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Effect of Plantain Peel Activated Carbon on the Treatment of Greywater

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ABSTRACT
Due to climate change, population increase, and urbanization, freshwater resources are getting depleted. This means that we need to find sustainable ways to conserve water. Greywater, which makes up as much as 75% of household wastewater, can be reused for non-potable purposes if it is treated correctly. This study examines the efficacy of plantain peels activated carbon (PPAC) in the treatment of greywater by adsorption. Plantain peels, an agricultural byproduct, were carbonized and chemically activated with phosphoric acid (H_3PO_4), potassium hydroxide (KOH), and zinc chloride ($ZnCl_2$) to create PPAC. Batch adsorption tests were used to see how well we could get rid of some contaminants such total dissolved solids (TDS),electrical conductivity (EC), turbidity, and pH. The results showed that the treatment significantly improved the water quality. The pH went from acidic (3.52–4.17) to near-neutral levels (4.79-7.53), the electrical conductivity (EC) went from 5.52–6.15 µS/cm to 4.48–4.97 µS/cm, and the total dissolved solids (TDS) reduced from 20.4–30.3 mg/L to 2.49–3.27 mg/L. An ANOVA comparing the control and PPAC treatment of greywater indicates no significant difference in the treatment means for pH. Furthermore, ANOVA indicated that the Fcalculated value exceeds the Fcritical value, and the P value is less than 0.05 at a 95% confidence level for EC, TDS and salinity, indicating that there was significant difference in treatment means. Even though the salinity increased (from 0.2–0.4 ppt to 0.5–0.9 ppt), it was still within safe levels. The results show that PPAC is a cheap, eco-friendly, and effective adsorbent that can greatly improve the quality of greywater. The report advocates for the implementation of decentralized, sustainable water treatment systems, especially in resource-limited regions, while encouraging waste-to-resource initiatives.

Keywords: Greywater treatment, activated carbon, plantain peel, adsorption, wastewater reuse, sustainable engineering

I. INTRODUCTION

Due to rapid urbanization, population growth, and weather changes, the world's water supply is running out. There is therefore need to find alternative water sources because freshwater resources are rapidly depleting. Reusing greywater, which is wastewater from activities like cooking, washing, and bathing is one option. Greywater, which makes up around 75% of household wastewater, can be safely recycled for uses like toilet flushing and irrigation (Olanrewaju and Ilemobade, 2015). Greywater contains many hazardous materials, such as oils, food scraps, suspended particles, surfactants, and harmful bacteria, despite being cleaner than blackwater (Filali et al., 2022). These contaminants can increase the chemical and biochemical oxygen demand (BOD and COD) if they are released into the environment untreated, which is detrimental to aquatic ecosystems and humans alike (Okereke et al., 2016, Tariq and Mushtaq, 2023). Phosphates, organic waste, and sodium lauryl sulfate are frequently found in greywater.Depending on how the family uses it, what cleaning agent they use, and how they clean, greywater's precise composition varies. Greywater might be simpler to treat because it is less contaminated than sewage. However, to ensure that its reuse is safe, appropriate treatment is required. Despite their widespread use, common techniques such as filtration, disinfection, sedimentation, and coagulation can be expensive to develop and maintain (Nolde et al., 2010). Although advanced techniques like membrane filtration and reverse osmosis are highly effective at pollutant removal, they are also highly costly and energy-intensive (Sharma et al., 2018).

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The conventional wastewater treatment systems are frequently costly, energy-intensive, and unavailable in underdeveloped or rural areas. Cheap, environmentally friendly, and decentralized treatment options have therefore grown in popularity. Since they are effective at eliminating odors, suspended particles, and organic pollutants, activated carbon adsorption has grown in popularity (Foo & Hameed, 2010). However, commercial activated carbon is often made from non-replaceable materials, such as coal, which makes it costly and environmentally harmful. Scientists have been investigating the production of activated carbon from agricultural waste, such as coconut shells, rice husks, and banana peels (Bhatti et al., 2016; Adegoke et al., 2020). A major crop in many tropical countries, plantains (Musa paradisiaca) produce a lot of peel waste that is frequently thrown away, which is bad for the environment. Due to their high cellulose, lignin, and carbon content, plantain peels are an excellent starting point for the production of activated carbon (Ahmad et al., 2012; Akinmoladun et al., 2021).

Through chemical or physical interactions, pollutants adhere to a solid object's surface, which is known as adsorption. According to Bansal and Goyal (2021), activated carbon is one of the best adsorbents due to its high attraction to organic molecules, porous structure, and large surface area (500–1500 m^2/g). It has three steps that make up the adsorption mechanism: the pollutants' diffusion to the external surface, their migration within the pore network, and their binding to the pore walls (Gao et al., 2019).

Activated carbon can be made in a variety of forms, including extruded (EAC), granular (GAC), and powdered (PAC). Every variety serves a distinct function. Given its long lifespan and potential for reuse, GAC is a popular option for fixed-bed filters in water treatment (Mohammed et al., 2021). Carbonization and activation are the two primary processes in the production of activated carbon from biomass. The process of carbonization involves heating organic material to 400°C to 600°C in an inert environment, such as nitrogen, in order to convert it into biochar. The surface area and porosity are increased by both chemical activation (using H_3PO_4, KOH, or $ZnCl_2$) and physical activation (using steam or CO_2) (Tadd et al., 2016).

The potential of plantain peel activated carbon (PPAC) as an economical and environmentally beneficial adsorbent for greywater treatment is investigated in this study. The study looks at the physicochemical changes in greywater following PPAC treatment, paying special attention to important parameters like salinity, turbidity, pH, TDS, and EC. The study advances our understanding of waste-derived adsorbents and aids in the development of environmentally friendly water treatment methods.

II. MATERIALS AND METHODS

The following apparatus was used for the production of activated carbon in the Chemical Engineering laboratory at Niger Delta University. The laboratory equipment utilized comprised an Electronic Compact Scale, Vecstar Furnace, Sample Collectors, Desiccators, Grinders, Conical Flask Water Bath, Electronic Weighing Balance, and conical flasks.

Fresh plantain peels were procured from a local market, washed, air-dried, and subsequently subjected to carbonization in the Vecstar furnace at 750 °C for 30 minutes. The samples were given time to cool, after which they were rinsed with tap water followed by distilled water. The cleaned samples were subsequently dried in the oven for 30 minutes. After the carbonization phase, the carbonized plantain peels were ground into a powder and sieved to achieve a particle size of 150 µm. The sieved carbonized samples were measured with an electronic weighing balance and placed into the conical flask. 0.1 mol of hydrogen tetraoxosulphate (IV) acid was introduced into the conical flask for impregnation/activation. The mixture was carefully stirred with a stirrer and subsequently placed in a hot water bath at 85 °C, with a mixing rate of 120 rpm for a duration of 6 hours. Impregnation persisted at ambient temperature for an additional 24 hours. The samples were filtered using filter paper and a funnel after being impregnated and rinsed with distilled water until the pH was neutral. The samples were subsequently desiccated in an oven at 105 °C for 24 hours to obtain the plantain peel activated carbon (PPAC). Greywater was collected from residential sources (kitchen sinks, showers, and laundry) and preserved in the refrigerator of the Agricultural and Environmental Engineering laboratory at Niger Delta University, Amassoma, Bayelsa State, for subsequent examination. A digital pH meter was employed to measure pH, an electrical conductivity meter to measure EC and TDS, a turbidity meter to evaluate turbidity, and a salinity meter to determine salinity.

The Batch Adsorption technique was utilized for treatment. Thirty grams (30g) of activated carbon derived from plantain peel were measured and subsequently combined with 50 ml of greywater in a conical flask, which was agitated in a hot water bath at 40 °C and 120

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rpm for a duration of 60 minutes. After 60 minutes, the mixture was filtered and examined for post-treatment outcomes (Olaoye and Owolarafe 2019).

III. RESULTS AND DISCUSSION

3.1 Physicochemical Analysis of Greywater

Results of the laboratory analysis of greywater before and after plantain peels activated carbon treatment are shown in Table 1. The results indicated that the treatment markedly enhanced the water quality. The pH transitioned from acidic (3.52–4.17) to near-neutral levels (4.79–7.53), the electrical conductivity (EC) decreased from 5.52–6.15 µS/cm to 4.48–4.97 µS/cm, the total dissolved solids (TDS) decreased from 20.4–30.3 mg/L to 2.49–3.27 mg/L and the salinity increased slightly from 0.2 – 0.4 ppt to 0.5 – 0.9 ppt.

Table 1. Physiochemical parameter of grey water before and after treatment

SAMPLE	CONDITION	PH	EC (µS/cm)	TDS (mg/l)	SALINITY (ppt)
I	Before	4.17	6.14	30.3	0.4
	After	5.72	4.48	2.49	0.5
II	Before	3.53	6.15	20.4	0.2
	After	4.79	4.97	3.27	0.8
III	Before	3.52	5.52	21.7	0.4
	After	7.53	4.77	3.25	0.9

Table 2. Anova summary between the control and PPAC treatment on greywater

Parameter	Control mean	Treatment mean	Control variance	Treatment variance	F cal	F crit	P value	*Treatment Remark
pH	3.74	6.01	0.14	1.94	7.45	7.71	0.052	NS
EC (µS/cm)	5.93	4.74	0.13	0.06	22.50	7.71	0.009	S
TDS (mg/l)	24.13	3.00	28.94	0.20	45.96	7.71	0.002	S
Salinity (ppt)	0.73	0.33	0.04	0.13	8.47	7.71	0.04	S

*Treatment Remark: S = Significant; NS = Not significant

3.2 Discussion

pH Adjustment: The initial pH of all samples was acidic, ranging from 3.52 to 4.17, this is likely due to the presence of organic acids from detergents and food waste. After treatment, pH increased significantly, with Sample III reaching neutrality (7.53). This shift indicates the reduction of acidic components, possibly through ion exchange or surface functional groups on PPAC (Aremu et al., 2021). However, Anova between the control and the PPAC treatment on the greywater show that there was no significant difference with the inequality between their treatment means (Table 2).

Electrical Conductivity and TDS: EC and TDS values decreased, indicating effective removal of dissolved ions and particulate matter. The high surface area and porosity of PPAC facilitated the adsorption of inorganic salts and organic colloids (Ekong et al., 2022). Also, Anova showed that the F cal is greater than F crit and the P value is less than 0.05 at 95 % confidence level for both EC and TDS (Table 2). It can the therefore be concluded that the inequality between the treatment means was significant

Salinity: An increase in salinity was observed post-treatment. Table 2 showed that the observed increase was significant as F cal is greater than F crit and the P value is less than 0.05 at 95 % confidence level. This may be attributed to the release of bound salts during the activation process or ion exchange reactions. However, all values remained below the WHO limit of 1.0 ppt, suggesting no immediate health risk.

The overall improvement in water quality aligns with findings from similar studies using agricultural waste-derived activated carbon (Ofoefule et al., 2020; Ndifelie et al., 2021). The effectiveness of PPAC can be attributed to its well-developed microporous structure and surface functional groups that enhance pollutant binding.

IV. CONCLUSION

This study demonstrates that plantain peel activated carbon (PPAC) is an effective, low-cost, and sustainable adsorbent for greywater treatment. The treatment significantly improved key water quality parameters, including pH, EC, TDS, and turbidity, bringing them closer to WHO and EPA standards. While an increase in salinity was observed, it did not exceed safe limits.

The use of PPAC not only provides a viable solution for greywater purification but also addresses the issue of agricultural waste management. This dual benefit supports circular economy principles and promotes environmental sustainability.

V. RECOMMENDATIONS

Optimize Activation Process: Further research should explore different activation agents and conditions to minimize salinity increase.

Scale-Up Studies: Pilot-scale trials are recommended to assess the performance of PPAC in real-world decentralized systems.

Community Adoption: Government and non-governmental organizations should promote PPAC-based treatment systems in rural and peri-urban areas.

Regulatory Framework: Policies should be developed to encourage safe greywater reuse and standardize treatment protocols.

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