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Assessment of *Azadirachta indica* and *Moringa oleifera* Leaves Powders as Alternative Coagulants for Water Purification

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Abstract

Azadirachta indica and *Moringa oleifera* leaves were assessed in relation to alum as alternative coagulants for raw water treatment. After the treatment of the raw water with these biomaterials; pH, turbidity, hardness, microbial count, and the conductivity of the resultant water was analysed. The results of the research show that neem leaves powder treated water had the pH within the range 6.79 ± 0.00 - 6.76 ± 0.01. Whereas, the pH range of 6.78 ± 0.01 - 6.88 ± 0.01 was found after the treatment of the raw water with *Moringa oleifera*. More so, the alum treated water had range of pH values as 3.36 ± 0.02 - 3.43 ± 0.01. The turbidity of the raw water was found to be 241.00 ±3.61 NTU. After treatment with the various coagulants, the following results were obtained: neem (84.33 ± 4.04 - 115.00 ± 5.00) NTU, moringa (126.00 5.29 - 161.00 ± 3.61) NTU, neem + moringa (37.33 ± 1.16 - 76.33 ± 1.53) NTU, and alum (67.40 ± 1.91 - 84.20 ± 3.33) NTU. In addition, the results indicated that the biomaterials acted comparably to alum with respect to hardness removal. More so, the electrical conductivity (EC) of the water was increased after the treatments with these coagulants, especially with the alum. The microbial load analyses showed that the neem and moringa treated water have less microbes than the alum. Though alum seems to have better performance for turbidity removal, however, the overall results are comparable. Again, the alum can be combined with these biomaterials in water purification seen that the biomaterials are more available, have better antimicrobial actions, and are known to have phytochemicals that give health benefits. In nutshell, waste water can be purified effectively with neem and moringa leaves powder.

Keywords: Biocoagulants; Sustainable process; Water purification; Kaana Asemave.

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1. Introduction

Water pollution from agricultural practices, domestic, and industrial activities have become a major problem facing developing countries and by extension a serious problem for the entire world [1–3]. Chemical substances [4], colloidal solids [5], loosen soil particles, agrochemical residue, industrial waste, run off etc are some the pollutants in question [6]. These pollutants can produce turbidity and colour that do not readily settle. Many across the world have no access to clean drinking water making people prone to water borne diseases such as cholera, typhoid, dysentery and diarrhea resulting to even death [7]. Thus, water pollution has serious environmental and human health impacts [8]. On the other hand, coagulation is the physicochemical process that involves the destabilization of colloidal suspended particles upon the addition of coagulant [9]. Coagulants are chemical substances which provide the purification mechanism for the removal of pollutants that are present as turbidity, color, and organic matters. They are also used to reduce the metal ion content in water. Thus, coagulation process is achieved by the addition of synthetic coagulant or biocoagulant followed by slow agitation (flocculation) that causes coagulation of colloidal particles so they can be separated by sedimentation [10]. Coagulation can be electrostatic coagulation (electrocoagulation), adsorptive coagulation, or precipitation coagulation (sweep coagulation). Adding a coagulant to water causes neutralization of the electrostatic surface potential of the particles. The resulting destabilized particles stick together upon contact forming larger solids known as 'flocs' sedimentation [5]. The common chemicals used to aid coagulation are aluminium sulphate ($Al_2(SO_4)_3$), ferric sulphate ($Fe_2(SO_4)_3$)[5,11], and also calcium hypochlorite. However, the use of conventional chemicals for water purification require skills in handling them (even to avoid their toxicity) and are costly; hence may be unavailable to rural localities. In developing countries, many people rely on dams, small streams, rivers, and lakes which are usually turbid and contaminated with microorganisms that may cause various diseases [10]. Therefore, in recent times, plant materials such as *Moringa oleifera*, *Jatropha curcas*, *Guar gum*, *Strychnos potatorum*, *Hibiscus sabdariffa*, and *Clidemia angustifolia* etc have been used as coagulants [5]. Furthermore, comparative studies of biocoagulants showed that banana peel powder was found to be the most effective, while banana stem juice had poor coagulation activity relative to papaya seed and neem leaf powders [11]. Other species of plants demonstrated as biocoagulants include; *Canna indica, Tamarindus indica, Typhaceae Family, Adenanthera pavonina, Azadirachta indica, Musa genus, Brassica genus, Sinapis genus* [9]. Also the synergy between *Moringa oleifera* seed powder and alum in the purification of domestic water was studied and found to have favourable characteristics at 60% alum and 40% *moringa oleifera* [7,12]. In addition, the use of biomass for purification of water is completely in line with the principles of Green Chemistry for use of renewable, benign, and biodegradable materials[13–21] in chemical process for sustainability. The benefits of this greener approach ranges from biodegradability [22], less toxic, non-corrosive [23], less cost, high availability, and renewable sources. Much more, they produce less sludge with high nutritional value [9,24]. More so, these materials do not affect the pH of the water under treatment [25]. Despite these advantages, natural coagulants are not widely deployed or domesticated in places where they are available [24]. Therefore, the aim of the research is to add credence on use and application of appropriate biomass as coagulant in water purification by looking at comparative assessment of neem and *Moringa oleifera* leaves powder in relation to alum.

2. Materials and methods

Flocculator, standard glassware, standard analytical tools, distilled water, leaves of *Moringa orifera* and neem plants were collected and used.

2.1. Sample preparation

Both the *Moringa orifera* and neem leaves were obtained fresh, washed separately with distilled water, and shade- dried for few days. Thereafter, they were subjected to hot air oven drying at 35 ºC to a constant weight and then crushed directly with grinder to powder form. The resulting materials were sieved by the IS standard sieve size of 90 micron. The obtained powder was then packaged and stored under a cool dry atmosphere for subsequent experiment [11,26]. See the materials in Figure 1.

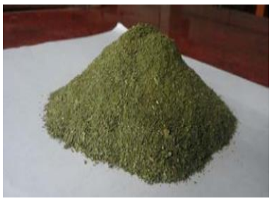
a  b 

Figure 1: The biomass used (a) neem leaves powder (b) Moringa Orifera leave powder

2.2. Methods

Jar test: Jar test apparatus or flocculator was used for coagulation experiments. The apparatus consists of four 1000 mL beakers and four paddles (20-200 rpm) that were used to analyze different samples simultaneously. The different coagulants (0.4 – 1.0 g/L)/ 1 L were charged into the raw water in each beaker. Initial slow stirring at 50 rpm for 15 min, followed by a rapid mixing at 150 rpm for 10 min, and then slow stirring at 50 rpm for 15 min were carried out. Finally the samples were allowed to settle for 30 min and supernatant waters were filtered and analyzed [26,27]. The filtered supernatant was used for determining different parameters including pH, turbidity, total hardness, electrical conductivity, and microbial count. The analyses were performed at room temperature, following the standard procedure for laboratory analysis of water adopted by the Benue State Water Board, in line with international best practices [28].

pH determination: The pH was determined with pH meter

Turbidity: This was determined using a turbidity meter. The turbidity meter was standardized with distilled water. The water sample was thoroughly shaken and a portion of it poured into the sample tube, making sure that no air bubbles are trapped. The sample tube was shaken vigorously and then thoroughly wiped dry and inserted into the sample holder of the meter and the reading noted. Calibration curve was prepared from standard turbidity suspension (Formazin Polymer which is a product of hydrazine sulphate and hexamethylenetetramine). Standard solutions of the suspension of concentrations of 5, 10, 15, 20, 25 and 30 cm^3 was prepared and used to determine the turbidities of the samples and to calibrate the instrument

[29]. Total hardness: The total hardness of the water samples were analyzed thus, about 10 mL of the water was measured into a beaker, to which three drops of buffer solution of pH = 7 was added and further a drop of maver hardness (indicator) added the solution was swirled to mix properly and titrated against EDTA [58]. $Total\ hardness\ (CaCO_3/L) = \frac{A \times B \times 1000}{mL\ Sample}$; Where A = volume ($cm^3$) of EDTA titrated with the sample; and B = mg $CaCO_3$ equivalent to 1.00 cm^3 EDTA. Electrical conductivity: The conductivity of the water sample prepared for analysis was determined with a conductivity meter [30]. Microbial test: The microbial test was carried out using the total plate count (TCP) media, which was prepared by dissolving 20.5 g of the TCP powder in 1 L of distilled water, autoclaved and allowed to cool. The TCP media was then poured into Petri dishes labeled 1 to 7 and inoculated for 24 h in an electro-thermal incubator. The growth of the microorganisms was then observed and counted per mL (number of microorganisms per mL of water samples) [12]

3. Results and discussion

The raw water was treated with varying amount (0.4 - 1 g/L) of the coagulants in order to find the optimal concentration of the coagulant. The experiments were conducted in triplicate hence the values are reported as the means ± the standard deviations for the various parameters tested. Therefore, the results of treated raw water with neem leaf powder, moringa leaf powder, mixture of neem and moringa leaves powders, and alum are represented in Tables 2, 3, 4, 5, respectively. Meanwhile, Table 1 gives the pH, turbidity, hardness, microbial count, and electrical conductivity of the raw water before the treatments.

Table 1: The raw water sample analysed parameters

pH	Turbidity (NTU)	Hardness (mg/L)	Microbial count (MPN)	Electrical conductivity (µS/cm)
6.86 ± 0.00	241.00 ±3.61	93.33 ± 23.09	220.00 ± 0.00	78.33 ± 0.58

Table 2: The values of the water parameters after treatment with neem leaves powder

Coagulant amount (g/L)	pH	Turbidity (NTU)	Hardness (mg/L)	Microbial count (MPN)	Electrical conductivity (µS/cm)
0.4	6.79 ± 0.00	97.67 ± 2.52	106.67 ± 11.55	173.33 ± 5.77	135.00 ± 0.00
0.6	6.79 ± 0.01	84.33 ± 4.04	86.67 ± 11.55	166.67 ± 15.28	143.33 ± .58
1.0	6.76 ± 0.01	115.00 ± 5.00	100.00 ± 20.00	163.33 ± 28.87	202.00 ± 3.46

Table 3: The values of the water parameters after treatment with *Moringa oleifera* leaves powder

Coagulant amount (g/L)	pH	Turbidity (NTU)	Hardness (mg/L)	Microbial count (MPN)	Electrical conductivity (µS/cm)
0.4	6.88 ± 0.01	135.00 ± 5.00	73.33 ± 11.55	213.33 ± 5.78	114.67 ± 8.08
0.6	6.81 ± 0.00	126.00 ± 5.29	86.67 ± 11.55	186.67 ± 11.55	121.00 ± 0.00
1.0	6.78 ± 0.01	161.00 ± 3.61	66.67 ± 11.55	180.00 ± 0.00	150.00 ±0.00

Table 4: The values of the water parameters after treatment with neem and *Moringa oleifera* leaves powder

Coagulant amount (g/L)	pH	Turbidity (NTU)	Hardness (mg/L)	Microbial count (MPN)	Electrical conductivity (µS/cm)
0.4	6.71 ± 0.01	43.33 ± 1.53	86.67 ± 11.55	166.67 ± 23.09	107.33 ± 0.58
0.6	6.66 ± 0.01	37.33 ± 1.16	106.67 ± 11.55	153.33 ± 23.09	142.33 ± 0.58
1.0	6.64 ± 0.00	76.33 ± 1.53	80.00 ± 0.00	126.67 ± 11.55	157.67 ± 0.58

Table 5: The values of the water parameters after treatment with alum

Coagulant amount (g/L)	pH	Turbidity (NTU)	Hardness (mg/L)	Microbial count (MPN)	Electrical conductivity (µS/cm)
0.4	3.43 ± 0.01	84.20 ± 3.33	93.33 ± 11.55	213.33 ± 5.78	279.67 ± 4.73
0.6	3.36 ± 0.02	76.03 ± 2.75	86.67 ± 11.55	190.00 ± 17.32	347.00 ± 1.00
1.0	3.40 ± 0.04	67.40 ± 1.91	90.00 ± 10.00	180. 00 ± 0.00	491.67 2.89

3.1. Effect of the coagulants on pH

The neem leaf powder treated water had the pH within the range 6.79 ± 0.00 - 6.76 ± 0.01. Whereas, the pH range of 6.78 ± 0.01 - 6.88 ± 0.01 was found after the treatment of the raw water with *Moringa oleifera*. When the neem and moringa leaves powders were combined and used for the raw water treatment, 6.64 ± 0.00 - 6.71 ± 0.01 varying pH were noted. More so, the alum treated water had range of pH values as 3.36 ± 0.02 - 3.43 ± 0.01; which is lower than that pHs found in the case of neem and moringa (see details in Table 2-5). Meanwhile, the acceptable pH by WHO for potable water is 6.5 – 8.5 [31,32]. The lower pH after treatment with alum is because of the produced sulphuric acid [33]. This is also due to the trivalent cation aluminium which serves a Lewis acid [34]. In the case of the biocoagulants the pHs remain fairly constant (about 6) and were within acceptable levels. Our findings again are similar to previous report of Aishwarya and his colleagues [32]. In fact, this is one copious demerit of alum in water purification [25]; making the pH of water to be lower. Though this issue can be corrected by adding lime, it can bring more cost in water purification.

3.2. Effect of the coagulants on turbidity

The permissible limit set by the WHO, Environmental Protection Agency, the NAFDAC, and other regulatory bodies for turbidity of potable water is 1 to 7 NTU [35,32]. In this study, the values of turbidity obtained were all above the standard value. However, significant reduction in turbidity was observed with the biocoagulants as well. The turbidity of the raw water was found to be 241.00 ±3.61NTU. After treatment with the various coagulants, the following results were obtained: neem (84.33 ± 4.04 - 115.00 ± 5.00) NTU, moringa (126.00 5.29 - 161.00 ± 3.61) NTU, neem + moringa (37.33 ± 1.16 - 76.33 ± 1.53) NTU, while, alum (67.40 ± 1.91 - 84.20 ± 3.33) NTU, see the details in Tables 2-5. The results showed reduction in turbidity on moving from dosage 0.4 to 0.6 g/L; and a sudden increase moving from 0.6 to 1.0 g/L with the biomass, unlike the alum. In general, the results of the removal of the raw water turbidity with these coagulants were comparable, especially the alum and the blend of neem + moringa leaves powders. Furthermore, the sudden increase in the turbidity after the optimum dosage concentration (0.6 g/L of the biocoagulants) can be associated to the subsequent contribution by the leaves powder particles since their presence supersedes the amount needed. Turbidity is directly correlated with the presence of clay particles, sewage solids, silt, sand washings, organic, and biological sludges present in water. Pathogenic organisms may be shielded by these particles and hence, escape disinfection. This parameter is also correlated to many other important parameters and the overall acceptability of water may be questioned when the turbidity is high [36]. However, this challenge can be overcome by filtering the water after treatment with the biocoagulants. Similarly, cactus and neem leaf powder were used as alternative coagulants in treatment of wastewater, it was found that the turbidity reduced by 65% and 55%, respectively. Furthermore, when 50:50 ratio of the biocoagulants and alum were used, the turbidity reduced down to 95% and 96%, respectively [26]. In a similar vein, turbidity reduction using biocoagulants in synergy with alum had efficiencies of about 95% and 96% for neem leaf and opuntia powders, respectively [39]. Also, efficiencies of turbidity removal was observed as 98%, 96%, and 98.8%, respectively with the use of neem leaf, orange peel powder, and alum as coagulants in treatment of dairy wastewater [27]. In another related research, it was observed that turbidity was decreased by 90% by using *Moringa oleifera* at dosage of 4 g/L [37]. In general, the ability of these biocoagulants in turbidity removal is comparative to alum. It has been particularly found that the active component of *M. oleifera* causing coagulation is the soluble protein that acts as a natural cationic polyelectrolyte during treatment and causes coagulation in turbid water [34,38]. Similarly, comparison of turbidity removal in water using alum and moringa was carried out and these coagulants were all found to be effective. However, the dosages required were different. The dosage required by the *Moringa oleifera* was 100 mg/L and for the same removal the dosage consumed in the case of alum was higher as 240 mg/L [33]. Also, previous report has it that batch coagulation test involving moringa, okra, Cassia auriculate, and C. procera gave maximum turbidity removal efficiencies of 55%, 58%, 52%, and 62%, respectively; for low turbid water and 86%, 83%, 68% and 73%, respectively for high turbid water. Thus, biocoagulants have bright future, because they are abundant, low price, environment friendly, multifunctionality, and their biodegradable nature in water purification [33].

3.3. Effect of the coagulants on hardness

The raw water sample itself has hardness level of 93.33 ± 23.09 mg/L which is in conformity with the acceptable amount of hardness for potable water [32]. The acceptable value for the hardness of potable water is 200 to 600 mg/L [35]. The results indicated that there was no much effect of the coagulants on the water hardness (look up for the details in Tables 1-5). Hardness determines the soap-consuming characteristics of water which results in formation of scum when soap is added. It leads to formation of deposition of scale in boilers, water heaters, and pipes. Hardness contributed by calcium and magnesium, bicarbonate and carbonate mineral species in water is called carbonate hardness; otherwise is called noncarbonate hardness (calcium chloride or magnesium sulphate are the precursors). Water that has hardness less than 61 mg/L is considered soft; 61-120 mg/L, moderately hard; 121-180 mg/L, hard; and more than 180 mg/L, very hard. Hardness aside being a natural characteristic of water, it enhances water palatability for drinking purposes. And most importantly, health studies in several countries in recent years indicate that mortality rates from heart diseases are lower in areas with hard water. It is understood that the chief disadvantages of hard waters are that they neutralize the lathering power of soap and more important, that they can cause blockage of pipes and severely reduced boiler efficiency because of scale formation. These effects will increase as the hardness rises to and beyond 200 mg/L [36].

3.4. Effect of the coagulants on electrical conductivity

The electrical conductivity (EC) is a physical parameter and has no direct health significance, however, conductivity shows significant correlation with parameters such as temperature, pH value, alkalinity, total hardness, calcium, total dissolved solids, chemical oxygen demand, chloride, and iron concentration of water [40]. The electrical conductivity value for the raw water was found to be 78.33 ± 0.58 µS/cm. However, the treatment with all the coagulants has increased the EC to rather higher values. This observation is so because the EC parameter measures the amount of conducting ions present in the sample. Thus, the coagulants have contributed ions into the water, hence the EC became high, especially with the alum. The varying EC obtained after the water treatment were; neem (135.00 ± 0.00 to 202.00 ± 3.46) µS/cm, moringa (114.67 ± 8.08 to 150.00 ± 0.00) µS/cm, neem + moringa (107.33 ± 0.58 to 157.67 ± 0.58) µS/cm and alum (279.67 ± 4.73 to 491.67 ± 2.89) µS/cm. Note again that conductivity is a measure of total dissolved solids (TDS) water and it varies considerable in different geographical regions owing to differences in the solubility of minerals; hence there is no standard value for it but high levels of it in drinking water maybe objectionable to consumers [34].

3.5. Effect of coagulants on microbial status of the water

The microbial status of the raw water sample was determined to be 220.00 ± 0.00 MPN. After treatment with the various coagulants, it was found that the combined coagulants (neem + moringa) gave the best result in the reduction of the microorganisms in the range of 126.67 ± 11.55 to 166.67 ± 23.09 MPN; unlike the conventional coagulant, alum which exhibited poor ability for microbial reduction. Similarly, the disinfection of drinking water in rural area using natural herbs (*Ocimum sanctum* and *Azadirachta indica*) confirmed antimicrobial activities of these plant materials against *Salmonella typhi* [41]. It is important to emphasize here that biocoagulants have been know to reduce microbial load better than alum, in addition to their effective reduction of turbidity in water, like alum. However, some weaknesses of biocoagulants in water purification include: application of high dosage which results in the increase of the concentration of total organic carbon (TOC) in the water. sedimentation time is relatively long compare to alum and as a consequence the water production rate will be decreased. Bacterial removal is not complete, therefore, a risk of secondary bacterial growth is possible to happen if water kept for long time [42].

4. Conclusion

The results of this study have revealed that neem and moringa leaves powders are effective alternative coagulants to the conventional alum for water purification. The biomaterials outperformed alum by producing treated water with appropriate pH and lesser microbial load. In addition, the performance of the biomaterials in turbidity removal are comparable to alum. Perhaps, for most effective result there is need for combination of alum with these biomaterials in water purification seen that the biomaterials are more available, better antimicrobial agents, and are known with phytochemicals of health benefits.

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