http://dx.doi.org/10.21172/ijiet.151.01

Balanites Aegyptiaca Seed as Coagulant in Water Purification: A Bench Scale Study

Jezhi, P.Y[1], Muhammad[2], I.M, Abdulkarim A.Y[3], Gutti B[4], Ahmed S.I[5], Atiku Y.M[6]
[1]*Department of Petroleum Resources, Kaduna-Nigeria*
[2,3,4,6]*Department of Chemical Engineering, Abubakar Tafawa Balewa University, Bauchi-Nigeria*
[5]*Department of Chemical Engineering, University of Maiduguri, Borno-Nigeria*

Abstract- Water treatment is a process used to improve the quality of water and make it more acceptable for specific end-use. The end-use may be drinking, industrial water supply, irrigation, maintenance etc. The increasing demand for drinking water has made the used of bio-friendly water treatment alternatives a welcome development. Lately, there has been so much interest in works over the use of natural coagulant to treat and disinfect water for safe usage. A laboratory study conducted on the use of balanites aegyptiaca seed showed its effectiveness in water treatment. This research moved a step forward by designing and constructing a bench scale water treatment plant utilizing balanites aegyptiaca seed extract and the powder as coagulant and disinfectant. The design process was carried out by adopting some design equations. Treatment units considered include coagulation/flocculation, sedimentation and filtration. The results of the extraction revealed oil yield to be 38.42% and density 0.83 g/cm3 at 5 hours extraction time and particle density 0.60 mm.Properties of the raw turbid water revealed turbidity to be 514 NTU, color 5600, conductivity 276 µs/cm, pH 7.10 and total coliform bacteria count 85 cfu/100 mL which were above the recommended set limits by WHO and NIS. The quality of the treated water using the prepared extract on the designed and fabricated bench scale treatment units revealed good reduction in turbidity from 514 NTU to 26.5 NTU, color from 5600 CTU to 290 CTU, total coliform count from 85 cfu/100 mL to 10 cfu/100 mL. The performance of the powdered coagulant revealed good reduction in turbidity from 514 NTU to 90.74 NTU, color from 5600 CTU to 900 CTU, total coliform count from 85 cfu/100 mL to 10 cfu/mL. It was observed that conductivity increases after the treatment but other inorganic constituents reducedsignificantly though not to the recommended set standard values. Total coliform counts did not exceed the maximum of 10 cfu/100 mL set by NIS/WHO and the pH is within the accepted range of 6.5-8.5, the 0-dosage treatment conducted also showed a reduction in all the tested parameters. The processed coagulant seed can be said to be a good coagulant and disinfectant for the treatment of highly turbid water.
Keywords: 'balanites aegyptiaca, seed, coagulant, purification, water, bench scale, turbidity'

I. INTRODUCTION

Surface water, well water or reclaimed water can contain suspended solids, colloidal matter, organics, hardness, silica, iron, manganese and other contaminants, thus it's treatment before consumption is of paramount importance. Bench scale studyof a water treatment plant hasthe advantage of not requiring large volume of sample testing, it also allows quick screening of various alternatives and provides room for testing various performance variables at a relatively low cost. It has been discussed that in the developing countries, more than 1.6 million people are using the unhygienic water and among them most of the people suffers from diarrhea and water related diseases (Kumar et al., 2017). The removal of turbidity and pathogens are important steps in water treatment process and generally, this is achieved using coagulation and chlorination processes. In conventional water treatment processes, aluminum sulphate (alum) and polyaluminum chloride (PAC) are widely used for turbidity removal, while chlorine is used for disinfection. Some studies reported that aluminum which is the major component of alum and polyaluminum chloride causes Alzheimer's disease (Vinitha et al., 2014). During water treatment, naturally organic matter (NOM) combine with Chlorine, applied for disinfection to generate disinfection by-products (DBPs) and in particular form halogenated DBPs, this increases the production of free radicals in the body (Clark & Silvaganesan, 1998).

According to Hendrawati et al. (2015), PAC and alum continuous usage in large amount is seen as potential threat for the health of processed water consumers because coagulant may still remain, although in small amount. Ecologically, the use of synthetic coagulant produces a certain amount of sludge sediment that is a pollutant for environment because the sludge is relatively difficult to degrade and can change the component of soil and water minerals from normal condition. Thus, in recent years there has been considerable interest in the development of natural coagulants. Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from plants such as Moringa oleifera (MO), Prosopis juliflora, Tamarindus indica and Cactus latifaria (Vinitha et al., 2014). Natural organic polymers have been used for more than 2000 years in India, Africa, and China as effective coagulants and coagulant aids in turbidity treatment. Natural coagulants have bright future and are concerned by many researchers because of their abundant source, low price, environment friendliness, multifunction, unlikely to produce treated water with extreme pH and biodegradable nature in water purification, highly biodegradable. Naturally occurring coagulants are usually presumed safe for human health (Phani and

Rajkumar, 2013). Balanites aegyptiaca (desert date) is a multi-usage tree which has beinga source of timber, fruit, seeds, medicinal extracts and potential industrial components. The north eastern and western parts of Nigeria have been cultivating Balanites aegyptiaca in large quantity without any research on the benefitsthat can be derivedfrom its seed which is considered as waste material (Samuel et al., 1997). Balanites aegyptiaca seed could be a potential natural coagulant in raw/wastewater treatment (Mohammed et al., 2018).

Irene (2000) have reported that bench – scale study enhances primary treatment in Brazil. Five waste water treatment plants were selected for the analysis. The result of the study revealed that jar test for all the five primary treatment plants resulted in FeCl3 achieving the best chemical oxygen demand (COD) and total suspended solid (TSS) removals, an optimal dosage of 50 mg/l Fecl3. During the study each of this bench - scale analyses tested a wide variety of coagulant and flocculants to optimize the dosing system for possible full- scale chemically enhanced primary treatment (CEPT). Muyibi et al. (2003) reported on enhanced coagulation efficiency of Moringa Oleifera seeds through selected oil extraction. Varying quantities of oil corresponding to 2% w/w, 25% w/w and 30% w/w kernel weight extracted from Moringa Oleifera seeds (S1, S2 and S3) were applied in the coagulation of kaolin suspension and turbid river sample from two different sources. The result revealed that sample S2 (25% w/w) gave the best turbidity removal corresponding to 91.7%, 95.5% and 99% respectively. The finding has shown that turbidity removal was found to increase with increase in initial turbidity during coagulation of model turbid water (kaolin suspension) and river water samples. Daniyan et al. (2011) reported on the use of Moringa Seed extraction in water purification. The result of their findings revealed that powder from the seed kernel of Moringa Oleifera contains some coagulating properties at loading doses of 6g/ 500ml and above that have similar effect as the conventional coagulum potash. The limitation to this research was that they have not focused on design of water treatments units. Kenneth (2012) worked on a sustainable low cost Phyto disinfectant- sand filter alternative for water purification. Quantitative research techniques were applied to test a Moringa- sand filter column for its disinfectant activity on separate contaminated water containing E. coli, Aeromonas hydrophila, total heterotrophic soil bacteria and fungi. Extraction of Moringa seed powder using solvent of varying polarity revealed more than 85% in- vitro anti-bacterial activity against E. coli (AT CC 11775) strain (indicator of faecal contamination of water) and 95% against Aeromonas hydrophila strain (known to resist chlorination) compared to control of both organism of 65% for aluminum sulphate and 80% for sodium hypochlorite. Ibironke and Ajoke (2012) reported on the Evaluation of the toxicological status of Balanites Aegyptiaca seed oil. During their study, a total of fourteen (14) rats fed with diets containing either 10% groundnut oil (control group) and 10% Balanites Aegyptiaca seed oil (experimental group) for six weeks thereafter blood samples and some organs of the rats were collected for analysis, toxicological effect was not detected on albino rats. The rats from the experimental group showed fairly similar body weight gain when compared with those from the control group. The liver of the two rats from the experimental group showed lesion signifying need for more refining of the seed oil before it can be safe for animal/human consumption.

Muhammad et al. (2015) reported on water melon as potential coagulant for water treatment. The finding revealed that when water melon seed cake was used in combination with alum higher color removal was achieved, going as high as 100 clarifications of color. However, the recommended ratio for the combined coagulant dose was 80% water melon seed powder and 20% alum as best water treatment was achieved with this specification. In addition, good coagulant efficiency of 89% was obtained using surface and medium turbid water from Gubi dam Bauchi-Nigeria. The limitation to this study was that other natural coagulants were not compared with the one tested during the study period.

Lilian et al. (2017) reported on water treatment with conventional and alternative coagulant. Two different coagulants were used from organic and inorganic source namely Moringa powder and aluminum sulphate, the finding revealed that Moringa Oleifera (MO) natural coagulant presented best results of color and turbidity removal when compared with aluminum sulphate chemical coagulant for all samples analyzed, although the findings show that there is an inherent MO solution color. In addition, MO revealed high turbidity removal (94.9%) and color removal (92.5%) with the best dosage of 20 mg/l. The limitation to this study is that treatment units were not used to assess the coagulant potential.

II. MATERIALS AND METHODS

The materials used in the study are the highly turbid water from a pond located in Piro village, Bauchi State and a slightly turbid water from Gubi Dam, Bauchi State to serve as the raw waters, balanites aegyptiaca seed obtained from a nearby bush in Bauchi was processed and prepared to serve as the natural coagulant.Distilled water, petri dishes, plastic containers, sterilizing bottles, T2014233 Wagtech turbidity meter, 324 Systronic pH meter, MP 600 Citizon electronic balance, 834 Schwabach Memmert oven, HR1757 Philips blender, 500 ml DXY Soxhlet

extractor, 700TM Phipps Jar Test machine, 7100 Wagtech photometer, Pyrex laboratory glass ware, 3078 Borosil desiccator, and designed/fabricated bench scale water treatment plant as presented in plate 1 were used in this study.

Plate I:Designed and Fabricated Bench Scale Water Treatment plant used in this study

2.1 Sample Preparation

Balanites aegyptiaca seed (BAS) obtained from a nearby bushin Bauchi was weighed and soaked in water for 5 hours, washed thoroughly to remove the pulp, dried, and reweighed.The shell was cracked to obtain the seed kernel. The exposed kernel was weighed then ground to increase the surface area. The ground sample was dried in an oven till constant weight and sieved. A known quantity of the ground kernel was charged into a Soxhlet extractor to extract out oil from the dried sample. The residue/cake from the extraction process was washed severally with distilled water and oven dried. The washed/dried residue was weighed and then kept in an air tight container for use as coagulant/ disinfectant.

2.1.1 Method of Oil Extraction

One hundred and fifty grams (150 g) of the prepared sample of Balanites aegyptiaca seed was taken inside a thimble made from thick filter paper, which was loaded into the main chamber of the Soxhlet extractor. The Soxhlet extractor was placed onto a flask containing the extraction solvent. The Soxhlet was then equipped with a condenser and 250 mL of the solvent was heated to reflux. The solvent vapor travelled up a distillation arm and flooded into the chamber housing the thimble of solid. The chamber containing the solid material was slowly filled with warm solvent. When the Soxhlet chamber was almost full, the chamber was automatically emptied by a siphon side arm, with the solvent running back down to the distillation flask. After many cycles the desired compound was concentrated in the distillation flask. In this study N-hexane was used as solvent. The miscella, a mixture of oil and solvent, from the distillation flask, which was concentrated, was then taken off for distillation (Islam, et al., 2015). The whole extraction process was repeated 8 times until the total of 1200 g of the sample was successfully extracted. Plate 3 presents the Soxhlet extraction set up.

III. RESULTS AND DISCUSSION OF RESULTS

3.1 Oil Extraction and Coagulant Performance

Table 1presents the values obtained for the factors (particle size, extraction time and temperature) used for the extraction of oil from Balanites Aegyptiaca seed kernel. The results showed that temperature, extraction time and particle size are among the factors that affected the yields of the extract during oil extraction from the seeds. Much yield was not obtained because the extraction time considered was not adequate enough to favor much yield of the extract. In addition, the mass per unit volume of the oil (density) was found to be 0.84 g/cm3. The results obtained is in compliance with the literature as reported by Sulaiman et al. (2016), this research finding is also in line with the works of Abadi and Omer, 2015 and Zaharaddeen et al., 2013. It was observed that the more the surface area the lower the extraction time and the more the yield of the extract as reported by Mohammed et al. (2018).

Table 1: Factors used and the responses obtained for the oil extraction

Particle size (mm)	Temperature ℃	Extraction Time (hr)	Oil yield (%)	Density g/cm3
0.6	50	4	38.42	0.83

When the dosage of the stock solution/extract increases there was a corresponding increase in both turbidity, color and pH, though the pH value is still within the range recommended as set by NIS 554. (2007), looking at the results of sample raw water before jar test and that of the jar test using extract, the increase in the value of the parameters particularly the turbidity and color are above the recommended limit as set by NIS 554. (2007), may be due to increase in dosage and increase in mixing speed. Details of the results are presented in Table 2 and Table 3, this observation is in line with the literature (Muhammad et al., 2015).

Table 2: Results for the Sample Raw Water before Jar test

Turbidity (NTU)	Color mg/Lpt	pH
3.65	35	7.09

Table 3: Results of Jar Test on Sample raw water Using Prepared Extract of Balanites Aegyptiaca Seed Powder

Volume (mL)	Turbidity (NTU)	Color mg/Lpt	pH	Contact time (Minute)	Settling time (Minute)	Mixing speed (rpm)
2.0	13.41	175	7.27	20	30	298
2.5	15.84	180	7.30	20	30	298
3.0	17.63	210	7.32	20	30	298
3.5	20.30	280	7.30	20	30	298

3.2 Properties of the Sample Raw Water using Processed Balanites Aegyptiaca Seed Powder

The results of jar test using Balanites Aegyptiaca seed powder at the contact time of 20 minute, settling time of 30 minutes and mixing speed of 298 rpm on raw water indicated that when 0.1 g was used there was increase in turbidity when compared with the results of Table 3 though is still within the range accepted by NIS 554. (2007) recommended for quality drinking water, other parameters tested were all within the accepted range by NIS 554. (2007). The deviation in values of other parameters tested may be due to the increase in the quantity of the powdered coagulant used and mixing speed, the results obtained are in agreement with similar work conducted as reported by Mohammed et al. (2018) and Muhammad et al., (2015), details of the result is as presented in Table 4 and table 5.

Table 4: Results of Jar Test Using Processed Balanites Aegyptiaca Seed Powder

Mass (g)	Turbidity (NTU)	Color mg/Lpt	pH	Contact time (Minute)	Settling time (Minute)	Mixing speed (rpm)
0.1	7.00	5	7.11	20	30	298
0.2	9.62	30	7.24	20	30	298
0.3	11.59	55	7.29	20	30	298
0.4	11.95	60	7.30	20	30	298

3.3 Properties of the Sample Turbid Water before Jar test and after Jar test using Prepared Stock Solution/Extract.

It was observed that when the extract of 2.0 mL from Table 6 was used on the turbid water, the turbidity reduces to 31.8 NTU from 556 NTU, pH from 7.15 to 6.74 and color from 5000 mg/Lpt to 200mg/Lpt, the results obtained indicated that coagulant used has stabilized the pH, reduced the cloudiness of the water and also its color which is in compliance with other similar research conducted on the use of natural coagulant for water purification as reported by Muhammad et al., (2015) and Muhammed et al., (2018). The deviation observed on the tested parameters was because of the increase in dosage which affected the turbidity, color and pH. Table 5 is the result for the sample turbid water before Jar test.

Table 5: Results for the Sample Turbid Water before Jar test

Turbidity (NTU)	Color mg/Lpt	pH
556	5000	7.15

Plate II: Image of the Sample Turbid Water before Jar Test

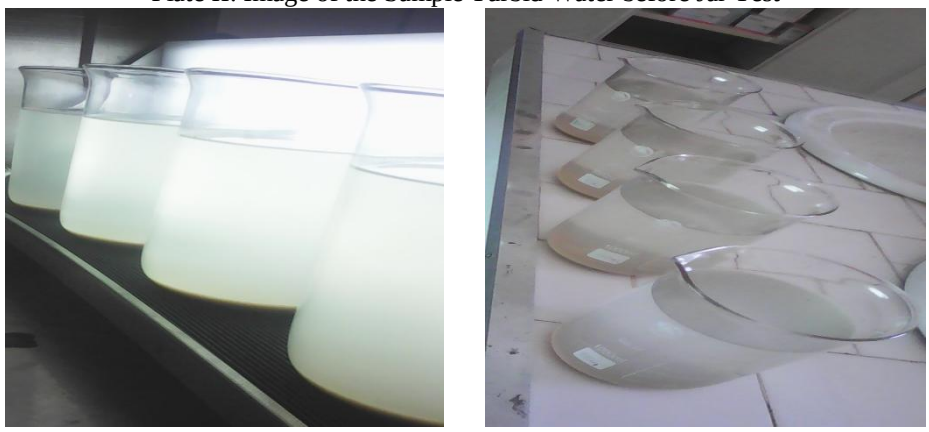

Plate III: Image of the Sample Turbid Water after Jar test using Prepared Extract of Balanites Aegyptiacaand Seed Powder

Table 6: Results of Jar Test on Sample Turbid Water Using Prepared Extract of Balanite Aegyptiaca Seed Powder

Volume (mL)	Turbidity (NTU)	Color mg/Lpt	pH	Contact time (Minute)	Settling time (Minute)	Mixing speed (rpm)
2.0	31.8	200	6.74	20	30	298
2.5	36.7	260	6.93	20	30	298
3.0	43.7	350	6.99	20	30	298
3.5	55.7	370	6.88	20	30	298

3.4 Properties of the Sample Turbid Water before Jar test and after Jar test using Processed Balanites Aegyptiaca Seed Powder.

The result of Balanites Aegyptiaca seed powder as coagulant after the Jar test showed that when 0.2 g of the processed coagulant was used on the turbid water during jar analysis there was reduction in turbidity from 556 NTU to 94.45 NTU, color from 5000 mg/Lpt to 790 mg/Lpt and pH from 7.15 to 7.65, the increase in pH may be attributed to dosage of Balanites Aegyptiaca seed powder used as coagulant for the experiment though the pH is

within the range of 6.5-8.5 as reported by Muhammad et al., (2015) and set by NIS 554. (2007). Detail of the result are shown in Table 7.0.

Table 7: Results of Jar Test Using Processed Balanite Aegyptiaca Seed Powder

Mass (g)	Turbidity (NTU)	Color mg/Lpt	pH	Contact time (Minute)	Settling time (Minute)	Mixing speed (rpm)
0.2	94.45	790	7.65	20	30	298
0.4	156	850	7.36	20	30	298
0.6	255	1300	7.19	20	30	298
0.8	344	2200	7.07	20	30	298

3.5 Physico-Chemical and Microbiological Properties of Turbid Water before Treatment Using the Fabricated Water Treatment Units.

The result of the physico-chemical and microbiological characteristic of the turbid water before treatment shows that all the parameters tested are above the recommended value set by NIS 554. (2007) for good quality drinking water hence, the need for the treatment. In addition, with the exception of pH and conductivity which are within the accepted range as reported by Muhammad et al., (2015) and set by NIS 554. (2007). In addition, it was observed that the turbidity has exceeded the range of 50-150 NTU which is classified as medium turbid water as reported by Doerr, (2005) in Muhammad et al. (2015). Details of the result is as presented in Table 8.

Table 8: Results of Turbid Water before Treatment

Parameters/Units		Turbid water before treatment
Temperature	°C	27.9000
pH		7.1000
Conductivity	$\mu s/cm$	276.0000
Total dissolve solid	mg/L	139.0000
Turbidity	NTU	514.0000
Color	mg/Lpt	5600.0000
Total suspended solid	mg/L	115.0000
Nitrate (NO3)	mg/L	19.0300
Iron (Fe)	mg/L	8.6000
Fluoride (F-)	mg/L	0.0000
Chloride (Cl-)	mg/L	5.5000
Sulphate (SO4)	mg/L	73.0000
Phosphate (PO4)	mg/L	2.0000
Potassium (K)	mg/L	32.0000
Copper (Cu2+)	mg/L	10.0000
Total alkalinity	mg/L	950.0000
Total Coliform Bacteria	cfu/100mL	85.0000

3.6 Physico-Chemical and Microbiological Properties of Turbid Water after Treatment

It was observed that the performance results of extract and powdered coagulant on the turbid water after treatment revealed that there is reduction in pH, color, total coliform count and other inorganic constituents after treatment. It was observed that pH decreases from 7.1 to 6.91, turbidity from 514 NTU to 26.5 NTU, color from 5600.00 mg/Lpt to 290.00 mg/Lpt and total coliform count from 85 cfu/100 mL to 10 cfu/100 mL. Other constituents present significantly reduced after treatment as presented in Table 9 when compared with the result presented in Table 8. This agreed with similar findings (Mohammed et al., 2018). In addition, when the powdered coagulant was used for the treatment on the fabricated treatment units there was also improvement in form of reduction in the content of potassium when compared with the result obtained when stock solution/extract was used as coagulant during the treatment process as shownin Table 9. The result of microbial count which was known by the determination of total coliform count revealed that Balanites Aegyptiaca seed powder and extract is a good disinfectant for water purification when comparison was made with the set standard of 10 cfu/100 mL as set by NIS 554. (2007). The turbid water used for the experiment which was subjected to treatment also showed remarkable reduction in its constituents, in all the results in Table 9 including that of the 0-dosage revealed remarkable reductionin the physico-

chemical and microbiological properties of the sample turbid water after treatment in the fabricated treatment units when compared with the results presented in Table 13, this findings is in line with the literature (Muhammad et al., 2015). In addition, it was also observed that coagulation –flocculation occurs within specific pH range, different pH provides different color as reported by Seynig and Shan. (2007). Detail of the result is as presented in Table 9.

Table 9: Performance Results of Extract and Powdered coagulant on the Turbid Water after Treatment

Parameters/Units		Coagulant extract	Powdered coagulant	0 – dosage
Temperature	℃	27.4000	27.3000	27.2000
pH		6.9100	7.2200	7.1700
Conductivity	$\mu s/cm$	441.0000	474.0000	424.0000
Total dissolve solid	mg/L	220.0000	237.0000	212.0000
Turbidity	NTU	26.5000	90.7400	234.6800
Color	mg/Lpt	290.000	900.0000	2300.0000
Total suspended solid	mg/L	20.0000	47.0000	130.0000
Nitrate (NO3)	mg/L	3.4892	4.8136	11.1760
Iron (Fe)	mg/L	0.3000	2.3000	5.7000
Fluoride (F-)	mg/L	0.1300	0.0000	0.0000
Chloride (Cl-)	mg/L	1.0000	1.6000	2.3000
Sulphate (SO4)	mg/L	0.0000	0.0000	52.0000
Phosphate (PO4)	mg/L	0.3100	0.9500	1.8000
Potassium (K)	mg/L	23.0000	9.5000	29.0000
Copper (Cu2+)	mg/L	0.4200	1.3000	2.6500
Total alkalinity	mg/L	155.0000	240.0000	400.0000
Total Coliform Bacteria	cfu/100mL	10.0000	10.0000	55.0000

Plate IV: Image of Treated Water via Fabricated Treatment Units Using Prepared Stock Solution/Extract of Balanites Aegyptiaca Seed Powder

Plate V: Image of Treated Water via Fabricated Treatment Units Using Processed Balanites Aegyptiaca Seed Powder

IV. CONCLUSION

The reportrevealed the result of the design of coagulation/flocculation tank and sedimentation tank with a capacity of 20 Liters with the corresponding actual size of over flow (sedimentation) of 7.460 Liters and design flow rate of 0.822 L/min.The result of the Balanites Aegyptiaca seed sample used as coagulant during sample preparation revealed an oil yield of 38.42% having a density of 0.83g/cm3 which is good enough for use as coagulant in water treatment.The results from the raw water samples revealed that most of the important water quality parameters tested were outside the set standard of NIS and WHO hence, the need for the treatment.The raw water treated by the application of coagulant extract and powdered coagulant using the fabricated bench scale water treatment plant showed a remarkable reduction in compliance with the set standards of NIS and WHO. In addition, the results of the 0-dosage obtained revealed a reduction in the tested parameters though not in compliance with the set standards of NIS and WHO.

V. RECOMMENDATION

Based on the findings from this study, it is recommendedto carry out an optimization of the treatment process using the processed bio-coagulant.The studies recommend the use of sand filter for economical and easier regeneration of the filter performance and the oil extraction from the seed (Balanites Aegyptiaca) should be based on design of experiment. Buffer solution instead of tap water should be used for effective microbial growth.

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