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over *Moringa Olifera* as a natural coagulant,
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Wastewater treatment potential of *Moringa stenopetala* over *Moringa oleifera* as a natural coagulant, antimicrobial agent and heavy metal removals

Asaminew Abiyu^{1*}, Denghua Yan², Abel Girma¹, Xinshan Song¹ and Hao Wang²

Abstract: *Moringa* is a multipurpose tree with considerable economic and social potential and its cultivation is currently being actively promoted in many developing countries. Seeds of this tropical tree contain water-soluble, positively charged proteins that act as an effective coagulant for water and wastewater treatment. This study evaluated the effectiveness of *Moringa oleifera* and *Moringa stenopetala* seed powder in water purification as a replacement coagulant. Water treatment with *M. stenopetala* was found to be more effective for water purification than treatment with *M. oleifera* seed. Indeed, it has been given little research and development attention. Unlike *M. oleifera*, little scientific research has been conducted on the properties and potential uses of *M. stenopetala* in general and its seeds in particular. However, the method should be encouraged in communities without safe water supply.

Subjects: Freshwater Biology; Water Quality; Water Science

Keywords: *Moringa*; *Moringa oleifera*; *Moringa stenopetala*; coagulant; purification water

ABOUT THE AUTHORS

Asaminew Abiyu is a Moringa Program Coordinator in the Hunger project Ethiopia International based NGO for the last 2 years. Asaminew received the Mission for change and development association in Ethiopia (MCDAE) award for his contribution and successful completion of the management and leadership courses in the year 2015. Asaminew holds an MSc degree in Environmental Science from Addis Abeba University Ethiopia, in the year 2013 and a BSc degree in Production Forestry from Hawassa University, Wondo Genet College of Forestry and Natural Resources, 2006 and BTh in Theology from Holy Trinity Theological University College, 2013 Addis Ababa, Ethiopia. Asaminew's objective is to seamlessly merge different projects with applied research in the service of communities. His research interest focuses on the complex connectivity of human and environmental relations, addressing indigenous ways of knowing, Green Energy, waste treatment, climate change and Hydrology. And now he is a PhD student at Donghua University, School of Environmental Science and engineering.

PUBLIC INTEREST STATEMENT

Moringa stenopetala is one of the facultative deciduous trees having multipurpose use. *M. stenopetala* has potential benefits for many purposes such as ecological, nutritional, medical, and industrial. It is also a good source of generating income to the rural poor. Various findings on the medicinal use of *M. stenopetala* support the traditional claim of the plant particularly its indigenous use for chronic diseases. The leaves are nutritious due to the presence of important micronutrients.

This review has focuses to address wastewater treatment potential of *M. Stenopetala* over *Moringa oleifera* as a natural coagulant, antimicrobial agent and heavy metal removals. Besides this review evaluates the effectiveness of *M. oleifera* and *M. stenopetala* seed powder in water purification as a potential replacement of coagulants. Water treatment with *M. stenopetala* is found to be more effective and efficient for water purification than *M. oleifera* seed powder.

1. Introduction

Water is one of the most vital natural resources for all life on Earth. The availability and quality of water have always played an important part in determining not only where people can live, but also their quality of life. Even though there always has been plenty of fresh water on Earth, water has not always been available when and where it is needed, nor is it always of suitable quality for all uses. Water must be considered as a finite resource that has limits and boundaries to its availability and suitability for use.

Lack of potable water is a huge problem and a major cause of death and disease in the world. According to WHO/UNICEF (2012), 783 million people worldwide are without improved drinking water, and the World Health Organization estimates that lack of proper drinking water causes 1.6 million deaths each year from diarrheal and parasitic diseases. In many parts of the world river water which can be highly turbid is used for drinking purposes. This turbidity is conventionally removed by treating the water with expensive chemicals; many countries must import expensive chemicals to clarify the water, limiting the amount they can afford to produce these imported chemicals with a great expense.

Conventional drinking water treatment includes, but is not limited to: coagulation, flocculation, sedimentation, filtration, and disinfection. Coagulation and filtration are the most critical unit processes (other than disinfection) determining success or failure of the whole system and they are the bottlenecks for upgrading treatment plants. The two units are so closely linked that the design of one affects the other. When they are well designed and operated, other units, such as flocculation and sedimentation, may not be required (Conley, 1961) and the burden on disinfection is significantly reduced.

Based on this, purification of drinking water is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. The goal is to produce water fit for a specific purpose. Most water is disinfected for human consumption (drinking water), but water purification may also be designed for a variety of other purposes, including fulfilling the requirements of medical, pharmacological, chemical and industrial applications. The methods used include physical processes such as filtration, sedimentation, and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light.

Purifying water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi, as well as reducing the amount of a range of dissolved and particulate material derived from the surfaces that come from runoff due to rain. Chemical coagulants like Aluminum sulfate (alum), FeCl_2 are used in municipal drinking water treatment plant for purification process. This excess use of amount of chemical coagulants can affect human health e.g. Aluminum has also been indicated to be a causative agent in neurological diseases such as pre-senile dementia.

Indeed, wastewater treatment is carried out to remove turbidity, chemicals, and microbiological pollutants that may constitute health hazards by series of unique processes. The most important stage of wastewater treatment is disinfection. Hence, natural coagulants have been used for centuries in traditional water treatment practices throughout certain areas of the world. The new study compares protein from the seeds of different varieties of Moringa trees that are grown in different countries. It also allows estimates of the optimum amount of seed extract that should be used to minimize residues in treated water. Powerful research tools such as those for neutron scattering are important to tackle challenges facing developing countries as well as industrialized regions. Use of Moringa seeds, both to substitute conventional materials in large water treatment plants and in small scale units.

2. Facts about Moringa tree

Moringa is multipurpose drought-resistant and salt tolerant farm tree cultivated predominantly in South Ethiopia (Jiru, 2016). According to Dechasa there are 13 species which are grouped into three morphological types (stem structural forms) namely the slender, the bottle and shrubs/bushes or tree. *Moringa stenopetala* is native to East Africa linking South Ethiopia, North Kenya and West Somalia—a region that is characterized by unreliable rain and affected repeatedly by drought. The tree has special attributes in reclaiming salt affected farms in the Rift Valley. The massive Moringa is a cabbage and camel tree is nutritious, rich in all vitamins grows when most dry land trees shed their leaves. It is a good source of sustainable food and feed (including bee forage) supplier. The cabbage tree is a small tree up to 12 m (39 ft), with a many-branched crown and sometimes with multiple trunks.

The leaves are bipinnate or tripinnate, with about five pairs of pinnae and three to nine elliptic or ovate leaflets on each pinna. The fragrant flowers have creamy-pink sepals, white or yellow petals, and white stamens. The fruits are long reddish pods with a greyish bloom. The cabbage tree was planted by agriculturalists on the complex system of terraces built high up in the Ethiopian Highlands, where they became domesticated and were bred to improve productivity, the taste of their leaves, and the size of their seeds. Since then, the improved trees have been introduced into other areas such as the Rift Valley. Multidimensional direct and indirect role of the societies has been reviewed for economic, social acceptability and environmental privilege has been presented from research results of the presenter and secondary information sources. Its role in the hydrological function compares to other major land use, land cover is compared and addressed from secondary and primary data.

M. stenopetala is mostly known for its importance as a nutritious vegetable food crop in the terraced fields of Konso, Ethiopia. In this way, it is similar to its Indian relative, *Moringa oleifera* (Jiru, 2016). It is also used for shading of capsicum and sorghum crops, as a companion plant; and additionally in folk medicine. Another use is the clarification and purification of water to make it potable. A powder made by grinding the seeds is found to be more effective at coagulating substances in suspension than the seeds of the closely related horseradish tree (*M. oleifera*), which is used for this purpose in India (Jiru, 2016).

M. stenopetala is a massive tree; it is native to Ethiopia and has been used for food and feeds in the south Ethiopia for centuries by the Konso, Darachie and other Nation and Nationalities Peoples of the South. In recent years, it has been distributed in almost all parts of the lowland and the midlands of Ethiopia. This important multi-purpose vegetable, fruit tree and oil crop has not been tapped in relation to its potential (Wakjira, Jiru, & Asaminew, 2016).

M. stenopetala is a drought-resistant multipurpose food and feed that can sustain when used under dry condition. It is rich in nutrition and multivitamins. The seed cake purifies water where turbidity and unsafe water is a common phenomenon in the lowland in general and the lowest and hottest prefer in particular. The tree originated in South Ethiopia around eastern and northern Turkan Lake, North Kenya and West Somali (Olson, 2001) cited as Wakjira et al. (2016). These spots are both the lowest and driest where conflict arises between the three neighboring countries due to shortage of animal feed. Moringa being a good quality, sustainable fodder provider can be termed as conflict resolver.

According to Keay, Moringa is a tree which belongs to the family Moringaceae, consisting of only one genus with about 13 species of deciduous trees (Keay, 1989) cited as Anjulo (2016). Among these, there are two popular and widely grown species of moringa as food for human consumption. *M. oleifera* is native of India, introduced into other countries in the tropics which is easily recognized by the compound pinnate leaves (2 or 3 times pinnate) and the long, narrow angular fruits containing large, usually winged seeds (Hutchinson & Dalziel, 1966) cited as Anjulo (2016). On the other hand *M. stenopetala* is native of East Africa, which is widely grown for its palatable leaves cooked for

human consumption in southern Ethiopia and northern Kenya. The compound leaves of this species are wider than *M. oleifera* and are preferred as cooked vegetables by the local communities in south and southwestern Ethiopia.

Reports showed that Moringa is extremely rich in vital nutrients and, can grow very fast in dry and impoverished areas of the world, where food is scarce. Moringa has been in use as a medicinal plant since time immemorial to heal and ease many diseases, starting from various inflammations to parasitic diseases, diabetes and cancers, shown by various reports. In this line, the recent works of the Ethiopian Public Health Institute (EPHI) are encouraging. Moringa has been gaining much popularity, as a very nutritious plant that can feed the needy people and may save various lives. Its leaves or leaf powder can be used successfully as a supplemental food to nourish children, pregnant or nursing women, and everyone else. Report showed that, Moringa seed contains up to 42% oil, which possess the highest quality (up to 72% oleic) and hence possess tremendous market values. The oil is required as cooking oil and as industrial oil, specific ingredient for medicines and detergents. In short, the role and prospects of Moringa in farming system apparently look bright, and thus need to be well understood and be given high attention in order to further improve and utilize its productivity and profitability in a sustainable manner.

2.1. The power of Moringa as natural coagulant

Use of natural coagulants for treatment of water and wastewater in developing countries is an area that is gaining interest. Tropical plants of the family of Moringa, are among some of the natural coagulants that have been studied for clarification of turbid water. Both *M. oleifera* and *M. stenopetala* is the most widely distributed, well-known and studied species of the family Moringaceae because of its previous economic importance as a source of the commercially important and more recently, as a multipurpose tree for arid lands and a source of water-purifying agents for developing countries (Morton, 1991).

M. oleifera is native to sub-Himalayan North-Western India and Pakistan but the plant was distributed to other areas of tropical Asia in prehistoric times and to other parts of the world including Malawi during the British colonial era. *M. stenopetala*, often referred to as the African Moringa tree, originates from southern Ethiopia and Kenya (Jahn, 1991) cited as Seifu (2015). The food, fodder, water clarifying and medicinal uses of the Moringaceae, especially *oleifera* are well documented and the trees are recommended for live fencing, inter-cropping, and pollution control (Moges, 2004; Morton, 1991).

The water-soluble Moringa seed proteins possess coagulating properties similar to those of alum and synthetic cationic polymers. The use of Moringa species for water clarification is a part of African indigenous knowledge. Jahn (1991) first studied and confirmed the coagulating properties of Moringa seeds after observing women in Sudan use the seeds to clarify the turbid Nile waters. *M. stenopetala* is less widely distributed than *M. oleifera* but *stenopetala* is reportedly more resistant to insect pests than other members of the family and its seeds are larger and easier to process than those of *oleifera* (Kayambazinthu, D., Forestry Research Institute of Malawi, personal communication). Although the water clarifying properties of *M. stenopetala* have not been as extensively studied as those of *M. oleifera*, Jahn, Musnad, and Burgstaller (1986) cited as Seifu (2015) reported that 100–150 mg/L of *M. stenopetala* was as effective in water clarification as 200 mg/L of *M. oleifera* which indicates that *stenopetala* is more effective than *oleifera*. The mechanism of coagulation by Moringa is not well understood and different authors have attributed it to existence of proteins and non-protein flocculating agents (Gassenschmidt, Jany, Tauscher, & Niebergall, 1995; Ndabigengesere, Narasiah, & Talbot, 1995; Okuda et al., 2001).

Although a number of papers are found on the water clarification properties of Moringa, only a few deal with heavy metal removal potential of Moringa. Metal ion removal ranging from 70 to 89% for lead, 66 to 92% for iron and 44 to 47% for cadmium using *M. oleifera* seed kernels and ram press cakes with initial metal concentration of 7 ppm and sorbent dose of 120 mg/L has been reported by

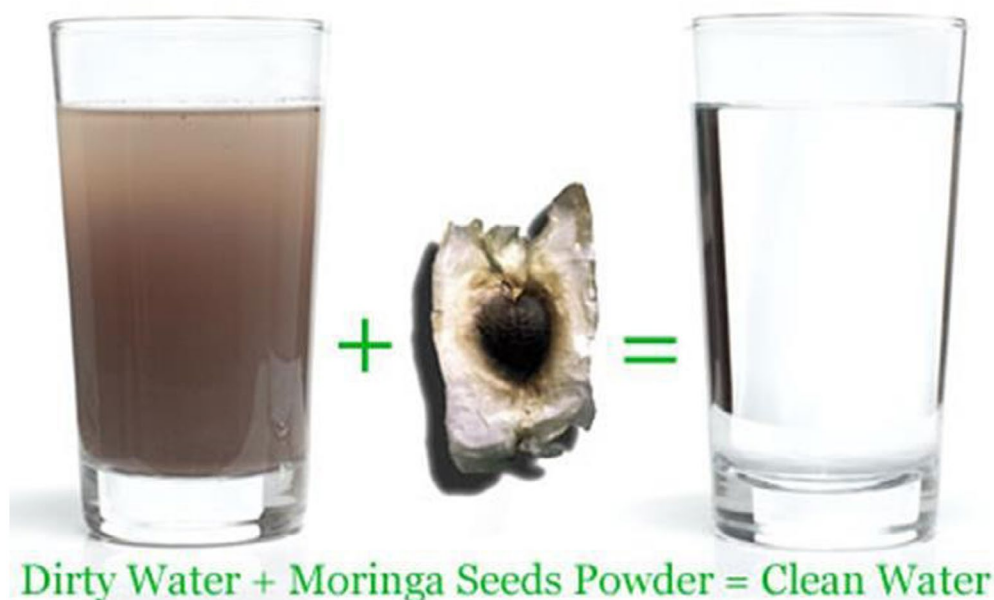
our group (Sajidu, Henry, Kwamdera, & Mataka, 2005). Study showed that, the removal and recovery of arsenic from aqueous system using shelled *M. oleifera*. The study revealed removal capacities of 60.21% As³⁺ and 85.6% As⁵⁺ at a biomass dosage of 2.0 g in 200 ml of 25 mg/L of the metal. Sharma, Kumari, Srivastava, and Srivastava (2006) reported favorable performance of bio-sorption of Cd²⁺, Cr³⁺ and Ni²⁺ on shelled *M. oleifera* seeds. The study reported that *M. stenopetala* is better than *M. oleifera* at removing lead from contaminated water (Mataka, Henry, Masamba, & Sajidu, 2006). Lead removal of 96% from initial concentration of 7 mg/L at a dosage of 2.4 g of seed powder in 100 ml of the metal solution had been reported. In continuation of the work, the present investigation reports the pH dependence of sorption of Cd²⁺, Zn²⁺, Cu²⁺ and Cr²⁺ cations on pure water and sodium chloride extracts of *M. stenopetala* and *M. oleifera*. The removal of organic and inorganic material from raw water is essential before it can be disinfected for human consumption. In a water treatment works, this clarification stage is normally achieved by the application of chemical coagulants which change the water from a liquid to a semi-solid state. This is usually followed by flocculation, the process of gentle and continuous stirring of coagulated water, which encourages the formation of “flocs” through the aggregation of the minute particles present in the water. Flocs can be easily removed by settling or filtration. For many communities in developing countries, however, the use of coagulation, flocculation and sedimentation is inappropriate because of the high cost and low availability of chemical coagulants, such as aluminum sulfate and ferric salts. The study reported that Moringa seeds treat water on two levels, acting both as a coagulant and an antimicrobial agent. It is generally accepted that Moringa works as a coagulant due to positively charged, water-soluble proteins, which bind with negatively charged particles (silt, clay, bacteria, toxin, etc.) allowing the resulting “flocs” to settle to the bottom or be removed by filtration. The antimicrobial aspects of Moringa continue to be researched. Findings support recombinant proteins both removing microorganisms by coagulation as well as acting directly as growth inhibitors of the microorganisms. While there is ongoing research being conducted on the nature and characteristics of these components, it is accepted that treatments with Moringa solutions will remove 90–99.9% of the impurities in water (Figure 1).

2.2. Water treatment with Moringa seeds

According to Jennifer (2015), solutions of Moringa seeds for water treatment may be prepared from seed kernels or from the solid residue left over after oil extraction (press cake). Moringa seeds, seed kernels or dried press cake can be stored for long periods but Moringa solutions for treating water should be prepared fresh each time. In general, 1 seed kernel will treat 1 L (1.056 qt) of water.

Figure 1. Water treatment using Moringa Seed.

Source: Jennifer (2015).



- Low turbidity NTU < 50 1 seed per 4 L (4.225 qt) water
- Medium turbidity NTU 50–150 1 seed per 2 L (2.112 qt) water
- High turbidity NTU 150–250 1 seed per 1 L (1.056 qt) water
- Extreme turbidity NTU > 250 2 seeds per 1 L (1.056 qt) water

Jennifer puts the following instructions to clean water with Moringa seeds

- (1) Collect mature Moringa seed pods and remove seeds from pods
- (2) Shell seeds (remove seed coat) to obtain clean seed kernels; discard discolored seeds.
- (3) Determine quantity of kernels needed based on amount and turbidity of water in general 1 seed kernel will treat 1 L (1.056 qt) of water.
- (4) Crush appropriate number of seed kernels (using grinder, mortar & pestle, etc.) to obtain a fine powder and sift the powder through a screen or small mesh.
- (5) Mix seed powder with a small amount of clean water to form a paste.
- (6) Mix the paste and 250 ml (1 cup) of clean water into a bottle and shake for 1 min to activate the coagulant properties and form a solution.
- (7) Filter this solution through a muslin cloth or mesh screen (to remove insoluble materials) and into the water to be treated.
- (8) Stir treated water rapidly for at least 1 min then slowly (15–20 rotations per minute) for 5–10 min.
- (9) Let the treated water sit without disturbing for at least 1–2 h.
- (10) When the particles and contaminants have settled to the bottom, the clean water can be carefully poured off.
- (11) This clean water can then be filtered or sterilized to make it completely safe for drinking.

The report puts the following sentence as dangers:

Secondary infection: The process of shaking and stirring must be followed closely to activate the coagulant properties; in the flocculation process takes too long, there is a risk of secondary bacteria growth during flocculation.

Recontamination: The process of settling is important. The sediment at the bottom contains the impurities so care must be taken to use only the clear water off the top and not allow the sediment to recontaminate the cleared water.

In general, water purified with Moringa seeds is acceptable for drinking only where people are currently drinking untreated, contaminated water. *M. oleifera* The *M. oleifera* is native to the sub-Himalayan tracts of north-west India, Pakistan, Bangladesh and Afghanistan (Makkar & Becker, 1997). This multipurpose tree has been introduced to Ethiopia over the last few years and is grown on nursery sites parallel to *M. stenopetala* in southern parts of the country. Both *M. stenopetala* and *M. oleifera* trees are the most commonly cultivated Moringa species in the tropics and subtropics which have the potential as alternative animal feed resources during dry periods of the tropics. However, the removal of heavy metals from wastewater of both Moringa species in raw water under Ethiopian conditions is hardly documented. Scholars indicated that *M. oleifera*, reduce turbidity of water. The reduction efficiency is higher for more turbid waters. Turbidity reduction exceeding 90% was achieved for all the three extracts on shallow well water with an initial turbidity of about 50 NTU. *M. oleifera* exhibited the most favorable results followed by *G. gum* and lastly *J. curcas*. The results indicated that *M. oleifera* can reduce turbidity of shallow well water. *M. oleifera* results for more turbid

water (200 NTU) was better than less turbid water. It was noted that pH of the samples increased as the concentration of the extracts increased. There was, in general, an overall reduction in the number of coliforms and *E. coli* after the water had been treated with *M. oleifera* (Abatneh, Sahu, & Yimer, 2014).

Similarly, in Sudan dry *M. oleifera* seeds are used in place of alum by rural women to treat highly turbid Nile water (Jahn et al., 1986) cited as Seifu (2015). In Northern Nigeria, the fresh leaves are used as a vegetable, roots for medicinal purposes and branches for demarcation of property boundaries and fencing. Studies by Eilert, Wolters, and Nahrstedt (1981) cited as Lüring and Beekman (2009) identified the presence of an active antimicrobial agent in *M. oleifera* seeds. The active agent isolated was found to be 4a Lrhamnosyloxy-benzyl isothiocyanate, at present the only known glycosidic mustard oil. Madsen, Schlundt, and Omer (1987) carried out coagulation and bacterial reduction studies on turbid Nile water in the Sudan using *M. oleifera* seeds and observed turbidity reduction of 80–99.5% paralleled by a bacterial reduction of 1–4 log units (90–99.9%) within the first one to two hours of treatment, the bacteria being concentrated in the coagulated sediment. Other scholars at Asia said that *M. oleifera*, native to India, grows in the tropical and subtropical regions of the world. It is commonly known as “drumstick tree” or “horseradish tree” (*Moringa can* withstand both severe drought and mild frost conditions and hence widely cultivated across the world. With its high nutritive values, every part of the tree is suitable for either nutritional or commercial purposes. The leaves are rich in minerals, vitamins and other essential phytochemicals. Extracts from the leaves are used to treat malnutrition, augment breast milk in lactating mothers. It is used as potential antioxidant, anticancer, anti-inflammatory, antidiabetic and antimicrobial agent. *M. oleifera* seed, a natural coagulant is extensively used in water treatment. The scientific effort of this research provides insights on the use of moringa as a cure for diabetes and cancer and fortification of moringa in commercial products. This review explores the use of moringa across disciplines for its medicinal value and deals with cultivation, nutrition, commercial and prominent pharmacological properties of this “Miracle Tree”.

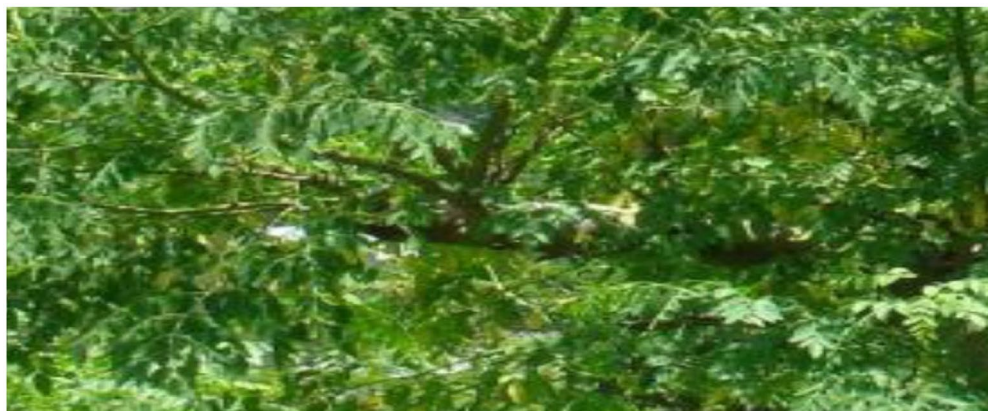
2.3. *M. stenopetala*

M. stenopetala known as African Moringa has a wide range of adaptation from the arid to humid climates and can be grown in a various land use patterns. It grows in the lowlands of west of the Great Rift Valley Lakes from arid to semi-humid areas altitudinal ranging from 390 m to about 2200 masl. It is a strategic multi-purpose tree plant in being a unique food tree in drought prone areas and has recently been distributed to other regions of Ethiopia, beyond its place of origin. Leaves are used for human consumption and animal feed (Aberra, Workinesh, & Tegene, 2011). A study conducted by Aberra, Bulang, and Kluth (2009) indicated that the leaves of *M. stenopetala* are rich in crude protein (28.2%) and contain reasonable amounts of essential amino acids. *M. stenopetala* is native to Ethiopia, and it is known by various vernacular names. It is called “Haleko” in Gofa areas, “Shelagda” in the Konso language, and “Shiferaw” in Amharic (Engels & Goettsch, 1991; Jahn, 1991; Teketay, 2010) cited as Seifu (2015). *M. stenopetala* is particularly important as human food because the leaves, which have high nutritional value (Abuye et al., 2003), appear toward the end of the dry season when few other sources of green vegetables are available (Figure 2). The leaves contain high amounts of essential amino acids and vitamins A and C (Abuye et al., 2003) cited as Seifu (2015).

Scholars said that *M. stenopetala* has also antimicrobial properties; the seeds of the tree are used to clarify muddy water (ICRAF, 2006b). The seeds of *M. stenopetala* have natural flocculating and antimicrobial properties (ICRAF, 2006b; Jahn, 1991) cited as Seifu (2015). Earlier experiments showed that whole crushed seeds of *M. stenopetala* were effective in removing turbidity from waters with high initial turbidity, and bacterial contamination was reduced by 90 to 99.9%. *M. stenopetala* seeds have better water purifying properties than *M. oleifera* (HDRA, 2002). The active coagulating substances are found in the cotyledons of the seeds (ICRAF, 2006a). A recent study (Hellsing et al., 2014) also indicated that proteins extracted from the seeds of the *M. stenopetala* tree are effective flocculent for particles dispersed in water and are attractive as a natural and sustainable product for use in water purification. *M. stenopetala* seed powder could be used to remove heavy metals and

Figure 2. *Moringa stenopetala* plant in the backyard of a farmer in southern Ethiopia.

Source: Seifu (2015).



industrial wastes from water. A study by Mataka et al. (2006) aimed at investigating the potential of *M. stenopetala* and *M. oleifera* for the removal of cadmium(II) ions from water indicated that *M. stenopetala* seed powder, at a dose of 2.50 g/100 ml, reduced the concentration of cadmium by 53.8%.

The leaves, roots, and seeds of *M. stenopetala* and *M. oleifera* have a long tradition of use in folk medicine. Various parts of the *M. stenopetala* tree are claimed to contain disease-preventing chemicals (Endeshaw, 2003). People with high blood pressure boil the leaves and drink the water to get relief from their ailment (Endeshaw, 2003). A recent report by Mengistu, Abebe, Mekonnen, and Tolessa (2012) indicated that *M. stenopetala* has blood pressure lowering effects. These researchers showed that crude aqueous leaf extract of *M. stenopetala* caused a significant drop in systolic blood pressure, diastolic blood pressure, and mean arterial blood pressure in normotensive anesthetized guinea pigs. Leaf extracts of *M. stenopetala* are used to lower blood glucose and cholesterol levels.

Ghebreselassie, Mekonnen, Gebru, Ergete, and Huruy (2011) reported that aqueous leaf extract of *M. stenopetala* is shown to increase body weight and reduce serum glucose and cholesterol levels in mice. Serum glucose and serum cholesterol levels decreased significantly after six weeks of treatment. They indicated the need for further studies in order to fractionate the active economic and social importance of *M. stenopetala*.

Moringa is a multipurpose tree of significant economic and social importance, as it has vital nutritional, industrial, and medicinal applications (Jahn, 1991; NRC, 2006). On the other hand, the rest of the species of moringa have not been studied in detail, and their potential uses have not been fully understood. *M. stenopetala* was domesticated in the east African lowlands and is indigenous to southern Ethiopia. Many different ecotypes and varieties of *M. stenopetala* are found in Ethiopia. *M. stenopetala* is often called “cabbage tree” and is an important indigenous vegetable in south western Ethiopia where it is cultivated as a food crop. The Gofa, Konso, Burji, and Gamo tribes consume its leaves as a vegetable, especially during the dry season (Abuye et al., 2003; Demeulenaere, 2001; Jahn, 1991) cite as Seifu (2015).

The economic status of an individual in low lands of southern Ethiopia is closely associated with the number of moringa trees they have in their backyard. For example, when a young man proposes marriage in the former administrative region of Gamo Goffa of the South Ethiopia, the girl's (bride) families enquire whether or not the would-be husband has Haleko trees in his farm (Endeshaw, 2003). Every part of *M. stenopetala* tree is important; different parts of the tree such as leaves, seeds, stem, and root of the tree are used for different purposes. Apart from being consumed as a vegetable, *M. stenopetala* is also marketed as a source of income in different countries. *M. stenopetala* leaves and pods are used as fodder for animals (ICRAF, 2006a).

Melesse, Getye, Berihun, and Banerjee (2013) reported that *M. stenopetala* leaf meal could be used as an alternative and inexpensive source of protein in the diets of grower Koekoek chicken breeds. They indicated that replacing roasted soybean with *M. stenopetala* leaf meal has resulted in general improvement of the growth performance, feed efficiency, and carcass yield of Koekoek chickens without affecting the vital organs. Gebregiorgis, Negesse, and Nurfeta (2012) reported that supplementing a basal diet of Rhodes grass hay with dried Moringa leaves improved dry matter intake, body weight gain, and nitrogen retention in sheep indicating that *M. stenopetala* can serve as a protein supplement to low-quality grass during the dry season under a smallholder sheep production system.

The leaves, roots, and seeds of *M. stenopetala* and *M. oleifera* have a long tradition of use in folk medicine. Various parts of the *M. stenopetala* tree are claimed to contain disease-preventing chemicals (Endeshaw, 2003). People with high blood pressure boil the leaves and drink the water to get relief from their ailment (Endeshaw, 2003). Mengistu et al. (2012) indicated that *M. stenopetala* has blood pressure lowering effects. This research showed that crude aqueous leaf extract of *M. stenopetala* caused a significant drop in systolic blood pressure, diastolic blood pressure, and mean arterial blood pressure in normotensive anesthetized guinea pigs. Leaf extracts of *M. stenopetala* are used to lower blood glucose and cholesterol levels. Ghebreselassie et al. (2011) reported that aqueous leaf extract of *M. stenopetala* is shown to increase body weight and reduce serum glucose and cholesterol levels in mice. Serum glucose and serum cholesterol levels decreased significantly after six weeks of treatment. They indicated the need for further studies in order to fractionate the active. Demeulenaere (2001) observed in some parts of southern Ethiopia, especially among the Konso people, that the abundance of *Moringa* species in the garden or on farmland was an indication of the social status of the owner among the society. The one with many Moringa tree in the garden or on farmland had a higher social status and was also considered as a prosperous person. In Konso, in the course of marriage engagement, a common query posed to the to-be husband is the abundance of Moringa trees in his garden. Their belief is that if the husband has many Moringa trees in his garden or farmland then to-be wife will have no problem to feed her babies even when drought occurs. For this reason Konso people especially young men are encouraged to plant Moringa in their garden as well as on their farmlands. A lesson to learn from this practice is that culture in itself has a great role in conservation and sustainable utilization of locally important tree species.

M. stenopetala is planted together with fruit trees in the cropped fields in southern Ethiopia and many other east African countries. Sometimes the trees are also used to provide partial shade for crops like sorghum in the southern Ethiopia. Whole plants have been used as hedges and fences. *M. stenopetala* can also be planted as a windbreak. As soon as the upper branches of the tree grew broader, the tree can be pruned to stimulate more profuse growth of their lower branches, thus thickening the hedge. Vegetables cultivated behind it profited from this protection. The species can also be grown as an ornamental tree in private gardens and home compounds.

2.4. Removal capacities of *M. stenopetala* and *oleifera*

The present study explores heavy metal sorption property of crude water and sodium chloride extracts of *M. oleifera* and *M. stenopetala* seed powder. The metals studied are cadmium, zinc, copper and chromium. Cadmium is one of the most toxic heavy metals without any known biological function. Zinc and copper, which are essential nutrients for plants and animals, can be toxic at very high concentrations. Chromium occurs in two redox states, Cr(III) and Cr(VI) with the former occurring as a cation and the later as an anion (chromate). Cr(III) is less toxic than Cr(VI). Because of the toxicities of cadmium and chromium the World Health Organization's maximum contaminant levels in drinking water are 0.003 and 0.05 mg/L, respectively (WHO and Parsons, 2004).

M. oleifera and *M. stenopetala* are common species among the species of the Moringa family, both species have many characteristics in common. They are commonly grown, but *oleifera* is widely cultivated and got research development attention (Seifu, 2015).

Comparison of removal capacities between *M. stenopetala* and *oleifera*; research indicated that *M. stenopetala* was more effective than *M. oleifera* in removing cadmium from water. Study results showed that Moringa seeds could be used as a less expensive biosorbent for the removal of cadmium (Cd) from polluted water. Reports indicated that *M. stenopetala* seed powder could remove lead from contaminated water (Mataka et al., 2006). Mataka reported that *M. stenopetala* was more effective in removing lead from water than *M. oleifera*.

Another study indicated that *M. stenopetala* seed powder could be used to remove chromium (Cr) from tannery effluent (Gatew & Mersha, 2013). The results showed that *M. stenopetala* seed powder at a dose of 1 g/100 ml and pH of 9.5 decreased the concentration of Cr in tannery waste by 99.86%. A similar study by Degefu and Dawit showed that the seed powder of *M. stenopetala* was found to be effective in the removal of chromium from tannery wastewater. *M. stenopetala* seed powder resulted in a 99.74% removal of chromium from tannery waste. The use of bioadsorbents like *M. stenopetala* seed powder that are easily available and effective for removal of heavy metals could be an innovative and economical approach for treatment of industrial wastewater. The seed of *M. stenopetala* is an important source of oil that could be used for cooking or for different industrial applications. A recent study reported that *M. stenopetala* seed oil could be used as a potential feedstock for biodiesel production. The study indicated that *M. stenopetala* seeds yield 45% w/w of oil. The oil contains 78% mono-unsaturated fatty acid and 22% saturated fatty acid. Oleic acid is the dominant fatty acid and accounts for about 76%. When mixtures of alcohols were used, the amount of ethyl ester formed was 30% that of methyl ester. The recommended way to use the oil as a fuel is as a mixture of esters. This study showed that *M. stenopetala* has a number of advantages compared to biodiesel fuels derived from other vegetable oils. Moreover, *M. stenopetala* seed cake obtained after oil extraction contains high protein content and can be used as an important protein supplement in animal feed. A research finding also indicated that *M. stenopetala* seed cake powder can be used for biogas production (Mekete, 2008).

In addition to the seeds, the roots of *M. stenopetala* can also be used to clarify dirty water. Nomadic peoples in the Omo Valley of Ethiopia apparently use the roots of wild *M. stenopetala* to clarify muddy water (Demeulenaere, 2001). The root is also used in traditional medicine to treat different ailments.

3. Way forward

To compare both moringa trees that is between *M. oleifera* and *M. stenopetala*; not only *M. oleifera* but using *M. stenopetala* also as a replacement coagulant for proprietary coagulants meets the need for water and wastewater technology in developing countries which is simple to use, robust and cheap to both install and maintain. Water purified with Moringa seeds, is acceptable for drinking only where people are currently drinking untreated, contaminated water.

Based on the reports, nutritional value, drought tolerance, fast growth, and many of its potential uses, *M. stenopetala* should be given due attention by all concerned bodies and considered a priority crop to alleviate malnutrition and reduce poverty. Despite the enormous economic and social values *M. stenopetala* has among the rural community it has been given little research and development attention. Unlike *M. oleifera*, little scientific research has been conducted on the properties and potential uses of *M. stenopetala* in general and its seeds in particular. This calls for detailed and rigorous scientific study on *M. stenopetala* in order to fully understand the characteristics of the plant and exploit its full potential.

Despite the enormous economic and social values *M. stenopetala* has among the rural community in southern Ethiopia, it has been given little research and development attention. Unlike *M. oleifera*, little scientific research has been conducted on the properties and potential uses of *M. stenopetala* in general and its seeds in particular.

4. Conclusion

For conclusion using *M. stenopetala* as a natural coagulant has advantage to many countries of the developing world. It could be viewed as sustainable, appropriate, effective and robust water treatment means. The effective enhancement of particular wastewater treatment processes can decrease reliance on the importation and distribution of treatment chemicals, creating a new cash crop for farmers and employment opportunities for the rural dwellers in particular.

In addition, the benefits derivable from Moringa tree are inexhaustible if all its usefulness is to be considered. No wonder some researchers regarded it as a miracle tree in backyards that have all nutritional needs, take care of medicinally, and purify water. The benefits endowed with this tree actually need to be explored in all ramifications especially its economic importance going by its profitability index in the study area as shown above. This study therefore recommends that more technologically improved methods of processing, packaging, and preservations should be adopted and encouraged for upward economic efficiency.

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Competing interests

The authors declare no competing interest

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