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OPTIMIZATION AND KINETICS FOR ADSORPTION OF A*MOXICILLIN ON ACT*IVATED CARBON DERIVED FROM BANANA PEELS

BY

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A RESEARCH PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CHEMISTRY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELORS DEGREE IN SCIENCE AND EDUCATION OF BUSITEMA UNIVERSITY.

MAY, 2026

DECLARATION

I CHEROP CONNIE, declare that this research project is my original work and has not been submitted to any other institution for academic credit

Signature: ....

Date: 28th/08./2026

APPROVAL

This research project has been submitted with the approval of the supervisor.

DR KIGOZI MOSES

Signature: ....

Date: 21/08/2026

DEDICATION

I dedicate this piece of work to GOD almighty for the gift of life and more blessings ahead. I also want to sincerely appreciate my supervisor for the unwavering support in doing this piece of work

ACKNOWLEDGEMENT

I would like to appreciate my friends and course mates for all the physical and emotional support during my stay here, I would also like to extend my heartfelt gratitude to the chemistry department of Busitema university for my career development throughout my stay here.

ABSTRACT

The increasing presence of antibiotic residues, such as amoxicillin (AMX), in wastewater poses significant risks to environmental and human health, necessitating sustainable, low-cost treatment methods. This study investigates the production of activated carbon from agricultural waste (banana peels) for the removal of amoxicillin from aqueous solutions.

Banana peel-activated carbon (BPAC) was prepared through chemical activation followed by carbonization (350–700°C). And UV spectrum. Batch adsorption experiments were conducted to determine the effects of pH (2–12), contact time, adsorbent dosage, initial AMX concentration, and temperature on removal efficiency.

Optimization studies indicated that maximum amoxicillin removal efficiency (~85–96%) occurred at an acidic pH (approx. 4.0–5.0), a contact time of 120 minutes, and an adsorbent dose of 1.2 g/L. Kinetic data were best described by the pseudo-second-order model, suggesting chemisorption as the rate-limiting step. The adsorption isotherm followed the Langmuir model, indicating a monolayer adsorption capacity. Activated carbon derived from banana peels is a sustainable and efficient bio sorbent for removing amoxicillin from wastewater. The process is spontaneous and influenced by pH and temperature, making it a viable alternative for the tertiary treatment of pharmaceutical-laden wastewater.

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LIST OF ABBREVIATIONS

AXN: Amoxicillin

HACBP: Hydrothermally Activated Carbon from Banana Peelings

Chapter 1: Introduction

1.1 Background

Amoxicillin, an antibiotic pharmaceutical organic pollutant, has emerged as a significant environmental concern due to its widespread use and subsequent release into aquatic ecosystems (Liping Zhu, 2024). Most wastewater treatment methods fail to completely eliminate amoxicillin, leading to its accumulation in surface waters. As a result, such an innovative and sustainable approach is required to address this constantly growing issue. Adsorption has attracted significant attention as a suitable method for removing organic pollutants, particularly amoxicillin, an antibiotic, from aqueous solutions due to its simplicity, efficiency, and cost-effectiveness. Activated carbon (AC) is one of the commonly used adsorbents due to its high surface are, porosity, environmental friendliness and ability to adsorb a wide range of contaminants. (Khanna & Vijhani, 2023)

The effectiveness of the adsorbent is influenced by various parameters, such as contact time, initial pollutant concentration, temperature, and solution pH. Understanding the adsorption kinetics is crucial for optimizing the removal process. Common kinetic models, such as pseudo-first-order and pseudo-second-order equations, help describe the rate of adsorption, while isotherm models, such as the Langmuir and Freundlich, describe adsorption capacity and mechanism. (Jamna Prasad Gujar, 2024)

This research proposal aims to explore the potential of activated carbon synthesized from banana peelings as an efficient adsorbent for the removal of amoxicillin from aqueous solutions. This study seeks to develop sustainable, low-cost solutions to mitigate pharmaceutical pollution in water bodies by investigating adsorption characteristics under varying conditions.

1.2 Problem Statement

The growing presence of amoxicillin (AMX) in water due to incomplete removal by standard wastewater treatment methods poses a real threat to the environment and human health. Amoxicillin is a widely used antibiotic and an emerging contaminant. It can lead to the development of antibiotic-resistant bacteria and disrupt aquatic ecosystems (Aaron Albert Aryee, 2022). Current methods for removing antibiotics have drawbacks such as high costs, complex operations, or toxic by-products. Adsorption with activated carbon is one of the most effective and affordable ways to remove pharmaceuticals from water. However, commercial activated carbon is costly and often made from non-renewable sources. There is increasing interest in using agricultural waste products, like banana peels, as sustainable and cheap sources for making activated carbon. Previous studies have shown that activated carbon made from banana peels (BPAC) can remove various pollutants, including some pharmaceuticals. Still, specific research is needed to optimize its creation and use for effectively adsorbing amoxicillin from contaminated water sources. This study therefore aims to remove amoxicillin from wastewater using highly effective, sustainable and eco-friendly adsorbent

1.3 OBJECTIVES

1.3.1 General objective

The general objective of this study is to develop an effective, low-cost, and environmentally friendly modified natural adsorbent from banana peels to remove amoxicillin pollutants from wastewater.

1.3.2 Specific objectives

i. To synthesize an effective and efficient adsorbent from banana peel biomass using hydrothermal activation

ii. To carryout adsorption, kinetic and isotherm studies.

1.4 Justification

One of the main reasons why antibiotic pollution remains a problem is that expensive, environmentally hazardous (unfriendly) industrial methods are used. There is therefore a need to develop effective, locally available, and low-cost methods for removing antibiotics from wastewater to replace expensive methods. The major sources of these natural adsorbents are agricultural wastes, whose efficacy and effectiveness can be enhanced through activation using various inexpensive methods. Several studies have been carried out on action of natural adsorbents on the removal of antibiotics from wastewater but the use of hydrothermally activated banana peels adsorbent has been left out; hence this study is to determine the effectiveness of hydrothermally activated banana peels adsorbent in the removal of amoxicillin pollutant and make awareness of its potential adsorption powers for the antibiotic.

1.5 significance

The successful investigation of the adsorption capabilities of the activated carbon synthesized from banana peels will provide an effective and efficient method for removing amoxicillin pollutant from wastewater thus contributing to environmental remediation efforts, utilizing agricultural wastes such as banana peels to produce activated carbon aligns with sustainable practice (1, 2025). The determination of the physical versus chemical nature of the adsorption through the low enthalpy values and kinetic fits, will enhance predictive modelling capabilities.

1.6 scope

The experimental research will aim to develop a higher-capacity adsorbent using banana peelings (obtained from Nagongera market, Tororo, Uganda), activated by the hydrothermal carbonization method using potassium hydroxide as the modifier, carried out at Busitema University, Nagongera campus laboratory, from December 2025 to March 2026. This research will involve the study of the effects of various experimental parameters on adsorption, such as pH, contact time, adsorbent dose, and adsorption kinetics. (Yadav, 2022)

1.7 Conceptual Framework

Shows relationships between variables.

Independent variables $\rightarrow$, dependent variables $\rightarrow$, and output $\rightarrow$ outcomes.

Presented with a simple diagram.

Domestic and Veterinary sources
Landfill
Pharmaceutical Industry
Water Sources
Detection methods
Treatment techniques
= Amoxicillin

Chapter 2: Literature review

2.1 sites and effects of amoxicillin waste water in Uganda

Amoxicillin waste water can obtained from hospitals like Mulago National Referral Hospital, Mengo Hospital and others due to its application in medical researches, as medicine, in microscopy (Gendrot et al., 2021), microbiology and pharmacology (Tardivo et al., 2005). The amoxicillin waste water is widely obtained from pharmaceutical supplies, medical waste and agricultural runoff (Kummerer, 2009). The usage of Amoxicillin beyond permissible levels leads to several adverse side effects which may include their accumulation in water bodies and contributing to the rise in antibiotic-resistant bacteria (matinez,2009;WHO,2014) This affects fauna in aquatic ecosystem (Oladoye, Ajiboye, Omotola, & Oyewola, 2022).

2.2 Some of the Methods for the removal of Amoxicillin pollutant from Waste Water.

Some of the methods of removal of amoxicillin pollutant from waste water include ; coagulation and flocculation, membrane filtration, ion exchange and adsorption (Malatji et al., 2021).

2.2.1 Coagulation-Flocculation Technique

The coagulation-flocculation technique is a technique which involves mainly three steps: coagulation, flocculation and decantation. Coagulation is achieved by adding a coagulant that aims at destabilizing the colloidal suspensions through neutralizing their charges. Flocculation is achieved by adding a flocculant leading to formation of flocs in the second step, also called the slow step. In this step, the small particles already destabilized during the first step are grouped to form flocs which sediment and separate easily from the water during the third and final stage called decantation (sedimentation) (Ihaddaden, Aberkane, Boukerroui, & Robert, 2022). The present work focusses on the use of a bentonite-based coagulant and cactus-based flocculant (Opuntia Ficus indica (OFIP)) in the elimination of methylene blue dye from waste water (Ihaddaden et al., 2022). Bentonite clay is known for its high specific surface area, negative surface charge density as well as its high cation exchange capacity and these properties show that it can contribute in the coagulation process. Opuntia Ficus indica act as a bio-flocculant and the molecules involved in the flocculation mechanism are macromolecular quercetin (a flavonoid with polyphenol groups) and water-soluble polysaccharides (starch).

The coagulation-flocculation technique is a simple and easy way to treat effluents from pharmaceuticals however, the method has some drawbacks like excessive usage of chemical coagulants in highly colored wastewater result in the creation of a large amount of harmful chemical sludge (Bushra, Mohamad, Alias, Jin, & Ahmad, 2021).

2.2.2 Membrane Separation Techniques

The membrane separation is one of the effective methods for removal of amoxicillin from the wastewater. The techniques of membrane separation include; Reverse osmosis (RO), electro dialysis, and Ultrafiltration (UF) and Nano filtration. Reverse osmosis involves the movement of water molecules from a region of higher concentration of the solute to a region of lower concentration of the solute (or pure water) through a semi-permeable membrane and application of hydrostatic pressure greater than the osmotic pressure (Ssekitto, 2023). Electro-dialysis is the removal of ionic components from aqueous solutions through ion exchange membranes under the driving force of an electric current. Electro-dialysis is like reverse osmosis except for it, current rather than pressure is used to separate ionic contaminants from water in which different ionic selective exchange membranes are used that allow only a specific type of ions to go through them (Korngold, Kock, & Strathmann, 1977). Ultrafiltration (UF) is a type of membrane filtration that separates particles based on their size using a semipermeable membrane that has a pore size that is fine enough to retain colloidal particles, viruses or large molecules. Suspended solids and solutes of high molecular weight are retained in the so-called retentate, while water and low molecular weight solutes pass through the membrane in the permeate (Bielska & Szymanowski, 2006). Nanofiltration (NF) is a membrane separation technique that uses nanometer-sized pores of pore sizes 1-10 nm to separate molecules based on size. It is a later invention among all the membrane processes that operates in the realm between reverse osmosis and ultrafiltration (Zhang et al., 2022). Nanofiltration membranes have smaller pore size than those used in microfiltration and ultrafiltration, but slightly bigger than those in reverse osmosis. The membranes are predominantly made of polymer thin films such as polyethylene terephthalate or metals such as aluminum. The pore dimensions are controlled by pH, temperature, and time during development with pore densities ranging from 1 to 106 pores per cm^2.

However, in these processes dense ceramic or polymeric membranes have been used, resulting in low permeability, thus to get the desired throughput (permeate flux), high operating pressure is required and even the commercially available polymeric membranes are very expensive and regeneration and reuse is a difficult task (Doke & Yadav, 2014).

2.2.3 Ion-Exchange Process

Ion-Exchange process is the process involves exchanging the amoxicillin ions with other ions that are bound to the resin which is usually made of a polymer matrix that contains functional groups that can attract and hold onto specific ions and in this case, the resin would be designed to attract and hold onto the amoxicillin ions and are always cation-exchange resin. Ammonium phosphomolybdate (APM) particles synthesized under ambient conditions can be used as cation-exchange resin for removal of Amoxicillin from waste water as long as the pH range permitted the pollutant to retain its cationic behavior. This is attributed to ion-exchange between ammonium ions in APM with cationic amoxicillin moieties and removal efficiency of 94.6% could be retained up to 16th cycle (Joseph, Radhakrishnan, Johnson, Joy, & Thomas, 2020).

The efficiency of the ion-exchange process depends on several factors, including the type of resin used, the concentration of the amoxicillin in the wastewater, and the flow rate of the wastewater through the column. This method is effective though expensive, introduces other impurities like cations in the water, the ion exchange resin itself can sometimes become the source of organic contamination and other draw backs may be experienced (Hubicki & Kołodyńska, 2012).

2.2.4 Electro-coagulation Method

Electro-coagulation is a technique that involves applying direct current to sacrificial electrodes that are submerged in an aqueous solution. It is a straightforward and efficient technique in removing the flocculating agent produced by electro-oxidation of a sacrificial anode and generally made of iron or aluminum in simple terms an electrocoagulation reactor is made up of an electrolytic cell with one anode and one cathode. When connected to an external power source, the anode material will electrochemically corrode due to oxidation, while the cathode will be subjected to passivation. During electrolysis, the positive side undergoes anodic reactions, while on the negative side, cathodic reactions occur. Consumable metal plates, such as iron or aluminum, are commonly used as sacrificial electrodes to continuously produce ions in the water. The released ions neutralize the charges of the particles and thereby initiate coagulation. The released ions take away undesirable contaminants either by chemical reaction and precipitation, or by causing the colloidal materials to coalesce, which can then be removed by flotation (Aoudj, Khelifa, Drouiche, & Hecini, 2015). The removal of MB by electrocoagulation (EC) process was investigated in the presence of sodium chloride as electrolyte, Stainless steel electrodes used as cathode and anode in the electrochemical cell and the results showed that the removal percent of 20 mg/L MB is 100%, using stainless steel electrodes with an interspace of 1.5 cm and 20 mA/cm^2 for 6 min in the presence of 0.1 M sodium chloride at natural pH (Titchou, Afanga, Zazou, Akbour, & Hamdani, 2020).

In this process, the treatment is done without including any chemical coagulant or flocculants hence lessening the amount of sludge which may be disposed but still there are challenges like the 'sacrificial electrodes' are dissolved into wastewater streams as an after effect of oxidation, and should be regularly replaced, the utilization of electricity may be expensive in numerous spots, an impermeable oxide film may be surrounded on the cathode prompting loss of productivity of the EC unit, high conductivity of the wastewater suspension is needed, gelatinous hydroxide may tend to solubilize occasionally and many others (Aoudj et al., 2015).

2.2.5 Adsorption

Adsorption is the phenomenon of attracting and retaining the molecules of a substance on the surface of a liquid or solid resulting in to higher concentration of the molecules on the surface (Bahl, Bahl, & Tuli, 2008). As contrast with different methods of Amoxicillin removal from waste water, adsorption method is prominent because of its straightforwardness and also accessibility of extensive variety of cheap adsorbents which may be from industrial wastes or agricultural wastes (natural adsorbents) like activated alumina, activated carbon, activated alumina coated silica gel, calcite, activated saw dust, activated coconut shell powder, activated fly ash, groundnut shell, coffee husk, rice husk and others (Rafatullah, Sulaiman, Hashim, & Ahmad, 2010). Bio-chars are the efficient adsorbents in the removal of contaminants from aqueous solution, have a low energy cost, and can be obtained from renewable and abundant precursors in comparison with industrial wastes and others. banana peelings can be toxic if left to accumulate in the environment and the alternative to this environmental pollution is to make the waste product into a valuable product; in this case, the peelings can be used as a precursor material for making hydrocars when modified using modifiers like potassium hydroxide, zinc chloride and others enhancing the adsorption efficiency and effectiveness.

2.3 UV-Vis Spectrophotometry in Determination of Amoxicillin Concentrations

UV –Vis spectroscopy is an analytical technique that measures the amount of discrete wavelengths of UV or Visible light that are absorbed or transmitted through a sample in comparison to a reference or blank sample.

The method uses light described by the different wavelengths to analyze and identify different substances by locating the specific wavelengths corresponding to the maximum absorbance. The machine employed in this technique is the UV/Vis spectrometer which may be a single beam or double beam spectrometer. The spectrometer consists of five major components which include; the light source, wave length selector, sample, detector and computer to process output. The most commonly used light sources in the technique is the tungsten lamps for visible light and deuterium lamp for UV light. The choice of wave length selector will always depend on the sample type and analyte. The most commonly used wave length selectors are the monochromators which are usually fitted with filters to narrow their wavelength selection and also improve on the signal to noise ratio.

Amoxicillin has a strong absorption band centered at ($\lambda_{max)}$ 230-273nm. The peak absorption of Amoxicillin using PBC is ($\lambda_{max)}$232nm. An appropriate light source and wave length selector is chosen and the light passes to the sample placed in a cuvette. For this case distilled water will be used as a blank sample and then Amoxicillin is the analyte of interest. It is advisable to use quartz cuvettes because quartz is transparent to most of the UV light. Plastics are discouraged for examination because plastic generally absorbs UV light. Light having passed through the sample; the detector converts the light into a readable signal.

The UV – Vi's spectroscopy information may be represented as a graph of absorbance, optical density or transmittance as a function of wave length. The wave length is always on the x – axis and the former on the y – axis. The graph is typically referred to as a spectrum. The absorbance (A) is equal to the logarithm of the fraction of light intensity before passing through the sample (*IO*) divided by light after passing through the sample (*I*). The fraction *I* divided by *IO* is called transmittance (*T*), which expresses how much light passed in the sample. The concentration of an analyte in solution can be determined by measuring the absorbance at some wavelength and applying the Lambert– Beer Law (Delgado, 2022).

$$A = \varepsilon \; lc = \log\left(\frac{I_o}{I}\right) = log\left(\frac{I}{T}\right) = -log(T)$$

2.4 Mechanism of Adsorption of Amoxicillin on Hydrochar

The adsorption of Amoxicillin onto hydrochar is based on physical or chemical process. In the physical adsorption mechanism, the forces of attraction existing between adsorbate and adsorbent are weak van der Waals forces and the amoxicillin molecules attach onto the adsorbent surface under the influence of van der Waals forces. The hydrochar provide a porous surface with functional groups that can attract and bind Amoxicillin molecules through interactions such as electrostatic forces, hydrogen bonding and Van der Waals force. Amoxicillin molecules carry a positive charge and the hydrocar surface has regions with opposite charge which lead to electrostatic interactions. In chemical adsorption mechanism the forces of attraction existing between adsorbate particles and adsorbent are almost of the same strength as chemical bonds, the functional groups on the hydrochar surface such as hydroxyl, carboxyl, and other oxygen-containing groups form bonds with the Amoxicillin molecules (Li et al., 2021).

2.5 Adsorption Isotherms

2.5.1 Langmuir Adsorption Isotherm

The Langmuir adsorption isotherm is used to describe the equilibrium between adsorbate and adsorbent system. The adsorbate adsorption is limited to one molecular layer at or before a relative pressure of unity is reached. It is assumed that the adsorption sites have equal affinities for molecules of adsorbate and that the presence of adsorbed molecules at one site will not affect the adsorption of molecules at an adjacent site. The Langmuir isotherms are useful for determining the efficiency of adsorbent at higher temperature (Azizian & Eris, 2021). It explains quantitatively the formation of monolayer adsorbate on outer surface of the adsorbent, and after that no further adsorption takes place. The theoretical Langmuir isotherm is valid for adsorption of solute from a liquid solution as monolayer adsorption on a surface containing a large number of identical sites (Hammond & Conner, 2013). The linear form of Langmuir equation is as follows;

$$\frac{1}{q_e} = \frac{1}{K_L q_m C_e} + \frac{1}{q_m}$$

Where; q_e is the amount of adsorbate absorbed per unit, q_m is the maximum adsorption capacity for monolayer adsorption, c_e is the equilibrium adsorbate concentration in solution and K_L is Langmuir constant. The graph of $\frac{1}{q_e}$ against $\frac{1}{C_e}$ gives a straight line where the vertical intercept = $\frac{1}{q_m}$ and slope = $\frac{1}{K_L q_m}$ from which constants; K_L and q_m can be calculated.

2.5.2 Freundlich Adsorption Isotherm

Freundlich isotherms are applicable only at lower temperature to provide an idea of adsorption phenomena and the monolayer coverage of the adsorbent. It is essentially empirical but often useful for data description. The equation generally agrees with the Langmuir equation and experimental data over moderate concentration ranges. It is also commonly used to describe the adsorption characteristics for the heterogeneous surface. Freundlich isotherm assumes unlimited sorption sites, which is correlated with a better heterogeneous surface of the adsorbent media (Wang & Guo, 2020). The linear form of the Freundlich equation is as follows;

$$\log q_e = \log \mathrm{K}_f + \frac{1}{\mathrm{n}(\log C_e)}$$

Where; K_f is the Freundlich adsorption capacity and n is the adsorption intensity, q_e is the amount of adsorbate adsorbed per unit weight of adsorbent and ` is the equilibrium adsorbate concentration in solution?

A plot of log q_e versus log C_e gives a linear graph with slope = $\frac{1}{n}$ and vertical =logK_f.

2.6 Kinetic Models

Kinetic models are used to test experimental data so as to examine the controlling mechanism of adsorption processes such as mass transfer and chemical reaction. There are several kinetic models proposed for the mechanism by which Amoxicillin is adsorbed on the surface of adsorbents. To analyze the adsorption kinetics of Amoxicillin onto the hydrothermally activated banana peelings(PBC), the pseudo-first-order and pseudo-second-order kinetic models are used to process the data (Revellame, Fortela, Sharp, Hernandez, & Zappi, 2020).

2.6.1 Pseudo First Order Model

The pseudo-first order rate model is used as a rate equation for assigning the rate of adsorption of an adsorbate into adsorbent. The linear form of the pseudo-first-order kinetic model is represented by the equation;

$$\frac{dqt}{dt} = K_1(q_o - q_t)$$

And the integrated pseudo first order rate equation is;

$$log(q_o - q_t) = \log q_e - \frac{K_1}{2.303}t$$

A linear graph of $\log(q_e - q_t)$ against time, t must be obtained for the data to fit the pseudo-first order rate mode(Revellame et al., 2020) .

2.6.2 Pseudo Second Order Model

The kinetic rate equation for the pseudo-second order adsorption reaction is expressed as;

$$\frac{dqt}{dt} = K_2(q_o - q_t)^2$$

And the integrated pseudo second order rate equation is;

$$\frac{1}{q_o - q_t} = \frac{1}{q_o} + K_2 t$$

Pseudo-second order kinetic expression for describing the adsorption of some ions onto the adsorbent is also useful for determining q_o and K_2 values from the graph of $\frac{t}{qt}$ against t after rearrangement of the above equation as;

$$\frac{t}{qt} = \frac{1}{K_2 {q_o}^2} + \frac{t}{q_o}$$

A linear graph of $\frac{t}{qt}$ against time, t must be obtained for the data to fit the pseudo-second order rate model. The slope of the graph = $\frac{1}{q_o}$ and the vertical intercept = $\frac{1}{K_2 {q_o}^2}$ hence q_o and K_2 values can be determined from the graph Where q_O and q_t in mg/g are the amount of adsorbed Amoxicillin at equilibrium and at any time t respectively. K_1 and K_2 are equilibrium rate constants of pseudo first and second order reactions.

Chapter 3: Materials and Methods

3.1 Materials and reagents

pH meter, thermally isolated magnetic stirrer, polytetrafluoroethylene (PTFE)-coated stir bar, orbital shaker, 250 mL Erlenmeyer conical flasks, centrifuge, beakers, measuring cylinders, pipettes, stopwatch, dry soft lint-free tissue (toilet paper), vortex mixer, magnetic stirrer MS7-H550-S, Oven and Autoclave reactor. Weighing balance of precision 0.1 mg and capacity of 210 g. UV-Vis spectrophotometer Jenway 7305 with a wavelength range of 230-273 nm and bandwidth 0.4 – 4.0 nm controlled using computer software. 1M Potassium hydroxide solution will be made by dissolving 56 g in sufficient deionized water to make 1L of solution and will be stored in a tightly sealed polyethene bottle. Deionized water, Amoxicillin and other necessary chemicals will be obtained from Abbott laboratory store-smc ltd (Kampala, Uganda). Raw banana peelings will be collected from the market in Nagongera Town Council, Tororo district, Uganda.

3.1.1 Preparation of Hydrothermally Activated Banana Peelings Carbon (HABPC)

Raw banana peelings (BP) were placed in deionised water for 24 hours to remove organic pollutants, dried at 60ºC for 24 hours prior to the hydrothermal activation process, and then milled into small particles with diameters of 2 mm or less. 20 g of milled BP were mixed with 240 ml of 1 M Potassium hydroxide solution in an autoclave reactor, tightened well, and then the reactor were placed in the oven at 220ºC for 12 hours. After 12 hours, the reactor was cooled, its contents filtered, and the hydrocars washed with deionised water several times until the pH is 7, then dried. HABPC powder was stored in a cleaned and dried container until it was ready for use for batch experiments.

3.1.2 Preparation of stock solution and calibration standards of Amoxicillin (AXN)

The stock solution of AXN was prepared by dissolving 1g of AXN (measured using a weighing balance of precision 0.1 mg and capacity of 210 g) in 1L of deionized water, then stirred with magnetic stirrer (MS7-H550-S) for 10 minutes and then diluted to a mark of 1000 mL volumetric flask to give the concentration of 1000 mg/L stock solution which was stored in a cleaned and dried bottle.

10 mL of 1000 mg/L of stock solution was diluted to 100 mL with deionized water in a volumetric flask to obtain 100 mg/L of standard solution with a dilution factor of 0.1.

Series of calibration standards were prepared by pipetting 2.50, 5.00, 7.50, 10.00, 12.50, 15.00, 17.50 and 20.00 mL of the 100 mg/L standard solution and then diluted to 50.0 mL with distilled water to make 5.0, 10.0, 15.0, 20.0, 25.0, 30.0, 35.0, 40.0 mg/L of AXN calibration standards respectively using the technique of $M_1V_1= M_2V_2$ where M_i is the corresponding concentration in a volume V_i.

3.1.3 Calibration of UV-Vis Spectrophotometer and Measurement of Amoxicillin Concentrations

A blank solution (deionized water) was placed in a cuvette (10 mm long), then inserted into the spectrophotometer and a maximum absorption wavelength for AXN, $\wedge_{\max}$ = 232nm was set to record the baseline absorbance so as to ensure accurate baseline readings. The corresponding absorbance of freshly prepared Amoxicillin calibration standards of 5.0, 10.0, 15.0, 20.0, 25.0, 30.0, 35.0, 40.0 mg/L were then measured by the UV-Vis spectrophotometer at wavelength of 232nm so as to generate a calibration curve, starting with that of a low concentration to the highest as recorded in Table 1. The concentrations of the Amoxicillin samples were determined by referencing the samples' absorbance values to the calibration curve obtained at 232nm. Before each measurement, the cuvettes and spectrophotometer components were thoroughly cleaned and dried with a lint-free, soft tissue (toilet paper) to avoid contamination.

3.2 Batch Adsorption Experiments

3.2.1 Effect of Adsorbent Dose on Amoxicillin Removal

A sample of 10 mg/L AXN solution were prepared by serial dilution. To different Erlenmeyer flasks containing 20 mL of this solution, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, and 1.6 g of the HABPC in powder form were added. The setup were left to stand for 20 minutes while shaking constantly at 200 rpm using an orbital shaker. After 20 minutes, each amoxicillin sample were separated from the HABPC by centrifugation process at 2000 rpm for 5 minutes and then the supernatant was analyzed by UV-Vis spectrophotometer at the wavelength for maximum absorbance of AXN, 232nm to determine the concentration of AXN adsorbed and the results were recorded in Table 2.

3.2.2 Effect of Contact Time on Amoxicillin Removal

12 samples of 20 mL of 10 mg/L Amoxicillin concentration were made by serial dilution and then placed in different Erlenmeyer flasks. To each flask, 1.4 g of HABPC were added and then the mixtures shaken using the orbital shaker at 200 rpm. The samples from the different flasks were picked after 5, 10, 15, 20, 25, 30, 35, 40 45, 50, 55 and 60 minutes. After the specific time, each dye sample were separated from the HABPC by centrifugation process at 2000 rpm for 5 minutes and then the supernatant was analyzed by UV-Vis spectrophotometer at the wavelength for maximum absorbance of Amoxicillin, $\wedge_{\max}$ = 232nm to determine the concentration of AXN adsorbed and the results recorded were in Table 3.

3.2.4 Effect of pH on Amoxicillin Removal

10 samples of 20 mL of 10 mg/L Amoxicillin concentration was prepared and placed in different Erlenmeyer flasks. The samples in the flasks were adjusted to pH values of range 3-11 using 0.1 M hydrochloric acid and 0.1 M sodium hydroxide solution. 1.4 g of HABPC in powder form were separately added in the flasks containing the samples and then the different mixtures shaken at 200 rpm in the orbital shaker for 20 minutes. After 20 minutes, each amoxicillin sample was separated from the HABPC by centrifugation process at 2000 rpm for 5 minutes and then the supernatant was analyzed by UV-Vis spectrophotometer at the wavelength for maximum absorbance of Amoxicillin, 232nm to determine the concentration of Amoxicillin adsorbed and the results were recorded in Table 5.

3.2.5 Effect of Initial AXN concentration on AXN Removal

8 samples of 20 mL of 5.0, 10.0, 15.0, 20.0, 25.0, 30.0, 35.0, 40.0 mg/L of AXN were prepared and placed in different Erlenmeyer flasks. To each flask, 1.4 g of HABPC were added and then the setup was left to stand for 20 minutes while shaking constantly at 200 rpm using an orbital shaker. After 20 minutes, each amoxicillin sample was separated from the HABPC by centrifugation process at 2000 rpm for 5 minutes, and then the supernatant was analyzed by UV-Vis spectrophotometer at the wavelength for maximum absorbance of Amoxicillin, $\wedge_{\max}$ =232 nm to determine the concentration of Amoxicillin adsorbed, and the results were recorded in Table 6.

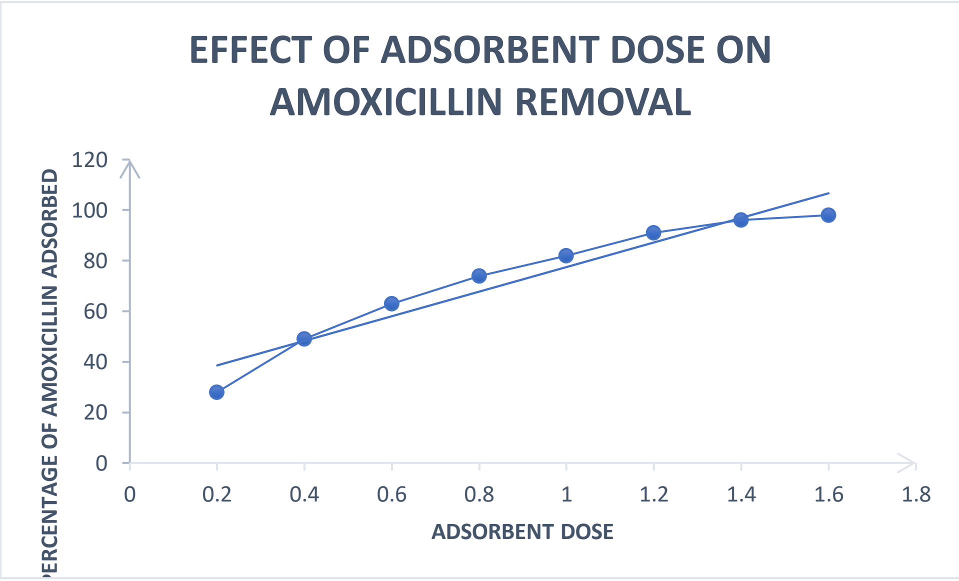
CHAPTER FOUR: RESULTS AND DISCUSSIONS.

Table 4.1: calibration values for standard amoxicillin at a UV wavelength of 232nm to 272nm

Concentration(mg|L)	Absorbance of amoxicillin
5.	0.148
10.0	0.246
15.0	0.348
20.0	0.446
25.0	0.599
30.0	0.667
35.0	0.779
40.0	0.889

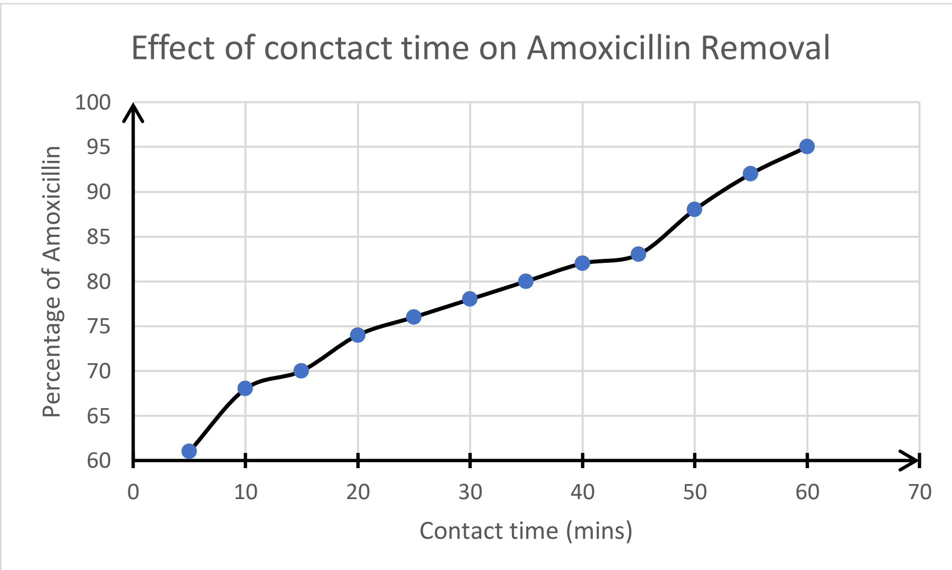
The above table shows the absorbance values of standard amoxicillin antibiotic at varying concentrations. These concentrations were measured in mg|L.

EFFECT OF ADSORBENT DOSE ON AMOXICILLIN REMOVAL



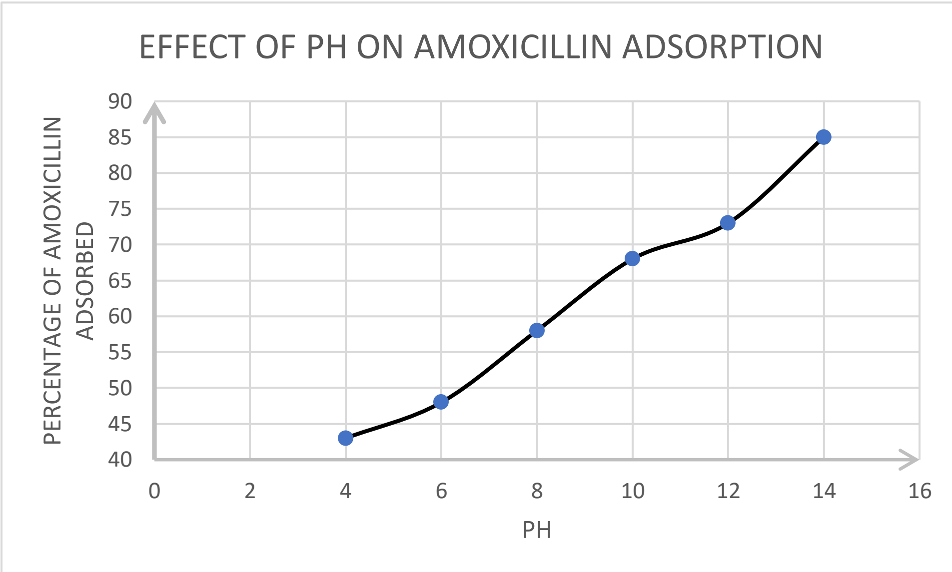
Figure; effect of adsorbent dose on amoxicillin removal

The percentage adsorption increased steeply from approximately 28% to 63% for dose 0.2 to 0.6 this rapid increase occurs because of vacant highly active adsorption sites to bind the anti-biotic molecules. The removal efficiency continues to gradually increase from 63 to 83% for the dose 0.6 to 1.2, this the remaining active sites of adsorbent surface begin to fill up reducing the speed of adsorption. The curve then flattens off between 88 and 94% from 1.2 to 1.6 AXN dose. This because the system is approaching adsorption equilibrium and the concentration of amoxicillin in solution is low.



Figure; Effect of contact time on amoxicillin removal

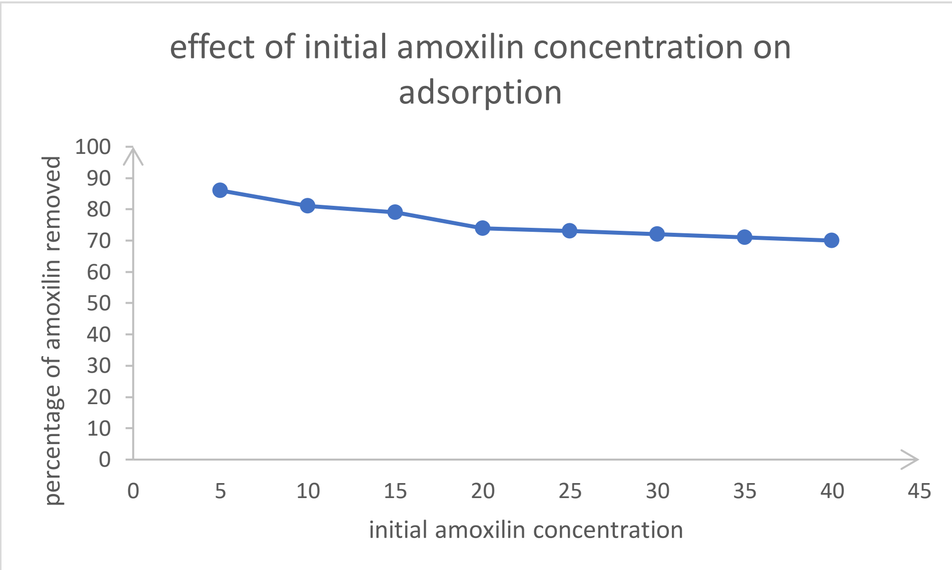
The removal efficiency generally increases with increase in contact time. The removal efficiency rapidly increases from 61.5% to 68.2% from 5 to 10 minutes. This because the adsorbent surface has vacant active sites leading to high adsorption. The removal efficiency gradually reduces from 10 to 45minutes. This is due to desorption effect where weakly bound amoxicillin molecules detach back to into solution due to repulsive forces. After 50 minutes the removal efficiency again increases rapidly to 60%,this is because the system is shifting towards a state dynamic equilibrium between adsorption and desorption.



Figure; effect of pH on amoxicillin adsorption

Amoxicillin adsorption generally increases with increase in PH. Initially at a PH of 4,the adsorption is low at 43%,this is due to the competiveness of the hydrogen ions with the AXN molecules for the adsorption sites. The adsorption efficiency then increase rapidly up to a PH of 11. At a PH of 14 maximum adsorption occurs. This therefore indicates that adsorption of AXN is efficient at alkaline conditions.

EFFECT OF INITIAL AXN CONCENTRATION ON ADSORPTION



Figure; effect of initial amoxicillin concentration on adsorption

From the graph above, as the concentration of initial AXN concentration increases, the percentage removal decrease.at the lowest initial concentration of AXN,THE PERCENTAGE removal is at its peak, this is because the ratio of available binding sites is very high allowing almost all molecules to adsorb.as the initial concentration increase from 5to 45 mg|L of 20ml,percentage removal steadily decrease. This is because as concentration increase, amoxicillin molecules quickly occupy all the vacant sites.

ADSORPTION ISOTHERMS

The Langmuir and the freundlich isotherms were studied and are a representation of the solute adsorbed per unit of adsorbent as a function of equilibrium concentration in bulk solution at a constant temperature. The two isotherm equations have been tested in this study.

The Langmuir isotherm

The Langmuir model is based on the assumption that maximum adsorption occurs when a saturated monolayer of solute molecules is present on the adsorbent surface, the Langmuir isotherm is given below

$$\boldsymbol{q = ac/(1 + ac): q = x/m}$$

Its linear form is shown below:

$$\boldsymbol{c/x = 1/b + ac/b}$$

Where C is the concentration of amoxicillin

in solution ,q is the fraction of amoxicillin adsorbed ,x is the amount of amoxicillin adsorbed per adsorbent is the maximum amount of amoxicillin adsorbed per adsorbent ,a and b are Langmuir constants.

The freundlich isotherm

The freundlich isotherm describes an empirical relationship of adsorption of solutes from a liquid to a solid surface and assumes the different sites with several adsorption energies are involved. This isotherm is the relationship between the amount of amoxicillin adsorbed per unit mass of adsorbent, q is the concentration of amoxicillin at equilibrium c.

$$q = kc^{1/n}$$

Where k and n are freundich constants, the characteristics of the system k and n are the indicator of adsorption capacity and adsorption intensity respectively.

$$\log q = \log k + \frac{1}{n} \log c$$

Adsorption kinetics

The pseudo first order and pseudo second order were used to describe he rate at which amoxicillin transfers from waste water to the banana peel activated carbon.

Pseudo-first-order $\ln qe - qt = \ln qe - k1t$

Where $_{qe}$ = amount of amoxicillin adsorbed at equilibrium.

$q_{t=}$amount of amoxicillin adsorbed at time t

K_1=rate constant of the pseudo-first order adsorption.

Pseudo-second-order $t/qt = 1/k2qe2 + 1/qe\ t$ where k_2 the rate constant of the pseudo-second-order adsorption.

CONCLUSION AND RECOMMENDATIONS

Based on the results, alkaline conditions favour the adsorption of amoxicillin from waste water and the optimum contact time for amoxicillin is 10 minutes, the adsorbent dose used in this study was enough to absorb the amoxicillin even at high concentrations. The equilibrium data was analyzed using Langmuir and freundlich adsorption isotherms. The adsorption mechanisms of amoxicillin adsorption onto hydrothermally activated banana peels followed the pseudo-second – order model and the pseudo-first-order kinetic model, therefore it was concluded that the adsorption kinetics for the hydrothermal adsorption of AXN is chemisorption indicating the rate – limiting step. Banana peel activated carbon provides a high surface area and porous structure capable for achieving AXN removal efficiencies frequently exceeding 90%under optimal conditions.

RECOMMENDATIONS

Hydrothermally activated banana peels can be adopted as an adsorbent material for the removal of amoxicillin from waste water since the results demonstrated THAT it has a high adsorption capacity for AXN removal in solution. When using hydrothermally activated banana peels for removing AXN from waste water, the following should be considered:

Limited time should be allowed for adsorption process so as to maximize amoxicillin removal in waste water.

Higher adsorbent dose should be used to ensure most of the AXN can be removed from waste water.

Alkaline PH conditions should be provided to provide optimum conditions for maximum amoxicillin removal.

Further studies should be conducted to characterize the activated carbon from banana peels and also determine factors for its efficiency in removal of amoxicillin from waste water since it is a known hazardous organic pollutant

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