Gardenroots: The Dewey-Humboldt, Arizona Garden Project

Established in 2010

Summary of Results

April 2013

Made Possible By:

Soil, Water and Environmental Science
The University of Arizona
College of Agriculture and Life Sciences

The University of Arizona
College of Pharmacy

Arizona Cooperative Extension

SRP Superfund Research Program

United States Environmental Protection Agency

Arizona Space Grant Consortium

Alfred P. Sloan Foundation 1934
NACME

WSP Water Sustainability Program
Our Water Future
Innovation • Collaboration • Education • Policy

Town of Dewey-Humboldt
Yavapai County

Thank you Gardenroots Participants!

We did it! I would like to give a special thanks to all 25 of the *Gardenroots* participants for their efforts, motivation and patience throughout this research project. Due to their hard work, this project has successfully characterized the uptake of arsenic by homegrown vegetables and the potential risks associated with home gardening in Dewey-Humboldt, Arizona.

This document provides a summary of the Gardneroots results, and is divided into sections: vegetables, soil and water. Each section will present the arsenic concentrations observed in the samples collected by the participants, and the calculated excess cancer risk range associated with those concentrations. Please refer to the frequently used terms section for definitions.

It has been a great pleasure working with the Dewey-Humboldt community, please feel free to contact me in the future with any questions, comments or concerns.

– Monica Ramirez-Andreotta, m.ramirezandreotta@neu.edu

Executive Summary of Gardenroots: The Dewey-Humboldt, AZ Garden Project

In February of 2011, University of Arizona (UA) graduate student Mónica Ramírez-Andreotta placed an announcement in the Dewey-Humboldt Newsletter to recruit gardeners to participate in the *Gardenroots* study. Training sessions were held in March 2011, to instruct citizen-scientists in the collection of garden vegetables, as well as irrigation water and soil samples. Additional educational activities were offered, such as gardening seminars (May 2011), a community health talk with UA researchers (June 2011), and a tour of the UA laboratories where the concentrations of arsenic in the collected vegetable, water, and soil samples were being measured (Nov 2011). At the "Results for Lunch: Your Soil, Water and Vegetable Outcomes" luncheon (Jan 2012), participants were given personalized booklets showing the results for their individual gardens. Booklets included "raw" data (i.e. milligrams of arsenic per kilogram of vegetable, fresh weight), calculations of how much each participant could eat from his or her own garden at different levels of estimated risk, and estimated risks associated with individual water and soil samples. Handouts with recommended safe practices for gardening were also provided. A complete overview of the project was presented to *Gardenroots* participants and the Yavapai Master Gardeners (June 2012). More recently, overall project results handouts were sent to participants and other interested community members (December 2012).

Twenty different types of vegetables falling into 9 different plant families were grown in the greenhouse and/or Dewey-Humboldt gardens. The results of this study show that the following vegetables generally had higher arsenic concentrations than vegetables tested in the 2010 US Food and Drug Administration (FDA) Market Basket nationwide study: lettuce, beans, onions, radishes, Brussels sprouts*, broccoli*, cabbage, beets, spinach*, peppers, carrot* celery* and corn*. Squash, cucumber*, and tomatoes were generally below the reported US FDA value. Kale, swiss chard, amaranth, and garlic were grown by community members, but these vegetables were not tested in the US FDA study, and so cannot be compared. For vegetables with an asterisk (*), only one sample of that vegetable was received. A major finding of the *Gardenroots* project is that, when combining greenhouse and home garden data, *Asteraceae* (lettuce) and *Brassicaceae* (radish, broccoli, brussels sprouts, kale, and cabbage) families were the top accumulators of arsenic. This finding has been reported in other studies.

Overall, the *Gardenroots* project showed that homegrown vegetables did take up arsenic. However, calculations of estimated average arsenic daily dose from the three potential exposure routes measured suggested that arsenic exposure was greatest from drinking water (when assuming the primary source of water for irrigation is also used for drinking), followed by incidental soil ingestion, with a relatively small contribution from homegrown vegetable ingestion. Thus, it is strongly recommended for Dewey-Humboldt community members to test drinking water yearly and to test soils prior to gardening. To be precautious and prudent, gardeners can modify gardening behavior to reduce incidental soil ingestion and limit the use of vegetables from the *Asteraceae* and *Brassicaceae* families.

For more information about the study and safe gardening practices, please visit the new Gardenroots webpage at http://www.superfund.pharmacy.arizona.edu/content/gardenroots or contact Janick Artiola (jartiola@cals.arizona.edu) or Sarah Wilkinson (wilkinso@pharmacy.arizona.edu). In addition, you are always welcome to contact Mónica (m.ramirezandreotta@neu.edu) who is now at Northeastern University in Boston, MA. She will always be a resource to the Dewey-Humboldt community.

gardenroots
The Dewey-Humboldt, Arizona Garden Project

Frequently Used Terms

That you will see throughout the results

Concentration – The amount of a chemical in a given mass of water, soil, or plant tissue.

Excess Cancer Risk – The lifetime cancer risk predicted to result from continuous exposure to a chemical at a certain concentration. This risk is in addition to any other existing cancer risk.

Maximum Contaminant Level (MCL) – The maximum amount of a regulated contaminant allowable in drinking water. The EPA sets standards for drinking water that all public water providers must meet. Note that private wells in Arizona are exempt from any drinking water regulations.

Parts per Billion (ppb) – Micrograms per liter (µg/L) or micrograms per kilogram (µg/kg). Elements in water are often measured in very small units. To help you visualize, one ppb equals:

- 2 drops of water in a typical 15,000 gallon backyard swimming pool
- One second of time in 31.7 years
- The first 16 inches of a trip to the moon

Parts per Million (ppm) – Milligrams per liter (mg/L) or milligrams per kilogram (mg/kg). Elements in water and soil are often measured in very small units. To help you visualize, one ppm equals:

- 1/4 cup of water in a typical 15,000 gallon backyard swimming pool
- One second of time in 11.6 days

Soil Arsenic Guidelines and Regulations – There are currently no federal arsenic standards for residential soils in the U.S., although some states have set clean up standards.

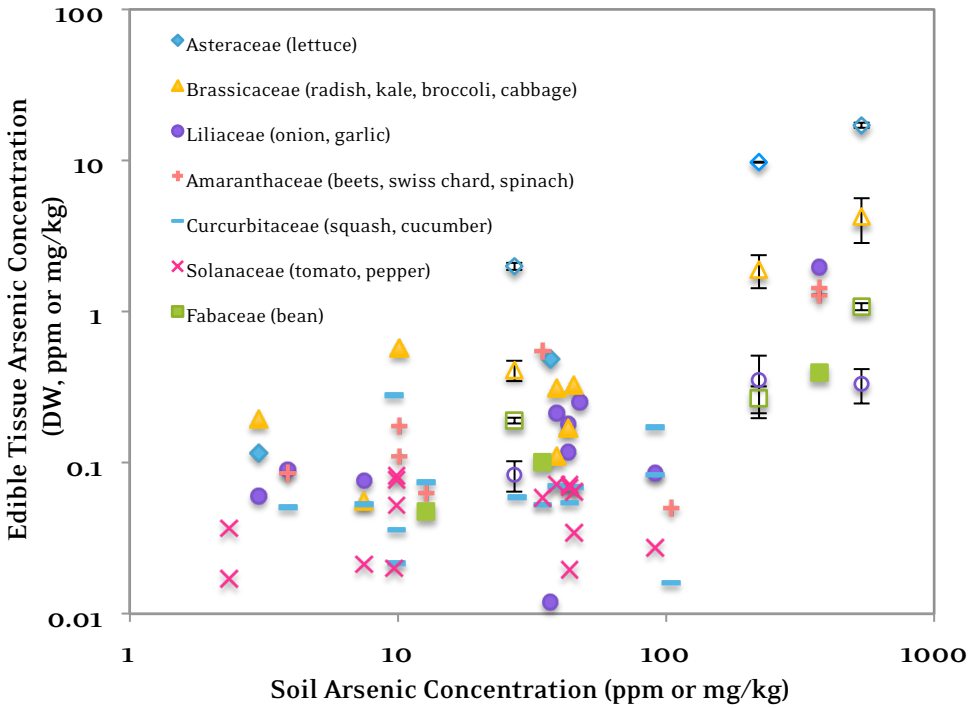
- **Arizona Soil Remediation Standard –** Arizona has established a soil remediation (clean up) standard of 10 milligrams of arsenic per kilogram of soil (mg/kg) for both residential and non-residential sites (AAC Title 18-7-205).
- **U.S. EPA Residential Regional Screening Level –** Risk-based concentrations of chemicals in soils that are calculated using what we know about the exposure to a chemical and what the U.S. EPA knows about the toxicity of the chemical. U.S. EPA considers these screening levels as initial cleanup goals, when applicable. They are not national cleanup standards, and are based on different target risks. The estimated values can range from 0.39 mg/kg to 39.0 mg/kg.
- **U.S. EPA Land Application of Biosolids for Home Vegetable Gardens –** Set at 41 mg/kg (U.S. EPA, Title 40, Section 503.13).

Target Risk – Setting the lifetime cancer risk to values like 1/10,000 (greater risk), 1/100,000, and 1/1,000,000 (lesser risk).

Vegetables Results: Greenhouse & Home Garden Study Combined

The vegetable results are from:

- The vegetables samples that were submitted by the *Gardenroots* participants. The home garden values in the graph are the solid symbols.
- The greenhouse study conducted at The University of Arizona's Controlled Environment Agriculture Center (Tucson, AZ), where four replicates of lettuce, bean, radish and onion were grown in three different soil treatments totaling 48 samples. The greenhouse values in the graph are the open symbols.



Please note: The legend only shows the symbol shape. The open symbols for Asteraceae, Brassicaeae, Liliaceae, Fabaceae represent the greenhouse data and the solid symbols are the home garden values for all the vegetables within the represented plant families. Also, a carrot, celery and corn samples were submitted, but are not represented in the graph.

Bioconcentration factor (BCF)

$$= \frac{Concentration\ of\ arsenic\ in\ vegetable}{Concentration\ of\ arsenic\ in\ soil}$$

The BCF is the ratio of the metal concentration in the edible portion in the vegetable (dry weight) and the metal concentration in the soil. The average BCF for the plant families from this entire study (dry weight ppm*) decreased in the following order:

1. *Asteraceae* (lettuce)
2. *Brassicaceae* (radish, kale, broccoli, brussels sprouts cabbage)
3. *Amaranthaceae* (beets, swiss chard, spinach)
4. *Cucurbitaceae* (squash, cucumber)
5. *Liliaceae* (onion, garlic)
6. *Solanaceae* (tomato, peppers)
7. *Fabaceae* (bean)

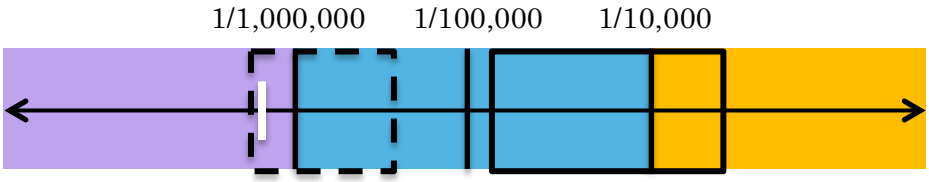
* ppm = parts per million or milligrams of arsenic per kilogram of vegetable (mg/kg))

The Asteraceae and Brassicaceae families accumulated more arsenic than did the other families. This observation is similar to the results reported in previous studies. Also, certain members of the Asteraceae and Brassicaceae families have been previously identified as hyperaccumulator plants, meaning they may have a genetic and physiological capacity to accumulate high amounts of metals.

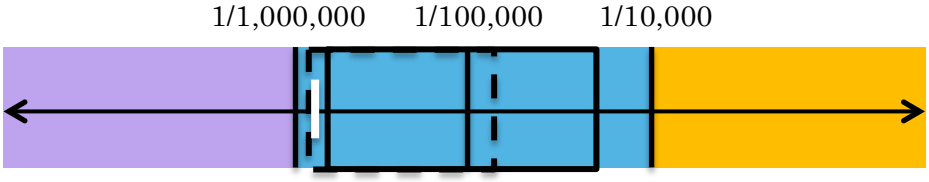
With this evidence, it is recommended that Dewey-Humboldt, Arizona home gardeners limit the use of vegetables from the Asteraceae and Brassicaceae families.

Potential risk associated with vegetable families

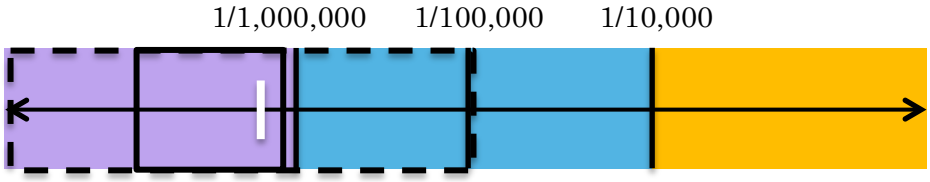
Asteraceae (lettuce)



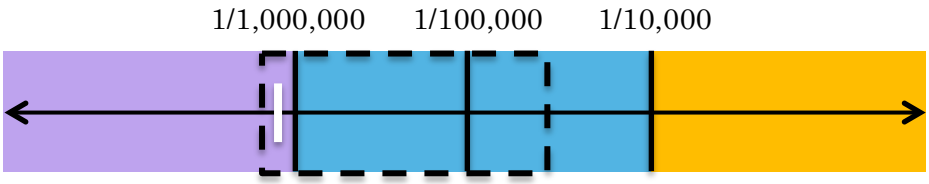
Fabaceae (bean)



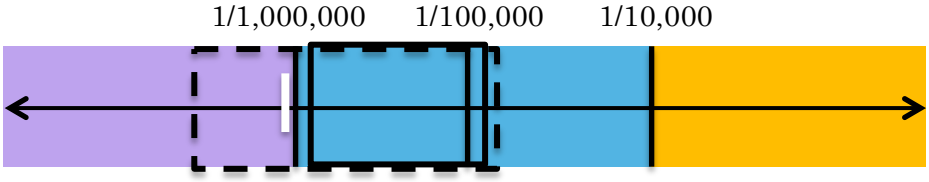
***Brassicaceae** (radish, broccoli, brussels sprouts, cabbage, kale)*



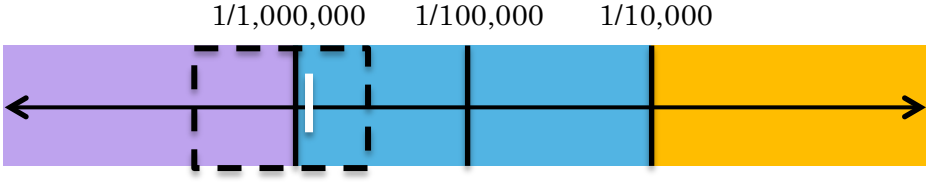
Amaranthaceae (beets, swiss chard, spinach)



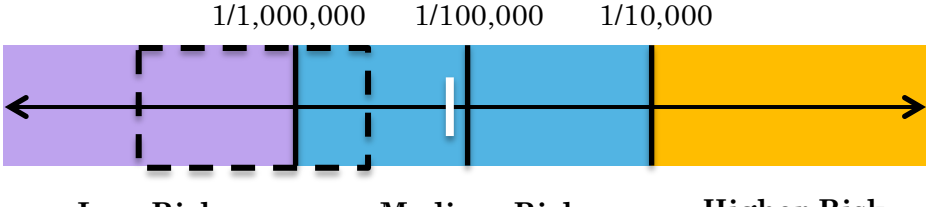
Liliaceae (onion, garlic)



Solanaceae (tomato, pepper)



Cucurbitaceae (squash, cucumber)



Low Risk **Medium Risk** **Higher Risk**

The risk ranges are shown in the dashed boxes for home garden vegetables and solid boxes for the greenhouse vegetables. The white line is for comparison, and represents the average number of excess cancer cases using the average arsenic concentrations for vegetables (in the given plant family) purchased in U.S. grocery stores (U.S. Food & Drug Administration's Market Basket study). The risk calculations include the measured arsenic concentrations from the home garden vegetables and the assumptions below:

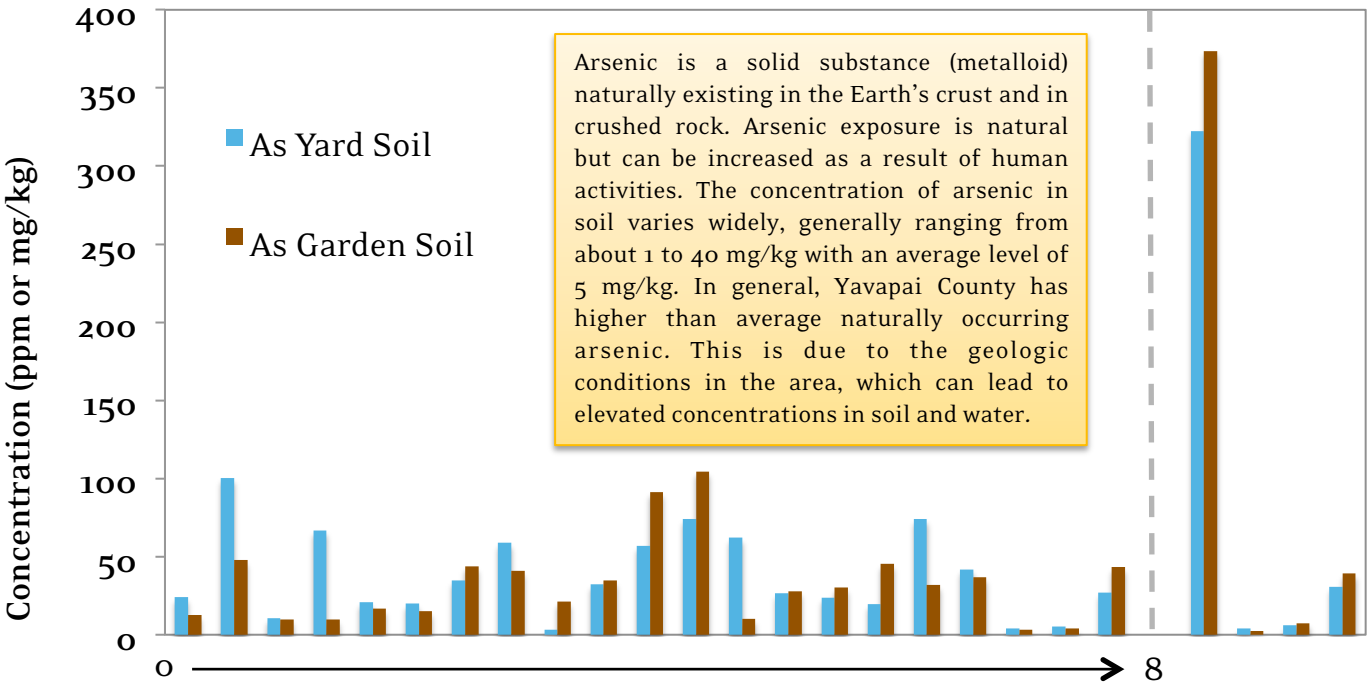
- A U.S. EPA intake rate for the vegetable, water or soil (incidental) one would be consuming daily
- Body weight (60 kg = 132 lbs.)
- Life span equal to 78 years
- Eating that vegetable, drinking the water or incidentally ingesting soil 350 days out of the year for 30 years
- U.S. Environmental Protection Agency's cancer slope factor
- Bioavailability of arsenic once it's in your body

There are uncertainties associated with the calculations, for example an individual living in the area will be eating the vegetable for 350 days a year for 30 years. This is unlikely due to limited vegetable growing seasons and changes in garden productivity. Therefore, the calculated risks are conservative, and the actual risk values would most likely be smaller.

Reading the figures

When you see 1/1,000,000 that means 1-in-a-million excess cancer cases above our already existing cancer risk.

Concentration of arsenic in home yard and garden soils

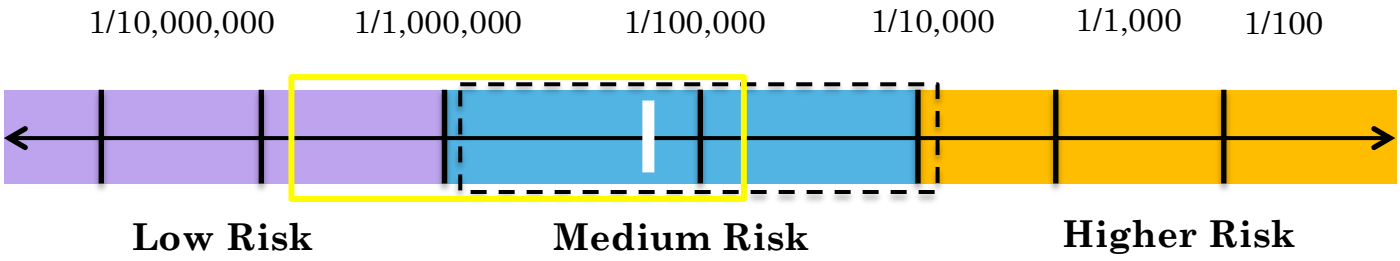


Arsenic concentrations in home garden and yard soils of participants. Distance from the Iron King mine tailings increases along the x-axis, from 0 to 8 miles in the northeast direction. The four samples to the right of the dotted line are sample locations towards the southeast, northwest, north and south of the tailings.

Gardenroots participants hypothesized that the closer to the tailings a home was, the higher the arsenic concentration would be in the soils. There is no obvious pattern to support this hypothesis. It should be noted that: 1) the number of *Gardenroots* samples is not sufficient to truly characterize the spatial distributions; 2) wind direction in the area changes seasonally; and 3) this area has been affected by both smelting and mine tailings, which produce different sized particles that can experience different levels of transport by wind.

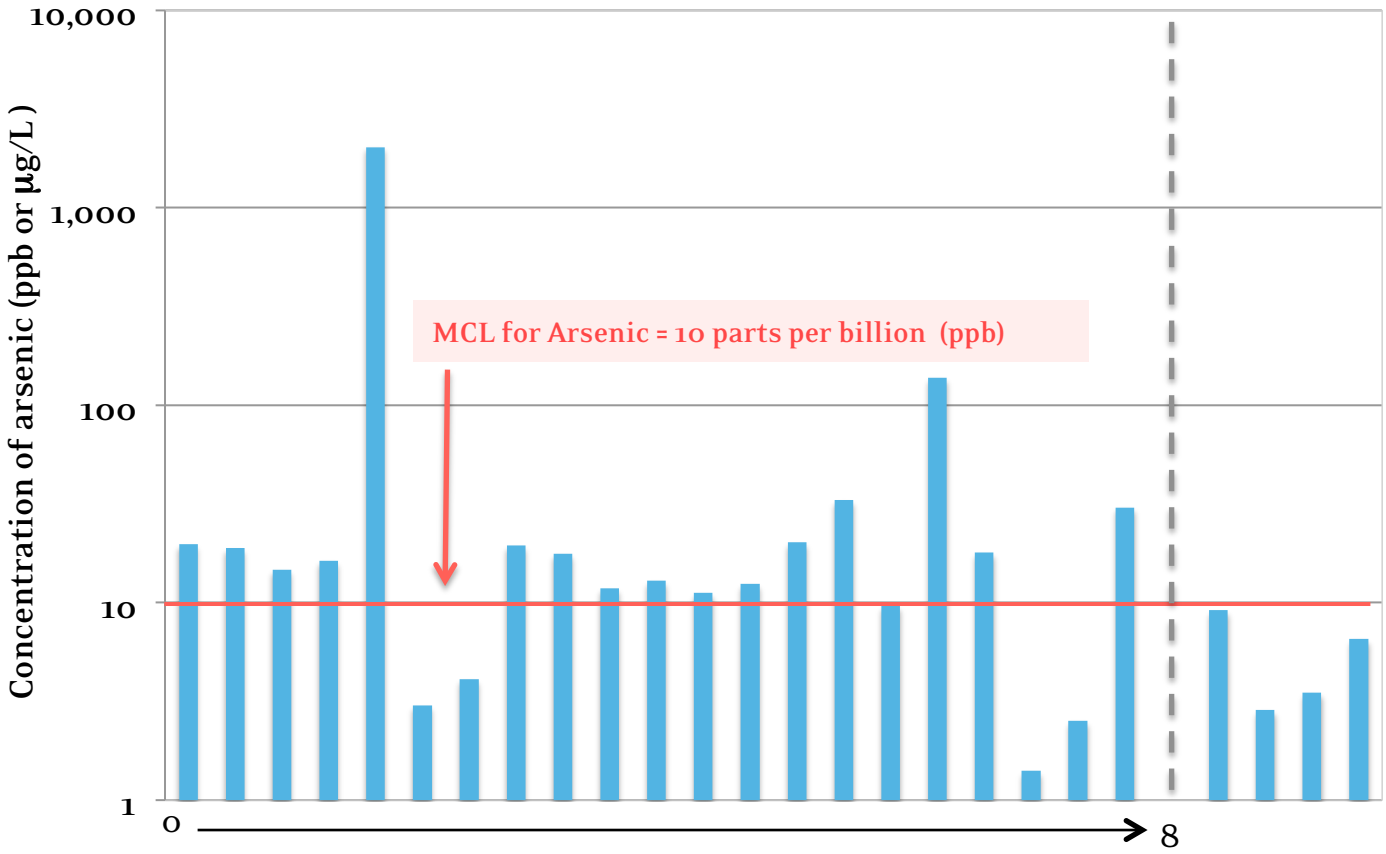
It was also hypothesized that the garden soils would have a lower soil arsenic level than the yard soils, given that the garden soils would be mixed with garden amendments. Interestingly, the average soil arsenic concentration in the yard soils (46.0 mg/kg) and garden soils (44.1 mg/kg) are similar, and 12 of the 25 home garden soil samples had a greater soil arsenic concentration than the yard soils. This highlights that commercially available and other local gardening amendments may contain arsenic.

Using the arsenic concentrations found in the garden soils, the potential risk was calculated using the same calculation described on page 5. Below, in the dashed box is the excess cancer risk range associated with those concentrations. The white line represents the potential excess cancer risk associated with the arsenic Arizona Soil Remediation Standard (10 mg/kg). The yellow box represents the potential excess cancer risk associated with the U.S. EPA Residential Regional Screening Level range (0.39 mg/kg to 39.0 mg/kg).



ppm = parts per million (milligrams of arsenic per kilogram of soil (mg/kg))

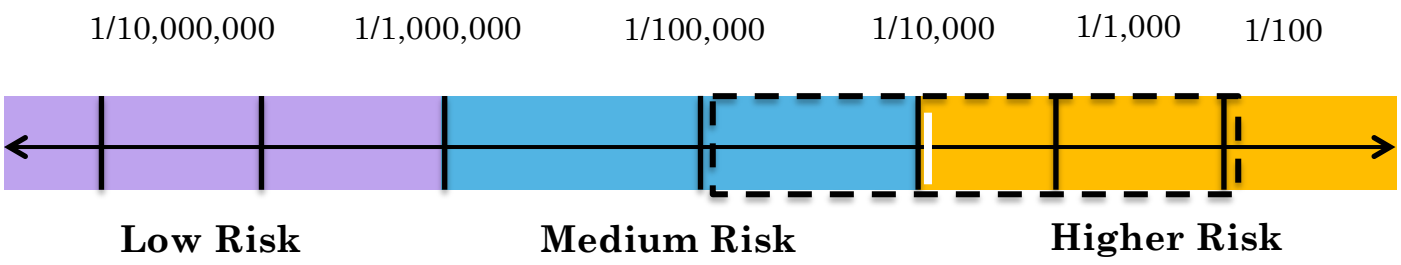
Concentration of arsenic in irrigation water samples



Arsenic concentration in irrigation water used by study participants. Each bar represents one study participant and the bars are in order of distance from the Iron King mine tailings site with distance increasing along the x-axis, from 0 to 8 miles in the northeast direction. The four samples to the right of the dotted line are sample locations increasing in distance, towards the southeast, northwest, north and south of the tailing.

The Maximum Contaminant Level (MCL) is the maximum amount of a regulated contaminant allowable in drinking water. The EPA sets standards for drinking water that all public water providers must meet.

Using the arsenic concentrations found in the irrigation water, the potential risk was calculated using the same calculation described on page 5. Below is the excess cancer risk range associated with those concentrations. The white line represents the excess cancer risk using the arsenic MCL.



ppb = parts per billion (micrograms of arsenic per liter of water (µg/L))

References – For More Information

Vegetables

- **U.S. Department of Agriculture (USDA)**
  http://www.choosemyplate.gov/food-groups/vegetables_amount_table.html
- **USDA – What's In The Foods You Eat Search Tool, 4.1**
  http://www.ars.usda.gov/Services/docs.htm?docid=17032
- **U.S. Environmental Protection Agency (USEPA) – Exposure Factors Handbook**
  http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252
- **U.S. Food and Drug Administration**
  http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/TotalDietStudy

Soils

- **Trace Elements in Soils and Plants.**
  Pendias, A.K., Pendias, H. 2001. 3rd ed. CRC Press: Florida
- **University of Arizona Superfund Research Program (UA SRP) – Community Information Sheets**
  http://www.superfund.pharmacy.arizona.edu/content/community-information-sheets-0
- **UA Well Owners Help**
  http://www.wellownerhelp.org/
- **USDA Natural Resources Conservation Service**
  soils.usda.gov
- **USEPA – Soil Screening Guidance**
  http://www.epa.gov/superfund/health/conmedia/soil/index.htm

Irrigation Water

- **Agency for Toxic Substances and Disease Registry**
  http://www.atsdr.cdc.gov/
- **City of Tucson – Water Quality Terms and Definitions**
  http://cms3.tucsonaz.gov/water/terms_and_definitions
- **UA SRP – Water Booklets**
  http://www.superfund.pharmacy.arizona.edu/content/water-booklets-0
- **USEPA - Ground Water and Drinking Water**
  http://water.epa.gov/drink/contaminants/index.cfm

Monica Ramirez-Andreotta's Dissertation: "Designing a Comprehensive, Integrated Approach for Environmental Research Translation: The *Gardenroots* Project to Empower Communities Neighboring Contamination", The University of Arizona, 2012. A copy will be made available at the Dewey-Humboldt Town Library, 2735 S Corral Street, Humboldt, AZ 86329.

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