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APPLICATION OF *MORINGA OLEIFERA* LAM. SEEDS IN WASTEWATER TREATMENT

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ABSTRACT

Coagulants play a vital role in treatment of raw water for both human and animal consumption. Aluminium sulphate is the most common and effective chemical coagulant for water treatment. However, chemical coagulants are cost-ineffective, toxic, are not eco-friendly and may also cause severe health issues like cancers and neurologic disorders including Alzheimer's disease. Therefore, natural and greener methods of water purification are crucial for safe and effective water treatment. Therefore, alternative natural and greener method of water purification is required. Seeds of *Vicia faba*, *Cicer arientinum*, *Jatropha curcas*, *Vigna unguiculata*, *Zea mays*, *Vigna mungo* etc. have also been used in water purification regimes. *Moringa oleifera* seeds contain anti-microbial properties and cationic water-soluble proteins (polyelectrolytes) which possess active coagulative properties that can remove the turbidity and heavy metals like Cu, Pb, Cr, Zn, etc from raw water, thus can treat impure water efficiently. Therefore, natural coagulants are preferred over chemical coagulants as they are feasible to use, affordable, eco-friendly and less toxic. This review provides explicit information on efficiency and use of *M. oleifera* seeds in water treatment and their relative comparison with that of routine chemical coagulants. Thus, further collaborative research (industry and academia) on the alternative greener techniques of water purification are still required to gain sustainability in water purification regimes in developing countries.

Keywords: *Moringa oleifera*, Water treatment, Aluminium sulphate, Polyelectrolyte, Cost-effective, Chemical coagulant.

Introduction

Drinking water is the basic need of human beings and is one of the most indispensable requirements for sustenance of life. About 1400 million cubic kilometres of water is available worldwide. Around 96.5% of this total volume is sea water and less than 3.5% is fresh water. Just 1.2% of freshwater is available for drinking purposes, with much of it being captured in glaciers and fields of snow. Safe drinking water is of paramount importance to health of humans. But availability of safe drinking water is a serious issue mostly for humans living in remote areas in developing. The water available to them is of poor quality and is not treated suitably because of high expenses. Reduced quality of water leads to scarcity of water (WWAP 2015). Approximately 1.2 billion people are unable to acquire safe drinking water. A large number of compounds have been identified drinking water worldwide and are considered potentially harmful and hazardous to human health (WHO, 2015). Water pollution is mainly caused due to overutilization of water resources, population explosion, domestic sewage, agricultural wastes including fertilizers, weedicides, pesticides, industrial wastes, oil spills, acid rains, etc. (WWAP 2015). Contaminated water contains various water-borne diseases like diarrhoea, typhoid, cholera, amoebic dysentery, giardiasis and certain neurological disorders. It has been estimated that about 6 million children die from diarrhoea every year in developing countries (WHO, 2015). Heavy metals like copper, chromium, lead, zinc and cadmium released into water bodies through various man-made activities are noxious and harmful water pollutants. Therefore, treatment of raw water is essential for the well-being of humans. Water treatment involves removal of contaminants from water bodies including micro-organisms, colloidal particles and other substances that are toxic to human health. The most common and effective method of water treatment is the chemical treatment which includes use of chemical coagulants like aluminium sulphate, ferric sulphate, ferric chloride, etc, but this method is associated with several disadvantages like cost-ineffectiveness and environmentally unstable, so people have switched over to natural methods of water treatment. At present, large number of effective natural coagulants has been identified like seeds of dolichos bean, chick pea, cow pea, corn, peanut, urad, etc. Of all the plant based natural coagulants, *Moringa oleifera* has proved to be one of the most effective coagulants for treatment of water, mostly in rural areas (Ghebremichael *et al*., 2005).

Water Treatment Procedures

Water pollution occurs due to various chemical, physical or biological contaminants dissolved in water lie suspended in water or get deposited on the water-bed. These contaminants cause deterioration of water quality thus making it unfit for human use, hence needs to be treated. Water is treated mainly through two ways viz. chemical and natural methods of water treatment.

Chemical Methods of Water Treatment

This is the most important and widely used method for water purification and treatment. In this method chemical

coagulants including aluminium and iron salts, chlorites, etc are used for water treatment (Tetteh and Rathilal, 2018). These chemical coagulants are used either as salts or polymers (Table 1). Polymers can be neutral or can have negative or positive charge. Out of various chemical coagulants like aluminium sulphate (alum), ferric chloride, ferric sulphate, etc., alum is the most popular and widely used coagulant in water-treatment procedures. Chemical purification process mainly includes coagulation, flocculation, sedimentation or flotation (Erger, 2003). Coagulation is an indispensable method which promotes aggregation of pollutants including suspended solid particles (Duan and Gregory, 2003). Flocculation promotes agglomeration and gravitational settling for removal of contaminants. Flotation is also gravity separation method in which selective hydrophobic particles gets separated from hydrophilic particles. Thus, chemical coagulants are the most effective water treatment methods but have severe effects both on environment as well as on human health.

Some of the advantages of chemical coagulants include-higher efficiency, used in low concentration, readily dissolvable in water and removes organic substances, *E. coli* (99%), heavy metals and turbidity (99%) of raw water up to larger extent. However, there are several disadvantages associated with chemical coagulants like they are highly toxic, non-degradable, highly expensive, corrosive and unfeasible to use. Besides their availability is also limited, and causes change in various parameters of water under treatment like pH, acidity, hardness, etc, also cause severe health issues like cancers and neurological disorders including Alzheimer's disease (Fig. 1).

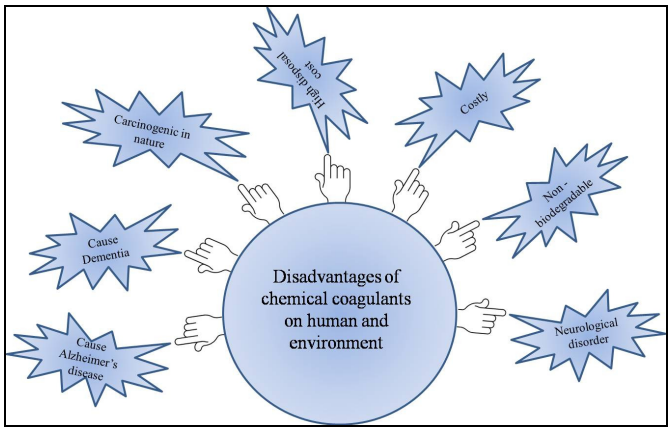

Fig. 1 : Disadvantages of chemical coagulants

Table 1 : List of some routine chemical coagulants.

Common name	Chemical formula	Molecular weight (g/mol)	pH	Advantages	Disadvantages	Reference
Alum	$Al_2(SO_4)_3.14H_2O$	474.39	3-4	Easy to handle, most effective	Effective over limited pH range(pH 6.5and 7.5), carcinogenic in nature	Haydar and Aziz, 2009; Jagaba *et al*., 2018
Ferric chloride	$FeCl_3.6H_2O$	162.22	3-4	Effective over wide pH range(pH 4 &11)	Adds some dissolved salts to water	Aboulhassan *et al*., 2006
Ferric sulphate	$Fe_2(SO_4)_3.3H_2O$	399.91	3-4	Effective over pH 4.6and8.8-9.2	Adds certain dissolved salts to water	Jiang and Lloyd,2002
Ferrous sulphate	$FeSO_4.7H_2O$	151.91	3-4	Not pH sensitive	Adds some dissolved salts to water	Parmar *et al*., 2011
Lime	$Ca(OH)_2$	74.00	12	Effective and Commonly used	Produces large amount of sludge	Lee *et al*., 2007
Calcium carbonate	$CaCO_3$	100.00	6-9	Treats water over wide pH range	Increase in pH leads to crystal growth	Lee *et al*., 2007
Polyal chloride (PAC)	$Al_2Cl(OH)_5$	174.45	5-8	Effective over wide pH range	Possess lesser solubility in water	Zouboulisand Tzoupanos, 2010

2.2 Natural methods of water treatment or Green techniques of water treatment

Natural methods of water treatment are the most preferred methods of water treatment due to their cost efficiency, environmental stability and easier availability especially in developing countries. Natural coagulants may help in reducing the health effects and costs of various chemical coagulants. Some of the common natural coagulants used in water purification include *Moringa oleifera*, *Cicer arietinum*, *Dolichos lablab*, *Vigna unguiculata*, *Zea mays*, etc. (Zhang *et al*., 2006; Guranatra *et al*., 2007; Choubey *et al*., 2012). Out of them, the most preferred and efficient natural coagulants are the seeds of *M. oleifera* which possess polyelectrolytes containing cationic proteins thus helping in coagulation and water purification (Ghebremicheal *et al*., 2005). It has been observed that *M. oleifera* seeds can eliminate turbidity and heavy metals up to a larger extent, thus it can replace chemical coagulants like alum in water purification. The table 2 which shows list of some routine natural coagulants in water treatment process and table 3 show the relative comparison between chemical and natural coagulants.

Table 2 : List of some routine natural coagulants in water treatment process.

Common name	Scientificname	Family	Plant parts	Reference
Drumstick tree / horseradish tree	*Moringa oleifera*	Moringaceae	Seeds	Ghebremicheal *et al*., 2005
Dolichos bean / hyacinth bean	*Dolichos lab lab*	Fabaceae	Fruits	Zhang *et al*.,2006
Chumbera	*Opuntia ficus-indica*	Cactaceae	Leaves	Shilpa *et al*.,2012
Ivvy gourd	*Coccinia indica*	Cucurbitaceae	Fruits	Patale and Pandya, 2012
Chickpea	*Cicer arietinum*	Fabaceae	Seeds	Choubey *et al*.,2012
Neem	*Azadirachta indica*	Maliaceae	Fruit	Sowmeyan *et al*.,2011
Barbados nut	*Jatropha curcas*	Euphorbiaceae	Seeds	Abidin *et al*., 2013
Mango	*Mangifera indica*	Anacardaceae	Fruit	Qureshi *et al*., 2011
Cowpea	*Vigna unguiculata*	Fabaceae	Seed	Choubey *et al*.,2012
Corn	*Zea mays*	Poaceae	Seed	Guranatra *et al*., 2007
Kidney bean	*Phaseolus vulgaris*	Fabaceae	Seed	Antov *et al*., 2010
Cactus	*Cactus latifollia*	Cactaceae	Leaves	Diaz *et al*.,1999
Guar Bean	*Cyamopsis tetragonoloba*	Fabaceae	Seeds	Pritchard *et al*., 2009
Peas	*Pisum sativum*	Fabaceae	Seeds	Hassan *et al*.,2012
Nirmali	*Strychnos potatorum*	Loganiaceae	Seeds	Vijayaraghavan *et al*., 2011
Peanuts	*Arachis hypogaea*	Leguminaceae	Seeds	Birima *et al*., 2013
Urad	*Vigna mungo*	Fabaceae	Seeds	Sotheeswaran *et al*., 2011
Locust bean	*Parkia biglobossa*	Fabaceae	Seeds	Adie *et al*., 2014
Water hyacinth	*Eichhornia crassipes*	Pontederiaceae	Seeds	Akinbile and Yusoff 2012

Table 3 : Comparison between chemical and natural coagulants.

Parameters	Chemical coagulants	Naturalcoagulants
Toxicity	Highly toxic to environment	Non-toxic to environment
Cost	Cost-ineffective	Cost effective
Stability	Environmentally unstable	Environmentally stable
Feasibility	Economically unfeasible	Economically feasible
Corrosiveness	Highly corrosive to materials	Non- corrosive to materials
Nature	Complex in nature	Simple in nature
Sludge properties	Generates hazardous and non-biodegradable sludge	Generates non-hazardous and biodegradable sludge
pH	Alters the pHof water Under treatment	Doesn't alter the pH of water under treatment
Availability	Less availability	More availability

Why *Moringa oleifera* seeds are preferred over chemical coagulants in water treatment?

Plant family Moringaceae encompasses 14 known species. Of these, *Moringa oleifera* Lam. is the well-known and utilized species. The *Moringa oleifera lam*. is a small, fast growing deciduous tree with a height of 5-12 m. *Moringa oleifera* is indigenous to many countries like Africa, South East Asia, Arabia, Pacific and South America. It has been reported that India is the largest producer of Moringa with an annual production of 1.1 to 1.3 MT from an area of 380 square kilometres. This tree is umbrella-shaped with densely covered leaves at the top of branchlets. The flowers are creamy-white, honey-scented, bee-pollinated and arranged in drooping panicles with 10 to 30 cm in length (Bhattacharya and Mandal, 2004). The fruits are light green, tender and slim up to 120 cm in length. *M. oleifera* seeds are round shaped having a diameter of 1 cm and an average weight 0f 0.3 gm. Seeds possess brownish coloured, semi-permeable, seed hull which possess papery wings which are three in number and run from top to bottom at angle of 120 degrees. Thus, *M.oleifera* seeds are greyish to white in colour with unique wing like structures. The seeds are environmentally sustainable, eco-friendly, affordable, non-corrosive to materials, producing small amounts of non-hazardous and bio-degradable sludge, don't alters the pH of water under treatment and are non-toxic methods of water treatment, hence preferred over chemical coagulants mostly because of their cost expenses, especially in developing countries (Fig. 2). It has been found that water purification property of *M. oleifera* seeds is mainly because of the action of proteins present in them. About 37% of proteins are present in seed kernel of *M. oleifera* (Pritchard, 2010). Thus, seed kernels of *M. oleifera* contains water soluble, low molecular weight, cationic proteins which act in similar way as that of chemical coagulants (Jahn, 1998). When *M. oleifera* seed powders containing these proteins are added to raw water, they bind to negatively charged particles present in raw water. These particles then grow in size and form flocks which are then allowed to settle down by gravity or are removed by filtration, thus playing an essential role in water purification

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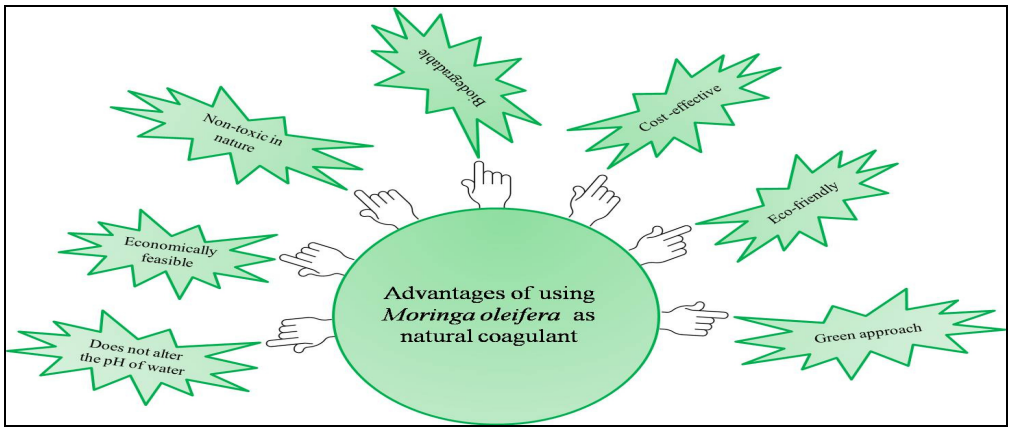

Fig. 2 Advantages of using *Moringa oleifera* seeds as natural coagulant in water treatment.

4. General procedure for preparation of Moringa coagulant solution from seed kernels

Removal of seeds from harvested Moringa pods

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Removal of husk and grinding of seed kernel

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Crushing and sieving of seed kernels (0.8mm mesh approx.)

↓

Seed powder (natural coagulant)

↓

Mixing of seed powder with small amount of clean water and formation of a paste

↓

Dilution of paste to required strength (from 0.5 to 5%)

↓

Filtering of insoluble material using fine mesh-screen or muslin cloth

↓

Addition of this milky white suspension to turbid water

↓

Continuously stirring the suspension for at least half a minute

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Then stir the water slowly and continuously for about 5 minutes at 15 to 20 rpm

↓

After stirring, cover the treated water and allow it to settle for at least 60 minutes

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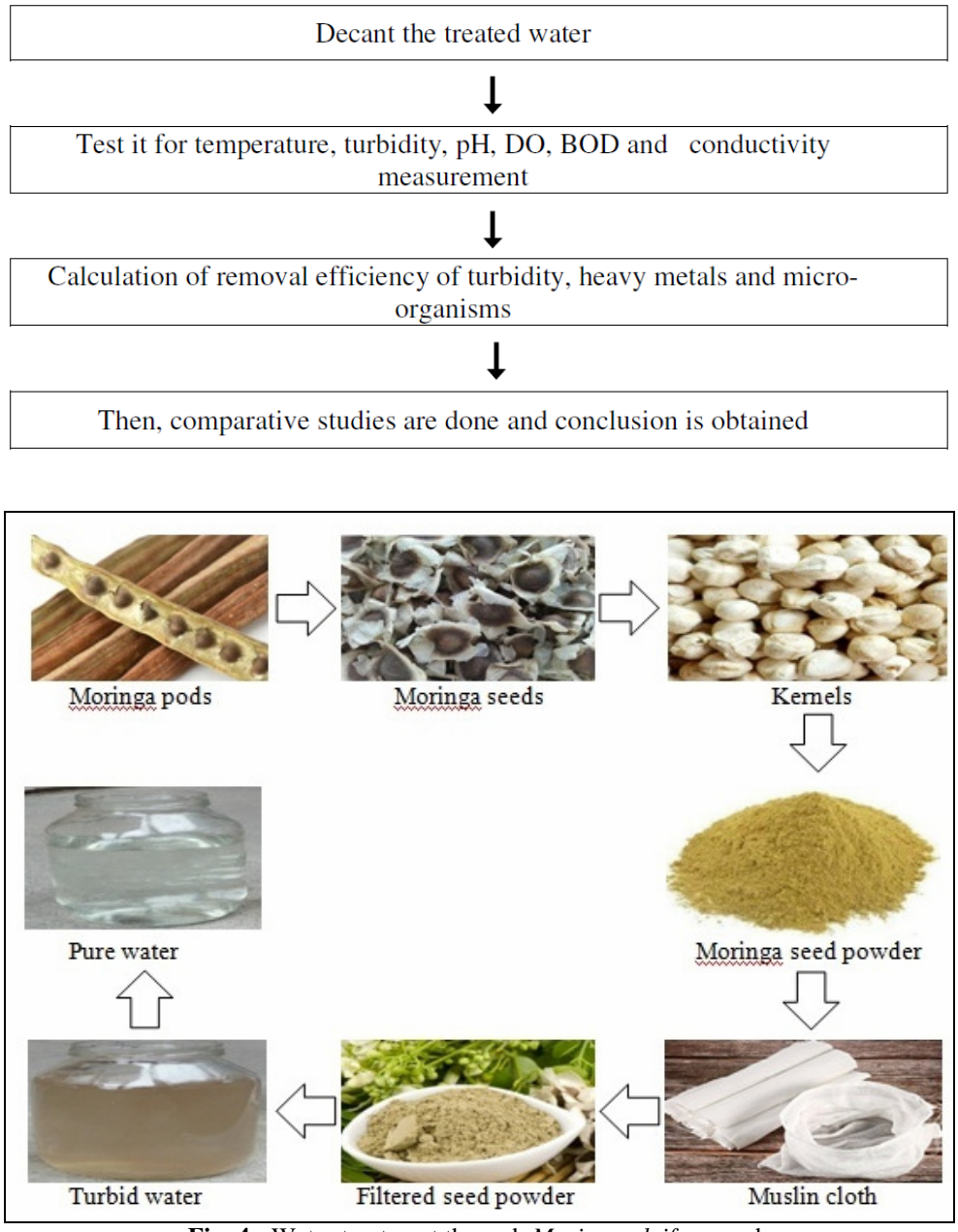

Fig. 4 : Water treatment through *Moringa oleifera* seeds

Table 4 : General coagulant dosage of Moringa seed powder used in turbid water.

Raw water turbidity (NTU)	Dosage range (mg/l)
<50	10-50
50-150	30-100
>150	50-200

Reports on waste water treatment using *Moringa oleifera* seeds

Muyibi and Evison, (1995) accidently discovered softening property of *Moringa oleifera* by carrying out jar tests using water from 4 different sources (two from shallow wells and two from surface) with *M. oleifera* as the primary coagulant. It was observed that turbidity reduced to 99% and hardness reduced between 60-70%. Nand *et al.* (2012) reported that locally available seeds like Moringa, Cow peas, Corn are used for adsorption of heavy metals like lead, chromium, zinc, cadmium, etc. with *M. oleifera* being the most effective in terms of heavy metal adsorption. It was found that *M. oleifera* seeds adsorbed zinc and chromium up to 50%, cadmium up to 60%, lead up to 80% and copper up to 90%.Ghebremichael *et al.* (2005) reported that purified protein of *M. oleifera* seeds possess coagulative and anti-microbial activities for surface water treatment by carrying studied on river Meuse and Delft canal waters. It was found that *M. oleifera* removed turbidity up to 97% for high turbid waters and up to 86% for low turbid waters. Besides this, *E. coli* was also removed completely. Nkurunziza *et al.* (2009) reported that *M. oleifera* reduced turbidity up to 95%, 99% and 99.8% with conc. of *M. oleifera* seeds being 150mg/l for 50 NTU water, 125mg/l for both 250 and 450 NTU water samples river water in Butre Rwanda. Besides, colour reduction was also found to be up to 90%.Pritchard *et al.* (2009) reported the water purifying efficiencies of *M. oleifera* against that of *Jatropha curcas*, *Cyamopsis tetragonoloba* for purification of shallow well water in Malawi. It was found that turbidity was removed up to 90% and faecal coliforms up about 80% with *M. oleifera* being the most effective coagulant followed by *Cyamopsis tetragonoloba* and *Jatropha curcas*. Poumaye *et al.* (2012),

reported removal of *Streptococci*, *Clostridium* and *E. coli* up to 62%, 95% and 97% respectively by using *M. oleifera* dried seed powder for purifying the river M'Poko surface water. Prasad and Rao (2013), reported that *M. oleifera* seed powders were taken at a concentration of 50, 100 and 150mg/l and treated with water samples followed by analysis of turbidity and pH. The results obtained showed that seed powder contained some coagulant properties and act as absorbent for water treatment and removed turbidity to a larger extent. Kazi and Virupakshi *et al*., (2013), reported that *M. oleifera* along with chickpea and Cactus were used as locally available natural coagulants for removal of COD and turbidity of tannery waste water. It was found that chick pea, *M. oleifera* and Cactus reduced turbidity to 81.20%, 82.02% and 78.54% reduced COD to 90%, 83.33% and 75% respectively. Thus, it was concluded that *M. oleifera* is the most effective natural coagulant and reduced turbidity to a larger extent. Kane *et al*., (2016) reported removal of turbidity and COD up to 90% and 75% respectively from domestic waste water by using alum and *M. oleifera* seed powder in the ratio of 50:50 (W/V) as a coagulant.

Thus, from the above review it can be concluded that *M. oleifera* is not only used in removal of turbidity of raw-water but also in the removal/lowering of COD, BOD, heavy metals, odour, salts and total solids Besides this, *M. oleifera* seeds as natural coagulant also possess several benefits like cost-effectiveness, biodegradability and feasibility in use.

Table 5 List of some published work using *Moringa oleifera* seeds along with other natural and chemical coagulants in waste water treatment.

S. No.	*M. oleifera* as natural coagulant	Methodology	Result	Reference
1	*M. oleifera* seed powder	*M. oleifera* seeds were used in treatment of water collected from 4 different sources (2 from shallow wells and 2 from surface water)	Turbidity was reduced up to 99% and hardness between 60- 70%	Muyibi and Evison, 1995
2	*M.oleifera* seeds along with cow pea and corn seeds	*M. oleifera* seeds were used in treatment of turbid water and their relative comparison with that of cow pea and corn seeds	Moringa seeds were found to be more effective and absorbed heavy metals like Zn and Cr up to 50%, Cd up to 60%, Pb up to 80% and Cu up to 90%	Nand *et al*., 2012
3	*M.oleifera*seed powder	*M. oleifera* seeds were used in treatment of surface river water (river Meuse and Delft canal waters)	Turbidity was removed up to 97% for high turbid waters and up to 86% for low turbid waters	Ghebremichael *et al*., 2005
4	*M. oleifera* seed powder	*M. oleifera* seeds were used in treatment of 3 river water samples in Butre Rwanda having initial turbidity 50,250 and 450 NTU at dosage of 150, 125 and 125mg/l of seed powder respectively	Turbidity was removed up to 95% (for 50 NTU), 99%(for 250 NTU) and 99.8%(for450 NTU) water samples	Nkurunziza *et al*., 2009
5	*M. oleifera* seeds along with alum	*M. oleifera* seed powder was used at dosage of 4, 6, 8, 10 and 12 g/l along with alum	The 12g /l treatment of Moringa and 10, 12 g/l alum treatment removed turbidity and coliform count up to greater extent that are acceptable as per WHO guidelines. Moringa treatment gave lower counts than alum	Amagloh and Benang, 2009
6	*M. oleifera* seeds along with other local seeds like peanuts, cow peas, urad and corn	Treatment was done on drinking water sample in 3 countries in South Pacific Islands i.e. Tonga, Kiribati and Fiji	Turbidity was removed to a greater extent with Moringa seeds being the most effective ones	Sotheeswaran *et al*., 2011
7	*M. oleifera* seeds along with alum	*M. oleifera* seed powder and alum were treated on water having contained turbidity 146 NTU and E. coli at 10^4/100 ml	Result showed that 84% turbidity and 88% E. coli were removed by *M. oleifera* seeds whereas alum removed greater than 99% turbdity and E. coli	Pritchard *et al*., 2010
8	*M. oleifera* seeds along with alum	Treatment was done on river M'Pokosurface water samples	*Streptococci*, *Clostridium* and *E. coli* count was reduced up to 62%,95% and 97% respectively	Poumaye *et al*., 2012
9	*M. oleifera* seeds along with alum	*M. oleifera* seed powder was used to treat turbid water at dosage of 50, 100 and 150 mg/l	The turbidity was removed to a large extent without any change in pH of treated water	Prasad and Rao, 2013
10	*M. oleifera* seeds along with alum	*M. oleifera* seeds were used for heavy metal removal from turbid water samples by employing double filtration	Cu was removed up to 95%, Pb up to 93 %, Cd up to 76% and Cr up to 70%	Ravikumar and Sheeja, 2013

11	*M. oleifera* seeds along with cactus and chick pea seeds	*M. oleifera* seeds along with cactus and chick pea seeds were used for treatment of tannery waste water	Turbidity was removed up to 82.02% by Moringa, 81.20% by chickpea and 78.54 % by cactus seeds. Thus, moringa seeds being the most effective one	Kazi and Virupakshi , 2013
12	*M. oleifera* seeds along with banana peel	Optimum dosage of 200mg/l for both Moring seeds and banana peel and 400mg/l for combination were used for treatment of contaminated ground water samples	Moringa seeds removed Pb up to 81% and combined dosage of M. seeds and banana peel removed Ni up to 74% and Cd up to 97%. Thus, it was concluded that combined dosage was more effective and was able to meet the WHO standards	Aziz *et al*.,2015
13	*M. oleifera* seed powder along with alum	*M. oleifera* seed powder and alum were used in the ratio of 50:50 (w/v) in treatment of domestic waste water	Alum removed turbidity up to 90% and M. seed powder Up to 75%	Kane *et al*., 2016
14	*M. oleifera* seeds along with alum	A blend of plant based natural and synthetic coagulants (*Moringa oleifera*/cactus/alum blend) was used for water treatment with a total coagulant dosage of 45mg/L	In the resultant water turbidity was reduced up to 2.7 NTU which are within required limits for portable water as per WHO guidelines	Gandiwa *et al*., 2020
15	*M. oleifera* seeds along with alum	The surface water samples were collected from three sites in Dongnai river Vietnam with turbidity ranging from 26-45 NTU. With coagulant dosage 0.15 ml/L.	In the rainy season the turbidity was removed from 88-94% while as in dry season it was removed from 88-95%. Results indicated that *M. oleifera* extract is the low cost and eco friendly material to treat the surface water.	Nhut *et al*.,2020

5. Advantages and disadvantages of using *Moringa oleifera* as natural coagulant

5.1 Advantages

- It is the cheapest and easiest method for treatment of water in developing countries particularly at household level.
- It doesn't alter the pH of water under treatment.
- Its efficiency is not dependent on pH of raw water.
- It doesn't alter the taste of water.
- It results in production of non-hazardous and bio-degradable sludge. Thus, acting as an environmentally sound technology.
- It is non corrosive to materials and non-toxic to environment.
- It is environmentally sustainable and economically feasible.

5.2 Disadvantages

- Coagulant should be prepared fresh as it is not available in pure form.
- The treated water might still contain certain pathogenic micro-organisms.
- The treated water might result in secondary increase of bacteria after coagulation.
- Coagulant needs to be used in large quantities for treating water.
- The treated water might produce odour after 2 days of treatment.

6. Other uses of *Moringa oleifera*

Moringa oleifera, a 'miracle tree' besides having water purification properties has several other wider applications as well.

6.1 Nutritive properties

Moringa oleifera is the store house of nutrients like minerals, fibres, proteins and vitamins. It has been reported that seeds of *M. oleifera* also contain about 13% saturated fats, 30-40% oil and 82% unsaturated fatty acids. Dry leaves of Moringa contain 10 times vitamin A than that of carrot, 9 times protein than yogurt, 17 times Ca than milk, 25 times iron than spinach, 15 times potassium than bananas and 7 times more vitamin C than orange (Fahey, 2005).

6.2 Medicinal properties

Moringa oleifera is reported to treat more than 30 diseases. Various parts of Moringa are used as anti-tumour, anti-ulcer, anti-spasmodic, anti-hypertensive, anti-inflammatory, anti-diabetic, anti-cancer and anti-oxidant agents (Farooq *et al*., 2012). Thus, Moringa is used to treat cancer, and type I and type II diabetes as well which is a major concern in present times.

6.3 Commercial applications

Ben oil obtained from Moringa seeds has wider industrial applications as it has high conc. of tocopherols, sterols and oleic acids. Thus, oil is used in perfume and lubricant industry. *Moringa oleifera* seed oil has also been considered as a potential source of biofuels (biodiesels) because of its low temperature and high viscosity index. Wood pulp of this tree may be used for paper making. Leaves can also be used as fertilizers. Thus, Moringa, a 'miracle tree' attracts a lot of research work.

Conclusion and Recommendations

The use of conventional varieties of Moringa is effective in generation of pure drinking water in developing countries where purchase of routine chemical coagulants is not affordable. Besides reducing the number of suspended

particles drastically, it also reduces the microbial count to a larger extent, thus, reducing water-borne diseases greatly. The plantation of Moringa should be encouraged especially at rural level as this tree is unknown to most of the small-scale farmers so in this respect all the key institutions along with researchers, private sector, district councils, stake holders, local communities and NGO's in water sector need to work together and fully participate in promotion of this 'miracle tree'. Besides it will also provide so much of benefit to the farmers during crop failure as every part of this tree like leaves, roots, flowers, pods, seeds, etc is beneficial in one or other way. In order to obtain high quality supply of coagulants, special breeding efforts should be applied. Further research on isolation of exact active compound responsible for removal of microbes and use of Moringa extract in heavy metal removal is still required. More research is further needed for disposal of sludge generated during application of natural coagulant in water purification. It is further recommended to make these natural coagulants more exquisite, less toxic, low cost and more efficient for treatment of water.

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