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EXTRACTS OF *MORINGA OLEIFERA* AS SAFER BIO-FLOCCULANTS COMPARED TO POPULAR CHEMICAL FLOCCULANT

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ABSTRACT

Rural communities in poor third world nations lack portable drinking water. Inhabitants of these communities often resort to heavy polluted water for drinking. Often, these water sources are shared with animals who also defecate in the same water, contaminates it and transmits disease to humans. The quest for clean drinking water has pushed poor local inhabitants to use flocculants for water purification. This study compared flocculants potential of *Moringa oleifera* leaves and seeds against popularly used local flocculants for purification of drinking water. Stream water samples from selected local communities were used in this study. Water samples were gathered and stored differently in sterilized twelve sealed containers. These containers were divided into four different groups. While groups 1 to 3 had four containers each, group 4 had only one container. Groups 1 and 2 were flocculated with different concentrations of *Moringa oleifera* seeds and leaves, respectively. Group 3 was flocculated with different concentrations of alum (potassium aluminium sulphate), a complex salt used locally for water purification. Group 4, the negative control, was a clean water hence not treated with either *Moringa* extracts or alum. The pH, total dissolved solids, conductivity and microbial counts were measured at three different time intervals (0, 12 and 24 hours). Total dissolved solids and conductivity gradually increased for both alum and *Moringa* with increasing concentrations but fell within the recommended drinking water standard. Concentrations of *Moringa* extracts did not affect the pH of water but alum acidified the water by reducing its pH from 7.29 to 5.42. Our results concluded that *Moringa oleifera* seed is a natural flocculants, and a potentially viable substitute to alum in treatment of water for safe drinking. Our results indicated that *Moringa oleifera* seeds has higher flocculants properties when compared to it leaves. This is evident since the seeds maintained water pH between 6.5 and 8.5 good for human immune system, which is the standard level set by the World Health Organization.

***Keywords**: Moringa oleifera, BIO-FLOCCULANTS, CHEMICAL FLOCCULANT*

INTRODUCTION

Water borne diseases pose serious problem in many parts of the country. According to Swarz (2000), about 1.6 million people compelled to use water in our communities have challenge with water purification. In Nigeria, water purification has been persistent both in the rural and urban centres. This has forced most inhabitants to use unsafe drinking water. The use of unsafe drinking water is a culprit in the rapid spread of most water-borne diseases. Many communities that suffer from the test number of waterborne disease are average or low income earners. The need for drinking water of high quality is increasing, as the non-polluted water sources are continuously decreasing.

The suspended materials in waters and wastewaters mostly arise from land erosion, the dissolution of minerals and the decay of vegetation and wastes from several domestic and industrial discharges. For any wastewater, such material may comprise suspended, dissolved organic and/or inorganic matter, as well as several biological organisms, such as bacteria, algae or viruses. This material has to be removed, as it causes deterioration of water quality by reducing the clarity (e.g. causing turbidity or colour), causing infection, and eventually carrying toxic compounds, adsorbed on their surfaces (Bratby, 2006). Various traditional and advanced technologies have been utilized to remove the colloidal particles from wastewater; such as ion exchange, membrane filtration, precipitation, flotation, solvent extraction, adsorption, coagulation, flocculation, biological and electrolytic methods (Radoiu *et al*., 2004). Among those methods, flocculation is one of the most widely used solid–liquid separation process for the removal of suspended and dissolved solids, colloids and organic matter present in industrial wastewater (Renault *et al*., 2009). It is a simple and efficient method for wastewater treatment, and has been extensively used for the treatment of various types of wastewater such as palm oil mill effluent, textile wastewater, pulp mill wastewater, oily wastewater, sanitary landfill leachates and others (Ahmad *et al*., 2005).

Flocculation is a common process used for removing suspended matter or treatment of water. The physical phenomenon of destabilization of colloids is induced by several chemical agents: polyalum salts, ferric chloride, etc. However, this process is normally very slow, so some chemical products (usually synthetic polyelectrolytes like polyacrylamides) are added to water in order to accelerate the coagulation process by increasing floc size. A wide range of flocculants (also known as coagulant aids) have been developed or designed to improve the flocculation process in wastewater treatment including synthetic or natural organic flocculants and grafted flocculants. Polymeric flocculants, synthetic as well as natural have become very popular in industrial effluent treatment due to their natural inertness to pH changes, high efficiency with low dosage, and easy handling (Singh *et al.,* 2000). However, the synthetic polymeric flocculants have the main problems of non-biodegradability and unfriendly to the environment, while the natural flocculants are concerned with moderate efficiency and short shelf life. In order to combine the best properties of synthetic and natural polymers, grafted flocculants have been synthesized and studied extensively recently (Bohuslav, 2005). The present review article classifies the flocculants that have been studied and applied in wastewater treatment into three categories including chemical coagulants/flocculants, natural bio-flocculants and grafted flocculants.

The aim of the study was to determine the flocculative properties of *Moringa oleifera* plant in the improvement of water quality.

COMMON USES OF *MORINGA*

(A)NUTRITIONAL

Moringa leaves and fruit pods are rich sources of calcium and iron, and good sources of vitamins A, B, and C and of protein including good amounts of the sulphur-containing amino acids, methionine and cystine (Rams, 1998).

(B) SEED OIL

Moringa seeds contain about 35% oil. The characteristics of *M. oleifera* seed oil are especially desirable, because of the current trends of replacing polyunsaturated vegetable oils with monounsaturated fatty acids (Abdulkarim *et al*, 2005). Moreover, the oil has the capacity to absorb and retain volatile substances and is therefore valuable in the perfume industry (Foidl *et al*., 2001).

(C) WATER PURIFICATION

Attracting attention in recent decades is the use of the dried, crushed seeds as a coagulant. Even very muddy water can be cleared when crushed seeds are added. Solid matter and some bacteria will coagulate and then sink to the bottom of a container. The cleaned water can then be poured off and boiled (Gupta and Chaudhuri, 1992). Current studies have shown that *Moringa* seeds and pods are effective in the removal of heavy metal and volatile organic compounds in the aqueous system. It can be added in oxidation 21 lagoons of wastewater treatment units to coagulate algae as well. The algae are removed by sedimentation, dried and pulverized, and then used as protein supplement for livestock (Akhtar *et al*., 2006).

FLOCCULATION

Flocculation involves the combination of small particles by bridging the space between particles with chemicals (Skousen *et al*., 1996). Essentially, coagulants aid in the formation of metal precipitate flocs, and flocculants enhance the floc by making it heavier and more stable. For this reason, flocculants are sometimes referred to as coagulant aids at water treatment operations (Shahid and Bhanger, 2006). Flocculation is mainly induced by inorganic metal salts, such as aluminium sulphate and ferric chloride. In some cases, these metal salts can be used in wastewater treatment without assistance of flocculants (Zhong *et al.,* 2003). Nowadays, the usage of inorganic coagulants has been reduced due to its inefficiency in wastewater treatment with small dosage and narrow application. In most of the cases, polymeric flocculants are preferable to facilitate separation process either with or without coagulant. Up to now, a wide range of flocculants have been designed to improve flocculation process in wastewater treatment. Polymeric flocculants, synthetic as well as natural have become very popular in industrial effluent treatment due to their natural inertness to pH changes, high efficiency with low dosage and easy handling (Singh *et al*., 2000). However, the synthetic polymeric flocculants have the main problem of non-biodegradability while the natural flocculants are concerned with moderate efficiency and short shelf life.

As flocculants plays the major role in flocculation process, the search for high efficient and cost-effective flocculants has always become the challenge in many studies. The main process variables that are commonly measured to justify the flocculation efficiency include settling rate of flocs, sediment volume (sludge volume index, SVI), percent solids settled, turbidity or supernatant clarity, percentage of pollutants removal or water recovery depending on the industrial application (Bohuslav, 2005). All these output variables are actually manifestations of the floc or aggregate size distribution and the shape and structure of flocs produced during the flocculation process. Bigger, stronger and denser flocs are preferable for good sedimentation, easy filtration and high clarification.

TYPES OF FLOCCULATION

Chemical Flocculants are conventional chemicals that are widely applied in industrial wastewater treatment. They are classified into two major groups: inorganic mineral additives/metal salts and organic polymeric materials. Example of Inorganic coagulants are alum, poly aluminium chloride, ferric chloride, ferrous sulphate, calcium chloride and magnesium chloride (Joo *et al*., 2007). Application of inorganic coagulants in wastewater is and its usage would cause environmental consequences leading to the production of large volumes of metalhydroxide (toxic) sludge that create disposal problems that increase metal (e.g. aluminium) concentration in treated water which may have human health implications (Flaten *et al*, 2001). Organic flocculant are linear water soluble polymers with repeating units of various monomers such as acrylamide and acrylic acid. In most cases, they are derived from oil-based and non-renewable raw materials (Suopajärvi *et al*., 2013). Commonly used polymeric flocculants include polyacrylamide, polyacrylic acid, poly(diallyldimethyl ammonium chloride) [DADMAC], polyamine and others (Singh *et al*., 2000).

Alum, with this formula: $K_2(SO_4).Al_2(SO_4)_3.24H_2O$ is potassium aluminium sulphate and a flocculant. Chemical flocculation with alum is aimed at removal of harmful bacteria, pathogens, colour, taste and odour producing substances in water.

Natural Bio-Flocculantsas a demand on the environmentally friendly materials in treating water and wastewater continue to increase; bio-flocculants have emerged to be promising alternative materials to replace conventional flocculants. Natural organic flocculants which are based on polysaccharides or natural polymers may be of great interest because they are natural products and environmentally friendly. Compared with conventional chemical flocculants, bio-flocculants are safe and biodegradable polymers, fairly shear stable, easily available from reproducible agricultural resources and produce no secondary pollution. In addition, as biopolymers are biodegradable, the sludge can be efficiently degraded by microorganisms (Renault *et al.*, 2009). Thus, they have high potential to be applied not only in food and fermentation processes, pharmaceutical, cosmetic, downstream processing but also in water and wastewater treatment.

HEALTH RISKS ASSOCIATED WITH CHEMICAL FLOCCULATION

Although water treated with chemicals are effective and used worldwide, scientific evidence shows that exposure to chemicals during coagulation with metal salts could be associated with adverse health effects (Driscoll and Letterman, 1995). Like chemical coagulants, disinfectants (chlorine in particular) combine with natural organic matter (NOM) that may be present in water to form trihalomethanes (THMs), which are carcinogenic and/or mutagenic by–products. These THM cannot be removed by conventional treatment methods and thus water to be chlorinated should either be free from natural organics, or if NOM is present an alternative disinfectant should be used (Tokmak *et al.*, 2004). Alternative disinfectants such as chlorine dioxide, chloramines and ozone are also associated with the formation of disinfection by- products (DBPs) that are toxic compounds and impart objectionable taste and odour (Sadiq and Rodriguez, 2004).

Irradiation with ultraviolet (UV) light is a promising alternative method of disinfection but it is expensive and leaves no residue and hence another disinfectant is required to disable bacteria and viruses. In addition, UV light can react with nitrate in water to produce nitrite, the precursor for methaemoglobinaemia in infants (Mole *et al.*, 1999). The search for disinfectants that are cheap, maintain acceptable microbiological quality and avoid chemical risks is one of the biggest challenges facing the water treatment industry (Bove *et al.*, 2002).

MATERIAL AND METHODS

MATERIALS

Leaves and seeds of *Moringa oleifera* were harvested at Ugbawka, Nkanu LGA, Enugu State, Nigeria. The potassium aluminium sulphate were purchased from Ogbete Main market in Enugu State, Nigeria.

METHODOLOGY

COLLECTION OF SAMPLE

Moringa oleifera leaves and seeds were identified by Prof. Eze of the Applied Biology and Biotechnology Department, Enugu State University of Science and Technology (ESUT), Agbani, Enugu State, Nigeria. Identified samples were harvested and air-dried. Water samples from streams in Agbani and Akpugo villages were collected and stored in sealed sterilized containers. Stored samples were taken to the laboratory for analyses.

TEST FOR FLOCCULANTS ACTION OF *Moringa Oleifera*

JAR TEST

The jar test method used was as described by Kalavathy *et al.*, (2017).

PHYSICOCHEMICAL ANALYSIS OF WATER SAMPLE

pH

A pH meter was used for this test. The pH meter was calibrated with two buffer solutions having pH 4.01 and 7.00. The water sample was placed in a beaker and the electrode rinsed with distilled water and placed in the sample. The readings were recorded.

COLOUR

This was taken using the Lovibone Nesslerizer Model 2150. A test tube was rinsed three times with the sample to be analysed and fitted into the test kit alongside another test tube filled with distilled water. The arrow buttons were rotated until the exact values displayed and recorded.

TOTAL DISSOLVED SOLUTES (TDS)

This was measured using the Mulit analyser (HACH, Cloverland). The electrode was placed in the sample in a beaker and the TDS key selected. The value displayed on the screen was recorded in mg/L.

CONDUCTIVITY

The conductivity of the samples was measured using Mulit analyser (HACH, Cloverland). This was calibrated by immersing the electrode in a reference buffer of 12.88µs/cm. The water sample was put in a beaker and the electrode rinsed in distilled water and lowered into the sample. The conductivity, in µs/cm of the sample was recorded.

STATISTICAL ANALYSIS

Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS) version 20.

Results

Table 1: Mean values of physicochemical parameters of raw water from streams in the three communities before treatment with *M. oleifera* leaves and seed extract.

Communities	Colour (HU)	pH	Turb (NTU)	TDS (mg/L)	Cond (µs/cm)
Agbani	66.11	7.29	24.59	69.11	140.98

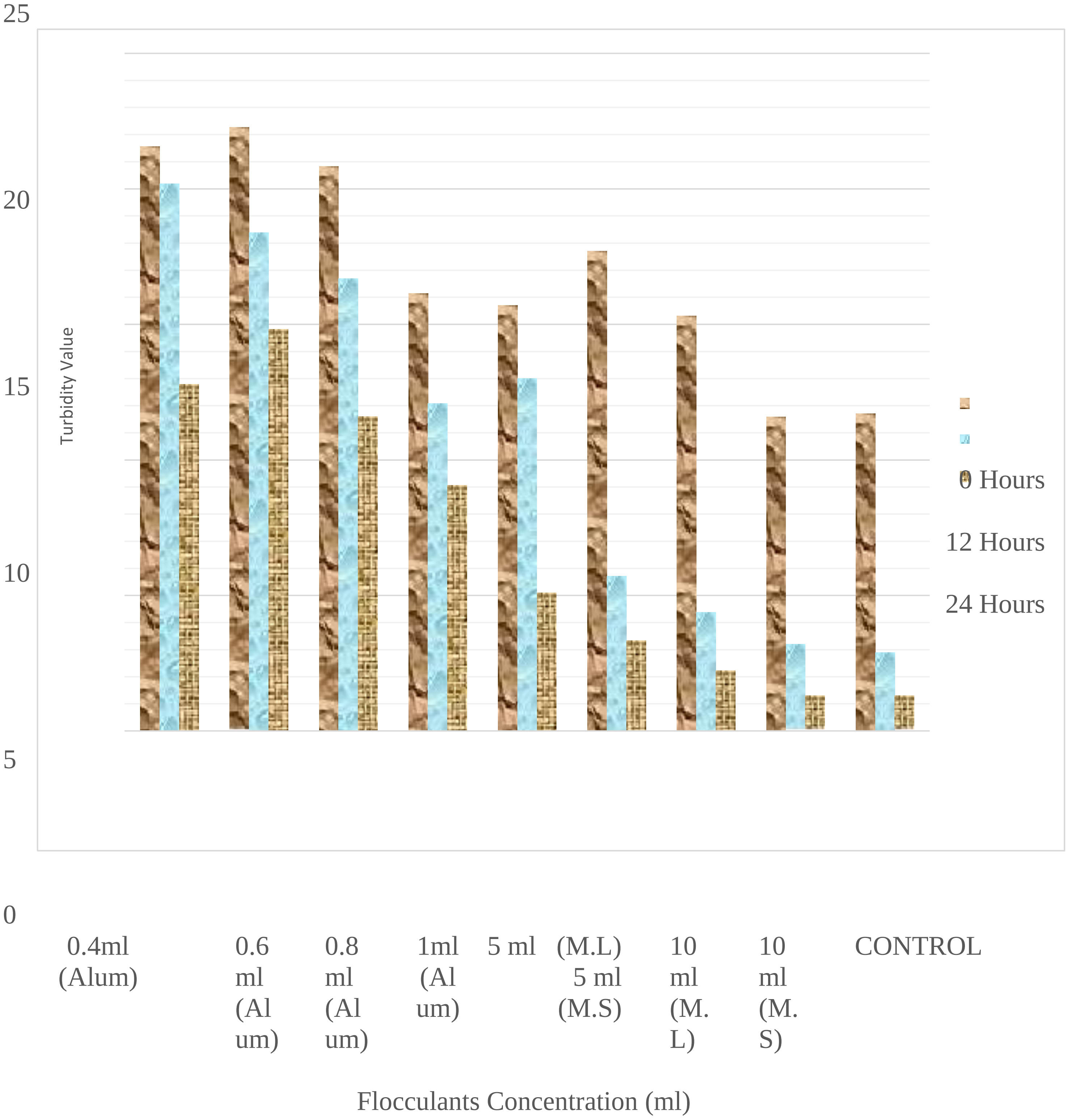
Figure 6: Influence of different concentrations of indicated flocculants on pH of stream water from Agbani after 0-12-24 hours treatment time using *Moringa* seed (M.S) and *Moringa* leaves (M.L).

0

0.4 ml (Alum)
0.6 ml (Alum)
0.8 ml (Alum)
1ml (Alum)
5 ml (M.L)
5 ml (M.S)
10 ml (M.L)
10 ml (M.S)
CONTROL

Flocculant Concentration (ml)

Figure 7: Influence of different concentrations of indicated flocculants on turbidity (Turb) of Agabni stream water after 0-12-24 h treatment time using *Moringa* seed (M.S),*Moringa* leaves (M.L) and Alum.



DISCUSSION

Moringa oleifera is an effective natural flocculants used in improving the physicochemical characteristics of water pH, turbidity, and conductivity. We recorded pH values of Agbani water samples from 7.29 to 7.0 at 0 hours of treatment with various *Moringa* concentrations. After 12 hours of treatment with *Moringa* extract, the pH values were within pH range of 7.16 – 6.94. After 24 hours of treatment with *Moringa*, pH values ranged from 7.04 – 6.80. Differences in the mean values among the treatment groups were not significant (P = 0.06) at 0-hour treatment. Significant differences were observed at 12 hours and 24 hours' treatment periods (P= 0.001 and P= 4.48x10-5), respectively. Similar trend of pH decline was observed with increasing alum concentration. The pH values at 0 hours ranged from 6.72 to 6.16 and 6.33 to 5.74 after 12 hours of treatment and 6.29 to 5.65 after 24 hours. In addition, pH values for the control were within the range of 7.16 to 7.04 from 0 hours to 24 hours. The pH values recorded were within the WHO international recommended standard of pH 6.5 to 8.5 for chemically treated water (WHO, 2006). The differences in the mean values among the treatment groups were significant (P = 4.75x10-8, P = 0.0004 and P = 4.89x10-5), respectively for the three treatment periods.

Turbidity values of the Agbani stream water were initially within ranges of 22.26 NTU to15.69 NTU. After 12 hours of treatment, it changed from 18.37 NTU to 12.99 NTU and 14.82 NTU to 5.09NTU after 24 hours of treatment with the different *Moringa* concentrations. Significant differences were observed between the treatment groups (P=0.02, 0.04 and 5.93x10-10), respectively for the three treatment periods. Mean values showed significant differences (P=4.27x10-7, 0.0002 and 0.0006) for the treatment periods, respectively. Control set-up recorded values between 21.56 NTU to 12.79 NTU from 0 hours to 24 hours. No significant difference was observed among mean values at 0 hour treatment period (P=0.13). However, 12 hours and 24 hours treatment periods showed significant differences (P=1.15x10-9 and 1.01x10-9), respectively.

Total Dissolved Solids (TDS) values for Agbani stream ranged from 74.57 to 78.38 for the different *Moringa* seeds and leaves concentrations with no significant differences among mean values (P=0.34, 0.62). Consequently, conductivity values ranged from 154.91 to 168.80 for the various *Moringa* seed and leaves concentrations with no significant differences among mean values (P=0.77, 0.53 and 0.55) for the three treatment periods, respectively. Mean TDS values for the various concentrations of alum were between 74.96 to 82.61 with 0 hour treatment period showing no significant difference (P=0.10). On the other hand, 12 and 24 hours' treatment periods showed significant differences among mean values (P=2.5x10-16 and 7.33x10-19). Conductivity values for the various concentrations of alum ranged from144.71 to 163.92 with no significant differences (P=0.47, 0.38 and 0.26) respectively at the three treatment periods. Control also recorded TDS values of 71.04 to 73.31 and corresponding conductivity values of 144.94 to 155.47 at the three treatment period.

The World Health Organization (WHO) classifies as standard drinking water with pH between 6.5 and 8.5 (WHO, 2006). Although pH usually has no direct impact on water consumers, it is one of the most important water-quality parameters. There were significant differences (p<0.05) between all water treatments at different coagulant concentrations on pH. We did not notice any change in the pH of water samples following treatment with *Moringa* extract. The pH ranged from 7.29 to 6.27 for the stream water samples. We recorded that alum reduced the pH of our water samples. The effectiveness of

M. oleifera as flocculants could be a factor of water soluble cationic proteins in the seeds. This suggests that basic amino acids present in *Moringa* seeds could be higher than that of the leaves and would accept a proton from water resulting in the release of a hydroxyl group. Alum at different concentrations significantly influenced the pH of the water causing a decrease with increasing concentrations. The addition of alum in the treatment procedure produced sulphuric acid which lowered the pH levels. This tendency towards increase in acidity could be due to the trivalent cation aluminium that can accept lone pair of electrons (Miller *et al*., 1984). Sulphuric acid reacts with the alkaline present in the water to lower its pH. Seeds of *Moringa* have high advantage over it leaves and alum in water treatment since no pH adjustment is required. Thus, *Moringa* extract maintained the water in its neutral state. In the *Moringa* seed-treated waters, turbidity increased with increasing concentration beyond the optimal concentration. This was due to re-stabilization caused by reversal of colloidal charge due to adsorption.

Our results showed that turbidity removal was dependent on settling time and the degree of turbidity of raw water. Total dissolved solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form. The TDS concentrations gradually increased for both flocculants with increasing concentrations with all the three settling times. This was probably due to increased levels of inorganic substances such as calcium, magnesium, bicarbonates, chlorides and sulphates. TDS values were however higher in alum-treated water than *Moringa*-treated water due to higher levels of aluminium and sulphates. An important aspect of TDS in respect to drinking water quality is its effect of taste. Water with TDS levels less than 600 mg/l is generally considered to be good and palatable (WHO, 2008).

Since TDS values of both streams treated with *Moringa* seed extract and alum were below 130mg/l, the water could be classified as palatable since the recommended guideline value of TDS in drinking water is 1000 mg/l based on taste (WHO, 2006). 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 in drinking water maybe objectionable to consumers (WHO, 2006). At 95% confidence level, there were significant differences ($p<0.05$) in conductivity between all the treatments at all the various coagulant dose concentrations. However, treatments with *Moring* seed, leaves and alum concentrations influenced conductivity of water greatly. Increasing concentrations of both flocculants was attended by increase in conductivity for stream water samples at the three settling times. This may be attributed to the increase in cationic polyelectrolyte in *Moringa* seeds and sulphate ions in alum as the concentrations increased thereby producing high dissolved solids that increased the conductivity.

CONCLUSION

In flocculation, *Moringa* seeds hardly affect pH of water as compared to alum which requires pH adjustment after treatment. This is likely to reduce the high cost of the current water treatment systems. Seeds of *Moringa oleifera* are viable anti-coagulant alternative to alum in the treatment of water for rural dwellers because it is cheaper and environmentally safe. Its use in water treatment must be combined with filtration or boiling before it could be considered safe for human consumption.

REFERENCES

Abdulkarim, S.M., Long, K., Lai, O.M., Muhammad, S.K.S. and Ghazali, H.M. (2005). Some physiochemical properties of Moringa oleifera seed oil extract education using solvent and aqueous enzymatic methods. Food Chemistry. 93: 253–263.

Ahmad, A.L., Ismail, S. and Bhatia, S. (2005). Optimization of coagulation–flocculation process for palm oil mill effluent using response surface methodology. Environment Science Technology. 39: 2828–2834.

Ahmad, A.L., Wong, S.S., Teng, T.T. and Zuhairi, A.(2008). Improvement of alum and PACl coagulation by polyacrylamides (PAMs) for the treatment of pulp and papermill wastewater. Chemical Engineering Journal.137: 510–517.

Akhtar, M., Hasany, S.M., Bhanger, M.I. and Iqbal, S. (2006). Absorption potential of Moringa oleiferapods for the removal of organic pollutants from aqueous solutions. Journal of Hazardous Materials. 141: 546–556.

Araújo, C., Melo, E., Alves, V. and Coelho, N. (2010). Moringa oleifera Lam. seed as a natural solid adsorbent for removal of Ag(I) in aqueous solutions. Journal of Brazilian Chemical Society. 21(9): 1727 – 1732.

Atawodi, S.E., Atawodi, J.C., Idakwo, G.A., Pfundstein, B., Haubner, R., Wurtele, G., Bartsch, H. and Owen, R.W. (2010). Evaluation of the polyphenol content and antioxidant properties of methanol extracts of leaves, stem and root barks of Moringa oleifera. Journal of Medicinal Food. 13(3): 710 – 716.

Biggs, S., Habgood, M., Jameson, G.J. and Yan, Y. (2000). Aggregate structures formed via a bridging flocculation mechanism. Chemical Engineering Journal. 80: 13–22.

Bratby, J. R. (2006). Coagulation and Flocculation with an emphasis on water and wastewater treatment. Journal of International Water Work Association, London. 34: 50 – 68.

Bohuslav, H.S. (2005). Coagulation and Flocculation. Chemical Engineering Journal. 30: 24 – 34.

Bove, F., Shim, Y. and Zeitz, P. (2002). Drinking water contaminants and adverse pregnancy outcomes. Environmental Health Perspective. 110(1): 61 – 74.

Cacerch, A., Cabrera, O., Morales, O., Mollinedo, P. and Mendia, P. (1991). Pharmacological properties of Moringa oleifera. Preliminary screening for antimicrobial activity. Journal of Ethnopharmacology. 33(3): 213 – 216.

Olson, M.E. and Carlquist, S. (2001). Stem and root anatomical correlations with life form diversity, ecology, and systematics in Moringa (Moringaceae). Botanical Journal of the Linnean Society. 135(4): 315 – 348.

Driscoll, C.T. and Letterman, R.D. (1995). Factors regulating residual aluminium concentrations in treated waters. Environmetrics. 6: 287 – 309.

Fahey, J.W. (2005). A review of the medical evidence for its nutritional therapeutic and prophylactic properties of Moringa oleifera. Tree for life Journal. 1: 5 – 5.

Flaten, T.P. (2001). Aluminium as a risk factor in Alzheimer's disease, with emphasis on drinking water. Brain Research Journal. 55: 187–196.

Foidl, N., Makkar, P.S. and Becker, K. (2001). The potential of Moringa oleifera for agricultural and industrial uses. The miracle tree and it multiple attributes of moringa. Tree for life Journal.4: 9 – 14.

Ghebremichael, K., Gunaratna, K., Henrikson, H., Burmer, H. and Dalhammar, G. (2005). A simple purification and activity assay for the coagulant protein from Moringa oleifera education. Water =Research. 32(11): 2338 – 2344.

Gupta, A. and Chaudhuri, M. (1992). Domestic water purification for developing countries. Journal of Water Supply Research and Technology-Aqua. 41(5): 290 – 298.

Joo, D.J., Shin, W.S., Choi, J.H., Choi, S.J., Kim, M.C., Han, M.H., Ha, T.W. and Kim, Y. (2007). Decolourization of reactive dyes using inorganic coagulants and synthetic polymer. Brain Research Journal. 73: 59–64.

Kalavathy, S., Giridhar, M.V.S.S. and Viswanadh, G.K. (2017). A jar test study on the use of alum and ferric chloride for turbidity removal. Proceedings of 4th National Conference on Water, Environment and Society (NCWES-2017). 339 – 344.

Makkar, H. and Becker, K. (1996). Nutritional value and anti-nutritional components of whole and ethanol extract education Moringa oleifera leaves. Journal of Animal Feed Science and Technology. 63(1): 211 – 228.

Miller, R.G., Kopfler, F.C., Kelty, K.C., Stober, J.A. and Ulmer, N.S. (1984). The occurrence of aluminium in drinking water. Journal of American Water Works Association.76: 84 – 91.

Mole, N., Fielding, M. and Lunt, D. (1999). The influence of UV disinfection on the formation of disinfection by-product, In: Disinfection By-products in Drinking Water. Current Issues: M. Fielding and M. Farrimond (educations), The Royal Society of Chemistry, United Kingdom. 94: 239 – 347.

Radoiu, M.T., Martin, D.I., Calinescu, I. and Iovu, H. (2004). Preparation of polyelectrolytes for wastewater treatment. Journal of Hazardous Materials. 106: 27–37.

Rams, J. (1998). Moringa a highly nutritious vegetable Tree. Tropical Rural and Island/atoll. Development Experimental station. Technical Bulletin. 22: 1 – 5.

Renault, F., Sancey, B., Badot, P.M. and Crini, G. (2009). Chitosan for coagulation/flocculation processes. Journal of Environmental Management. 45: 1337–1348.

Sadiq, R. and Rodriguez, M.J. (2004). Disinfection by–products (DBPs) in drinking water and predictive models for their occurrence. Science of the Total Environment. 321: 21 – 46.

Shahid, I. and Bhanger, I. (2006). Effect of season and production location on antioxidant activity of Moringa oleifera leaves grown in Pakistan. Journal of Environmental Management. 19(7): 544–551.

Swarz, D. (2000). Water clarification using Moringa oleifera. Journal of Gate Technical Information. 24: 1 – 5.

Singh, R.P., Karmakar, G.P., Rath, S.K., Karmakar, N.C., Pandey, S.R., Tripathy, T., Kanan, K., Jain, S.K. and Lan, N.T. (2000). Biodegradable drag reducing agents and flocculants base education on polysaccharides: materials and applications. Journal of Environmental Management. 40: 46–60.

Skousen, J., Lilly, R. and Hilton, T. (1996). Special chemicals for treating acid mine drainage in Morgan town. Journal of Hazardous Materials. 24: 173 – 180.

Suopajärvi, T., Liimatainen, H., Hormi, O. and Niinimäki, J. (2013). Coagulation–flocculation treatment of municipal wastewater based on anionized nano-celluloses. Chemical Engineering Journal. 231: 59–67.

Tokmak, B., Capar, G., Dilek, F.B. and Yetis, U. (2004). Trihalomethanes and associated potential cancer risks in the water supply in Ankara, Turkey. Environmental Research. 96: 345-352.

WHO, (2006). Guidelines for Drinking-Water Quality. First Addendum To Third Edition. 1: 488.

WHO, (2008). Guidelines for Drinking-Water Quality. Third Edition Incorporating The First and Second Addenda. 1: 218.

Zhong, J., Sun, X. and Wang, C. (2003). Treatment of oily wastewater produce from refinery processes using flocculation and ceramic membrane filtration. Journal of Separation and Purification Technology. 32: 93 – 99