The Effectiveness of the Use of *Moringa oleifera* Seeds in the Removal of Metal Based Contaminants from Contaminated Water

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Abstract
Potable water is a limited yet vital resource in our society. Obtaining it through the purification of natural water is therefore of global importance. One of the main challenges in water purification is the ability to distribute affordable purification devices to the people in need efficiently. This project utilizes the abundant *Moringa oleifera* (abbrev. Moringa) seeds to coagulate contaminants in non-potable water. We demonstrate that the Moringa seed purification is a feasible way to remove metal ion contaminants from water, especially in underdeveloped/developing areas where Moringa plants are readily available. We believe our results offer a new avenue of using natural materials to purify water in adequate quantity and have the potential to mitigate water crises in the developing world.

1 Introduction

Water is one of the most precious resources on our planet because no life process is viable without it. However, 97 % of the Earth's supply is salty water from the oceans, roughly 2% is frozen in ice glaciers, and only about 1% is suitable for human consumption [1]. Unsurprisingly, 663 million people around the world lack access to safe drinking water [2]. This plight marks wide ranges of areas from the southeast region of Tamil Nadu, India to parts of Africa such as Ethiopia and Chad. People living in these regions have to rely on muddy ponds nearby for all of their water-related daily needs such as cooking, drinking, etc. Nowadays, while bottled water is available in many of these places, the underprivileged majority still has to resort to filthy ponds for their daily needs. Over the years, several solutions have been proposed to address these crises. Some of these include germicidal tablets [3], which need constant replenishment, and the obtained filtered water is prohibitively expensive for the rural poor. Another solution is the LifeSaver® Bottle [4], which contains a carbon filter with 15 nm holes to prevent even the smallest virus from passing through. These technologies are solid, yet the solutions they provide are impractical because of the high cost and logistics involved in getting the devices to the people in need. An effective solution to this crisis must be simple to operate and preferably use the material easily available to the people living in their specific locations. Such a solution would not only provide drinkable water for everyday life but also empower the people with domestic technologies they can readily use and adapt by themselves.

Water is also a dwindling resource. A large portion of the clean water once available to humans is now contaminated, including lakes, ponds, and rivers. Expanding economies release into natural water sources increasing volumes of pollutants: detergents, insecticides and herbicides, volatile organic compounds (VOCs), perchlorate, fertilizers, industrial chemical waste, heavy metals [5], and the list goes on. Biological contaminants, such as pathogens, salmonella, E. Coli bacteria, norovirus, and many parasitic worms, have also caused major concern [6]. The presence of any of these substances or microorganisms in drinking water has the potential to cause serious damage to consumers' health and well-being.

A species of plant that is common in the regions in need of potable water is *Moringa oleifera (“Moringa”)* [7]. “Moringa” is rich in many nutrients, and is a common part of the South Indian diet. The material inside the seeds is not soluble in water; instead, it is a coagulator with meshy structural features. We envision that this material from Moringa seed could serve to remove contaminants from water. In this project, we set to demonstrate the ability of Moringa seedy materials to remove several typical containments, including Cr^{3+}, Fe^{3+}, Ni^{2+}, and Cu^{2+} ions [6], from “standard waste water”.

2 Materials and Procedures

2.1 Moringa seed Preparation

The *Moringa oleifera* seeds, purchased from Amazon.com, were de-shelled and ground into a fine powder with a mortar and pestle, as shown in Fig (1). On average, each seed produced approximately 0.3g of powder. To make enough powder for experimentation, 50 Moringa seeds were de-shelled, crushed into fine powder, and stored away in a sterile jar for use during experiments.

Fig. (1) Moringa

2.2 Plant Water

Pre-treatment water was provided from a water treatment plant to test the effects of Moringa. We focused on two parameters: turbidity and residue after evaporation. For residue after evaporation, 10g of the pre-treatment water was placed into 3 glass containers, then 10g of deionized sterile water was placed into 2 other glass containers for comparison. These 5 glass containers were arranged on a hot plate as shown in Fig (3), and heated until all of the water in the 5 containers had evaporated. The weight before and after water removal were recorded. The before and after treatment with Moringa solutions were then compared using a turbidity meter and recorded. The obtained results are discussed in section 3.2 below.

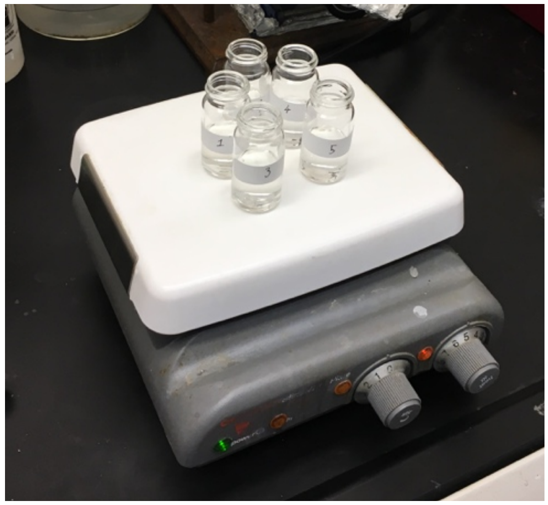

Fig. (2) Evaporation of pre-treatment water

2.3 Chemical Preparation

The metal ions that were chosen for the test were Ferric Ion (Iron (III)), Chromic Ion (Cr(III)), Nickelous Ion (Ni(II)), and Cupric Ion (Cu(II)). To better handle and control these chemicals, Iron Chloride ($FeCl_3$), Py($ClCrO_3H$), Nickel (II) Acetate ($Ni(OAc)_2$), and Copper sulfate ($CuSO_4$) were used. “Standard waste solutions” based on these chemicals were prepared by dissolving them in deionized water, and the concentration of the containments measured between 100ppm to 200ppm. A proportioned amount of each substance in the 100ppm to 200ppm range was introduced into 50g of water using a spatula and then stirred until completely dissolved.

2.4 Moringa Experiments

For consistency, the ratio of 3g of Moringa per 100g of water was maintained throughout the experiments. Specifically, each test tube used held approximately 5g of water with 0.15g of Moringa.

First, 5g of the $FeCl_3$ solution was introduced to the test tube. A proportionate amount of Moringa (0.15g) was added to the test tube. The test tube was capped and then shaken vigorously by hand for 10 seconds. The test tube was then placed in the centrifuge for 2 minutes to speed up the coagulating and settling process. After 2 minutes, the test tube was then gently placed in the test tube rack. When the Moringa and the contaminants coagulated and settled to the bottom of the test tube, a pipet was used to carefully extract the water at the top of the test tube and place it into a glass container, as seen in Fig (3). This process was repeated for the other solutions with two trials each.

The metal ion contaminants before and after the Moringa treatment were then measured using an atomic absorptions spectrometer (AAS) and the results are discussed in section 3.3 below.

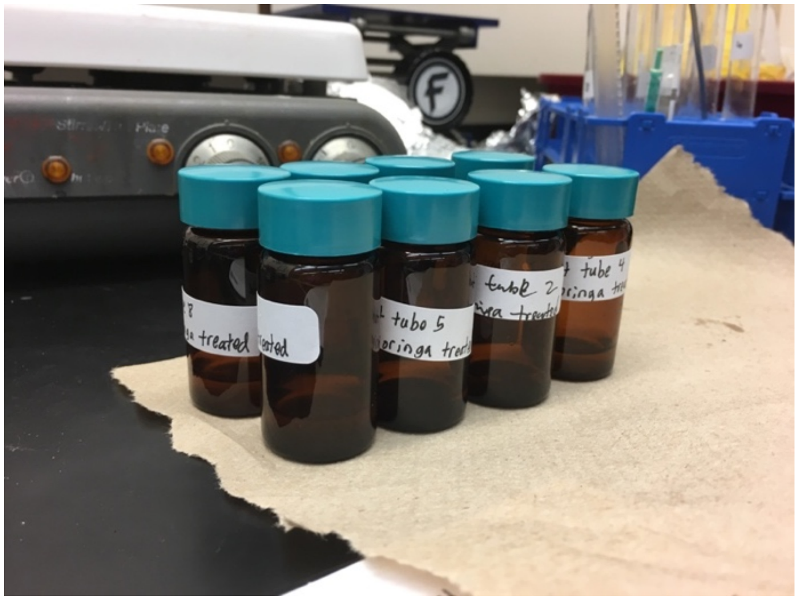

Fig. (3) Moringa processed solutions to be tested for turbidity

3 Results and Discussion

3.1 Characteristics of Moringa seeds

Moringa seeds are cheap and readily available in tropical regions that are coincidently facing the worst water crises [8]. These seeds are soft and nutritious. We tested the solubility of these seedy materials in various solvents. FT-IR spectrum shown in Fig (5), obtained from a Bruker FX 70 FT-IR system in ATR mode, shows complicated structural features. While it is difficulty to elucidate the detailed structures, some typical functional groups, including hydroxyl and amine groups, are clearly shown.

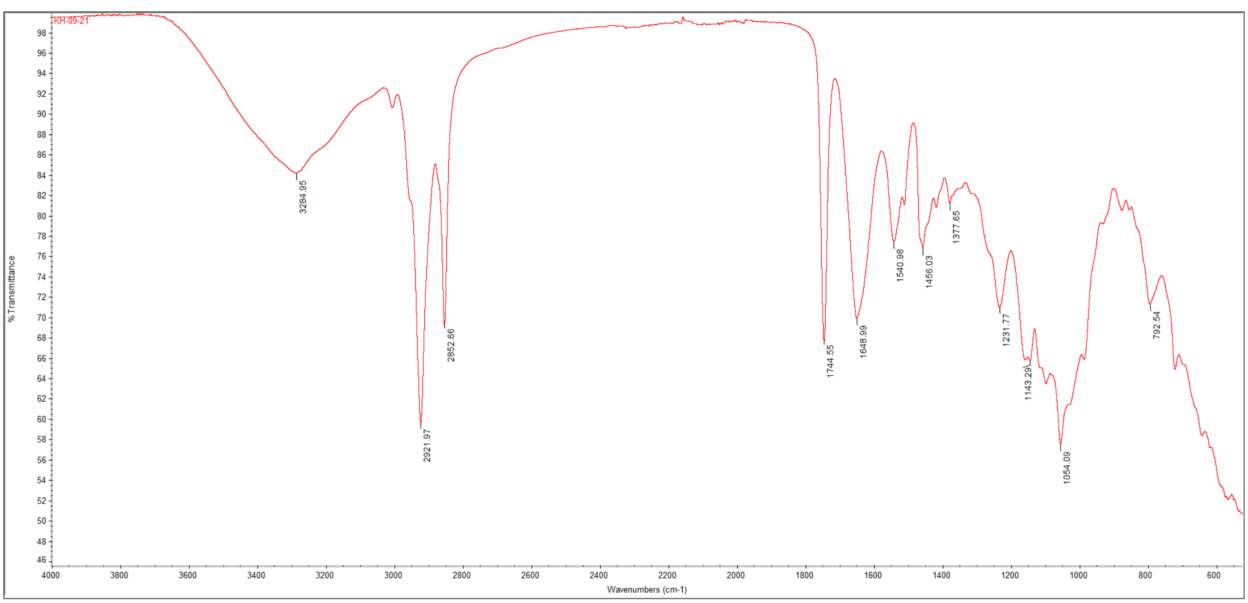

Fig. (5) FT-IR spectrum of Moringa seeds

The presence of amine groups shows that the Moringa has potential to remove biological contaminants such as bacteria from contaminated water.

3.2 Effectiveness of Moringa in treating plant water

Table (1) pH and turbidity of plant water before and after treatment

Plant Water	pH	Turbidity (NTU)
Before treatment	5.87	17.0
After treatment	6.34	1.9
% change	+8.00	-88.8

Table (2) Residue of the plant water before and after treatment

Plant Water	Residue	Control (DI water)
Before treatment (ppm)	277.7	~5
After treatment (ppm)	63.6	~5

The pre-treatment plant water is acidic and has turbidity of 17 NTU. With the use of the Moringa seed powder, the pH of the plant water increased by 8%. The pH after Moringa treatment was closer to 7 than before the Moringa treatment. This demonstrates and proves Moringa's ability to remove the acidic components from plant water. There is also a significant reduction in turbidity (88%), which proves Moringa's effective removal of particulates in contaminated water. In addition, Moringa seed is also effective in removing solid sediments through coagulation, as indicated in the residue test in Table 2.

3. 3 Effectiveness of Moringa in removing metal ions

Table (3) Effectiveness in removing metal ions calculated from prepared solutions; measured with atomic absorption spectra

	Cr	Cu	Ni	Fe
Before (ppm)[a]	149.6	92.5	157.9	141.8
After (ppm) [b]	14.1	21.0	17.9	9.2
% removed	90.6	77.3	88.7	93.5

The metal ions studied here are common contaminants in the water in developing countries [5]. Using a single Moringa treatment, it was demonstrated that Moringa is effective in the removal of these metal ions from water. All of the samples had more than 75% of the total metal ion contamination removed. In the Iron (Fe) solution, 93.5% of the contaminant in the original solution was removed by the Moringa treatment. In the Chromium (Cr) solution, 90.6% of the contaminant in the original solution was removed by the Moringa treatment. In the Nickel (Ni) solution, 88.7% of the contaminant in the original solution was removed by the Moringa treatment. And in the Copper (Cu) solution, 77.3% of the contaminant in the original solution was removed by the Moringa treatment. This data proves Moringa is a reasonably effective purifying agent for metal ions. The possible mechanism is a combination of chemical absorption and physical coagulations.

4 Conclusions and future work:

Moringa seed powder can be an effective natural water purification material for the developing world. It effectively removes a significant percentage of an array of metal ions from contaminated water. Moringa also removes acidic substances to bring water closer to pH neutralization. Its significant reduction of turbidity in grey water further indicates its effective removal of particulate pollutants.

Further studies are needed to explore the effectiveness of Moringa as an antimicrobial agent. Other common contaminants such as pesticides and fertilizers require detailed study to validate and enhance Moringa's abilities as a natural purifying agent. With the validation and development of Moringa purification process, a larger percentage of the world may be able to produce its own potable water.

5 References

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