Effects of De-Oiled Jute Seed and Cottonseed Extracts as Natural Polymeric Coagulants for Surface Water Treatment

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Abstract. Developing countries are currently facing intense drinking water shortages due to paucity of funds to set-up potable water treatment plants. This has led to the outbreak of waterborne diseases resulting in huge medical spending for the government. Employing natural bio-polymers (Cottonseed (Gossypium hirsutum) [CS] extracts and de-oiled Jute seed (Corchorus olitorius) [JS]) for surface water treatment presents an alternative to improving the quality of drinking water in rural communities. This study was therefore aimed at comparing the effectiveness of the two natural bio-polymers for improving surface water quality. The oils were extracted using n-hexane as extractor solvent (with water at about 40-70°C) for six (6) hours and the seed residues were used to prepare extract stock solutions for the water treatment. Measured water samples (100 ml) were treated using the bio-polymer extracts employing different doses (10, 20, 30, and 40 ml). Physico-chemical analysis of the treated samples using CS and JS extracts yielded optimum treatment values of 7.2 and 6.89 for pH; 24.45 and 19.48 NTU for turbidity; 92.41 and 0.52 µs/cm for conductivity; 120.55 and 149.67 mg/l for BOD while 208.82 and 237.32 mg/l were recorded for COD. These corresponds to total reduction efficiencies of 14.98 and 34.31% (pH); 32.19 and 58.37% (Conductivity), 55.5% and 64.56% (turbidity), 36.86 and 60.4% (BOD) and 52.34 and 64.40% (COD) for CS and JS respectively. These results show the potentials and limitations of the two biopolymers as alternative coagulants if applied at optimum concentrations. They can be utilized to reduce waterborne diseases in rural communities lacking basic water treatment facilities.

1. Introduction

Inadequate facilities for producing potable water in most African countries has led to the consumption of contaminated water from streams, river, ponds and wells [1]. Water from these sources is usually...
contaminated with pathogens that could cause water-borne diseases to man. The recent sustainable development goal 6 (SDG 6) synthesis report on water and sanitation estimates that more than 2 billion people live in countries experiencing high water stress [2]. This cuts across all continents and limits sustainability, social and economic development [1]. In 2017, the World Health Organization report estimated that about 159 million people depend on surface water [2]. Furthermore, [3] reported that about 80% of the diseases in developing countries are water-related. This number is expected to increase due to the gradual population growth putting the water-stressed communities at greater risk compounded by factors such as environmental impact resulting from climate change, overstretched or inadequate treatment facilities. Surface and groundwater sources are often polluted by industrial effluents, herbicides and insecticides from agricultural activities and pollution of underground water by percolating polluted water and runoff.

There is an urgent need to develop and promote sustainable cost-effective alternatives that can be applied in combating water-related risk posed by poor drinking water. The utilization of environmentally friendly natural bio-polymers can help mitigate these challenges. Historically, natural biopolymers have been used to clarify drinking water before the discovery of synthetic aluminium and iron salts [4,5]. Although synthetic salts give better results in water purification systems, their drawbacks such as reduction of water pH, impaired efficiency in low-temperature systems and resultant health risk (such as Alzheimer’s disease and prehensile dementia), impact on water conveyance systems (pipe corrosions) outweigh their merits [6] (Srinivasan et al., 1999). On the other hand, the benefits of natural bio-polymers in water treatment are enormous. They have shown advantages in biodegradability, low toxicity and low residual sludge production [7,8]. Most importantly, they are capable of purifying drinking water without significant impact on the pH. Several plant coagulants have been identified by scientists in several parts of the world [8]. Some natural bio-polymers commonly used as primary or auxiliary water clarification process includes Cactáceos, Nirmali (Strychnos potatorum Linn.), Tannins and Moringa oleifera [9,10,8,11]. Among these biopolymers, the use of Moringa oleifera has received the widest attention from researchers. The increasing interest in biopolymers as effective natural alternatives in water purification have endeared them for use in domestic water treatment in rural communities of Africa and Asia [12,13].

The authors aim to investigate the performance of de-oiled jute seed and cottonseed extracts as a contribution to the expanding list of known low-cost, environmental-friendly and sustainable alternative for surface water treatment in rural communities.

2. Materials and Methods

2.1 Seeds Collection and Preparation
Cottonseed (CS) and jute seed (JS) were collected from Adabo market Saki, Oyo State, Nigeria. The seeds were manually selected and milled using a domestic electric blender. The CS powder and JS powder were sieved with a 500 µm sieve. About 20 g of the powdered seeds were placed in three porous thimbles and place in a Soxhlet extractor (with water at 40-70°C) using 500 ml of n-hexane as extractor solvent. The extractors were operated for six (6) hours each. The oil was obtained after evaporation using electrostatic heating mantle to remove the hexane solvent from the extracted oil. The solids were dried at room temperature (33°C) over a period of 24 hours. Figure 1 shows the oil extraction and treatment process. The stock solutions were prepared by dissolving 50 g of the residues (obtained from extraction) in 180 ml of distilled water. The mixtures were stirred for 20 minutes at room temperature (19±2°C) to promote water extraction of the coagulant proteins as described by [14] The solution was then passed through Whatman no.1 filter paper to obtain the filtrate which was used as the stock solution. Figure 1c shows the residue obtained from the extraction process.
Figure 1. Shelled cottonseed (a), Shelled jute seeds (b), Residue of cottonseed after oil extraction (c), Soxhlet apparatus during oil extraction (d), Extracted cottonseed oil (e), Extracted Jute seed oil (f), Stock solution of Jute seed and cottonseed (g - i).

2.2 Water Sample Collection and Characterization
The surface water was obtained from Awba dam reservoir that lies between latitudes 70 26’ to 70 28’ N and longitudes 30 35’ to 30 54’ E. It is located within the premises of the University of Ibadan, Ibadan Nigeria and is a tributary of Ona River. Cheesbrough’s method [15] for stream water sample collection was used to obtain water samples. About 4 litres of the collected sample was transported to the laboratory in an insulated plastic cooler maintained at 4°C. The water samples were analyzed in triplicates for five (5) physico-chemical parameters using standard methods described by APHA [16].

2.3 Batch Treatment Experiments
Different doses of coagulant extracts (10, 20, 30, and 40 ml) were added to 100 ml raw water samples and stirred rapidly using an electric shaker at 120 oscillations per minute for 15 minutes to ensure uniform dispersion of particles and release active components of the seed into the water as reported by Golestanbagh et al. [17]. The 100 ml improvised containers containing the raw water treated with the various volumes of cottonseed and Jute seed extracts were then left to stand for about 6 hours after which the supernatants were separated from the sludge and characterized for some physico-chemical properties (pH, electrical conductivity, turbidity, biochemical oxygen demand and chemical oxygen demand).
3. Results and Discussion

3.1 Characteristics of Awba Dam Reservoir Water

From the analysis carried out on the reservoir water samples, the pH of the raw water sample was slightly alkaline (7.81) and falls within the WHO permissible limit of 6.5 - 8.5. Other physico-chemical parameters of the raw surface water are presented in Table 1.

| S/No | Parameters       | Raw Values  | WHO Guideline |
|------|------------------|-------------|---------------|
| 1    | pH               | 7.81±0.03   | 6.50-8.50     |
| 2    | Conductivity (µs/cm) | 3.82±0.65   | 400.00        |
| 3    | Turbidity (NTU)  | 54.96±4.00  | 5.00          |
| 4    | BOD (mg/l)       | 302.31±12.25| Nil           |
| 5    | COD (mg/l)       | 586.61±14.30| 2.00-5.00     |

A medium ranged turbidity of 54.96 NTU as classified by Doerr [18] was recorded. Doerr categorized water turbidity as Low (<50 NTU), medium (50-150 NTU) and high (>150 NTU). Turbidity describes the cloudiness of the water usually caused by suspended particles, chemical precipitates, organic particles and organisms. The turbidity value of the raw water indicates moderate organic matter and low suspended solids content. However, WHO [19], recommends a turbidity value of not more than 5 NTU for drinking water, it should ideally be below 5 NTU). Electrical conductivity is an estimator that gives the amount of total dissolved salts or ions in water. A low conductivity value of 3.82 µScm was obtained for the raw surface water. This value is by far lower than the WHO permissible limit of 400 µScm. The low reservoir water conductivity may have been influenced by a number of factors such as watershed geology, wastewater from nearby point sources, and runoff from non-point sources, atmospheric inputs, evaporation rates and bacterial metabolism [20].

| S/N   | Parameters | Raw Value | JS Coagulant Dose (ml) | CS Coagulant Dose (ml) |
|-------|------------|-----------|------------------------|------------------------|
| 1     | pH         | 7.81      | 6.89*                  | 5.17                   |
| 2     | Conductivity (µs/cm) | 3.82      | 1.58                  | 2.80                  |
| 3     | Turbidity (NTU) | 54.96    | 24.75                 | 23.50*                |
| 4     | BOD (mg/l)  | 302.31    | 126.32                | 120.55*               |
| 5     | COD (mg/l)  | 586.61    | 214.50                | 208.82*               |

Note: Values in bold with superscripts (*) indicate the optimum physico-chemical parameter values of the treated water sample at optimum doses in comparison with WHO (2017) permissible limits.

3.2 Effect of Coagulant Dose on pH of Treated Water

In line with WHO guideline, the initial pH of 7.81 falls within the acceptable limit. The influence of the two plant coagulants on the pH is presented in Table 2. The cottonseed and Jute seed extracts had significant effects on the treated water pH which decreased from 7.81-5.13 and 7.81-6.64 for CS and JS respectively.
coagulant doses respectively. This collaborates with the findings of Gabriel, et al. (2019) where the pH also decreased from an initial value of 4.8 to 7.1, 6.8, 6.6 and 6.2 with 5, 15, 30 and 50 gL$^{-1}$, of coagulant doses respectively. On the other hand, *Moringa oleifera* coagulant did not influence the water pH, which remained neutral at all doses [21]. A similar trend was also reported by Jones [22]. An overall reduction efficiency of 14.98% and 34.31% at 10 ml dose for CS and JS was obtained for treated water pH (Table 3). While the water treated using jute extract falls below the WHO permissible limits for the selected doses except samples treated with 10 ml doses. The sample treated with CS extract falls within the WHO permissible range given for all samples as shown in Table 1, indicating its performance as a better bio-polymer alternative for surface water treatment.

### 3.3 Effect of Coagulant Dose on Treated Water Conductivity

The EC value of the reservoir water is generally low, indicating a very low dissolution of salts in the reservoir. Electrical conductivity (EC) of the treated water samples using the two plant coagulants are presented in Table 2. It is a direct function of the total dissolved salts in the water, hence the index is used to represent the total dose of soluble salts in water. The conductivity decreased from an initial value of 3.82 to 0.52 and 2.41 µs/cm at 20 ml dose for the two seed extracts respectively (Table 2). An overall optimum reduction efficiency of 32.19 and 58.37% were obtained for CS and JS respectively (Table 3). Both coagulants effectively reduced the conductivity level of the water well below the permissible limit of 400 µs/cm signifying their effectiveness in treating surface water.

### 3.4 Effect of Coagulant Dose on Treated Water Turbidity

Figure 2 illustrates the effect of the different coagulant dosage added to the raw water at a settling time of 6 hours while Table 2 shows the effect of the different coagulant dosage (10, 20, 30 and 40 ml) in treating the reservoir water with initial turbidity of 54.96. The treatments yielded optimum residual turbidity of 17.33 and 23.50 NTU at 10 ml for JS extract and CS extract, yielding optimum turbidity removal efficiencies of 55.51 and 64.56% for CS and JS extracts respectively (Table 3). Though these values lie above the 5 NTU limit set by WHO, there are greater possibilities of further reducing turbidity by increasing the bio-polymer doses [23]. This finding agrees with previous studies by [24] and [25] who used *Moringa oleifera* (MO) extract to treat varying turbidity levels. Natural extracts consist of multiple molecules which exhibit high interaction with particles in water by adsorption and bridging action. Previous researchers have recommended that bio-polymer dosed should be proportionate to the particle dose for effective flocculation activity [26, 27].

![Figure 2](image-url)  
**Figure 2.** Effect of bio-polymer dose on turbidity reduction.
3.5 Effect of Coagulant Dose on Treated Water BOD

Biological Oxygen Demand which is the amount of dissolved oxygen needed by anaerobic biological organisms to break down organic material present in water at a given temperature over a specific period. It has a great influence on its degradable organic material as the higher the BOD, the higher the volume of organic material and the lower the BOD, the lower the organic content. The BOD value was reduced from an initial value of 302.31 mg/l to a minimum value of 120.55 and 149.67 mg/l for JS extract and CS extract respectively. This is accompanied by an overall reduction efficiency of 60.12% for JS extract and 36.86% CS (Table 1 2 and 3). The activity of some inherent micro-organisms in the reservoir could enhance the self-cleaning ability of the water body [28]. According to WHO drinking water guidelines [19], there are no health guidelines proposed for BOD, however, higher values of BOD are a potential threat to aquatic life and prevents the exchange or absorption of dissolved oxygen [28].

Table 3. Optimum removal efficiencies of the biopolymers.

| S/No. | Parameters       | Total Reduction Efficiencies (%) |
|-------|------------------|----------------------------------|
|       |                  | JS Extract | CS Extract         |
| 1     | pH               | 34.31       | 14.98              |
| 2     | Conductivity (µs/cm) | 58.37       | 32.19              |
| 3     | Turbidity (NTU)  | 64.56       | 55.51              |
| 4     | BOD (mg/l)       | 60.12       | 36.86              |
| 5     | COD (mg/l)       | 64.40       | 52.34              |

3.6 Effect of Coagulant Dose on Treated Water COD

Chemical Oxygen Demand indicates the amount of organic compound in water. It is the oxygen required to oxidize soluble and particulate organic matter in water. Treated water COD values ranged from 208.82 - 231.55 mg/l for JS while a higher range of 237.32 - 287.30 mg/l was recorded for CS extract. The COD value reduced from an initial value of 586.61 mg/l to a final value of 208.82 and 237.32 mg/l for JS extract and CS extract respectively. This yielded an overall reduction efficiency of 64.40% for JS extract and 52.34% for CS extract. As shown in Table 3, JS extract recorded a better reduction efficiency despite achieving final COD values that fall below the WHO permissible standard for the two biopolymers.

4. Conclusion

It could be seen from the study that, Jute seeds reduced the pH below WHO recommended values and both Jute seeds and Cottonseed could not reduce the turbidity to 5 NTU WHO limit. Since an appreciable amount of extract is required for a specific quantity of surface water, it may not be economical for commercial applications and could have a negative impact on the water quality after treatment. Synthetic coagulants can be used to argument the efficiency of these biopolymers when a large volume of surface water is to be treated. Further research is also proposed to establish the water pollutant threshold limits under which these bio-polymers will perform optimally.

References

[1] United Nations Sustainable Development Goal 6 2018 Synthesis Report 2018 on Water and Sanitation; United Nations: New York, NY, USA, 2018. http://www.unwater.org/publications/executive-summary-sdg-6-synthesis-report-2018-on-water-and-sanitation/ accessed May 2019

[2] World Health Organization and United Nations Children’s Fund 2017 Progress on
Drinking Water. Sanitation and Hygiene: 2017 Update and SDG Baselines. https://www.who.int/news-room/fact-sheets/detail/drinking-water. (accessed 31 May 2019).

[3] Rosmawanie M., Mohamed R., Al-Gheethi A., Pahazri F., Amir-Hashim M K and Nur-Shaylinda, M Z 2018 Sequestering of Pollutants from Public Market Wastewater Using Moringa Oleifera and Cicer Arietinum Flocculants. Journal of Environmental Chemical Engineering 6 2417-28.

[4] Sutherland, J.P., Folkard, G.K., Grant, W.D. (1990). Natural Coagulants for Appropriate Water Treatment: A Novel Approach. Waterlines. 8 4 30–2.

[5] Asrafuzzaman M., Fakhruddin A N M, Hossain M A 2011 Reduction of Turbidity of Water Using Locally Available Natural Coagulants. ISRN Microbiology 1–6.

[6] Srinivasan P T, Viraraghavan T and Subramanian K S 1999 Aluminium in Drinking Water: An Overview. Water SA. 25 1 47–56.

[7] Beltrán-Heredia J, Sánchez-Martín J and Gómez-Muñoz M C 2010 New Coagulant Agents from Tannin Extracts: Preliminary Optimisation Studies. Chemical Engineering Journal. 162 3 1019-25

[8] Yin C Y 2010. Emerging Usage of Plant-Based Coagulants for Water and Wastewater Treatment. Process Biochemistry 45 1437-444.

[9] Özacer M and Şengil I 2003 Evaluation of tannin biopolymer as a coagulant aid for coagulation of colloidal particles. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 229 1-3 85-96.

[10] Babu R and Chaudhuri M 2005 Home Water Treatment by Direct Filtration with Natural Coagulant. Journal of Water Health 3 27-30.

[11] Kaur A, Kumari C, Tripathi A, Kakade A and Li X 2019 Development and Efficacy Analysis of a Moringa Oleifera Based Potable Water Purification Kit. Journal of Water Process Engineering 27 37-46.

[12] Broin M, Sataella C, Cuine S, Kokou K, Peltier G and Joe T 2002 Flocculent Activity of a Recombinant Protein from Moringa Oleifera Lam. Seeds. Applied Microbiology and Biotechnology 60 114–9.

[13] Fatombi J K, Lartiges B, Aminou T, Barres O and Caillet C 2013 A Natural Coagulant Protein from Copra (Cocos Nucifera): Isolation, Characterization, and Potential for Water Purification. Separation and Purification Technology 116 35-40.

[14] Okuda T, Baes A U, Nishijima W and Okada M 1999 Improvement of Extraction Method of Coagulation Active Components from Moringa Oleifera Seed. Water Research 33 15 3373–78.

[15] Cheesbrough M 2006 District Laboratory Practice in Tropical Countries. Cambridge University Press Pg. 62.

[16] APHA. 1995 Standard Method for the Examination of Water and Wastewater, 18th edition. American Public Health Association. Washington D C

[17] Golestanbagh, M., Ahamad, I.S., Idris, A. and Yunus, R. (2011). Effect of Storage of Shelled Moringa Oleifera Seeds from Reaping Time on Turbidity Removal. Journal of Water and Health. 9 597–602.

[18] Doerr B, 2005 Moringa water Treatment. An Echo Technical Note, Education Concerns for Hunger Organization (ECHO), North Fort Myers, USA.

[19] WHO 2017 Guidelines for Drinking-water Quality, 4th edition, Geneva, World Health Organization. https://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/ (Accessed 11 June 2019).

[20] Pal M, Nihar R, Samal P K R and Malabika B R 2015 Electrical Conductivity of Lake Water as Environmental Monitoring – A Case Study of Rudra Sagar Lake Electrical Conductivity of Lake Water as Environmental Monitoring – A Case Study of Rudrasagar Lake. Journal of Environmental Science, Toxicology and Food Technology 9 3 66-71.

[21] Adesina O A, Fatima A, Adeyinka Y, Mayowa L and Akindele O 2019 Response Surface
Methodology Approach to Optimization of Process Parameter for Coagulation Process of Surface Water Using Moringa Oleifera Seed. *South African Journal of Chemical Engineering*. In Press.

[22] Jones A N 2018 Evaluating the Water Treatment Potential of Hibiscus *Sabdariffa* Extracts. *Nigerian Research Journal of Engineering and Environmental Sciences* **3** 2 665-73.

[23] Gabriel M, Mpeketula M and Monjerezi A 2019 Evaluation of Coagulating Efficiency and Water Borne Pathogens Reduction Capacity of Moringa Oleifera Seed Powder for Treatment of Domestic Wastewater from Zomba, Malawi. *Biochemical Pharmacology*. In Press.

[24] Muyibi S A and Evison L M 1995 Optimizing Physical Parameters Affecting Coagulation of Turbid Water with Moringa Oleifera Seeds. *Water Resources* **29** 2689-95.

[25] Katayon S, Megat Mohd Noor M J, Asma M, Thamer M A, Liew Abdullah A G, Idris A, Suleyman A M, Aminuddin M B and Khor B C 2004 Effects of Storage Duration and Temperature of *Moringa Oleifera* Stock Solution on its Performance in Coagulation. *International Journal of Engineering and Technology* **1** 146-51.

[26] Gregory J 2005 Particles in Water: Properties and Processes. CRC Press Taylor and Francis Group, IWA publishing, Caxton Street, London. 1-179.

[27] Gregory J and Barany S 2011 Adsorption and Flocculation by Polymers and Polymer Mixtures. *Advances in Colloid and Interface Science* **169** 1-12.

[28] Narasimha G, Sridevi A, Reddy A V S and Reddy B R 2011 Effect of Cotton Ginning Mill Effluents on Soil Enzymatic Activities and Nitrogen Mineralization in Soil. *Journal of Chemical and Pharmaceutical Research*. **3** 128-37.