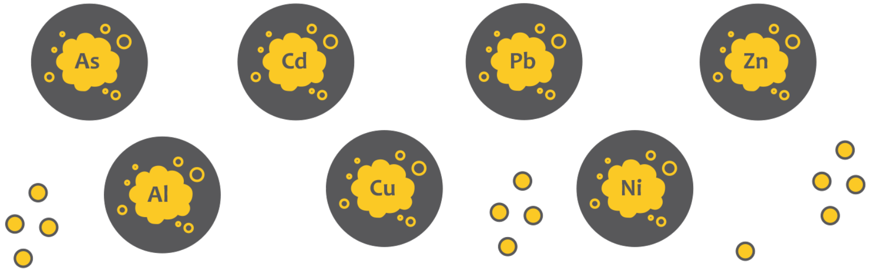
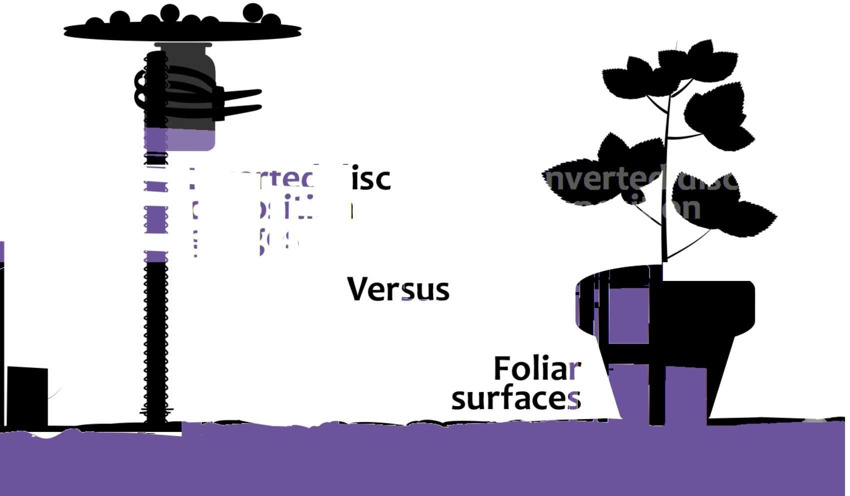


Foliar surfaces as dust and aerosol pollution monitors: An assessment by a mining site

March 24, 2022
Dust Workshop
Kira Zeider



Introduction

- Mining emissions pose an especially high threat to environmental and public health due to the high potential of contaminant concentration and emission of particulates (Csavina et al., 2012)

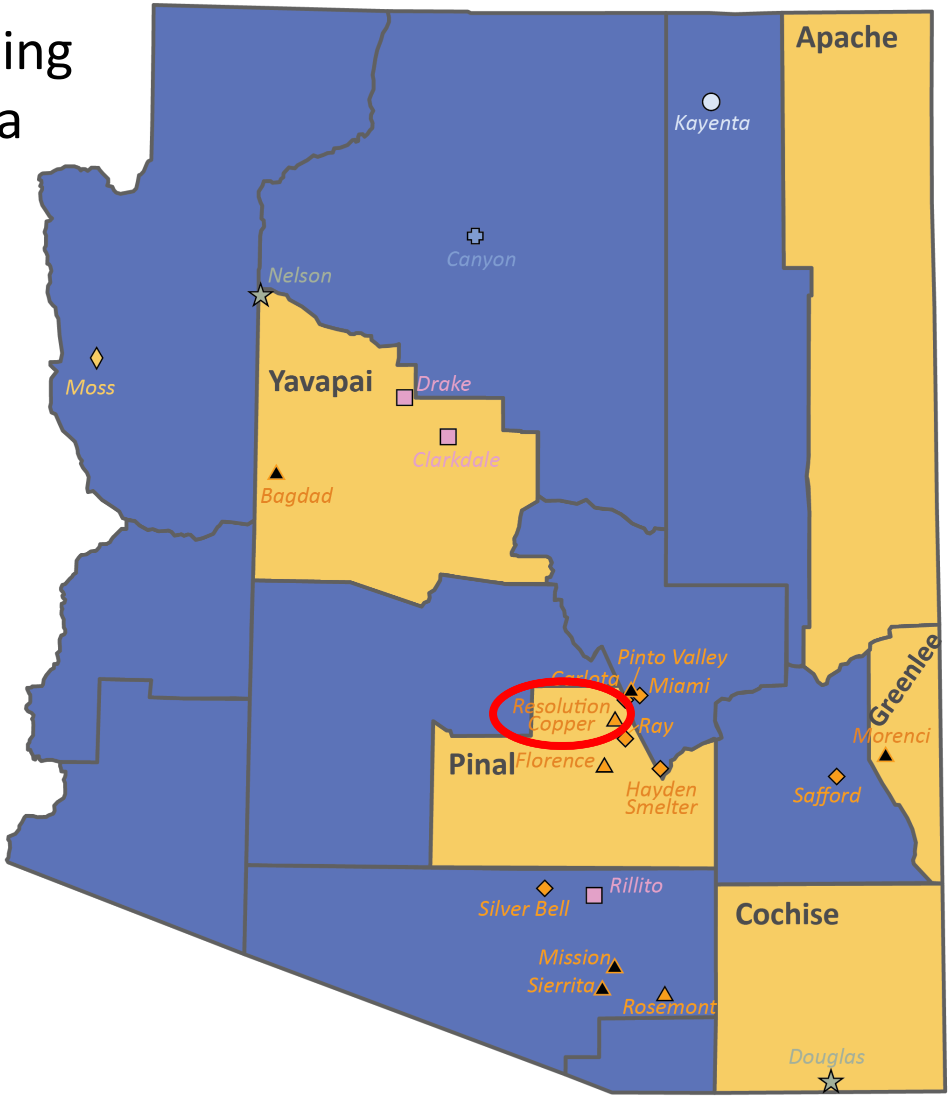
- This is of particular concern for arid and semi-arid regions that cover approximately one-third of the global land area (Seinfeld and Pandis, 2016)

- Extensive research in recent years in Arizona and northern Mexico have shown that heavy metals and metal(loid)s are efficiently emitted from smelting processes and mine tailings (Camacho et al., 2011; Csavina et al., 2014)

Background

(Now demolished) smelter from Resolution Copper (formerly Magma Copper)

Sites with major mining products in Arizona



Mine Products

- Cement
- Coal
- Copper
- Copper Development
- Copper, Molybdenum
- Gold, Development
- Lime
- Uranium, Development

gardenroots
A Citizen Science Garden Project

from Arizona Geological Survey, 2015

Motivation

gardenroots
A Citizen Science Garden Project

- Assesses residential environmental quality of communities neighboring resource extraction activities through a co-created citizen science design (Ramírez-Andreotta et al., 2015; Sandhaus et al., 2019; Manjón et al., 2020)

- Based on local observations and historical knowledge, community champions reached out to the UA's National Institute of Environmental Health Sciences' Superfund Research Program in 2018 with environmental quality concerns → Research Translation Core PI Ramírez-Andreotta began partnership building

In Loving Memory of

Roy C. Chavez

Chair/Spokesperson, Concerned Citizens and Retired Miners Coalition (Chair is now Henry C. Muñoz Sr.)

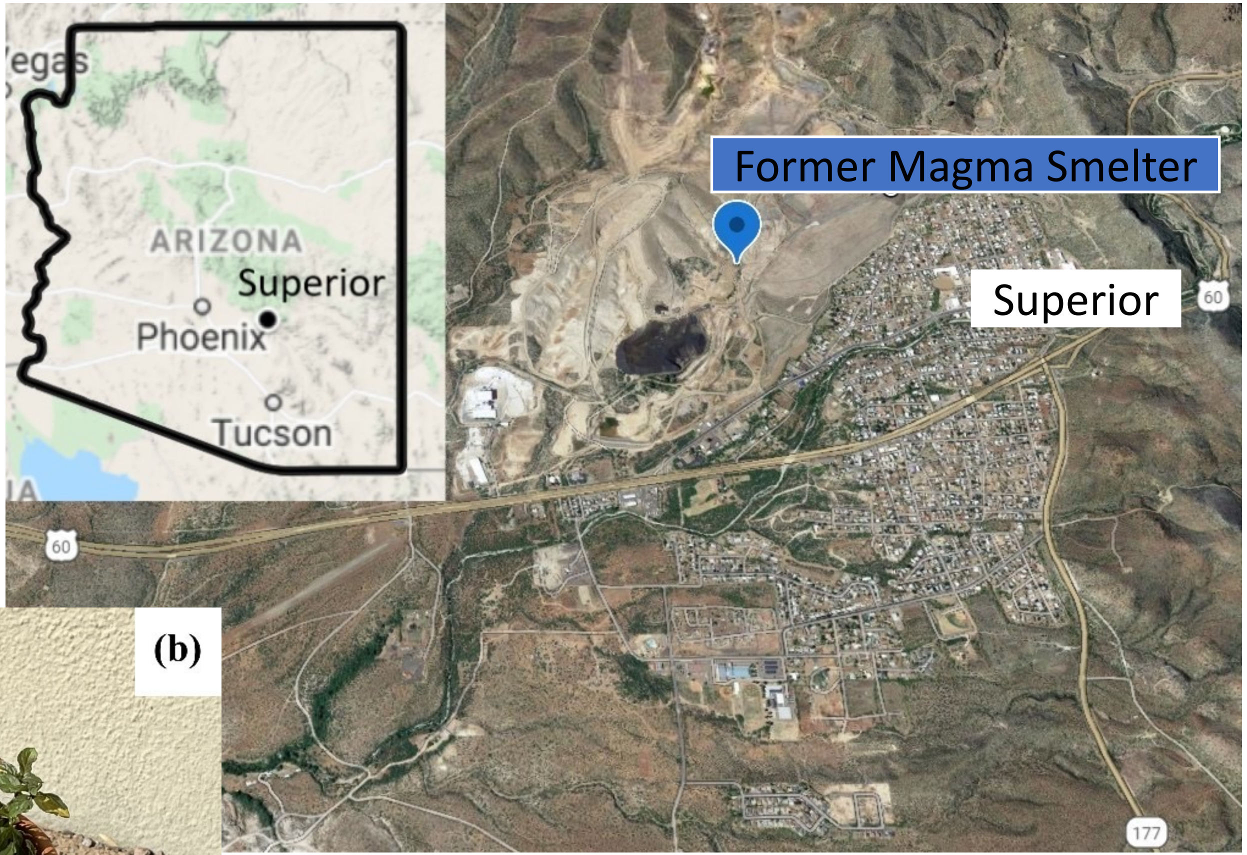
Goal of the Study

- Assess whether dust passively collected on plant leaves (foliar dust) can serve as a low-cost air monitor and indicator of metal(loid)-laden aerosols

- If proven successful, this simple, straightforward technique is broadly applicable to many sites where air monitoring is desired and sampling resources are limited

Methods

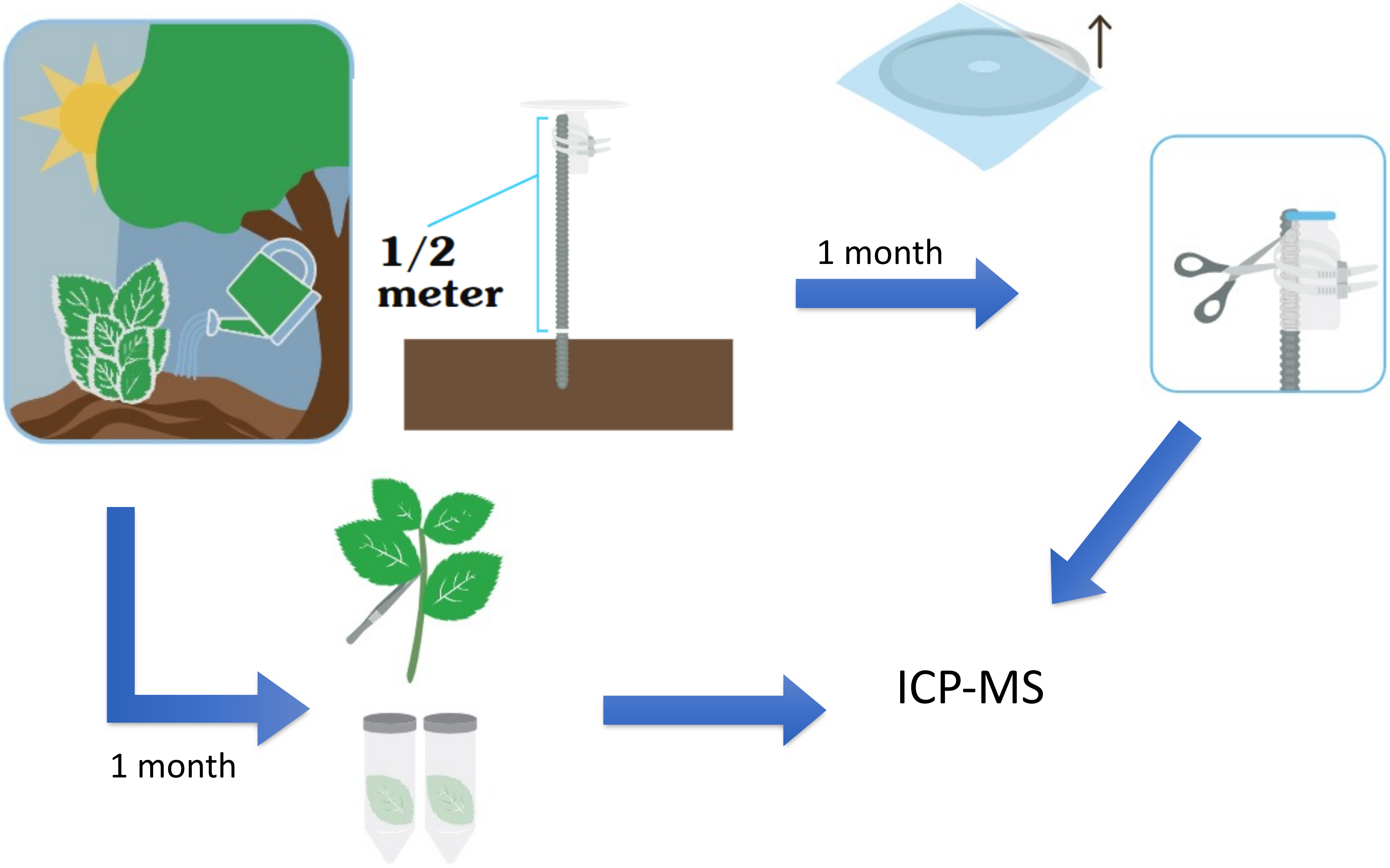
Sampling apparatus (a: frisbee, b: peppermint)



Superior, AZ and layout of surrounding town

Methods – Sampling Process

17	Frisbee
22	Foliar

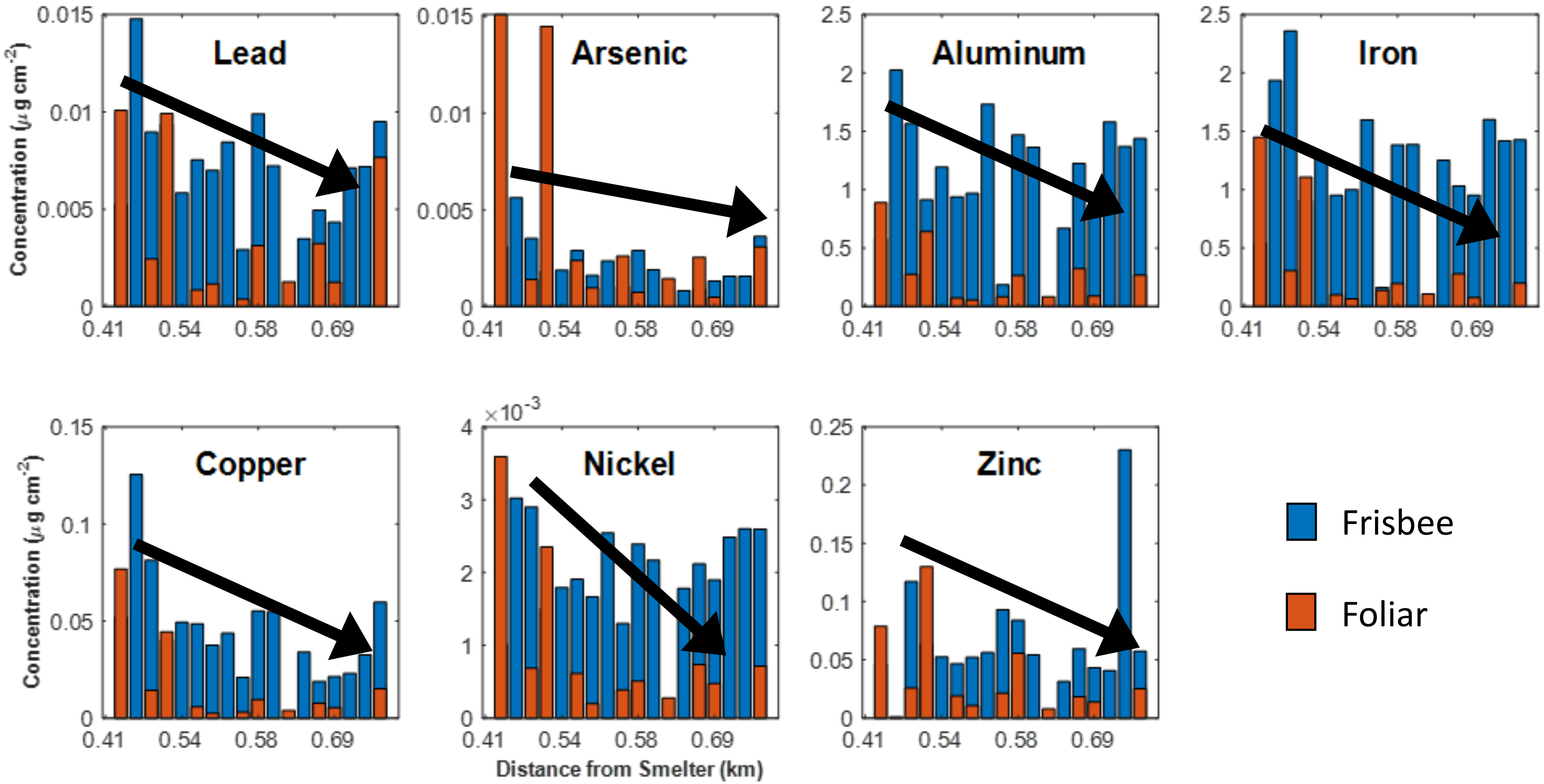


Results

Distance (km from smelter)	Frisbee ($\mu g\ cm^{-2}$)							Foliar ($\mu g\ cm^{-2}$)						
	Pb	As	Al	Fe	Cu	Ni	Zn	Pb	As	Al	Fe	Cu	Ni	Zn
0.4 - 0.79	0.010	0.004	1.270	1.436	0.075	0.002	0.057	0.007	0.010	0.603	0.954	0.045	0.002	0.078
0.8 - 0.99	0.007	0.002	1.034	1.081	0.045	0.002	0.050	0.001	0.002	0.064	0.084	0.004	0.000	0.015
1 - 1.49	0.007	0.002	1.188	1.134	0.044	0.002	0.072	0.002	0.002	0.144	0.147	0.005	0.000	0.028
1.5 - 2.0	0.005	0.001	1.134	1.251	0.026	0.002	0.081	0.002	0.002	0.208	0.177	0.007	0.001	0.016
51.8	0.009	0.004	1.438	1.427	0.060	0.003	0.057	0.008	0.003	0.269	0.201	0.015	0.001	0.025

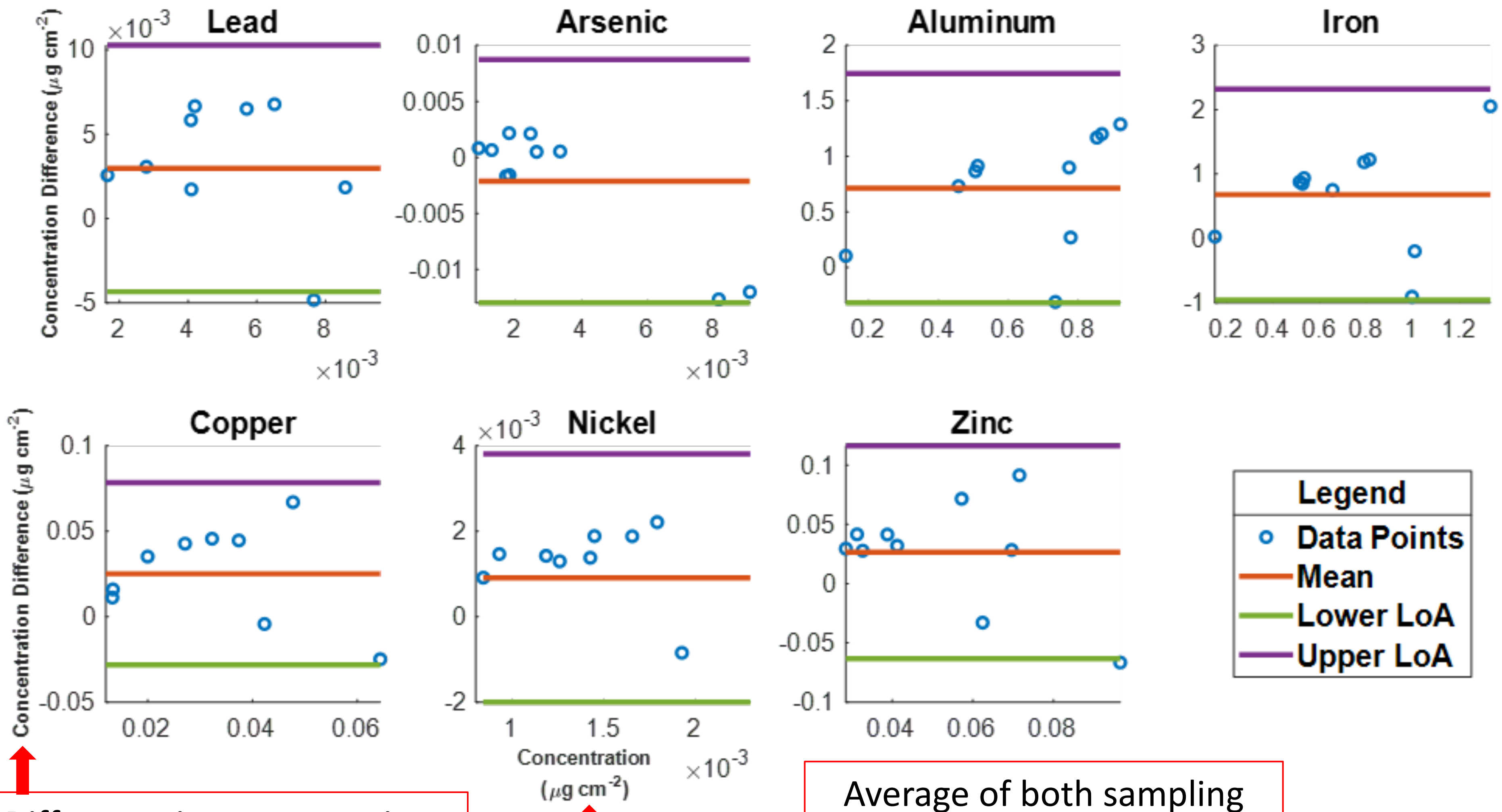
- Frisbee sampled higher concentrations per element per distance, on average
- 51.8 km generally had highest element concentration

Concentration mostly decreased with increased distance from smelter



Two-Sample t-Test	Pb	As	Al	Fe	Cu	Ni	Zn
Standard Error	0.00	0.00	0.12	0.18	0.01	0.00	0.01
Degree of Freedom	7	5	8	6	8	6	6
T Statistic	2.19	-0.64	8.30	5.37	3.07	3.53	2.39
P-value	0.97	0.27	1	0.99	0.99	0.99	0.97
ICC Coefficients	0.39	0.36	0.03	0.08	0.30	0.01	-0.11

- Null hypothesis failed to be rejected for any metal(loid) from the two-sample *t*-test
  - Null: average concentration of each metal(loid) was the same for both sampling methods ($p < 0.05$)
- Intraclass correlation coefficient (ICC) results indicated poor agreement between the contaminant concentrations from the frisbee and foliar methods



Difference in concentration between the two methods

Average of both sampling methods at a given distance

Bland-Altman Plot

Used to compare two measurement techniques, given one is a “standard”

Frisbee is considered standard based on published study

Limits of Agreement (LoA): 95% of the data should lie between these limits (if normally distributed)

- These plots implied a bias (higher concentration) toward one collection method: frisbee
- LoA indicated moderate agreement between sampling techniques overall

Enrichment Factor

- Indicator of anthropogenic origin
- Reference species: Fe

0-10	Crustal
10-100	Moderate contamination
100+	Significant contamination

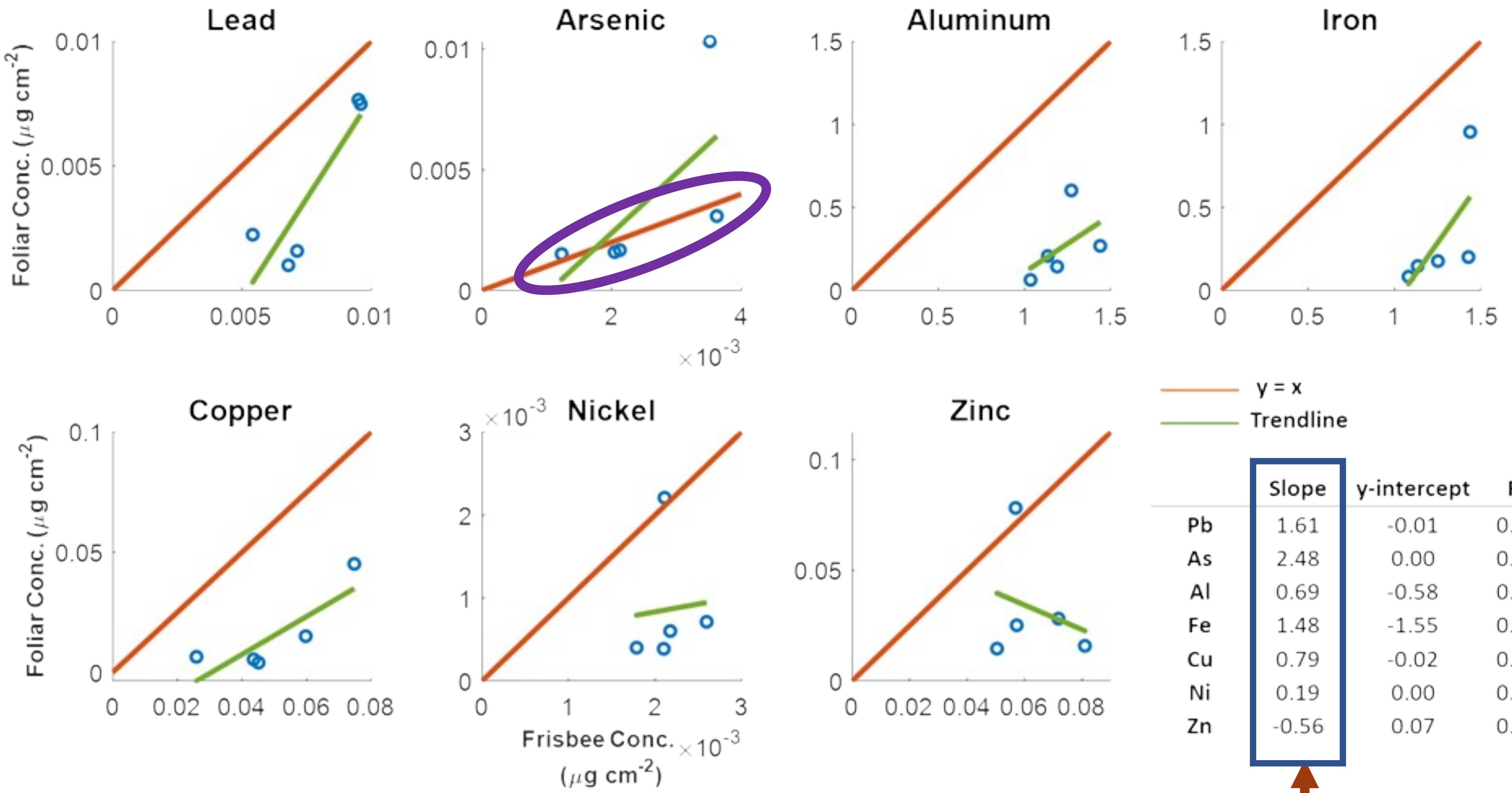
$$EF = \left[\frac{C_{n,sample}}{C_{ref,sample}}\right] / \left[\frac{C_{n,baseline}}{C_{ref,baseline}}\right]$$

(Goldschmidt, 1937)

	Number of points		Pb		As		Al		Cu		Ni		Zn	
Distance (km)	Frisbee	Foliar	Frisbee	Foliar	Frisbee	Foliar	Frisbee	Foliar	Frisbee	Foliar	Frisbee	Foliar	Frisbee	Foliar
0.4 - 0.79	4	6	25.0	23.4	30.8	101.2	0.5	0.4	30.5	23.1	0.8	1.1	65.2	101.5
0.8 - 0.99	3	4	20.6	40.5	20.7	200.5	0.6	0.4	21.5	23.8	0.9	2.0	60.2	213.9
1 - 1.49	4	6	28.3	31.9	28.6	122.9	0.6	0.5	29.8	19.2	1.6	1.3	224.0	223.4
1.5 - 2.0	5	4	13.8	44.9	10.1	80.8	0.5	0.7	10.7	25.6	0.9	2.3	80.5	161.4
51.8	1	2	21.2	110.7	25.9	165.5	0.6	0.8	21.3	37.6	0.9	1.9	51.2	165.2

- Pb, As, Cu, and Zn all indicate non-crustal origin (i.e. anthropogenic influence)
- Significant contamination: foliar – Pb (51.8 km), As, Zn; frisbee – Zn (1-1.49 km)

- Most slopes close to 1 – indicating agreement between methods
- Outlier was kept in dataset because it represented samples closest to former smelter



	Slope	y-intercept	R^2
Pb	1.61	-0.01	0.79
As	2.48	0.00	0.45
Al	0.69	-0.58	0.25
Fe	1.48	-1.55	0.45
Cu	0.79	-0.02	0.71
Ni	0.19	0.00	0.01
Zn	-0.56	0.07	0.07

Datasets match: Slope = 1

Impact

- There is some statistical evidence to support the claim that foliar collects similar metal(loid) concentrations as an inverted disc (frisbee)
- Metal(loid) EF values indicated non-crustal origins, such as anthropogenic sources of metal(loid)s
    - Exception of Al and Ni
- Since there is evidence of enrichment, correlation between methods, and citizen/community science potential, this study should be repeated with different types of plants
- Increase frequency of sampling collection and take environmental conditions into collection consideration

Acknowledgements

- Dr. Mónica Ramírez-Andreotta
- Dr. Armin Sorooshian
- Nicole Van Overmeiren
- Kyle P. Rine
- Shana Sanhaus
- Dr. A. Eduardo Saez
- Henry C. Muñoz Sr., Concerned Citizens and Retired Miners Coalition
- Superior, AZ Gardenroots participants

Ramírez-Andreotta
Integrated Environmental Science & Health Risk Laboratory

gardenroots
A Citizen Science Garden Project

NIH National Institute of Environmental Health Sciences
Your Environment. Your Health.

NASA/Space Grant Program

Superfund Research Center

Center for Environmentally Sustainable Mining