



Comparative Investigation of Lophira Alata Sawdust and Activated Carbonized Sawdust in Treating of Heavy-Metal Contaminated Water

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Abstract. The Lophira alata wood sawdust obtained for this study was first thoroughly washed with distilled water to remove impurities, then dried under controlled conditions, and subsequently divided into two equal portions. The first portion was retained and used directly as the unmodified sawdust sample. The second portion underwent further treatment: it was carbonized at a temperature of 600 °C for 4 hours to enhance its structural properties, and then chemically activated using 2 M KOH for 24 hours at room temperature to improve its adsorption capacity. Both prepared samples were utilized as adsorbents for the removal of Nickel (Ni²⁺) ions from aqueous solutions. Key operational parameters affecting adsorption, including contact time, adsorbent dosage, and pH, were systematically investigated. Additionally, the physicochemical characteristics of both adsorbents were evaluated to understand their performance. The results revealed that increasing the sawdust dosage, contact time, and solution pH significantly enhanced the adsorption efficiency. Moreover, the activated-carbonized sawdust demonstrated a higher adsorption capacity compared to the unmodified sample. Therefore, Lophira alata sawdust, particularly in its activated-carbonized form, is an effective, low-cost material for removing toxic heavy metals from wastewater.

Keywords: Lophira alata, Sawdust, Carbonized Sawdust, heavy Metal, Contaminated Water.

I. Introduction

Water is an essential resource for life, sustaining human health, agriculture, and industrial activities (Obruché et al., 2019). The availability of clean and safe water is crucial for the development and well-being of societies worldwide (Addo et al., 2011). However, rapid industrialization, urbanization, and agricultural intensification have led to the contamination of water bodies with various pollutants, including heavy metals,



which pose significant environmental and public health risks (Umudi et al., 2025). Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), and arsenic (As) are non-biodegradable, persistent, and toxic even at low concentrations.

Once introduced into aquatic ecosystems, these metals tend to accumulate in sediments and biota, ultimately entering the food chain and causing chronic health problems in humans and wildlife, such as kidney damage, neurological disorders, and carcinogenic effects (Erienu et al., 2022). Globally, the discharge of untreated or inadequately treated industrial effluents remains a leading source of heavy metal contamination in surface and groundwater (Ekpo et al., 2023). Industries such as mining, metal plating, battery manufacturing, textiles, and tanneries often release effluents containing elevated concentrations of heavy metals.

Conventional water treatment methods, including chemical precipitation, ion exchange, membrane filtration, and coagulation-flocculation, have been widely applied to remove heavy metals from wastewater (Umudi et al., 2025). Although effective, these methods have several limitations, such as high operational costs, production of secondary sludge, complex maintenance, and inefficiency at low metal concentrations. Consequently, there has been an increasing demand for alternative, cost-effective, and environmentally friendly technologies for heavy metal remediation (Abeokuta et al., 2025). Adsorption has emerged as one of the most promising techniques for heavy metal removal due to its simplicity, high efficiency, and adaptability.

The process involves the accumulation of heavy metal ions onto the surface of solid materials (adsorbents), which can effectively reduce metal concentrations in water to acceptable levels (Itodo et al., 2021). Activated carbon is widely regarded as a benchmark adsorbent due to its high surface area, porosity, and chemical stability. It has been successfully applied to remove various contaminants, including heavy metals, dyes, and organic pollutants (Aglanu & Appiah, 2014). However, the high cost of commercial activated carbon often limits its widespread use, particularly in developing regions where low-cost alternatives are urgently needed. In recent years, research has increasingly focused on the utilization of agricultural and industrial by-products as low-cost adsorbents for heavy metal removal.

Materials such as rice husks, coconut shells, sawdust, bagasse, and nutshells have demonstrated significant adsorption potential due to the presence of functional groups, such as hydroxyl, carboxyl, and phenolic groups, which can bind heavy metal ions (Umudi et al., 2025). Among these, sawdust—a lignocellulosic by-product of timber processing—has received considerable attention. Sawdust is abundant, renewable, and often considered waste, making it an economically attractive and environmentally sustainable option for water treatment (Bentum et al., 2011).

The adsorption efficiency of sawdust can be further enhanced through chemical or thermal modification, such as carbonization or activation, which increases its surface area, pore volume, and availability of binding sites. *Lophira alata*, commonly known as African ironwood, is a hardwood species native to West and Central Africa. Its dense wood is primarily used in construction and furniture, producing considerable amounts of sawdust as a by-product (Ekpo et al., 2025). Recent studies have highlighted the



potential of *Lophira alata* sawdust as a natural adsorbent for the removal of heavy metals from contaminated water.

The presence of lignin, cellulose, and hemicellulose in the sawdust provides multiple functional groups that interact with metal ions through mechanisms such as ion exchange, complexation, and adsorption (Obruche et al., 2018). Moreover, chemical or thermal activation of *Lophira alata* sawdust can enhance its physicochemical properties, resulting in activated carbonized sawdust with higher adsorption capacities. Despite the growing body of research on low-cost adsorbents, comparative studies evaluating the efficiency of raw sawdust versus activated or carbonized sawdust remain limited (Ogwuche & Obruche, 2020). Understanding the differences in adsorption performance, surface characteristics, and metal-binding mechanisms between these two forms is essential for optimizing treatment strategies and promoting the sustainable use of agricultural and industrial waste materials.

Such comparative analyses provide insights into whether the additional processing required for activation or carbonization justifies the improvement in heavy metal removal efficiency, particularly in the context of cost, scalability, and environmental sustainability (Festus-Amadi et al., 2021). This study, therefore, aims to conduct a comparative evaluation of *Lophira alata* sawdust and activated-carbonized *Lophira alata* sawdust in the adsorption of heavy metals from contaminated water. By examining factors such as adsorption capacity, removal efficiency, kinetics, and isotherm behavior, the research seeks to determine the effectiveness of raw versus activated sawdust. Additionally, the study explores the potential of using these low-cost adsorbents as a viable alternative to conventional methods, thereby contributing to sustainable water management and pollution mitigation strategies. The findings of this research are expected to inform environmental engineers, policymakers, and local communities about the feasibility of employing locally available biomass resources for water purification, offering both economic and ecological benefits.

II. Materials and Method

Materials

All chemicals used in this study were of reagent grade and required no additional treatment. Nickel Sulphate (NiSO_4) with 99.99% purity, potassium hydroxide (KOH) at 90% purity, and Buffer Solution were provided by Merck. The unmodified *Lophira Alata* sawdust sample and the activated-carbonized *Lophira Alata* sawdust sample were sourced from the Unenurhie community in Delta State. Distilled water was obtained from the Chemistry Laboratory at Delta State College of Education in Mosogar, Delta State.

Collection of samples

The procedure for sample collection, identification, and treatment adhered to the methodology established by Obruche et al. (2025). The *Lophira Alata* wood sawdust was collected from a local sawmill situated in the Akpata area along Upper Siluko Road in the Egor local government area of Benin City, Edo State. A large quantity of fine sawdust particles was gathered. The salts of the heavy metals intended for adsorption were sourced from the Chemistry Department laboratory, specifically Nickel Sulphate (NiSO_4).



Preparation of sample

The samples preparation were conducted following the protocols outlined by (USEPA, 2004; Obruché et al., 2019; and Umudi et al., 2025). The sawdust was sun-dried until all moisture was eliminated. It was then filtered through a sieve with a mesh size of 53 micrometers to separate the very fine particles. The sawdust sample was split into two portions: the first portion served as the unmodified sawdust sample, while the second portion was carbonized, activated, and used as the activated-carbonized sawdust sample.

Preparation of the Carbonized Sawdust

The remaining sawdust intended for carbonization was placed in a clay pot and heated in an oven at 1000°C for 4-5 hours. This process was conducted in batches until all sawdust samples were carbonized (Oram, 2014).

Activation of the Carbonized Sawdust

Ash Content Determination This determination was conducted in accordance with Umudi et al., (2025). The carbonized sawdust was activated using 2M KOH. The process of producing activated carbon from sawdust involved chemical activation, specifically the thermal decomposition of the raw material that was impregnated with the activating agent (2M KOH).

Potassium Hydroxide is a powerful dehydrating agent that can change the structure of carbon to create a porous form. The samples were treated with an excess of 2M KOH chloride for 24 hours at room temperature. It's important to note that increasing the amount of the activating agent enhances the contact area between the material and the agent, which in turn increases the surface area and porosity of the carbon. After activation, the samples were thoroughly washed with distilled water until all residual activating agent on the activated carbon surface was removed. This was done by regularly checking the pH of the filtrate after each wash until it reached neutrality (pH 7). Following this, the samples were dried in an oven for 30 minutes at 1000C for 2 hours.

Characterization of the Unmodified Sawdust and the Activated-Carbonized Sawdust

The unmodified sawdust and the activated carbon were characterized based on their physical and chemical properties. The physical properties of both the unmodified sawdust and the activated carbon include moisture content, ash content, and bulk density, while the chemical properties consist of pH, contact time, and sawdust dosage.

Moisture Content

The Moisture Content method was employed for this analysis (Olowu et al., 2010). Moisture content refers to the amount of water present in a material. It can also be described as the quantity of water physically bound to the activated carbon under normal conditions. The moisture content of both the unmodified sawdust and the activated carbon is often necessary to define and express their properties in relation to the net weight of the carbon.

In this research project, the moisture content of the unmodified sawdust and the activated carbon was determined using the oven drying method. 2g of the dried unmodified



sawdust and the activated carbon were weighed and placed into a pre-dried crucible, then put in an oven at 110 C until a constant weight was achieved over 2 hours. After drying, the crucible were removed, cooled in a dessicator and then weighed. The moisture content was calculated in by:

$$\% \text{ Moisture Content} = \frac{W_1 - W_2}{W_1} \times 100$$

Ash Content

The adsorption experiment was conducted using a batch method (Oduro et al.; 2001). Ash refers to the inorganic residue that remains after the removal of water and inorganic matter through heating, serving as an indicator of the total minerals present in the sample. The ash content represents the materials that remain following the carbonization and activation processes of the carbon material. In this research project, 2 g of dried activated carbon was measured and placed into a preheated porcelain crucible with a known weight. The combined weight of the crucible and the dried activated carbon was recorded, after which it was transferred to a muffle furnace and heated at 600°C for 2 hours until no further weight loss was observed.

Following the heating process, the crucible was allowed to cool in a desiccator and then reweighed to determine the weight of the ash. The weight of the residual ash, expressed as a percentage of the original weight of the activated carbon, constituted the ash content of the activated carbon. The percentage of ash content was calculated using the following formula:

$$\% \text{ Ash Content} = \frac{\text{Weight of Ash}}{\text{Weight of Sample}} \times 100$$

Bulk Density

The bulk density was examined in this research are referenced from (Ugochukwu et al., 2025). The bulk density of a powder is defined as the weight of the powder divided by the volume it occupies, typically expressed in g/ml. This measurement can serve as a general indicator of particle size and dispersion, which may influence the consistency of material flow and indicate packaging quantity. The bulk density of activated carbon is influenced by the shape, size, and density of its individual particles. In this research project, the bulk density of the samples was determined by filling a graduated cylinder (10ml) with dry, unmodified sawdust and activated carbonized sawdust up to the top graduation. This was achieved by gently tapping the cylinder on the table, followed by weighing the cylinder along with the sample, and finally calculating the bulk density by dividing the weight of the sample by the volume of the cylinder. The formula is provided as:

$$\text{Bulk density} = \frac{W_{MAT}}{V_{MAT}}$$

pH

The pH level of activated carbon indicates if it is acidic or basic. When activated carbon exits the kiln, it is usually slightly basic, with a pH around 8. A high pH suggests excessive contaminants, while a low pH, particularly in acid-washed activated carbon, indicates that the acid hasn't been thoroughly rinsed out. Typically, activated carbons are designed for a pH range of 6-8. In this study, 1g of the sample was measured and placed in a beaker. 100ml of distilled water was added to the sample and stirred for one hour. The samples were allowed to settle before measuring the pH with a pH meter.



Contact Time

The impact of contact time on the adsorption of Ni ions was examined. 1.0g of each adsorbent (unmodified sawdust and activated-carbonized sawdust) was placed in 5 beakers containing 100 ml of metal solution at an initial concentration of 20 mg/L. The solutions were stirred at a constant speed of 180rpm for different time intervals ranging from 20 to 120 minutes at a stable pH of 6. The final concentration of each solution was measured using an Atomic Adsorption Spectrophotometer (AAS), and the percentage of Ni²⁺ was calculated.

Sawdust Dosage

The influence of sawdust dosage on the percentage removal of metallic ions was studied by changing the adsorbent dose between 0.1 to 0.4g. Different amounts of adsorbents (from 0.1 to 0.4g of unmodified sawdust and activated-carbonized sawdust) were placed in 4 sample bottles with 100ml of metal solution at an initial concentration of 20 ppm. The solutions were stirred at a constant speed of 180 rpm for a set contact time of 120 minutes and a stable pH of 6.0. The final concentrations of the solutions were then measured using an Atomic Adsorption Spectrophotometer (AAS), and the percentage removal of Ni²⁺ was calculated.

Adsorption Experiment

The adsorption experiment was conducted using a batch method (Obruche et al.; 2018). The procedure for the adsorption experiment involves adding a specific amount of the prepared adsorbent, which includes both unmodified sawdust and activated-carbonized sawdust, to the diluted solutions of heavy metals (Nickel). The setups were prepared in batches and subjected to different conditions, being agitated with a mechanical shaker at 120rpm for 1 hour. After this, the adsorbent was filtered from the solution. The concentration of heavy metals remaining in the various solutions was determined using an Atomic Adsorption Spectrophotometer (AAS), model AA500. The different conditions under which the batch experiments were conducted were recorded.

Statistics Data Analysis

The data is presented in tables as mean \pm SD. All descriptive statistics and graphs were generated using Microsoft Excel version 10.

III. Results and Discussion

This section presents and discusses the results of the data analysis conducted for this study, which are displayed in tables 1-8.

Physicochemical Properties of Unmodified Sawdust

From the unmodified sawdust, the following were the physicochemical properties obtained:

Table1: Physicochemical properties of Unmodified Sawdust

Parameter	Result Obtained
Moisture Content (%)	2.64
Ash Content (%)	1.20
Bulk Density (g.cm-3)	0.89



PH

7.02

Physiochemical Properties of Activated-Carbonized Sawdust

From the activated-carbonized sawdust, the following were the physiochemical properties obtained:

Table 2: Physicochemical properties of Activated-Carbonized Sawdust

Parameters	Result Obtained
Moisture Content (%)	1.05
Ash Content (%)	1.40
Bulk Density (g.cm-3)	0.35
PH	7.02

Adsorption of Nickel Ion by Unmodified Sawdust and the Activated-Carbonized Sawdust

The tables presented below were derived from the results of the AAS analysis conducted on the different filtrates obtained from experiments utilizing both unmodified sawdust and activated-carbonized sawdust for the adsorption of Nickel ions.

Table 3: Effect of Unmodified Sawdust Dosage on Adsorption of Nickel Ion

Sawdust Dosage (G)	Initial Concentration (Mg/L)	Equilibrium Concentration (Mg/L)	Amount Adsorbed (Mg/Kg)
0.1	100	2.24	97.76
0.2	100	1.11	98.89
0.3	100	0.74	99.26
0.4	100	0.54	99.46

Table 4: Effect of Activated-Carbonized Sawdust Dosage on Adsorption of Nickel Ion

Sawdust Dosage (G)	Initial Concentration (Mg/L)	Equilibrium Concentration (Mg/L)	Amount Adsorbed (Mg/Kg)
0.1	100	0.25	99.75
0.2	100	0.09	99.91
0.3	100	0.05	99.95
0.4	100	0.03	99.97

Table 5: Effect of PH of Unmodified Sawdust on Adsorption of Nickel Ion

PH	Initial Concentration (Mg/L)	Equilibrium Concentration (Mg/L)	Amount Adsorbed (Mg/Kg)
3	100	6.48	93.52
4	100	1.62	98.38
5	100	0.81	99.91
6	100	0.58	99.42

Table 6: Effect of PH of Activated-Carbonized Sawdust on Adsorption of Nickel Ion

PH	Initial Concentration (Mg/L)	Equilibrium Concentration (Mg/L)	Amount Adsorbed
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			(Mg/Kg)
3	100	3.20	96.80
4	100	0.65	99.35
5	100	0.37	99.63
6	100	0.27	99.73

Table 7: Effect of Contact Time of Unmodified Sawdust on Adsorption of Nickel Ion

Contact Time (Min)	Initial Concentration (Mg/L)	Equilibrium Concentration (Mg/L)	Amount Adsorbed (Mg/Kg)
20	100	2.74	97.26
40	100	1.27	98.73
80	100	0.84	99.16
100	100	0.60	99.40
120	100	0.46	99.54

Table 8: Effect of Contact Time of Activated Carbonized Sawdust on Adsorption of Nickel Ion

Contact Time (Min)	Initial Concentration (Mg/L)	Equilibrium Concentration (Mg/L)	Amount Adsorbed (Mg/Kg)
20	100	1.14	98.86
40	100	0.53	99.47
80	100	0.35	99.65
100	100	0.49	99.51
120	100	0.15	99.85

IV. Discussion

The results indicate that a higher dosage of sawdust for Nickel ions leads to a greater adsorption rate. However, when compared to the table, it is clear that activated-carbonized sawdust adsorbs more heavy metal ions than the unmodified sawdust sample. A detailed look at the pH of the unmodified sawdust sample (table 1) shows that at pH 3, approximately 93.52 mg/kg of Nickel ions was adsorbed. At pH 4, 98.38 mg/kg was adsorbed. At pH 5, 99.19 mg/kg was adsorbed. At pH 6, 99.42 mg/kg of Nickel ions was adsorbed. This indicates that as pH increases, the amount of toxic metals adsorbed by the adsorbent also increases.

The same trend is observed with the activated carbonized sawdust, but it adsorbs more toxic metals than the unmodified sawdust sample. For instance, at pH 3, the activated-carbonized sawdust adsorbs 96.82 mg/kg of Nickel ions. At pH 4, it adsorbs 99.35 mg/kg. At pH 5, 99.63 mg/kg of Nickel ions is adsorbed. At pH 6, 99.73 mg/kg of Nickel ions is adsorbed by the activated carbonized sawdust, showing that it adsorbs more compared to the unmodified sawdust. The impact of contact time on both the unmodified and activated-carbonized sawdust samples for Nickel shows that as the time increases from about 20 minutes to 120 minutes, the adsorption rate also rises.

The results showed that increasing the dosage of sawdust, contact time, and pH for both Nickel and Cadmium ions led to a higher adsorption rate. Thus, we can conclude that



the adsorption rate rises with more adsorbent dosage, longer contact time, and higher pH. The table results indicated that activated-carbonized Sawdust adsorbed more than unmodified Sawdust because the activation process enhances the surface area and porosity of the carbon structure, allowing the activated adsorbent to capture more toxic metals compared to unmodified Sawdust. The order of selectivity for adsorption based on the increase in adsorption rate is: Activated-carbonized Sawdust > Unmodified Sawdust sample. Similar observations have been documented by Obruché et al. (2025)

V. Conclusion

From the comparative study of heavy metal ion removal using *lophira alata* wood sawdust adsorption, we can draw several conclusions. Firstly, *lophira alata* is an excellent and cost-effective adsorbent for removing heavy metal ions from wastewater. Secondly, activated-carbonized Sawdust is the most effective for heavy metal removal in water solutions.

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