Comparative Study of the Effectiveness of Banana and Lemon Peels Powder as Natural Coagulants for Domestic Wastewater Treatment

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ORIGINAL RESEARCH

Abstract- The effect of chemical coagulants on the properties of effluent of treated wastewater necessitated the investigation of the use of natural-based coagulants as possible alternatives. Natural coagulants used were used with the aim of investigating their effectiveness in treating domestic wastewater compared to alum. One (1) litre of domestic wastewater was treated with fifteen (15) different total dosages of 0.8 g, 2.4 g and 4.0 g of banana peel, lemon peel and mixture of banana and lemon peels powder and one (1) dosage of 0.25 g of alum. The parameters tested were pH, turbidity, total dissolved solids (TDS), hardness and colour. The raw wastewater had values of pH, TDS, turbidity, colour and total hardness as 4.7, 901 mg/l, 899mg/l, 8440 pt-co and 1245 mg/l respectively. The best percentage removals were 86.2%, 73.7% and 76.4% for turbidity, TDS and colour at the optimum dosage of 2.4 g/l lemon peels powder. Lemon peel of 2.4g/l also led to improvement of pH from 4.7 to 6.5 (27.7% increase). Maximum hardness reduction was 24.9% with mixture of 0.6 g lemon and 0.2 g banana peels powder. Generally, lemon peels powder showed the potential to perform better as natural coagulant in wastewater treatment and in combination with banana peels. It gave better results than alum except in colour reduction which was 85.6% using alum. It is therefore recommended that lemon peel should be used for domestic wastewater treatment.

Keywords- Banana peel, Lemon peel, Natural Coagulant, Wastewater treatment

1 Introduction

In many countries of the world people suffer lack of access to safe drinking water. WHO (2022) reports that over 2 billion people live in water-stressed countries and it is expected to get worse because of climate change and population growth. Water is a precious and essential commodity for life and living and its availability in the required quantity and quality at the right time and place is not always guaranteed. The most effective strategy against water scarcity is by treating and recycling wastewater in order to increase water supply (Maquet, 2020; Mahendra and Sultana, 2020). A study carried out by Laminou et al (2015) showed the total amount of domestic wastewater generated in parts of Maradi City, Niger Republic, was about 44.95m^3 per day for 1393 individuals. Mesdaghinia et al (2015) also estimated the per capita domestic sewage generated as 186.06 ± 7.85 litres per day. This shows that appreciable quantity of wastewater is generated every day from use of water and the wastewater can become nuisance in the environment if not properly managed. Recycling protects the environment by reducing the risk of pollution from wastewater discharge (Maquet, 2020). There is need to treat wastewater for recycling and reuse for domestic and non-domestic purposes; this is essential for sustainability (Angelakis et al., 2012). The treatment and reuse of wastewater would increase the quantity of water available for use. Treatment of wastewater is required to make it fit to be returned into the water resources cycle (Priyatharishini et al, 2019).

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One of the first processes in wastewater treatment is coagulation which has been practiced since earliest times with the main objective of removal of colloidal impurities hence also removing turbidity from water and wastewater (Mauriya and Daverey, 2017; Ayyappan et al, 2019). Turbidity has been described as one of the main problems in water treatment process because the chemical based inorganic coagulants used may leave residues that can affect human health (Dollah et al, 2019). Chemicals have been employed to achieve coagulation. These include metal salts of iron and aluminum which are widely applied in wastewater treatment as primary treatments for the removal of particulate and organic matter effectively (Alwi et al. 2013; Choy et al, 2014; Tetteh and Rathilal, 2019). The chemicals applied in water treatment as coagulants have achieved various levels of success but there are side effects to the effluent and the sludge. The presence of aluminum sulphate and ferric chloride in the water may provoke some neurological and pathological diseases (Rajendran et al., 2015).

Application of appropriate wastewater treatment technologies, which are effective, low cost and simple to operate, is a key component aimed at increasing the coverage of wastewater treatment. Natural coagulants such as plant extracts from seeds, leaves, roots, barks, and fruits can be used in the water purification system as coagulants (Seghosime et al, 2017; Subashree et al, 2017; Maurya and Daverey, 2018; Priyatharishini et al, 2019; Zaidi, 2019; Mahendra and Sultana, 2020). They are renewable resources and available even in rural areas. However, lack of adequate knowledge on the exact nature and mechanism of how these substances work toward removing impurities in water make them less likely to compete with conventional treatments. There is need to assess the viability and effectiveness of these natural plant extracts for use in wastewater treatment.

Research carried out by Anhwange et al (2009) to analyse the mineral content of banana peels indicated the mineral concentrations as potassium (78.10), calcium (19.20), sodium (24.30), iron (0.61), manganese (76.20), bromine (0.04), rubidium (0.21), strontium (0.03), zirconium (0.02) and niobium (0.02) in mg/g. Also, Janati et al (2012) analysed lemon peels and found that they have the following mineral contents, sodium (755.5), potassium (8600), calcium (8452.5), copper (4.94), iron (147.65), magnesium (1429.50), zinc (13.94) and phosphorus (6656) in mg/100g. This study investigates the effectiveness of lemon and banana peels as coagulants in domestic wastewater treatment. The main objective is to evaluate turbidity removal efficiency in domestic wastewater with the use of lemon and banana peels or their combination and how they compare with the use of alum as coagulants.

2 Materials and Methods

2.1 Materials

Lemon (Citrus Limon) peel, Banana (Musa Acuminata species) peel and Alum (Aluminum Sulphate) were used as coagulants and domestic wastewater (kitchen). Equipment used in the laboratory include: Six-Paddle Rotor Jar Test Flocculator, field spectrophotometer, Portable pH/EC/TDC/Temp Meter and HACH DR/890 Colorimeter.

2.1.1 Preparation of Natural Coagulant from Lemon and Banana Peel

Lemon and Banana peels were removed from the fruits and thoroughly washed with clean water to remove dirts (Plates 1 and 2). Clean lemon and banana peels were oven dried for 48 hours at 60 °C to ensure the water content are fully absorbed (Plates 3 and 4) before pounding in mortar with pestle to turn them into powder and sieving through sieve of 0.6 mm aperture (Plates 5 and 6).

Plate 1: Fresh Banana Peels

Plate 2: Fresh Lemon Peels

Plate 3: Dry Banana Peels

Plate 4: Dry Lemon Peels

Plate 5: Ground Banana Peel

Plate 6: Ground Lemon Peel

2.1.2 Preparation of Chemical Coagulant

Alum being the only chemical coagulant used in the study was prepared by pounding. Plates 7 and 8 show the alum in its whole state and ground alum respectively.

Plate 7: Alum

Plate 8: Ground Alum

2.1.3 Collection of Wastewater

Domestic wastewater was collected from kitchen wastewater, kept cool and transported to the laboratory at Abubakar Tafawa Balewa University, Bauchi for analysis.

2.2 Laboratory Analysis

2.2.1 Coagulation Jar Test

In the laboratory, the domestic wastewater samples were allowed to settle again for 30 minutes and decanted before testing. Coagulation test experiments were performed by jar floc test method with a Six-Paddle Rotor Jar Test Flocculator. Seventeen (17) beakers were each filled with 1 liter of wastewater. The desired quantities of coagulant in different proportions were then added for the coagulation test, the quantities by weight are as shown in Table 1.

Table 1. Coagulant Dosage Per Sample

	Coagulants Dosage		
Sample	**Lemon Peels (g)**	**Banana Peels (g)**	**Alum (g)**
0	0	0	0
1	0	0	0.25
2	0.4	0.4	0
3	1.2	1.2	0
4	2.0	2.0	0
5	0.2	0.6	0
6	0.6	1.8	0
7	0.8	3.2	0
8	0.6	0.2	0
9	1.8	0.6	0
10	3.2	0.8	0
11	0.8	0	0
12	2.4	0	0
13	4.0	0	0
14	0	0.8	0
15	0	2.4	0
16	0	4.0	0

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The suspension in each beaker was stirred at 100 rpm for rapid mixing after which there was slow mixing for 10 minutes. Thereafter each mixture was left for one hour to allow settling and the sample was filtered with muslin cloth as reported by (Alwi *et al.*, 2013: Qasim, 2018).

2.2.2 Physico-Chemical Analysis

Physico-chemical parameters of raw and treated domestic wastewater were analyzed according to methods as shown in Table 2. These followed the standards presented in American Public Health Association (APHA) (2012).

Table 2. Physico-chemical Parameters and Methods of Analysis

S/№	Parameter	Method Used
1	Turbidity	Absorptometric method
2	Total dissolved Solids	Portable pH/EC/TDC/Temp Meter
3	Temperature	Portable pH/EC/TDC/Temp Meter
4	Colour	APHA Platinum-Cobalt Standard Method
5	Total hardness	Complexometric method
6	pH	Portable pH/EC/TDC/Temp Meter

Absorptometric method: A Colorimeter was used for the measurement. The stored program number for turbidity was entered. The sample cell was filled with 10 ml of deionised water (the blank) and placed into the cell holder and tightly covered with the instrument cap. The stored program number for turbidity was entered. The zero button was then pressed. Another sample cell was filled with 10 ml of the main sample and the sample cell was placed into the cell holder. The sample cell was tightly covered with the instrument cap, the read button was pressed and the result was displayed and recorded.

Portable pH/EC/TDC/Temp Meter: The meter was switched on and the sample stirred before the tip of the probe (4cm) was submerged into the water sample to be tested. TDS, Temperature and pH modes were selected one after the other and a few minutes given for the reading to adjust and stabilise before the values were recorded.

APHA Platinum-Cobalt Standard Method: The Colorimeter was switched on by pressing the power key. The sample cell was rinsed with distilled water. A sample cell was filled with 10 ml of deionized water (the blank) and the surface of the cell was wiped with a soft cloth. The blank was placed into the cell holder and tightly covered with the instrument cap. The stored program number for APHA color was entered. Then the zero button was pressed. Another sample cell was filled with 10 ml of sample and the surface of the cell was wiped with a soft cloth; the sample cell was placed into the cell holder and tightly covered with the instrument cap. Then the read button was pressed and the result was displayed.

Complexometric method: 100 ml of water sample was pipetted into 250 ml conical flask and then drops of sodium hydroxide added to increase pH to between 9.5–10. The flask was swirled, and three drops of indicator was added to get a wine-red color. The burette was filled with Ethylene Diamine Tetra Acetic Acid (EDTA) and the sample titrated until color changes to sharp blue. The titre reading was taken and total hardness was calculated using Equation (1).

$$Total\ hardness\ (CaCO_3)(ppm) = \frac{Titre\ x\ A\ x\ 100}{Volume\ of\ sample} \quad (1)$$

Where: A = mg $CaCO_3$ equivalent to 1.00 ml of EDTA titrant.

3 Results and Discussions

The results of the tests carried out on the samples are shown in Table 3. The pH of the raw wastewater tested was 4.7 while the treated samples had pH ranging between 4.3 and 6.5 as shown in Table 3. This showed that the wastewater sample was slightly acidic. There was an increase of 27.7% in pH with 2.4 g/l lemon peel powder while 2.4 g/l of banana peel powder showed a pH increment of 6%. Matthew et al (2015) obtained 14% increment in pH after coagulation and flocculation for both Moringa Oleifera extract and banana peel powder. The results in Table 3 were used to calculate and plot the percentage reduction for total dissolved solids, turbidity, colour and hardness as shown in Fig. 1 - 4.

Table 3. Characteristics of Raw and Treated Wastewater

Sample №	pH	TDS (mg/l)	Turbidity (NTU)	Colour (pt-co)	Total hardness ($CaC0_3$) (mg/l)
0	4.7	901	899	8440	1245
1	4.3	676	204	1197	1470
2	4.3	677	484	2590	1055
3	4.3	582	533	4863	1045
4	4.7	662	486	4350	1035
5	4.4	787	643	6500	1225
6	4.6	739	555	5075	1170
7	4.4	822	640	6313	2000
8	4.8	627	865	4175	935
9	4.6	670	610	6100	1195
10	4.7	458	419	4125	1000
11	4.7	590	440	3850	990
12	6.5	237	124	1988	940
13	4.7	801	769	8080	1060
14	4.8	701	487	4713	1010
15	5.0	567	412	3688	1320
16	4.6	577	388	3908	1400

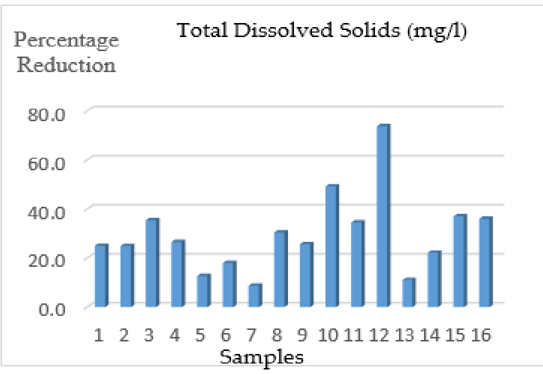

Fig. 1: Percentage Reduction of TDS

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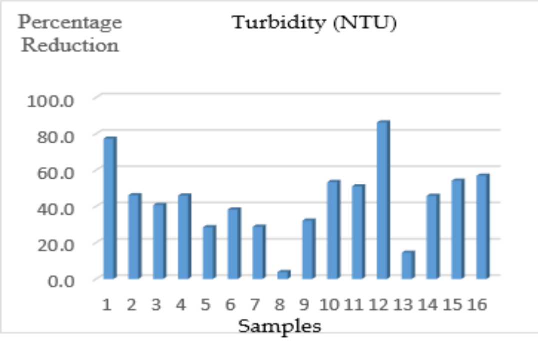


Fig. 2: Percentage Reduction of Turbidity

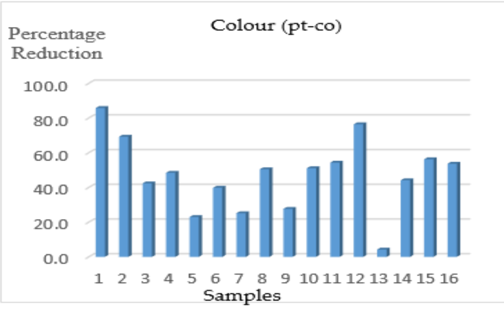


Fig. 3: Percentage Reduction of Colour

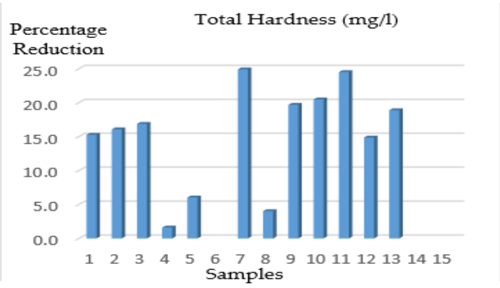
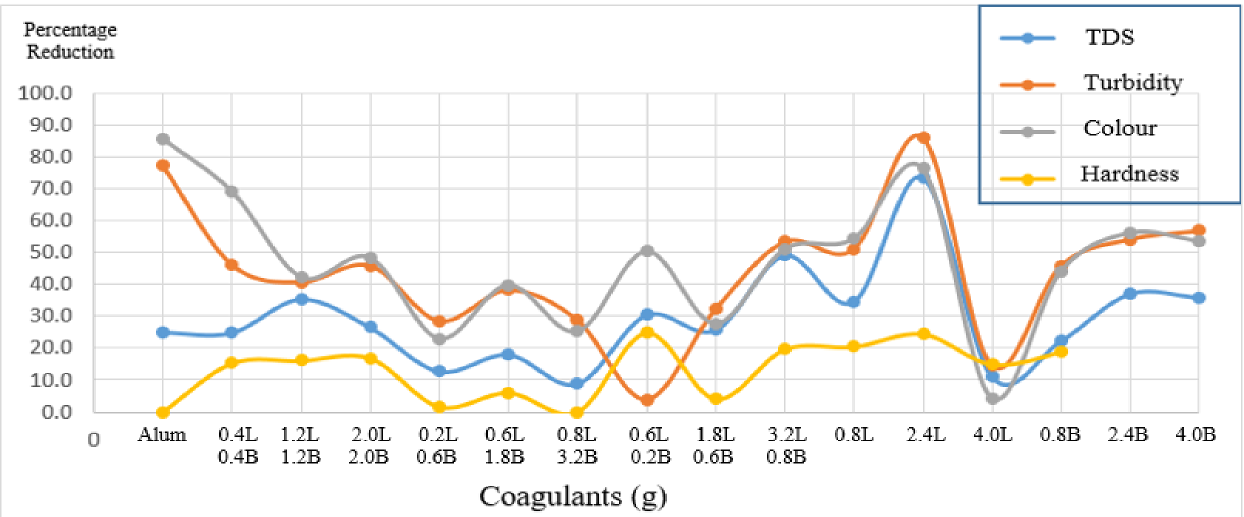


Fig. 4: Percentage Reduction of Total Hardness

The TDS percentage reduction of the samples ranged between 8% to 73.7% as shown in Figs. 1 and 5. The highest TDS reduction was obtained in sample 12 which was treated with 2.4 g of lemon peel powder. Increasing the quantity of lemon peel powder to 4.0 g reduced the percentage TDS to 11.1%. The lowest reduction obtained was the sample treated with a mixture of 0.8 g of lemon and 3.2 g of banana peel powder with TDS reduction of 8.8 percent while mixture of 3.2 g of lemon and 0.8g of banana peel powder improved TDS reduction to 49.2%. The percentage reduction of TDS using different dosages of banana peel powder ranged between 22 and 37.1%. This showed that the lemon peel powder improved the TDS reduction better than the banana peel powder for the samples tested. In research by Matthew et al (2015) addition of banana peel powder to wastewater increased TDS from 350 mg/l to 6880 mg/l. They attributed the TDS increment to the addition of the powder, which was sieved through 2.36mm sieve. After filtration of the mixture TDS reduced to 500 mg/l.

For turbidity, percentage reduction in the samples ranged between 14.5% and 86.2% as shown in Figs. 2 and 5. From the results sample 12 which was treated with 2.4 g of lemon peel powder gave the highest turbidity reduction, even better than alum. Increase in dosage of lemon peel powder to 4.0 g however showed a drastic decrease in turbidity reduction to14.5%. This showed that in as much as lemon peel powder has shown good effect at reducing turbidity, exceeding the optimum dosage can have a negative effect on the turbidity quality of the treated wastewater. The best turbidity reduction for banana peel powder was 56.8% using 4.0 g/l. Priyatharishini et al (2019) found that banana peel extract efficiently worked at dosage of 100 mg/l as the turbidity removal achieved was almost 79%. Also, Azamzam et al (2022) had the best turbidity removal dose of 80% using 0.6 g/l of banana peel powder with an average particle size and diameter of 978 ± 37 nm and 602 ± 13 nm, respectively.



(L = Lemon Peel Powder and B = Banana Peel Powder)

Fig. 5: Comparison of Different Dosages of Lemon and Banana Peels Powder

The results obtained however compared favourably with Subashree et al (2017), who investigated coagulation activity of lemon and banana peel powder in water treatment. They concluded that among the natural coagulants used in the study for turbidity reduction, lemon peel was found most effective as it reduced up to 75.89% turbidity from the raw turbid water. Combining the lemon and banana peels in different proportions for this research did not yield better results in terms of turbidity reduction.

The best colour reduction was achieved using 0.25 g of alum having about 85.8% reduction as shown in Figs. 3 and 5. Among the natural coagulants 2.4 g of lemon peel powder resulted in the highest colour reduction of 76.4% while 4.0 g resulted in the lowest reduction of 4.3%. Mixture of 1.2 g each of lemon and banana peel powder equally gave a good reduction in colour of 69.3% while 2.4 g of banana peel powder gave 56.3% colour reduction. Other dosages that gave over 50% colour reduction were mixtures of 0.4 g each of lemon and banana peel powder, 0.6 g lemon and 0.2 g banana peel powder, 3.2 g lemon and 0.8 g banana peel powder, 0.8 g of only lemon peel powder and 4.0 g of only banana peel powder. Generally, though both banana and lemon peel powder and their mixtures at some dosages resulted in good colour reduction in the samples, the lemon peel powder showed more effectiveness.

A mixture of 0.6 g lemon and 0.2 g banana peel powder resulted in the highest hardness reduction of 24.9% while 2.4 g of lemon peel powder gave the next best hardness reduction of 24.5%. as shown in Figs. 4 and 5. Increasing the dosage of lemon peel to 4.0 g resulted in the sharp decrease of hardness reduction to 14.9%. An increase in hardness was observed for samples treated with alum, 2.4 g banana peel powder, 4.0 g banana peel powder and a mixture of 0.8 g lemon and 3.2 g banana peel powder. This result still showed the effectiveness of lemon peel in hardness reduction. Fig. 5 summarises the comparative performance of the different lemon and banana peel powder dosages, showing that dosage of 2.4 g of lemon peel powder is more effective than the other dosages in treating the domestic wastewater sample.

4 Conclusion

The results obtained from this study compared the use of locally available lemon and banana peels as natural coagulants in the treatment of domestic wastewater. From the results obtained lemon peel powder proved to be more effective than banana peel powder and mixtures of lemon and banana peel powder in different proportions. Lemon peel powder gave the best reduction in turbidity, TDS, colour and hardness after treatment as 86.2%, 73.7%, 76.4% and 24.9% respectively. Hence, lemon peel powder has the potential to function as natural coagulant in wastewater treatment. The optimum dosage of lemon peel that was effective in reduction of all the parameters tested was 2.4 g/l except hardness. It is therefore recommended to be used for preliminary treatment of domestic wastewater with similar characteristics as the one in this study. The treated wastewater can be used for non-potable purposes like garden watering, toilet flushing and others. Lemon peel powder has compared favourably with alum in domestic wastewater treatment and can be used as a substitute coagulant. When properly designed and applied, lemon peels can play a role in reducing the pressure on the available fresh water since the treated wastewater can be put to use for some domestic purposes.

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