Coagulation of turbid waters using *Moringa oleifera* seeds from two distinct sources

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Abstract Samples of turbid water prepared under laboratory controlled conditions were tested using natural coagulant–flocculant *Moringa oleifera* seeds from Burundi, Central Africa, and from Mahajanga, Madagascar. Coagulation–flocculation and sedimentation experiments were conducted using jar test equipment. For these tests, 5% *Moringa oleifera* solutions (w/w in water) were prepared using shelled and non-shelled seeds from the aforementioned countries. The results show that, in both cases, the shelled seeds provide much higher turbidity removal than the non-shelled ones. In addition, the volume of sludge produced was approximately 30% of that of conventional coagulants such as alum. Finally, it was concluded that seeds from Burundi were of superior quality than those of Madagascar. In fact, higher dosages of these seeds, of up to four times, were required in order to attain the same level of turbidity as the Burundi seeds.
Keywords *Moringa*; natural coagulants; water treatment

Introduction

Water treatment often requires the removal of turbidity and suspended matter. As the particulate matter is extremely small, coagulants and flocculants such as aluminium sulfate, ferric chloride and polyelectrolytes are employed. Although these chemicals are quite effective, they remain expensive. In addition, recent studies show that certain health risks, such as the incidence of Alzheimer's disease, are associated with the usage of aluminium salts (AWWA, 1990; Miller *et al*., 1984). Another problem is the large quantities of chemical sludges that are produced, e.g. aluminium hydroxide, and which are difficult to treat from an economic standpoint (James and O'Melia, 1982). Lastly, chemical coagulants are, for the most part, produced in western countries and as such, are out of easy reach to developing countries in Asia or Africa. Therefore, there is a great deal of interest in the search for more environmentally acceptable coagulants that can be used in conjunction with chemical coagulants. The answer lies in the developing nations around the equator that have *Moringa oleifera* plants growing freely in the wild, as well as in rural areas. In many cases, these plants serve as fence ornamentation, as fodder to the domestic animals, in the preparation of culinary recipes, as herbal remedies, as well as cooking oil.

Around the world, there are some 14 different varieties of *Moringa oleifera* possessing varying degrees of coagulating efficacities. Numerous studies have shown that *Moringa oleifera* seeds possess effective coagulating properties (Jahn, 1988; Karewa, 1986) including the removal of turbidity. Hence, pathogenic micro-organisms can also be removed by this coagulant. It has been found that the active coagulation agents are dimeric cationic propteins of molecular weights around 13 kilo-Daltons (kDa) and having iso-electric points between 10 and 11 (Fink, 1984). Our previous studies on *Moringa oleifera* have dealt with the mechanism of coagulation (Ndabigengesere *et al*., 1995) and the significance of operational parameters such as intensity and duration of mixing (Ndabigengesere and Narasiah, 1998). As previously mentioned, the coagulating properties of *Moringa oleifera* seeds vary widely with geographical location of the plant, climate, altitude and soil

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characteristics. The present study was undertaken to examine the influence of the above factors in the efficiency of reducing the pollutional load of drinking water. *Moringa oleifera* seeds from two countries, namely Burundi and Madagascar, were chosen for comparison.

Materials and methods

First, samples of dry pods of the *Moringa oleifera* seeds were collected from south Burundi in Central Africa and from Tananarive, Madagascar, which lies in the Indian Ocean approximately 2000 km further south than Burundi. The pods were then cleaned in order to remove any foreign matter and were carefully stored in plastic containers under laboratory conditions of 22 ± 1°C and a relative humidity of about 82%. In order to obtain uniform water quality during the testing period, a model turbid water was prepared using water from the Sherbrooke city municipal water supply. Table 1 shows the main characteristics of the tap water. As can seen from the table, the water is relatively soft and free of suspended and dissolved matter.

Synthetic turbid water

A model turbid water was prepared in the laboratory by adding kaolin to the above tap water. Depending upon the experiment, 3–5 g of different grades of kaolin were added to 1 L tap water. The suspension was then stirred for 30 minutes and allowed to settle for 24 hours. The supernatant was removed and stored in plastic bottles. This stock solution was then diluted using the tap water to obtain a turbidity of about 100 NTU. This model turbid water was constantly agitated to prevent sedimentation and to maintain a constant turbidity.

Preparation of *Moringa* seeds

In the present study, dry shelled and non-shelled seeds were tested for their coagulating properties. The kernel of the shelled seeds were ground to a fine powder using a domestic electric grinder. The non-shelled seeds were also ground the same way to a fine powder. Using each of the above two powders, 5% solutions (5 g of powder in 100 mL water) were prepared for testing. The two suspensions were stirred for 30 minutes using a magnetic stirrer and then filtered through a Whatman filter paper (2.5 μm) followed by another membrane filter of 1.2 μm. The final filtrates were then used for all the experiments. The following abbreviations are used to describe the various experiments conducted:

- *CNB*. Stock solution prepared from non-shelled seeds from Burundi.
- *CSB*. Stock solution prepared from shelled seeds from Burundi.
- *CNM*. Stock solution prepared from non-shelled seeds from Madagascar.
- *CSM*. Stock solution prepared from shelled seeds from Madagascar.
- *RM, SM, ST*. Rapid mixing, slow mixing and settling time, respectively.

Table 1 Quality parameters of Sherbrooke city tap water

Parameter	Value
pH	7.3
Turbidity	<1.0 NTU
Conductivity	150 mmho/ cm^{-1}
Total hardness	46.0 mg/L
Phosphates	0.50 mg/L
Acidity	4.4 mg/L
Alkalinity	52.0 mg/L

Jar tests
Jar tests were conducted using standard equipment with 6 L glass beakers, a stirring mechanism and a base illuminator. In each beaker a different volume of *Moringa oleifera* extract was added and stirred simultaneously. The rotational speed was adjusted, in most cases, to 100 rpm for 2 minutes for rapid mixing and 40 rpm for 20 minutes for slow mixing, followed by 30 minutes of settling. The following parameters were measured during the study: temperature, pH value, total hardness, turbidity, electrical conductivity, and total organic carbon (TOC).

Instrumentation
The following instrumentation was used: Phipps and Bird Jar tester, Hellige Turbidimeter (Orbeco-Hellige, Model-No.965), pH-meter (bench top/ISE meters, Model 710A) and conductivity meter (Hach). For hardness measurement an EDTA Titrimetric method (as per *Standard Methods* 2340C) was used. A total carbon analyser (Dohrmann) was also used.

Results and discussion
The characteristics of both types of seeds were determined in the laboratory and the results from this analysis are summarized in the following table.

Thus, it can be seen that the percentage of humidity in the seeds of both countries is relatively the same. Seeds from Madagascar have slightly less shell weight than their counterparts from Burundi. However, the seeds from Madagascar are larger in appearance and also heavier.

Turbidity and conductivity of non-shelled seeds
Coagulation tests were conducted using synthetic turbid water prepared from non-shelled seeds. From Figure 1, it is observed that the *Moringa* seeds from Madagascar are much less effective in reducing the turbidity than the ones from Burundi (note: initial turbidity = 96 NTU). In fact, in order to reduce the turbidity from 60 NTU to 30 NTU requires a dosage of coagulant about 18 mL/L of CNB compared to that of about 50 mL/L of CNM.

Table 2 Seed characteristics from Burundi and Madagascar

Characteristics	Burundi	Madagascar	Remarks
Average weight of non-shelled seed	0.227g	0.246g	
Average weight of shelled seed	0.177g	0.205g	
% volume of water contained in the seed	4.80%	5.60%	Dried for 3 days at 105°C

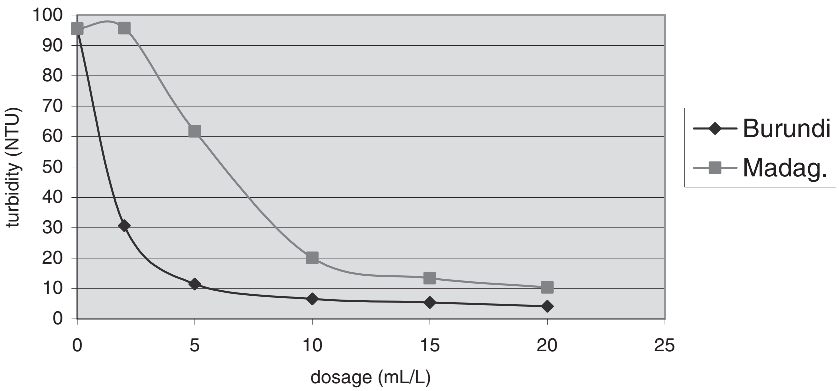

Figure 1 Turbidity measurements for non-shelled seeds from Burundi and Madagascar (RM: 2 min. at 160 rpm; SM: 20 min. at 40 rpm; ST: 30 min.)

In addition to turbidity, conductivity was measured for both types of samples. As noted from Figure 2, the addition of the coagulants increases the conductivity by almost 200%. Thus, an increase in the dosage of coagulants will affect the process of coagulation by modifying the pH. Taking into account experimental errors, there is not a significant difference between the two coagulants.

Effect of shelled seed compared to non-shelled

The above experiments were repeated with shelled seeds from both countries. The results are presented in Figure 3 (note: initial turbidity = 104 NTU).

From above, it can be seen that the lowest turbidity acceptable for drinking water, namely 1 NTU, can be achieved with a dosage of 1 mL/L of shelled seeds CSB and 4 mL/L of CSM. This dosage is significantly less than that required for the non-shelled seeds of either CNB or CNM. It is also observed that adding more coagulant than the optimum dosage would not necessarily improve the turbidity removal.

Treating low turbidity

Experiments were repeated using non-shelled *Moringa* seeds for removal of low turbidity of 6 NTU. The results are presented in Figure 4.

It is curious to see that at low values of turbidity, the addition of the coagulant actually increases the turbidity. At about 20 mL/L dosage, there were minute flocs being formed. The pH value dropped from an initial value of 7.45 to 7.0 at a dosage of 15 mL/L.

In the case of shelled seeds, experiments run under similar conditions showed very little

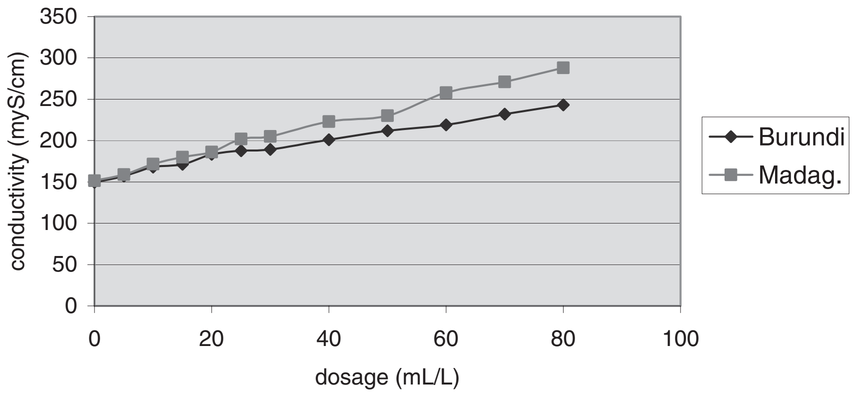

Figure 2 Conductivity measurements of non-shelled seeds from Burundi and Madagascar (RM: 2 min. at 160 rpm; SM: 20 min. at 40 rpm; ST: 30 min.)

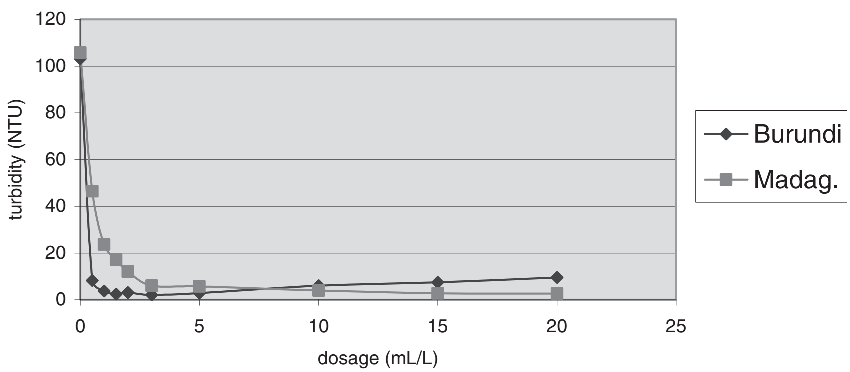

Figure 3 Turbidity measurements of shelled seeds from Burundi and Madagascar (RM: 2 min. at 100 rpm; SM: 20 min. at 40 rpm; ST: 30 min.)

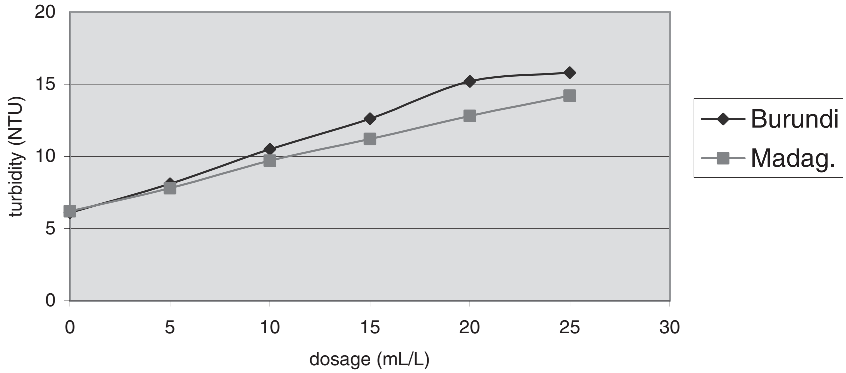

Figure 4 Turbidity measurements for non-shelled seeds for the removal of low turbidity of 6 NTU (RM: 10 s at 160 rpm; SM: 5 min. at 30 rpm; ST: 20 min.)

change in turbidity for an initial turbidity of 9 NTU. This seems to suggest that for very low turbidity removal, the above coagulants may not be suitable.

Finally, a few experiments were conducted to determine the effect of non-shelled *Moringa* seeds on the hardness of water. Figure 5 shows that there is a significant increase in carbonate hardness from an initial 32 mg/L to about double that value at a dosage of about 100 mg/L. This is contrary to the findings of Myubi and Evison (1995) who report that *Moringa* can reduce the hardness of water. However, it must be mentioned that their experiments were conducted using very hard waters.

Effect of non-shelled seeds on TOC

Experiments were run to assess the effect of the coagulant dosage on the organic matter content of the treated water as well as on the sludge produced.

As shown below, the total organic carbon increases almost linearly with dosages from 10mL/L to more than 250 mL/L for both coagulants. This is due to the fact that *Moringa* solutions contain organic matter in the form of soluble organic proteins. Whether this is a disadvantage as far as the treated water is concerned is a matter to be further investigated. As for the sludge, its volume is approximately 30% of that produced by chemical coagulants such as alum. Furthermore, organic sludges from natural coagulants are readily biodegradable.

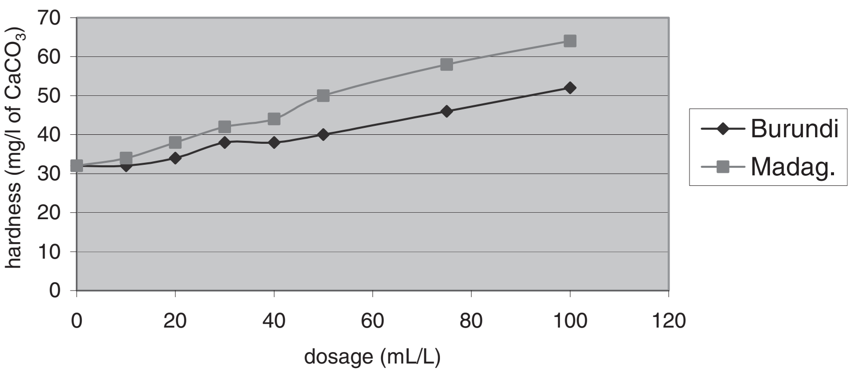

Figure 5 Hardness measurements for seeds from Burundi and Madagascar (RM: 2 min. at 100 rpm; SM: 20 min. at 40 rpm; ST: 30 min.)

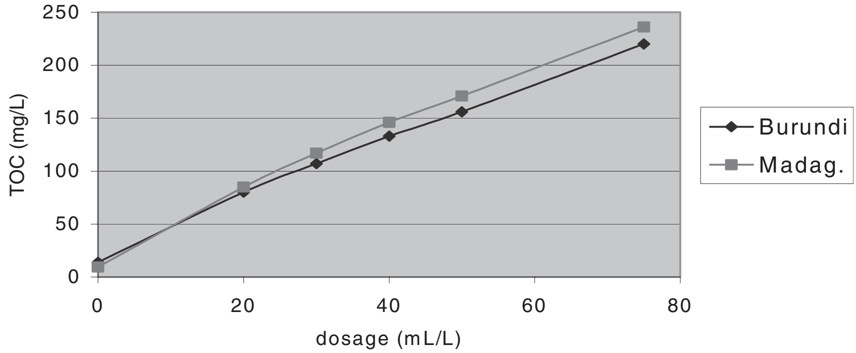

Figure 6 Total organic carbon measurements on seeds from Burundi and Madagascar (RM: 2 min. at 100 rpm; SM: 20 min. at 40 rpm; ST: 30 min.)

Conclusions

The following conclusions can be drawn from the study of *Moringa oleifera* seeds from Burundi and Madagascar.

- The shelled seeds are far more effective than the non-shelled ones in reducing turbidity from waters.
- In order to achieve similar turbidity removal, it is necessary to add 5–10 times the amount of non-shelled seeds compared to shelled seeds. This has an obvious impact on the economics of treatment, as additional time and expense are required to separate the grains from the *Moringa* seed shells.
- The *Moringa* seeds from Burundi seem to be far superior to those from Madagascar for turbidity removal as well as other water quality parameters. To obtain the same degree of turbidity it is necessary to add 2–4 times more CSM or CNM than CSB or CNB. The reasons behind this remain unclear.
- Similar results were obtained for Burundi and Madagascar seeds as far as pH values, electrical conductivity, hardness and total organic carbon concentrations were concerned.
- For both types of seeds, conductivity, hardness and TOC increased as the dosage of coagulant increased.

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