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A Review of the Applications of *Moringa oleifera* Seeds Extract in Water Treatment

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Abstract
Moringa oleifera is a single family of shrubs and trees that is cultivated in the whole of tropical belt. It belongs to the family *Moringaceae* and is one of the 14 known species. The tree has been described as a multi-purpose tree for life. It has, in recent times, been advocated as an outstanding indigenous source of highly digestible protein, Ca, Fe, Vitamin C, and carotenoids suitable for utilization in many of the developing regions of the world where undernourishment is a major concern. The seeds are eaten green, roasted, powdered and steeped for tea or used in curries. It has found applications in medicinal uses, as cosmetics, in food supplements, and in water treatment. One of the active ingredients in the *M. oleifera* seed has been identified as a polyelectrolyte. Its use for coagulation, co-coagulation, or coagulant aid has been a subject of investigation in many parts of the world. Softening of water with *M. oleifera* has also been identified to have potential advantage since it is accompanied by very low reduction in alkalinity, which is required to provide the necessary buffering capacity to achieve required treatment objectives. Many researchers have also identified the presence of an active antimicrobial agent in *Moringa oleifera* seeds. This paper presents a review of these various applications of *M. oleifera* seeds extract in water treatment and highlights the areas requiring further investigations.
Key words: *Moringa oleifera*, seeds extract, water coagulation, softening, disinfection.

1. Introduction
The provision of potable water is an enormous undertaking, especially in developing countries. This is so because the chemicals required for treatment, namely: alum for coagulation, polyelectrolytes as coagulant aids, lime for softening and pH correction, and chlorine for disinfection; needs to be imported with scarce foreign exchange. In reaction to this, local materials are being considered as a substitute. *Moringa oleifera* seeds extract has been a subject of research by several scholars in this regard.
Jahn (1986) noted that *M. oleifera* is a single genus family of shrubs and trees cultivated in the whole of the tropical belt. In Northern Nigeria, Sani (1990) reported the use of the leaves as vegetable and for medicinal purposes while the stem is used for demarcating property. Many researchers (Muyibi, et al 1995a, b; Suarez, et al 2005; Bichi, et al 2012) have reported its use in surface water treatment. In this paper, a review of the applications of *Moringa oleifera* seeds extract in water treatment is presented and the areas that require further works by researchers highlighted.

2. Occurrence of *Moringa oleifera*
According to Wikiepedia (2009), *Moringa oleifera*, commonly referred to as Moringa, is the most widely cultivated variety of the genus *Moringa*. The tree itself is rather slender with drooping branches that grows to approximately 10 m in height. However, it normally is cut back annually to one meter or less, and allowed to re-grow, so that pods and leaves remain within reach. Wikipedia (2009) noted that *Moringaceae* is a single genus family with 14 known species. Of these, *Moringa oleifera* Lam (syns. *Moringa pterygosperma* Gaertn.) is the most widely known and utilized species. A native of the sub-Himalayan regions of north-west India, *Moringa oleifera* (*M. oleifera*) is now indigenous to many countries in Africa, Arabia, South East Asia, the Pacific and Caribbean Islands; and South America. Commonly known as the 'horse-radish' tree (arising from the taste of a condiment prepared from the roots) or 'drumstick' tree (arising from the shape of the pods), *M. oleifera* has a host of other country specific vernacular names (*Zogale* in Northern Nigeria), an indication of the significance of the tree around the world.
Rajangam (2001) reported that India is the largest producer of Moringa with an annual production of 1.1 to 1.3 million tonnes of tender fruits from an area of 380 km². Among the states, Andhra Pradesh leads in both area and production (156.65 km²) followed by Karnataka (102.8 km²) and Tamil Nadu (74.08 km²). In other states, it occupies an area of 46.13 km². Tamil Nadu is the pioneering state insomuch as it has varied genotypes from diversified geographical areas, as well as introductions from Sri Lanka.

2.1 Description of M. oleifera
NRC (2006) reported that Moringa has a tuberous taproot, whose presence helps explain the species' tolerance to drought conditions. Normally umbrella shaped, the tree comes with a lax crown of graceful, airy foliage, whose feathery effect is due to the finely trip innate division of the leaves. The leaves are densely crowded at the tops of

the branchlets. Depending on climate, the foliage is evergreen or deciduous and, from a distance, reminiscent of a legume like leucaena or calliandra.
In season the tree is enshrouded in creamy white, honey-scented flowers arranged in drooping panicles 10-30 cm long. Flowers (Plate 1) are insect pollinated and "require a large number of insect visitations," with carpenter bees being the most common guests (Bhattacharya, et al 2004). Flowers and fruits (pods) can be produced twice a year; though in many places, flowering and fruiting occur all year-round. The fruits are initially light green, slim and tender, eventually turning dark green and firm. Depending on genotype, they are up to 120 cm long. While most are straight a few are wavy and some curly. In cross-section most are rectangular but a number are triangular and some are round. Fully mature, the dried seeds are surrounded by a lightly wooded shell with three papery wings.

2.2 Species Information

***Botanical Name*:** *Moringa oleifera* Lamarck
***Synonyms*:** *Moringa pterygosperma* Gaertner; *Moringa zeylanica* Pers.; *Guilandina moringa* L.
***Family*:** Moringaceae

Moringa oleifera

Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
(unranked):	Rosids
Order:	Brassicales
Family:	Moringaceae
Genus:	***Moringa***
Species:	***M. oleifera***

Plate 1: *Moringa oleifera* Flower (NRC, 2006)

Because of its wide distribution nature, Moringa has various common names in various localities. Some of these, according to National Research Council (2006) are: *English*: moringa, horseradish tree, drumstick tree, sujuna, ben tree, ben oil tree; *French*: ben ailé, ben oléifère, benzolive, arbre radis du cheval; *Spanish*: ben, árbol del ben, paraiso, morango, Moringa; *Portuguese*: acácia branca, marungo, muringa, moringuiero; cedro (Brazil); *Arabic*: ruwag, alim, halim, shagara al ruwag (Sudan); *Swahili*: mzunze, mlonge, mjungu moto, mboga chungu, shingo; *Yoruba & Nago*: èwè igbale, èwè ile, èwè oyibo, agun oyibo, ayun manyieninu, ayèrè oyibo; *Fulani*: gawara, konamarade, rini maka, habiwal hausa; *Hausa*: zogall, zogalla-gandi, bagaruwar maka, bagaruwar masar, shipka hali, shuka halinka, barambo, koraukin zaila, rimin turawa; and *Ibo*: Ikwe oyibo

2.3 Related Species

The National Research Council (2006) noted that, out of the 14 *Moringa* species only *M. oleifera* has been accorded research and development. The rest remain almost unknown to science. The other 13 species are: *Moringa drouhardii* (Madagascar), *Moringa concanensis* (mostly India), *Moringa arborea* (northeastern Kenya), *Moringa hildebrandtii* (Madagascar), *Moringa oleifera* (India), *Moringa borziana* (Kenya and Somalia), *Moringa ovalifolia* (Namibia and extreme southwestern Angola), *Moringa peregrina* (Horn of Africa, Red Sea, Arabia), *Moringa longituba* (Kenya, Ethiopia, Somalia), *Moringa stenopetala* (Kenya and Ethiopia), *Moringa pygmaea* (northern Somalia), *Moringa rivae* (Kenya and Ethiopia), *Moringa ruspoliana* (Kenya). NRC (2006) also noted that perhaps these other species could provide even better food ingredients, flocculants, antibiotics, oils, or wood; perhaps they have their own unique qualities; but no one knows at present.

2.4 Active Ingredients in M. oleifera Seeds

Ndabigengesere et al. (1995) found that the shelled *Moringa oleifera* contains 36.7% proteins, 34.6% lipids, and 5% carbohydrates. The un-shelled *Moringa oleifera* contains 27.1% proteins, 21.1% lipids, and 5.5 carbohydrates. Folkard et al (1989) identified the active ingredient in the M. o*liefera* seed to be a Polyelectrolyte. According to Jahn (1988), the moringa flocculants are basic polypeptides with molecular weights ranging *from* 6,000 to 16,000 daltons. Six polypeptides were identified with their amino acids being mainly glutamic acid, proline, methionine, and arginine. Bina (1991) identified the active ingredient as a polypeptide acting as cationic polymers; and Ndabigengesere et al (1995; 1998) reported that the active ingredients in an aqueous *Moringa* extract are dimeric cationic proteins with molecular weights of about 13 000 daltons and iso-electric point of between 10 and 11.

Preliminary studies by Gassenchmidt et al. (1995), on the active ingredients of *Moringa oleifera* as a coagulant, have suggested that the active components are cationic peptides of molecular weight between 6.5 – 7.0 kDa. The extract of *Moringa oleifera* was described by Ndabigengesere et al. 1995 as dimeric cationic proteins with molecular mass of 12-14 kDa. Tauscher, (1994) mentioned that the sequence of one of the *Moringa oleifera* proteins is oppositively charged 6 kDa polypeptide. *Moringa oleifera* seed extract was described as water-soluble protein with a net positive charge (Nkhata, 2001). Broin et al (2002) mentioned that the molecular weight is 6 kDa and that *Moringa oleifera* contains eight (13.1% positively charged amino acids, 7 arginines and 1 histidine) and only one (1.6%) negatively charged residue (aspartic acid). As a consequence, the protein in solution is highly positively charged. Broin et al (2002) also proposed that the coagulation mechanism is mainly relies on patch charge mechanism. Interestingly, according to the same study, this protein is also very rich in glutamine (14- residues, 23%). The high density of glutamine residues could favour floc formation through H-bonding among proteins coating the particles. Kebreab et al. (2005) mentioned that there were no characteristic differences (molecular weight and pI) between the proteins extracted by different methods. In all cases the coagulants were proteins, as determined by the dye binding method and absorbance at 595 nm. Kebreab et al (2005) additionally mentioned that the protein fraction obtained during the research does not consist of a single, homogenous protein, but is a mixture of proteins with similar physical characteristics; and using mass spectrometry analysis of the protein also indicated a dominant protein with molecular weight of 4.75 kDa.
Eilert *et al* (1981) also identified an active anti-microbial agent in the seeds. When isolated, it was found to be *4α-4-rhamnosylox.y-benzyl-isothiocynate,* the only known glycosidic mustard oil at present. The compound is readily soluble in water at 1.3µmol/L and is non-volatile.

3.0: Applications of *Moringa oleifera* in Water Treatment

The use of natural materials of plant origin to clarify turbid surface waters is not a new idea. Many believe the Biblical book of *Exodus* (15:23-27) is the earliest written reference to what is most likely *Moringa* being used to purify water (probably *Moringa peregrina*,): "And the people murmured against Moses, saying, "What we shall drink?" And he cried unto the Lord; and the Lord showed him a tree, which when he had cast into the waters, the waters were made sweet…." (NRC, 2006)
The traditional use of the *M. Oleifera* seeds for domestic household water treatment has been well known to certain rural areas in the Sudan (NRC, 2006). In the West Asia, one of the best known uses for Moringa is the use of powdered seeds to flocculate contaminants and purify drinking water (Berger, et al 1984; Gassenchmidt, et al 1995; Olesen, 1987), but the seeds are also eaten green, roasted, powdered and steeped for tea or used in curries (Gassenchmidt, et al 1995). This tree has in recent times been advocated as an outstanding indigenous source of highly digestible protein, Ca, Fe, Vitamin C, and carotenoids suitable for utilization in many of the so-called "developing" regions of the world where undernourishment is a major concern. These various uses have been documented by many researchers (Fahey, 2005; Fahey, et al 2001; Fahey et al 2002; Fuglie, 1999, 2002; Goplan, et al 1971; Palada, 1996; Sampson, 2005; Talalay, et al 2001; Faizi, et al, 1994a, b; Kumar and Pari, 2003; Rao, et al, 1999; Bharali, et al 2003)
Detailed studies have been carried out on the use of *Moringa oleifera* seeds extract in water treatment (Eilert, 1978; Fahey, et al 2001, 2002; Jahn, 1986, 1988; Kaser, et al 1990; Okuda, et al 1999; Okuda et al 2001a, b; and Muyibi, et al 2003). A review of the works carried out in this regard is presented in the following sections.

3.1 Processing of Moringa Oleifera seeds Powder and Extracting the Active Ingredients

The first stage in the application of *Moringa oleifera* seeds extract in water treatment is the production of *Moringa oleifera* seeds powder. This normally involves manually removing the seed coat and wings, grinding the seeds in to fine powder using a domestic blender, and sieving. Earlier researchers (Muyibi, eta al 1995a,b) used the grinded powder without sieving. Later researchers (Okuda et al 1999; Okuda, et al 2001a, b; Ali, 2010; Bichi, et al 2012a,b, c) sieved the powder through a 210 µm sieve. The second stage comprises extracting the active ingredients. Earlier researchers used mixing in water and filtering through Mosley cloth (Muyibi, et al 1995a, b). Later researchers use mixing with a stirrer and filtering with whattman filter paper (Muyibi, et al, 2003). Ali (2010) used six different methods: normal aqueous extraction (M1), normal salt extraction (M2), oil removal followed by aqueous extraction (M3), oil removal followed by salt extraction (M4), oil removal followed by aqueous extraction and micro-filtration or cross flow filtration (M5), and oil removal followed by salt extraction and micro-filtration or cross flow filtration (M6). The extracted bio-active constituents were then applied to determine the method with best results. Ali (2010) found that oil removal followed by salt extraction and microfiltration produced the best result for the application of Moringa oleifera in water coagulation.
Bichi, et al (2012a), on the other hand, found that oil removal and aqueous extraction produced the best result for its application in water disinfection. Zaika (1988) noted that extracting solvents could bring about variation in specie extractive components, which may influence their antimicrobial activities. Gan, et al (2011) studied the extraction of polyphenolic compounds from *P. speciosa* pod powders using 50% acetone solution, based on the

result from a preliminary study which showed that 50% acetone yielded the highest content of polyphenols compared to methanol, ethanol, ethyl-acetate and hexane. Oluseyi and Francisca (2009) also reported that Hexane extraction of antimicrobial agent of *Buchholzia Corcea* (Wonderful Kola) showed inhibitory zone of 21mm for *E. coli* and methanolic extract showed inhibitory zone of 30mm for *E. coli*.

3.2 Use of Moringa oleifera as Coagulant

Coagulation is by far the most widely used process to remove the substances producing turbidity in water. These substances normally consists largely of clay minerals and microscopic organisms and occur in widely varying sizes ranging from those large enough to settle readily to those small enough to remain in suspension for a very long time. Colloidal and fine impurities in water possess a certain anticoagulation stability which is due to the presence of hydrate shells or a double electric field around particles. This anti-coagulation stability of impurities can be disturbed by heating, freezing, addition of electrolytes to water or by the application of a magnetic field. This problem is most often solved by coagulating hydrophilic and hydrophobic impurities. (Nikoladze et al, 1989).

The active ingredient in the *M. oleifera* seed has also been identified as a polyelectrolyte (Folkard *et al* 1989). Its use for coagulation, co-coagulation, or coagulant aid has been a subject of investigation in many parts of the world. Most of these works have been documented by Jahn (1986), Jahn (1988), Folkard *et al* (1989), Sani (1990), Bina (1991), Ndabigengesere *et al* (1995), Muyibi and Okuofu (1995), Muyibi and Evison (1996), and Buthalezi, et al (2009).

3.2.1Moringa oleifera as a Primary Coagulant

Many researchers like Folkerd, et al (1989); Muyibi and Okuofu (1995); and Kaser, et al (1990) have reported the potential use of *M. oleifera* seed extracts as a primary coagulant. Madsen *at al* (1987) in a study carried out in Sudan using the Nile river water found that there was a fall in turbidibity, within 1 hour, from 2000 FTU to 1-2FTU for the Blue Nile water; from 50FTU to 10FTU for the White Nile water and from 300FTU to 10FTU for the irrigation canal water. Folkard *et al* (1989), working in Malawi, evaluated the performance of M. o*leifera* and *M. Stenopetola* in the flocculation of turbid water with alum. They found that both M. o*leifera* and M. *Stenopetola* gave equivalent performance to alum in the clarification of highly turbid waters. There was, however, a limit to the effectiveness of the seeds on low turbidity waters, the limit varying depending on the source.

In another study carried out in Kano-Nigeria, Sani (1990) reported a 92.99% reduction in turbidity within 2 hours settling period for initial turbidities ranging 205-986NTU using M. o*leifera* dosages of 40 - 400mgll depending on initial turbidities. In a similar study by Muyibi and Okuofu (1995) working in Kano-Nigeria, three water samples from Challawa water works, Thomas reservoir and Rimin Gado water were used. It was found that turbidity removal varied from 26.5% to 45% for Challawa water, 32.5% to 83.3% for Thomas reservoir water, and 27.8% to 49.1% for the Rimin Gado reservoir water. They also noted that for Thomas reservoir water, for example, at initial turbidity of 90 NTU, the turbidity removal was 83% while at 60NTU initial turbidity, removal dropped to 63%. It was then concluded that, in general, turbidity removal increase with increase in initial turbidity of the raw water sample. These results corroborated the earlier findings by Jahn (1988), Folkard et al (1992 and Kaser et *al* (1990).

Muyibi and Evison (1996) also worked in Kano and used water samples from Challawa and Dambatta water works, and Rimin Gada reservoir. The report showed that for Challawa and Dambatta water works water samples, turbidity removals were 36-98.2% and 14.3-99.4% respectively, with the dosage varying from 100 to 450mg/l and 100 to 250mg/l, respectively. The optimum dose of *M. Oleifera* for the two samples was 250mg/1.

For the Rimin Gado reservoir water samples, turbidity removal varied from 17.1-95.7% with the M. *Oleifera* dose varying from 100 to *450mg/l.* It was however, observed that in this case, turbidity removal was probably inhibited by the humic substances and high natural colour of the water samples. Muyibi and Okuofu (1995) noted that since *M. Oleifera* is a polyelectrolyte (Weber, 1972), it may not be effective as a primary coagulant for low turbidity water because such waters contain low concentration of colloidal particles, with a low rate of inter particle contact in such systems. This is later collaborated by Muyibi and Evison (1995a).

Most works on the use of *M. oleifera* in coagulation employ the parameters used in conventional jar tests to evaluate the coagulating efficiency of the seed extract. However, Muyibi and Evison (1995) investigated among others, the multiple effects of physical parameters of rapid and slow mixing rates and times on coagulation of turbid water with *M. oleifera.* Using the single factor method of optimization and optimum dosage, it was observed that at initial turbidity of 50 NTU (low turbidity), the rapid mix velocity gradient and time was 432/s and 1 min respectively. Also for initial turbidity of 225-750 NTU (moderate to high), the optimum rapid mix velocity gradient and time was *443/s* and 4 min respectively. The residual turbidity recorded was < 10 NTU in all cases. Similarly, the optimum slow mix velocity gradient and time recorded were 149.9/5 and 20 min for low turbidity water; and 208.3/5 and 25min for medium and high turbidity water.

3.2.2 Co-coagulation of M. Oleifera with Alum

Investigations were carried out on the use of *M. oleifera* in conjunction with alum. Felkard *et al* (1989) reported dramatic improvements in floc characteristics and significant savings in imported alum usage of the order of 50 to 80%. Muyibi and Okuofu (1995) also observed that the floes formed in conjunctive use were bigger, denser and settled faster after slow mixing, than when alum *or M. oleifera* alone were used. Furthermore, rates of floc formation and settling were reported to be comparable to alum in the range of raw water turbidities (26-40 NTU) considered. Saving in alum use in the range of 40-80% was similarly reported, depending on the raw water and the quality of the product water desired.

In the same study, it was noted that as optimum dose of alum was reduced by 80%, 60%, and 40% and the *M. oleifera* seed dose increased by 10mgll from *20mg/l* to *50mg/l,* respectively the residual turbidity of the water decreased. In another study, Muyibi and Evison (1996) reported a saving of up to 40% in alum use when *M. oleifera* was used as a co-coagulant. The lowest residual turbidity was recorded at a combination of *30mg/l* alum + *40mg/l M. oleifera.*

3.2.3 M. oleifera as a Coagulant Aid

Since *M. oleifera* seed extract is a polyelectrolyte, it may be able to function as a coagulant aid, using alum as the primary coagulant (Jahn, 1982). This possibility was a subject of study in recent times. Muyibi and Okuofu (1995) reported that in one investigation, the optimum dose of alum without *M. oleifera* was *40mg/l.* When *M. oleifera* was used as a coagulant aid, the optimum dose of *M. oleifera* was found to be *10mg/l* while alum was 20mgll. The optimum time of application of *M. oleifera* was found to be 50 seconds' after slow mixing. It was further noted that the floes formed were dense and settled faster than with alum alone. The residual turbidity was also found to be much lower than that of alum alone.

3.3 Use of Moringa oleifera in water Softening

Softening is the removal of ions which cause hardness in water. Hardness is caused mainly by calcium and magnesium ions, or at times, by iron, manganese, strontium, and aluminum ions. Hardness causes excessive soap consumption and scale formation in hot water pumps, boilers and pipes. Public water supplies should not exceed 300 to *500mg/l* of hardness; although, aesthetically, a hardness greater than 150mgll is unacceptable (Corbitt, 1990). Because the cost *of* chemicals for softening is high, local materials are being considered as substitutes. *M. oleifera* seed extract has been identified as a potential softening agent (Muyibi and Evison, 1995a; Muyibi and Evison, 1996; Muyibi and Okuofu, 1996).

Barth *et al* (1982) reported that initial hardness *of* water varying from 80300mg/l $CaCO_3$ was found to have been reduced to between 50-70% after coagulation and softening with *M. oleifera.* Sani (1990), using water samples from Watari and Challawa rivers, and from Yarimawa and Kofar Kabuga wells, reported total hardness reduction from 54mg/l to 25mg/l $CaC0_3$ for river Watari water while using 40-200mg/l *M. oleifera* dosage. This reduction was from 95 to 30mg/l $CaC0_3$ for Challawa water using *50-250mg/l* M. o*leifera* dosage. For Yarimawa well water, the reduction was from *11.2mg/l* at *100mg/l M. oleifera* t09.8mg/l at *400* mg/l *M. oleifera* dose; whereas for Kabuga well water sample, the hardness reduced from 21 mg/l to 17mg/l $CaC0_3$ as M. o*leifera* dosage increased from 0 - 250mg/l, but at 150mg/I, the hardness went up to *20*mg/l and leveled off to 15mg/l $CaC0_3$ at 250mg/l *M. oleifera* dosage.

Muyibi and Okuofu (1995) studied the softening of water samples from 17 hand-dug wells in Kano Nigeria, and found that the residual hardness decreased with increased dosage of *M. oleifera.* It was also observed that for the same initial hardness, water samples containing both calcium and magnesium hardness required higher doses *of* M. o*leifera* than those containing only calcium hardness. Muyibi and Evison (1995a) using water samples from 4 sources of varying hardness in England also observed that hardness reduction increased with increasing dosage of *M. oeifera.* This was later corroborated in another study by Muyibi and Evison (1996). In this work, it was further reported that for water samples with hardness values of 50 to 600mg/l $CaC0_3$, softening with *M.* o*leifera* was found to be dependent on the initial hardness of the water and the seed extract dosage. Muyibi and Okuofu (1995) also found that the absorption isotherm for softening with *M. oleifera* was linear and of approximately the Langmuir type. This was later corroborated in another study by Muyibi and Evison (1996).

Softening of water with *M. oleifera* has a potential advantage since it is accompanied by very low reduction in alkalinity, which is required to provide the necessary buffering capacity to achieve required treatment objectives (Muyibi and Okuofu (1996), Muyibi and Evison (1995a); Muyibi and Evison (1996).

3.4 Use of *Moringa oleifera in* Water Disinfection

The gravest of all dangers to which water supplies can be exposed is contamination by pathogenic organisms. Disinfection is a chemical process for eliminating pathogenic microbes from an environment. Chemical agents that have been used as disinfectants include halogens, phenols, alcohols, heavy metals, dyes, soap and detergents, ammonia compounds, hydrogen peroxide, and various alkalis and acids (Metcalf and Eddy, 1991). The most common of these are the oxidizing chemicals, and chlorine is the most universally used. However, chlorine has problem of decay and reduced concentration as the water flows through the distribution network (Devarakonda,

et al, 2010). It also has the potential for forming carcinogenic and mutagenic disinfection by-products (DBPs) (Goveas, et al, 2010). Disinfectants and their by-products may also be associated with increased risks of cardiovascular diseases, cancers, and birth defects. Although such risks are low, Arbuckle et al., (2002); Bove et al., (2002); and Woo, et al., (2002) noted that associations with such diseases could not be ruled out.

These, and the high cost of chlorine, especially in developing countries where it needs to be imported, makes it imperative to look for cheaper alternatives that are also environmentally friendly. Studies by Eilert, et al (1981); Suarez, et al (2003), Suarez, et al (2005), Fisch, et al (2004), Thilza, et al (2010), and Bukar, et al (2010) identified the presence of an active antimicrobial agent in *Moringa oleifera* seeds.

Eilert *et al* (1981) identified 4α-*4-rhamnousyloxy-benzyf-isothiocynate* as an active antimicrobial agent in *M. Oleifera.* This is readily soluble to water at 1.3umol/l and is non-volatile. In a study using pure *4α-4-rhamnotyloxy-benzylsothiocynate* isolated from defatted *M. Oleifera* seeds, the antimicrobial action of *M. Oleifera* was investigated on three bacteria species - *Bacillus Subtilis* (gram -ve) , *Serratia Marcescens* (gram -ve) and *Mycobacterium Pheli.* The result showed that B. *Subtlis* was completely inhibited by 56μmol/l and *M. Pheli* by *40μ*mol/l. Only partial inhibition was observed for S. *Macesscens* in the range of concentration considered.

The effect of residual turbidity on the antimicrobial action of *M. oleifera* was also reported. Folkard (1989), using extract of *M. Stenopetala,* was able to achieve 90% reduction of *Herpes simplex* virus and *Orf* virus. Whereas re-growth of *Serratia Marinatubra* occurred at high dosage (800rng/l), no re-growth w*as* observed at lower seed dosage. In each case, the initial sample turbidity was between 20 to 25 NTU with residual turbidities in the range of 3-8NTU. However, Jahn (1986) reported that residual turbidities greater than 100NTU was companied by bacterial removal of only 0-36%.

Thilza, et al (2010) reported that Moringa leaf stalk extract had mild activities against *E. coli* and *Entrobacter aerogenes*. Bukar, et al (2010) also studied the antimicrobial activities of Moringa Seed Chloroform extract and Moringa Seed Ethanol extract. They found both to have inhibitory effects on the growth of *E. coli* and determined the Minimum Inhibitory Concentration (MIC) to be >4mg/ml. Thilza, et al (2010) using extract from Moringa leaf stalk, found that at dilutions of 1000mg/ml, 700mg/ml, 400mg/ml, and 200mg/ml, only mild activity against *E. coli* and *Entrobacter Aerogenes* was noticed. They also found that the highest activity was produced by *E.Coli* at 1000mg/ml which comparatively was less than that of the standard drug tetracycline (250mg/ml).

Suarez *et al* (2003) had reported that Moringa seeds protein may be a viable alternative to chemicals commonly used as food preservatives or for water disinfection. Bichi, et al (2012a) has shown that its highest disinfection action was achieved with the use of de-fatted seed cake and extracting the active ingredients by aqueous extraction. Bichi, et al (2012b) also found that the optimal conditions for the extraction of the bioactive compounds to be 31 minutes mixing time, 85 rpm mixing speed and 3.25 mg/mL Moringa dosage. In another study, Bichi, et al (2012c) developed a kinetic model for the application of *Moringa oleifera* seeds extract in water disinfection and determined the coefficient of specific lethality (Λcw) for *E. coli* inactivation to be 3.76 L mg-1 min-1. The mode of attack of the Moringa seeds extract on the *E.coli* cell was explained as by rupturing the cell and damaging the intercellular components, when water dips in to the cell which causes it to swell more and burst leading to death.

4. Discussions

The application of Moringa Oleifera seeds extract in water coagulation and softening has received a lot of attention. Currently, *M. Oleifera* coagulant is being used in many countries including Malawi, Sudan, Egypt and Malaysia. Moringa coagulants are also being patented by many researchers.

The mechanism of the action of *Moringa oleifera* seeds extract in water disinfection as well as the kinetics of this action is yet to be fully understood. The effect of the method of seed processing on the disinfection action of Moringa is also a researchable area. These understandings would also pave way for its practical application in the field.

The safety of using *M. oleifera* in water treatment has also received some attention. Sani (1990) reported the use of leaves as vegetables and for medicinal purposes in Northern Nigeria. Berger *et al* (1984) in a study on the toxicology of *M. oleifera* seed concluded that it may not constitute a serious health hazard. Muyibi and Evison (1995a) suggested that further studies need to be carried out to ensure the complete safety of using *M. oleifera* in water treatment. Folkard, et al (1992) however reported that, to date, all the studies have concluded that there is no evidence to suggest any acute or chronic effects on humans, particularly at the low doses required for water treatment.

5. Conclusion and Recommendations

Moringa oleifera seeds can be used as a coagulant to replace conventional coagulants, flocculant, hard water softener, disinfectant, and for removing of heavy metal in drinking water treatment. Thus improved application

of this should be encouraged, especially in rural water supplies where the water requirement is relatively small and the production of Moringa is likely to be high and constant. Thus in order to improve on the application of *M. oleifera* in water treatment, certain questions still needs to be answered. The following are some of the areas requiring further investigations.

i) The effect of grain size on the extraction of the active ingredients
ii) The effect of shelf life on the coagulating, softening and disinfection property of the extract
iii) The mode of attack of the extract on the microbes
iv) Isolation of the exact active compound responsible for the ant-microbial activity
v) Further work on the use of the extract in the removal of heavy metals
vi) Development of pilot plant for the subsequent application of the extract in the field.

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