Yam Peels as Adsorbent for the Removal of Copper (Cu) and Manganese (Mn) in Waste Water

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ABSTRACT

This paper investigated the use of yam peel as a natural adsorbent for the removal of Copper (Cu) and Manganese (Mn) from waste water. The yam peels were thoroughly washed with distilled water, dried, pulverized and carbonized. The carbonized yam peel was then characterized for its particle sizes, moisture content, ash content, volatile matter, Methylene Blue number, Iodine number. The raw yam peels were prepared using the same procedure, but was not carbonized. The adsorption of Mn(II) and Cu(II) ions were investigated using adsorption experiment at room temperature. The effect of contact time, metal ion concentration and dosage were evaluated. The residual concentrations of the metal ions were determined by Atomic Absorption Spectrophotometer (AAS). Experimental data obtained were analyzed using Kinetic models and Isotherms such as Pseudo- First order kinetic models, Pseudo-second order kinetic models, Langmuir isotherms and Freundlich isotherm. The analysis showed that the pseudo-second order kinetic model best described the adsorption of the metal ions; (Cu; $r^2 = 0.991$ for RYP and $r^2 = 0.834$ for AYP) and (Mn; $r^2 = 0.958$ for RYP and $r^2 = 0.896$ for AYP) and the experimental data best fit the Freundlich model; (Cu; $r^2 = 0.564$ for RYP and $r^2 = 0.871$ for AYP) and (Mn; $r^2 = 0.685$ for RYP and $r^2 = 0.736$ for AYP). Finally, optimum removal efficiencies of 30.54% for Mn(II) and 39.62% for Cu(II) were obtained for AYP at concentrations of 50mg/l and mass dosage of 1.0g, 120 minutes contact time and a pH of 6.8.

Keywords: Activated Yam Peel; Raw yam Peel; Adsorption; Cu; Mn; Kinetics; Isotherm

1.0. Introduction

Water is essential for life. All known forms of life depend on water, and water safe and suitable for drinking is called *Potable Water*. There is a lack of Potable water in Africa, most of our water is unsafe for consumption. An important step towards resolving this global crisis is to understand its magnitude of how many people lack access to safe drinking water and sanitation (WHO and UNICEF 2000). Despite widespread recognition of the importance of improved water and sanitation and heavy investment by international donors and governments in developing countries in extending water supply systems, more than half the population of rural areas still lack access to clean drinking water. Due to this distressed situation people in rural areas are forced to use traditional sources of water that are polluted (WHO and UNICEF 2000).

Contaminated drinking water and inadequate supplies of water for personal hygiene and poor sanitation are responsible for about 4 billion cases of diarrhoea each year that cause 2.2 million deaths, mostly among children under the age of five (WHO 2003) These waters are contaminated by metals which find their way into drinking water via industrial and consumer waste or from acidic rain, breaking down soils and releasing heavy metals into streams, lakes, rivers and groundwater. These metals, if found at high levels is detrimental to human health. Hence, there is a need for ways to improve our drinking water to make them safer for consumption.

There is an increasing need for the use of safer materials and eco-friendly materials to be used in the treatment process of our drinking water. This has given rise to the use of natural adsorbents from

agricultural waste materials which are highly effective in the treatment of waste water and drinking water especially in the removal of heavy metals (Badmus et al 2007). However, the availability of these materials for use as natural adsorbents is highly affected by seasonal variation. The use of rice husk, coconut shell, corn cobs, palm nut chaff among others are agricultural waste materials that have been used in the productions of adsorbents but are available in appreciable amount in the rainy season. Hence, the need to find adsorbents whose availability is not strongly affected by climate. This paper will therefore determine the potential of yam peels as natural adsorbents for removal heavy metals from water.

2.0. Materials and Methods

2.1. Equipment/Materials/Chemicals

Equipment, materials and chemicals used for this research work are presented as shown in Tables 1, 2 and 3.

Table 1: Equipment used

Equipment Name	Model	Manufacturer	Year
Atomic Adsorption Spectrophotometer (AAS)	SOLAR 969	UNICAM SERIES	2010
Weighing Balance	Kern 001	England	2010
Hot Plate with Magnetic Stirrer	HJ-3D	England	2010
Turbidimeter	Jenway 6035	England	2010
Oven	DHG 9101-2A	Searchtech UK	2010
Scanning Electron Microscope (SEM)	APEX 3020	England	2010
Digital microprocessor pH meter	Hanna pH	England	2010

Table 2: Reagents used

Reagents Name	Grade	Minimum Assay
Sodium Thiosulphate	Analytical grade	98% w/w
Distilled Water	100% distilled	100% distilled
Elemental Copper	Analytical grade	95% w/w
Elemental Manganese	Analytical grade	95% w/w
Methylene Blue	Analytical grade	99% w/w
Iodine Solution	Analytical grade	99.5% w/w
Zinc Chloride	Analytical grade	97% w/w

Table 3: Materials used

Name	Description
Yam Peel	Yam by product
Sample Bottles	Marcaty Bottles
Funnels	Pyrex
Beakers	Pyrex
Reagent Bottles	Pyrex
Whatman Filter Paper	150mm diameter

2.2. Collection/Preparation of Adsorbent

Yam peels was collected from various homes and from Toseton Kitchen, a restaurant located at Benin-Lagos expressway. The peels were thoroughly washed with distilled water, dried and pulverized. Carbonization was done using the method recommended by (Ekpete et al. 2011) with slight

modification as follows. A predetermined weight of the pulverized sample was placed in a muffle furnace which allows limited supply of air at a temperature of 350°C for 30-60 minutes. The carbonized samples were then activated using the method recommended by (Ekpete et al. 2011) with slight modification as follows: 25g of the charred sample was soaked in 250ml of 5.5M ZnCl₂ solution. The mixture was thoroughly mixed until it formed a paste. The paste was then transferred to an evaporating dish which was placed in a furnace and heated at 200°C for thirty minutes. This was allowed to cool and washed with distilled water to remove the residue salt, oven dried at 105°C for one hour, grind using mortar and pestle and sieved with 0.6µm sieve. The activated carbon was then characterized for its particle sizes, moisture content, ash content, volatile matter, Methylene Blue number, (Badmus et al 2007). The raw Yam Peels followed the same process as that of the activated Yam Peel, except it wasn't carbonize.

2.3. Performance of Activated Carbon

Some of the parameters used to characterize the performance of the activated carbon includes:

2.3.1. Determination of pH

The standard test method for determination of activated carbon pH given in (ASTM, D3838-80) was used. 1.0g of activated carbon was weighed and transferred into a beaker 50ml of distilled water was measured and added and stirred for two hours. The samples were allowed to stabilize before the pH was measured using a digital pH meter (Hanna pH 210 model). (Ekpete O.A, Horsfall .M, Tarawou)

2.3.2. Determination of Iodine Number

In the determination of the Iodine Number, 10ml of 5% by weight HCl was added to 1g of activated carbon and was allowed to boil for 30 seconds. After the solution was cooled to room temperature, 100ml of 0.1N iodine solution was added. The content was shaken vigorously and filtered 25ml of the filtrate was titrated against 0.1N Sodium Thiosulphate using starch as indicator. The iodine number was defined as the quantity of iodine adsorbed in (mg/g carbon) as residual iodine concentration (ASTM, D4607-94).

2.3.3. Methylene Blue Number

The methylene blue number is defined as the maximum amount of dye adsorbed on 1.0g of adsorbent. In this method, 1g of activated carbon was placed in contact with 10.0ml of 25mg/l. Methylene blue solution for 24 hours at room temperature followed by intermittent shaking the solution was thereafter filtered using Whatman Number one filter paper and an aliquot solution was taken for analysis. The remaining concentration of Methylene blue was analyzed using an Atomic Adsorption Spectrophotometer. The amount of Methylene blue adsorbed was calculated using the mass balance equation:

$$q = \frac{v}{m} [C_o - C_e] \quad (1)$$

Where, q defines the metal uptake [mg/g], C_o and C are the initial and equilibrium metal ion concentration in the wastewater [mg/l] respectively, V is the water sample volume (ml) and M is the mass of adsorbent used (g) (Cleiton et al 2011)

2.3.4. Moisture Content Determination

Thermal drying method was used in the determination of moisture content of the samples 1.0g of the dried activated carbon was weighed and placed in washed, dried and weighed crucible. The crucible was placed in an oven and dried at 105°C to constant weight for 1 hour. The percentage moisture content (%MC) was computed as follows (Rengaraj et al 2002):

$$\text{Moisture Content (\%)} = \frac{\text{loss of weight on drying (g)}}{\text{initial weight of sample (g)}} \times 100 \quad (2)$$

2.3.5. Surface Area, Micropore Volume and Total Pore Volume Estimation

The surface area, micropore volume and total pore volume of the activated carbon were estimated using the iodine and Methylene blue number. The iodine and Methylene blue numbers were determined using standard methods as described in 2.3.2 and 2.3.3 respectively. Data obtained were then analyzed using standard software (SCAC- Structural Characterization of Activated Carbon).

2.4. Preparation of Waste Water (Aqueous Solutions)

The metal stock solution was prepared by dissolving elemental copper of analytical grade in distilled water. The stock solution was diluted in distilled water to obtain concentrations ranging from 5 to 60mg/l.

2.5. Investigation of Adsorption Parameters

2.5.1. Effect of Adsorbent Dosage

This is one of the parameters that strongly affect the sorption phenomenon in the dose of the adsorbents. This may be due to the increase in availability of surface active sites resulting from the increased dose of the adsorbent (Saceed et al, 2005). Effect of adsorbent dose was investigated by varying weight of Activated Yam Peel (AYP) ranging from 0, 2, 4, 6, 8, 10 and 12g which were contacted with 50ml of the wastewater for an equilibrium adsorption time of 2 hours at a fixed adsorption temperature of 30°C.

2.5.2. Effect of Contact Time

The kinetic studies were performed to determine the adsorption rates of the adsorbent and the minimum contact time for adsorption. 12g of the adsorbent was contacted with 100ml of solution in each sample bottle at adsorption temperature of 34°C. The content was stirred using a magnetic stirrer for different increment of time ranging from 0, 20, 40, 60, 80, 100 and 120 minutes. Samples were collected at the different time intervals, filtered through Whatman No – 1 filter paper, and an aliquot solution was taken for analysis to determine the equilibrium concentration and the overall effects of contact time on the adsorption process.

2.6. Adsorption Efficiency

The impact of adsorption process was studied by monitoring the effects of adsorption on conductivity, dissolved oxygen, and amount of metal ion removed.

Conductivity/dissolved oxygen level were monitored before and after adsorption to evaluate the impact of adsorption process. The amount of heavy metal ions removed during the series of batch investigation was determined using the mass balance equation given by (Raghuvanshi et al 2004):

$$q = \frac{v}{m} [C_o - C_e] \quad (3)$$

Where, q defines the metal uptake [mg/g], C_o and C_e are the initial and equilibrium metal ion concentration in the wastewater [mg/l] respectively, V is the water sample volume (ml) and M is the mass of adsorbent used [g].

The efficiency of metal ion removal (%) was calculated using the following mass balance equation of the form (Badmus et al 2007):

$$\text{Removal Efficiency (\%)} = \left(\frac{C_o - C_e}{C_o} \times 100 \right) \quad (4)$$

Where C_o and C_e are the metal ion concentrations (mg/l) in the water sample before and after treatment respectively.

2.7. Adsorption Isotherm Studies

The adsorption isotherm indicates how the adsorbent molecules distribute themselves between the liquid phase and the solid phase when the adsorption process reaches an equilibrium state to give a relationship between the amount of adsorbate removed and the amount remaining (Dawodu et al, 2012). The experimental isotherm data set obtained were fitted with Langmuir and Freundlich adsorption isotherm models to ascertain the equilibrium relationship between the amount of metal ion removed and the amount still left in solution. The applicability of the isotherm equations was compared by judging the correlation coefficient, r^2 (Ho, 2004)

2.7.1. Freundlich Isotherm Model

The general form of this isotherm is given as:

$$q = k_f C_e^{\frac{1}{n}} \quad (5)$$

Where, q = Amount adsorbed (g), K = Freundlich capacity constant, C_e = Equilibrium concentration (ppm), $1/n$ =Freundlich intensity parameter.

A linear form of this expression is given as $[\log (q) = \log (K_r) + 1/n \log (C)]$ and values of K and n were calculated from the intercept and slope of the plot of $[\log (q)$ against $\log (C)]$ (Qadeer, 2004).

2.7.2. Langmuir Isotherm Model

Activation energy of the adsorption process was determined using Svant Arrhenius equation of the form:

$$K = A e^{\frac{-E}{RT}} \quad (6)$$

Where, K is the rate constant of the adsorption process, A is the frequency factor, R is the molar gas constant, T is the thermodynamic temperature and E is the value of the activation energy of the adsorption process

The linearized form of the equation is given as:

$$\ln K = \ln A - \frac{E}{RT} \quad (7)$$

A linear plot of $(\ln K_{ad})$ against $1/T$ gives an intercept that is equal to $\ln A$ and a slope that is equal to E/R from where the activation energy of the adsorption process can be determined (Raghuvanshi et al 2004).

2.8. Adsorption Rate Constant

The rate constant of adsorption (K_{ad}) measures the time domain for the adsorption process, it is the time dependent study of adsorption process. The first order is constant for the adsorption of metal ion. The granular activated carbon was studied using the Lagergren equation (Ho, 2004)

$$\log [q_e - q] = \log q_e - \frac{K_{ad} t}{2.303} \quad (8)$$

Where (q_e and q) = the amount of a specific metal ion adsorbed at equilibrium and at a time t respectively and K_{ad} = the rate constant for the adsorption of a specific metal ion.

2.9. Adsorption Kinetic Studies

Pseudo-first order, pseudo-second order and elovich kinetic model were applied in this research study to describe the reaction – controlled mechanism for the sorption of Cu and Mn ions.

2.9.1. Pseudo First Order Kinetic Model

The pseudo first- order rate expression of Lagergren based on the solid capacity is expressed as follows:

$$\frac{dq}{dt} = K_t (q_e - q_t) \quad (9)$$

Where, q_e and q_t are the adsorption capacity at equilibrium and at time t , respectively ($\text{mg} \cdot \text{g}^{-1}$), K_t is the rate constant of pseudo first-order adsorption (Langergren et al 1898). After integration and applying boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$, the integrated form of equation (7) becomes:

$$\text{Log } [q_e - q_t] = \text{Log } [q_e] - \frac{k_{ad}t}{2.303} \quad (10)$$

Where, q_e and q_t = amount adsorbed at equilibrium and at time (t) respectively, mathematically:

$$\text{Log } [q_e - q_t] = \text{Log } q_e - \frac{k_{ad}t}{2.303} \quad (11)$$

Where, $2.303 [\text{slope}] = K_{ad}$

The linear plots of $\text{Log } [q_e - q_t]$ versus time (t) showed the appropriateness of the above equation and subsequently the first order nature of the adsorption process involved (Langergren et al 1898).

2.9.2. Pseudo second – order kinetic model

The pseudo-second order kinetic rate equation is expressed as:

$$\frac{dq}{dx} = K_2 (q_e - q_t)^2 \quad (12)$$

Where; K_2 = the rate constant of pseudo – second order adsorption ($\text{gmg}^{-1} \text{min}^{-1}$)

For the boundary condition, $t = 0$ to $t = t$ and $q_t = 0$, to $q_t = q_t$, the integrated form of the above equation becomes:

$$\frac{1}{q_e - q_t} = \frac{1}{q_e} + K_2 t \quad (13)$$

Which was the integrated rate law for a pseudo second order reaction, the above equation was rearranged to obtain the equation below:

$$q_t = - \frac{1}{\frac{1}{K_2 q_e^2} + \frac{t}{q_e}} \quad (14)$$

This has a linear form;

$$\frac{t}{q_t} = - \frac{1}{K_2 q_e^2} + \frac{1}{q_e} (t) \quad (15)$$

If the initial sorption rate is $h = K_2 q_e^2$, Then equation (12) and (13) becomes:

$$q_t = \frac{t}{\frac{1}{h} + \frac{t}{q_e}} \quad (16)$$

The plot of $(\frac{t}{q_t})$ against (t) gave a linear relationship from which q_t and K_2 was determined from the slope and intercept of the plot (Ho, 2006).

3.0. Results and Discussions

3.1. Characterization of Activated Yam Peel (AYP)

Results from the characterization of AYP is presented in Table 4. It was observed that the pH of AYP was 6.8 which indicates an acidic condition. The moisture content was 9.8% which indicates dry yam peel. The surface area of $412 \text{m}^2/\text{g}$ was obtained after analysis of the data of the methylene blue value and iodine number of the AYP, using standard software (SCAC- Structural Characterization of Activated Carbon). Also, the total pore volume and micropore volume as presented in the table were $0.21 \pm 0.02 \text{mg/g}$ and $0.13 \pm 0.02 \text{ml/g}$ respectively. This indicates that AYP is a good adsorbent for metal ion removal.

Table 4 Physical Properties of Adsorbent

Parameter	Value
Ash Content (%)	7.8
Moisture Content (%)	9.8
Total Pore Volume (mg/g)	0.21±0.02
Iodine Number	456
Surface Area (m ² /g)	412±45
Volatile Matter	4.8
Mean Particle Size (mm)	0.106
pH	6.8
Methylene Blue Number	18
Micropore Volume (ml/g)	0.13±0.02

3.2. Adsorption Studies

3.2.1. Effects of Adsorbent Dose

Figures 1 and 2 illustrates the effect of adsorbent dosage on sorption efficiency for Cu(II) ions and Mn(II) ions. It was evident that the amount of metal uptake increases from 264mg/g to 1980.00mg/g for 0.2g and 1.2g respectively for Cu Using Activated Yam Peels and also the efficiency of the removal increases as the adsorbent dosages of both Cu and Mn increase. While an efficiency for Cu at a peak of 39.62% for Activated Yam Peel, the Raw Yam Peel gave an efficiency of 15.76%. Also for Mn, an efficiency of 29.60% was gotten for the Activated Yam Peels while the efficiency for Raw Yam peels was 14.75%.

3.2.2. Effects of Contact Time

The effects of time for the adsorption of Mn(II) and Cu(II) ions were studied between 20 and 120 minutes and the results obtained are as illustrated in figures 3 and 4. The maximum adsorption capacity observed at beforehand for any of the metals may be due to large number of vacant sites available, which later slowed down and may be attributed to exhaustion of remaining surface sites and repulsive force between the adsorbent and metal ions and possibility of impurities intervening in the solutions, thereby causing variations.

Figure 1: Effect of Dosage on the Efficiency of Cu(II) removal onto Raw and Activated Yam Peels

Figure 2: Effect of Dosage on the Efficiency of Mn(II) removal onto Raw and Activated Yam Peels

Figure 3: Effect of Contact time on the Efficiency of Cu(II) removal onto Raw and Activated Yam Peels

Figure 4: Effect of Contact time on the Efficiency of Mn(II) removal onto Raw and Activated Yam Peels

3.3. Adsorption Isotherm

Adsorption isotherm models are relevant in adsorption studies since they can be employed to determine the relationship between the adsorbent – adsorbate interaction in other to establish the potential of the adsorbent materials. To visualize the adsorbent – adsorbate relationship, experimental data obtained from the batch adsorption studies were analyzed using the empirical Langmuir and Freundlich isotherm models. Results obtained are presented in figures: 5, 6, 7, 8, 9, 10, 11 and 12 respectively.

Figure 5: Linearized Langmuir Isotherm for Cu adsorption onto Raw Yam Peels

Figure 6: Linearized Langmuir Isotherm for Cu(II) adsorption onto Activated Yam Peel

Figure 7: Linearize Langmuir Isotherm for Mn(II) adsorption onto Raw Yam Peels

Figure 8: Linearized Langmuir Isotherm for Mn(II) adsorption onto Activated Yam Peels

Figure 9: Linearized Freundlich Isotherm for Cu(II) adsorption on to Raw Yam Peels

Figure 10: Linearized Freundlich Isotherm for Cu(II) adsorption onto Activated Yam Peel

Figure 11: Linearized Freundlich Isotherm for Mn(II) adsorption onto Raw Yam Peel

Figure 12: Linearized Freundlich Isotherm for Mn(II) adsorption onto Activated Yam Peels

From the results of Figure 5 and 6, an appreciable coefficient of determination (R^2), appreciable difference was observed between the computed values or the coefficient of determination (R^2). For Figure 5; R^2 was observed to be 0.680 while for Figure 6; R^2 was 0.758. The difference in the R^2 values can be attributed to the effect of activation on the performance of the yam peels as absorbent for copper ion removal. It shows therefore that activated yam peels possess better affinity for copper compared to raw yam peels. The higher affinity of activated yam peels towards copper removal was again established in the Freundlich isotherm plot as observed in Figure 9 and Figure 10 respectively. In Figure 9, computed R^2 value was observed to be 0.564 raw yam peels while for Figure 10 computed R^2 value was observed to be 0.871 for activated yam peels.

An overview of Figures 5,6,9,10 revealed that Freundlich isotherm model had the highest value of R^2 in terms of Copper ion removal. The implication is that Freundlich isotherm model best explained the absorption of copper onto yam peels. Hence, in the task of predicting the absorption capacity of yam peels for copper ion removal, Freundlich isotherm model ranked better than Langmuir. The suitability of Freundlich isotherm model in predicting the absorption capacity of yam peels was further established in the absorption of Mg^{2+} ions onto raw and activated yam peels as observed in Figure 11 and Figure 12 respectively. From the results of Figures 11 and 12, the computed R^2 value were observed to be 0.685 for yam peels and 0.736 for activated yam peels.

Comparative analysis of Figures 6,7,8,9,10,11, and 12 revealed that activated yam peel performed better than the raw yam peels in terms of Cu^{2+} and Mg^{2+} ions removal. In addition, raw yam peels showed higher potential for Mg^{2+} ion removal as observed in Figure 11 while activated tam peels has better potential for Cu^{2+} ion removal as observed in Figure 10.

3.4 Kinetic Studies

Thus the adsorption of $Cu(II)$ and $Mn(II)$ onto raw and activated yam peel was best described by the Pseudo Second Order Kinetic model being that the value of R^2 is closer to one as illustrated in Figures 13, 14, 15, 16, 17 and 18.

Figure 13: Pseudo-first order (Lagergren model) kinetics plot of $Cu(II)$ adsorption onto Raw Yam Peel

Figure 14: Pseudo-first order (Lagergren model) kinetics plot of $Cu(II)$ adsorption onto Activated Yam Peels

Figure 15: Pseudo-second order kinetics plot of Cu(II) adsorption onto Raw Yam Peels

Figure 16: Pseudo-second order kinetics plot of Cu(II) onto Activated Yam Peels

Figure 17: Pseudo-second order kinetics plot of Mn(II) onto Raw Yam Peels

Figure 18: Pseudo-second order kinetics plot of Mn(II) onto Activated Yam Peels

To understand the kinetic behavior and establish the reaction mechanism during the fixation of Cu^{2+} and Mg^{2+} ions onto the active sites of the raw and activated yam peels, absorption data obtained during the batch absorption studies were analyzed using selected reaction kinetic model such as pseudo first order postulated by Lagergren and Hoard McKay pseudo second order kinetic model as presented in Figures 13,14,15,16,17 and 18 respectively.

Analysis of figures 13,14,15 and 16 respectively the absorption of Cu^{2+} ion onto raw and activated yam peels reveals that the adsorption of Cu^{2+} onto yam peels follows a pseudo-second order kinetic model with computed r^2 values of 0.991 for raw yam peels and 0.834 for activated yam peels. The implication is that, the rate limiting step for the absorption of Cu^{2+} onto yam peels is chemical reaction (chemisorptions) for which the reaction mechanism follows a pseudo second order kinetics.

For the absorption of Mg^{2+} onto raw and activated yam peels, as observed in Figures 17 and 18, it was also revealed that the controlling step for absorption process is the chemical reaction and the reaction mechanism follows the pseudo second order kinetic.

4.0. Conclusion

From the overall analysis of the results obtained, this study indicates that:

- i) Yam peels which are cost effective and relatively easy can serve as better alternative to imported and highly expensive commercial activated carbon for Cu^{2+} and Mg^{2+} ion removal. The adsorptions of these metals were found to be dose and time dependent. The Optimum Conditions for the removal of these metals are initial Concentrations of 50mg/l and mass of 1.0 g this is where the efficiency is highest.
- ii) Activated yam peels are better candidates for metal ion removal compared to raw yam peels hence there is need to always activate the absorbent before use.
- iii) Freundlich isotherm model was the best model that explained the absorption of Cu^{2+} and Mg^{2+} ions onto raw and activated yam peels should be employed to determine the absorption capacity of yam peels as absorbent for wastewater treatment.
- iv) The rate limiting step for the absorption of Cu^{2+} and Mg^{2+} onto raw and activated yam peel is chemical reaction (chemisorption) and the reaction mechanism follows the pseudo second order kinetic model.

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