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Coagulation-Flocculation in Water Treatment using Calotropis Procera Leaves: A case study of River in Kaduna, Nigeria

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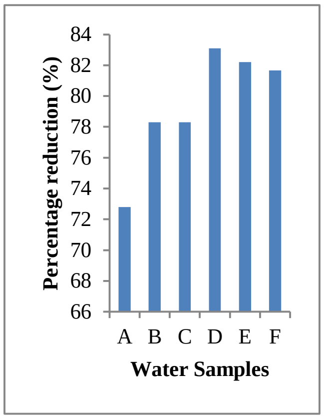
Graphical abstract



Percentage turbidity reduction of the samples

Abstract

This research was carried out to evaluate the effectiveness *Calotropis procera* leaves as an alternative to the use of chemicals as coagulants in water treatment. *Calotropis procera* leaves were plugged, washed with distilled water, cut into small pieces and then dried in an oven to a constant weight. After which the leaves were grinded into various particle sizes of 1 mm, 2 mm and 0.71 mm. Raw water from River Kaduna at Kabala and Kakuri areas within Kaduna metropolis were treated with different samples classified based on the dried *Calotropis procera* leaves particle size and weight, sampling location and the treatment time. The physico-chemical characteristics of the treated samples were all within the allowable standard by World Health Organization (WHO). The results show that the treated water sample D with 0.71 mm particle size and 40 g weight of the dried *Calotropis procera* leaves gave the highest percentage reduction in turbidity. Treatment of the samples with *Calotropis procera* leaves gave a significant reduction in coliform count from 21 per 100 ml to 1 per 100 ml in treated water samples E and F. This study shows that *Calotropis procera* can be used as a low-cost, environmentally friendly substitute coagulant for water and wastewater treatment.

Keywords: Calotropis procera; coagulation; physico-chemical; bacteriological; coliform; contaminant

1.0 INTRODUCTION

Coagulation-Flocculation is an important process in water and wastewater treatment used for the removal of heavy metals, total suspended solids (TSS), Chemical Oxygen Demand (COD) and turbidity [1-4]. Most common coagulants are aluminum based salts and iron-based salts. Other coagulant includes polyacrylamide (PAA) and chitosan, a biodegradable, non-toxic linear cationic polymer of high molecular weight [5-10]. However, previous researches have shown that chemicals used for water treatment causes serious health hazards especially when an error occurs during the treatment process. High level of aluminum sulphate in the brain has been identified as a risk factor for Alzheimer's disease and as a causative agent in neurological diseases such Foreign exchange problem as pre-senile dementia [11-13]. Other reports also suggest that alum may be carcinogenic in water application [14]. There have also been concerns on the negative effects of the use and disposal of aluminum sulphate into the environment through the continuous usage of alum as a coagulant in water treatment. This is due to non-biodegradable nature of the sludge from the waterworks and high cost of disposal [15-16]. The high cost of these chemicals has been found to contribute to about 35 to 70% of recurrent expenditure in water treatment plant [13].

Researches on the use of natural coagulants such as *Moringa stenopetala*, *Moringa oleifera, Hypoestis verticillaria* and other plants as substitutes for domestic water treatment have been reported [17-18]. *Moringa oleifera* leaves and seeds have been found effective in clarifying turbid raw water, an as a primary coagulant and flocculant as fast as that of Alum and in heavy metal ion removal [17]. Treatment with *Moringa* seed powder can leave water clear with 90-99% of the bacteria removed [18]. Plants usually are composed of lignin and cellulose as major constituents and may also include other polar functional groups of lignin, which includes alcohols, aldehydes, ketones, carboxylic, phenolic and ether groups. These functional groups have ability to bind heavy metal by replacement of hydrogen ions for heavy metal ions in solution or by donation of an electron pair from these groups to form complexes with metal ions in solution. An analysis using Fourier transform infrared spectroscopy (FTIR) indicate the involvement of hydroxyl ion (OH^-), alkane (-CH), nitrile ($-NO_2$) and carboxyl group (-COO) chelates in metal binding [19].

The potentials of *calotropis procera* leaves in purification of water and it ability to drastically reduced total viable count of microorganism have also been reported and its performance in coagulation and sludge conditioning capabilities have been reported to be similar to aluminum sulphate (alum) [16-17]. Calotropis procera leaves were not only an active coagulant, but also showed antimicrobial effects on gram-positive and gram-negative bacteria. This can be attributed to the presence of some active ingredients such as mudarin, yellow bitter acids and calotropin in the leaves of *Calotropis procera*. Most of these compounds particularly calotropin have been reported to have anti-bacterial properties [17].

Adequate potable water supply problems are still eminent particularly in developing countries because of inadequate financial resources. The cost of water treatment is increasing, and the quality of river water is not stable due to suspended and colloidal particle load caused by land development and high storm runoff during the rainy season. Due to many problems created by the use of synthetic coagulants such as aluminum sulphate enumerated earlier, there is therefore need for further studies on the application of non-chemicals, low-cost, preferably natural coagulants which are available locally. This study is therefore aimed at evaluating the effects of time, particle size and quantity of Calotropis procera leaves on its performance as a coagulant and antibacteria in the treatment of water from River Kaduna, Nigeria.

2.0 EXPERIMENTAL

Calotropis procera leaves were collected within the environment of Kaduna Polytechnic, Kaduna State, Nigeria. The leaves were plugged and washed with distilled water repeatedly and cut into small pieces. The leaves were then dried in an oven at 50^{o}C for 24 hours until a constant weight was achieved. After which the leaves were grinded into various particle sizes of 0.71 mm, 1 mm and 2 mm .The water samples were collected from River Kaduna at Kabala and Kakuri areas within Kaduna metropolis using a clean container. The raw water characteristics are shown in Tables 2 and 3.

2.1 Physio-Chemical Test

Temperature and conductivity were measured using thermometer and conductivity meter respectively. pH was determined using Hath comparator while turbidity meter was used to determine the turbidity. Titrimetric method of analysis was also employed for alkalinity value, chloride, hardness, total solids, suspended solids, metals and non metals.

2.2 Bacteriological Test

The bacteriological analysis was conducted using the standard pour plate method as recommended by UNEP (1996b). This was done using apparatus such as autoclave, conical flasks, incubator, pipette, spint lamp, test tube and cotton wool. Ethanol and nutrient agar were also used as reagent.

2.3 Water Treatment

The samples were classified based on the dried *Calotropis procera* leaves particle size and weight, sampling location and the treatment time. This is shown in Table 1. Sterile containers labeled A to F were filled with 1400 ml of water samples. The water samples were then treated with different quantities of *Calotropis procera* leaves of different particle sizes. These containers were securely covered and allowed for a fixed period of time after which samples were taken for analysis.

3.0 RESULTS AND DISCUSSION

The results for physico-chemical properties of treated water samples from Kabala and Kakuri area are shown in Tables 2 and 3 respectively. The raw water characteristics were similar. However, samples from Kakuri have higher chloride, total dissolved solid and coliform count. This may be attributed to industrial activities and additional water run offs since Kakuri is located downstream. The turbidity raw water from the two sources has turbidity value of 18 NTU which is above the WHO standard for drinking water quality.

The pH values of all the treated samples conform to the WHO of 6 - 8.5 [17]. There was a reduction in the conductivity of the samples from 350 NS/m for raw water. The conductivity of all samples were within the WHO standard requirement of 1000 NS/m. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge) [20].

Table 1 Water samples classification

	Kabala Area			Kakuri Area		
	Sample A	**Sample B**	**Sample C**	**Sample D**	**Sample E**	**Sample F**
Time (mins)	30	60	90	30	60	90
Particle size (mm)	0.71	1	2	0.71	1	2
volume of water (ml)	1400	1400	1400	1400	1400	1400
Weight of Leave (g)	40	45	50	40	45	50

Table 2 Physico-chemical properties of treated samples from Kabala

Parameter	Unit	Sample A	Sample B	Sample C	Raw water	WHO
pH	-	7.2	7.1	7.1	7.40	6.5-8.5
Conductivity	NS/m	120	109	109	350.5	1000
Turbidity	NTU	4.9	3.9	3.9	18.00	5
Hardness	Mg/L	252	191	181	512.00	500
Chloride	Mg/L	12	8	9	220.10	75
Sulphate	Mg/L	21	17	20	233	200
Total suspended solid	Mg/L	2	2	2	80.00	<10
Total dissolved solid	Mg/L	22	22	20	320.00	500
Alkalinity	Mg/L	32.0	44	44	50.00	100
Colour		Colourless	Colourless	Colourless	Colourless	Clean/clear
Test/Odour		Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Temperature	ºC	30.16	30.1	30.42	30.47	Ambient
Calcium	Mg/L	14.9	14.5	14.3	18.9	50
Magnesium	Mg/L	4.1	4.2	4.1	4.5	30
Manganese	Mg/L	-	-	-	-	
Coliform count		2	3	2	20	

Table 3 Physico-chemical properties of treated samples from Kakuri

Parameter	Unit	Sample D	Sample E	Sample F	Raw water	WHO
pH	-	6.9	7.0	6.9	7.50	6.5-8.5
Conductivity	NS/m	50	49	48	350.00	1000
Turbidity	NTU	3.0	3.2	3.3	18.00	5
Hardness	Mg/L	480	505	505	521	500
Chloride	Mg/L	22	21	21	214	75
Total suspended solid	Mg/L	2	4	4	28.00	<10
Sulphate	Mg/L	41	41	42	233	200
Total dissolved solid	Mg/L	20	21	21	400.0	500
Alkalinity	Mg/L	39	39	39	51	100
Test/odour	Offensive	Slightly offensive	Slightly offensive	Slightly offensive	Offensive	Clean/clear
Colour		Colourless	Colourless	Colourless	Colourless	Satisfactory
Calcium	Mg/L	13.0	13.0	12.9	13.1	50
Magnesium	Mg/L	3.2	4.0	4.1	4.7	30
Temperature	ºC	28.6	29.6	29.9	29.4	Ambient
Manganese	Mg/L	-	-	-	-	
Coliform Count		2	1	1	21	

There was no significant variation in temperature of the water sample. The values of Total Dissolve Solids (TDS) were within the recommended specification of World Health Organization of 500 mg/l. The analysis also showed a high reduction of suspended solids for all the samples. The results for calcium, magnesium and alkalinity were also within the specified standard of World Health Organization.

The percentage reductions in turbidity after treatment for the various samples are shown in Figure 1 below. Treated water sample D has the highest percentage reduction of 83.1%. Moreover, the turbidity values of all the samples after treatment as shown in Tables 2 and 3 were lower than the allowable value of 5 NTU by the WHO. The higher effectiveness observed for samples from Kakuri even at different weights may be attributed to higher total suspended solids present in raw water from Kabala as shown in Tables 2 and 3.

The increase in public awareness of the health, environment and safety hazards associated with the use of chemicals for water treatment causes serious health risk particularly when an error occurs during the treatment process. The high cost of chemicals and the increasingly stringent environmental regulations together with the new requirements of the medical and food industries for ultra-pure and high added value products have pointed out the need for the development of new and clean technologies for the processing of food products. Therefore, c*alotropis procera* leaves being a natural product provided an excellent alternative to the use of chemicals in water treatment.

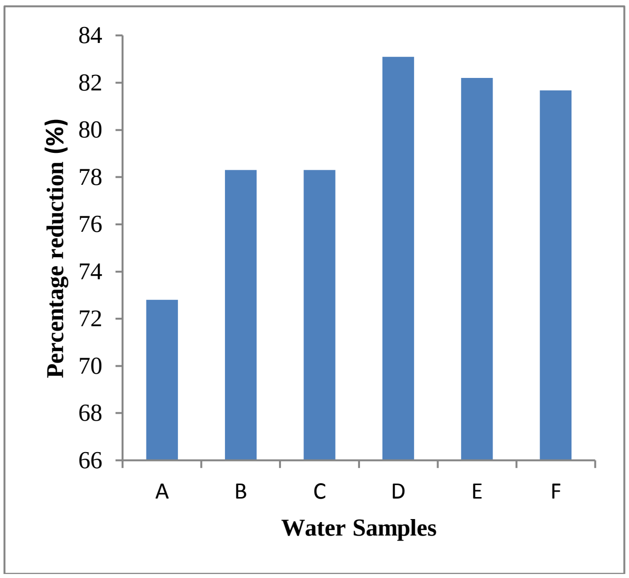


Figure 1 Percentage turbidity reduction of the samples

Table 4 shows the effect of treatment on the coliform count. Treatment of the samples with *Calotropis procera* leaves gave a significant reduction in coliform count from 21 per 100 ml to 1 per 100 ml in treated water samples E and F. The coagulating properties of the leaves might have also helped in trapping the microorganisms. This may also be attributed to the presence of some active ingredients such as mudarin, yellow bitter acids and calotropin in the leaves of *Calotropis procera*. Most of these compounds particularly calotropin have been reported to have anti-bacterial properties [17].

Table 4 48 hours bacteriological results using nutrient agar

Sample	Dilution Factor	Total coliform per 100ml
A	101	2
B	101	3
C	101	2
D	101	2
E	101	1
F	101	1

4.0 CONCLUSION

Water samples from different points in Kaduna metropolis were collected, analyzed and treated with *Calotropis procera* leaves. The physico-chemical characteristics of the treated samples were all within the allowable standard by WHO. The results show that treated water sample D with 0.71mm particle size and 40g weight of the dried *Calotropis procera* leaves gave the highest percentage reduction in turbidity. Treatment of the samples with *Calotropis procera* leaves gave a significant reduction in coliform count from 21 per 100ml to 1 per 100ml in treated water samples E and F. This study shows that *Calotropis procera* can be used as a low-cost, environmentally friendly substitute coagulant for water and wastewater treatment.

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