INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Orange Peels as Activated Carbon Charcoal For Cu (II) Ions Elimination From Water Sources

Fatima A Al-Qadri[1]*, Khomasa Mubareek Alsaeree[2], Reem Ali Alsaeree[2], Refea Mesefer Alyamee[2]

1 Professor of Science, Faculty of Science and Art in Sharurah, Najran University, Najran, Najran, Saudi Arabia
2 Graduated students, Department of Chemistry, Najran University, Najran, Saudi Arabia

OPEN ACCESS

Received: 21-07-2024

Accepted: 21-08-2024

Published: 12-09-2024

Citation: Al-Qadri FA, Alsaeree KM, Alsaeree RA, Mesefer Alyamee R (2024) Orange Peels as Activated Carbon Charcoal For Cu (II) Ions Elimination From Water Sources. Indian Journal of Science and Technology 17(36): 3733-3742. https://doi.org/10.17485/IJST/v17i36.2378

* **Corresponding author**.

fatimaalqadri@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Objectives: The goal of this work is to create inexpensive Orange Peel Activated Carbon (OPAC) for the environmentally friendly to eliminate of Cu (II) from its aqueous solution. Methods: activated carbon made by calcining orange peels at 500°C to cause them to burn. **Methods:** The samples were characterized using FTIR, transmission electron microscopy, and nitrogen adsorption-desorption. Cu (II) was adsorbed in a batch procedure utilizing 0.25 g of (OPAC) and 100 mL of solution with varying beginning concentrations ranging from 20–80 mg/L. The investigation focused on the effects of variables pH, temperatures, concentrations, dosages, and times on the adsorption capacity. Thermodynamic parameters were computed, adsorption kinetics were assessed using pseudo-first and pseudo-second-order were computed models, and the adsorption isotherms were fitted using the Langmuir and Freundlich models. **Findings**: The stretching of the hydroxyl groups is shown by peaks at 3100 and 4000 cm^{-1} as well as the 3300–3800 cm^{-1} region in the FTIR. Findings: the functionalized (OPAC). N_2 adsorption isotherm revealed a hysteresis loop in the p/p0 region between 0.2 and 1. The surface area of obtained mesoporous OPAC was 0.99 nm. The maximum adsorption capacity (79.056 mg/g). Removal of Cu (II) was 99%. The adsorption process was spontaneous and less random, as indicated by the negative values of thermodynamic parameters (ΔS° -14.0, ΔH°-54.76, and ΔG°-60.36 $kJ.mol^{-1}$). According to the findings, orange peel has a high surface area and is highly porous, which allows it to effectively remove over 99% of harmful heavy metals from water sources. **Novelty**: The study proves that orange peel can be effectively used as one of the best-quality, reasonably priced, readily available, eco-friendly bio-sorbents that is also beneficial to the economy in the long run.

Keywords: Orange peel; Cu (II); Adsorption; Kinetic; Thermodynamic; IFTR

1 Introduction

One major environmental issue that requires attention is the presence of pollutants in the water. The paper offers a solution to this issue by going over the manufacturing and testing of activated carbon derived from orange peels, which efficiently extracts methyl red (MR) from aqueous solutions. The surface area, bulk density, particle size, and proximate analysis of the adsorbents are among their characteristics.[1]. Activated carbon (ACs) represents a highly effective technique used to synthesize ACs for cationic methylene blue (MB) and anionic methyl orange (MO) dye adsorption using orange peel (OP), a less expensive precursor than the costly coal- and coir-based precursors. To examine the effects of activation reagents on dye removal mechanisms and efficiencies, H_2SO_4, NaOH, KOH, $ZnCl_2$, and H_3PO_4 were used to activate the pre-carbonized OP[2]. Pollution from heavy metals and artificial coloring compounds in aquatic environments has negative effects on many levels, health being the most important. Previous studies have demonstrated that the concentrations of heavy metals (Cu, Cr, Pb, Fe, and Zn) in the effluent from several companies are much higher than the WHO recommended levels[3]. Although its production can be expensive at times and requires the use of activating chemicals that may leach into solution and cause secondary contamination, activated carbon is the most widely used adsorbent material[4,5]. Activated carbon, which magnetically generated orange peels as the precursor and $ZnCl_2$ as the activating agent, was used to remove acid orange 7 dye from water, and the resultant surface area was satisfactory[6]. Eosin dye was adsorbed in an aqueous medium using lemon peel, a natural sorbent. Using lemon peel as a bio-sorbent, adsorption was used to get rid of the anionic dye eosin. By comparing all of the bio-sorbent parameters, the monolayer adsorption capacity that is appropriate for the exothermic adsorption process was shown, indicating that lemon peel is an accessible and reasonably priced bio-sorbent for the removal of eosin dye from aqueous media[7]. The Aim of this project is to produce porous activated carbon with a high surface area, high purity, and high efficiency from orange peels. This rich material will act to remove harmful and toxic heavy metals like Cu (II) from water sources, with a removal rate of almost 99% of these metal ions. The proper method or technique used for this study is adsorption. The efficiency of the isotherms and kinetics model approach was evaluated under ideal conditions, and the effects of a number of variables, such as pH, adsorbent mass, contact time, and thermodynamic properties of the Cu (II) adsorption by activated carbon, were evaluated.

2 Materials

Ferric oxide ($Cu(NO_3)_2$), and sodium hydroxide (NaOH) of analytical grade were purchased from Merck, respectively. 1000 mg/L of stock solution was made with redistilled water and diluted as needed to make a working solution.

2.1. Instrumentation

A Perkin-Elmer Lambda 35 spectrophotometer with 1.0 cm3 quartz cells and an 8 nm/sec scan speed was utilized for the spectrophotometric observations. A glass-calomel electrode assembly of a Jenway 3305 pH meter that was accurate to 0.01 pH units was used to measure the pH. To mix the liquids, a Jenway 1000 magnetic stirrer was utilized. It is necessary to identify the samples' surface functional groups. An NOVA 2200e surface area and pore size analyzer from Quanta Chrome Instruments was used to calculate the nitrogen (N_2) adsorption-desorption isotherms at 77.5 K. The sample's specific surface area was calculated using the BET (Brunauer-Emmett-Teller) method, and the pore size distribution was examined.

2.2. Activation carbon adsorbent preparation

Activated carbon was made via a modified process[8]. Briefly, orange peels were purchased from a local market, thoroughly cleaned with deionized water, and then dried separately at 100 °C for a full day. The dried skins were then broken down into particles with diameters between 100 and 300 mm. After the extra liquid was drained away, the material was dried for 12 hours at 100 °C in the oven. The carbon was then heated to 500 °C for three hours in a furnace. The chemically activated carbon was cleaned with distilled water and then dried at 100 °C. Orange Peel Activated Carbon (OPAC) is the term used to describe this carbon.

2.3. Adsorption experiments

In the adsorption batch, 50 mL of the stock solution containing 100 mg L^{-1} of Cu (II) was added to a glass jar. The pH of the resultant mixture was then adjusted with diluted HNO_3 or NaOH. Following that, sonication was carried out for 30 to 120 minutes at room temperature using the solution and a predetermined quantity of adsorbent (1-4 g). The supernatant was centrifuged at 2000 rpm for three minutes. The outcomes show what three or more tests produced. To calculate the amount of

Cu (II) adsorbed onto the sorbent, use Equation (1).

$$q_{e=} \quad \frac{c_0 - c_e}{W} XV \tag{1}$$

Where q_e is the amount of the adsorbate that was adsorbed in mg. g^{-1}, C_o and C_e are the initial and equilibrium concentrations of Cu (II) in water after removal process (mg. L^{-1}), respectively, V is the solution volume (L) and mg is the amount of OPAC material (g). The adsorption efficiency (% RE) was used as the analytical response using Equation (2).

$$Removal\,\% = \frac{c_o - c_e}{C_0} x100 \tag{2}$$

2.4. Kinetic Adsorption

Kinetic and isotherm tests were performed under optimal conditions on each sample to identify the features of the adsorption response. Adsorption isotherms were examined at initial Cu (II) concentrations ranging from 20 to 80 mg. L^{-1}, while kinetic studies were conducted over exposure times ranging from 30 to 120 minutes. The formulas for these models have been the subject of much discussion in the literature[9,10].

3 Results and Discussion

3.1. FTIR spectroscopic studies

The Fourier transform infrared spectroscopy method Cu (II) was used to identify the functional groups that are present in both biomasses and contributed to the adsorption of Cu (II) ions. Figure 1 shows the orange peel activated carbon's infrared spectrum graphics before the Cu (II) ion adsorption process. The peaks in the spectrum demonstrate how complex the bio-adsorbents are. Strong peaks between 3100 and 4000 cm-1 indicate that the hydroxyl groups are stretching; the literature places these groups between 3300 and 3800 cm^{-1}. Carbonyl's C=O stretching is responsible for the peaks that occur between 500 and. A vibration of 1500 cm^{-1} represents the vibration of the carboxyl groups in orange peels. The FTIR method is a helpful tool for verifying the removal of metal ions. The FTIR spectrum revealed that the primary component of the modified orange peel was cellulose, which has functional groups like carboxyl and hydroxyl that can connect metal ions in aqueous solutions (b). Every peak connected to the carboxyl and hydroxyl groups has moved to a higher wave number, according to the FTIR spectra of an orange peel that has been modified and loaded with Cu (II) ions (B). According to this theory, the ions' absorption into the orange peel was made possible by interactions between Cu (II) ions and COO- and OH- groups.

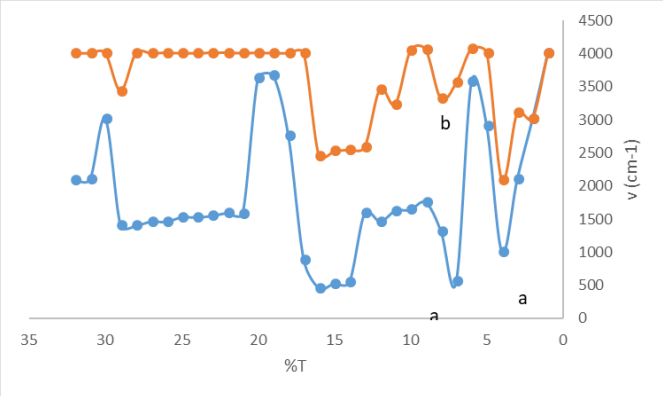

Fig 1. FTIR of: (a) Orange activated carbon. (b) after Cu (II) loaded

3.2. Surface properties of the orange peel

The N_2 adsorption isotherm was used to examine the diameters, pore volumes, and BET surface areas of the OPAC. These values are related to capillary condensation, a characteristic of mesoporous materials, and are, in that order, 0.99 nm, 168.29 m^2, and

0.399 m^3. g^{-1}. It is demonstrated by this, according to the International Union of Pure and Applied Chemistry, that activated carbon is a mesoporous material with pores smaller than 50 nm. The high specific surface area and mesoporous structure of OPAC imply a high adsorption capacity of the adsorbates.

3.3. Electron canning Microscope (SEM)

The surface morphology and elemental composition of the OPAC were investigated using SEM; the resulting images and spectra are displayed in Figure 2 . The efficient synthesis of a highly porous material with surface pores is shown by the SEM images shown in Figure 2 **a** and **b**. Because it provides sufficient open spaces for the desired adsorbates, this porous structure enables effective adsorption.

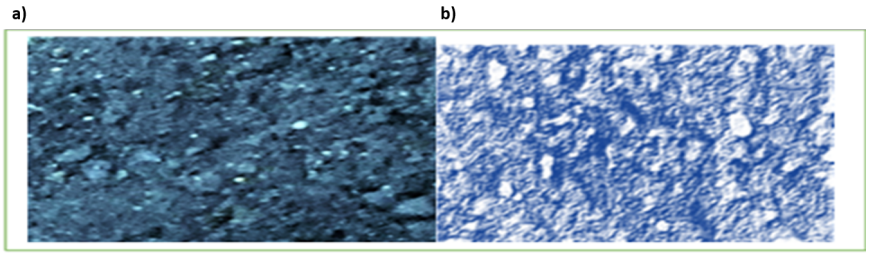

Fig 2. SEM images of (a), orange peel activated carbon (b) after adsorption of Cu (II)

3.4. Dosage of adsorbent

The removal effectiveness increases quickly as the adsorbent mass is increased from 1 g to 4 g, reaching 99% at a dosage of 3 g. This is because there are more accessible adsorption sites and a larger surface area of the adsorbent. When Cu (II) adsorption reached equilibrium and q_{max} efficiency of 73.8 mg g^{-1} at 4 g, it stopped reacting to more adsorbent. Determining the adsorbent's capacity for adsorption at a specific initial concentration requires consideration of the adsorbent dose. The variation in adsorption capabilities at different adsorbent dosages could be attributed primarily to the availability of adsorption sites. Increased adsorbent dosage resulted in an increase in surface area and active sites accessible for adsorption. Even though increasing the adsorbent dosage increased the interference of the adsorbent surface among the active groups, as illustrated in Figure 3, there was not enough driving force for the adsorbate to diffuse into the adsorbent surface and be adsorbed, resulting in a lower equilibrium concentration of Cu (II) [11].

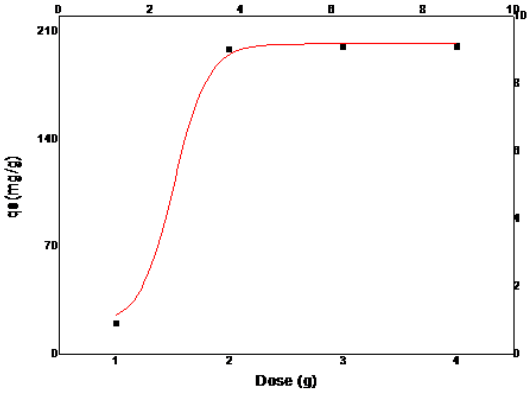

Fig 3. Dose of Cu (II) on the surface of Activated carbon produced from orange Peel

3.5. Contact time

Equilibrium time is another important factor in the waste water treatment process. The results of this study show, the examined relationship between contact time and Cu (II) removal efficiency. According to the findings, both the percentage of Cu (II) removed and the adsorption efficacy for Cu (II) increased with increasing contact time and reached equilibrium after 30 and 120 minutes, respectively. The OPAC structure's increased porosity facilitated both a quicker adsorption during the first contact time and a quicker mass transfer of Cu (II) from the solution onto the OPAC. Another crucial element in the wastewater treatment process is equilibrium time. This indicates that the Cu (II) binding sites on the adsorbent have good accessibility. OPAC has two distinct methods for adsorbing Cu (II). OPAC's mesoporous material has an easy time adsorbing Cu (II) because of its many active sites and significant mass transfer driving force in the early phases of adsorption. Nonlinear adsorption results from the accumulation of a substantial layer of Cu (II) on the OPAC surface over time, which reduces the quantity of active sites and blocks Cu (II) migration. At 90 minutes, the best percentage removal of Cu (II) was achieved, with a percentage of 99.66%, following the recommended contact times of 30 and 90 minutes.

3.6. Data of Isotherms results

The equilibrium relationship between the concentration of adsorbate in the solution at a specific temperature and the amount of adsorbate adsorbed on the adsorbent surface is displayed by isotherms. To fit experimental adsorption data, numerous adsorption models are available in the literature. The distribution of the adsorption molecules throughout the liquid and solid phases is shown by the adsorption isotherm, which is generated when the adsorption process reaches equilibrium. With increasing concentrations, the adsorbed amount only slightly increases, showing a horizontal plateau at higher values and a vertical climb at lower concentrations. The adsorption capacity at equilibrium (q_e) increased when the initial concentration of Cu (II) increased from 38.98 mg g-1 to 79.056 mg g^{-1} at 40 mg. $L^{-1.}$ Cu (II) ion concentrations of 80 mg. L^{-1} produced the highest result, 159 mg/g. The mass transfer driving force was enhanced by the initial concentration, which led to an increase in Cu (II) ion adsorption [12].

3.7. Effect of Temperature

Cu (II) ion adsorption onto OPAC was investigated at initial solution concentration of 60 mg L^{-1} at 70°C, 80°C, 90°C, and 100°C. As the temperature rose from 90°C to 100°C, there was an increase in both the adsorption and percentage removal of Cu (II). At 70°C and 100°C, the amount of Cu (II) metal ions that adsorbed onto OPAC was 118.81 mg g^{-1} and 119 mg $g^{-1,}$ respectively. The sorbent's surface chemistry was altered by adsorbent degradation, which reduced the adsorption of heavy metal ions and increased the availability of active functional groups. Temperatures of 70°C, 80°C, 90°C, and 100°C were investigated for their effects on the sorption on OPAC. Furthermore, at higher temperatures, the bonds changed to aid in the desorption process. The thickness of the boundary layer decreased with increasing temperature due to the limited capacity for adsorption caused by metal ions escaping from the surface into the solution phase. Researchers discovered that by employing dried sugar beet pulp as a sorbent, they could absorb Cu (II) ions at an equilibrium absorption capacity of 24.6 to 12.3 mg g^{-1} at a temperature increase of 25 to 45 °C.

3.8. Adsorption Isotherms

Two models demonstrated good performance for Cu (II) ion adsorption on the OPAC. These models of adsorption isotherms were Langmuir and Freundlich models.

3.9. Langmuir Isotherm

According to the findings, the Langmuir model performed better for the particular adsorption than the Freundlich model. This meant that a homogenous adsorption process was possible. As Table 1 illustrates, the maximum adsorption capacity of Cu (II) ions was 159 mg g^{-1}, surpassing or matching previous findings. Plotting C_e/q_e vs. Ce yields a straight line with a slope of $1/q_{max}$, as seen in Figure 4 . The results for the adsorption of Cu (II) ions in OPAC were well fitted using the Langmuir isotherm, as indicated by the correlation coefficient R^2 of 0.97. The slope and intercept were used to determine the Langmuir constants, b and q_{max}, which were related to the adsorption energy and maximum adsorption capacity. The monolayer adsorption, or Langmuir, isotherm is represented by the following equation [13]. Comparing the current investigation to the previous studies,

the adsorption capacity was higher.

$$\frac{C_e}{q_e} = \frac{1}{q_{max}.b} + \frac{1}{q_{max}} .Ce \quad (3)$$

where C_i is the starting Cu (II) concentration. The key characteristics of the Langmuir isotherm can be described in terms of a dimensionless equilibrium parameter (R_L). This parameter's definition is as follows: The unfavorable adsorption is indicated by the R_L value: $R_L > 1$; favorable: linear: $R_L = 1$; or irreversible: R_L = 0.0.0037, 0.00018, 0.00012, and 0.0092 were determined to be R_L .The values of R_L were in the range of 0–1, which indicated that the adsorption of Cu (II) metal cations onto the Activated carbon produced from Orange Peel was favorable The model parameters and correlation coefficients for the Freundlich and Langmuir isotherms for the adsorption of Cu (II) ions on activated carbon made from orange peel are listed in Table 1. These results led to the hypothesis that the most reasonable explanation for the phenomenon of Cu (II) ion adsorption on activated carbon derived from orange peel is the Langmuir isotherm.

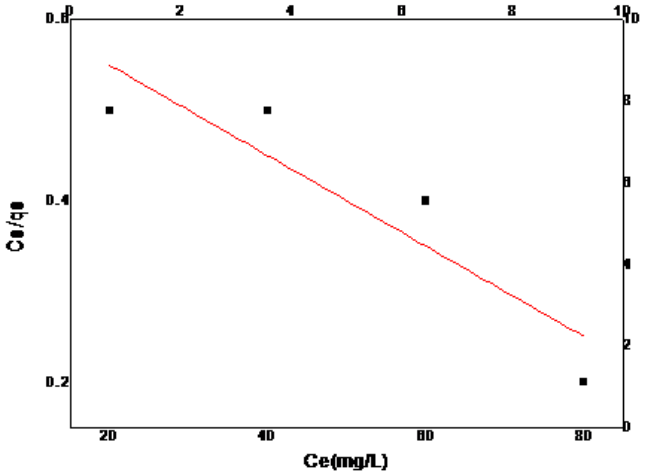

Fig 4. Langmuir isotherm adsorption of Cu (II) on the surface of Activated carbon produced from

3.10. Freundlich Isotherm

The equilibrium amount adsorbed per unit of adsorbent (mg.g^{-1}) and equilibrium concentration (mg.L^{-1}) are denoted by q_e and C_e, respectively, in the Freundlich isotherm experimental model. All other amounts are measured in milligrams. The terms adsorption capacity and intensity are represented by K_f and n, respectively. They are impacted by the adsorbate as well. The K_f and n Freundlich equilibrium constants are found by plotting log q_e vs. log Ce, which produces a straight line with a slope of n. Additionally affected by the adsorbate are values of n between 1 and 10 (1/n less than 1). Compare log q_e with log Ce in Figure 5 . The Freundlich equilibrium constants K_f and n can be calculated using the straight line whose slope is n and which is generated by Ce. When n is between 1 and 10 and (1/n) is less than 1 When n > 1, the most prevalent condition describes the distribution of the active center of the surface and any factor that makes the adsorbent-adsorbate interaction lessen as surface density increases; n values between 1 and 10 indicate perfect adsorption. The n value in the current study, which ranged from 1 to 10, suggested that orange peel's activated carbon and metal ions were physically bonded. As can be observed in Figure 5 and Table 1, its value was n is 1, and its Kf value was 0.77. The following equations were used to obtain the Freundlich constants K_f and n.

$$logq_e = logK_f + \frac{1}{n} logC_e \quad (4)$$

Table 1. Langmuir and Freundlich isotherms

Langmuir			Freundlich		
q max (mg. g^{-1})	b (L.mg^{-1})	R2	n	K_f	R_2
159	1.11	0.96	1	0.77	0.99

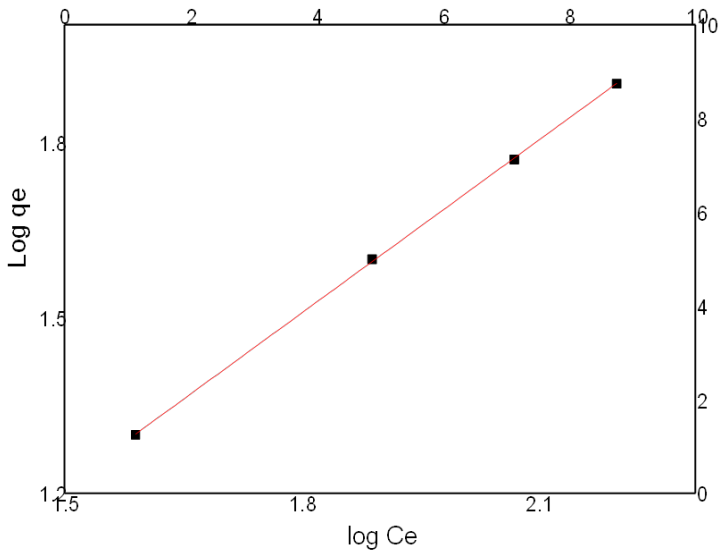

Fig 5. Freundlich isotherm adsorption of Cu (II) on the surface of Orange Peel Activated carbon

Table 2. Adsorption profile of activated carbon withvarious raw materials toward heavy metals as prior studies

Raw materials	Heavy metal	q_e (mg/g)	isotherm	References
Orange peel	Cu (II)	159	Langmuir,	the present study
Orange peels/$MnFe_2O_4$	Cu (II)	46.86	Langmuir,	(13)
Moringa olifera	Cu (II)	10.01	Langmuir,	(14)
Orange Peels	Cu (II)	28.06	Langmuir,	(15)

3.11. Adsorption kinetics studies

The adsorption mechanisms and possible rate-determining phases were investigated using a kinetic model. While the pseudo-first-order model depends on solid capacitance, the pseudo-second-order model accurately replicates the sorption of analytes from aqueous solutions when chemisorption incorporating valence forces occurs. This includes the exchange or sharing of electrons between forces, adsorbents, and forces[16]. The pseudo-second-order equation, with R^2 values of 0.997 and 0.999, respectively, offers the best match for Cu (II). Table 3 displays the kinetic parameters for the pseudo-1st and pseudo-2nd order orders. Pseudo-first-order kinetic models can be produced using the following equation

$$ln(\,q_e - q_t\,) = lnq_e - k_1\,.t \tag{5}$$

where q_e and q_t (mg. g^{-1}) are the amounts of Cu (II) ions adsorbed onto Orange Peel Activated carbon surface at equilibrium and time t, respectively; and K_1 (min^{-1}) is the rate constant of the pseudo-first-order kinetic model. A straight line was obtained by plotting ln (q_e-q_t) against t. This straight line was used to determine -K_1.

Table 3. Kinetic parameters and correlation coefficients of first pseudo and second pseudo-order

Metal ion	q_e.exp mg.g^{-1}	First-order kinetic mode			Second-order kinetic mode		
		q_e, cal(mg.g^{-1})	K_1 (min)	R_2	q_e, cal(mg.g^{-1})	K_2 (g/.g^{-1})(min)	R_2
Cu (II)	121	4.815	-0.00103	0.77	125	1.00	0.99

3.12. Pseudo-second-order reaction

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} \ . t \tag{6}$$

The findings show that the chemisorption process is used to adsorbed the Cu (II) OPAC adsorbent and that the pseudo-second-order binding mechanism is predominant. The process involves the valence force, which is responsible for the transfer of electrons between the dyes and the adsorbent. Additionally, there is a strong affinity between Cu (II) and the adsorbent. Evidence for this can be found in the short half-adsorption time that was attained after the majority of the Cu (II) was eliminated.

3.13. Thermodynamic Parameters

The thermodynamic parameters of the process were the changes in the standard enthalpy (H°), standard entropy (S°), and standard free energy (G°) that came about as a result of transferring a unit mole of solute from the solution onto the solid-liquid interface. The following formulas were used to calculate the values of H° and S°:[11]

$$lnkc = \frac{\triangle S}{R} - \frac{\triangle H}{RT} \tag{7}$$

$$\triangle G = -RTlnK \tag{8}$$

where R is the universal gas constant (8.314 J/(mol.K); T (K) is the absolute temperature in Kelvin, and Kc is the linear adsorption distribution coefficient, which is defined as follows: Kc = Co/Ce, where Co and Ce (mg/L) are the initial adsorbate concentration and concentration of the adsorbate remaining in the liquid phase at equilibrium, respectively. ΔG° is the free energy of adsorption, ΔH° (kJ/mol) is the enthalpy change, and ΔS° (J/(mol. K)) is the entropy change.

Based on the slope and intercept of the log K versus temperature plot in the Kelvin plot, and the values of H° and S° are obtained. The information acquired about the thermodynamic parameters is shown in Table 4. An exothermic adsorption is indicated by a negative H° value. The adsorption reaction may indicate either an associative or dissociative process based on the negative value of S°. An associative mechanism was used in the adsorption process if S° is negative. In this case, adsorption was facilitated by the creation of an active complex between the adsorbent and the adsorbate[17]. The entropy S° value's sign indicated that the degree of randomness of the adsorbate at the solid/solution interface changed during the adsorption process, either becoming less random (S°< 0) or becoming more random (S° > 0).[18]. A negative value for G° indicated that the adsorption process was spontaneous, but a positive value for G° with increasing temperature suggested that the adsorption was non-spontaneous and that the spontaneous nature of the adsorption was negatively associated with temperature.[19]. The adsorption process in this study was exothermic, as indicated by the value of H°, and it was also spontaneous, as indicated by the negative values for G° and entropy S °, which were both less random.

Table 4. Thermodynamic parameters

T (K)	% Removal	ΔG° (kJ.mol^{-1})	ΔH° (kJ.mol^{-1})	ΔS° (kJ.mol^{-1}.k^{-1})
343	99.01	-33.88.	-54.7 6	-14.0
353	99.02	-85.48		
363	99.02	-60.36		
373	99.69	-46.83		

4 Conclusion

The purpose of the study was to produce activated carbon from orange peel that would effectively remove metal ions by having a high surface area and good porosity which was mesopores. Experimentally activated carbon had produced by heating in a furnace for three hours to 500 °C, and were characterized using different methods. The findings collected disclosed a specific surface area and pore widths of 0.99 nm, 168.29 m^2, and 0.399 m^3. g^{-1}, in that order. We then looked at activated carbon's (OPAC) capacity to adsorb out Cu (II) from aqueous solutions. The great cycle adsorption performance of activated carbon at doses of 0.25 g. L^{-1}, 20 mg. L^{-1} for the initial Cu (II) concentration, 150 min for the equilibrium adsorption period, and a pseudo-second-order kinetics-based chemisorption mechanism are the study's strongest points. Cu (II). The ideal reaction temperature was 120 °C, and adsorption capacity increased with temperature. Adsorption was regulated by both the Freundlich and Langmuir models; the highest predicted adsorption capacity of the Langmuir model was 159 $mg.g^{-1}$. The novelty of orange peels is the unique properties of orange peels, such as their high surface area and appropriate mesoporous properties, enable the creation of various substances such as silica ash and activated carbon, which are used to purify water sources of harmful heavy metals. The prospects of this study is to encourage the highly motivated researchers to use orange peels as a major source for producing precursors that will help address the problem of water pollution. The recommendations for more clarification and possibilities for the future are also noteworthy. Future studies will look at removing different types of water pollutants, like heavy metals, from water sources like wastewater. This study shows that an inexpensive and easily accessible adsorbent for extracting copper from wastewater is activated carbon made from orange peels. Its enormous surface area also makes it a practical material for many applications, including catalysts and adsorbents.

Acknowledgment

The authors express their gratitude to the Sharurah Science and Art Faculty at Chemistry Department, Najran University for their support in completing this work.

References

1) Saied ME, Shaban SA, Mostafa MS, Naga AOAE. Efficient adsorption of acetaminophen from the aqueous phase using low-cost and renewable adsorbent derived from orange peels. *Biomass Conversion and Biorefinery*. 2024;14:2155–2172. Available from: https://doi.org/10.1007/s13399-022-02541-x.
2) Bediako JK, Lin S, Sarkar AK, Zhao Y, Choi JW, Song MH, et al. Evaluation of orange peel-derived activated carbons for treatment of dye-contaminated wastewater tailings. . *Environmental Science and Pollution Research*. 2020;27:1053–1068. Available from: https://doi.org/10.1007/s11356-019-07031-8.
3) Lewoyehu M. Comprehensive review on synthesis and application of activated carbon from agricultural residues for the remediation of venomous pollutants in wastewater. *Journal of Analytical and Applied Pyrolysis*. 2021;159:105279–105279. Available from: https://doi.org/10.1016/j.jaap.2021.105279.
4) Çatlıoğlu F, Akay S, Turunç E, Gözmen B, Anastopoulos I, Kayan B, et al. Preparation and application of Fe-modified banana peel in the adsorption of methylene blue: process optimization using response surface methodology. *Environmental Nanotechnology, Monitoring & Management*. 2021;16:100517–100517. Available from: https://doi.org/10.1016/j.enmm.2021.100517.
5) Eddy NO, Garg R, Garg R, Aikoye AO, Ita BI. Waste to resource recovery: mesoporous adsorbent from orange peel for the removal of trypan blue dye from aqueous solution. *Biomass Conversion and Biorefinery*. 2023;15:13493–13511. Available from: https://doi.org/10.1007/s13399-022-02571-5.
6) Bukhari A, Ijaz I, Zain H, Gilani E, Nazir A, Bukhari A, et al. Removal of Eosin dye from simulated media onto lemon peel-based low cost biosorbent. *Arabian Journal of Chemistry*. 2022. Available from: https://doi.org/10.1016/j.arabjc.2022.103873.
7) Khalill A, Mangwandi C, Salem MA, Ragab S, Nemr AE. Orange peel magnetic activated carbon for removal of acid orange 7 dye from water. *Scientific Reports*. Available from: https://doi.org/10.1038/s41598-023-50273-3.
8) Zhao W, Zhao Y, Zhang H, Hao C, Zhao P. Efficient removal of cationic and anionic dyes by surfactant modified Fe3O4 nanoparticles. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*. 2022;633:127680–127680. Available from: https://doi.org/10.1016/j.colsurfa.2021.127680.
9) Gurer AG, Aktas K, Akcetin MV, Unsar AE, Asilturk M. Adsorption isotherms, thermodynamics, and kinetic modeling of methylene blue onto novel carbonaceous adsorbent derived from bitter orange peels. *Water, Air, & Soil Pollution*. 2021;232:1–17. Available from: https://doi.org/10.1007/s11270-021-05090-7.
10) Gugushe AS, Mpupa A, Munonde TS, Nyaba L, Nomngongo PZ. Adsorptive removal of Cd, Cu, Ni and Mn from environmental samples using Fe3O4-zro2@ APS nanocomposite: kinetic and equilibrium isotherm studies. *Molecules*. 2021;26:3209–3209. Available from: https://doi.org/10.3390/molecules26113209.
11) Cheng S, Zhao S, Xing B, Liu Y, Zhang C, Xia H. Preparation of magnetic adsorbent-photocatalyst composites for dye removal by synergistic effect of adsorption and photocatalysis. *Journal of Cleaner Production*. 2022;348:131301–131301. Available from: https://doi.org/10.1016/j.jclepro.2022.131301.
12) Mpupa A, Nqombolo A, Mizaikoff B, Nomngongo PN. Enhanced adsorptive removal of β-estradiol from aqueous and wastewater samples by magnetic nano-akaganeite: adsorption isotherms, kinetics, and mechanism. . *Processes, 2020*;8. Available from: http://dx.doi.org/10.3390/pr8091197.
13) Asif H, Munir R, Albasher G, Sayed M, Muneer A, Mansha A, et al. Fabrication of green magnetized ferrite biochar nanocomposites from orange peels/MnFe2O4, peanut shells/CuFe2O4, tree twigs/Ni Fe2O4, and wood/CoFe2O4: characterization and application as adsorbents for adsorption/desorption/stability of basic Blue-XGRRL dye with possible mechanisms. *Ecosystems and Society*. 2024;73:217–238. Available from: https://doi.org/10.2166/aqua.2024.266.
14) Medhin AFG, Lera IL. Performance of polyaniline doping induced active surface area of Moringa olifera for heavy metal removal from wastewater. *Adsorption*. 2024;30(6):1359–1375. Available from: https://dx.doi.org/10.1007/s10450-024-00507-1.
15) Afolabi FO, Musonge P. Synthesis, Characterization, and Biosorption of Cu2+ and Pb2+ Ions from an Aqueous Solution Using Biochar Derived from Orange Peels. *Molecules*. 2023;28(20):7050–7050. Available from: https://dx.doi.org/10.3390/molecules28207050.

16) Elsayed AE, Osman DI, Attia SK, Shoukry EM, Mostafa YM, Taman AR. A study on the removal characteristics of organic and inorganic pollutants from wastewater by low cost biosorbent. *Egyptian Journal of Chemistry*. 2020;63:1429–1442. Available from: https://doi.org/10.21608/ejchem.2019.15710.1950.
17) Serban GV, Iancu VI, Dinu C, Tenea A, Vasilache N, Cristea I, et al. Removal efficiency and adsorption kinetics of methyl orange from wastewater by commercial activated carbon. *Sustainability*. 12939;17. Available from: https://doi.org/10.3390/su151712939.
18) Sajad A, Ganjidoust H. Using banana peel waste to synthesize BPAC/ZnO nanocomposite for photocatalytic degradation of Acid Blue 25: Influential parameters, mineralization, biodegradability studies. *Journal of Environmental Chemical Engineering*. 2021;9:106010–106010. Available from: https://doi.org/10.1016/j.jece.2021.106010.
19) Belete G, Zewde D. Hagenia abyssinica leaf powder as a novel low-cost adsorbent for removal of methyl violet from aqueous solution: Optimization, isotherms, kinetics, and thermodynamic studies. *Environmental Technology & Innovation*. 2022;28:102577–102577. Available from: https://doi.org/10.1016/j.eti.2022.102577.