Irish International Journal of Engineering and Applied Sciences
Irish J. Eng. A. Sci.
Volume: 9; Issue: 02,
March-April, 2025
ISSN: 2965–3325
Impact Factor: 4.84
Advance Scholars Publication
Published by International Institute of Advance Scholars Development
https://aspjournals.org/Journals/index.php/iijeas

PERFORMANCE EVALUATION OF RECYCLED PLANT-BASED ACTIVATED CARBON FOR CASSAVA WASTEWATER TREATMENT: CASE STUDY OF COCONUT AND PALM KERNEL SHELLS

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Keywords: *Cassava Wastewater, Toxins, Removal Efficiency, Activated Carbon, Treatment*

Abstract: *Environmental pollution from poor cassava wastewater management have been a serious concern for local industries across the developing world. As such, different cassava wastewater treatment strategies have been adopted across the world, particularly the developing Nations to curb the proliferation of toxins. This work therefore is to evaluate the toxins removal efficiency of two plant-based activated carbon products for the treatment of the cassava wastewater effluents. The two plant-based treatment media used for comparison were coconut and palm kernel shell activated carbon samples. Parameters analysed were Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chloride, Sulphate (SO_4^{2-}), pH, Total Hardness (TH), Total Bacterial Count, Iron (Fe^{2+}), and Cyanide. Out of the Ten (10) parameters analyzed, Iron concentration was lowered equally by the two media. The palm kernel shell activated carbon treatment achieved 50% efficiency of the treated parameters (Electrical Conductivity, TDS, Chloride, Sulphate, and Cyanide), while the coconut shell activated carbon treatment achieved 40% efficiency of the treated parameters (pH, TH, and Total Bacterial Count). TSS concentrations increased dramatically following treatment with activated carbon derived from coconut and palm kernel shells. The palm kernel shell treatment resulted in a higher TSS than the coconut shell treatment. Despite treatment with plant-based activated carbon samples, the levels of EC, TSS, and cyanide were much higher than the FEPA (surface water and land disposal limitations) and EPA/WHO effluent discharge guidelines.*

1. INTRODUCTION

Activated carbons can be derived from a wide array of carbonaceous materials, including coconut shells, palm kernel shells, nut shells, olive stones, oil-palm stones, agricultural residues, and various others. The production of activated carbon typically consists of two phases: carbonisation of the precursor material in an

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oxygen-free environment and activation of the carbonised material using water and/or CO_2. Volatile substances are emitted during the carbonisation process, and the residual solid carbon structure is typically referred to as char. In the subsequent activation phase, char interacts with activating agents to produce activated carbon (AC) characterised by enhanced pore structure and surface characteristics (Zhang *et al,* 2007).

Cassava wastewater is an industrial leftover found during the processing of cassava into various fermented products such as Garri, Fufu etc. Adewoye et al. (2005), demonstrated in his study that the Physico-Chemical characteristics, including Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), of the cassava wastewater varied from the Federal Environmental Protection Agency (FEPA) (1991), the maximum amount allowable for effluent discharge into water bodies and environment. Not only does it give rise to the aforesaid chemicals in the wastewater, Okunade and Adakalu (2013), they argued that cyanide has been constantly present in cassava wastewater as Cyanogenic Glycosides which hydrolyzes to dangerous form as Hydrocyanic acid (Olayinka, 2013). In addition, the deteriorated cassava peels were said to contain hydrocyanic acid and caused undesirable odor (Okunade and Adakalu, 2013). When waste is not adequately handled, it interferes with the environment, which diminishes the aesthetic value of the particular location used for waste disposal and causes harm to the environment. According to NIS (2007), high concentration of cyanide (>0.01 mg/l) in water is particularly dangerous to human health since cyanide affects the Thyroid and the central nervous system, leading to paralysis. Cassava wastewater contained contaminants that are harmful to natural fish population. High Biochemical Oxygen Demand contained in cassava wastewater, depletes the Dissolved Oxygen (DO) needed for the survival of aquatic life in the receiving water bodies (Adegoke *et al.,* 2020).

Due to the hazardous compounds inherent in cassava wastewater, simple and efficient systems for cassava wastewater treatment have evolved. According to Okoduwa, *et. al.,* (2017), there are so many methods (chemical, physical, and biological) that are accessible for the treatment of effluents, depending on the source, composition and properties of the effluents. Treatment of cassava mill effluents prior to discharge minimises the impacts on the receiving environment and one of such treatment could be achieve using activated carbon (Okoduwa *et al.,* 2017).

The use of plant-based activated carbons for cassava wastewater treatment will not only boost the output of the cassava processing businesses but also contribute to a more sustainable environment. These materials' ability to remove contaminants depends on a variety of criteria, including their physical, chemical, and biological nature. Consequently, the goal of this study is to investigate the effectiveness of two plant-based

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activated carbon products (coconut shells and palm kernel shells) for cassava wastewater treatment.

2. STUDY OBJECTIVES

The aim of this study is to identify a most suitable material needed to detoxify and degrade cassava wastewater using Coconut and Palm kernel shells activated carbon, before discharging to the environment. The objectives are;

(i) To produce activated carbon from coconut shell.
(ii) To produce activated carbon from palm kernel shell.
(iii) To collect and analyze the characteristics of cassava wastewater after treatment with the two methods.
(iv) To compare and determine the effectiveness of these two materials on cassava wastewater treatment.

3.0: MATERIALS AND METHOD

In the lab, the following tools were used to create the plant-based activated carbon. Among the equipment used in the lab were a Vecstar Furnace, Sample Collectors, Desiccators, Sewers, Grinders, Conical Flask Water Bath, Electronic Weighing Balance, and Conical Flask.

The initial phase in the carbonisation process was to wash and sun-dry the coconut and palm kernel shells to remove moisture. Following that, the materials were carbonised for 30 minutes at a time at a temperature of 750°C in the Vecstar Furnace. The samples were allowed to cool before being washed with tap water and then distilled water. The samples were cleaned and then dried in the oven for 30 minutes.

After the carbonisation process, the carbonised samples were crushed into a powder and sieved. Before the sieved carbonised samples were put into the conical flask, they were weighed using an electronic weighing balance. The conical flask was treated with 0.1 mol of hydrogen tetraoxosulphate (iv) acid for impregnation/activation. Following thorough stirring with a stirrer, the mixture was put in a hot water bath that was set at 850°C and kept moving at a rate of 120 revolutions per minute (rpm) for six hours. The impregnation continued at room temperature for a further twenty-four hours. After being impregnated, the samples were filtered using a funnel and filter paper after being rinsed with water. The samples were then dried in an oven set to 110°C for 24 hours (Sait and Derya 2015).

The laboratory study was conducted out at the Chemical Laboratory of Niger Delta University Amassoma Bayelsa State, while the cassava wastewater was collected from a cassava processing facility in Yenagoa. Activated carbon from coconut shells (30g) and palm kernel shells (30g) were weighed individually, mixed with 50ml of cassava wastewater in a conical flask, and agitated for 60 minutes at 40°C and 120 rpm in a hot water bath. This was an example of the batch adsorption method in action. The mixes were filtered and tested independently for the identification of different pollutants after 60 minutes (Olaoye and Owolarafe 2019).

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3.1: Sample collection

As soon as the samples were collected, they were put in iced coolers to be transported to the lab and kept in a refrigerator. According to Simon *et al.* (2023), the water quality criteria that were examined were heavy metals and physico-chemicals, and they were examined using accepted laboratory techniques. The criteria were pH, cyanide, electrical conductivity (EC), dissolved solids (TDS), sulphate (SO_4^{2-}), iron (Fe^{2+}), total suspended solids (TSS), and chloride.

Data were documented after the activated carbon made from coconut and palm kernel shells was added to the raw cassava wastewater for filtration in this study. These results were contrasted with the raw wastewater values and the Nigerian Federal Environmental Protection Agency's (FEPA, 1991) effluent disposal criteria for land and surface water. Furthermore, as shown in Tables 1.0 and 2.0 below, the outcomes were contrasted with the effluent discharge guidelines established by the Environmental Protection Agency (EPA, 2004) and the World Health Organisation (WHO, 2014). The effectiveness of activated carbon derived from coconut and palm kernel shells in eliminating impurities from cassava wastewater was also demonstrated in the tables.

4.0: RESULTS AND DISCUSSION

Table 1.0: Result of Parameter levels (Conductivity, TDS, TSS, Chloride & Sulphate) from Cassava Wastewater and Efficiency of Removal Using Coconut and Palm Kernel Shell Based Activated Carbon

Sample	Raw Untreated Cassava Wastewater Sample	Activated Carbon Shells of Coconut Treated Sample	Activated Carbon Shells of Palm Kernel Treated Sample	LIMITS FOR DISCHARGE INTO SURFACE WATER (FEPA, 1991)	LIMITS FOR LAND APPLICATION (FEPA, 1991)	EPA/WHO EFFLUENT DISCHARGE STANDARDS (2004; 2014)
Conductivity (us/cm)	1212	1198	1165	1000		750.5
TDS(mg/l)	557	272	257	2,000	2,000	1200
TSS (mg/l)	783	1088	1443	30		100
Chloride (mg/l)	437	472	384	600	600	500
Sulphate (mg/l)	12.82	13.66	11.59	500	1000	750

Figure 1.0 below is a chat of the treatment efficiency of the plant-based activated carbon produced from coconut and palm kernel shells. The chat compared the treatment results of parameters such as

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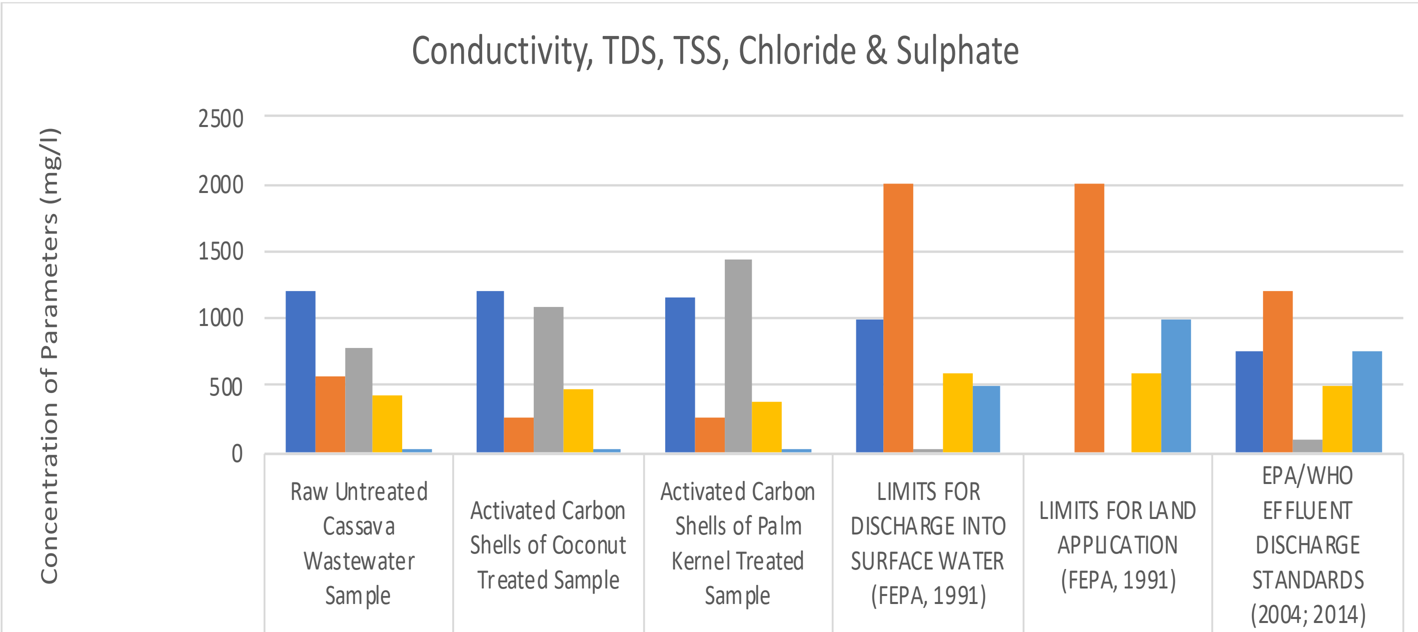
Conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chloride and Sulphate to the EPA/WHO and FEPA effluent disposal standards.



	Raw Untreated Cassava Wastewater Sample	Activated Carbon Shells of Coconut Treated Sample	Activated Carbon Shells of Palm Kernel Treated Sample	LIMITS FOR DISCHARGE INTO SURFACE WATER (FEPA, 1991)	LIMITS FOR LAND APPLICATION (FEPA, 1991)	EPA/WHO EFFLUENT DISCHARGE STANDARDS (2004; 2014)
Conductivity (us/cm)	1212	1198	1165	1000		750.5
TDS(mg/l)	557	272	257	2,000	2,000	1200
TSS (mg/l)	783	1088	1443	30		100
Chloride (mg/l)	437	472	384	600	600	500
Sulphate (mg/l)	12.82	13.66	11.59	500	1000	750

Samples & Standard Values

Figure 1.0: Treatment Efficiency of Coconut and Palm Kernel Shells Activated Carbon for some Parameters (Conductivity, TDS, TSS, Chloride and Sulphate) as Compared to local (FEPA) and global (WHO) Effluent Discharge Standards

Figure 1.0 above depicts the trend of contaminants removed from cassava wastewater as parameters were reduced. Conductivity values decreased from 1212 mg/l in the untreated sample to 1198 mg/l and 1165 mg/l in the coconut and palm kernel treated samples, respectively. However, the treated samples still exceeded FEPA and WHO's mandated effluent discharge limits. The raw untreated cassava wastewater sample's total dissolved solids content (TDS) was decreased from 557mg/l to 272mg/l and 257mg/l for both coconut and palm kernel shell activated carbon treated samples, respectively, which was less than the FEPA and

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WHO discharge limits of 2000mg/l and 1200mg/l. However, TSS, chloride, and sulphate concentrations rose following treatment with activated carbon derived from coconut and palm kernels, but remained within the effluent disposal limits. The coconut activated carbon treated samples had greater levels of chloride and sulphate than the palm kernel shell activated carbon treated samples. This meant that the palm kernel shell activated carbon treated chloride and sulphate more effectively than the coconut shell activated carbon. It was also shown that the TSS concentration increased more in raw samples treated with palm kernel activated carbon than in coconut shell samples, indicating that coconut shell activated carbon was more effective in treating TSS.

Table 2.0 displays the treatment effectiveness of coconut and palm kernel shell activated carbon treatment medium.

Table 2.0: Result of Parameter levels (pH, TH, TSS, & Total Bacterial Count) from Cassava Wastewater and Efficiency of Removal Using Coconut and Palm Kernel Shell Based Activated Carbon

Sample	Raw Untreated Cassava Wastewater Sample	Activated Carbon Shells of Coconut Treated Sample	Activated Carbon Shells of Palm Kernel Treated Sample	LIMITS FOR DISCHARGE INTO SURFACE WATER (FEPA, 1991)	LIMITS FOR LAND APPLICATION (FEPA, 1991)	EPA/WHO EFFLUENT DISCHARGE STANDARDS (2004; 2014)
pH	4.4	4.7	4.5	9	9	9
Total Hardness (mg/l)	10	2.9	15			500
Total bacteria count (cfu/ml)	62	21	56	400		100

Figure 2.0 below is a chat of the treatment efficiency of the plant-based activated carbon produced from coconut and palm kernel shells. The chat compared the treatment results of parameters such as pH, Total Hardness (TH), and Total Bacterial Count to the EPA/WHO and FEPA effluent disposal standards.

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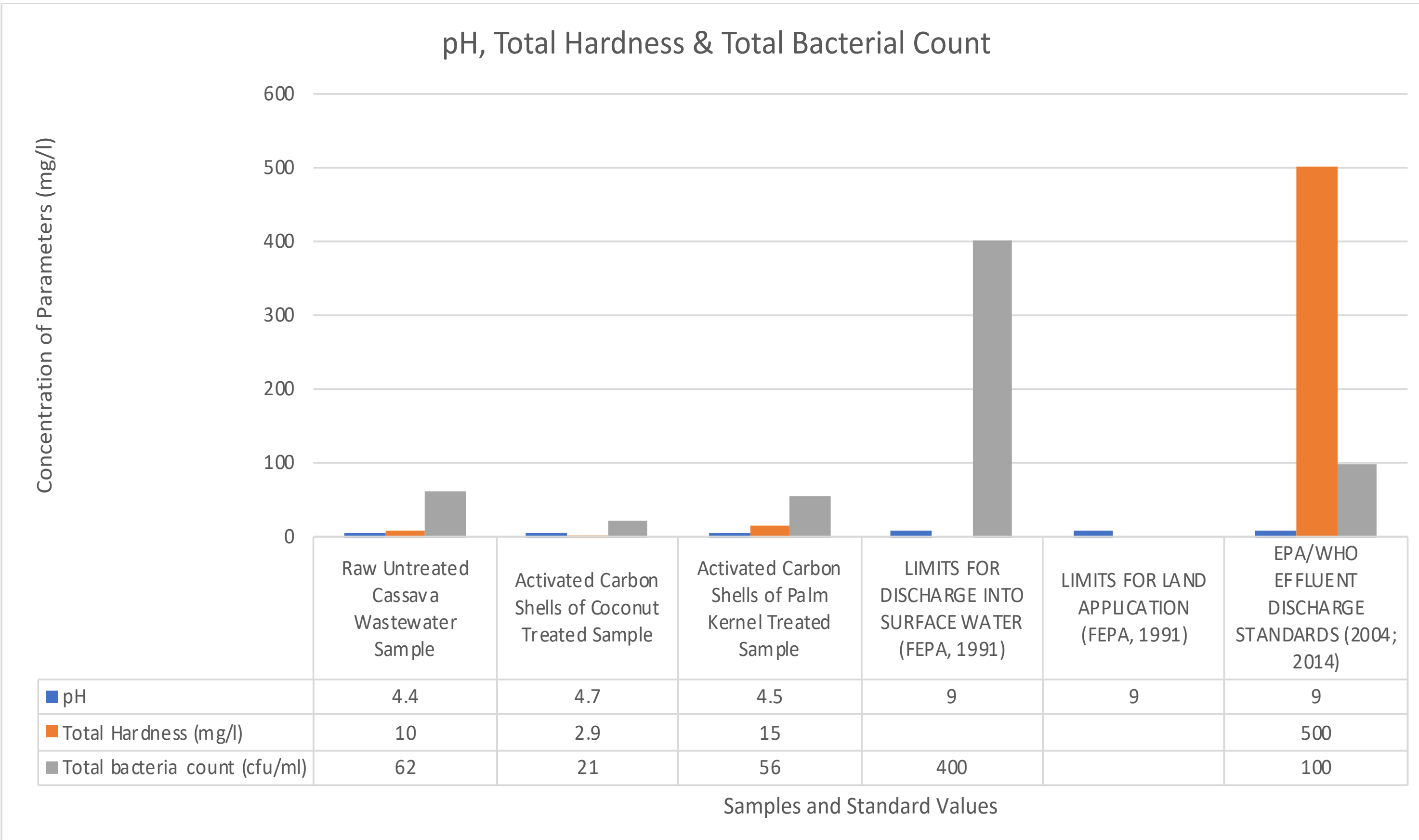

Figure 2.0: Treatment Efficiency of Coconut and Palm Kernel Shell Activated Carbon for pH, TH and Total bacterial count as Compared to local (FEPA) and global (WHO) Effluent Discharge Standards

The pH of the treated samples rose slightly, from 4.4 in the untreated sample to 4.7 and 4.5 in the coconut and palm kernel activated carbon treated samples. However, the range remained within FEPA and WHO's wastewater disposal limits of 9.0. Similarly, treatment with activated carbon samples lowered Total Hardness and Total Bacterial Count and were still under FEPA and WHO wastewater disposal limits.

Table 3.0 displays the treatment effectiveness of coconut and palm kernel shell activated carbon treatment medium.

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Table 3.0: Result of Parameter levels (Iron & Cyanide) from Cassava Wastewater and Efficiency of Removal Using Coconut and Palm Kernel Shell-Based Activated Carbon

Sample	Raw Untreated Cassava Wastewater Sample	Activated Carbon Shells of Coconut Treated Sample	Activated Carbon Shells of Palm Kernel Treated Sample	LIMITS FOR DISCHARGE INTO SURFACE WATER (FEPA, 1991)	LIMITS FOR LAND APPLICATION (FEPA, 1991)	EPA/WHO EFFLUENT DISCHARGE STANDARDS (2004; 2014)
Iron (mg/l)	0.6	0.7	0.7	20		2
Cyanide (mg/l)	0.622	0.572	0.556	0.1		0.1

Figure 3.0 below is a chat of the treatment efficiency of the plant-based activated carbon produced from coconut and palm kernel shells. The chat compared the treatment results of parameters such as Iron, and Cyanide to the EPA/WHO and FEPA effluent disposal standards.

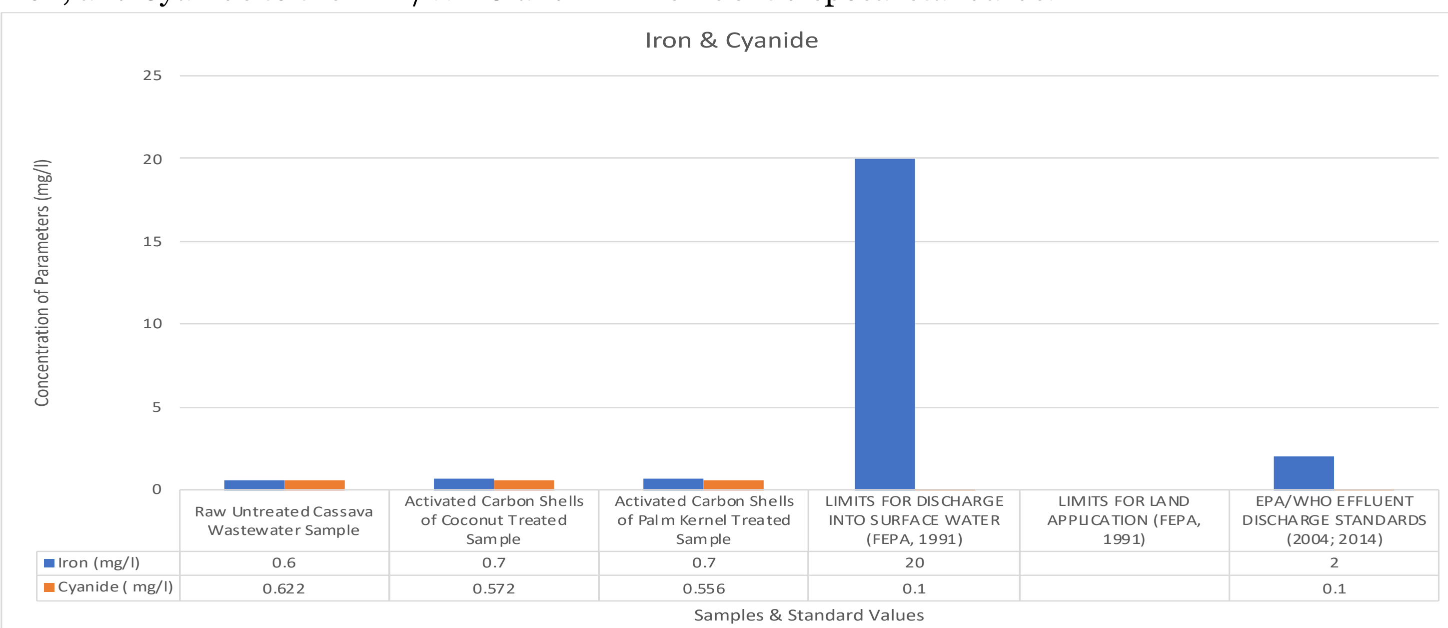

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Figure 3.0: Treatment Efficiency of Coconut and Palm kernel Activated Carbon for some Parameters (Fe and Cyanide) as Compared to local (FEPA) and global (WHO) Effluent Discharge Standards

Similar to TDS, TSS, Chloride and Sulphate, Iron concentration slightly increased from 0.6mg/l of the untreated sample to 0.7mg/l for both of the coconut and palm kernel activated carbon treated media, which were all still within the global effluent discharge limits. The Cyanide concentrations however reduced from 0.622mg/l in the raw untreated cassava wastewater sample to 0.572mg/l in the coconut shell activated carbon treated sample, and 0.556mg/l in the palm kernel shell activated carbon treated sample. It was further observed that the concentration of cyanide in all the samples (raw untreated sample, coconut and palm kernel shell treated samples), were higher than both the local (FEPA) and global (WHO) effluent discharge standards.

Summarily, out of the Ten (10) parameters analyzed with the coconut and palm kernel shells activated carbon. Iron concentration was lowered equally by the coconut shell activated carbon, as well as the palm kernel shell activated carbon. Whereas, 50% efficiency of treated parameters (Electrical Conductivity, TDS, Chloride, Sulphate and Cyanide) was achieved with the palm kernel shell activated carbon, the remaining 40% of parameters (pH, TH, and Total Bacterial Count) treatment efficiency was attributed to the coconut shell activated carbon treatment. The TSS concentration increased remarkably after treatment with both coconut and palm kernel shell activated carbon. The TSS increased more with the palm kernel shell treatment than the coconut shell treated samples. Though treated with the plant-based activated carbon samples, the levels of, EC, TSS, and Cyanide were well above the FEPA (Surface water and land disposal limits) and EPA/WHO effluents discharge standards.

5. CONCLUSION

The pH of wastewater is an important performance indicator that demonstrates the cleanliness and environmental friendliness of the wastewater. In general, coconut shells and palm kernels are excellent absorbents due to their capacity to lower concentrations of physiochemical parameters and heavy metals. The absorption efficiency of absorbents are determined by their loading weight, contact time, mesh size, ambient temperature, and the temperature at which the absorbents were heated before to usage, also known as calcination. The results of this investigation revealed that palm kernel shell activated carbon has the maximum uptake efficiency, whereas coconut shell has the lowest absorption capacity. The absorbents' absorption efficiency rises with increasing calcination temperature, while all other parameters stay constant.

6. ACKNOWLEDGMENT

the author wishes to acknowledge the assistance and contributions of the laboratory staff of

Department of Agricultural Engineering, Niger Delta University (NDU), toward the success of this work.

7. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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