Water Purification using *Moringa oleifera* and Other Locally Available Seeds in Fiji for Heavy Metal Removal

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Abstract

In this paper, the use of local seeds to improve the quality of drinking water in Fiji was investigated. Analysis of the heavy metals cadmium, copper, chromium, lead and zinc were performed before and after treatment of water with the local seeds Moringa oleifera, Arachis hypogaea (peanuts), Vigna unguiculata (cowpeas), Vigna mungo (urad) and Zea mays (corn). The results showed that Moringa seeds were capable of absorbing the heavy metals tested compared to other seeds in some water samples. The percentage removal by Moringa seeds were 90 % for copper, 80 % for lead, 60 % for cadmium and 50 % for zinc and chromium.

Keywords: Moringa oleifera, water treatment, coagulant and heavy metals.

1.0 Introduction

Pollution of surface and groundwater from agriculture, domestic and industrial activities has not been regularly monitored and recorded as a problem. This may be due to the absence of a problem or the lack of monitoring facilities in the Pacific Island Countries (Litidamu *et. al.* 2003). 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 (World Health Organisation 2004). Heavy metals are the most harmful of the chemical pollutants and are of particular concern due to their toxicities to humans (Manahan 2005). Metals and metalloids with atomic weights ranging from 63 to 200.6 g/mol and densities greater than 4.5 g/cm^3 are stable in nature (Lata and Rohindra 2002)

There are 59 elements classified as heavy metals and out of these five are considered to be highly toxic and hazardous heavy metals (Lata and Rohindra 2002). These are cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn) which are released into the environment by human activities or through natural constituents of the earth's crust.

Cadmium pollutants in water may occur from industrial discharge and mining waste (Manahan 2005). Cadmium contamination is caused by its release in wastewaters and contamination from fertilizers and air pollutants. Cadmium is more toxic than lead and chromium. 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 (Baird 1999). Hence, cadmium removal in water using natural polyelectrolytes such as *Moringa* seeds would be an advantage (Muyibi et. al. 2002a).

Chromium is widely distributed in the earth's crust and is used in metal plating (Crosby 2002). In general, food appears to be the major source of chromium intake and on the basis of guideline value, there are no adequate toxicity studies available to provide long-term carcinogenicity study (Sawyer et. al. 2003). In epidemiological studies, an association has been found between exposure to chromium (VI) by the inhalation route and lung cancer (World Health Organisation 2004).

Copper is both an essential nutrient and a drinking water contaminant (Sawyer et. al. 2003). Recent studies have shown effects of copper in drinking water on the gastrointestinal tract, but there is some uncertainty regarding the long term effects of copper on sensitive populations such as carriers of the gene for Wilson disease and other metabolic disorders of copper homeostasis (Sawyer et. al. 2003).

Lead in water arises from a number of industrial and mining sources and is the most widely distributed of all toxic metals (Crosby 2002). Lead in water causes serious problems such as anaemia, kidney disease and affects the nervous system (Crosby 2002). Placental transfer of lead in humans affects babies and young children absorb 4–5 times as much lead as adults (World Health Organisation 2004). The lead toxicant accumulates in the skeleton and causes adverse health effects and interferes with calcium metabolism and with vitamin D metabolism (Baird 1999). However, evidence from studies in humans show adverse neurotoxic effects other than cancer occurring at very low concentrations of lead (World Health Organisation 2004). Therefore, there is need for the removal of lead from all drinking water.

Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes (World Health Organisation 2004). Zinc is found in industrial waste and used in metal plating. Therefore, sources of zinc in water are mainly from industrial discharge and natural sources (Xue and Sigg 1994). The removal of zinc is important for water treatment processes in producing good quality water (Fatoki and Ogunfowokan 2002).

This paper evaluates *Moringa oleifera* (the local Fijian variety) seeds as coagulants and reports an economical and environmentally safe method of water purification. This will show the way to improve the quality of drinking water in the rural areas. This paper also reports the use of other locally produced seeds such as peanuts (*Arachis hypogaea*), cowpeas (*Vigna unguiculata*), urad *(Vigna mungo*), corn (*Zea mays*) that have almost similar types of cationic polyelectrolytes as in *Moringa* seeds (Whitaker and Tannenbaum 1977) and compares their effectiveness in purifying drinking water.

2.0 Materials and Method

As a precautionary exercise standard procedures were followed for sample handling and collection (APHA 1998). All cleaned glassware were soaked in 10% HNO_3 overnight for metal analysis and washed with distilled and deionised water before they were used.

The analysis of the samples were carried out soon after collection and stored in a refrigerator for further analysis. The calibration standards of metals were prepared according to the Standard Methods for Examination Water and Wastewater analysis (APHA 1998). The conditions for the Atomic Absorption Spectrophotometer (AAS) were optimized according to the recommended setting for each of the metals of interest with background correction using high purity grade acetylene fuel. The concentrations of metals were prepared in the linear range (Perkin Elmer 1993). For specific metal analysis, standard solutions of known concentrations were used and the effect of the additions of *Moringa* or other local seeds on metal adsorptions was tested. The seed paste of *Moringa* and all other seeds were prepared by taking approximately 0.1 g of the seed powder and mixing it with about 5 cm^3 of water. The paste of *Moringa* seeds and other seeds was poured through the muslin cloth and the strainer to the water samples that were to be purified. All experiments were conducted at room temperature and after being allowed to stand for two hours, the samples were analysed using the AAS.

The absorbance of the standards was measured and a graph of net absorbance against the concentration of the element in the standard solutions was plotted to get the calibration plots. From the calibration graphs, the concentrations of the metals copper, cadmium, chromium, zinc, and lead adsorbed by *Moringa* and other local seeds were determined.

3.0 Results and Discussion

Natural and synthetic polyelectrolytes are used in flocculating particles. Natural compounds that can be used are starch and cellulose derivatives, protein materials and gums composed of polysaccharides (Manahan 2005). In this research, *Moringa* seeds and other local seeds were investigated and their ability to aid metal removal from drinking water was investigated.

Figure 1 shows that *Moringa* seeds have a high percentage removal of heavy metals compared to bean (cowpeas), urad, peanut and corn. *Moringa* shows more than 50 % of metal removal and the highest percentage removal was achieved for copper and lead. Bean (cowpeas) and peanuts do not show very high percentages of metal removal while copper and cadmium had less than 15 % of metal adsorption. Corn and urad show metal removal but their heavy metal removal percentages were low.

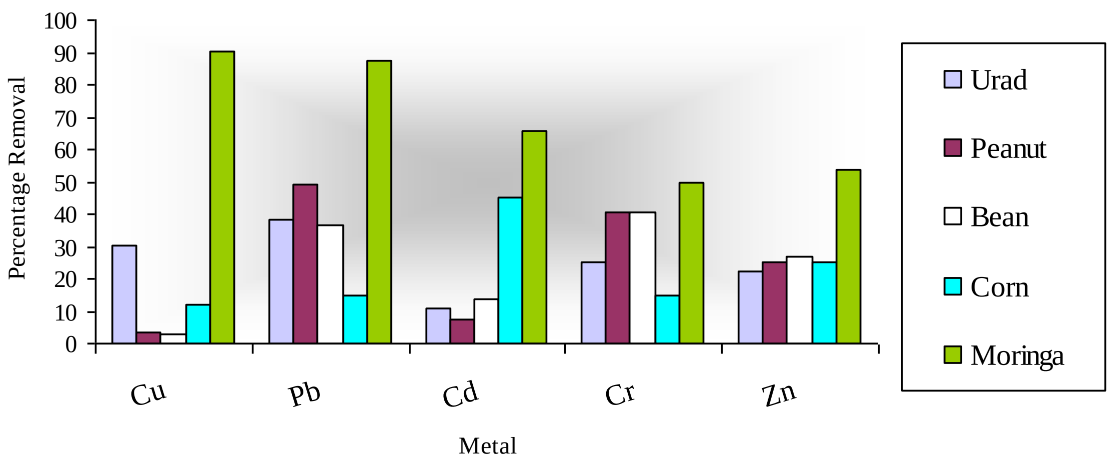

Figure 1: Percentage Removal of Heavy Metals Using *Moringa* and other Local Seeds

The adsorption of metals using *Moringa* is limited to the adsorption surface. This is because *Moringa* is a cationic polyelectrolyte of short chain and low molecular weight (Muyibi et. al. 2002b). Heavy metals and solids that have high charges than *Moringa* colloidal surface will remove high percentage of metals compared to other seeds. The mechanism that brings about the adsorption of heavy metals is through the positive metal ion 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 *Moringa* and other seeds such as proteins. Due to its hydrophilic character, several hydrogen bonds are formed among polyelectrolyte and water molecules (Oliveira 2001). Polyelectrolyte coagulant aids have structures consisting of repeating units of small molecular weight forming molecules of colloidal size that carry electrical charges or ionisable groups that provide bonding surfaces for the flocs. Adsorption describes attachment of ions and molecules from seed protein by means of specific mechanisms (Benes and Steinnes 1995). Further research on this could help determine the mechanisms of the reaction.

However, adsorption is one of the processes affecting speciation, migration and biological availability of trace elements in natural water (Benes and Steinnes 1995). Metal ions in coagulation react with proteins and destroy them in water (Gregor et. al., 1997). Metal adsorption occurs due to the high protein content of the seeds except for corn where starch is one of the non-ionic polymers that aid the adsorption (Raghuwanshi et. al. 2002).

The *Moringa* seeds showed adsorption of metals for which the percentage adsorption for copper was about 90 %, lead was about 80 %, cadmium was 60 %, and chromium and zinc were about 50 % which were higher compared to other local seeds.

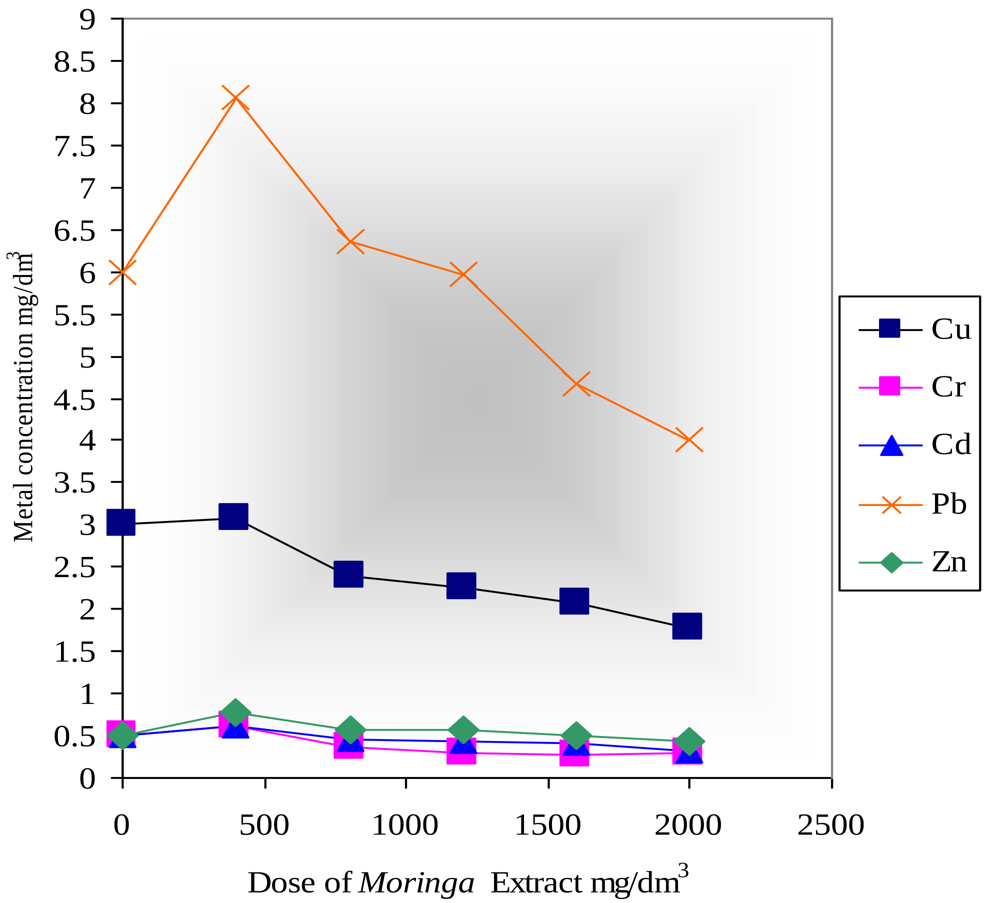

Figure 2: Effect of *Moringa* Seeds at Varying Doses on Metal Levels

The removal of metals increases with the increasing dose of *Moringa* seeds coagulants as shown in Figure 2. This analysis was carried out using standard metal ion solutions and method of standard addition was used for the determination of metal ions after spiking the solution with varying *Moringa* seed dosages. This was then analysed using AAS and the concentrations were calculated using the standard calibration graphs of the desired metals. *Moringa* seeds have shown to be more efficient in metal removal in water. The flocculation activities of *Moringa* seeds are based on the electrostatic patch charge mechanism (Muyibi *et al*. 2002a). Studies have shown that the seeds have the capability to adsorb metal cations and attract highly toxic compounds (Muyibi *et al*. 2002a). A laboratory study showed that *Moringa* has the potential to adsorb the heavy metals from the leachate and from industrial wastewater (Muyibi *et al*. 2002a). This research shows that the method can be used for heavy metal removal from drinking water and wastewater.

In this study the local *Moringa* seeds did not significantly have toxic effects but aided in improving the water quality for drinking purposes. The mechanism of coagulation with the seeds of *Moringa oleifera* consists of adsorption and neutralization of the colloidal positive charges that attract the negatively charged impurities and metals in water. The results obtained in this study were comparable with the performance achieved in heavy metal removal by previous workers such as Muyibi *et al* (2002a) using *Moringa oleifera* extracts.

Conclusion

Locally available seeds such as *Moringa*, peanuts (*Arachis hypogaea*), cowpeas (*Vigna unguiculata*), urad *(Vigna mungo*) and corn (*Zea mays*) were used for water purification. The data obtained showed that *Moringa* seeds were much more effective in water purification in terms of adsorption of metals. Thus, interventions to improve the quality of drinking water will provide significant benefits to the health of people in the Pacific. The use of local *Moringa* seeds as primary coagulants for clarification is useful in the production of drinking water in developing countries where purchase of other chemical coagulants are expensive and the operating costs are high for metal removal. This research will only help detect future problems of heavy metal levels in drinking water and how inexpensive natural coagulants can be used for water purification.

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