Coagulative Behaviour of Banana Peel (*Musa Spp*) in Greywater Turbidity Reduction

Roland Songotu Kabange[1], Peter Dinko[1], Musah Saeed Zango[2] Michael Affordofe[3]

[1]*Department of Civil Engineering, Faculty of Engineering and Technology, Kumasi Technical University, P. O. Box 854, Kumasi, Ghana.*

[1*]*Department of Environmental Health and Sanitation, Accra School of Hygiene, Korle Bu, P. O. Box GP 753, Accra Ghana.*

[2]*Geological Engineering Department, University for Development Studies, SoE, P. O. Box TL 350, Tamale, Ghana.*

[3]*Department of Environmental Health and Sanitation, Accra School of Hygiene, Korle Bu, P. O. Box GP 753, Accra, Ghana.*

ABSTRACT

There has been a global rise in greywater generation and water scarcity over the past decade due to population growth and rapid urbanization. Greywater treatment and reuse are, therefore, inevitable to augment the dwindling water resources. Peels of Musa spp (banana peels) are scientifically recognized as natural and eco-friendly coagulant but are a public health threat and waste in urban centers today. Besides, Ghana currently has scanty meaningful data on the use of peels of Musa spp application to treat greywater. This research, therefore, investigates the potential of using peels of Musa spp for greywater treatment. The study prepared a natural coagulant by grinding Musa spp and dissolving it in distilled water, and the solution was filtered to extract the active ingredient. Further, a coagulation jar test was conducted on the collected greywater samples. Greywater turbidity was reduced by 88% to 11.7 NTU from an initial 98 NTU with the introduction of optimum coagulant dosage of 70 ml. Significant greywater turbidity reduction suggested the presence of high levels of suspended solids. The research recommends scaling-up the use of peels of Musa spp as a natural coagulant for greywater treatment.

Keywords: *Banana peels, greywater turbidity, greywater treatment, coagulant, Ghana.*

1.0 INTRODUCTION

Greywater is wastewater generated from the household but excludes toilet wastewater (blackwater) (Rodda et al., 2011; Ilemobade et al., 2013). Climate change contributes to pollution and dwindling water resources for consumptive purposes (Patra et al., 2023). There is, therefore, an increasing gap between available water supply and demand. Population explosion and urbanization, however, result in large volumes of greywater generation in households, which end up in the open drains and water bodies without treatment (Elhegazy & Eid, 2020). Ghaitidak and Yadav (2013) found that about 65% of household wastewater flow was greywater.

Treated greywater has a high potential for reuse since it is less pathogenic and can be treated at minimal cost to augment the already scarce water resources (Ghaitidak and Yadav, 2013). Resources conserved in greywater treatment and reuse are energy, water, and money (Mandal et. al., 2011). Greywater treatment and reuse also minimize water pollution through untreated greywater disposal and over-dependence on available water resources (Oteng-Peprah et al., 2018). The extent of water pollution is dictated by acceptable water characteristics established by international and national standards (Cantera-Cantera et al., 2020). Detritus-based wastewater treatment using peels of *Musa spp*, cassava and yam, and moringa leaves as natural coagulants is an ecologically friendly technique compared to synthetic coagulants which produce by-products with detrimental effects on the environment (Rayer et al., 2024).

The use of synthetic coagulants such as Aluminum Sulfate (Alum), Ferric Chloride, Polyaluminum Chloride (PAC), Polyacrylamide (PAM), Polydadmac (PolyDiallyldimethylammonium Chloride), Polyamine, Polyelectrolytes, Ferrous Sulfate, Calcium Hydroxide (Lime) and Sodium Aluminate for water and wastewater treatment is a common global practice for centuries, partly due to the availability, ready prepared nature, and tested properties. Natural organic matter's aromatic fractions usually react with chlorine in the water treatment process to produce a variety of disinfection by-products, including trihalomethanes. These disinfection by-products are carcinogenic and not environmentally friendly, so sustainable alternatives are recommended. These coagulants are, therefore, inappropriate for greywater treatment due to the adverse health implications on humans and large quantities of toxic sludge generation (Mokhtar et al., 2019). Coagulation and flocculation are chemical treatment processes commonly used for greywater treatment. They involve adding chemicals to greywater to destabilize the suspended particles and allow them to clump together (flocculate) (Rakesh et al., 2020). These processes remove dissolved and suspended solids, oils, greases, detergents, and other organic compounds from greywater (Mohd Asharuddin, 2020; Mohd Asharuddin et al., 2021). The flocs are then removed from the greywater by sedimentation or filtration. Coagulants neutralize the particles' charges and cause them to aggregate (Shaikh & Ahammed, 2023). Common flocculants used in greywater treatment include polymers, such as Polyacrylamides and Polyethyleneimines (Ishak et al., 2020). Peels of *Musa spp*, yam, cassava, and moringa leaves contain tannins, which can break zeta potentials of suspended, and dissolved solids in water, resulting in flocs formation (Mohd Asharuddin, 2020). Globally, freshwater quantities keep diminishing globally, primarily due to anthropogenic activities (Mishra, 2023). Little is known about data on cost-effective and eco-friendly coagulants used for greywater treatment, and the application of natural coagulant in greywater treatment. Besides, the available scanty data on natural coagulant application in Ghana are often scattered in the literature. Greywater treatment systems generally support Sustainable Development Goals six (6), which seeks to guarantee accessibility and sustainable management of water and sanitation for all (Siwila and Kapesa, 2022). To complement the water scarcity challenge, reduce greywater turbidity, and improve available data on natural coagulants for greywater treatment in Ghana, this research employed peels of *Musa spp* as a natural coagulant to determine the generated greywater turbidity from selected households in Jamestown, Accra.

This research therefore sought to use waste to treat waste in a densely populated Jamestown community where high volumes of waste are generated without proper disposal technologies, thereby, evaluating the effectiveness of peels of *Musa spp* in greywater turbidity reduction in Jamestown households in Accra, Ghana.

To achieve this aim, the study's specific objective is to investigate greywater turbidity before and after a coagulant application using natural coagulant prepared from peels of *Musa spp*.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used for this research were Ethanol (70%) purchased from TLB Laboratory Equipment shop and peels of *Musa spp* gathered from Jamestown and Accra markets. Also, acquired were Laboratory blender, analytical balance, 25 ml pipette, sterile whirl Pak, turbidimeter, knife, 100 ml measuring cylinders, and Imhoff cone.

2.2 Sampling and Laboratory Procedure

Greywater from three (3) households were sampled purposively out of fifty-four (54) households used for the study since the greywater was found to have similar turbidity levels as well as parameters that are associated with turbidity. The sampling was done with emphasis on households with a high number of inhabitants and varying activities that produce greywater such as laundry, cooking, and carwash. sampling sites were selected based on size and complexity of the household. For example, households that generate high volumes of greywater from varying processes were selected over households generating smaller quantities from single source.

100 ml of each greywater sample was taken into a sterile whirl Pak with the aid of a metallic laboratory sampler. The sample was kept in an ice chest at 4 °C under ice packs and then transported to the laboratory within one (1) hour. The greywater sample turbidity was measured and recorded. The procedure was repeated for the three (3) samples and the one with the highest turbidity was selected for further analysis with the prepared natural coagulant.

100ml of sampled greywater was pipetted into a 500ml volumetric cylinder and the turbidity recorded with an electronic turbidimeter. The sample was then transferred into an Imhoff cone and allowed undisturbed for 30 minutes to 1 hour. The new turbidity was recorded after all settleable solids are removed by gravitational sedimentation.

2.2.1: Map of Study Site

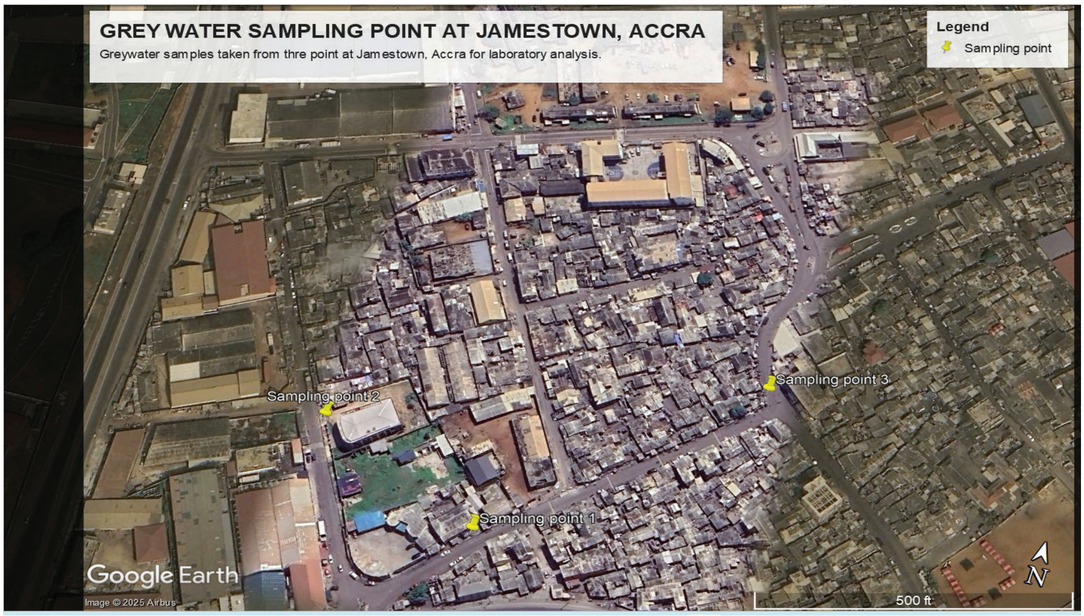


Figure 1: Map of Study Site and Sampling Points for the Study.

Three (3) sampling points were considered subject to expert judgement and the varying greywater discharged.

2.3 Natural Coagulant Preparation

Peels of *Musa spp* were cut into sizes greater than or equal to 5 cm. The peels were washed with 70% ethanol to remove microbial colonies and other contaminants. Samples were dried in an oven at a temperature of 80°C for 30 minutes to reduce moisture content up to 80%. The dried samples were grounded to particle sizes greater than or equal to 0.06 micrometers in diameter. 60 g of the grounded sample was measured and dissolved in 100 ml of distilled water.

The solution was filtered to extract the active ingredients of *Musa spp* (Tannins) (Shukla et al., 2020;organic waste materials, like coconut shell, orange peels, and banana peels were used to produce activated carbon. Chemical activation was carried out using phosphoric acid (H3PO4 Priyatharishini, Mokhtar and Kristanti, 2019;Vilardi, Di Palma and Verdone, 2018; and Banga, Varshney and Kumar, 2015).

2.4 Jar Test

Six (6) different measuring cylinders of 1.2 liters each were mounted, cleaned with distilled water, and allowed to dry. The measuring cylinders were labelled 1, 2, 3, 4, 5 and 6 and 1.0 liter of raw greywater was measured and put in each measuring cylinder. Prepared coagulants of volumes 10 ml, 20 ml, 30 ml, 40 ml, 50 ml, and 60 ml were pipetted into measuring cylinders 1, 2, 3, 4, 5 and 6 respectively. The solution was stirred mechanically at 80 rpm with a stirring rod and the resultant solution was allowed to settle undisturbed for 30 to 60 minutes (Priyatharishini et al., 2019). The settled greywater samples turbidities were measured using a turbidimeter. The study plots a graph of raw greywater turbidity, greywater turbidity after plain sedimentation, and greywater turbidity after natural coagulant application against the volume of coagulant used.

2.5 Data Analysis

Statistical analyses were performed using R software (R version 3.4.3) to represent the dose of coagulant produced from peels of *Musa spp* as ordinate and its effectiveness on the abscissa. A table of dose and corresponding turbidity was also represented with the same statistical package.

3.0 RESULTS

3.1 Effect of plain sedimentation of turbidity of greywater

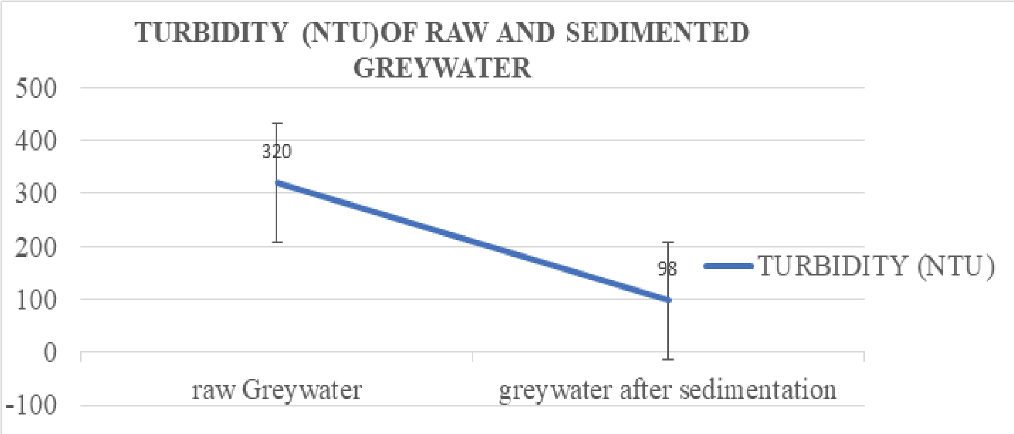
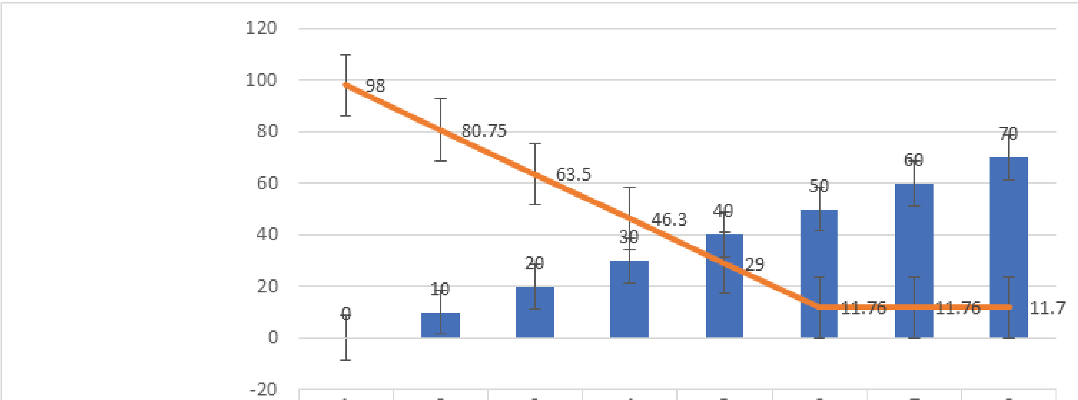


Figure 2: Turbidity of raw greywater plotted against turbidity greywater after sedimentation.

The graph (figure 2) shows the turbidity level of greywater sampled from the field plotted against the turbidity of greywater after sedimentation.

3.2. Performance of coagulant produced from peels of *Musa spp* on greywater



	1	2	3	4	5	6	7	8
DOSE OF COAGULANT	0	10	20	30	40	50	60	70
TURBIDITY (NTU)	98	80.75	63.5	46.3	29	11.76	11.76	11.7

Figure 2: Greywater turbidity under various quantities of coagulant addition

The graph (Figure 3) shows the performance of natural coagulant prepared from peels of *Musa spp* on turbidity removal of greywater. The bars in the graphs shows the dosage of natural coagulant added in the jar test whereas the line indicates the turbidity levels after coagulant addition.

3.3 Impact of Musa spp peel coagulant on other physico-chemical parameters of greywater

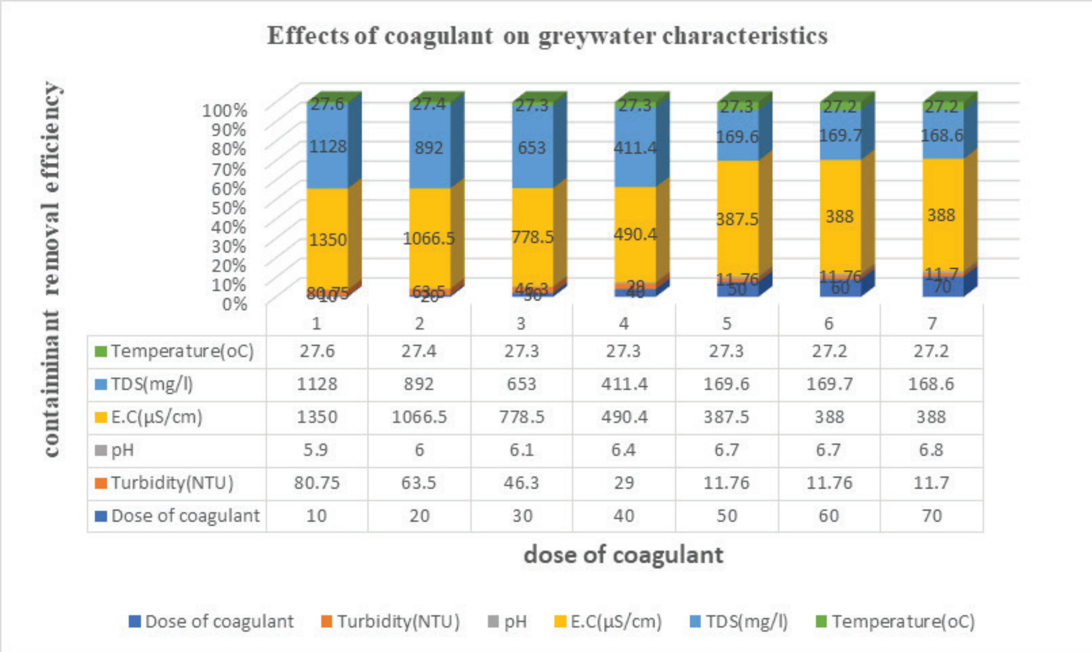


Figure 3: Effects of different dose of coagulant on greywater characteristics

The graph (Figure 3) shows the effect of the natural coagulant addition of other physico-chemical greywater parameters such as temperature, total dissolved solids, electrical conductivity, and $_{p}$H.

4.0 DISCUSSION

This study investigated the effectiveness of coagulant prepared from peels of *Musa spp* to reduce turbidity in greywater in Jamestown, Accra. Numerous studies point out that *Musa spp*, cassava, yam peels, and moringa leaves contain tannins and lignin which break the zeta potentials within dissolved, suspended, and colloidal particles in water to cause flocculation and enhance efficient removal of contaminants (Melesse et al., 2018**.** Figure 1 depicts the efficacy of *Musa spp* peels as a natural coagulant for greywater treatment while Figure 2 shows the impact of different dose of coagulant on temperature, potential of hydrogen, total dissolved solids and turbidity.

The study found that greywater turbidity was initially reduced from 320 NTU to 98 NTU by gravitational sedimentation. Thereafter, turbidity further reduced from 98 NTU to 80.75 NTU (17.4%) with 10 ml coagulant addition, from 98 NTU to 63.5 NTU (35.7%) by the addition of 20 ml coagulant, from 98 NTU to 46.3 NTU (52.7%) with 30 ml coagulant, from 98 NTU to 29 NTU (70.4%) with 40 ml coagulant, from 98 NTU to 11.76 (87.9%) with 50 ml coagulant, from 98 NTU to 11.76 (88%) with 60 ml, and from 98 NTU to 11.70 NTU (88.2%) with 70 ml coagulant. Beyond the 70 ml coagulant addition, any additional coagulant did not significantly reduce the greywater turbidity. A similar study found that *Musa spp* peels were very effective in wastewater turbidity removal at 88% efficiency under optimal conditions (Mokhtar et al., 2019).

Earlier, the study investigated the *Musa spp* peels' effectiveness in turbidity reduction in wastewater by dissolving 10 ml, 20 ml, 30 ml, 40 ml, 50 ml, 60 ml, and 70 ml in one (1) liter of greywater each in a jar test and discovered that optimum coagulant dosage for treatment is similar to this research finding (Priyatharishini et al., 2019).

However, other studies found that the coagulative behaviour of *Musa spp* peel decreases when the alkalinity of wastewater increases within the range of pH 8 to pH 12 (Jahin et al., 2024). The investigation, therefore, points out that *Musa spp* peel can perform very well in acidic conditions. The mean pH of greywater used for this study is 6.8, which agrees with most greywater studies due to the nutrients and food contained in most greywater samples. This explains why *Musa spp* peels used as a coagulant perform well in greywater turbidity reduction.

The optimum coagulant dosage for efficient greywater treatment was 70 milliliters coagulant per liter of greywater, compared to an optimum dosage of 90 ml per liter of greywater found in an earlier study (Priyatharishini et al., 2019). Greywater turbidity reduction from 320 NTU to 98 NTU (Figure 1) suggested the presence of high levels of settleable solids. There was greywater turbidity reduction because of the decrease in dissolved and suspended solids in the greywater.

These settleable solids are attributed to the turbulent flow of greywater through drains resulting in the rigorous mixing of greywater with solids. Furthermore, greywater turbidity was reduced from 98 NTU to 11.6 NTU by adding a coagulant prepared with *Musa spp* peels (representing 80% treatment efficiency). This finding meant that *Musa spp,* used as a natural coagulant in wastewater treatment is beneficial due to its organic nature and the absence of disinfection by-product formation compared to chloride and hypo chloride use. Additionally, *Musa spp* extract concentration determines the efficiency and efficacy of the coagulant. The ability of microorganisms to absorb onto surfaces of solids, settleable removals, dissolved, colloidal, suspended, and other solids result in disease-causing organisms (pathogens) removal. Therefore, *Musa. spp* usage as a coagulant directly removes pathogens by causing solids, which serve as a medium of microorganism absorption to form flocs and eventually settle. The peels of *Musa spp* generation rate as waste in Jamestown is high due to the densely populated nature of the town. It implies that enough waste can be generated daily and used as a natural coagulant for wastewater treatment.

5.0 CONCLUSION AND RECOMMENDATIONS

The study in Jamestown households determined *Musa spp* peels' effectiveness in reducing greywater turbidity. The findings indicate the existence of pollution in Jamestown's generated greywater with a mean turbidity of 320 NTU. The greywater consisted of settleable and colloidal solids, which provided a conducive environment for microbial growth with the adverse public implications. Gravitational sedimentation exclusively reduced turbidity from 320 NTU to 98 NTU (representing a reduction of 69.4%), suggesting that settleable solids largely accounted for the greywater turbidity. Peels of *Musa spp* reduced greywater turbidity from 98 NTU to 11.76 (representing an 88% reduction). The optimum coagulant dosage for efficient greywater treatment was 70 milliliters per liter. Any additional coagulant did not produce significant greywater turbidity reduction. Significant greywater turbidity reduction suggests the presence of high levels of suspended solids.

Though other sodium ion concentration levels might yield different turbidity removal results, *Musa spp* peel effectiveness (as a natural coagulant) recorded a p^H of 6.9. Therefore, *Musa spp* peels can be an effective natural coagulant for greywater treatment and other wastewater of similar characteristics. In a densely populated Jamestown community where high volumes of *Musa spp* peels are generated daily as waste, the adoption of this simple technology to reduce greywater turbidity and improve greywater recyclability is economically and socially feasible. The benefits of *Musa spp* use as a natural coagulant in wastewater treatment are its organic nature and the absence of disinfection by-product formation.

The microorganisms' ability to absorb onto surfaces of solids, settleable removals, dissolved, colloidal, suspended, and other solids result in disease-causing organisms (pathogens) removal. The study suggests that an eco-friendly and cost-effective greywater treatment system using *Musa spp* peels as a coagulant could be piloted and rolled out in Jamestown and other towns with similar greywater characteristics. It is recommended that local and national dialogue on wastewater treatment is tailored towards the use of substances considered generally as waste as coagulant to achieve liquids and solids waste treatment simultaneously.

Author Contribution

This research piece was conducted by Peter Dinko as part of the requirement for the award of a master's degree in water and environmental engineering at the Kumasi Technical University. The research was principally supervised by Professor Roland Songotu Kabange and co-supervised by Ing. Dr. Musah Saeed Zango. Mr. Michael Affordofe provided technical guidance and proof-reading during the conduct and write up of the research.

Funding

The research did not receive any external funding. The entire study was sponsored by the corresponding author.

Acknowledgement

The author acknowledges the support of Dr. Dennis Nii Kpakpo Adotey, Head of Environmental Chemistry Laboratory, Ghana Atomic Energy Commission, Margaret Armah and Abraham Anyagre who supported during sampling and transport of logistics to the study site and laboratory.

Conflict of Interest

The author declares that the study was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

REFERENCES

Akhtar, N., Syakir Ishak, M. I., Bhawani, S. A., & Umar, K. (2021). Various natural and anthropogenic factors responsible for water quality degradation: A review. *Water*, *13*(19), 2660.

Banga, S., Varshney, P. K., & Kumar, N. (2015). Purification of *Jatropha curcas* based biodiesel by dry washing, using banana peel and mushroom powder as natural adsorbents. *Biofuels*, *6*(5–6), 261–267. https://doi.org/10.1080/17597269.2015.1092101

Camara, M., Liying, W., Arouna, S., Diawara, A., Ze, Y., & Yu, L. I. (2024). *Digital Mapping of the General Population and Housing Census Based on the Geographical Information System*.

Cantera-Cantera, L. A., Calvillo-Tellez, A. and Lozano-Hernandez, Y. (2020). Turbidity, dissolved oxygen, and pH measurement system for greywater treatment process by electrocoagulation. *Journal of Technological Development* 4 (14), 20 - 27.

Elhegazy, H., & Eid, M. M. (2020). A state-of-the-art-review on grey water management: A survey from 2000 to 2020s. *Water Science and Technology*, *82*(12), 2786–2797.

Ghaitidak, D. M. and Yadav, K. D. (2013). Characteristics and treatment of greywater - a review. *Environmental Science and Pollution Research* 20, 2795 - 2809

Ilemobade, A. A., Olanrewaju, O. O. & Griffioen, M. L. (2013). Greywater reuse for toilet flushing at a university academic and residential building. *Water* SA 39 (3)

Ishak, S. A., Murshed, M. F., Md Akil, H., Ismail, N., Md Rasib, S. Z., & Al-Gheethi, A. A. S. (2020). The application of modified natural polymers in toxicant dye compounds wastewater: A review. *Water*, *12*(7), 2032.

Jahin, H. S., Khedr, A. I., & Ghannam, H. E. (2024). Banana peels as a green bioadsorbent for removing metals ions from wastewater. *Discover Water*, *4*(1), 36.

Mandal, D., Labhasetwar, P., Dhone, S., Dubey, A. S., Shinde, G. & Wate, S. (2011). Water conservation due to greywater treatment and reuse in urban settings with specific context to developing countries. *Resources, Conservation and Recycling* 55 (3), 356 - 361.

Melesse, A., Steingass, H., Schollenberger, M., & Rodehutscord, M. (2018). Component composition, *in vitro* gas and methane production profiles of fruit by-products and leaves of root crops. *The Journal of Agricultural Science*, *156*(7), 949–958. https://doi.org/10.1017/S0021859618000928

Mishra, R. K. (2023). Fresh Water availability and Its Global challenge. *British Journal of Multidisciplinary and Advanced Studies*, *4*(3), 1–78. https://doi.org/10.37745/bjmas.2022.0208

Mohd Asharuddin, S. (2020). *Coagulation and flocculation process using cassava peel starch modified with lemongrass extract for pollutants removal in raw water*. Universiti Tun Hussein Onn Malaysia.

Mohd Asharuddin, S., Othman, N., Altowayti, W. A. H., Abu Bakar, N., & Hassan, A. (2021). Recent advancement in starch modification and its application as water treatment agent. *Environmental Technology & Innovation*, *23*, 101637. https://doi.org/10.1016/j.eti.2021.101637.

Mokhtar, N. M., Priyatharishini, M. & Kristanti, R. A. (2019). Study on the effectiveness of banana peels coagulant in turbidity reduction of synthetic wastewater. *International Journal of Engineering Technology and Sciences* 6 (1). https://doi.org/10.15282/ijets.v6i1.2109.

Oteng-Peprah, M., Acheampong, M. A. & DeVies, N. K. (2018). Greywater characteristics, treatment systems, reuse strategies and user perception - a review. *Water, Air, and Soil Pollution* 229 (255).

Patra, S., Shilky, Kumar, A., & Saikia, P. (2023). Impact of land use systems and climate change on water resources: Indian perspectives. In *Advances in Water Resource Planning and Sustainability* (pp. 97–110). Springer.

Priyatharishini, M., Mokhtar, N. M., & Kristanti, R. A. (2019). Study on the Effectiveness of Banana Peel Coagulant in Turbidity Reduction of Synthetic Wastewater. *International Journal of Engineering Technology and Sciences*.

Rahman, M. M. (2024). Waste biomass derived chitosan-natural clay based bionanocomposites fabrication and their potential application on wastewater purification by continuous adsorption: A critical review. *South African Journal of Chemical Engineering*.

Rakesh, S., Ramesh, P. T., Murugaragavan, R., Avudainayagam, S., & Karthikeyan, S. (2020). Characterization and treatment of grey water: A review. *IJCS*, *8*(1), 34–40.

Rayer, E. J., Muhamad, M. S., Apandi, N. M., Sunar, N. M., & Ali, R. (2024). Combined Effects of Banana Peels and Pith as Dual Natural Plant-Based Coagulants for

Turbidity Removal. *Journal of Advanced Research in Applied Mechanics*, *116*(1), 75–87.

Rodda, N., Carden, K., Armitage, N. and Plessis, H. M. (2011). Development of guidelines for sustainable irrigation use of greywater for gardens and small-scale agriculture in South Africa. *Water* SA 37 (5)

Shaikh, I. N., & Ahammed, M. M. (2023). Use of coagulation for on-site greywater reuse. In *Resource Recovery in Municipal Waste Waters* (pp. 291–317). Elsevier.

Shukla, S. K., Al Mushaiqri, N. R. S., Al Subhi, H. M., Yoo, K., & Al Sadeq, H. (2020). Low-cost activated carbon production from organic waste and its utilization for wastewater treatment. *Applied Water Science*, *10*(2), 62. https://doi.org/10.1007/s13201-020-1145-z

Siwila, S. and Kapesa, E. (2022). Treatment of domestic greywater using fly ash as an adsorbent incorporated in a slow sand filtration system. *Water Practice and Technology* 17 (5), 961. https://doi.10.2166/wpt.2022.047

Vilardi, G., Di Palma, L., & Verdone, N. (2018). Heavy metals adsorption by banana peels micro-powder: Equilibrium modeling by non-linear models. *Chinese Journal of Chemical Engineering*, *26*(3), 455–464. https://doi.org/10.1016/j.cjche.2017.06.026