Odubiyi, O.A.** (2011), Production and experimental efficiency of activated carbon from local waste Bamboo for waste water treatment. *Intl J of Engr and Appl Sci.* 3(2), 8-17

[13]. **Yahya, M.A., Al-Qodah, Z. and Ngah, C.W.Z** (2015), Agricultural bio-waste material as potential sustainable precursors used for activated carbon production: A review. *Renewable and Sustainable Energy Reviews,* 46, 218-235

[14]. **Yakout, S.M. and El-Deen, S.** (2011), Characterization of activated carbon prepared by phosphoric acid activation of olive stones. *Arabian J. of Chemistry,* 9 (2016), 1155-1162

[15]. **Aki, M.A., Yousef, A.M., and AbdElnasser, S**. (2013), Removal of Iron and Manganese in water samples using activated carbon derived from local agro-residues. *J ChemEng Process Technol*, 4(4): 1-10

[16]. **Okoroigwe, E.C., Ofomatah, A.C., Oparaku, N.F. and Unachukwu, G.O.** (2013), Production and Evaluation of activated carbon from palm kernel shells (PKS) for economic and environmental sustainability. International Journal of Physical Sciences, 8(19) 1036-1041

[17]. **Ayotamuno, M.J., Okparanma, R.N., Ogaji, S.O.T. and Probert, S.D.** (2007), Chromium removal from flocculation effluent of liquid-phase oil-based drill-cuttings using powdered activated carbon. *Appl. Energy. 84,1002-1011.*

[18]. **Olatunji, O.M., Ekpo, C.M. and Ukoha-Onuoha, E.** (2017), Preparation and Characterization of activated carbon from Avacado Pear (Persea Americana) seed using H_2SO4, HNO_3, and H_3PO_4 activating agents. *Intl. J. of Ecological Sci and Environ Engr.* 4(5), 43-50