The effects of natural, bio-absorbent substances on heavy metal removal

Crystal Clear

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Abstract

Water is the most important substance on this planet - without it, there would be no life. Water pollution is one of the biggest problems we face today, especially in the place we reside, Grahamstown, South Africa. The purpose of this project is to test whether natural, bio-absorbent substances can remove heavy metals from contaminated water. Our approach is to design a filter to maximize the removal of heavy metals from contaminated water using the selected substances. The project aims to create an easy and cheap way to remove heavy metals from contaminated water using natural substances found in South Africa, as where we live in South Africa, the water is badly contaminated with heavy metals. We are also experiencing a severe drought, so we want to preserve our water. Our aim is to take dangerous, contaminated water that before would be undrinkable due to heavy metal contamination, and purify it to make it drinkable without using expensive, dangerous chemicals and machinery.

Key Words

Heavy-metal, water, bio-absorbent, filter

The Purpose of the Research Paper

Water pollution is one of the biggest problems we face today and scientists are continually trying to develop inexpensive, easy and ingenious ways to purify water. The main contaminants of water are bacteria, gasoline, toxic waste, parasites, harmful materials and heavy metals [1]. One of the more hazardous of these water contaminants is heavy metals because they dissolve in water to form a colourless solution which cannot be distinguished by the eye, and therefore comes across as ordinary, pure water [2]. A heavy metal is a dense metal that is (usually) toxic at low concentrations. Examples of heavy metals found in our municipal drinking water are lead, mercury and arsenic [3-4]. Once consumed, heavy metals cannot be expelled by the body but instead, remain inside the body forever, posing severe health risks to individuals that consume water contaminated with heavy metals. Negative effects of heavy metals include depression and anxiety as well as damage to vital organs – lungs or kidneys [5]. The only way to identify the presence of heavy metals is through water tests and once identified, there are standard removal methods, such as Ion Exchange. Another common substance used in filters is carbon, however, certain herbs have been shown to be more effective than pricy carbon filters in removing heavy metals from water [6].

Ion exchange can attract soluble ions from a liquid phase to a solid phase. It is widely used to remove heavy metals from aqueous solutions [7]. In this process a cations- or anions-containing ion exchanger is used to remove metal ions in the solution. It can only be used for dilute metal solutions and the method is highly sensitive to the pH of the aqueous phase.

This project aimed to make use of organic plant materials to test their bio-absorbance of heavy metals. A number of studies have shown that various organic materials are able to remove heavy metals from effluents, household waste and industrial wastes [8-13]. To our knowledge, the combinations of organic materials used here are novel. Our first combination includes charcoal, chai seeds and *Eichhorina crassipes*; our second combination includes charcoal, dried coriander, seaweed and *Eichhornia crassipes*; our third combination includes Moringa powder, chia seeds, dried seaweed, charcoal and *Eichhornia crassipes*; our final combination includes Moringa powder and seaweed. Each of these combinations were tested for their ability to remove heavy metals from water.

The purpose of this project is to test whether natural, organic, bio-absorbent substances can remove heavy metals from contaminated water and which substances/ combination of these substances are the most effective in doing so. This project would also educate the population of Grahamstown, many of whom only have access to unfiltered municipal water, on the presence and dangers of heavy metals in our vital water resources, and aim is to offer an easy and affordable way to eradicate heavy metals from drinking water. We hypothesise that particular combinations of the materials will be able to remove heavy metals better than others and that an optimal combination will be found.

Method of Research

The investigation was carried out in two parts. Part A describes the procedures used for the preparation of the various materials used in the filter; the filter set up; filtration process and the analysis of the samples for metal absorption. Part B describes the proposed filter design.

Part A: Experimental Procedures

Materials used:

Tables 1 and 2, and Figure 1, show the organic materials that were used individually and in various combinations, in the initial filtering process. Table 1 shows the materials that were used when metal strip tests were used to test for metal removal while Table 2 shows the materials used when Inductively Coupled Plasma Mass Spectrometry (ICPS) was used for measuring heavy metal removal.

Table 1 showing the materials tested in the experiment where the results were tested using metal strip tests and the "ColorPix" application

Bio-absorbent Materials Tested
Dried Coriander
Moringa Tree Seeds
Dried Seaweed
Chia Seeds
Dried Rooibos Tree Leaves
Eichhornia crassipes
Charcoal
Dried Coriander, Moringa Tree Seeds
Dried Coriander, Rooibos Leaves
Dried Coriander, Dried Seaweed
Dried Coriander, Chia Seeds
Moringa Tree Seeds, Rooibos Leaves
Moringa Tree Seeds, Dried Seaweed
Moringa Tree Seeds, Chia Seeds
Rooibos Leaves, Dried Seaweed
Rooibos Leaves, Chia Seeds
Dried Seaweed, Chia Seeds
Dried Coriander, Moringa Tree Seeds, Rooibos Leaves
Dried Coriander, Moringa Tree Seeds, Dried Seaweed
Dried Coriander, Moringa Tree Seeds, Chia Seeds
Dried Coriander, Rooibos Leaves, Dried Seaweed
Dried Coriander, Rooibos Leaves. Chia Seeds
Dried Coriander, Dried Seaweed, Chia Seeds
Moringa Tree Seeds, Rooibos Leaves, Dried Seaweed
Moringa Tree Seeds, Rooibos Leaves, Chia Seeds
Moringa Tree Seeds, Dried Seaweed, Chia Seeds
Rooibos Leaves, Dried Seaweed, Chia seeds

Table 2 showing the materials tested in the experiment where the results were tested using Inductively Coupled Plasma Mass Spectrometry (ICPS)

Materials Tested using ICPS
Charcoal, Chia seeds, *Eichhornia crassipes*
Charcoal, Dried Coriander, Dried Seaweed, *Eichhornia crassipes*
Eichhoprnia Crassipes, Morniga Powder, Chia Seeds, Charcoal, Dried Seaweed
Moringa Powder, Dried Seaweed

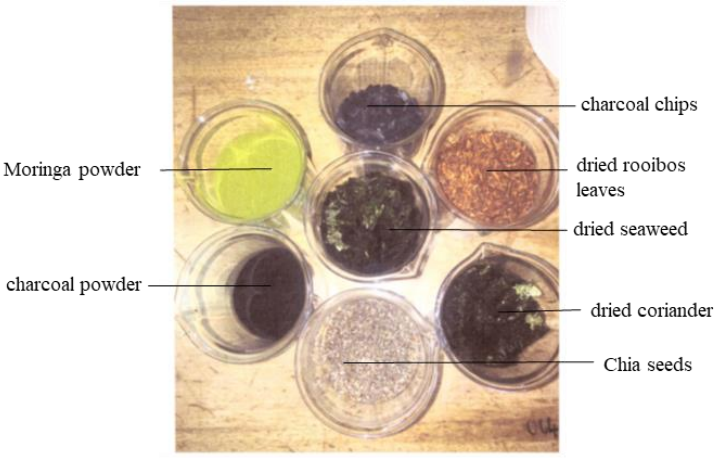

Figure 1: Photograph showing the various bioabsorbent materials used in the filtering process.

Preparation of Materials Used:

Coriander leaves were removed from the stem and were placed incubated at 80^0C for 24 hours. Moringa Tree Seeds were incubated at 80^0C for 24 hours. Organic raw Moringa powder was purchased from a local health shop. *Exclonia maxima* seaweed was placed incubated at 45^0C for 48 hours. Organic Rooibos Tea Leaves were purchased. Organic dried Chia Seeds were purchased. *Eichhornia crassipes* bulbs, roots and leaves were cut off the plant and were incubated at 80^0C for 72 hours. Food grade dried activated charcoal powder was purchased.

Filter Set-Up Procedure:

A 40cm glass tube (diameter 23mm) was clamped at a 30º angle. A piece of cheese cloth, cut 10cm by 10cm, was placed at the bottom end of the glass cylinder and was held in place by an elastic band with tight tension. A glass beaker was placed underneath the glass cylinder to catch the sample water. Sample bottles were used to store the samples.

Filtering Process:

Contaminated municipal drinking water was collected from a tap source and used for all testing.

The filter substances (100g) were placed in the lower end of the glass cylinder using a glass rod and metal forceps. Contaminated drinking water (50ml) was poured into the top of the glass cylinder and the water was left to run through and trickle into the collection beaker. Samples of filtered water (20ml) were collected in the beaker situated under the glass cylinder. The water samples were decanted into sample bottles and labelled with the date and filter substance. This procedure was repeated 3 times for each filter substance/combination to find an average result. Water samples (50ml) were run through the empty glass cylinder and collected to act as the control sample showing metal content of samples before filtering.

Testing for heavy metal removal:

Metal strip tests were purchased and used for the assessment of heavy metal removal by placing each strip individually into each filtered water sample for 20sec. The strip was removed and left to dry. An application called "ColorPix" was used to photograph and measure the percentage difference in the saturation of the colour between the control and each sample. Inductively Coupled Plasma Mass Spectrometry (ICPS) was used to quantify the percentage heavy metal removal in the samples where the heavy metal removal was most successful.

PART B: Filter Design

The process started off with our team of young innovative designers thinking about the community and the country we live in. We set out to create a simple but effective filter that can either be made at home with scrap materials or made using affordable materials. We aimed for the filter to be compatible for various plastic bottles so the process of designing the shape was at hand. First thing was coming up with process sketches and determining the best and most suitable design. Secondly, further development of the chosen design was done in order to perfect the design. The final 2D sketch was made before attempting the first 3D sketch using Google Sketch up. The final 3D sketch was made and was sent to be printed by a 3D printer using 3D printer filament.

Results

The percentage of different metals being removed from contaminated water after being treated with the most effective natural, bio-absorbent substance(s) for each given metal is shown in Table 3 and Figure 2. The most effective substance(s) for removing general heavy metals from contaminated water was a combination of Dried Coriander and Dried *Ecklonia maxima* Seaweed in a ratio of 1:1. This substance removed the most general heavy metal from the contaminated water, more than any of the other substance(s) tested for general heavy metal removal. It removed 33.1% of the general heavy metal present in the contaminated water. The most effective substance(s) for removing the metal Arsenic from contaminated water was a combination of Dried Coriander, Moringa Tree seeds and Dried *Ecklonia maxima* Seaweed in a ratio of 1:1:1. This substance removed the most Arsenic from the contaminated water, more than any of the other substance(s) tested for Arsenic removal. It removed 33.7% of the Arsenic present in the contaminated water. The most effective substance(s) for removing the metal Aluminium from contaminated water was a combination of Dried Coriander, Moringa Tree seeds and Chia seeds in a ratio of 1:1:1. This substance removed the most Aluminium from the contaminated water, more than any of the other substance(s) tested for Aluminium removal. It removed 37.3% of the Aluminium present in the contaminated water. The most effective substance(s) for removing the metal Lead from contaminated water was a combination of Dried Coriander, Rooibos leaves and Dried *Ecklonia maxima* Seaweed in a ratio of 1:1:1. This substance removed the most Lead from the contaminated

water, more than any of the other substance(s) tested for Lead removal. It removed 35.0% of the Lead present in the contaminated water. The most effective substance(s) for removing the metal Mercury from contaminated water was the substance Dried Coriander. This substance removed the most Mercury from the contaminated water, more than any of the other substance(s) tested for Mercury removal. It removed 37.3% of the Mercury present in the contaminated water. Table 4 and Figure 3 show that arsenic could not be picked up by the ICP Machine as the amount was too small to be detected. The substances charcoal, chia seeds and *Eichhornia crassipes* were the most effective in removing lead. It removed lead by 66, 48%. Charcoal, dried coriander, dried seaweed and *Eichhornia crassipes* was the most effective combination for removing iron from water removing it by 33,37%.

Table 3 showing the percentage of different metals being removed from contaminated water after being treated with the most effective natural, bio-absorbent substance(s) for each given metal

Type of metal being removed from contaminated water	Percentage of metal removed by most effective natural, bio-absorbent substance(s) (%) using strip test
General Heavy Metals	33.1 - Dried Coriander, Dried *Ecklonia maxima* Seaweed.
Arsenic	33.7 - Dried Coriander, Moringa Tree seeds, Dried *Ecklonia maxima* Seaweed.
Aluminium	37.3 - Dried Coriander, Moringa Tree seeds, Chia seeds.
Lead	35.0 - Dried Coriander, Rooibos leaves, Dried *Ecklonia maxima* Seaweed.
Mercury	37.3 - Dried Coriander

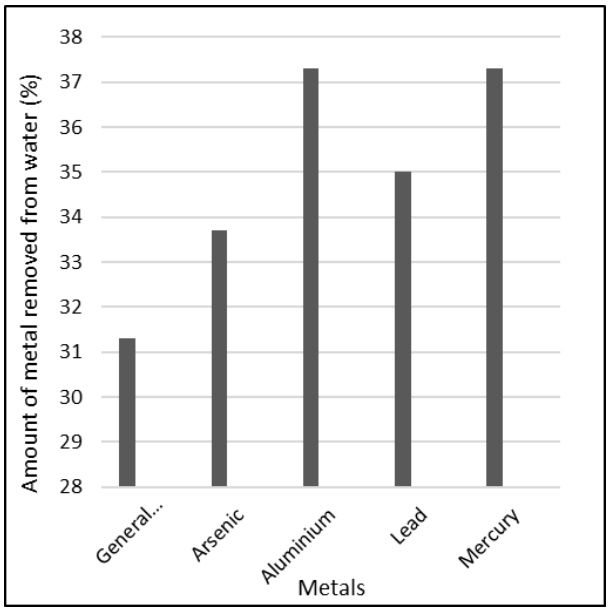

Figure 2: Graph showing the percentage of different metals being removed from contaminated water after being treated with the most effective natural, bio-absorbent substance(s) for each given metal using strip tests

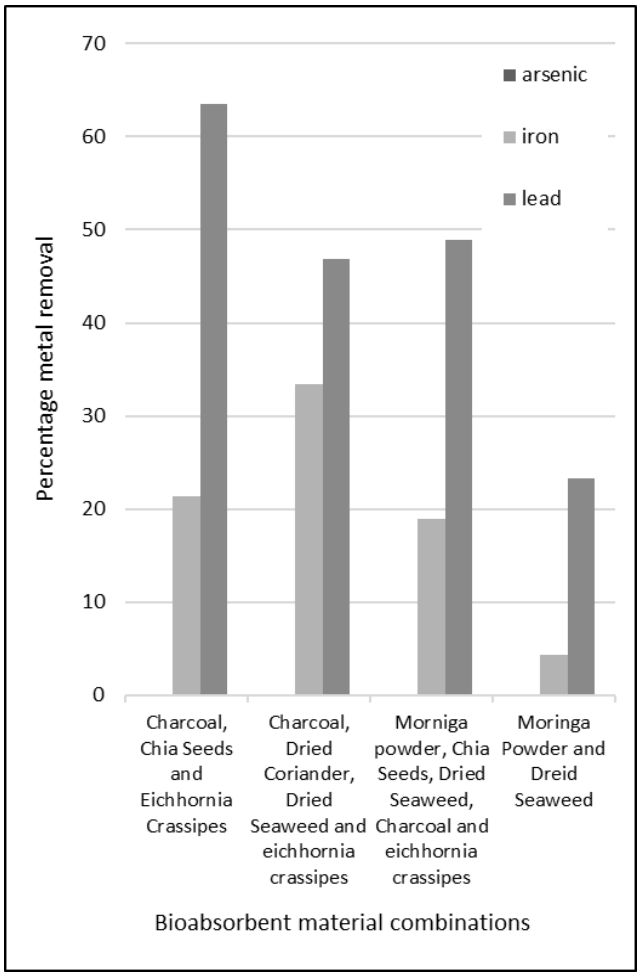

Figure 3: Graph showing the percentage of arsenic, iron and lead removal from water using natural, bio-absorbent substances using ICPS.

Table 4 showing the percentage of arsenic, lead and iron removed from water using different types of natural, bio-absorbent substances using ICPS

Natural, bio-absorbent substances	Arsenic (%)	Iron (%)	Lead (%)
Charcoal, Chia seeds, *Eichhornia crassipes*	Amount too small to detect	21.41	63.48
Charcoal, Dried Coriander, Dried Seaweed, *Eichhornia crassipes*	Amount too small to detect	33.37	46.83
Eichhoprnia Crassipes, Morniga Powder, Chia Seeds, Charcoal, Dried Seaweed	Amount too small to detect	19.00	48.86
Moringa Powder, Dried Seaweed	Amount too small to detect	4.33	23.28

The 2D filter design drawings are shown in Figure 4.

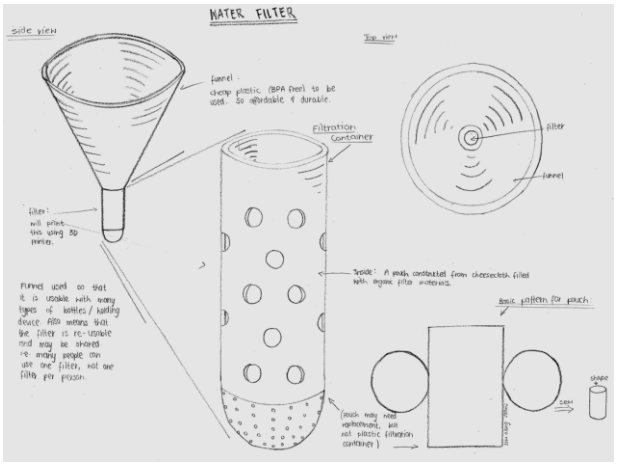

Figure 4: Sketch drawings (2D) of proposed filter

The design is a cylinder shape as this allows it to fit in a bottle comfortably, as the aim is for this filter to be used in bottles. The holes in the cylinder allow water to seep through slowly ensuring filtration and purifying of the water. As seen on the 2D drawing, there are larger holes on the sides of the cylinder and smaller holes at the base of the cylinder. This is so the water does not all go out of the base and accumulate, rather the water can filter and escape at the bottom and at the sides of the filter. This results in slower filtration which in turn increases the effectiveness of the purification of the water and better results are achieved. A funnel is attached so the water is easily poured in and through the filter, so no water is wasted.

Conclusion

The hypothesis for the investigation was correct. Treating contaminated water with the various natural, bio-absorbent substances did decrease the amount of general heavy metals, arsenic, lead, mercury and aluminium in water. The substance which is a combination of dried coriander and dried *Ecklonia maxima* seaweed in a ratio of 1:1 was the most effective in removing general heavy metals from contaminated water. While the substance which is a combination of dried coriander, Moringa tree seeds and dried *Ecklonia maxima* seaweed in a ratio of 1:1:1 was the most effective in removing arsenic from contaminated water. Whereas, the substance which was made up of a combination of dried coriander, Moringa tree seeds and chia seeds in a ratio of 1:1:1 was the most effective in removing Aluminium from contaminated water. While the substance which is a combination of dried coriander, rooibos leaves and dried *Ecklonia maxima* seaweed in a ratio of 1:1:1 was the most effective in removing lead from contaminated water. Finally the substance dried coriander was the most effective in removing Mercury from contaminated water. Using ICPS testing, we found that the substances charcoal, chia seeds and *Eichhornia crassipes* were the most effective in removing lead. It removed lead by 63,48%. Charcoal, dried coriander, dried seaweed and the *Eichhornia crassipes* was the most effective substance for removing iron from water by 33,37%. The results show that all natural, bio-absorbent substances remove heavy metals from water, some more effectively than others. The results showed that dried coriander, dried seaweed and charcoal are very effective in removing heavy metals from contaminated water. ICPS testing is more accurate in testing for heavy metals than heavy metal strip tests and so the data generated from these tests are the most reliable.

Future work

We are in the process of charring water hyacinth bulbs, leaves and roots. The charred water hyacinth will be turned into a fine ash which will be placed in the filter. The reason for charring the water hyacinth is that when it is charred the substance becomes negatively charged (anions). Metal ions are positively charged (cations) therefore they will be attracted to the charred material resulting in improved metal removal from the water. Water hyacinth is an alien plant to South Africa and is extremely invasive due to its uncontrollable growth in water bodies. However, the plants thirst for nutrient absorption has made it useful phytoremediation [14]. In order to see if the filter substance/s are reusable (and still effective), an investigation of how many times it can be reused for metal removal should be investigated. Systems containing living, growing plants tissues could also be tested.

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