Heavy Metal Removal from Water using *Moringa oleifera* Seed Coagulant and Double Filtration

Ravikumar K, Prof.Sheeja A K

Abstract— The quality and accessibility of drinking water are of paramount importance to human health. Drinking water may contain disease-causing agents and toxic chemicals and to control the risks to public health, systematic water quality monitoring and surveillance are required. Thousands of chemicals have been identified in drinking water supplies around the world and are considered potentially hazardous to human health at relatively high concentrations. Heavy metals are the most harmful of the chemical pollutants and are of particular concern due to their toxicities to humans. *Moringa oleifera* seed acts as a natural coagulant, adsorbent and antimicrobial agent. It is believed that the seed is an organic natural polymer. The coagulation mechanism of the *Moringa oleifera* coagulant protein has been described as adsorption, charge neutralization and interparticle bridging. It is mainly characteristic of high molecular weight polyelectrolyte. Analysis of the heavy metals cadmium, copper, chromium, and lead were performed before and after treatment of water with Moringa oleifera seed coagulant. The results showed that Moringa seeds were capable of adsorbing the heavy metals tested in some water samples. The percentage removal by Moringa seeds were 95 % for copper, 93 % for lead, 76 % for cadmium and 70 % for chromium. In this study the advantage of proposing a sequential process using coagulation with *Moringa oleifera* seed and double filtration (Up-flow roughing filtration followed by rapid filtration) for the removal of heavy metals from water is analysed.

Index Terms—Adsorption, Coagulaion, Double filtration, Heavy metals, Moringa oleifera, Rapid filters, Roughing filters, Turbidity.

1 Introduction

THE need for simple, reliable and effective method of water treatment led to the application of plant materials, including seed coagulants of *Moringa oleifera*. The *Moringa oleifera* (MO) tree grows in tropical and subtropical regions around the world and its seeds have been used in drinking water treatment in small scale in Sudan and India for generations. The coagulant in the seed is a protein that acts as a cationic polyelectrolyte. The soluble particles in the water attaches to the active agent that binds them together creating large flocs in the water. Previous studies indicate that *Moringa oleifera* is an efficient coagulant for the removal of turbidity in both water and waste water treatment.

The *Moringa oleifera* is one of the natural coagulants that have been tested over the years as an alternative to the use of inorganic and synthetic coagulants. Disadvantages of inorganic and synthetic coagulants are it causes Alzheimer's disease and similar health related problems, reduction of pH, high costs, production of large sludge volume and low efficiency in coagulation of cold water. Moringa oleifera has potential in water treatment- as a coagulant, a soften agent and bactericidal agent. Advantages of *Moringa oleifera* as a natural coagulant are its low cost, produces lesser volume of biodegradable sludge, and it does not affect the pH of the water. Moringa oleifera is a sustainable, low cost, locally available, simple, reliable, acceptable, eco-friendly and household level point of use water treatment coagulant/technology most suitable for developing countries where major population use contaminated water for drinking purposes.

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Literature survey reveals that *Moriga oleifera* plant is the most inexpensive credible alternative for providing good nutrition and to cure and prevent a lot of diseases [1]. Aqueous extract of *Moringa oleifera* showed strong and superior antibacterial activity against bacterial strains such as Staphylococcus aureus, Bacillus subtilis, Eschreiashia coli and Pseudomonas aeruginosa [2]. *Moringa oleifera* is the best natural coagulant that can replace aluminium sulphate (Alum) which is widely used all around the world [3]. Acid extract of natural polyelectrolyte *Moringa oleifera* seed is very effective as a coagulant for removal of fluoride from water [4]. Removal of turbidity and hardness can simultaneously be done by using *Moringa oliefera* seed extract with 1.0M sodium chloride solution (MO-Nacl) [5]. *Moringa oliefera* seed extract against E. coli by TVC method reduced >99.9% E.coli count [6]. Efficient reduction (80.0% to 99.5%) of high turbidity produces an aesthetically clear supernatant, concurrently accompanied by 90.00% to 99.99% bacterial reduction [7].

Distilled water extract of *Moringa oleifera* seed powder achieved 90 to 95% sedimentation of the suspended particles in underground and surface water samples [8]. Increased dose of *Moringa oleifera* seed powder showed reduction in turbidity, TDS, TS, hardness, chlorides, alkalinity, acidity, MPN and SPC in ground water samples [9]. *Moringa oleifera* as a coagulant agent provided significant results, which justify its use as an alternative coagulant in the process of coagulation/flocculation of produced water (which is the waste that has the highest volume during the production and exploration of oil) [10]. Shelled blended *Moringa oleifera* seed as a biosorbent removes C.I. Acid Orange 7 from the aqueous systems [11].The percentage removal by *Moringa oleifera* seeds were 90% for copper, 80 % for lead, 60 % for cadmium and 50% for zinc and chromium [12].Coagulation - flocculation process using *Moringa oleifera* seeds

International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

after oil extraction (MOAE) as a natural coagulant presents a viable alternative for the treatment of Palm Oil Mill Effluent (POME) [13].The efficiency of coagulation-photooxidation processes for removing color from a landfill leachate by using *Moringa oleifera* coagulation as a pre-treatment was effective[14].

The operation of the Hindustan Coca Cola Beverages Private Limited (HCBP) Plant has polluted drinking water by its careless and irresponsible disposal of sludge and treated effluents. Particularly hard hits are the dalits, tribals, women and chidren of the sorrounding area. As the water supply deteriorated, the women have to travel about 5 kms to fetch drinking water. Serious damage caused by the contamination of aquifers and springs had adversely affected agriculture yield and productivity.

The water in Plachimada and sorrounding area is contaminated with copper, cadmium, lead and chromium, more than the admissible level by the World Health Organisation. The Kerala Agricultural University has found that the fodder, milk and egg samples collected from Plachimada area contain the above elements at toxic levels. In 2003, the district medical officer advised the people of Plachimada that their water was polluted and unfit for consumption.

Cadmium is more toxic than lead and chromium. Cadmium and certain cadmium compounds are listed by International Agency for Research on Cancer (IARC) as carcinogenic. Cadmium at extreme levels causes itai-itai disease and at low levels over prolonged periods causes high blood pressure, sterility among males, kidney damage and flu disorders. Exposure to chromium (VI) by the inhalation route may cause lung cancer (World Health Organisation 2004). Copper is both an essential nutrient and a drinking water contaminant. Recent studies have shown effects of copper in drinking water on the gastrointestinal tract, carriers of the gene for Wilson disease and other metabolic disorders. The toxic effects of lead include nervous system disorders, anemia, decreased hemoglobin synthesis, cardio vascular diseases and disorders in bone metabolism, renal function and reproduction.

Concentrations of heavy metals are high in the Periyar river near the industrial estate and the concentration is high in pre monsoon period. The chemical factories discharges their effluents to Periyar river and it eventually reach in to the Cochin estuary. The flow of water discharged through the river is very low in pre monsoon period, which cause the high concentration of metals in lake and river. In Muvattupuzha river the heavy metal concentration is high near the news print factory. At present, water in the open wells in the area is unfit for drinking.

Different technologies may be applied to diminish these levels in water for consumption. This study was an effort to investigate the water treatment potential of indigenous plant coagulant *Moringa oleifera* seeds with double filtration for removal of heavy metals.

The objectives of the study were

1. To identify a sustainable, low cost, locally available, simple, reliable, acceptable, eco-friendly, household level point of use water treatment technology most suitable for rural population of developing countries
2. To find a process that allowed efficient removal of heavy metals from aqueous systems.
3. To evaluate the up-flow roughing filtration process followed by rapid filtration as a suitable method for the separation of the flocs formed using the *Moringa oleifera* seed coagulant.
4. To determine the removal efficiency of various heavy metal concentrations in water using Moringa oleifera coagulation and double filtration.

2 MATERIALS AND METHODS

2.1 Preparation of MO Seed Powder

Dry MO pods were collected from Varkala, Trivandrum. Pod shells were removed manually; kernels were grounded in a domestic blender and sieved through 600micro meter stainless steel sieve..

2.2 Aqueous Extract

Aqueous extract was prepared by using 200ml of distilled water and 25 g of MO seed powder, mixed by a magnetic stirrer for 60 minutes and settled for 20 minutes. *Moringa oleifera* aqueous extract is finally filtered through 20µm paper filter

2.3 Coagulant Activity Test

Jar test was conducted to determine the effective dosage of coagulant to reduce the heavy metals of the samples. The standard procedure was 1 min of rapid mixing (120 rpm) followed by 15 minutes of slow mixing (30rpm) for flocculation and 60 minutes of settling.

2.4 Multistage drinking water filtration

By providing roughing filter pretreatment, suspended solids are decreased. Rapid sand filtration is still a viable method of water treatment most suitable for raw water sources with turbidity and suspended solids. Multistage filtration has been shown to be an efficient and effective drinking water treatment technique for source water with high turbidity, organic matter, and suspended solids.

2.4.1Filtration test with roughing filter

In vertical-flow roughing filters the water to be treated flows in sequence through the three filter compartments filled with coarse, medium and fine filter material. The size of the three distinct filter material fractions is generally between 25 and 3 mm, and graded, for example, into fractions of 25-16mm, 16-8mm and 8-3mm.

Roughing filtration was conducted directly after the coagulation and flocculation processes with *Moringa oleifera* and separates the suspended solids. Vertical-flow roughing filter was operated at 0.3 to 1.0 m/h filtration rates. The separated solids, which accumulate mainly in the coarse filter fraction next to the filter bottom, can be easily flushed out with the water stored in the filter. Therefore, the use of upflow roughing filter in layers was used.

2.4.2 Filtration test with rapid sand filter

In rapid sand filters the water to be treated flows in sequence through the three filter compartments filled with coarse, medium and fine filter material. The size of the three distinct filter material fractions is generally between 50 and 0.5 mm, and graded, for example, into fractions of 25-50mm, 13-25mm and 0.5-1mm. Rapid sand filtration was conducted directly after the roughing filtration and separates the last remaining flocs that failed to disappear during roughing filtration. The filtration rate for a rapid filter is 5-10 m/h.

2.4.3Double Filtration Experiments

Jar tests were carried out in the following conditions: 1 minute rapid mixing and 10 minutes slow mixing. An up-flow roughing filtration stage was chosen because it is a process with a high efficiency in the removal of light flocs. As a second stage a conventional rapid filter was adopted.

The washing of the roughing filter was carried out through lower drainage, and the washing of the rapid filter was counter current. The

International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

bed of the upflow gravel roughing filter was made up of three layers of gravel of different granule measures.

3 RESULTS AND DISCUSSIONS

A. Coagulation activity test results of synthetic water samples containing heavy metals

Coagulation- flocculation was done using shelled blended, oil extracted and crude extract of *Moringa oleifera* seed powder. These coagulants were extracted by using a standard preparation method.. Optimum doses of 2 g/L coagulants were used for different water samples containing heavy metals concentrations of 5 mg/l. The optimum dosage is the minimum dosage of coagulant corresponding to the removal of heavy metals present in the water samples. At optimum dosage of 2 g/L of coagulant, the final heavy metal concentrations reduced considerably, but the turbidity increases in all four synthetic heavy metal water samples as shown in Table 1.

Table 1. Final Heavy metal concentrations and the respective increase in turbidity levels after coagulation treatment with filtrated *Moringa oleifera* coagulant

Heavy metals with initial concentration of 5 mg/l	Final Heavy metals concentration in mg/L	Removal efficiency in %	Final turbidity
Copper	0.25	95	73
Lead	0.35	93	78
Cadmium	1.2	76	86
Chromium	1.5	70	92

B. Test results of synthetic heavy metal water samples after upflow roughing filtration.

Samples of water collected from the outlet of roughing filter were used for analyzing the turbidity and heavy metals. Table 2 represents the results of turbidity removal from treated water with various heavy metals of concentration 5mg/l, after upflow roughing filtration. An up-flow roughing filtration stage was chosen because it is a process with a high efficiency in the removal of light flocs. The bed of the upflow gravel roughing filter was made up of three layers of gravel of different granule measures.

C. Test results of synthetic heavy metal water samples after upflow roughing filtration and rapid filtration (double filtration)

Samples of water collected from the outlet of rapid filter were used for analyzing the turbidity and heavy metals concentrations. Table 2 represents the results of turbidity removal, after upflow roughing filtration and rapid sand filtration (double filtration).

Table 2. Turbidity (NTU) after upflow roughing filtration and double fitration

Heavy metals with initial concentration of 5 mg/l	Turbidity after upflow roughing Filtration NTU	Turbidity after double Fitration NTU
Copper	11	2
Lead	15	2
Cadmium	16	3
Chromium	19	3

The combined coagulation and double filtration process is an alternative for heavy removal, since the coagulation process is effective in removing metal ions and double filtration complements the process by reducing the turbidity to the limits. In this study, the double filtration step was performed just after coagulation in order to remove colour and turbidity caused by the addition of *Moringa oleifera* coagulant, so as to meet the standards for water potability. Therefore, the utilization of the combined treatment allows for the production of fully treated water. It is known that the filtration process is not efficient for the removal of metal ions, which indicates that heavy metals retention was mainly due to the process of coagulation with the coagulants obtained from *Moringa oleifera*. Thus, it is more likely that the mechanism of interaction between the *Moringa oleifera* proteins and heavy metals was ion adsorption and charge neutralisation.The MO seed powder has been termed as potential heavy metal removing agent due to its oxygen and nitrogen donating carboxylate and amino groups.MO seed powder extraction with salt increased the removal efficiency. The adsorption of metals using MO is limited to the adsorption surface. This is because MO is a cationic polyelectrolyte of short chain and low molecular weight. The mechanism that brings about adsorption of heavy metals is through the positive metal ions that forms a bridge among the anionic polyelectrolyte and negatively charged protein functional groups on the colloidal particle surface. There is formation of complexes with the heavy metals and the organic matter of MO seeds such as proteins. Due to hydrophilic character, several hydrogen bonds are formed among polyelectrolyte and water molecules. Polyelectrolyte coagulant aid have structures consisting of repeating units of small molecular weight forming molecules of colloidal size that carry electri-

International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

cal charges or ionisable groups that provide bonding surface for the flocs. Adsorption describes attachment of ions and molecules from seed protein by means of specific mechanism. Metal ions in coagulation react with proteins and destroy them in water. Metal adsorption occurs due to the high protein content of the seeds. The flocculation activities of MO seeds are based on the electrostatic patch charge mechanism. Studies have shown that seeds have the capability to adsorb metal cations and attract highly toxic compounds.

4 Conclusion

Moringa oleifera is an environmentally-friendly natural coagulant most suitable for the treatment of water containing undesirable heavy metal concentrations. Based on the experimental test results; the following conclusion can be drawn.

1. The optimum dosage of *Moringa oleifera* aqueous extract for synthetic water samples containing heavy metal concentrations of 5mg/L was 2g/L and the removal efficiencies were 95%, 93%, 76% and 70% of copper, lead, cadmium and chromium respectively.
2. The process of up flow roughing filtration followed by rapid filtration is suitable for the separation of the flocs formed using *Moringa oliefera* seed coagulant.
3. It is an eco-friendly technology that is economically more advantageous than other treatment alternatives.
4. In accordance with the above conclusions, it is suggested that aqeous extract of *Moringa oleifera* seed powder treatment with coagulation and flocculation followed by double filtration (roughing filters followed by rapid filtration) is considered in the event of expansion or construction of small scale waterworks, presuming that an adequate amount of plantations are established.

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