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Effectiveness of *Moringa oleifera* seed as coagulant for water purification

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The high cost of treated water makes most people in the rural communities to resort to readily available sources which are normally of low quality exposing them to waterborne diseases. It is in this light that this research was carried out to confirm the effectiveness of powder extracted from mature-dried *Moringa oleifera* seeds which is commonly available in most rural communities of Africa. This was done using Completely Randomised Design with loading doses of 4, 6, 8, 10, and 12 g/L of the powder processed from *Moringa* seeds, and aluminium sulphate (alum) as coagulant. A control (water from the pond with only distilled water without alum and *Moringa* treatments) was also included. The turbidity, pH, and conductivity and total coliform were determined for all the samples. The turbidity for the samples ranged from $\log_{10}0.30$ to $\log_{10}1.36$NTU while the conductivity ranged from $\log_{10}2.29$ to $\log_{10}2.72$ µS/cm. The 12 g/L treatment of *Moringa* and 10 and 12 g/L alum treatments gave values that are acceptable according to the World Health Organisation (WHO) guidelines for safe drinking water. The control sample gave the higher extremes values which are unacceptable. The pH values (7.29 to 7.89) obtained for the treatments were in the recommended range set by WHO. The Most Probable Number per 100 ml for total coliform counts had values from 2 to 17 at 95% confidence limits. The *Moringa* treatment gave lower counts. Findings of this research lend support to earlier works recommending the use of *Moringa* for water treatment.

Key words: Water, powder, Moringa, alum.

INTRODUCTION

Water is used for several purposes by humans but the level of purity of the water being consumed is very crucial since it has a direct effect on health. The conventional method of water purification using aluminium sulphate (alum) and calcium hypochlorite puts pressure on the nation's over-burdened financial resources since they are imported thereby making treated water very expensive in most developing countries and beyond the reach of most rural folks. Hence, they resort to sources such as dams, dug outs, streams, rivers, and lakes. Water from these sources is usually turbid and contaminated with micro-organisms that cause many diseases including guinea worm and bilharzia. According to Postnote (2002), water-borne diseases are one of the main problems in developing countries; about 1.6 million people are compelled to use contaminated water and more than a million people (of which two million are children) die from diarrhoea each year.

Earlier research findings of Crapper et al. (1973) and Miller et al. (1984) showed that the chemicals used for water purification can cause serious health hazards if an error occurs in their administration during the treatment process. These reports suggested that a high level of aluminium in the brain is a risk factor for Alzheimer's disease. However, Davis (2006) found no conclusive evidence linking aluminium with Alzheimer's disease. Also, studies by workers (Letterman and Driscoll, 1988; Mallevialle et al., 1984; Miller et al., 1984) have raised doubts about the advisability of introducing aluminium into the environment by the continuous use of aluminium sulphate as a coagulant in water treatment.

There is therefore the need to investigate the use of non-chemicals which would be available locally in most developing countries. The use of natural materials of

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plant origin to clarify turbid water is not a new idea (Bina, 1991; Folkard et al., 1989; Jahn, 1986, 1988; Kaser et al., 1990; Sani, 1990; Sutherland et al., 1992) cited by Ndabigengesere et al. (1995) and Madsen et al. (1987). Among all the plant materials that have been tested over the years, powder processed from the seeds from *Moringa oleifera* has been shown to be one of the most effective as a primary coagulant for water treatment and can be compared to that of alum (conventional chemical coagulant) (Madsen et al., 1987; Oslen, 1987; Postnote, 2002). It was inferred from their reports that the powder has antimicrobial properties. Earlier studies have found *Moringa* to be non-toxic (Grabow et al., 1985), and recommended it use as a coagulant in developing countries (Barth et al., 1982; Bhole, 1987; Jahn, 1988; Müller, 1980) cited by Ndabigengesere et al. (1995) and Olsen (1987). The use of *Moringa* has an added advantage over the chemical treatment of water because it is biological and has been reported as edible. However, not much has been done in Ghana using *Moringa* as a coagulant in water purification system. The cost of this natural coagulant would be less expensive compared to the conventional coagulant (alum) for water purification since it is available in most rural communities in Ghana where treated water is a scarce resource. It is in this light that this research was carried out to confirm the effectiveness of powder extracted from mature-dried *Moringa oleifera* seeds which is commonly available in most rural communities in Ghana.

It is a well established fact as proven in several publications that the quality parameters of drinking water include its turbidity, conductivity, pH and microbial load.

The main objective of this study is to confirm the effectiveness of powder processed from *M. oleifera* seeds as water coagulant.

MATERIALS AND METHODS

Coagulants used

The seeds were harvested when they were fully matured. This is determined by observing if there are any cracked pods on the plants. The pods that were plucked were cracked to obtain the seeds which were air-dried at 40°C for two days. The shells surrounding the seed kernels were removed using knife and the kernels were pounded using laboratory mortar and pestle into powder and sieved using a strainer with a pore size of 2.5 mm² to obtain a fine powder. This method is a slight modification of the one proposed by Ghebremichael (2004). This was the coagulant prepared from *Moringa.*

The aluminium sulphate (alum) used in the study was obtained from the Bolgatanga branch of Ghana Water Company.

Experimental design

A Completely Randomised Design was used for this experiment. The treatments given were the varying concentrations of alum, powder produced from *Moringa* seeds, and the control (no alum or *Moringa* powder). Each treatment effect on the response (turbidity, pH, conductivity, total coliform counts) was repeated 4 times except the total coliform count which was carried out in triplicates.

Sample preparation

Fifty (50) litres of sample was fetched from a pond situated behind the Navoro Hall of the Navrongo Campus, University for Development Studies. This was further dispensed into 33 beakers. The volume of sample in each beaker was 1000 ml.

Five different concentrations of the stock solutions for the loading dose were prepared by weighing 4.0, 6.0, 8.0, 10.0 and 12.0 g of alum and *Moringa* powder separately into a beaker containing 1000 ml of distilled water. The mixtures in the beakers were stirred using a glass rod to obtain a clear solution. A 1000 ml of distilled water with no alum or *Moringa* powder was kept as the control treatment.

Laboratory analyses

The jar test was used. A 3 ml of the various concentrations including the control of all the loading dosages prepared were measured into a beaker containing 1000 ml of the pond water. The solutions were mixed rapidly for 2 min; followed by 10 min of gentle mixing using glass rod to aid in coagulant formation. The suspensions were left to stand without disturbance for 1 h. This is the method adopted since there is no standard method for conducting the jar test (Ndabigengesere et al., 1995). The supernatants formed were decanted and subjected to turbidity, pH, conductivity, and total coliforms count measurements.

pH measurement

The pH of the sample was read using a calibrated Crison pH meter Basic C20. A volume of 200 ml of the supernatants obtained from the beakers containing the treatments was measured into a beaker. The pH meter probe was then inserted making sure it did not touch the beaker. The pH reading was then taken from the LCD display after it had stabilized.

Conductivity measurement

The samples used for the pH measurements were used for the conductivity test. A calibrated Crison Conductimeter Basic C30 was used. The conductivity meter probe was then inserted making sure it did not touch the beaker. The reading was recorded from the LCD display after it had stabilized.

Turbidity measurement

This was carried out on supernatants obtained after the treatments have been administered into the beakers containing the pond water using a HACH DR/2000 Direct reading spectrophotometer from Ghana Water Company Limited, Bolgatanga Branch. This is a multipurpose spectrophotometer. It was configured to read turbidity at the wavelength of 750 nm specified for measuring turbidity. Distilled water was first poured into a 25 ml cuvette and inserted into the spectrophotometer. The calibration button was pressed and the instrument was then calibrated. Each of the samples to be read was poured into a 25 ml cuvette and inserted into the spectrophotometer. The turbidity of the samples was displayed on the LCD panel of the instrument in Nephelometric Turbidity Units (NTU). After each reading, the spectrophotometer was calibrated again with the distilled water before being used on the next sample.

Total coliform using most probable number (MPN) procedure

In determining the most probable number of coliforms that were present in each of the treated water samples, the multiple tube fer
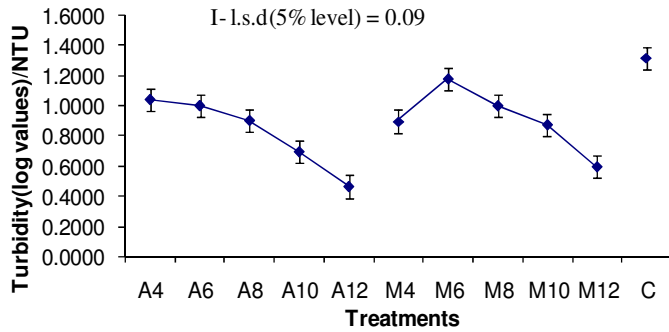
Figure 1. Effect of *Moringa* and alum as coagulant at varying concentrations on turbidity of pond water

fermentation method was adopted. Lactose broth was used as the medium for the bacteria growth. Two types of the lactose broth were prepared. These were the single strength lactose broth (SSLB) and the double strength lactose broth (DSLB).

In the single strength, 13.0 g of the lactose powder was weighed and dissolved in 1000 ml of distilled water. An amount of 0.08 g Alazin Red was measured and added to the solution. The solution was then stirred gently for 10 min on a magnetic stirrer to dissolve and mix well.

The double strength was prepared using exactly a double of each of the weights of the reagents used. This solution was put on a magnetic stirrer and stirred gently for 10 min.

A volume of 1.0 ml of the control, 10.0 and 12.0 g of both *Moringa* and alum treatments supernatants were measured and introduced into test tubes containing 10 ml of the double strength lactose broth and 10 ml of the single strength lactose broth. Another volume of 0.1 ml of the same supernatants above was measured and introduced into another set of test tubes containing 10 ml of the single strength lactose broth. The test tubes were then incubated for 24 h at 37°C after which they were analysed. The results obtained were compared with Wright et al. (2004) to obtain the most probable number at 95.0% confidence level.

Data analysis

Analysis of variance (ANOVA, General Linear Model Procedure) was conducted to assess whether significant ($p < 0.05$) variations existed among the treatments given to assess their effectiveness as water coagulants. The data generated for conductivity and turbidity were transformed into log values before the analysis. Multiple mean comparisons using least significant difference (LSD) were computed to ascertain where the differences existed. Analysis of data was computed using GenStat Discovery Edition III, 2008.

RESULTS AND DISCUSSION

From Figure 1 above, the turbidity values ranged from $log_{10}0.30NTU$ to $log_{10}1.36NTU$ for all the treatments used. Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibres, saw-dust, wood ashes, chemicals and coal dust. Any substance that makes water cloudy will cause turbidity (http://www.h2ou.com/h2wtrqual.htm#References). The treatments used gave significant differences ($p < 0.001$) on turbidity. The declared WHO guideline for conductivity provided for safe drinking water is 5NTU ($log_{10}0.700NTU$)

(WHO, 2006). The 10.0, 12.0 g of alum, and 12.0 g of *Moringa* treatments recorded values that were acceptable according to the WHO (2006) guideline for drinking water. As expected, the control treatment gave the highest turbidity value of $log_{10}1.32NTU$.

It is clearly seen that higher concentrations of *Moringa* powder of 12.0 g/1000 ml loading dose as coagulant gives similar effect on turbidity compared with alum of loading doses of 10.0 g/1000 ml and 12.0 g/1000 ml. This shows that *Moringa* can be adopted for water purification. This is likely to lead to cost reduction in the conventional water treatment using alum and no threat to human life in case of overdose as stated in the findings of Crapper et al. (1973), Kaggwa (2001) and Martenson et al. (1995). The method of allowing water to settle without any coagulant is not efficient as proven by the treatment results. The result of this study shows that the quality of water for consumption for rural communities in Ghana can be improved by first adding powder from *Moringa* before the generally recommended "boil before use" strategy (Figure 2).

Conductivity which is a measure of total dissolved solids (TDS) in water 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 (WHO, 2006). The conductivity ranged from $log_{10}2.29$ to $log_{10}2.72$ µS/cm for the varying concentrations of all the coagulum used. The F-test p-value less than 0.001 indicate that there are significant differences among the means due to the concentrations of the different coagulants use. The conductivity value of $log_{10}2.72$ µS/cm recorded for the control was extremely high indicating the presence of dissolved impurities. This indicates that turbid water which is allowed to stand with no treatment is an inadequate procedure for removing dissolved and floating particles. It could be efficient if the turbid water is left to stand for a very long time. The conductivity measurements followed a similar pattern as the turbidity measurements. Increasing concentrations of both the alum and *Moringa* treatments led to decrease in conductivity values. It can be deduced that higher loading dose other than the ones used for *Moringa* in this work can be adopted to decrease water conductivity and turbidity in water meant for consumption in most rural communities in Ghana. The *Moringa* treatment values ranged from $log_{10}2.34$ to $log_{10}2.50$ µS/cm; and $log_{10}2.30$ to $log_{10}2.49$ µS/cm when the alum was used.

pH

At 95.0% confidence level, there was significant difference ($p < 0.001$) among all the treatments at the varying loading dose concentrations on the pH. The recommended acceptable range of pH for drinking water specified by WHO (2006) is between 6.0 and 8.0. The treatments gave a range of 7.2 to 7.9 which falls within the
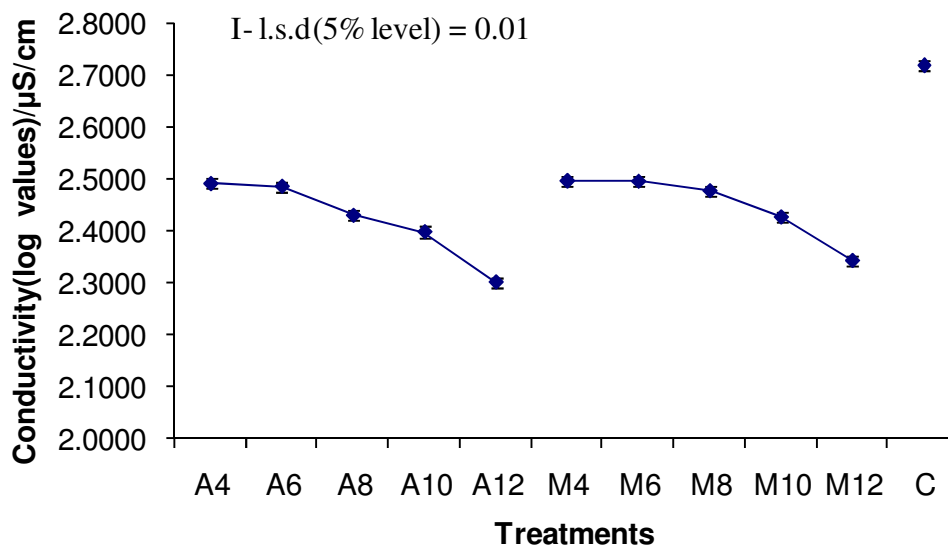
Figure 2. Effect of *Moringa* and alum as coagulant at varying concentrations on conductivity of pond water.
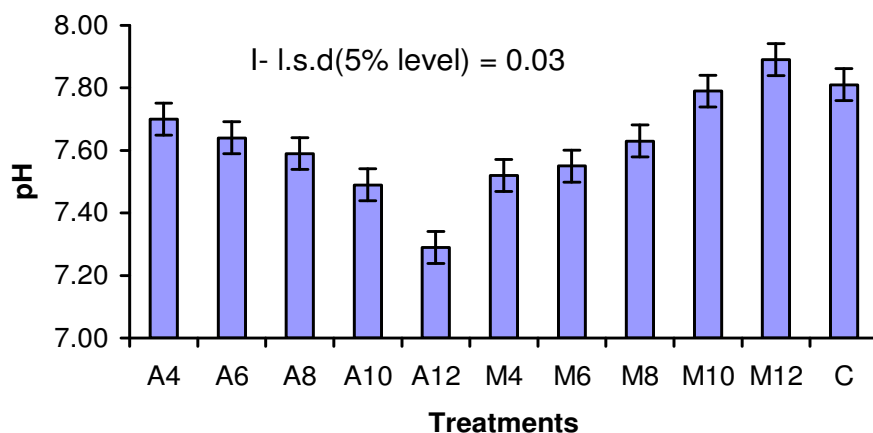
Figure 3. Effect of *Moringa* and alum as coagulant at varying concentrations on pH of pond water. A(x): Alum at xg/1000 ml; M(x): *Moringa* at xg/1000 ml; C: Control

Table 1. Total coliform counts per 100 ml of the samples.

Sample	DSLB 10 ml	SSLB 1 ml	SSLB 0.1 ml	MPN/100 ml*
A4	3	0	0	8
M4	0	1	0	2
A5	3	0	0	8
M5	1	0	0	2
C	3	2	1	17

* Most Probable Number (MPN) at 95% confidence level
DSLB   Double strength lactose broth SSLB Single strength lactose broth. **Source:** Wright et al. (2004)

reduced as the concentrations of the dosing solutions were increased. This could be explained by the fact that the solutions were becoming more acidic. This was attributed to the fact that the alum in the treatment procedure produced sulphuric acid which lowered the pH levels. The increase in acidity could be due to the trivalent cation aluminium which serves a Lewis acid. Thus it can accept a lone pair of electrons. The reverse was observed with the *Moringa* treatment. The pH increases with increasing concentrations of the *Moringa* coagulant. Ndabigengesere et al. (1995) reported that the action of *M. oleifera* as a coagulant lies in the presence of water soluble cationic proteins in the seeds. This suggests that in water, the basic amino acids present in the protein of *Moringa* would accept a proton from water resulting in the release of a hydroxyl group making the solution basic. This accounted for the basic pH values observed for *Moringa* treatments compared with alum treatments.

From Table 1, it was observed that the *Moringa* coagulant treatment had an added advantage of reducing microbial load. It gave a lower count of 2 for the Most Probable Number (MPN) of total coliform per 100 ml with both the 10.0 and 12.0 g *Moringa* treatment while the conventional recorded a count of 8 coliforms per 100 ml. This supports findings of Schwarz (2000) that the process of flocculation removes about 90 -99% of bacteria which are normally attached to the solid particles. The control treatment had the highest counts of coliform (17/100 ml). This affirms earlier stated recommendation above that raw water without treatment is not safe for drinking.

The seed kernels of *M. oleifera* according to Schwarz (2000) contain lower molecular weight water-soluble proteins which carry a positive charge. When the seeds are crashed and added to water, the protein produces positive charges acting like magnets and attracting predominately negatively charged particles such as clay, silk, and other toxic particles. Under proper agitation, these bound particles then grow in size to form the flocculates which are left to settle by gravity. This accounted for the effectiveness of *Moringa* as a coagulant for raw water purification.

Conclusion and Recommendation

The results obtained show that powder from seed kernels of *M. oleifera* contains some coagulating properties at loading doses of 10 g/L and above that have similar effect as the conventional coagulum, alum. This lends support to earlier findings of the use of powder processed from *Moringa* seeds as a coagulant in water purification system (Madsen et al., 1987; Postnote, 2002; Barth et al., 1982; Bhole, 1987; Jahn, 1988; Müller, 1980; Olsen, 1987) cited by Ndabigengesere et al. (1995). *Moringa* coagulum has an added advantage of having antimicrobial properties. Considering the fact that *Moringa* coagulum can be locally produced, its use in water purification should be encouraged. This is likely to reduce the high cost of the current water treatment systems.

It is recommended that a combination treatment of alum and *Moringa* in different proportions be investigated to establish their effectiveness in treating raw water.

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