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Simultaneous Adsorption of Nickel, Cadmium, Nitrate and Phosphate from Abattoir Wastewater Using Biowaste Biochars

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Abstract

Adsorption can be one of the most effective methods of simultaneous elimination of nickel (Ni), cadmium (Cd), phosphate (PO₄), and nitrate (NO₃) from an environment. It is also the easiest, cheapest, and most environmentally friendly method. The study evaluated the adsorption of nickel, cadmium, nitrate, and phosphate from abattoir effluent using coconut husk biochar and sheanut shell biochar. The study employed different dosages of 100 mL of abattoir wastewater with a 60-minute contact time and a fixed rotatory speed. Coconut husk biochar and sheanut shell biochar efficiencies in nickel removal were 100% and ranged from 99.77% to 99.98%, respectively, and in cadmium removal were 95.21% to 99.96% and 96.05% to 99.19%, respectively, of abattoir effluent. Coconut husk and sheanut shell biochar adsorbed nitrate and phosphate with efficiencies of 99.72% to 99.83% and 99.79% to 99.90%, and 99.94% to 99.96% and 99.95% to 99.98%, respectively. The sheanut shell biochar and coconut husk biochar in abattoir wastewater at varied grams (0.5, 1.0, 2.0, and 3.0 g) showed effective removal efficiency. The Freundlich model best describes the Cd, Ni, NO₃, and PO₄ adsorption on biochars from the K_F, n, and R² values. This indicates the pollutants adsorption is efficient, chemical in character, and the biochars are structurally heterogeneous and have high affinity to Cd, Ni, NO₃ and PO₄ ions that exist in the abattoir wastewater. Coconut husks and sheanut shells can be efficient and affordable adsorbents for harmful metals and nutrients from wastewater from abattoirs and other sources.

Keywords: Simultaneous adsorption; Biowaste biochar; Toxic metals; Abattoir wastewater

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INTRODUCTION

The unregulated discharge of abattoir effluent poses a threat to aquatic ecosystems and human livelihoods, pollutes water resources, and degrades soil quality. Abattoir wastewater often contains high levels of lead, cadmium, chromium, and other heavy metals. Wastewater contaminates water bodies and the environment, which may, in the long run, pose a high risk to public health (Mushtaq et al., 2020). Abattoir effluent poses a significant challenge to natural water quality and aquatic life. Chromium, nickel, lead, cadmium and zinc are among the several metals that are extremely injurious to humans and the environment (Li et al., 2019). Significant health impacts from toxic metals in wastewater include cancer, developmental and stunted growth, death, organ and nervous system damage. Exposure to lead and mercury may cause the cells of the human immune system to attack each other, a condition known as autoimmunity. This may result in circulatory, kidney, nerve, and joint problems, including rheumatoid arthritis. The condition of autoimmunity can cause damage to the developing fetal brain (Attia et al., 2010). In eutrophication, dangers posed to animals, people, and plants are mostly caused by phosphate. Nitrate is one of the main nutrients from slaughterhouse effluents (Konneh et al., 2021). Excessive phosphate and nitrate in wastewater discharge are a major issue everywhere because these nutrients eutrophicate water bodies and promote the growth and spread (Berkessa et al., 2019). High NO₃ levels in drinking water have negative impacts on aquatic life, for instance, the development of aquatic animals, algae and fish. They can also have teratogenic and methemoglobinemia effects on the growth of children. Global bodies and some countries have established phosphate and nitrate discharge limits to mitigate some of these consequences. The discharge of phosphates into water bodies, for instance, rivers and lakes, is mandated by the European Union (EU) to be below 0.07 mg/L for rivers and 0.01 mg/L for lakes (European Commission, 1991). The USEPA (United States Environmental Protection Agency, 2022) also strongly advises a maximum permissible NO₃ level in drinking water of 10 mg/L.

There are many conventional methods (chemical precipitation, coagulation, flocculation, membrane filtration, and biological treatment) of treating wastewater as well as removing toxic metals from the environment (Azimi et al., 2017). However, these strategies frequently have a number of drawbacks, such as high running costs, sludge production, inadequate contaminant removal, and reduced efficiency when treating complex wastewater containing many pollutants. Utilising biomass sources like coconut husks and sheanut shells to create biochar has shown great promise for removing heavy metals and nutrients from wastewater. Adsorption is one of the effective methods of removing NO₃ and PO₄. It is also efficient, eco-friendly, quick, simple, and thought to be a low-cost strategy (Liu et al., 2018; Zhao et al., 2019).

The simultaneous removal of organic pollutants and toxic metals from industrial wastewater is achieved by an adsorption

mechanism using different interfaces, which improves both adsorbate and adsorbent characteristics for effective pollutant removal (Ajiboye et al., 2021). Biochar is a good adsorption process material. Increasingly, humans are focusing their attention on the biochar application for the adsorption of nutrients (Konneh et al., 2021). Using biochar derived from biowaste under controlled conditions by clean technology. The properties of the target pollutant and biochar dictate the efficiency with which it adsorbs water pollutants (Jellali et al., 2021). Application of heavy metal-polluted wastewater treatment by biowaste biochar is ascribed to the fact that it possesses numerous functional groups and has emerged as an area of great concern with high removal efficiency, green technology prospects, and economic viability (Batool et al., 2023). Biowastes contain high nutritional value, and biochar produced from them is of great application in the rejuvenation of the environment (Dowiejuah et al., 2024). It is also porous, heterogeneous, and contains active sites for adsorption, biochar derived from biowaste is also suitable to adsorb heavy metals in wastewater (Dowiejuah et al., 2024). This adsorbing property was found to be appropriate for As³⁺ removal at 90%, Cu²⁺ at 93%, and other ions in water, such as Cd²⁺, Ni²⁺, and Zn²⁺ (Shukla et al., 2020). Mechanical robustness, ease of manufacture, rate of desorption and adsorption, recyclability and regenerability, selectivity for different metals, cost, and efficiency of adsorption are all the criteria that decide on the choice of an adsorbent material to be utilized in green applications (Gupta et al., 2020). Sheanut shells and coconut husks, which are generally low-cost and accessible locally, can be employed in producing biochar as low-value-added biomass. Production of biochar from coconut husk and sheanut shell for metal and nutrient treatment is an adequate use for high-value waste treatment. The research was therefore to evaluate the adsorption potential of coconut husk and sheanut shell biochar of nickel, cadmium, phosphate and nitrate removal from abattoir wastewater.

Materials and Methods

Coconut husk and sheanut shell collection

Coconuts were collected from Kumasi Metropolis, Ashanti Region of Ghana and were weighed after being physically taken off the fruit and cleaned of debris. The sheanut shells, which were used as feedstock to produce biochar, came from Nyankpala in Ghana's Northern Region, Tolon District.

Sheanut shell and coconut husk biochar production

Biochar was produced using coconut husks and sheanut shells in the Agricultural Sub-sector Improvement Programme laboratory, Nyankpala Campus, Ghana. To stop coconut husks and sheanut shells from deteriorating and decomposing, they were properly air-dried for five days and freed from moisture content at ambient temperature. They were then broken into smaller pieces, put into an electric muffle furnace, and charred for 45 min at 350 ± 5 °C. This was repeated several times to yield the coconut husk and sheanut shell biochar, which were

ground and sieved using a 2 mm standard sieve. The 100 g of coconut husk biochar and sheanut biochar were each separately weighed for the different laboratory experiments.

Initial analysis of abattoir wastewater

The concentrations of nickel (Ni), cadmium (Cd), phosphate (PO₄), and nitrate (NO₃) of abattoir wastewater were found to be 6.30, 5.55, 2.60, and 9.30 mg/L, respectively. Ni and Cd analyses were done using a Flame/Graphite Furnace Atomic Absorption Spectrophotometer. The spectrophotometer was used to analyse phosphate, and the Cadmium Reduction Method was used to determine nitrate. The pH of the toxic metals and nutrients in abattoir wastewater was determined using pH meter, which ranged between 7.15 and 7.98, whereas the temperature was 25 °C before the experiment.

Adsorption experiment

The adsorption experiment was carried out at the Spanish Laboratory. With the help of a Sartorius Analytical Weighing Scale CP 125 S, some weighted grams (0.5, 1.0, 2.0, and 3.0 g) of coconut husk biochar and sheanut shell biochar were measured correctly before putting them in a well-labelled conical flask. A measuring cylinder was then utilised for adding 100 mL of abattoir wastewater to the quantity of adsorbent contained in the conical flasks, and was shaken on a rotating orbital shaker for 60 minutes at 150 revolutions per minute. The temperature and pH were determined using a pH meter. The abattoir wastewater was filtered using glass funnels after one hour in the orbital shaker and then poured into 35 mL plastic bottles. The University of Ghana's Ecological Laboratory analysed the filtered samples (elutes).

Nitrate (NO₃-N) analysis

The Cadmium Reduction Method was used for nitrate analysis. A Hach spectrophotometer (Model DR. 2010) was used to measure the amount of nitrate in each sample. 10 mL of the sample was filled in the spectrophotometer sample cell and supplemented with one Nitrate 5 Nitrate Reagent Powder Pillow (AWWA, 1998). After that, the mixture was violently shaken for one minute (AWWA, 1998). The solution was given five minutes to react. The mixture's orange colour denotes the presence of nitrate. Another cell was loaded with 10 mL of just the material after five minutes (blank) (AWWA, 1998). For calibration, the spectrophotometer was filled with the blank sample. The sample prepared was then loaded in the cell holder to measure the NO₃⁻ at 500 nm in mg/L (AWWA, 1998).

Phosphate (PO₄³⁻) analysis

The 10 mL of prepared sample water was added, and upon addition of Phos Ver 3 Phosphate Powder pillow, the contents of the cell were immediately stirred (AWWA, 1998). There was a two-minute window for reactions. The mixture's blue colouring indicates the presence of phosphate. To calibrate the other sample cell (the blank), 10 mL of sample was added to the blank before being put into the cell holder (AWWA, 1998).

The sample prepared was loaded in the cell holder after the reaction time, and the phosphorus level was read at 890 nm. Results were shown in mg/L PO₄³⁻ on the Spectrophotometer (AWWA, 1998).

Calculations of nickel and cadmium, nitrate and phosphate adsorption efficiency using coconut husk biochar and sheanut shells biochar

For every adsorbent uptake and metal concentration, the equilibrium was quantified with the symbol Q_e (Dada et al., 2012). Henceforth, the above mathematical expression can be utilized to determine the adsorption efficiency:

$$Q_e = \frac{C_i - C_f}{M} \times V \dots\dots\dots(1)$$

The adsorption capacity percentage can be calculated as follows:

$$\% \text{ Removal} = \frac{C_o - C_e}{C_o} \times 100 \dots\dots\dots (2)$$

Where M: amount of biochar, Cf: pollutant's concentration in equilibrium, and Ci: initial contaminant concentration, Q_e: adsorption capacity, and V: volume of solution.

Adsorption isotherms

The desorption of an adsorbed gas molecule onto a similar solid surface is the most suitable application of the Langmuir isotherm model (Zhang et al., 2020). Langmuir adsorption, initially designed to model gas-solid phase adsorption (Ayawei et al., 2017), was applied to compare the diverse adsorbents' adsorptive capacities. The Langmuir isotherm characterizes surface coverage in the context of an abattoir wastewater dynamic equilibrium between the relative rates of desorption and adsorption (El-Desouky et al., 2021). Yet, the adsorption quantity is relative to the quantity of the available surface, even though the desorption amount is directly relative to the quantity of the covered biochar surface. The primary goal of the isotherms is to research and analyze the adsorption capacity of toxic metals and the interaction between the metal and the adsorbent (Kharrazi et al., 2020).

The models of Langmuir and Freundlich were used to fit the data. The given equation is as follows:

$$\text{Langmuir model: } q_e = \frac{Q_o K_L C_e}{1 + K_L C_e} \dots\dots\dots (3)$$

In the model, heterogeneous adsorption sites with multilayer adsorption are considered (Ayawei et al., 2017).

$$\text{Freundlich model: } q_e = K_F C_e^{1/n} \dots\dots\dots(4)$$

Where K_L: Langmuir constant (L/mg), K_F: Freundlich constant (mg g⁻¹), Q_e: Langmuir maximum adsorption capacity (mg/g), C_e: saturation concentration (mg/L) of the pollutant, $\frac{1}{n}$: adsorption intensity, and n: a constant that indicates the adsorption intensity.

Results and Discussion

Adsorption efficiency of biowaste biochars for nickel and cadmium

The coconut husk biochar adsorption capacity was 100% for nickel in the abattoir wastewater (Table 1). Coconut husk biochar adsorption efficacy at dosages of 0.5, 1.0, 2.0, and 3.0 g varied between 95.21% and 99.96% for cadmium from the abattoir wastewater (Table 1). Adsorption efficacy of cadmium at dosages of 0.5, 1.0, 2.0, and 3.0 g employing sheanut shell biochar from the abattoir wastewater varied from 96.05% to 99.19% (Table 1). Nickel adsorption efficiency at dosages (0.5, 1.0, 2.0, and 3.0 g) by sheanut shell biochar ranged from 99.77% to 99.98% from the abattoir wastewater (Table 1).

The sheanut shell biochar and coconut husk biochar in abattoir wastewater at varied grams (0.5, 1.0, 2.0, and 3.0 g) showed effective removal efficiency. The experiments showed that the biochars had a higher affinity for nickel in the abattoir wastewater. Hence, the biochars can be environmentally friendly, economically effective, easy to operate, and have strong and efficient adsorption. The percentage removal is low at lower doses of adsorbent but increases with higher doses of coconut husk biochar and achieves its maximum (optimisation range) around 1.0 g of coconut husk biochar (Shrestha et al., 2021). This might occur as a consequence of the metal ions inhabiting nearly all of the open active sites. Due to the increased coconut husk biochar doses nearer to the freely available active sites amount, the elimination percentage is increased (Rathi et al., 2021). In another similar experiment, Algerian cork powder with a pH of 6 has a cadmium adsorption efficiency from an aqueous solution of 64.48% (Krika et al., 2016). Algerian cork powder as an adsorbent with a maximum pH of 6 has 64.48% efficiency in the Cd removal from an aqueous solution, in an analogous experiment (Krika et al., 2016).

Experiments conducted by Binti Naihi et al. (2022) for the production of activated carbon from palm kernel shells to remove cadmium using NaOH, were performed under different concentrations with a similar contact time. The maximum cadmium removal efficiency within 30 minutes ranged from 93% - 94% but improved from 96% - 97% as contact time increased to 150 minutes. The prolonged contact time increases cadmium adsorption efficiency. On the other hand, Rachmat et al. (2018) researched the morphology of cacao pod husk carbonised for three hours at 300°C, and the surface of the material was rough and heterogeneous and had

pores with unequally spaced pores, hence efficient for adsorption, and was treated with 2 M HCl for four hours at 80 °C.

Adsorption efficiency of biowaste biochars for nitrate and phosphate

Coconut husk biochar efficiency for adsorption was between 99.79% and 99.90% for the nitrate from the abattoir wastewater (Table 2). Coconut husk biochar efficiency for adsorption with varying dosages of 0.5, 1.0, 2.0, and 3.0 g was between 99.95% and 99.98% for the phosphate from the abattoir wastewater (Table 2). The adsorption efficiency of nitrate at different dosages by sheanut shell biochar ranged from 99.72% to 99.83% from the abattoir wastewater (Table 2). The adsorption efficiency of phosphate at different dosages by sheanut shell biochar from the abattoir wastewater ranged from 99.94% to 99.96% (Table 2). The sheanut shell biochar and coconut husk biochar in abattoir wastewater at varied grams (0.5, 1.0, 2.0, and 3.0 g) showed effective removal efficiency. The biochars had a higher affinity for nitrate in the abattoir wastewater. In an experiment conducted by Konneh et al. (2021), it was established that the rise in biochar mass (from 0.5 g to 1.50 g) led to increased NO₃-N and NO₂-N removal percentage.

For biochar dosages of more than 1.50 g, this results in a progressive decrease in the nutrient removal. This observation can be elucidated by a progressive rise in the amount of surface area that is accessible for adsorption (Gierak and Łazarska, 2017). However, the cluster of particles, which consequently hides the available adsorption sites, can also be responsible for the slow decline that occurs after 1.5 g (Liang et al., 2016; Hafshejani et al., 2016) found similar effects of adsorbent dose on the anion removal from aqueous solutions.

Conventional biochar's ability to adsorb phosphate was often poor, and in some instances, it even released phosphorus that was already present in the material, raising the phosphorus concentration in the solution (Zheng et al., 2013). The adsorption effectiveness for phosphate at each concentration was found to be just 2 - 8% in this study's analysis of the phosphate removal of simple biochar. The micro-pore high-density structure and high surface area, specifically, which provided the phosphate ions with an active site, were mostly responsible for the phosphate adsorption on the biochar. Physical deposition was where phosphate ions migrated to the biochar surface, though its effect was limited (Ajmal et al., 2020).

Table 1: Results of biochars adsorption for nickel and cadmium

Coconut husk biochar	Metal	Initial concentration (mg/L)	Final concentration (mg/L)	Percentage (%)
0.5 g	Ni	6.30	0	100
1.0 g	Ni	6.30	0	100
2.0 g	Ni	6.30	0	100
3.0 g	Ni	6.30	0	100
0.5 g	Cd	5.55	0.006	99.89
1.0 g	Cd	5.55	0.002	99.96

2.0 g	Cd	5.55	0.024	99.57
3.0 g	Cd	5.55	0.266	95.21
Sheanut shell biochar	Metal	Initial concentration (mg/L)	Final concentration (mg/L)	Percentage (%)
0.5 g	Ni	6.30	0.014	99.77
1.0 g	Ni	6.30	0.011	99.83
2.0 g	Ni	6.30	0.006	99.9
3.0 g	Ni	6.30	0.013	99.98
0.5 g	Cd	5.55	0.219	96.05
1.0 g	Cd	5.55	0.204	96.32
2.0 g	Cd	5.55	0.166	97.00
3.0 g	Cd	5.55	0.045	99.19

Table 2: Biowaste biochars adsorption efficiency of nitrate and phosphate

Coconut husk biochar	Nutrient	Initial concentration (mg/L)	Final concentration (mg/L)	Percentage (%)
0.5 g	NO ₃	2.90	0.0062	99.79
1.0 g	NO ₃	2.90	0.0058	99.8
2.0 g	NO ₃	2.90	0.0054	99.81
3.0 g	NO ₃	2.90	0.0028	99.9
0.5 g	PO ₄	9.40	0.0044	99.95
1.0 g	PO ₄	9.40	0.0033	99.96
2.0 g	PO ₄	9.40	0.0026	99.97
3.0 g	PO ₄	9.40	0.002	99.98
Sheanut shell biochar	Nutrient	Initial concentration (mg/L)	Final concentration (mg/L)	Percentage (%)
0.5 g	NO ₃	2.90	0.0081	99.72
1.0 g	NO ₃	2.90	0.0072	99.75
2.0 g	NO ₃	2.90	0.007	99.75
3.0 g	NO ₃	2.90	0.005	99.83
0.5 g	PO ₄	9.40	0.0055	99.94
1.0 g	PO ₄	9.40	0.0042	99.96
2.0 g	PO ₄	9.40	0.0038	99.96
3.0 g	PO ₄	9.40	0.0033	99.96

Table 3: Data modelling results for metals and nutrients in abattoir wastewater

Langmuir	Coconut		Sheanut shell		Coconut		Sheanut shell	
Parameter	Cd	Ni	Cd	NO ₃	PO ₄	NO ₃	PO ₄	
Q _{max} (mg/g)	1.29 x 10 ⁻³	-4.89 x 10 ⁻³	-5.38 x 10 ⁻³	-4.05 x 10 ⁻³	-2.88 x 10 ⁻³	-2.45 x 10 ⁻³	-2.12 x 10 ⁻³	
K _L (l/mg)	0.46	-3.09	-3.04	-1.18	-2.71	-7.16 x 10 ⁻¹	-2.0	
R _L	3.54	-18.45	-15.9	-2.41	-24.47	-1.08	-17.76	
R ²	0.13	0.40	0.62	0.56	0.94	0.68	0.97	
Freundlich parameters								
1/n	7.28 x 10 ⁻¹	-7.90 x 10 ⁻³	-1.08 x 10 ⁻²	-3.40 x 10 ⁻³	-1.10 x 10 ⁻³	-8.50 x 10 ⁻³	-2.20 x 10 ⁻³	
N	1.37	-344.80	-29.90	-294.12	-909.10	-117.65	-454.55	
K _F (mg/g)	3441.91	605.06	527.47	284.32	933.25	350.17	972.3	
R ²	0.45	0.81	0.86	0.5	0.92	0.62	0.95	

Adsorption isotherms of biowaste biochars

In the abattoir wastewater, the Langmuir isotherm was used in this study for the determination of the nutrients and toxic metals to adsorb onto the biowaste biochars. The maximum adsorption capacity (Q_{max}) of Cd was 1.29×10^{-3} mg/g, that of NO_3 was -4.05×10^{-3} mg/g, and that of PO_4 was -2.88×10^{-3} mg/g for coconut husk biochar adsorption (Table 3). The maximum adsorption capacity (Q_{max}) ranged from -4.89×10^{-3} mg/g for Ni, -5.38×10^{-3} mg/g for Cd, -2.45×10^{-3} mg/g for NO_3 , and -2.12×10^{-3} mg/g for PO_4 for sheanut shell biochar adsorption. The Q_{max} (mg/g) of biochars was extremely low and negative towards Cd, Ni, NO_3 , and PO_4 , indicating poor interaction and unstable adsorbing process between Cd, Ni, NO_3 , and PO_4 , and coconut husk and sheanut shell biochars. R_L value for NO_3 was -2.41, and PO_4 was -24.47 for coconut husk biochar, and NO_3 was -1.08, PO_4 was -17.76 for sheanut shell biochar (Table 3). Zhang et al. (2015) assert that Langmuir adsorption must take place in a single layer with no linkages and no steric barrier between molecules. This is caused by the intermolecular forces, which quickly decrease as the ion moves away from the adsorbent surface. The Langmuir isotherm is employed when the process of adsorption is monolayered with a set number of sites (Ayawei et al., 2017). The suitability of the experiments with the surface sites heterogeneity of biowaste biochars adsorption was ascertained by the Freundlich isotherm for the toxic metals and nutrients. The $1/n$ values obtained for Cd were 7.28×10^{-1} for sheanut shell biochar, -7.90×10^{-3} for Ni, and -1.08×10^{-2} for Cd coconut husk biochar (Table 3). The N values of toxic metals measured were 1.37 for Cd for sheanut shell biochar, -344.8 for Ni, and -29.9 for Cd for coconut husk biochar (Table 3). The $1/n$ values obtained from the nutrients were -3.40×10^{-3} and -8.50×10^{-3} for NO_3 , -1.10×10^{-3} and -2.20×10^{-3} for PO_4 for coconut husk biochar and sheanut shell biochar, respectively (Table 3). The values of K_F (mg/g) for harmful metals in all the experiments ranged from 527.47 to 3441.91 (Table 3). All of the experiments' K_F (mg/g) values fell within this range from 284.32 to 972.30. The Freundlich isotherm coefficient of determination values for toxic metals ranged between 0.45 and 0.86, while the nutrient values were approximately 0.5. The $1/n$ for Cd and Ni were higher than one, which suggests that sheanut shell biochar exhibited cooperative adsorption. The $1/n$ values of cadmium were below one, indicating that metal ions initially took up higher energy positions and eventually moved to lower energy positions during adsorption on heterogeneous surfaces. The K_F (l/g) value for biochars was high for Cd, Ni, NO_3 and PO_4 , indicating higher interaction and a stable adsorption process between Cd, Ni, NO_3 and PO_4 , and biochars. High constant values indicated higher interaction between the pollutants (adsorbate) and adsorbents (Tran et al., 2019). Even though Cr and Ni were low, indicating a weak interaction between Cr and Ni and sheanut shell biochar. The lower constant values exhibited that the interaction between them is weak (Tran et al., 2019). The Freundlich model best describes the Cd, Ni, NO_3 , and PO_4 adsorption on biochars from the K_F , n , and R^2 values. This indicates the Cd, Ni, NO_3 , and PO_4

adsorption is efficient, chemical in character, and the biochars are structurally heterogeneous and have high affinity to Cd, Ni, NO_3 and PO_4 ions that exist in the abattoir wastewater.

pH and temperature of the abattoir wastewater

The pH is important when trying to adsorb metals from wastewater. The pH of the toxic metals and nutrients in abattoir wastewater ranged between 7.15 and 7.98, whereas the temperature was 25 °C before engaging with biowaste biochars. The degree to which different pollutants ionise during treatment depends on the pH of the wastewater, as does the surface charge of the adsorbents. The procedure for employing both traditional and unusual adsorbents. All of the hazardous metals under consideration were removed with remarkably high efficiency at the pH level at which the experiments were carried out. In a study conducted by Malik and Dahiya (2017), it was reported that the pH of the solution influences metal ion removal, i.e., increased pH enhances the process. The removal percentage of every toxic metal ion increases as batch pH increases. Ni at pH 6, after which there is a drastic reduction in metal removal as a result of precipitation as soluble hydroxides of metal and/or desorption. It must be noted that the rate of removal of Ni was initially fast but then slowed down with increased pH. A study reported the optimum pH for the Ni (II) adsorption by different sorbents to be between 5 and 7 (Bansal et al., 2022). Under low pH (2 - 3), there are additional H^+ ions accessible to compete with toxic metal ions for the sites of adsorption on the adsorbent. Moreover, most of the functional groups are protonated at low pH (Khorshidi et al., 2020). This will decrease the binding sites accessible for the metal ions' adsorption.

Conclusion

The effectiveness of affordable biowaste biochars in removing Ni, Cd, NO_3 and PO_4 from abattoir effluent was very high throughout the experiment. The coconut husk biochar adsorption capacity was 100% for nickel and 95.21% and 99.96 % for cadmium in the abattoir wastewater. Adsorption efficacy of cadmium at dosages of 0.5, 1.0, 2.0, and 3.0 g employing sheanut shell biochar from the abattoir wastewater varied from 96.05% to 99.19% and 99.77% to 99.98% for nickel from the abattoir wastewater. The Freundlich model best describes the Cd, Ni, NO_3 , and PO_4 adsorption on biochars from the K_F , n , and R^2 values. Coconut husks and sheanut shells can be employed as efficient and affordable adsorbents for harmful metals and nutrients from wastewater from abattoirs and other sources.

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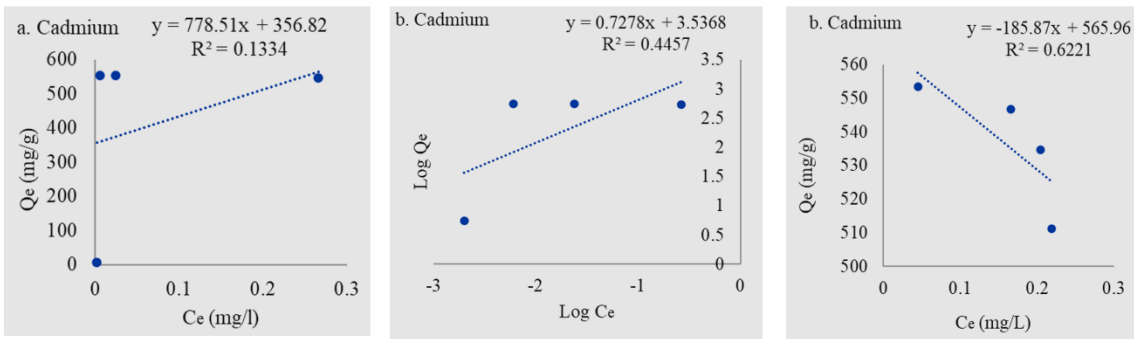
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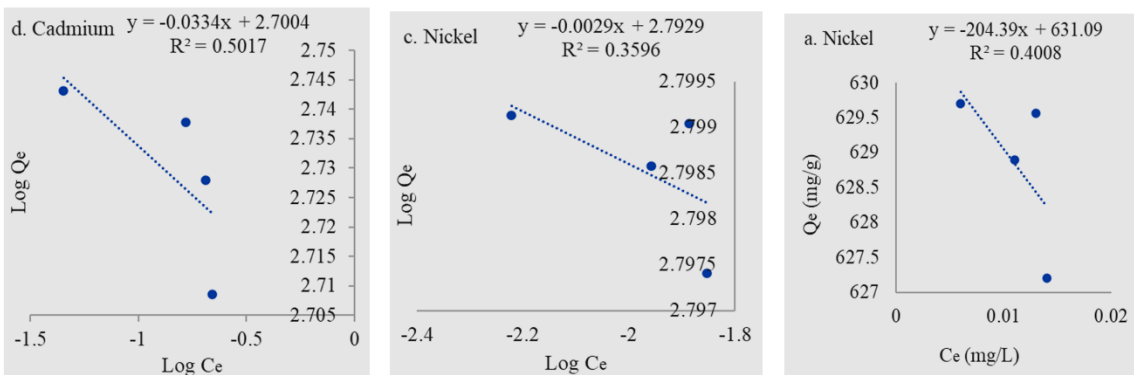
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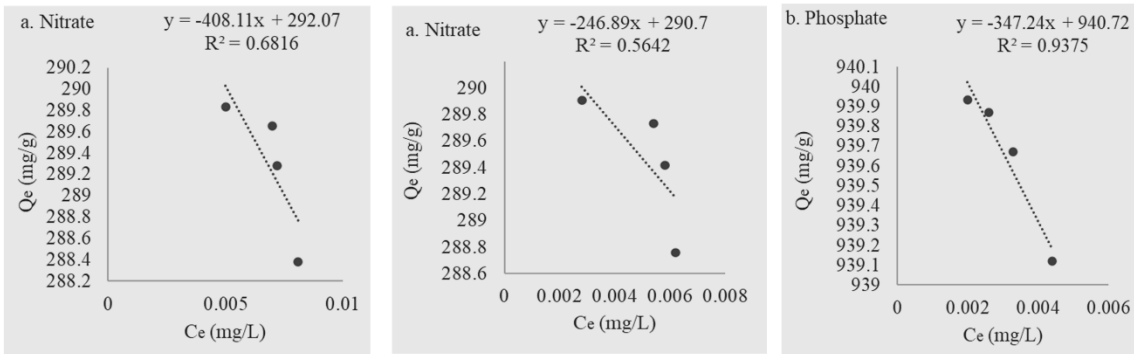
Appendix 1: Freundlich isotherm of the Cadmium, nitrate and phosphate adsorption by sheanut shell and Coconut husk biochar



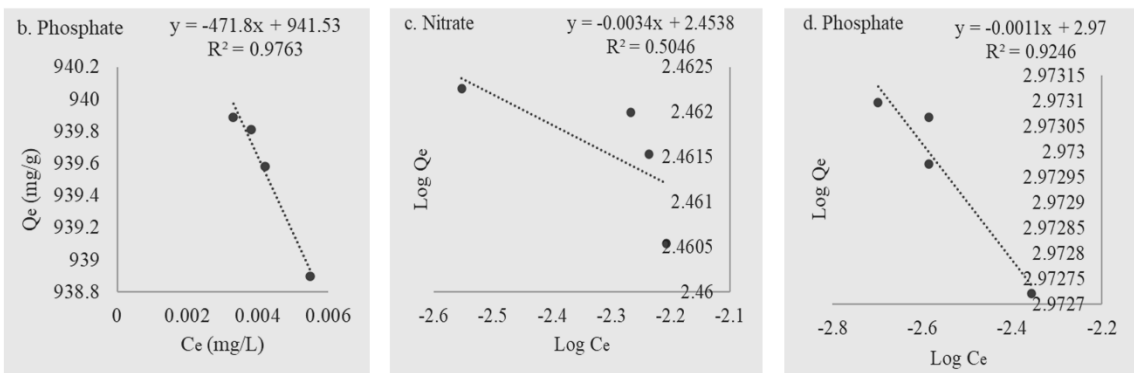
Langmuir isotherm of the cadmium adsorption by coconut husk biochar



Langmuir isotherm of the nickel and cadmium adsorption by sheanut shell biochar



Langmuir isotherm of the nitrate and phosphate adsorption by sheanut shell biochar



Langmuir isotherm of the nitrate and phosphate adsorption by coconut husk biochar