Investigating Arsenic, Lead and Mercury Accumulation in Culturally Relevant Crops and Low-Cost Environmental Public Health Intervention Strategies

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Abstract

Metal uptake by plants may pose health risks to human who feed on crops grown near mining sites. This study focuses on arsenic (As), lead (Pb), and mercury (Hg) accumulation in specific crops. This experiment will be a greenhouse study with two steps. The first step investigates the ability of sesame, corchorus, lentil and arugula to accumulate As, Pb and Hg in their edible tissue. These plants were selected to their cultural relevance, worldwide consumption, and representation of a broad range of plant families. Soil medium will be a mixture of mining waste with elevated As, Pb, and other metals brought from Iron King Mine and Humboldt Smelter Superfund Site (IKMHSSS) mixed with garden soil. IKMHSSS are facilities have contaminated ground water and soil attributable to the mine and smelter sources. Both are located in residential areas of Dewey-Humboldt, Arizona. The above crops will be grown in four soil treatments: 0%, 25%, 50% and 75%. The edible portion will undergo microwave digestion and be analyzed via inductive coupled plasma mass spectrometry. Crops that are commonly consumed cooked, such as corchorous leaves and lentil seeds will be traditionally prepared (e.g. boiled) to examine the effects of cooking on metal accumulation in the edible parts. The second step of the project is designed to investigate the effectiveness of phyto-protection using known metal- hyperaccumulators. In this second experiment, sesame, corchorus, lentil, and arugula will each be grown along with a hyperaccumulator in the same soil treatments as explained above. Both the crops and hyperaccumulator will be analyzed to determine whether the hyperaccumulator reduced the crop's As, Pb and the other metals uptake. The first step of the project will elucidate the uptake pattern of As, Pb and Hg by culturally relevant crops and whether preparation and cooking effects metal accumulation. For the second step of this project, it is anticipated that this work will provide a low-cost public health intervention strategy for farmers and communities growing near in soil that have been impacted by mining waste.

Background

Vegetables such as okra, corchorous, arugula, lentil, and tomato might be a health risk when grown in a contaminated areas. Several countries are known to have these vegetables as part of their daily life. For example, Egypt and North Africa are known for dishes of corchorus and lentil, Saudi Arabia and India with arugula and Okra, and Yemen with sesame products. Many people are unaware of the risk created by mining near those crops. The countries mentioned above have environmental pollution that may result in the contamination of agricultural lands and reduction of soil quality. Plants absorb nutrients from soil including contaminants. Arugula is known to accumulate several heavy metals (Dotse and Charles, 2010) but Pb, As and Hg have not been tested. Corchorus can accumulate high contents of both Pb (193 microgram/g dry wt) and Hg (47.5 microgram/g dry wt) when the soil is over fertilized (Oyedele et al., 2006). However, arsenic seems to receive little attention for each arugula and corchorous. Sesame was found to accumulate Pb at high amounts (25 to 47 microgram/g dry wt) as a range from upper and lower parts of the plant (Gupta and Sarita, 2006). In addition, sesame accumulates arsenic at a level of 2.4 microgram/g dry wt in roots, 1.68 microgram/g dry wt in leaves and 0.8 microgram/g dry wt in seeds (Kundu and Pal, 2012). Nothing have been clear about mercury on sesame. The lentil plant appears to be an understudied in crop. The allowed levels of each of As, Pb and Hg are 10, 15 and 2 microgram/L respectively (EPA) and (WHO).

Objectives

Experiment 1:

- Do arugula, lentil, sesame, and corcorous accumulate Pb, As and Hg in parts that are used as foods? Does this pose a risk to human health according to the standards?
- What is relationship between the concentrations of these contaminants (metals) in the soil and the accumulation in plants tissues?
- Does cooking have any effect on the metal concentrations in the edible plant tissues? If the edible portions of the plant are boiled, what effect will the water quality have on the concentration of As, Pb, and Hg?

Experiment 2:

- Phytoprotection might be tested to see if it can reduce the amount of contamination in crop tissues. For example, sunflower, Helianthus annuus L, can accumulate high amounts of contaminants in its roots such as lead (140 mg/g dry wt) (Dushenkov et al., 1997), but nothing was found for arsenic or mercury, thus:
- Is the hyper-accumulator able to outcompete for metals and then alleviate the amounts of metals in crops?


Sunflower


Corchorus

Methods and Design

Experiment 1

In the greenhouse:

- Garden soil was mixed with mining waste.
- The chosen soil was Sun Gro Horticulture Soil.
- Mine waste was brought from IKMHSSS site.
- The soil was well mixed in a cement mixer.
- Each plant was grown in four treatments of 0%, 25%,50% and 75%, and each treatment will have four replicates.
- One-gallon pots for each of arugula, lentil, corchorous plants and two -gallon pots for the sesame plants since it is a larger plant.
- 8 pots for the control plants of one-gallon.
- The control plant had two treatments : 0% and 25%.

Experiment 2

- Grow a hyper-accumulator next to each plant in the same pot. The hyper-accumulator plants are still to be determined.


Arugula seedlings


Sesame plants


Lentil seedlings

Table 1: Names, size, classifications and used parts for analysis.

Name	Plant size	Family	Part of plant used
Arugula or Eruca	Small	Brassicacea	Raw leaves
Corchorus L.	1m	Tiliaceae	Raw and Cooked Leaves
Lentil or Lens	.25 to 0.5 m	Fabaceae	Seeds raw and cooked
Sesame or Sesamum	0.5 to 2 m	Pedaliaceae	Seeds and oil

Expected Results

Based on previous studies, it is anticipated that the crops will absorb contaminants and metals and accumulate unacceptable loads in the tissues. Therefore, we expect that each of the arugula, sesame, lentil and corchorous will absorb and accumulate these specific metals; Pb, As and Hg. However, it is unknown in which parts of the crop the accumulation will be higher. It is also expected that the sunflower plant will reduce the concentrations of metals that accumulate in the crops. That is because sunflower plant is reported to accumulate large amounts of metals specifically lead (Dushenkov et al 1997). Cooking might have effects on the metals in food. As in food may increase specifically if water has As in it (Signes et al 2008). The cooking method also might increase the amount of Hg. However, some metals might stay and preserve the same amount even after cooking such as Pb (Cristiana et al 2012). It might be the effect of temperature, water quality and the material combination used in processing.

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