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Removal of Chromium from Waste Water Using Yam Peel Activated Carbon

J. T. Utsev and M. O. Onah

***Abstract*— The paper examined the use of yam peel to develop an adsorbent material with good surface characteristics for the removal of chromium (vi) from waste water. Activated carbons were produced from yam peel under varying conditions; temperature, time and preparation sequence in order to determine the optimum conditions. Its efficiency on the adsorption of chromium from waste water was investigated through batch adsorption studies using direct reading spectrophotometer. Samples of yam peels, 100g each were carbonized under varying temperatures of 100, 200, 300, 400, and 500ºC ,with varying carbonization time of 20, 30, 40, 50 and 60 minutes. The result revealed that 80% of chromium was removed at 200ºC and 40 minutes as the optimum carbonization temperature and time respectively. Effect of preparation sequence was equally evaluated, i.e. raw (powdered form), carbonization without activation, activation with (ZnCL2) before carbonization and activation after carbonization with (ZnCL2) and their adsorbing capacities under an initial concentration of 0.05mg/l were obtained to be 20, 100,100 and 60% respectively. Further increase in concentration results in 100% chromium removal for activation before carbonization and 80% for carbonization without activation. Hence, yam peel activated carbon is recommended for the removal of chromium from wastewater using activation before carbonization procedure at the above optimum conditions.**

***Index Terms*— Chromium, Yam peel, Activated carbon, Extracts, Water Treatment.**

I. INTRODUCTION

Pollution occurs when pollutants contaminate the natural surroundings; which brings about changes that affects our normal life styles adversely. Pollutants are the key elements or components of pollution which are generally waste materials of different forms. Pollution occurs in different forms: air, water, soil, radioactive, noise, heat/ thermal and light. Among the various forms of pollution, water pollution is of great concern because water is the primary necessity of life and extremely essential for the survival of living organisms [9]

Water pollution occurs when water bodies such as rivers, lakes, etc. are contaminated as a result of direct or indirect of pollutants without adequate treatment. This affects both plants and organism living in these water bodies by damaging both the individual species and the biomass. In addition to the release of substances, such as chemicals or microorganisms, water pollution may also include the release of energy, in the form of radioactivity or heat, into bodies of water. Increase in pollution has adverse effect on water pollution as it seriously increase the rate of activities on earth surface causing the discharge of pollutants. Into the water bodies by industries. Dyes from textile industries produce large amount of colour effluents into water bodies which prevent the penetration of sunrise thus affecting the aquatic system which is unacceptable according to the standard of world health organization [6]

Chromium is a metal that is mostly being used as a major focus in water and wastewater treatment because of its hexavalent form. Chromium is considered to be one of the most toxic pollutants, and its carcinogenic and teratogenic characteristics makes it a serious health concern. Chromium can be released to the environment by industrial operations, such as metal finishing industry, inorganic chemical production and iron/steel industries. The acceptable limit of chromium in water for drinking is 0.1mg/l [19].

The prevalence of some heavy metals in aquatic system have become a matter of attention due to their toxic effect to the ecosystem, agriculture and human health [5] [8]. Research works have been carried out for effective removal of various heavy metals from solution using some natural adsorbents which are economically useful like Agricultural wastes [17]. Wastewater can therefore be identified as the source of water that is contaminated by the above mentioned pollutants [1].

The various treatment methods for the removal of chromium, colour and dyes from waste water are alum, lime, ferric, sulphate, ferric chloride, chemical oxidation using chlorine and have been published by many researches such as sedimentation with clarification, coagulation and flocculation, chemical oxidation, filtration using membranes, adsorption, biodegradation etc. Among this method, adsorption which is a process where a solid is used for removing a soluble substance from the water currently appears as the best treatment in order to remove chromium and colour from waste water using activated carbon.

Activated carbon apart from being a special type of carbonaceous substance, it is highly crystalline in nature and developed internal pore structure, which creates internal pore network due to activation. Carbon has high surface area, porosity, greater strength and organic material, which makes it a good raw material for the synthesis of activated carbon [18]. Substitute materials tested includes saw dust, coal reject, sewage slag, automobile tyres and straw.

However, attempts by some indigenous researchers have been towards investigating the adsorption capacity of local materials such as kernel shells [16], mango seed shells [4], maize cobs [2], coconut shells [12] etc. However, the yam peels which are in such abundance in some parts of Nigeria can be used for waste treatment thereby reducing its environmental pollution. To this end, investigating the effectiveness of yam peel as an adsorbent material with

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good surface characteristics for the removal of chromium from waste water became the targeted aim of the research.

II. MATERIALS AND METHODS

The yam peels used in this research were collected from Makurdi Local Government Area of Benue State. The peels were removed from the roots and washed with distilled water and air dried to remove moisture. The activated carbon made from the yam peel did not impact any colour, taste and odour to the water when added to it. The air dried yam peel was powdered in a grinder and sieved through sieve 300 µm.

The yam peel activated carbon (AC) was characterized by the following properties: pH using EUTECH instrument pH meter, particle bulk density was determined using [3] procedure, external surface area was calculated using [14] procedure, while, thermal drying method of was used in the determination of the moisture content of the samples. The ash content/ volatile matter of the yam peel activated carbon was determined using standard test method for ash content-ASTM D 2866-94. The specific gravity and activated carbon yield (%) of the yam peel were determined using appropriate standard testing methods [7].

Proximate analysis of yam peel was carried out and the properties of the sample (yam peel) such as crude protein, fat/oil, ash, moisture content, crude fibre and carbon content were determined. The optimum carbonization temperature of yam peel was determined by varying the carbonization temperatures of 100, 200, 300, 400 and 500oC respectively at constant time of 30minutes. 100g each of yam peel was carbonized in the muffle furnace. The carbonization temperature of the sample that removes the highest amount of chromium was taken as the optimum carbonization temperature of yam peel. After which, the optimum time of carbonization was determined by varying the carbonization time at constant temperature. 100g each of the yam peel was carbonized under carbonization times of 20, 30, 40, 50 and 60minutes. The carbonization time of the sample that removed the highest amount of chromium was taken as the optimum carbonization time of yam peel.

A. *Batch Adsorption Experiment*

Before carrying out the batch adsorption experiment, the sample was activated with Zinc Chloride (ZnCl). Carbonization of the activated yam peel was then carried out in model SXL muffle furnace in accordance with the method described by [12]. The waste water to be treated was simulated in the laboratory with a stock solution of chromium (VI) by dissolving 0.5g of potassium dichromate ($K_2Cr_2O_7$) in 100ml of distilled water to obtain the concentration of chromium in wastewater.

The sorption isotherm and kinetics experiments were performed by batch adsorption techniques which was carried out by mixing specific amount of the activated carbon (yam peel) in (mg) with 100ml of distilled water with certain initial chromium present. The following were determined; variation of initial concentration, activation before carbonization, variation of speed, variation of contact time variation of flocculating temperature and variation of pH.

III. RESULTS AND DISCUSSION

A. *Proximate Analysis of Yam Peel*

The result of proximate analysis as shown in Table 1 presents low amount of moisture content 8.56, ash 5.71, crude fibre 2.68, crude protein 4.38, fats & oil 0.75 and high amount of carbon 77.92.

TABLE I: PROXIMATE ANALYSIS OF YAM PEELS

Compounds	Percentage composition
Moisture content	8.56
Ash content	5.71
Protein content	4.38
Fats and Oil content	0.75
Crude fibre	2.68
Carbon	77.92

Yam peel was characterized and found to have a low amount of moisture content and ash content of 8.56% and 5.71% respectively, while the crude fibre peel of the sample gave 2.68% which fibre peel of the sample gave 2.68% which makes it a good activated Carbon, as confirm by other works [10] [13] [15].

Crude protein was found to be was found to be 4.38%. Crude protein is an organic compound and since low organic material is necessary to produce activated carbon with low ash content [13]. The carbon content is gotten from the sum of all the compounds present in the sample subtracted from 100.

B. *Optimum Carbonization Temperature of Yam Peels*

The optimum carbonization temperature of yam peel was determined by varying temperatures of 100, 200, 300, 400 and 500oC at a constant time of 30minutes. 0.4g of the adsorbent of each carbonization temperature was added to the stimulated waste water and placed under the flocculator and allowed to flocculate for 30minutes at speed of 200rpm. After which it was filtered and analysed for residual chromium concentration using a spectrophotometer. At 200oC the optimum carbonization temperature was obtained since it removed the highest amount of chromium.

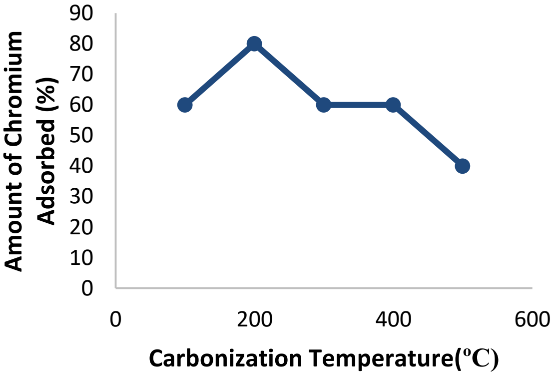

Fig. 1. Chromium Adsorbed verses Carbonization Temperature of Yam Peel.

C. Optimum Carbonization Time of Yam Peels

The optimum carbonization time of yam peels was determined by varying the carbonization time of 20, 30, 40, 50 and 60minutes at the optimum carbonization temperature of 200oC. 0.4g of the adsorbent of each carbonization temperature at 200ºC was added to the stimulated waste water and placed under the flocculator and allowed to flocculate for 30minutes at speed of 200rpm. After which it was filtered and analysed for residual chromium concentration using a spectrophotometer. The result shows that the adsorbing capacity of the carbonized sample increases with increase in carbonization time. At 40minutes and 50minutes after which the residual chromium concentration started decreasing with increase in carbonization time. At 40minutes the optimum carbonization time was obtained since it removed the highest amount of chromium first and the purpose of research is to investigate the method that is economical.

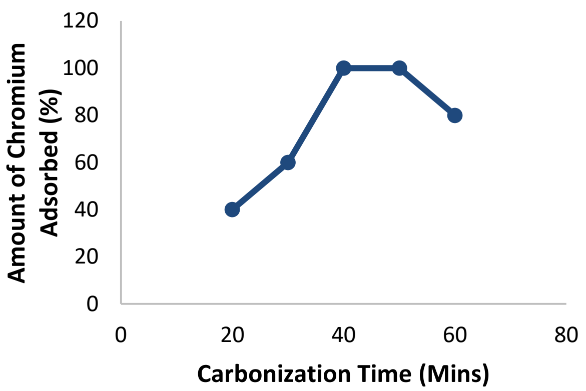

Fig. 2. Chromium Adsorbed verses Carbonization Time of yam Peel.

D. Effect of Preparation Sequence/Method on Chromium Removal

The essence of varying the preparation method is to determine the best preparation technique under which activated carbon perform best. The following methods were compared, yam peel in its raw powdered form, yam peel carbonized without activation, yam peel activated after carbonization and yam peel activated before carbonization. Using the optimum temperature and time of 200ºC and 40 minutes gotten respectively and a flocculating speed of 200rpm, 0.4g of the dose was used at an initial concentration of 0.05mg/l. The amounts of chromium remained in each of these methods were 0.04mg/l for raw powdered form, 0.00mg/l for carbonized only, 0.02mg/l for activated after carbonization and 0.00mg/l for activated before carbonization. The percentage chromium removed were 20, 100, 60 and 100% respectively. From the results obtained in Table 2, the lowest amount of chromium of 20% was removed by the raw sample (powdered form) and 60% was removed by activated after carbonization. From the same table, it is seen that carbonization without activation and activation before carbonization removed 100% chromium and are therefore considered to be both best. However, discussing from the economical point of view, carbonization without activation is considered as the optimum preparation procedure for an initial concentration of 0.05mg/l.

TABLE II: The amount of chromium removed with different preparation procedures.

Preparation Procedure	**Cr^{6+} remained (mg/l)**	**Cr^{6+} removed (mg/l)**	**% Cr^{6+} removed**
Raw powdered form	0.04	0.01	20
Carbonized without activation	0.00	0.05	100
Activated after carbonization	0.02	0.03	60
Activated before carbonization	0.00	0.05	100

From the result on the table above, activation before carbonization and carbonization without activation gave 0.00mg/l at an initial concentration of 0.05mg/l further experiments were carried out to know the best procedure using samples from the two methods but with increased concentration of 0.15mg/l. as presented in Table 3, the result revealed activation before carbonization to be the optimum preparation procedure since it adsorbed the highest amount of chromium 100%.

TABLE III: Comparing the best method in the removal of chromium at 0.15mg/l.

Preparation Procedure	**Cr^{6+} remained (mg/l)**	**Cr^{6+} removed (mg/l)**	**% Cr^{6+} removed**
Carbonized without activation	0.03	0.12	80
Activated before carbonization	0.00	0.15	100

E. Characterization of Yam Peel Activated Carbon

TABLE IV: Characterization of yam peel.

Parameter	**Yam Peel Activated Carbon**
Ph	7.20
Bulk density g/cm^3	0.67
Surface area m^3/g	118.4
Moisture content %	2.8
Ash content %	26
Volatile matter %	54
Specific gravity	1.08
Carbon yield %	78

The parameters for the characterization of the activated yam peel are summarized in Table 4 above which shows that, the bulk density is 0.67. Generally, the lower the bulk density, the higher the porosity and surface area. This means that it has good quality activated carbon.

F. Batch Adsorption

The batch adsorption experiment was run using Stuart scientific flocculator SW1 and the following were determined.

Effect of Initial Concentration: The initial concentration was varied by using dose of 0.05mg/l, 0.10mg/l, 0.25mg/l, 0.35mg/l, 0.45mg/l and 0.60mg/l with an initial concentration of 0.10mg/l at a speed of 200rpm, dose of 0.4g and temperature of 200ºC. The following results were obtained at 0.05mg/l chromium removed was 100%, 0.10mg/l was 100%, 0.25mg/l was 90%, 0.35mg/l was 70%, 0.45mg/l was 50% and 0.60mg/l was 30%. From Figure 3, it was discovered that the highest amount of chromium was removed at the 0.10mg/l dose and 0.05mg/l which were 100% but 0.10mg/l is picked as the best concentration because it was at that dose that the residual chromium concentration started decreasing with increase in dose.

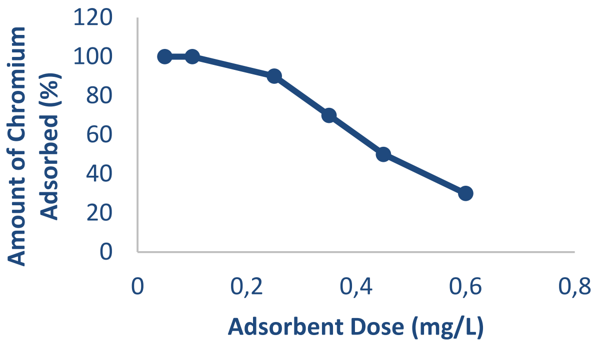

Fig. 3. Chromium Adsorbed verses Adsorbent concentration.

Effect of Dose for Activation before Carbonization: The activation before carbonization was varied by using dose of 200mg, 400mg, 600mg, 800mg, and 1000mg with an initial concentration of 0.10mg/l at a speed of 200rpm, dose of 0.4g and temperature of 200ºC. The following results were obtained, at 200mg chromium removed was 70%, 400mg was 100%, 600mg was 100%, 800mg was 90% and 1000mg was 80%. From Figure 4 below, it was discovered that the highest amount of chromium was removed at the 400mg and 600mg dose which were 100% but 400mg was picked as the best because it was at that dose that the residual chromium concentration started increasing with increase in dose.

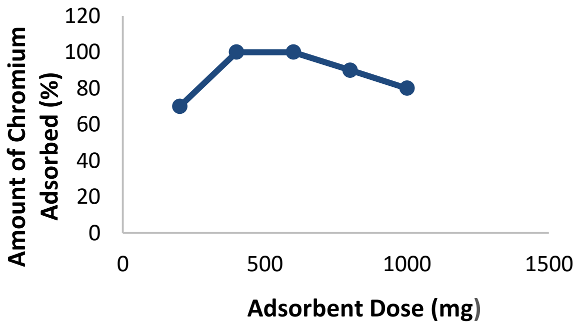

Fig 4. Chromium Adsorbed verses Adsorbent concentration for Activation before Carbonization.

Effect of Speed: Speeds of 90rpm, 180rpm and 260rpm were varied at an initial concentration of 0.10mg/l dose of 0.4g and temperature of 200ºC. The following results were obtained at the speed of 90rpm, chromium removed was 80%, 180 rpm was 100% and 260rpm 90%. As presented in Figure 5 below, it was discovered that the highest amount of chromium was removed at the speed of 180 which was 100% and is therefore, picked as the best speed.

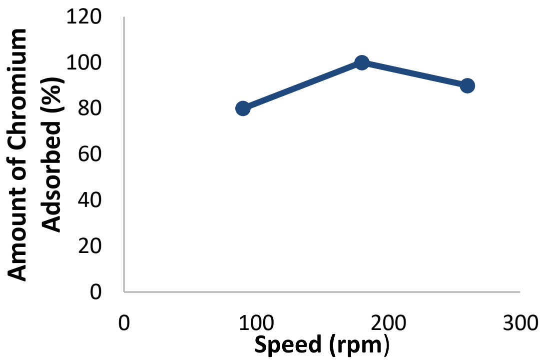

Fig 5. Chromium Adsorbed verses Speed.

Effect of Contact Time: Contact time were varied at 10mins, 20mins, 30mins, 40mins and 60mins respectively with an initial concentration of 0.10mg/l at a speed of 200rpm, dose of 0.4g and temperature of 200ºC. The following results were obtained, at 10mins chromium removed was 80%, 20mins was 90%, 30mins was 100%, 40mins was100% and 50mins was 100%. The highest amount of chromium was removed at the 30mins, 40mins and 60mins which were 100% but 30mins was picked as the best because it was at that dose that the residual chromium concentration started increasing with increase in time (Figure 6).

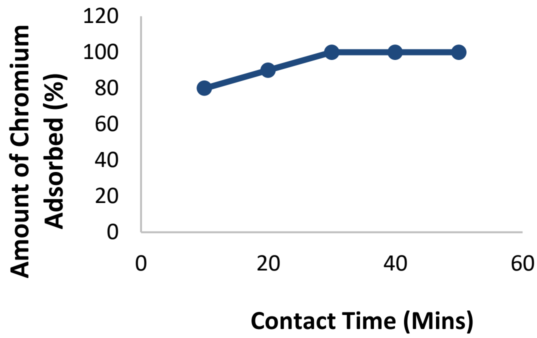

Fig 6. Chromium Adsorbed verses contact time.

Effect of Flocculating Temperature: Flocculating temperatures were varied at 20ºC, 30ºC, 40ºC, 50ºC, and 60ºC respectively with an initial concentration of 0.10mg/l at a speed of 200rpm, and dose of 0.4g . The following results were obtained, at 20ºC chromium removed was 80%, 30ºC was 100%, 40ºC was 90%, 50ºC was 90% and 60ºC was 80%. The highest amount of chromium was removed at the 30ºC, was 100% and is therefore, the best flocculating temperature as shown in Figure 7.

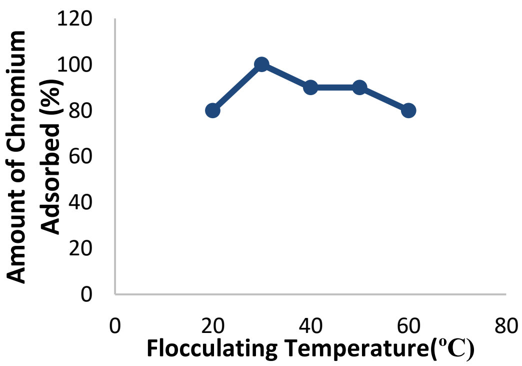

Fig 7. Chromium Adsorbed verses Flocculating Temperature.

*Effect of pH: p*H of the solution was varied at 4.00, 6.00, 7.00, 8.00 and 10.00 respectively with an initial concentration of 0.10mg/lat a speed of 200rpm, dose of 0.4g and temperature of 200ºC. The following results were obtained, at 4.00 chromium removed was 80%, 6.00 was 100%, 7.00 was 100%, 8.00 was 90% and 10.00 was 90%. Figure 8 shows the effect of pH, where the highest amount of chromium was removed at the 6.00 and 7.00 *p*H which was 100%. The 7.00 *p*H is picked as the best since it is neutral and the 6.00 is slightly alkaline.

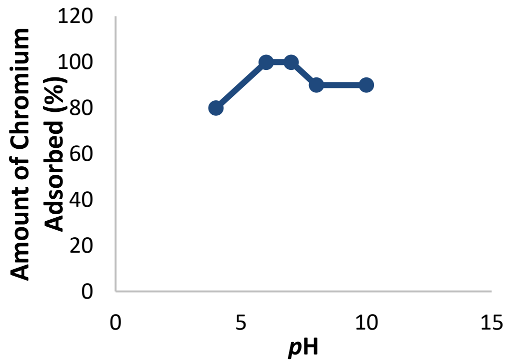

Fig 8. Chromium Adsorbed verses pH.

IV. CONCLUSION AND RECOMMENDATIONS

Yam peels were used to develop an adsorbent material with good surface characteristics for the removal of chromium (VI) from waste water. Activated carbons were produced from yam peel under varying conditions; temperature, time and preparation sequence in order to determine the optimum conditions. From the results, the optimum carbonization temperature of yam peel was investigated to be 200ºC. The optimum carbonization time of yam peel was investigated to be 40 minutes. Yam peel based activated carbon performs best when activated before carbonization. Activated carbon prepared from yam peel is capable of removing chromium from waste water. Optimum variation of initial concentration was investigated to be 0.10mg/l. Optimum dose of activation before carbonization was investigated to be 400mg. Optimum variation of speed was investigated to be 180rpm. Optimum variation of contact time was investigated to be 30 minutes. Optimum variation of flocculating temperature was investigated to be 30ºC. Optimum variation of pH was investigated to be 7.00.

Based on the result of this study, it is recommended that, the use of activated carbon should be encouraged since it is a means of waste control. Optimum carbonization temperature and time of 200ºC and 40minutes respectively should be used for yam peel for optimum results. Carbonization without activation should be adopted as the preparation procedure for chromium concentration lower than 0.05mg/l. However, for higher initial concentration of chromium, activation before carbonization should be adopted as the preparation procedure. The use of activated carbon should not be restricted to waste water but also to other fields of applications.

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Eng. Dr. J. T. Utsev was born in Benue State, Nigeria. He is a Senior lecturer in the Department of Civil Engineering, University of Agriculture, Makurdi, Nigeria. He holds a Ph.D in Water Resources and Environmental Engineering from University of Nigeria, Nsukka, Nigeria in 2011. He is a COREN registered engineer with about 30 academic publications in both National and International journals and the current Acting Director, Centre for Entrepreneurship Development, University of Agriculture, Makurdi, Nigeria. His area of research interest is Water Resources and Environmental Engineering. He has attended several National and International conferences, workshops and a recipient of several awards. He is married and blessed with children.

E-mail: utsevterlumun@gmail.com+2348036738719.