INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 3, p. 269-281, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

# The use of indigenous plant species for drinking water treatment in developing countries: a review

**Moa Megersa[1*], Abebe Beyene[1], Argaw Ambelu[1], Bizuneh Woldeab[1]**

[1]*Department of Environmental Health Science and Technology, Jimma University, Jimma, Ethiopia*

Article published on September 25, 2014

**Key words:** Coagulation, disinfection, indigenous plants, water treatment.

**Abstract**

Although universal access to safe and piped water is an important long-term solution, it is very expensive and challenging to implement in developing countries in the short term. Hence, improving both physicochemical and microbiological quality of drinking water at a household level is believed to be effective in preventing infectious diarrhea. There are a number of household water treatment technologies proven to be effective in coagulation and disinfection. At present, a number of effective coagulants and disinfectants have been identified of plant origin. Of the large number of plant materials that have been used over the years, the seeds from *Moringa oleifera* have been shown to be one of the most effective primary coagulants for water treatment, especially in rural communities. In addition, indigenous knowledge indicates that there are several plant species that can be used as a coagulant and disinfectant. Out of which seeds of *Prosopis juliflora, Dolichos lablab* and leaves of *Opuntia ficus indica* showed effectiveness in coagulation. Although, plant species have enormous advantage in water treatment, they also have limitation. The major limitation is the release of organic matter and nutrients to apply at large scale. From these review, it can be concluded that plant species have the potential to serve as a complementary water treatment agent especially in rural areas.

***Corresponding Author:** Moa Megersa ✉ moamegersa78@gmail.com

## Introduction

Drinking water is a basic human need including food, shelter and clothing. Thus the water we drink is essential ingredients for our wellbeing and a healthy life. In developing countries, large sections of the population may be dependent on raw water for drinking purposes without any treatment whatsoever (Enderlin, 1997). And this water source can be polluted by various ways like chemicals, agricultural runoff and human and animal feces. In addition, unhygienic handling of water during transport or within the home can contaminate previously safe water (WHO, 2007b).

The world health organization has estimated that up to 80% of all diseases and sickness in the world is caused by inadequate sanitation, polluted water or unavailability of water however, 10% could be prevented by improvements related to drinking water, sanitation, hygiene and water resource management (WHO, 2008). Despite the wide recognition of the importance of improved water and sanitation and heavy investment by international donors and governments in developing countries in extending water supply systems, over 780 million people are still without access to improved sources of drinking water and success still leaves more than 605 million people without access to safe water in 2015 mainly in sub Saharan Africa (UNICEF/WHO, 2012). The people at greatest risk due to unsafe water are children, people living under unsanitary conditions and the elderly (WHO, 2006). But this can be reduced through the provision of household water treatment techniques (WHO, 2007a) and potentially billions of people can benefit from effective household water treatment. Household water treatment applications are any of a range of technologies, devices or methods employed for the purposes of treating water at the household level or at the point (WHO, 2011).

At present, a number of effective coagulants have been identified of plant origin. Of the large number of plant materials that have been used over the years, the seeds from *Moringa oleifera* have been shown to be one of the most effective primary coagulants for water treatment, especially in rural communities (Ghebremichael *et al*., 2005). In addition, indigenous knowledge indicates that there are several plant species that can be used as a coagulant and disinfectant.

A few studies have attempted to review the use of plants on water purification, but they focused either on particular plant species (Yongabi, 2010; Bichi, 2013), or on restricted plant parts e.g. Seeds of plant species (Edogbanya *et al*., 2013). Here we present a review of the reported indigenous plant species used for water treatment without restriction of plant parts and type. Furthermore, we identify gaps in knowledge, and suggest perspectives for future research.

## Methods

*Search strategy and inclusion criteria*

Pertinent literature was searched in different electronic data bases. Such as, Pubmed, Google scholar, Cochrane library, EMBASE, HINARI and hand search conducted in English language regardless of publication date. The key words of the first step were “Household water treatment techniques” or “Household water treatments in turbidity reduction” and then the searches were carried out “Natural coagulants and turbidity”, Natural coagulants and microbial load”, Plant materials and microbial load reduction”, “Plant materials and turbidity reduction”. The studies included for this review are experimental studies conducted in laboratory to assess the potential of natural coagulants and disinfectants in turbidity and microbial load reduction for drinking water.

We reviewed a total of seventy articles that provided information about the use of plant species to treat turbid water. A list was produced showing name (s), part (s) and references for each species. The precision of botanical identification in this review depended on that from original sources. An attempt was done to verify from different data bases. In some cases, only the genus was provided in the literature (e.g. (Al-Sameraiy, 2012; Sarah *et al.*, 2008) and we did not attempt to refine the information to the species level and we put it as it is.

*Natural coagulants and disinfectants used for water treatment*

There are about 2, 50,000 higher plants species on earth, out of these, more than 80,000 are medicinal (Joy *et al.,* 1998). Sofowora (1982) reported that Africa has as much as 300, 000 medicinal plants. Historical accounts of traditionally used medicinal plants depict that different medicinal plants were in use as early as 5000 to 4000 BC in China, and 1600 BC by Syrians, Babylonians, Hebrews and Egyptians (Dery *et al.,* 1999). Considerable indigenous knowledge system, from the earliest times, is found linked with the use of traditional medicine in different countries (Farnsworth, 1994).

Beyond their human health and livestock treatments plants have been used historically for water treatment and there is evidence to suggest that communities in the developing world have used plant based materials as one strategy for purifying drinking water (Sarah *et al.*, 2008). Therefore, natural coagulants and disinfectants can play a vital role for water sector that facing challenge today on how to give more people access to clean drinking water by cost effective means, especially the rural poor who cannot afford any water treatment chemicals, without affecting the health of their environment (Davy, 2001).

*Plant species used as coagulant and disinfectant*

In many rural communities of developing countries water clarification methods like flocculation, coagulation, and sedimentation are often impractical because of the high cost of equipment and low availability of chemical coagulants (Grabow *et al.,* 1985). Natural plant extracts have been used for water purification for many centuries and Egyptians inscription afforded the earliest recorded knowledge of plant materials used for water treatment, dating back perhaps to 2000BC in addition to boiling and filtration (Fahey, 2005).

In recent years there has been considerable interest in the development of usage of natural coagulants which can be produced extracted from microorganisms, animal or plant tissues. These coagulants should be biodegradable and are presumed to be safe for human health (Sciban *et al.*, 2009). In addition, natural coagulants produce readily biodegradable and less voluminous sludge that amounts only 20– 30% that of alum treated counterpart (Narasiah *et al.*, 2002).

Nowadays a number of effective coagulants have been identified of plant origin. Some of the common ones include *Moringa olifiera*, *Solanum incunum*, *Ocimum sanctum*, *Azadirachta indica, Triticum aestivum, Phyllanthus emblica* and *Strychnos potatorum and others* (Table, 1). Of the large number of plant materials that have been used over the years, the seeds from *Moringa oleifera* have been shown to be one of the most effective primary coagulants for water treatment especially in rural communities (Ndabigengesere and Narasiah, 1998; Ali *et al.*, 2010; Sotheeswaran *et al.*, 2011; Yahya *et al.*, 2011).

*Taxonomic diversity and growth habit*

Forty plant species, belonging to 38 genera and 22 families, are reported to be used as coagulant and disinfectant (Table 1). Although most information was available at the species level, sometimes only the genera was provided. Among the reported plant species, *Moringa oleifera* was the frequently studied plant species for water treatment.

Among the families that contributed more plant species were the Fabaceae, represented by 10 species (25%), Fagaceae with 4 (10%) species, Malvaceae with 3 (7.5%), and other 19 families contributing 23 (57.5%) species are represented by 1 or 2 species (Table 2).

The result of growth form analysis of plants showed that trees constituted the highest proportion being represented by 17 (42.5%) species, while there were 14 (35%) herb species, 7 (17.5%) shrubs and 2 (5%) vines (Figure 1).

**Table 1.** List of plant species used as coagulants and disinfectants.

| Scientific name | Family | Genera | Plant parts | Habit | Reference | Uses |
|---|---|---|---|---|---|---|
| *Moringa oleifera* Lam. | Moringaceae | Moringa | Seed | Tree | Ndabigengesere *et al.*, 1995 Gebremichael *et al.*, 2005 | Coagulation and disinfection |
| *Phaseolus vulgaris* L. | Fabaceae | Phaseolus | Seed | Herb | Sciban *et al.*, 2006 | Coagulation |
| *Opuntia ficus indica* (L.) Mill. | Cactaceae | Opuntia | Leaves | Shrub | Shlipa *et al.*, 2012 *Zhang et al.*, | Coagulation and |
| *Dolichos Lablab* L. | Fabaceae | Lablab | Fruit | Herb | 2006 | disinfection |
| *Senna alata* (L.) Roxb. | Fabaceae | Senna | Leaves | Shrub | Aweng *et al.*, 2012 | Coagulation |
| *Castanea sativa* Mill. | Fagaceae | Castanea | Seeds | Tree | Sciban *et al.*, 2009 | |
| *Aesculus hyppocastanum* L. | Sapindaceae | Aesculus | | Tree | | |
| *Quercus robur* L. | Fagaceae | Quercus | | Tree | | |
| *Q. rubra* L. | Fagaceae | Quercus | | Tree | | |
| *Quercus cerris* L. | Fagaceae | Quercus | | Tree | | |
| *Coccinia indica* (L.) Voight | Cucurbitaceae | Coccinia | Fruits | Vine | Patale and Pandya, 2012 | Coagulation |
| *Cicer arietinum* L. | Fabaceae | Cicer | Seeds | Herb | Choubey *et al.*, 2012 | Coagulation and disinfection |
| *Phoenix spp.* | Arecaceae | Phoenix | Seeds | Tree | Alsemirey, 2012 | Coagulation |
| *Azadirachta indica* A.Juss. | Meliaceae | Azadirachta | Fruit | Tree | Sowmeyan *et al.*, | Coagulation |
| *Luffa cylinderca* M.Roem. | Cucurbitaceae | Luffa | Fruit | Vine | 2011 | Coagulation |
| *Aloe barbadensis* Mill. | Alloaceae | Aloe | Seeds | Herb | Yongabi *et al.*, 2011a, Yongabi *et al.*, | Coagulation and disinfection |
| *Jatropha curcas* L. | Euphorbiaceae | Jatropha | Seeds | Tree | 2011b | Coagulation and disinfection |
| *Citrus aurantifolia* (Chrism.) Swingle | Rutaceae | Citrus | Fruit | Tree | | Coagulation and disinfection |
| *Hibiscus sabdarifa* L. | Malvaceae | Hibiscus | Calyx | Herb | | Coagulation and disinfection |
| *Garcinia kola* Heckel | Guttiferae | Garcinia | Seeds | Herb | | Coagulation and disinfection |
| *Carica papaya* L. | Caricaceae | Carica | Seeds | Tree | | Coagulation and disinfection |
| *Mangifera Indica* L. | Anacardaceae | Mangifera | Fruit | Tree | Qureshi *et al.*, 2011 | Coagulation |
| *Parkinsonia aculeata* L. | Fabaceae | Parkinsonia | Seed | Tree | Marhobe and Gunaratna 2012 | Coagulation and |
| *Vigna unguiculata* (L.) Verdc. | Fabaceae | Vigna | Seed | Herb | | disinfection |
| *Trigonella foenum-graecum* L. | Fabaceae | Trigonella | Seed | Tree | Ramamurthy *et al.*, 2012 | Coagulation |
| *Strychnos potatorum* | Loganiaceae | Strychnos | Seed | Tree | Ramamurthy *et al.*, 2012 | Coagulation |
| *Cuminum cyminum* L. | Apiaceae | Cuminum | Seed | Herb | | |
| *Cyamopsis tetragono* | Fabaceae | Cyamopsis | Seed | Herb | Pritchard *et al.*, 2009 | Coagulation and disinfection |
| *Zea mays* L. | Poaceae | Zea | Seed | Herb | Guranatra *et al.*, 2007 | Coagulation |
| *Abelmoschus esculentus* (Moench) | Malvaceae | Abelmoschus | Gum | Herb | Renuka *et al.*, 2013 | Coagulation |
| *Calotropis Procera* (Aiton) W.T.Aiton | Aclepiadaceae | Calotropis | Flower | Shrub | | |
| *Manihot esculenta crantz* | Euphorbiaceae | Manihot | Root | Shrub | Vara, 2012 | Coagulation and disinfection |
| *Ocimum sanctum* L. | Lamiaceae | Ocimum | Leaves | Shrub | Sunil *et al.* 2011 | Disinfection |
| *Triticum aestivum* L. | Poaceae | Triticum | Leaves | Herb | | |
| *Phyllanthus emblica* L. | Phyllanthaceae | Phyllanthus | Leaves | Tree | | |
| *Cactus latifaria* | Cactaceae | Cactus | Leaves | Shrub | Diaz *et al.*, 1999 | Coagulation |
| *Prosopis juliflora* (Sw.) DC. | Fabaceae | Prosopis | Pod | Tree | | |
| *Pisum sitavum* L. | Fabaceae | Pisum | Seed | Herb | Hassan *et al.*, 2012 | |
| *Corchorus tridens* L. | Malvaceae | Corchorus | Leaves | Herb | Jodi *et al.*, 2012 | |
| *Solanum incunum* L. | Solanaceae | Solanum | Leaves | Shrub | Kihampa *et al.*, 2011 | Coagulation and disinfection |

*Plant parts used to treat turbid water*

Natural plant extracts have been used for water purification for many centuries. Most of these extracts are derived from the seeds, leaves, pieces of bark or sap, roots and fruit extracts of trees (Pritchard *et al.*, 2009). In this review, the highest number of species 22 (55%) were reported to be used for their seeds these were followed by leaves (7, 17.5%), fruits (6, 15%) and 5 others (calyx, flower, pod and bark) covered 12.5% (Figure 2).

Protein is reported to be the main component responsible for coagulation-flocculation process thus studies reported that seed is the place where high level of protein is accumulated (Booth *et al.*, 2010). For instance seeds of *Moringa oleifera, Carica papaya* and *Dolichos lablab are* reported to have coagulation and disinfection activities (Yongabi, 2011b) and seeds are frequently cited plant parts used in water treatment. However, other plant parts are also used like leaves of *Solanum incunum* and *Ocimum sanctum* (Kihampa *et al.*, 2011). According to Amagloh and Benang (2009) mature seed extracts of *Moringa oleifera* are more effective in turbid waters than immature seed extracts.

**Table 2.** Taxonomic diversity of plants used for water treatment.

| Family | Number of Genera | Percentage | Number of species | Percentage of species |
|---|---|---|---|---|
| Fabaceae | 10 | 26.3 | 10 | 25.0 |
| Fagaceae | 2 | 5.2 | 4 | 10.0 |
| Malvaceae | 3 | 7.8 | 3 | 7.5 |
| Cactaceae | 2 | 5.2 | 2 | 5 |
| Cucurbitaceae | 2 | 5.2 | 2 | 5 |
| Euphorbiaceae | 2 | 5.2 | 2 | 5 |
| Poaceae | 2 | 5.2 | 2 | 5 |
| Other 15 families | 15 | 39.4 | 15 | 37.5 |
| Total | 38 | 100 | 40 | 100 |

*Performance of plant species on turbidity*

It was reported in various literature that plant species have capability of turbidity reduction though their performance varies. The dosage required depends on turbidity ranges mean that as initial turbidity of water sample increased, the required optimum dosage of coagulant also increased (Katayon *et al.*, 2006). All of the reported natural coagulants were more efficient in higher turbidity ranges than lower and medium turbidity waters either in artificially prepared or natural turbid raw water including surface and ground water (Nkurunziza *et al.*, 2009; Asraffuzaman *et al.*, 2011, Kihampa *et al.*, 2011, Yongabi *et al.*, 2011; Mangale *et al.*, 2012a; Mangale *et al.*, 2012b). The residual turbidity decreases to a certain dosage of natural coagulants, which is referred to as the optimized dose and above the optimum results in increased turbidity (Blix, 2011). For example, the result of Kihampa *et al.* (2011) showed the extracted dose of *Solanum incanum* displayed an optimal dose of 2 ml (2 × $10^{-5}$ g/ml) for treating turbid water samples of initial turbidities of 450, 300 and 105 NTU. The corresponding average percentage removals were 99.78, 99.11 and 97.14 at residue turbidities of 1, 2.67 and 3 NTU, respectively and Shilpa *et al.*, (2012) reported the optimum dosage of *Opuntia ficus indica* and *Dolichos lablab* to be 20mg/L, removal efficiency was found to be 89.03% and 77.10% respectively.

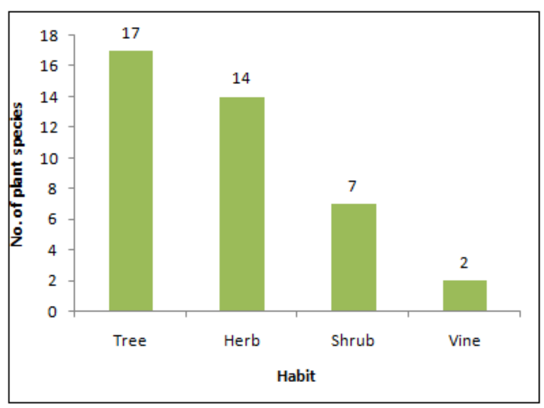


**Fig. 1.** Habit of plant species used for water treatment.

Increasing dosage of coagulants beyond certain limit do not improve the removal of turbidity; in fact this increased significantly the residual turbidity of the coagulated sample (Katayon *et al.*, 2006). Muyibi and Evison (1995) explained this as overdosing resulted in the saturation of the polymer bridge sites and caused restabilization of the destabilized particles due to insufficient number of particles to form more interparticle bridges.

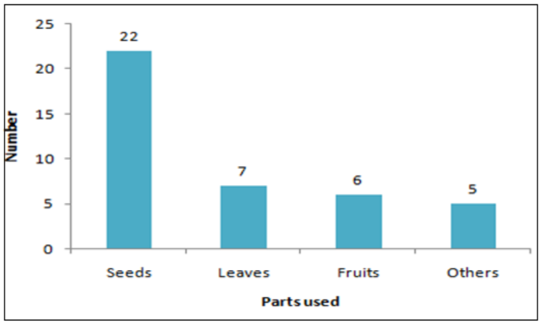


**Fig. 2.** Plant parts used for the treatment of turbid water.

Researches indicated that Plant coagulants even showed a better coagulation effect than synthetic coagulant counterpart e.g Alum (Kihampi *et al.*, 2011; Yongabi *et al.*, 2011).

*Performance of plant species against bacteria*

Plant species also showed promising result in antimicrobial effect. Comparing with coagulation properties of plant species, little is known about the potential existence of natural disinfectants (i.e., substances with the ability to kill or inactivate pathogenic microorganisms), even though many herbs and plant extracts are used in traditional medicine and as pesticides in developing countries (Robert *et al.*, 2009). Researchers reported antimicrobial activity of *Dolichos lablab, Moringa oleifera, Azadirachta indica* and other plant species (Table 1). Yongabi *et al.* (2011) found that *Moringa oleifera, Jatropha curcas* and *Hibiscus* showed a better coagulation and disinfection activity with the methanol extracts. The antimicrobial effect could be attributed due to both flocculation (Nwaiwu and Lingmu, 2011) and bactericidal action (Oluduro *et al.*, 2010).

*Active component of the plant materials*

In coagulation and disinfection, a substantial number of active compounds have been isolated from various parts of plant species. Even researchers tried to investigate the specific part where the active agent is located. For instance, Ndabigengesere *et al.*, (1995) reported that the active agents of *Moringa oliefera* are located in the seed kernel rather than seed bark. Sarah *et al.* (2008) in their study on Oppuntia spp. found that the active agents are located in whole pads without skin. Thus, isolating the active component is critical not only to understand the coagulation mechanism, but also to develop pretreatment practices for potential field implementation (Sarah *et al.*, 2008). The coagulation mechanism of *Moringa oliefera* was reported to be through charge neutralization (Ndabigengesere *et al.*, 1995) whereas the predominant coagulation mechanism for *Opuntia* spp. is adsorption and bridging, whereby clay particles do not directly contact one another but are bound to a polymer-like material form (Sarah *et al.*, 2008).

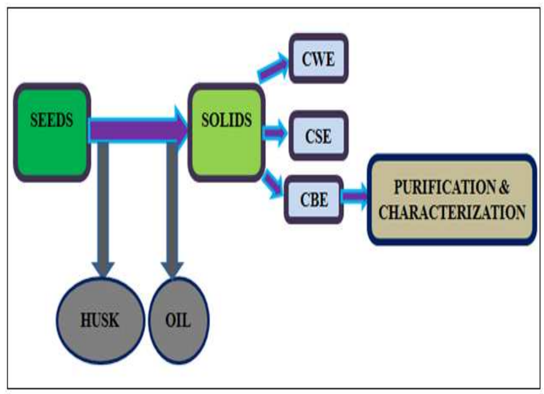


**Fig. 3.** Steps involved in coagulant protein extraction and characterization. Crude water extract (CWE), Crude salt extract (CSE), Crude buffer extract (CBE) adopted from (Gunaratna *et al.*, 2007).

The active coagulating component can be extracted from the plant parts and used in pure or semi pure form, thus reducing the total amount of organic material added to the treatment process which may resulting in the possibility for undesired and increased microbial activity (Gebremichael *et al.*, 2005; Sarah *et al.*, 2008). However the active component identified varies on type of extraction mean that whether extracted by water or salt. The chemical composition of the active coagulating agent of *M. oleifera* has been debated (Sarah *et al.*, 2008) for instance water extraction of *Moringa oleifera* has been shown that the active agent in extracts is cationic proteins that harbors very good coagulation properties which is used in extremely low dosages than that used for crude seed extract (Ndabigengesere *et al*., 1995) and Gassenschmidt *et al.* (1995) identified the active component cataionic peptides of molecular weight ranging from 6 to 16 kDa and isoelectric pH value of 10. Whereas Okuda *et al.* (2001) reported that the active component from an aqueous salt extraction was not a protein, polysaccharide or lipid, but an organic polyelectrolyte with molecular weight of about 3.0 kDa. However, Gebremichael *et al.* (2005) determine that both water and salt extract are cationic proteins with molecular weights less than 6.5 kDa. This suggests that the water and salt extract may be of different nature (Gebremichael *et al*., 2005).

The active agent of other species other than *Moringa oleifera* was also identified by Sarah *et al*., (20008) they come up with a result that mucilage is suspected active agent which contribute to the coagulation behavior of *Opuntia* spp. Moreover, they reported that the galacturonic acid can be a component which plays a role in turbidity reduction by *Opuntia* spp. and independently, arabinose, galactose, and rhamnose were displayed no coagulation activity; however, added in combination with galacturonic acid, these sugars were able to reduce turbidity between 30% and 50%. Galacturonic acid added independently was able to reduce turbidity by more than 50%.

Comparing salt and water extracts, Gunaratna *et al.* (2007) and Sarpong and Richardson (2010) reported that salt extraction of powdered *M. oleifera* seeds substantially improves overall coagulation efficiency than water extract and Gunaratna *et al*., (2007) explained the possibility of having high coagulation activity is due to the fact that salt is thought to associate with opposite charged groups in the protein.

*Purification of natural coagulants*

The limitation of natural coagulants and disinfectants include organic load and residual (storage). Therefore, Purification of natural coagulants is vital in order to reduce organic load (Ndabigengesere *et al*., 1995; Gebremichael *et al*., 2005) and helps to use in a large scale because of the fact that the crude extract is not generally suitable for large water supply systems where the hydraulic residence time is very high (Gebremichael *et al*., 2005) and this is indicated in the result of (Katayon *et al*., 2006) who reported coagulation efficiency of *Moringa oleifera* decreased as storage duration increased.

Another disadvantage of natural coagulants for example *Moringa oliefera* is its efficacy only for highly turbid water (Gunaratna *et al*., 2007). Therefore, active agents should be purified and characterized using different techniques, namely dialysis, ultrafiltration, lyophilisation, ion-exchange, chemical precipitation, SDS-PAGE and electro phoresis (Ndabigengesere *et al*., 1995). Isolating the active component is critical not only to understand the coagulation mechanism, but also to develop pretreatment practices for potential field implementation (Sarah *et al*., 2008).

Gebremichael *et al.* (2005) came up with a simple and rapid method of extraction and purification of *Moringa oliefera* coagulating proteins. They purified using High-trap CM FF 1 mL cation exchanger column on an Akta explorer (Pharmacia Biotech) and MOCP is highly thermostable and reduces microbial populations.

Protein extraction and characterization involved the following step which is shown in figure 3.

A study on purification of the coagulant protein from *Moringa oleifera* seed by single step ion exchange by Gebremichael *et al*., (2005) able to reduce COD values of 12 000 mg/L to 96 % after purification.

*Advantages of plant coagulants and disinfectants*

Natural coagulants and disinfectants have enormous advantages in water treatment.

Natural coagulants produce less sludge volume compared with Alum (Ndabigengesere *et al.*, 1995; Blix, 2011) and they require no pH adjustment (Ndabigengesere *et al.*, 1995). They are great interest for low cost water treatment (Gebremichael *et al.*, 2005) and help to provide pure water for world population especially for developing countries who hardly get pure water and an additional benefit of using coagulants derived from natural products like *Moringa oleifera,* is that a number of useful products may be extracted from the seed. In particular, edible and other useful oils may be extracted before the coagulant is fractionated. Residual solids may be used as animal feed and fertilizer, while the shell of the seed may be activated and used as an adsorbent. The coagulant is thus obtained at extremely low or zero net cost (Gebremichael *et al.*, 2005).

Usage of natural products also reduces the formation of disinfectants that deteriorate human health and their byproducts are organic and biodegradable and reduced risk of handling (Ndabigengesere *et al.*, 1995; Ozakar *et al.*, 2002; Yongabi *et al.*, 2011). Moreover, Grabow *et al.* (1985) indicated that use of *M. oleifera* as a primary coagulant does not pose a human health threat.

*Future research that should be considered*

This study reported the potential of indigenous plant species conducted in randomized controlled experiments to improve drinking water quality regarding turbidity and microbial load. The result of this review revealed that plant species have a potential in reducing turbidity and microbial load. Turbidity and microbial removal mechanism and active agent of indigenous plants that plays a significance role in coagulation and flocculation should be investigated in detail though, there are studies on *Moringa oleifera* (Gebremichael *et al.*, 2005) and Oppuntia spp. (Sarah *et al.* 2008). Moreover, different simple purifying mechanisms should be investigated in order to reduce organic load and recontamination. It is particularly important that such trials be applied at small scale (household) level and scalability of this technology should be investigated. However, toxicological test of natural coagulants and disinfectants is also crucial before implementing the laboratory result to the field. In addition, comprehensive cost effectiveness and cost benefit analyses will also be crucial to be made in order to see the affordability of natural coagulants and disinfectants to the poor community living in developing countries.

## Conclusions

World population increasing year to year and reaching 7 billion in 2012 whereas an access of getting pure water remains a problem especially for people who live in developing countries. The severity is much observed in rural dwellers who is their source of drinking water is surface (raw) water which is not purified and this results for transmission of waterborne diseases.

To reduce such like problems and the strong push to meet the drinking water needs of the developing world have led to the recent growing interest in using plant based natural coagulants and disinfectants and plant species showed promising result in coagulating and disinfecting raw water. The widely studied plant is *Moringa oleifera* which used as primary coagulant and coagulant aid. Other plant species also showed a very good result in coagulating turbid water however few reports are available in disinfecting capability of plant species therefore studies should focus in disinfecting ability of natural products.

Beyond their advantages over Alum, natural coagulants have also limitation. For instance they increase organic load in the water which tend reestablization to occur. In addition water treated with natural coagulants (e.g. Moringa) was reported only used for 24 hours and inefficiency of treating low turbid water is another problem. To avoid the above stated problems researchers are investigating the active component rather than relying on crude extraction and protein was reported to be the major active component used in coagulation.

In general, other plants should be studied in order to tackle the problem of quality water especially in developing countries. In such a case plant species can contribute to advancing the goal of sustainable water treatment technologies that are themselves sustainable.

**Acknowledgments**
We are very much grateful to the financial and logistic support provided by the Ethiopian.

Ministry of Water and Energy and International Foundation for Science. We are also grateful to everyone that helped us find the literature used in this review.

**References**

**Ali EN, Muyibi SA, Salleh HM, Alam MDZ, Salleh MRM.** 2010. Production of natural coagulants from *Moringa oleifera* seed for application in treatment of low turbid water. Journal of Water Resource and Protection **2,** 259-266.

**Al-Sameraiy M.** 2012. A novel water pretreatment approach for turbidity removal using Date seeds and Pollen sheath. Journal of Water Resource and Protection **4,** 79-92.

**Amagloh FK, Benang B.** 2009. Effectiveness of *Moringa oleifera* seed as coagulant for water purification. African Journal of Agricultural Research 4 **(1)**, 119-123.

**Asrafuzzaman M, Fakhruddin ANM, Alamgir Hossain M.** 2011. Reduction of turbidity of water using locally available natural coagulants. International Scholarly Research Network Microbiology, 1-6.

**Aweng ER, Anwar AI, Siti Rafiqah MI, Suhaimi O.** 2012. *Cassia alata* as a potential coagulant in water treatment. Research Journal of Recent Sciences **1(2),** 28-33.

**Bichi MH.** 2013. A Review of the applications of *Moringa oleifera* seeds extract in water treatment. Civil and Environmental Research **3(8),** 1-10.

**Blix A.** 2011Enhancing the capacity of seeds as turbidity removal agents in water treatment. Degree project, Royal Institute of Technology, Sweden.

**Booth J, Nykiforuk C, Shen Y, Zapalchinski S, Szarka S, Kuhlman P, Murray E, Morck D, Moloney MM.** 2010. Seed based expression systems for plant molecular farming. Plant Biotechnology Journal **8,** 588-606.

**Choubey S, Rajput SK, Bapat KN.** 2012. Comparison of some natural coagulantsbioremediation. International Journal of Technology and Advanced Engineering **2(10),** 429-434.

**Davy N.** 2001. Moringa as alternative to aluminum sulfate. **In:** *people and system for* water, sanitation and health, 27th WEDC conference236-238 Lusaka.

**Dery BB, Ofsynia R, Ngatigwa C.** 1999. Indigenous knowledge of medicinal trees and setting priorities for their domestication. Shiryanga region, Tanzania, Nairobi, Kenya. International center for research in agroforestry.

**Diaz AN, Rincon A, Escorihuela N, Fernandez E, Chacin CF, Forster A.** 1999. Preliminary evaluation of turbidity removal by natural coagulants indigenous to Venezuela . Process Biochemistry **35,** 391–395.

**Enderlin.** 1997. Water quality requirements. In: Helmer R, Hespanhol I, eds. *Water* pollution control - A guide to the use of water quality management principles. UNEP, 23-54.

**Edogbanya PRO, Ocholi OJ, Apeji Y.** 2013. A review on the use of plants' seeds as biocoagulants in the purification of water. Continental Journal of Biological Science **6(2),** 26 – 32.

**Fahey J.** 2005. *Moringa Oleifera*; A review of the medical evidence for its nutritional therapeutic and prophylactic properties. Part 1. Accessed 15 Dec. 2008. www.treesforlifejournal.org

**Farnsworth NR.** 1994. Ethnopharmacology and drug development in ethnobotany and the search for new drugs. Ciba foundation symposium 185 chic ester, UK: John Wiley and Sons, 42-59.

**Gassenschmidt U, Jany KD, Tauscher B, Niebergall H.** 1995. Isolation and characterization of a flocculating protein from *Moringa oleifera* Lam. Biochimica et Biophysica Acta, **1243,** 477-481.

**Gebremichael KA, Gunaratna KR, Henriksson H, Harry B, Gunnel D.** 2005. A simple purification and activity assay of the coagulant protein from *Moringa oleifera* seed. Water Research **39,** 2338-2344.

**Grabow W, Slabert JL, Morgan WSG, Jahn SA.** 1985. Toxicity and mutagenicity evaluation of water coagulated with *Moringa oleifera* seed preparations using fish, protozoan, bacterial, coliphage, enzyme, and Ames Salmonella assays. Water SA, **11,** 9 –14.

**Gunaratna KR, Garcia B, Andersson S, Dalhammar G.** 2007. Screening and evaluation of natural coagulants for water treatment. Water Science and Technology: Water Supply **7,** 19–25.

**Hassan MN, Vivek S, Unnisa SA.** 2012. Purification of turbid water with *Pisum sativum* seeds and solar energy. International Journal of green and Herbal Chemistry **1(3),** 296-301.

**Jodi ML, Birnin-Yauri UA, Yahaya Y, Sokoto MA.** 2012. The use of some plants in water purification. Global Advanced Research Journal of Chemistry and Material Sciences **1(4),** 71-75.

**Joy PP, Thomas J, MathewS, Skaria BP.**1998. Medicinal plants. Kerala Agricultural University, Naya Prokash, Calcutta, 210p.

**Katayon S, Megat MJ, Mohd N, Asma M, Abdul Ghani LA, Thamer AM, Azni I, Ahmad J.Khor BC.** 2006. Effects of storage conditions of *Moringa oleifera* seeds on its performance in coagulation. Bioresource Technology **97,** 1455–1460.

**Kihampa C, Mwegoha WJS, Kaseva ME, Marobhe N.** 2011. Performance of *Solanum incunum* L. as natural coagulant and disinfectant for drinking water. African Journal of Environmental Science and Technology **5(10),** 867-872.

**Mangale SM, Chonde SG, Raut PD.** 2012a. Use of *Moringa oleifera* (Drumstick) seed as natural adsorbent and an antimicrobial agent for ground water treatment. Research Journal of Recent Sciences **1(3),** 31-40.

**Mangale SM, Chonde SG, Raut PD.** 2012b. Study of *Moringa oleifera* (Drumstick) as natural adsorbent and an antimicrobial agent for river water treatment. Journal of Natural Product and Plant Resources **2(1),** 89-100.

**Marobhe NJ, Gunaratna RK.** 2012. Effect of coagulant protein from *Parkinsonia aculeata* and Citrus juice on bacteria isolated from Ruvu River in Tanzania. International Journal of Applied Sciences and Engineering Research **1(5),** 714-724.

**Muyibi SA, Evison LM.** 1995. Optimizing physical parameters affecting coagulation of turbid Water with *Moringa oleifera* seeds. Water Research **29,** 2689–2695.

**Narasiah KS, Vogel A, Kramadhati NN.** 2002. Coagulation of turbid waters using *Moringa oleifera* seeds from two distinct sources. Water Science and Technology: Water Supply **2,** 83–88.

**Ndabigengesere A, Narasiah KS, Talbot BG.** 1995. Active agents and mechanisms of coagulation of turbid water using *Moringa oleifera*. Water Research **29(2),** 703–710.

**Ndabigengesere A, Narasiah KS.** 1998. Quality of water treated by coagulation using *Moringa oleifera* seeds. Water Research **32(3),** 781–791.

**Nwaiwu NE, Lingmu B.** 2011. Studies on the effect of settling time on coliform reduction using *Moringa oleifera* seed powder. Journal of Applied Science and Environmental Sanitation **6,** 279-286.

**Nkurunziza T, Nduwayezu JB, Banadda EN, Nhapi I.** 2009. The effect of turbidity levels and *Moringa oliefera* concentration on the effectiveness of coagulation in water treatment. Water Science and Technology **59(8),** 1551-1558.

**Okuda T, Baes AU, Nishijima W, Okada M.** 2001. Isolation and characterization of coagulant extracted from *Moringa oleifera* seed by salt solution. Water Research **35(2),** 405–410.

**Oluduro OA, Aderiye BI, Connolly JD, Akintayo ET, Famurewa O.** 2010. Characterization and antimicrobial activity of 4-(**ß**-d-glucopyranosyl-→ 4-**a**-l rhamnopyranosyloxy)-benzyl thiocarboxamide; a novel bioactive compound from *Moringa oleifera* seed extract. Folia Microbiology **55(5),** 422-426.

**Ozacar M, Ayhan SI.** 2002. The use of tannins from Turkish acorns (Valonia) in water treatment as a Coagulant and Coagulant Aid. Turkish Journal of Engineering and Environmental Science **26,** 255-263.

**Patale V, Pandya J.** 2012. Mucilage extract of *Coccinia indica* fruit as coagulant-flocculent for turbid water treatment. Asian Journal of Plant Science and Research **2(4),** 442-445.

**Pritchard M, Mkandawire T, Edmondson A, O'Neill JG, Kululanga G.** 2009. Potential of using plant extracts for purification of shallow well water in Malawi. Journal of Physics and Chemistry of the Earth **34,** 799-805.

**Qureshi K, Bhatti I, Shaikh MS.** 2011. Development of Bio-coagulant from pit for the purification of turbid water. Sindh University Research Journal (Science Series) **43(1),** 105-110.

**Ramamurthy C, Maheswari MU, Selvaganabathy N, Kumar SM, Sujatha V, Thirunavukkarasu C.** 2012. Evaluation of eco-friendly coagulant from *Trigonella foenum- graecum* seed. Advances in Biological Chemistry **2,** 58-63.

**Renuka MS, Binayke A, Jadhav MV.** 2013. Application of natural coagulants in water purification. International Journal of Advanced Technology in Civil Engineering **2(1),** 118-123.

**Robert L, Matthews, Michael R, Templeton, Sabtri K, Tripath, Kiran B.** 2009. Disinfection of waterborne coliform bacteria by Neem oil. Environmental Engineering Science **26,** 1435-1441.

**Sarah MM, Ezekiel JF, Vinka, Oyanedel C, James AS, Julie BZ.** 2008. Toward understanding the efficacy and mechanism of *Opuntia* spp. as a natural coagulant for potential application in Water treatment. Environmental Science and Technology **42,** 4274–4279.

**Sarpong G, Richardson CP.** 2010. Coagulation efficiency of *Moringa oleifera* for removal of turbidity and reduction of total coliform as compared to aluminum sulfate. African Journal of Agricultural Research **5(21),** 2939-2944.

**Sciban M, Mirjana GA, Mile TK.** 2006. Extraction and partial purification of coagulation active components from common bean seeds. Acta Periodica Technologica **37,** 37-43.

**Sciban M, Mile K, Mirjana A, Biljana S.** 2009. Removal of water turbidity by natural coagulants obtained from chestnut and acorn. Bioresource Technology **100,** 6639–6643.

**Shilpa BS, Akanksha, Kavita, Girish P.** 2012. Evaluation of Cactus and Hyacinth Bean peels as natural coagulants. International Journal of Chemical and Environmental Engineering **3(3),** 187-191.

**Sofowora A.** 1982. Medicinal Plants and Traditional Medicine in Africa. 256 p, John Wiley and Sons, Ltd. New York.

**Sotheeswaran S, Nand V, Matakite M, Kanayathu K.** 2011. *Moringa oleifera* and other local seeds in water purification in developing countries. Research Journal of Chemistry and Environment **15(2),** 135-138.

**Sowmeyan R, Santhosh J, Latha R.** 2011. Effectiveness of herbs in community water treatment. International Research Journal of Biochemistry and Bioinformatics **1(11),** 297-303.

**Sunil BS, Nitin WI, Shrikant SP.** 2011. Performance evaluation of natural herbs for antibacterial activity in water purification. International Journal of Engineering Science and Technology **3(9),** 7170-7174.

**UNICEF/WHO.** 2012. Joint Monitoring Program for Water Supply and Sanitation Estimates for the use of Improved Drinking-Water Sources Ethiopia. wssinfo. org, 13PP.

**Vara S.** 2012. Screening and evaluation of innate coagulants for water treatment: a sustainable approach. International Journal of Energy and Environmental Engineering **3,** 29.

**WHO.** (World Health Organization). 2006. Guidelines for Drinking Water Quality, First Addendum to Third Edition Recommendations **1.** (Accessed 22.02.12). http://www.Who.int/watersanitationhealth/dwq/gdwq0506.pdf

**WHO.** (World Health Organization) 2007a. The World Health Report – a Safer Future: Global Public Health Security in the 21st Century, Geneva.

**WHO.** (World Health Organization) 2007b. Combating waterborne diseases at the household level. Geneva.

**WHO.** (World Health Organization) 2008. Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health, Geneva.

**WHO.** (World Health Organization) 2011. Evaluating household water treatment options: Health-based targets and microbiological performance specifications, Geneva.

**Yahya DS, Enemaduku AM, Eru EO.** 2011. The use of Moringa seed extract in water purification. International Journal of Research and Ayurveda Pharmacy **2(4),** 1265-1271.

**Yongabi KA.** 2010. Biocoagulants for water and waste water purification: a review. International Review of Chemical Engineering **2,** 444-458.

**Yongabi KA, Lewis DM, Harris PL.** 2011a. Application of phytodisinfectants in water purification in rural Cameroon. African Journal of Microbiological Research **5(6),** 628-635.

**Yongabi KA, Lewis DM, Harris PL.** 2011b. Indigenous plant based coagulants/disinfectants and sand filter media for surface water treatment in Bamenda, Cameroon. African Journal of Biotechnology **10(43),** 8625-8629.

**Zhang J, Fang Z, Yuhong L, Hong Y.** 2006. A preliminary study on cactus as coagulant in water treatment. Process Biochemistry **41,** 730–733.