

A Novel, Eco-Friendly Bioremediation of Lead-Contaminated Water

Abstract

Lead exposure is a global problem, especially in developing countries where lead poisoning accounts for 853,000 annual deaths. The objective of this experiment was to design an eco-friendly method for the bio-remediation of lead-contaminated water which would alleviate this problem. The Moringa Oleifera (MO) seeds were the main component of the bio-remediation system because they are locally available and have adsorbing properties that could be used in purifying heavy metal-contaminated water. It was hypothesized that with this method it would be possible to significantly reduce lead in effluent water. The procedure included designing and constructing a filter, de-oiling Moringa seeds, preparing heavy metal-contaminated water, experimenting with Moringa treatment and sand filtration, and testing samples with an AA-Spectrometer. The variables tested were dosage of Moringa, pH, treatment time, and effects of initial concentration and 2-Stage Filtration. The hypothesis was supported by results. The pre-treatment with Moringa and filtration through the sand filter was most efficient - 100% removal of lead after one treatment and filtration. The treatment with only Moringa seeds was also very effective – over 96% of lead removal. The optimal conditions for lead removal are 3g/100mL of Moringa at pH=8 and 20min pre-treatment time. Moreover, this pre-treatment/filtration method for lead removal is simple, extremely cost-effective, and environmentally-friendly. It has great potential to be the ultimate bio-remediation method for lead removal in developing countries.

Purpose

- **240 million people** exposed to Lead
- Lead exposure accounts for **853,000 deaths annually**
- **Most susceptible:** children and pregnant women
- Can cause brain damage, seizures, hearing loss, behavioral problems, learning disabilities, and lower IQ
- **15 -18 million children in developing countries** suffer permanent brain damage as a result

Objective

The objective of this experiment was to design a method for eco-friendly bioremediation of lead-contaminated water, which could be used in developing countries at the household level.

Hypothesis

I predict that by using Moringa Oleifera seeds and the sand filter, it will be possible to significantly reduce the concentration of lead in effluent water.

Research



Figure 1 - "Moringa Tree"
www.learnaboutnature.com

Moringa Oleifera (Drumstick Tree)

The Moringa Oleifera seeds have been found to have adsorption properties, which can be used for water purification. These seeds are **widely available in developing countries, sustainable, and inexpensive.**

How do Moringa crushed seeds work?

- Have been found to have adsorption properties
- Ion exchange and Van der Waals forces on surface of biomass
- COOH is responsible for adsorption of heavy metals
- Amphoteric character with Point of Zero Charge (PZC) between pH 6 and 7 at pH < PZC – becomes positive; at pH > PZC – becomes negative

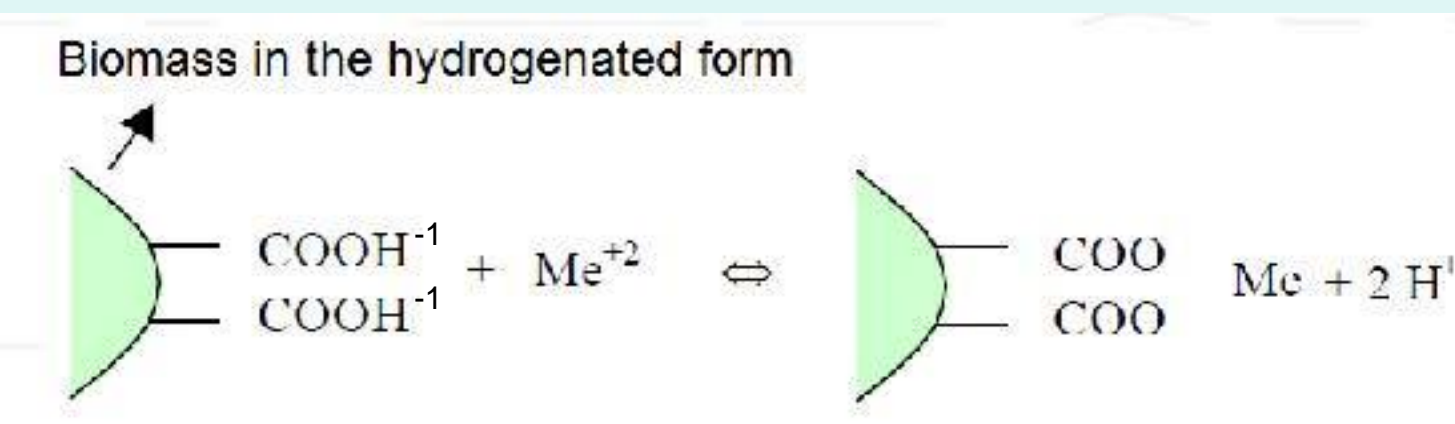


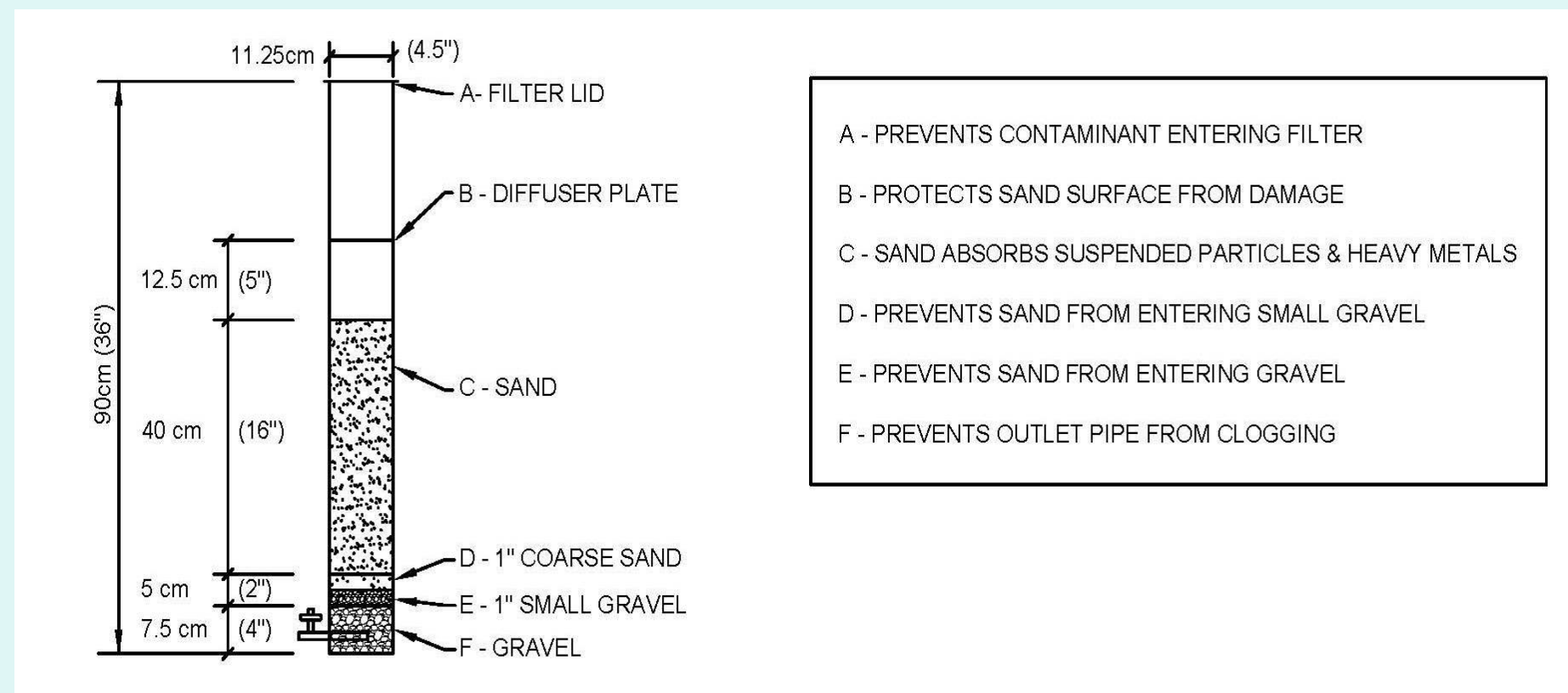
Figure 2
Schematic Diagram of an ion exchange mechanism
Cleide S. Araujo et al.

Materials and Methods

Filter Design

- Total height of the sand column – 16" – based on Darcy's Law
- Q = KA *(depth of filter media+8" depth of excess water)/depth of sand
- Q= flow rate (8oz/min), K= hydraulic conductivity(0.5"/min), A=area

Figure 3 - Filter Design



Materials

- Moringa seeds
- Large size gravel
- Small size gravel
- Coarse sand
- Play sand
- Glass stirring rods
- Pipettes
- Grinder
- Liquid measuring cup
- 100 ml graduated cylinders
- Plastic jugs with caps
- (1) 3', 4.5" dia acrylic tube
- (1) 4.5" dia diffuser plate
- (1) on-off valve
- pH meter
- Soxhlet apparatus
- Atomic Absorption Spectrometer (Varian AA240FS)
- Mixer
- Muslin cloth
- (2) Timers
- Distilled water
- Deionized water
- Lab notebook



Figure 4 - Filter

Procedure:

1. Assembling the filter (acrylic tube, end plate, lid, water valve)
2. Building a filter based on design to include gravel, small gravel, coarse sand, regular sand, and dispersion plate
3. De-oiling of Moringa with Soxhlet apparatus after seeds were shelled, grinded & dried (160 F)
4. Treatment of lead contaminated water with Moringa to establish optimum conditions:
 - dosage of Moringa (0.1, 0.2, 1, 3 & 4g/100mL) at pH 7, 350 rpm
 - 20min, 5ppm of Pb
 - pH (5, 6, 7, and 8), 3g/100mL MO, 350 rpm, 20min, 5ppm of Pb
 - time of treatment (10, 15, 20, and 25min), 3g/100mL MO at 350 rpm, 5ppm of Pb
5. Testing effect of initial Pb concentration on efficiency of lead removal with treatment of Moringa
 - Concentrations of 0.03, 0.3, 3, and 5 ppm of Pb tested with 3g/100mL MO at 350 rpm, and pH 7 for 20 min.
6. Experimenting with 2-Stage Filtration:
 - Prepare 8L of HM water, treat with MO at pH=7 for 20min, then run through the filter. Discard first 3.5L, additional 4L treat again with Moringa, then run through the filter again. Obtain 100mL samples at each step.
7. Heavy metal concentration testing: FAA Spectrometer, then concentration calculated from calibration graphs.



Figure 5
De-Oiling of MO Seeds

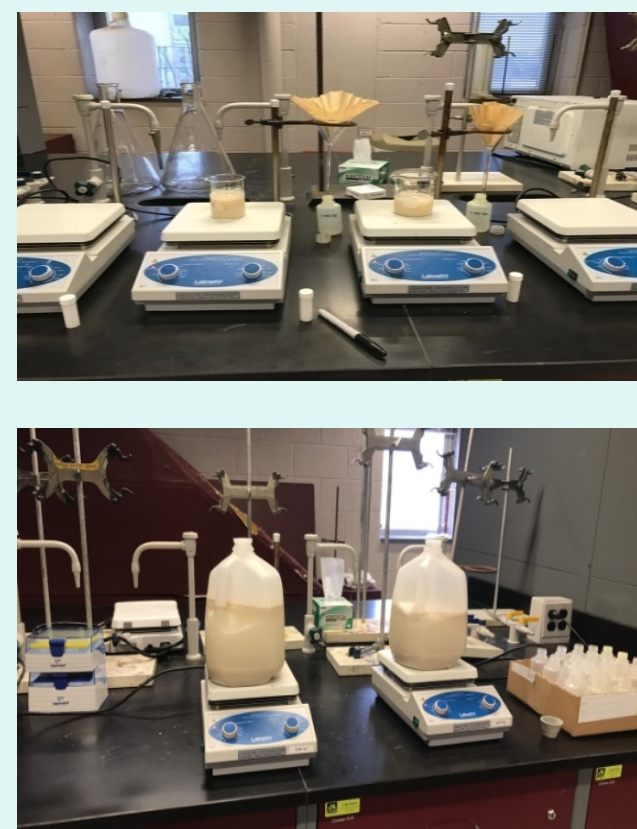
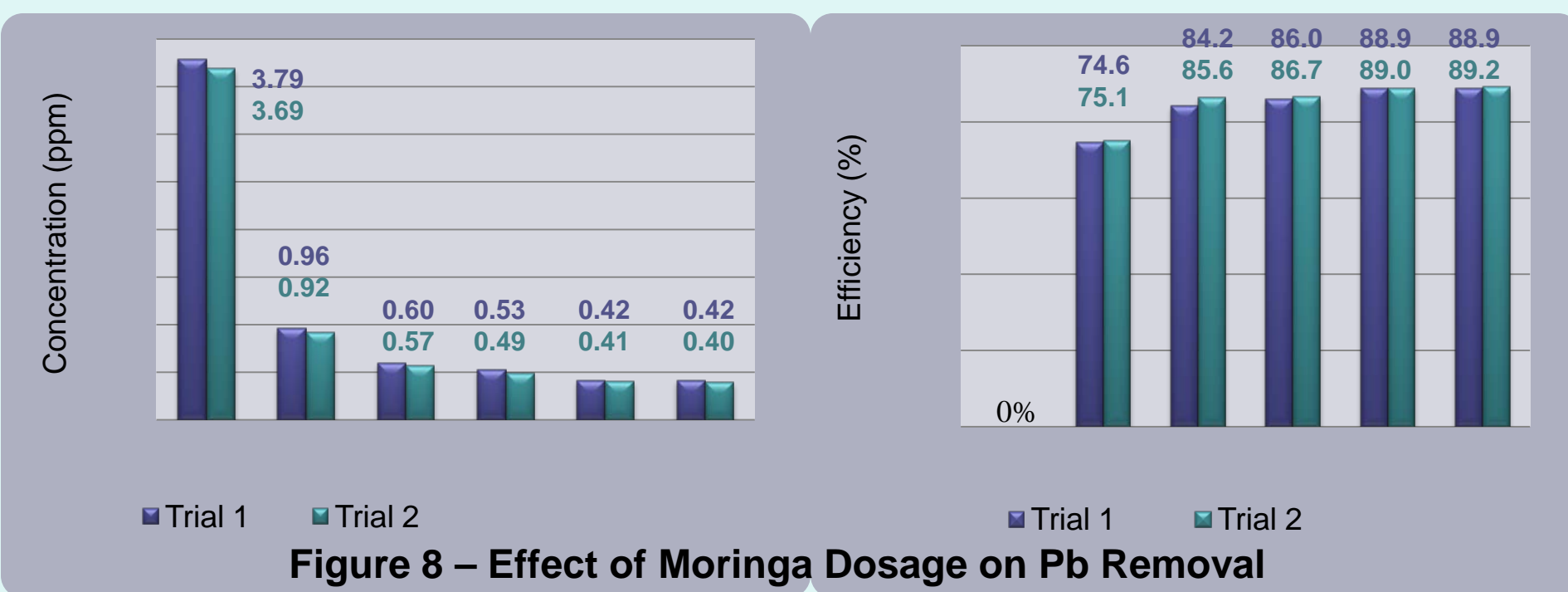


Figure 6- Pre-Treatment of HMW with Moringa seeds

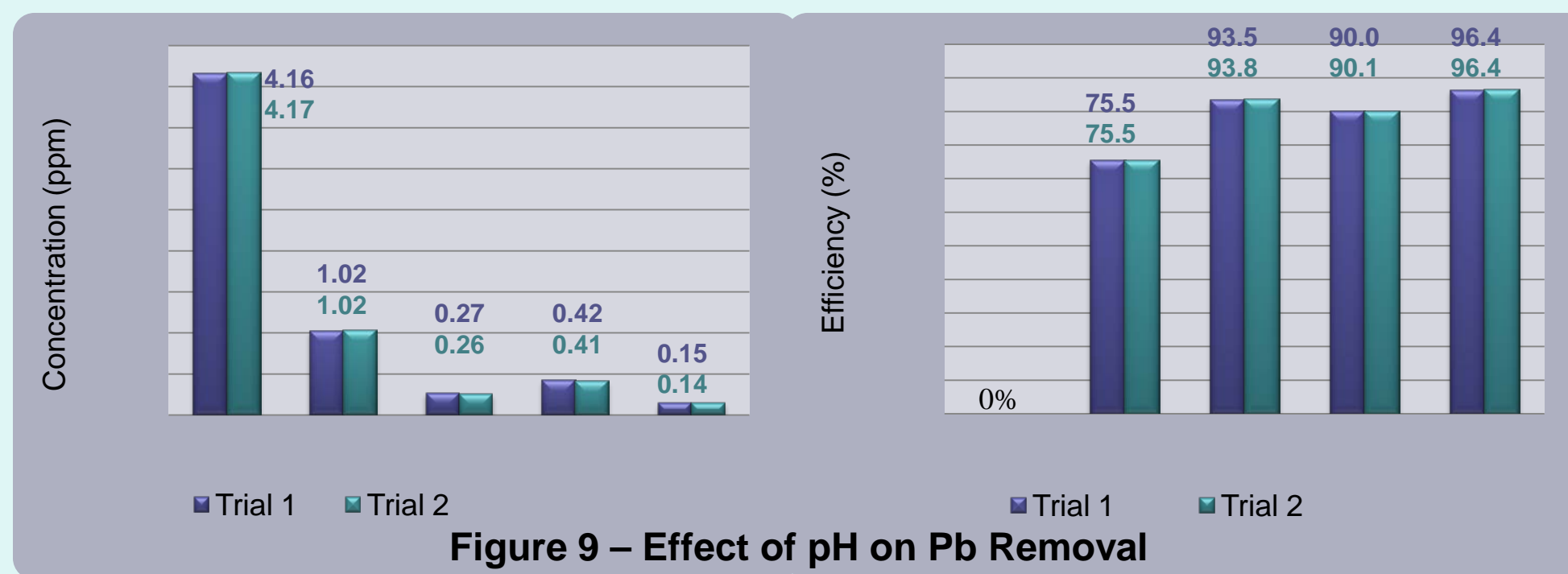
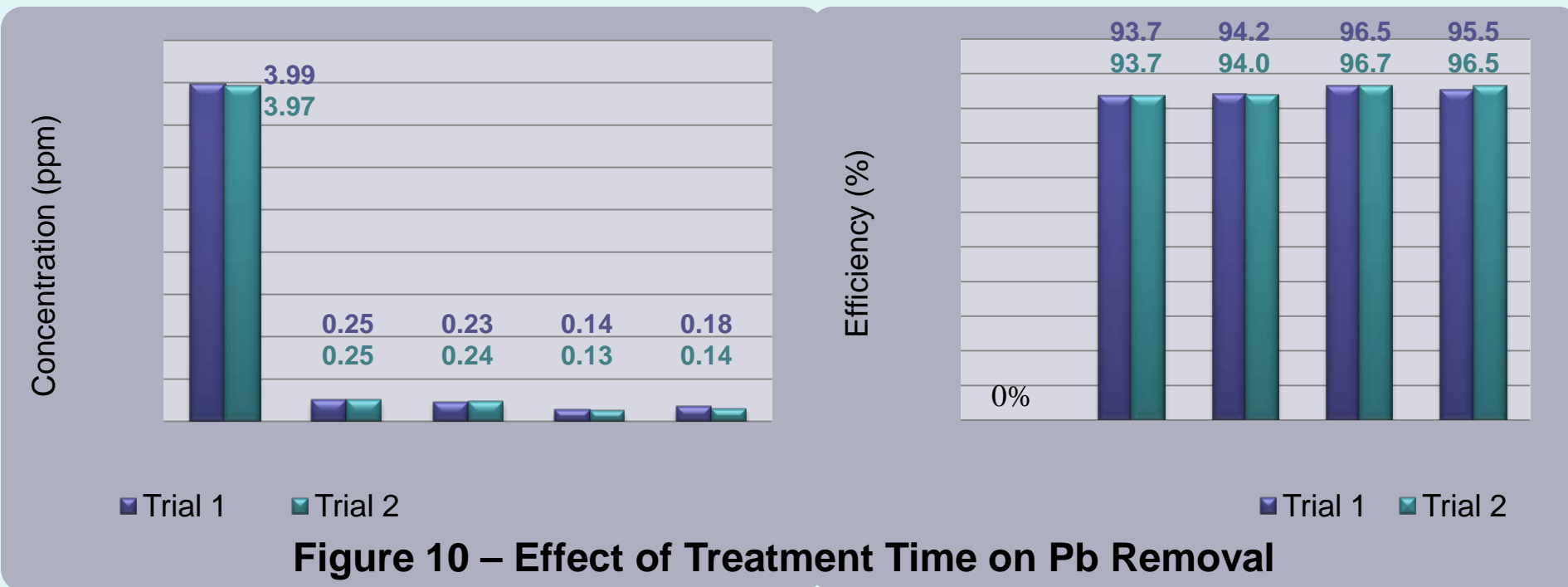


Figure 7 - Testing with FAA Spectrometer

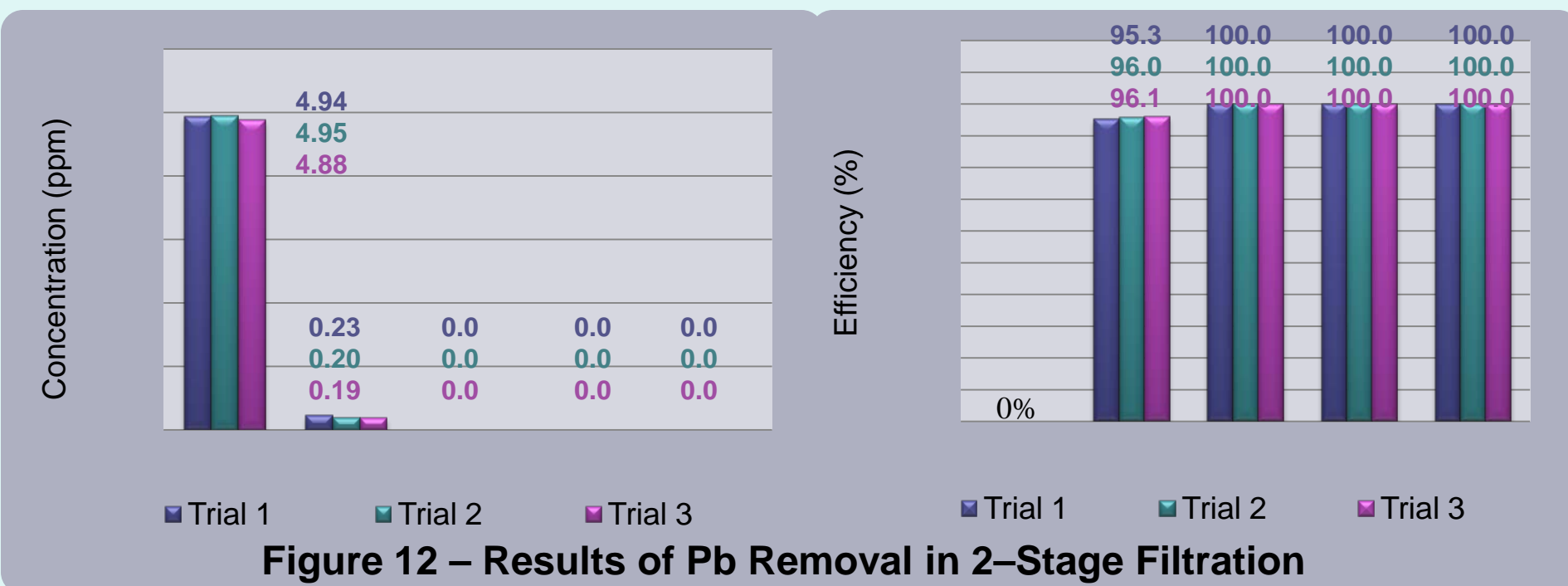
Results and Interpretation



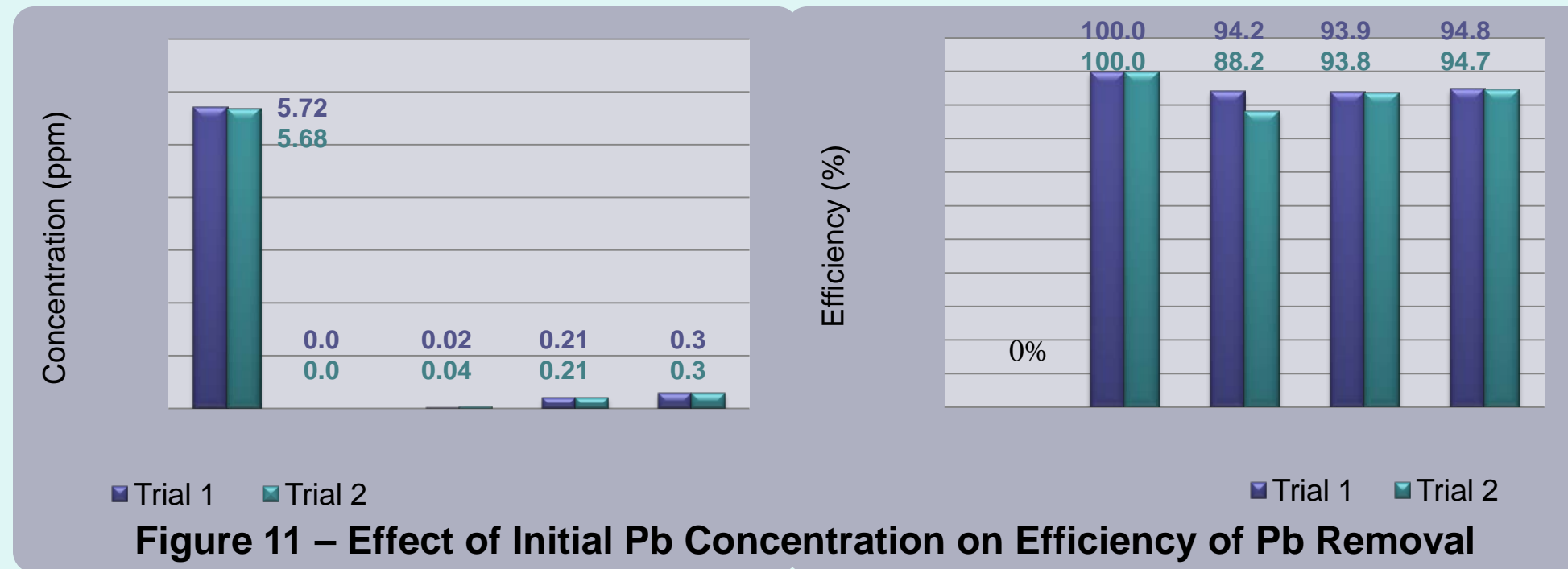
Efficiency of Pb removal increased with dosage up to 3g/100mL, and after that, it remained constant.



Efficiency of Pb removal increased with the time of treatment up to 20min, and after that, there was no significant change in Pb removal.



Efficiency of Pb removal was affected by pH of the treated water with maximum removal obtained at pH=8 and 96.4% of Pb removal.



2-Stage Filtration was very effective with 96% of lead removal after just one treatment with Moringa and 100% removal after first filtration.

Results cont.

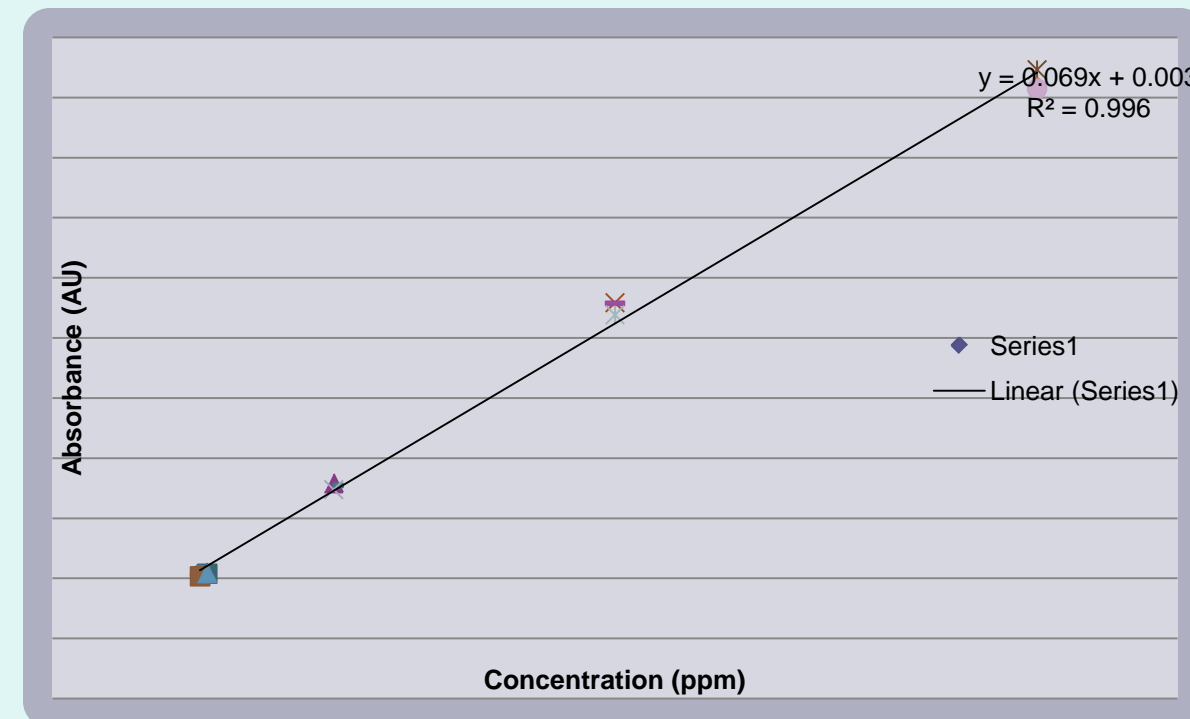


Figure 13
Samples Tested after Treatments with Moringa

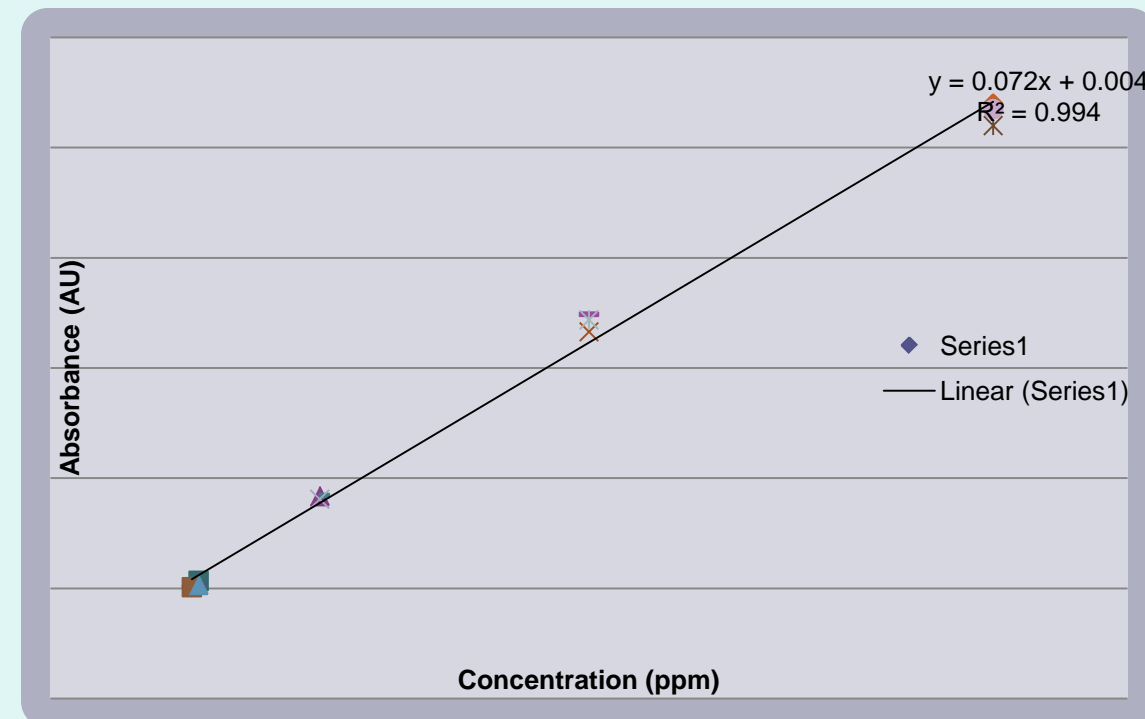


Figure 13
Samples Tested after 2-Stage Filtration

5 standards were prepared for Pb with concentrations of 0.05, 0.1, 1, 3, and 6ppm. Based on the known standard concentrations, absorbance was calculated and assigned to each standard, and Peak Absorbance Calibration Curves were created. Using Absorbance Calibration Curves, concentration was calculated for all tested samples.

Discussion

Since this method of lead-contaminated water purification is one-of-a-kind, there is not much data available to compare with other similar bioremediation systems.

- 2-Stage filtration produced great results – 100% of lead removal and clear water to drink (not available similar research and results to compare).
- Treatment with only Moringa seeds resulted in efficiency removal of 96% for Pb, while in another study with Moringa Oleifera for removal of lead, (Alfonso et al. 2013) the results were much lower - 69.2% Pb.
- Unexpected results were obtained after experimenting with the sand filter. It appears that sand also has adsorbing properties that aid in the proposed bioremediation of lead-contaminated water (similar research and results to compare are not available).

Conclusion

Hypothesis was supported by the results – I was able to significantly reduce the concentration of lead in contaminated water.

- Highest Pb removal was obtained with 3g/100mL MO at pH=8 and 20 min treatment time
- Efficiency of lead removal with Moringa pre-treatment was not affected by initial concentration
- Treatment with only Moringa seeds was very effective – over 96% of lead removal
- 2-Stage filtration was most effective -**100% removal** of lead after just one treatment and one filtration - clean water to drink

Pre-treatment/filtration method for lead removal is simple, extremely cost-effective, environmentally-friendly, and has great potential for removal of lead in developing countries.

This method of pre-treatment/filtration can also be used in the US in areas with elevated concentrations of lead in drinking water.

Future Research

Future experimentation can be done to address the following:

- Effectiveness of treatment with Moringa and filtration through sand filter on removal of other heavy metals
- Saturation time before filter needs to be renewed
- Recovery of heavy metals from biomass
- Effect of sand alone on removal of heavy metals

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