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Investigating the Physico-Chemical Properties of Groundnut Shell and Its Effects on Hospital Waste Water

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ABSTRACT: Hospital waste could be dangerous to the ecological balance and public health. The absence of efficient sewage treatment plant in many countries especially in Nigeria and national discharge standards for hospital wastewater has necessitated the need for hospital wastewater treatment. This study investigates the physico-chemical properties of groundnut shell and its effects on hospital waste water. Chemical reagents and materials were used for preparation, extraction and identification of phytochemical components in groundnut shell. Isolation and characterization of the microbial load in hospital waste water was carried out, X-ray fluorescence and FTIR analysis was done. Result showed the presence of *E. coli*, *Salmonella* spp, *Staphylococcus* Spp, *Enterobacter* Spp and *Serratia* in untreated hospital water and *E. coli* is absent in the treated one. Physico-chemical treatment of hospital waste is an effective parameter to monitor water treatment as PH, temp, electrical conductivity, total dissolved solid, total suspended solid, COD, turbidity, salinity, level of sulphate, nitrate and water level significant decreased. There was a statistically significant reduction ($P<0.05$) in the heavy metals present in hospital water waste before and after treatment with groundnut shell. Langmuir isotherm model with correlation reliability (R^2) value of 0.91 was found to be better fit for the experimental data obtained than Freundlich isotherm model with correlation reliability (R^2) value of 0.77. The optimization of the groundnut shell treatment process, such as varying the concentration of groundnut shell and the possibility of combining groundnut shell treatment with other treatment methods were recommended for future study.

KEYWORDS: Hospital waste water, groundnut shell, biosorption, COD, BOD, physiochemical.

1.0 INTRODUCTION

Hospitals produce a significant amount of wastewater, ranging from 400 to 1200 liters per bed, which contains microorganisms, heavy metals, toxic chemicals, and radioactive elements (Soni, Begum & Kumar, 2009). The untreated discharge of pathological and infectious waste can lead to the spread of communicable diseases, posing a threat to public health and ecological balance (Chitnis *et al*., 2004). Due to the lack of efficient sewage treatment facilities in many countries, including Nigeria, and the absence of national discharge standards for hospital wastewater, the search for cost-effective natural materials for treating hospital wastewater is necessary, especially in low-income communities (Saha, Sarkar, Chakraborty, & Majumder, 2017). A rising amount of attention is being paid to removing heavy metal ions from industrial wastewater as a result of the problem of water pollution. Since they are readily accessible and frequently represent underused resources, natural materials have been recognized as a low-cost adsorbent that may be employed for this purpose (Ahmed, Ahmaruzzaman, & Saha, 2016).

Groundnut shell is a cost-effective and renewable natural material that can be used for treating hospital wastewater and they are readily available as waste products from the food industry. Groundnut, also known as peanut, belongs to the botanical family Fabaceae (Leguminosae), commonly referred to as the legume, bean or pea family (Royal Botanical Gardens 2013).The use of groundnut shells as a means of treating hospital wastewater is an emerging field of research. Groundnut shells have been found to be a promising natural material for the removal of various pollutants from hospital wastewater (Pala, Hameed, & Ahmad, 2014). Groundnut shells are effective adsorbents for treating hospital wastewater because of the presence of various phytochemicals, including tannins and phenolic compounds. These phytochemicals play a vital role in the adsorption properties of groundnut shells and help to enhance their ability to remove pollutants from wastewater (Abdulraheem, *et al*., 2021).

The physical and chemical properties of groundnut shells are important in determining their adsorption capacity for pollutants in hospital wastewater. The physical properties include the surface area, pore size distribution, and bulk density. The surface area of groundnut shells varies depending on the method of preparation and ranges from $0.15m^2/g$ to $1445m^2/g$ (Njoku *et al*., 2019).The pore size distribution is also an important factor as it determines the accessibility of the adsorbate molecules to the adsorption sites on the surface of the adsorbent.

The chemical composition of groundnut shells is also important in determining their adsorption capacity. Groundnut shells contain mainly cellulose, hemicellulose, and ligniwell as small amounts of proteins, fats, and minerals (Njoku *et al*., 2019).The cellulose and hemicellulose components are responsible for the adsorption of organic pollutants, while the lignin component contributes to the adsorption of heavy metals (Sulaymon, Abdullah & Ahmed 2021). The presence of functional groups such as carboxylic, hydroxyl, and amino groups on the surface of groundnut shells also enhances their adsorption capacity for pollutants (Njoku *et al*., 2019).

The adsorption of pollutants onto groundnut shells occurs through several mechanisms, including physical adsorption, chemisorption, and ion exchange. Physical adsorption is the most common mechanism and involves the weak interaction between the adsorbate molecules and the surface of the adsorbent through van der Waals forces, hydrogen bonding, and electrostatic forces (Sulaymon, Abdullah & Ahmed 2021). Chemisorption, on the other hand, involves the formation of chemical bonds between the adsorbate molecules and the functional groups on the surface of the adsorbent. Ion exchange occurs when the adsorbent surface contains charged functional groups that can exchange ions with the adsorbate molecules.

Numerous studies have demonstrated the efficacy of groundnut shells in removing heavy metals, dyes, and other pollutants from hospital wastewater. Groundnut shells have been shown to be effective in removing various pollutants from hospital wastewater, including heavy metals, organic compounds, and pathogens. For example, a study found that groundnut shell-based activated carbon was effective in removing lead, copper, and zinc from hospital wastewater, with removal efficiencies of 99.2%, 98.8%, and 94.2%, respectively (Adesina, Oyetunji, & Ajayi, 2021). Based activated carbon was effective in removing methylene blue, a model organic compound, from hospital wastewater, with a removal efficiency of 99.4% (Sulaymon, Abdullah & Ahmed 2021). Groundnut shells have also been shown to have antimicrobial properties and can remove pathogenic bacteria from hospital wastewater (Njoku *et al*., 2019)

A study on the adsorption of heavy metals from hospital wastewater using activated carbon derived from groundnut shell was carried out where the use of activated carbon derived from groundnut shells was used for the removal of heavy metals from hospital wastewater. The results showed that the activated carbon was effective in removing heavy metals such as lead, cadmium, and zinc from the wastewater. It was however concluded that groundnut shells have great potential as a low-cost alternative to commercial adsorbents for the treatment of hospital wastewater [16].

This study aims to determine the phytochemical properties of groundnut shell, the microbial load in hospital waste water, the physio-chemical parameters of hospital waste water from UPTH Port Harcourt, the effects of grounded groundnut shell on the physiochemical parameters of the hospital water and the absorption efficiency of groundnut shell in removal of heavy metal (Cu) using Langmuir and Freundlich model.

2.0 MATERIALS AND METHOD

2.1 Materials

2.1.1 Collection and Identification of Sample

Groundnut shell was gathered from groundnut vendors at Rumuokoro market. Dr. Chimezie Ekeke of the Department of Biotechnology University of Port Harcourt recognized the groundnut shell. They were taken to Port Harcourt Rivers State's Ignatius Ajuru University of Education's Biological Research Laboratory Department.

2.1.2 Equipment Used

The mass of the adsorbent was precisely measured using an electronic balance (ZSA 120) with a precision of 0.001g. Whatmann (150 mm) filter paper and 250 mL round bottomed flasks with reflux condensers were employed in the Kjeldahl apparatus (Gallenkamp, England). The pH was measured using a pH meter (HACH, SensionTM + mm150, South Africa). For the digestion of wastewater, a hot plate (IKA®RET, China) was employed. An analysis of the metal ion concentration was conducted using a flame atomic absorption spectrometer (Analytikjena, Germany). For drying adsorbents, a convection oven (J.P. SELECTA, Spain) was utilized. Adsorbents were kept in plastic Ziploc bags (USA) until use. Heavy metal was analyzed using atomic absorption spectrophotometer.

2.1.3 Chemicals Used

Cu stock solutions were produced, extracted, and diluted to the proper concentrations. From a standard solution of 1000 mg L^{-1}, copper solution was created (BDH reagents, England). For pH correction, 0.1 mol L^{-1} of HCl and 0.1 mol L^{-1} of NaOH were utilized. The wastewater and adsorbents were acid-digested using HNO_3 and $HClO_4$. All of the trials utilized distilled water. The amount of cellulose, hemicellulose, and lignin was measured using enrichment cellulose (EC), $K^2Cr^2O^7$, H_2SO_4, acetic acid, and sulfuric acid. The following methodology was used to record the amounts of cellulose, hemicellulose, and lignin. The mixture of 40g of groundnut shells and 800ml of 2m KOH was heated at 80C while being stirred for five hours.

2.2 Method

2.2.1 Preparation of Wastewater Samples

To dissolve larger particles in the sample and breakdown organic compounds, acid digestion using 55% nitric acid was performed in order to calculate the total metal content. The wastewater samples were filtered before being combined with 10mL of concentrated nitric acid in a 250mL beaker. The combination was then heated until it was almost dry. Once the material had cooled, 1mL additional concentrated nitric acid was added until the digesting process was complete. This digestion broke down the organic substance. After being washed down with distilled water to remove silicate and other insoluble materials from the beaker, the sample was filtered into a 100 mL volumetric flask. Following that, distilled water was used to raise each sample to the predetermined level.

2.2.2 Phytochemical Test on the Extract

Some phytochemical tests were carried out on the crude extracts to determine the presence the presence of Alkaloid, Anthraquinone, Flavonoid, Glycoside, Saponin, Steroid, Tanin, Terpenoids, Phytate, Oxalate. Phytochemicals were determined qualitatively using the methods described. The phytochemicals were also determined quantitatively using standard methods

2.2.3 Physicochemical Composition of Untreated and Treated Water

Physicochemical composition (pH, temperature, colour, odour, total suspended solids and total dissolved solids, alkalinity, hardness, chemical oxygen demand, biological oxygen demand, turbidity, conductivity, chloride, nitrate, phosphate, sulphate and heavy metal ions) that are essential to determine the quality of water in the untreated water, filtrate from the commercial activated charcoal (FCAC) and filtrate from the groundnut-based activated charcoal (FGAC) were determined accordingly following standard methods.

2.2.4 Microbial Identification

E. coli: Eosine methylene blue agar was used for this analysis. The medium was prepared according to manufacturer's specification; by weighing and dissolving 36glL, sterilized at 121^0C for 15min, allowed to cool to about 45^0C, poured aseptically into sterile Petri dishes and allowed to solidify. The sample was serial diluted and 0.1mil aliquote of inoculums was inoculated on the medium using the spread plate techniques. The plates were incubated at 37^0C for 24hrs and colonies with greenish metallic sheen were counted to obtain colony forming unit per gram (cfulg) of samples. The colonies were sub-cultured on a freshly prepared nutrient agar and subjected to biochemical tests for identification.

Staphylococcus Sp*:* Mannitol salt agar was used to perform this test. The medium was prepared according to manufacturers' direction by weighing and dissolving 111glL, sterilized by autoclaving at 121^0C allowed to cool to about 45^0C, poured into sterile Petri dish and allowed to solidify. The sample was serial diluted and o.1ml aliquot was aseptically inoculated on the medium using the spread plate technique. The plates were incubated at 37^0C for 24hrs and colonies with yellow colour were counted to obtain colony forming unit per gram (culg) of sample. Colonies were sub-cultured on a freshly prepared nutrient agar medium and subjected to biochemical tests for characterization or identification.

Salmonella & Shigella*: Salmonella Shigella* agar was used to detect the presence of *Salmonella* and *Shigella*. The medium was prepared according to manufacturer's instruction; by weighing and dissolving 63glL, heated to boil, allowed to cool to about 45^0C, poured into sterile Petri dishes and allowed to solidify. The samples were serial diluted and 0.1ml aliquot of inoculums was aseptically inoculated using spread plate technique. The plates were incubated at 37^0C for 24 hrs. there was no evidence of *Salmonella* and *Shigella*

Coliform*:* Maccoukey agar was used for this analysis. The medium was prepared according to manufacturer's standard weighing and dissolving 37glL, sterilized by autoclaving at 121^0C, allowed to cool to about 45^0C, poured into sterile Petri dishes and allowed to solidify. The samples were serial diluted and exactly 0.1ml aliquots of inoculums were aseptically inoculated on the medium using spread plate technique. The plates were incubated at 37^0C for 24 hrs. No visible growth was seen. Streaking was done in three different segments, heating the wire loop at interval. Streaked plates were incubated at 37^0C for 24h. Thereafter, distinct colonies that developed from streaked plates were transferred on afar slant and incubated at 37^0 C for 24 h to obtain stock culture.

2.2.5 Sensitivity Test

Six-millimeter diameter discs were made using cork borer and filled with the desired concentrations (10mg/ml, 20mg/ml and 30mg/ml) of the extract of *Moringa oleifera* seeds. Commercial antibiotic Norfloxacin (10/ml) and Chloramphenicol (30 mg/ml) were used as reference standard to determine the sensitivity of the isolates. Disc was directly placed onto the bacterial culture. The plates were allowed to stand for 5 hours at room temperature for extract to diffuse into the agar and then incubated at 37^oC overnight. The entire test was conducted in duplicate. Antibacterial activities were evaluated by measuring inhibition zone diameters as recommended by National Committee for Clinical Standard (1999).

2.2.6 Heavy Metal Analysis

The heavy metal present in the samples were analyzed using atomic absorption spectrophotometer. Two (2) grams of the respective sample was transferred into a Kjeldahl; 20ml of concentrated nitric acid (HNO_3) was added and the sample pre-digestion by heating gently for 20mins. More acid was thereafter added and digestion continue Digestion was stopped when a clear digest was obtained. The flask was cooled and the content transferred into 50ml volumetric flask and made to the mark with distilled water. The digested samples were analyzed for heavy metals (Pb, Cr, Cu, Ni, Fe and Ca) by Atomic Absorption Spectrophotometer (AAS) of UNICAM 919 model. The equipment absorbed the digested sample and gives the concentration of the metals present in the sample (WHO, 2011).

2.2.7 Data Analysis

Descriptive statistics, such as histograms, percentages, and linear regression, were used in the data analysis. In order to handle them, Microsoft Office Excel 2016 was used. To assess how favorable the results were, Freundlich and Langmuir adsorption isotherms and capacity were also employed. SPSS (version 2016) was used to evaluate the effect of groundnut shell on heavy metals in hospital waste water.

3.0 RESULTS

The result of the qualitative phytochemical analysis of groundnut shell extract is presented in Table 1. The result shows the presence of Alkaloid, Flavonoid, Glycoside, Saponin, Steroid, Terpenoids, Phytate and Oxalate in varying means. Anthraquinone was absent in this study

Table 1: Qualitative Phytochemical Composition of Ground Shell Extract

S/N	Phytochemicals (%)	Qualitative
1	Alkaloid	+++
2	Anthraquinone	-
3	Flavonoid	++
4	Glycoside	++
5	Saponin	+++
6	Steroid	+
7	Tanin	+++
8	Terpenoids	+++
9	Phytate	++
10	Oxalate	+

The result of the quantitative phytochemical composition of groundnut shell extract is presented in Figure 1. The result showed that saponin was found to be the highest occurring phytochemical in groundnut shell.

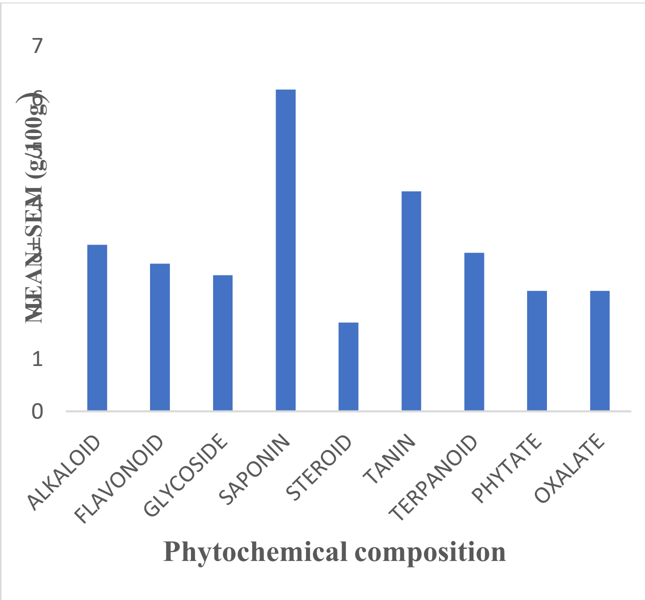

Figure 1: Phytochemical composition of groundnut shell extract

Result of the isolation, identification and characterization of disease-causing microorganisms on hospital waste water treated with groundnut shell ethanol extract is presented in Table 2. Result shows the presence of *E. coli*, *Salmonella* spp, *Staphylococcus* spp, *Enterobacter* spp, *Serratia* Sp in untreated hospital water and absence of *E. coli* in the treated one.

Table 2: Isolate, characterize and identify disease causing microorganisms on hospital waste water treated with groundnut shell ethanol extract.

	E. coli	*Salmonella spp*	*Staphyloco ccus spp*	*Enterobact er spp*	*Serratia Sp.*
Treated hospital Wastewater	Absent	Present	Present	Present	Present
Untreated hospital Wastewater	Present	Present	Present	Present	Present

Result of the microbial count in hospital waste water is found in Figure 2. Result showed that the total heterotrophic count after 24hrs in untreated hospital water is 78.67±1.86 × 106, which significantly reduced to 53.33±0.33 × 10^6 in the treated hospital waste water. The total heterotrophic fungal count after 96hrs in the untreated hospital water was 9.67±0.88 × 103, which significantly reduce to 6.33±0.33 × 10^3 after treatment with ground shell. In feacal coliform after 24hrs, 116.67±6.67 × 10^6 was observed in the untreated hospital waste water and 100.00±0.00 × 10^6 after treatment. In *E. coli* after 24hrs, 12.33±0.33 × 10^4 was observed in untreated waste water and 0.00±0.00 × 10^4 in the treated hospital waste water.

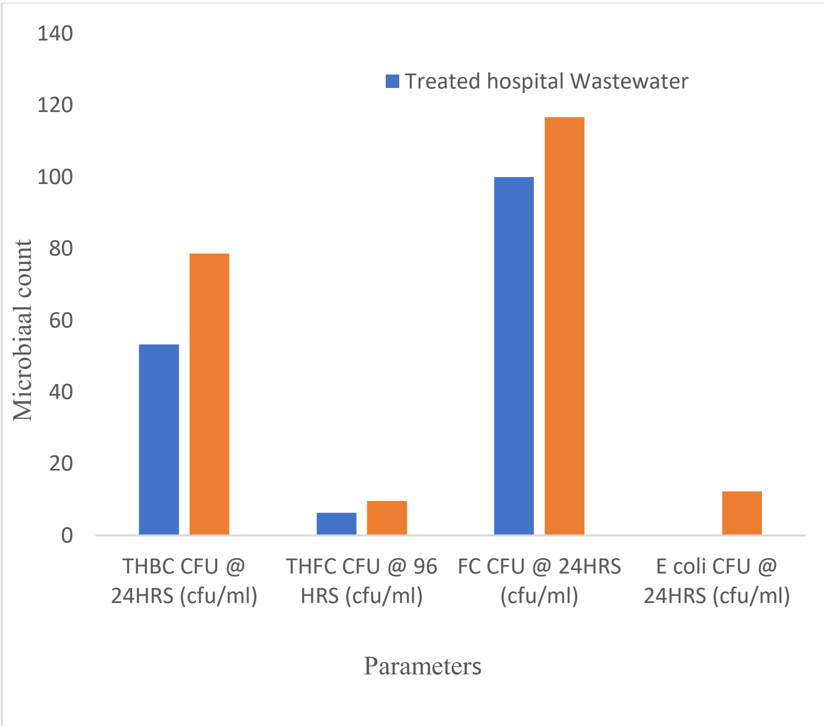

Figure 2: Microbial count of the hospital waste water

The result of the fungal isolate/identification of the microbial load in hospital waste water is presented in Table 4. It shows the presence of some fungi like *Aspergillus flavus, A. fumigates, A. niger, A. parasiticus, fusarium* spp and mucor spp, isolated from the untreated hospital wastewater while in the treated, *Aspergillus parasiticus, fusarium* and mucor spp were isolated. *Aspergillus flavus, A. fumigates* and *A. niger* were quite minute.

Table 3: Fungal Isolate/Identification of the microbial load in hospital waste water

SAMPLE >	*Aspergillus flavus*	*Aspergillus fumigates*	*Aspergillus niger*	*Aspergillus parasiticus*	*Fusarium spp*	*Mucor spp*	*Penicillium Spp*
TREATED	DL	DL	DL	PRESENT	PRESENT	PRESENT	ND
WASTE	PRESENT	PRESENT	PRESENT	PRESENT	PRESENT	PRESENT	ND

Key: ND = Not Detected; <DL= Less Than Detectable Limit

Figure 3 shows result of the physiochemical composition of waste water treated with grinded groundnuts shell extract comparison. The study shows that in untreated, the pH has 6.35±0.02 while the treated has 6.83±0.03, in untreated, Temperature has 27.36±0.01 while the treated has 27.44±0.00, in untreated, electrical conductivity has 2791.15±2.27 while the treated has 2125.00±4.77, in untreated, TDS has 1786.33±1.45 while the treated has 1360.00±3.06, in untreated, TSS has 7.38±0.02 while the treated has 7.43±0.01, in untreated, COD has 2.09±0.05 while the treated has 2.33±0.01, in untreated. Turb has 9.76±0.04 while the treated has 7.36±0.04 while the treated has 7.36±0104, in untreated, salinity has 1553.67±7.71 while the treated has 1220.67±7.26, in untreated, sulphate has 56.89±0.34 while the treated has 43.22±0.03, in untreated Nitrate has 76.51±0.44 while the treated 78.62±0.45 and in untreated, phosphate has 33.56±0.06 while the treated has 21.36±0.21 in this study.

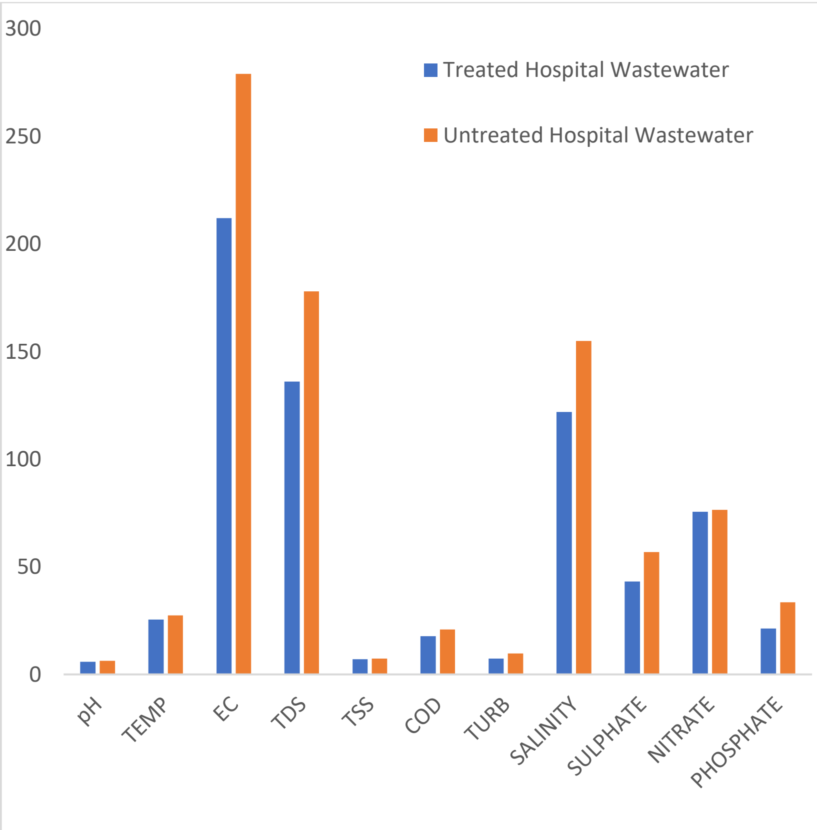

Figure 3: Physio-chemical parameters of hospital waste water

The result of the x-ray fluorescence analysis of groundnut shell on hospital waste water is presented in Figure 4. Result shows a significant difference in the concentration of potassium oxide in both treated and untreated hospital waste water. This was closely followed by concentration difference in calcium oxide. None of the elements either quantitatively or qualitatively, whose atomic number is below sodium in the periodic table was observed. Sodium both in elemental form or in oxide form was observed in treated groundnut shell powder due to the sodium hydroxide used for its treatment while it is absent in untreated and ash groundnut shell powders

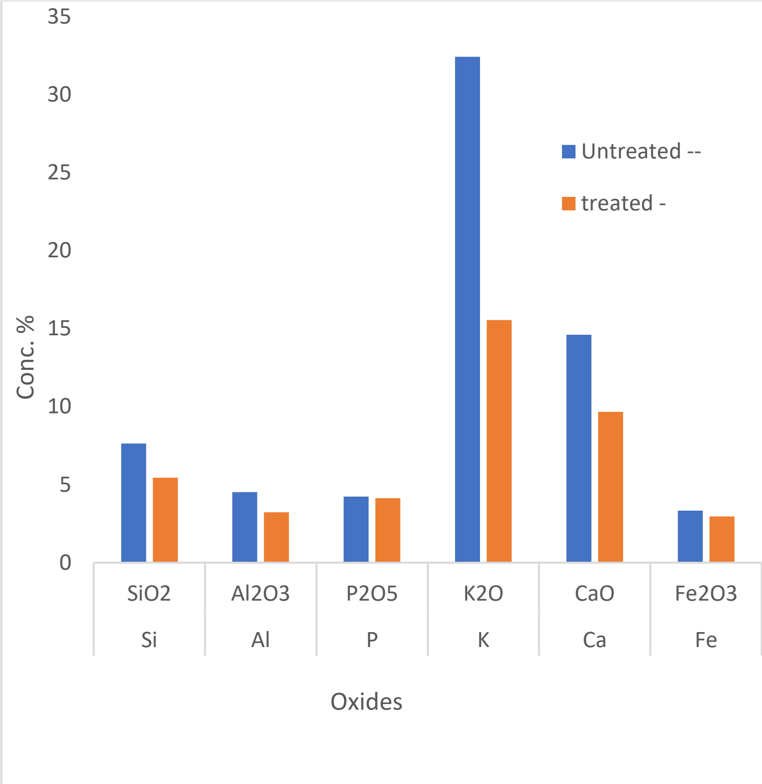

Figure 4: X-ray fluorescence analysis of groundnut shell on hospital waste water

Figure 5 shows a high cellulose (38.6%) content in groundnut shell, followed by lignin (34.1%), hemicellulose (23.5%), pectin (12.5%) and ash (6.2%).

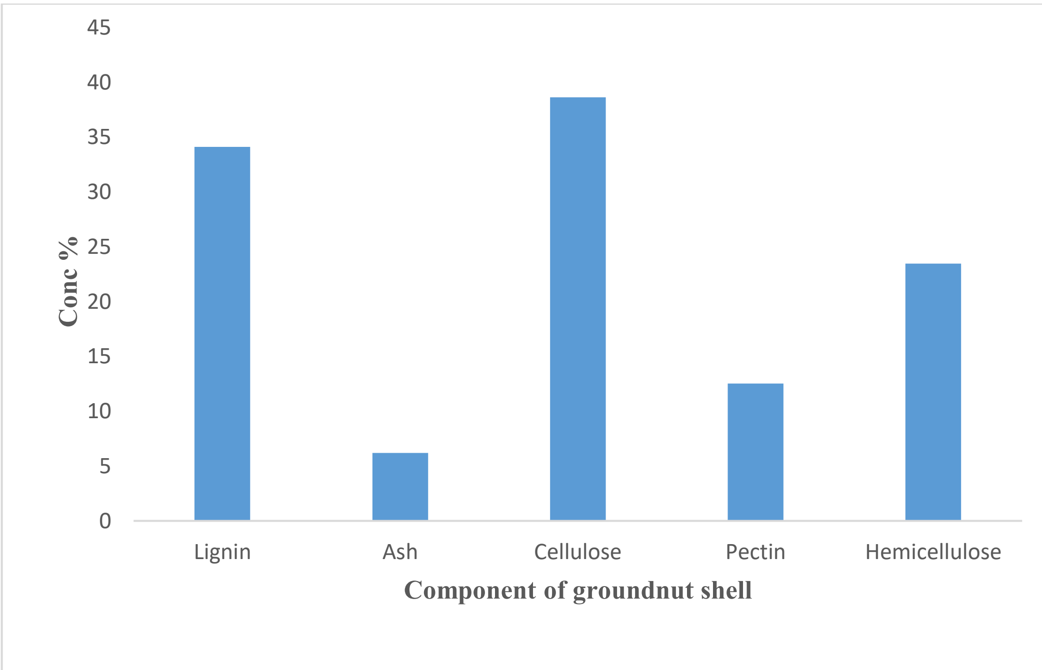

Figure 5: X-ray fluorescence analysis on groundnut shell components

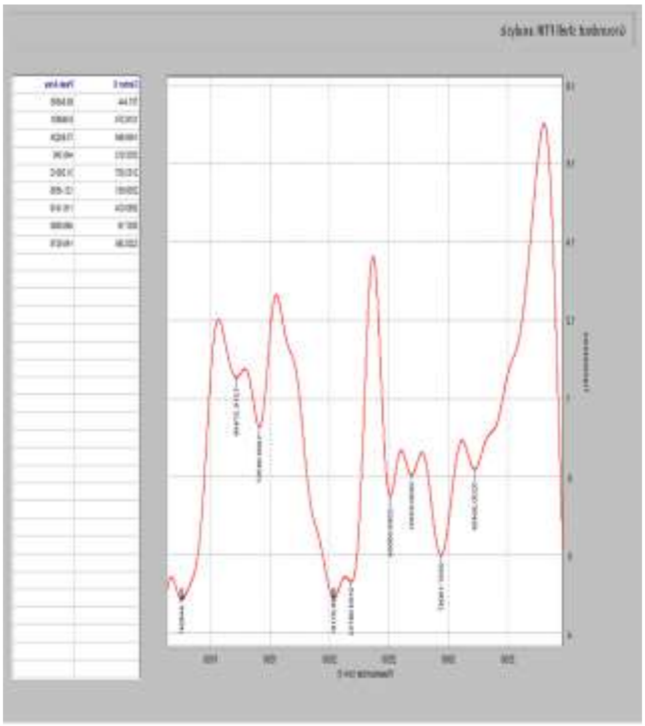

Figure 6: FTIR analysis of groundnut shell on hospital waste water

Figure 7 result of heavy metal composition of hospital waste water treated with grinded groundnuts shell in comparison shows that I untreated Fe has 80.35±0.60 while the treated has 65.20±2.83, in untreated, Mg has 63.68±0.12 while the treated has 47.5±1.93, in untreated, Co has 0.37±0.02 while the treated has 0.23±0.03, in untreated, Cu has 5.17±0.06 while the treated has 2.60±0.05, in untreated, Cd has 0.02±0.00 while the treated has 0.00±0.01 while treated has 0.18±0.00. In both untreated and treated, both Ni and Hg were absent in this study.

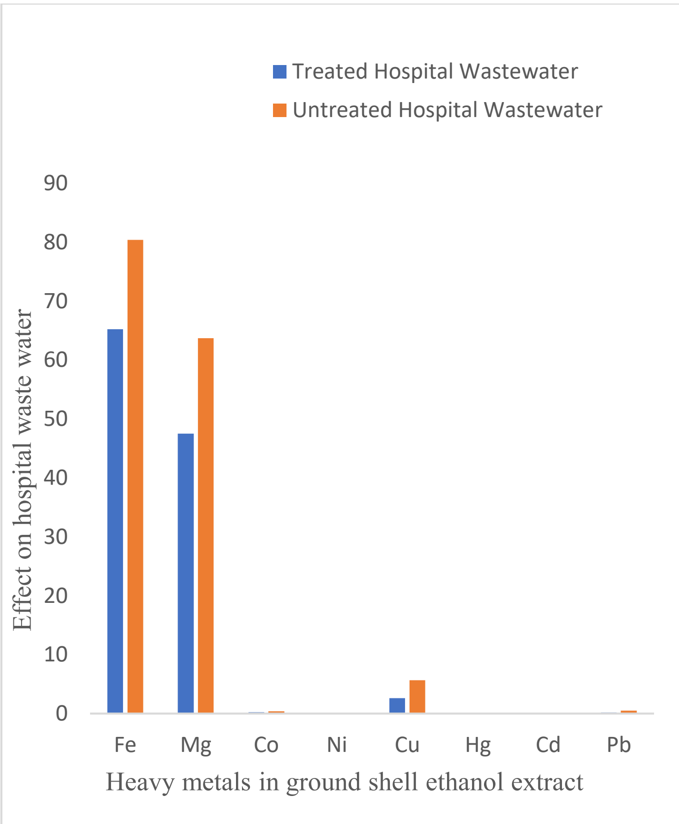

Figure 7: Effect of groundnut shell extract on heavy metal composition of hospital wastewater

Result of the water absorbance of groundnut shell is presented in Figure 8. Result shows the respective percentage water absorption were 6%, 8%, 10%, 16%, 18% and 20% with respect to time. From the plots, it is evident that weight fraction of reinforcement is affected by time. Higher temperatures seem to accelerate the moisture uptake behavior.

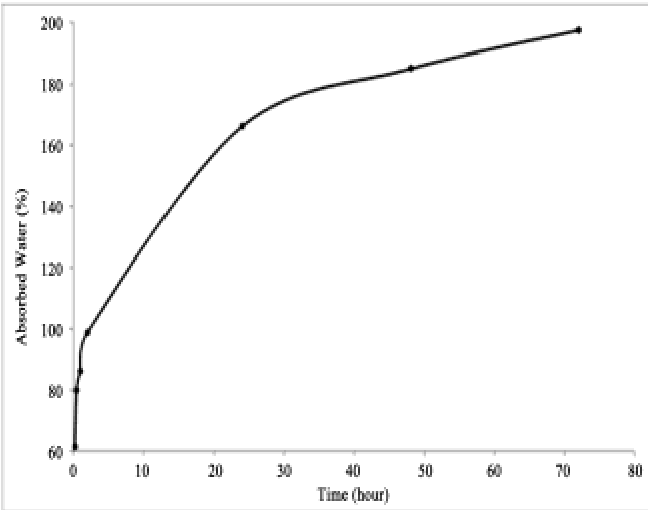

Figure 8: Water absorption of groundnut shell

Experiments were conducted to determine the adsorption isotherm of Cu using from hospital wastewater using groundnut shell. Different dosage of the adsorbent was used; 5, 10, 15, 20 and 25 in 100 ml of the wastewater with pH of 4. Adsorption isotherm which is determined in this study is Langmuir and Freundlich model.

The Langmuir model assumes that the adsorption process follows a specific adsorption isotherm, which describes how the amount of solute adsorbed onto the surface varies with the equilibrium concentration of solute in the solution. The Langmuir isotherm assumes that the adsorption process reaches a maximum limit, or saturation point, where all available adsorption sites on the surface are occupied by solute molecules. The Langmuir isotherm linear model is given in equation (1) as

$$\frac{C_e}{q_e} = \frac{1}{K_L q_{max}} + \frac{C_e}{q_{max}} \qquad (1)$$

Where

q_e (mg/g) = Equilibrium Adsorption capacity

Ce (mg/L) = Equilibrium Adsorbate Concentration

q_{max} (mg/g) = Maximum Adsorption Capacity

K_L (L/mg) = Langmuir isotherm constant

The experimental data were fitted to this Langmuir model and the graph of C_e/q_e against C_e was drawn (Figure 9).

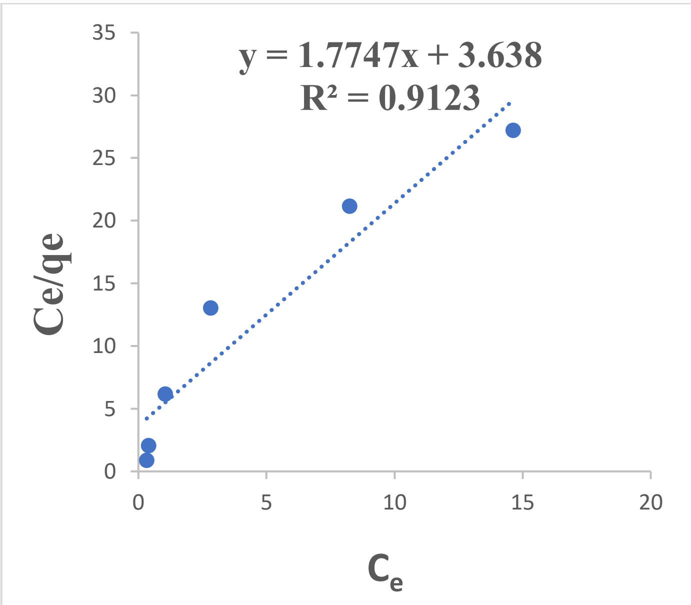

Figure 9: Langmuir isotherm model for adsorption of Cu using groundnut shell

The slope and intercept of the graph is 1.78 and 3.64 respectively. The Longmuir isotherm parameters K_L and q_{max} were obtained from the plot.

Slope = $\frac{1}{q_{max}}$, $q_{max} = \frac{1}{Slope} = 0.57$ mg/g.

Therefore, the maximum adsorption capacity of groundnut shell in removal of copper is 0.56.

Langmuir isotherm constant (K_L) = $\frac{1}{intercept} \times q_{max}$

$K_L = \frac{1}{3.64} \times 0.56 = 0.157 L/g$

The Freundlich model is an empirical isotherm equation used to describe the adsorption of a solute onto a solid surface. It assumes that the adsorption process is non-uniform and multilayered. Equation 2 denotes the Freundlich isotherm model.

$$\text{Log } q_e = \log k + (1/n) \log Ce \quad (2)$$

where q_e is the amount of solute adsorbed per unit weight of adsorbent (in mg/g), Ce is the equilibrium concentration of the solute in the solution (in mg/L), k and n are constants that depend on the adsorbent-solute system. The plot of log (q_e) versus log (Ce) gave a straight line with slope 1/n and intercept log(k) as shown in Figure 9.

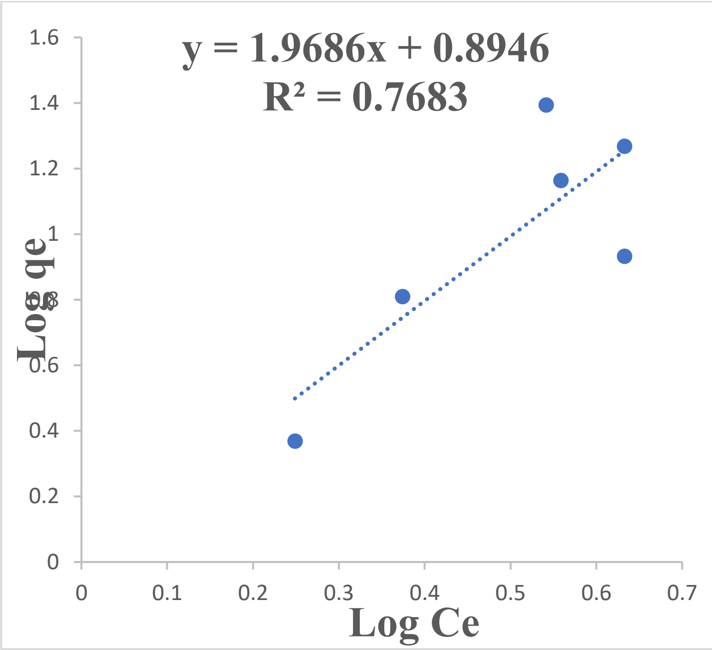

Figure 10: Freundlich isotherm model for adsorption of Cu using groundnut shell

Slope = $\frac{1}{n}$, $n = \frac{1}{1.97} = 0.51$.

Log K = 0.8946; K = Antilog0.8946 = 5.338

Therefore, K = 5.338, which means that the adsorbent has a relatively high adsorption capacity for the adsorbate under the given conditions. This value of K also indicates that the adsorption process is favorable, as higher values of K indicate stronger adsorption. From Figure 10 and through linear regression analysis, the correlation coefficient R^2 (the percent of variation shared between the two variables.) was found to be 0.7263. This value is between 0.7 and 1.0, which shows that the activated groundnut shell is good for adsorption. The outcome however showed that Langmuir isotherm model is a better fit for the experimental data obtained than Freundlich isotherm model as showed from the R^2-value obtained in figure 9 and 10.

4.0 DISCUSSION

4.1 Phytochemical Composition of Groundnut Shell

The findings presented in the study show that the groundnut shell contains a range of phytochemicals, including alkaloids, flavonoids, glycosides, saponins, steroids, tannins, terpenoids, phytate, and oxalate. These compounds have various biological activities, such as antioxidant, anti-inflammatory, and antimicrobial properties, which make groundnut shell a potential source of natural products for medicinal and industrial uses. The study's results are consistent with previous research conducted on the phytochemical composition of groundnut shell. For example, a study reported the presence of alkaloids, flavonoids, glycosides, saponins, steroids, tannins, and terpenoids in groundnut shell (Singh *et al*., 2017). It corresponded with another study that found high amounts of saponins, tannins, and flavonoids in groundnut shell (Asaolu, & Oyeyemi, 2015).

One potential application of the phytochemicals present in groundnut shell is in the removal of heavy metals from contaminated water, particularly hospital wastewater. Heavy metals are a significant source of pollution in wastewater, and their presence can have detrimental effects on human health and the environment. Several studies have shown that phytochemicals present in plant materials have the potential to remove heavy metals from contaminated water. A study reported that saponins and tannins extracted from Chinese medicinal herbs were effective in removing heavy metals from wastewater (Zhang *et al*., 2018) Another similar study found that phytochemicals extracted from *Moringa oleifera* seeds were effective in removing heavy metals from water (Khan, Nazir, Rehman, Shah, & Shah, 2017).

The presence of saponins, tannins, and terpenoids in high amounts in groundnut shell makes it a potential candidate for the removal of heavy metals from wastewater. Saponins are known to form complexes with metal ions, which can be removed from water by adsorption or precipitation. Tannins can also form complexes with heavy metals, leading to their removal from water. Terpenoids have been shown to have chelating properties, which can facilitate the removal of heavy metals from contaminated water (Khan, Nazir, Rehman, Shah, & Shah, 2017).

4.2 Microbial Isolation, Characterization and Identification

The presented microbial load in hospital wastewater shows the presence of four different genera of bacteria, including *Staphylococcus sp, E. coli, Enterobacter sp, Salmonella spp,* and *Serratia sp*. These genera differ in their cell morphology, motility, Gram reaction, spore, catalase, oxidase, Indole, Citrate, MR, gas, slant, butt, and sugar fermentation characteristics. The identification of these genera in hospital wastewater is consistent with other studies that have reported the presence of similar genera in hospital wastewater. A study reported the presence of *Enterobacter*iaceae, including *Enterobacter spp* and *Serratia spp*, in hospital wastewater (Mena, Gerba, & Haas, 2021). Another study reported the presence of *Staphylococcus* aureus and *E. coli* in hospital wastewater (Bhatia, Kaur, Kumar, Goyal, & Sharma, 2020).The presence of these genera in hospital wastewater has significant implications for the study of waterborne pathogens and the potential transmission of infectious diseases. Therefore, proper treatment of hospital wastewater is critical to prevent the spread of infectious diseases. The identification of different genera in hospital wastewater, as shown in the presented results, is consistent with other research and highlights the potential risk of waterborne pathogens in hospital wastewater.

Table 4 shows the presence of different fungi species in treated and waste samples. The identified species include *Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Aspergillus parasiticus, Fusarium spp, Mucor spp, and Penicillium spp*. The samples differ in their fungal species composition, with waste samples showing the presence of all identified species, while treated samples showed no detectable levels of *Aspergillus flavus, Aspergillus fumigatus, and Aspergillus niger*. The presence of these fungi species in waste samples is consistent with other studies that have reported the presence of similar fungi in different waste sources. This corresponded with reported the presence of Aspergillus niger and Penicillium spp in different types of municipal waste Another study reported the presence of *Fusarium spp* and *Mucor spp* in dairy waste (Hamid, Abo-State, & El-Deeb, 2018).

The presence of these fungi species in waste samples has significant implications for the management of waste and potential health hazards. Some of the identified fungi species are known to produce mycotoxins, which can have toxic effects on human and animal health (Bennett, & Klich, 2003). Therefore, proper management and treatment of waste are essential to prevent the spread of fungal contamination. In conclusion, the presence of different fungi species in treated and waste samples, as shown in the presented data, is consistent with other research and highlights the potential risk of fungal contamination in waste. Proper waste management and treatment are critical to prevent the spread of fungal contamination and protect public health.

4.3 Physio-chemical Composition of Hospital Waste Water Treated with Groundnuts shell

The physiochemical parameters of treated and untreated hospital wastewater have been presented in the Figure 3. These parameters include pH, temperature, electrical conductivity, total dissolved solids, total suspended solids, chemical oxygen demand, turbidity, salinity, sulfate, nitrate and phosphate. The pH values of treated and untreated hospital wastewater were found to be 5.83 and 6.35, respectively. These values are slightly acidic and fall within the range reported by previous studies. A study on hospital wastewater in Pakistan reported a pH range of 5.0-7.5 [25]. Similarly, a study on hospital wastewater in India reported a pH range of 5.5-7.5 [26]. These findings correspond with that obtained in this study.

The temperature values of treated and untreated hospital wastewater were found to be 25.44°C and 27.36°C, respectively. These values are within the range of temperatures reported by other studies. For example, a study on hospital wastewater in India reported a temperature range of 22-28°C (Khan *et al*., 2018). Another study on hospital wastewater in Nigeria reported a temperature range of 22 (Kamaludeen, Abdulraheem, & Abdulhameed, 2019). The present study shows that electrical conductivity (EC) and total dissolved solids (TDS) values of treated hospital wastewater were found to be 1.37 dS/m and 684.8 mg/L, respectively, while the EC and TDS values of untreated hospital wastewater were 1.80 dS/m and 894.6 mg/L, respectively. These values are consistent with those reported in previous studies. For instance, a study on hospital wastewater in France reported TDS concentrations ranging from 650 to 1300 mg/L (Sablayrolles, Andrès, & Albasi, 2013). Similarly, a study by Ma *et al*. (2016) on hospital wastewater in China reported TDS concentrations ranging from 500 to 2000 mg/L.

The total suspended solids (TSS) and turbidity (TURB) values of treated hospital wastewater were found to be 148.8 mg/L and 111.9 NTU, respectively, while the TSS and TURB values of untreated hospital wastewater were 368.4 mg/L and 241.4 NTU, respectively. These values are relatively high and are consistent with those reported in previous studies. A study hospital wastewater in Malaysia reported TSS concentrations ranging from 200 to 400 mg/L (Ng, Ahmad, & Wong, 2019). Another study on hospital wastewater in Spain reported turbidity values ranging from 25 to 133 NTU (Díaz-Delgado, González-López, López, & Quiroga, 2017). The chemical oxygen demand (COD) value of treated hospital wastewater was found to be 260.1 mg/L, while the COD value of untreated hospital wastewater was 481.2 mg/L. These values are relatively high and are consistent with those reported in a study on hospital wastewater in South Korea, who reported COD concentrations ranging from 300 to 1500 mg/L (Kim, Kwon, Kim, & Lee, 2015).

The salinity, sulfate, nitrate and phosphate values of both treated and untreated hospital wastewater were within the range reported on hospital wastewater, carried out in China, who reported salinity values ranging from 0.12 to 1.67 g/L, sulfate concentrations ranging from 63.5 to 84.7 mg/L, nitrate concentrations ranging from 11.6 to 26.1 mg/L, and phosphate concentrations ranging from 4.2 to 6.9 mg/L [34]. Overall, the physiochemical parameters of the treated and untreated hospital wastewater in this study are consistent with those reported in previous studies, indicating that the treatment process used in this study was effective in removing some of the pollutants present in hospital wastewater. However, the high values of TSS, TURB, and COD in both treated and untreated hospital wastewater highlight the need for more effective treatment processes to minimize the impact of hospital wastewater on the environment.

4.4 Effect of groundnut shell on physio-chemical composition of hospital waste water

Figure 7 shows the concentration of eight heavy metals in treated and untreated hospital wastewater before and after treatment with groundnut shell. The heavy metals measured were Fe, Mg, Co, Ni, Cu, Hg, Cd, and Pb. Comparing the concentrations of heavy metals in untreated and treated wastewater, it can be seen that the treatment with groundnut shell reduced the levels of all heavy metals. The reduction was more significant for some metals, such as Fe, Mg, and Cu, which showed a reduction of over 10 mg/L. Previous research has also shown the effectiveness of various types of adsorbents, including agricultural waste, in removing heavy metals from wastewater. A study investigated the use of coconut shell and peanut husk for removing heavy metals from industrial wastewater and found that the adsorbents were effective in removing heavy metals (Fadiji, Chigbo, Alabi, Ogunyemi, Awotoye, & Osibajo, 2020).

Another study by Ibrahim *et al*. (2018) investigated the use of banana peels as an adsorbent for the removal of heavy metals from wastewater. The study found that the banana peel adsorbent was effective in reducing the concentrations of heavy metals, with a removal efficiency of up to 98%.

Comparing the effectiveness of groundnut shell with other agricultural waste materials, a study investigated the use of sugarcane bagasse and coconut shell as adsorbents for the removal of heavy metals from acid mine drainage. The study found that both materials were effective in removing heavy metals, with a reduction in heavy metal concentrations of up to 99% (Taffarel, & Rubio, 2010).

The effectiveness of adsorbents in removing heavy metals from wastewater depends on several factors, including the type of adsorbent, the properties of the adsorbent, the characteristics of the wastewater, and the operating conditions during treatment. Groundnut shells are a type of agricultural waste that has been found to be effective in removing heavy metals from wastewater due to their high surface area, porosity, and abundance.

4.5 Isotherm Model

Langmuir and Freundlich are the two most commonly used isotherm models. The Langmuir isotherm is a concept of the adsorption leading to a monolayer without interaction among the adsorbate molecules. The adsorption takes place at specific sites within the adsorbent. Result from the study showed that the R^2 value, which is the indicative of the actual deviation between the experimental points for Langmuir isotherm, was found to be 0.91. The values of Qm and Km were determined for the adsorbent from the intercept and slopes of the linear plots. The values were 0.51 mg/g and 0.157 L/g, respectively. The correlation coefficient of 0.91 shows that groundnut is good for adsorption of copper. This finding is in agreement with that of

Freundlich isotherm models indicate that the adsorption process conducted on a heterogeneous surface and adsorption capacity is related to the concentration of the adsorbent [38]. Kf indicates adsorption capacity and $1/n$ measures adsorption intensity. The linear isotherm correlation coefficients (R^2) indicate that the equilibrium data are better described by the Freundlich isotherm with an R^2 value of 0.88 as shown in Figure 10. The Kf and $1/n$ values obtained in this study were 0.37 and 0.92 respectively. The value for $1/n$ for the activated carbon is less than 1, which indicates normal and favorable adsorption and more heterogeneous surfaces with more functional groups that favor the adsorption.

5.0 CONCLUSION

Result from the study shows that groundnut shell contains Alkaloid, Flavonoid, Glycoside, Saponin, Steroid, Terpenoids, Phytate and Oxalate in varying quantities, with saponin as the most abundant of the phytochemicals. *E. coli*, *Salmonella* spp, *Staphylococcus* spp, *Enterobacter* spp and *Serratia* Sp are present in untreated hospital water and *E. coli* is absent in the treated one. There is a significant difference in the total heterotrophic count, total heterotrophic fungal count, faecal count *E. coli* colony faecal count of microbes present in hospital water waste and the treated one. Physico-chemical treatment of hospital waste is an effective parameter to monitor water treatment as PH, temp, electrical conductivity, total dissolved solid, total suspended solid, COD, turbidity, salinity, level of sulphate, nitrate and water level significant decreased. There is a significant difference between the treated and untreated hospital water in terms of heavy metal content. This shows that groundnut shell is an effective tool in hospital waste water treatment. The experimental data obtained from the study were best fitted with Langmuir isotherm model with an R^{2-}value of 0.91, which indicates that the adsorption process was conducted on a homogeneous surface and that the adsorption sites are independent of each other.

6.0 RECOMMENDATIONS

Based on the study of investigating the physico-chemical properties of groundnut shell and its effects on hospital waste water, there are several areas that could be recommended for further study:

1. The effectiveness of groundnut shell as a treatment option for other types of waste water, such as agricultural or industrial waste water.
2. The long-term effects of using groundnut shell for waste water treatment, including the sustainability of the treatment and any potential impacts on the environment.
3. The optimization of the groundnut shell treatment process, such as varying the concentration of groundnut shell or the length of time it is in contact with the waste water.

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