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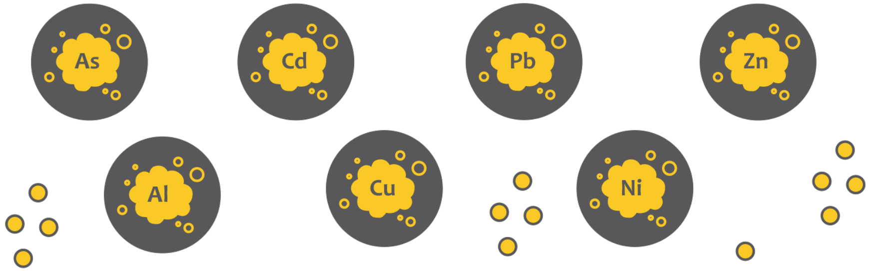
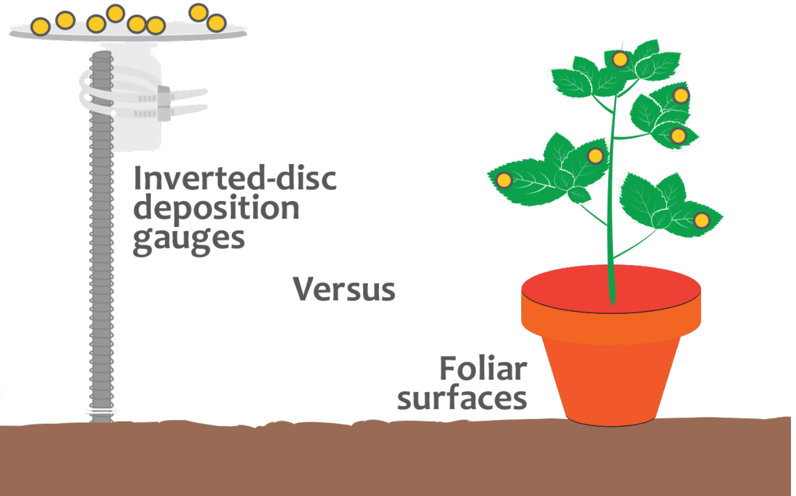


Foliar surfaces as dust and aerosol pollution monitors: An assessment by a mining site

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)

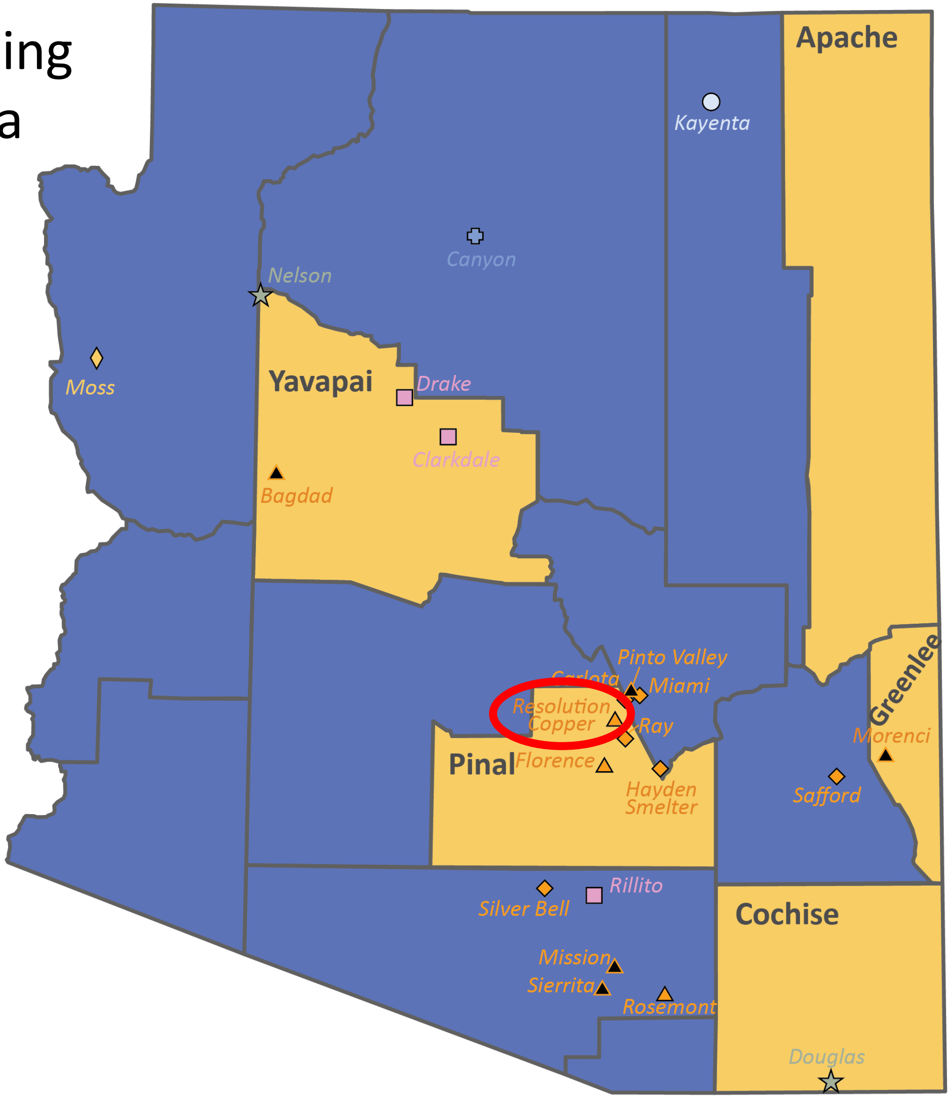
- This is of particular concern for arid and semi-arid regions that cover approximately one-third of the global land area (Seinfeld and Pandis, 2016)

- 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

Sites with major mining products in Arizona

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



Mine Products

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

from Arizona Geological Survey, 2015

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Motivation

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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.)

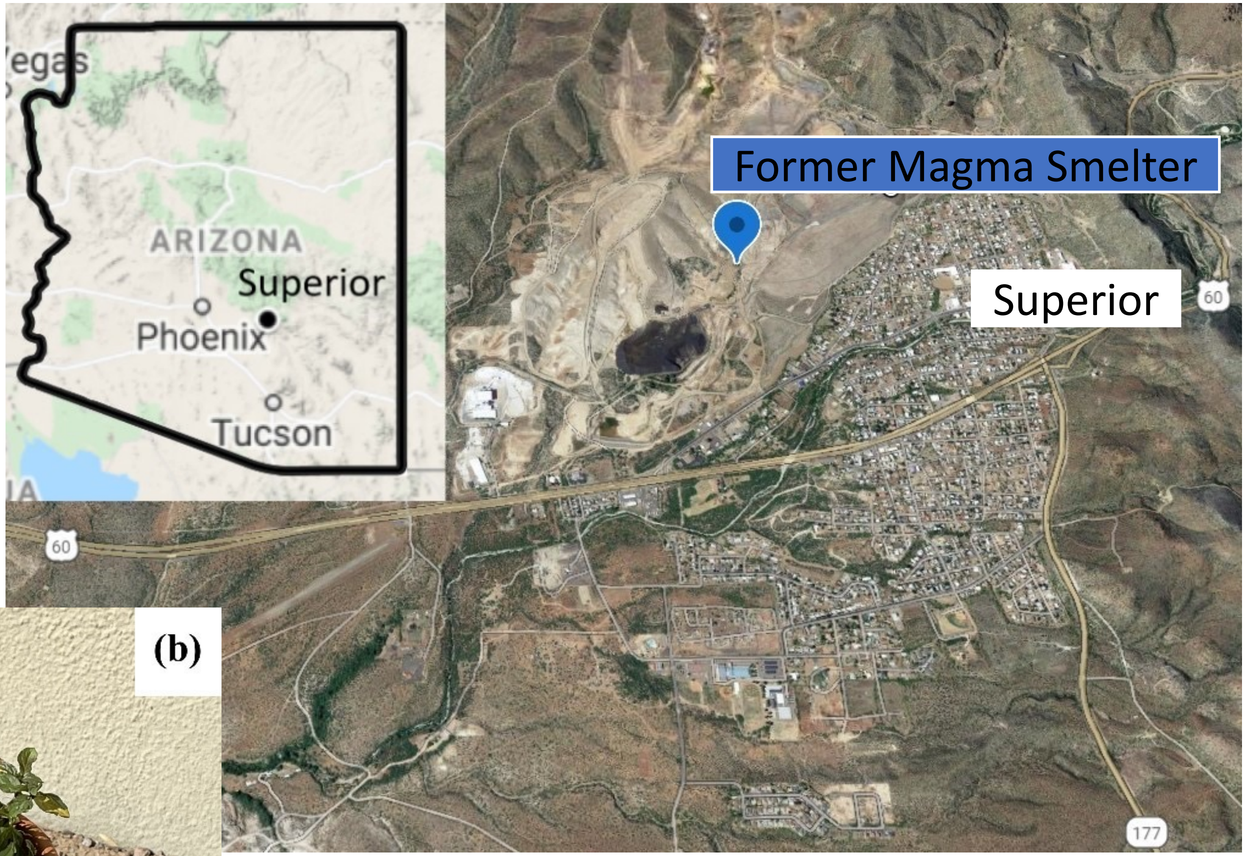
Goal of the Study

- 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

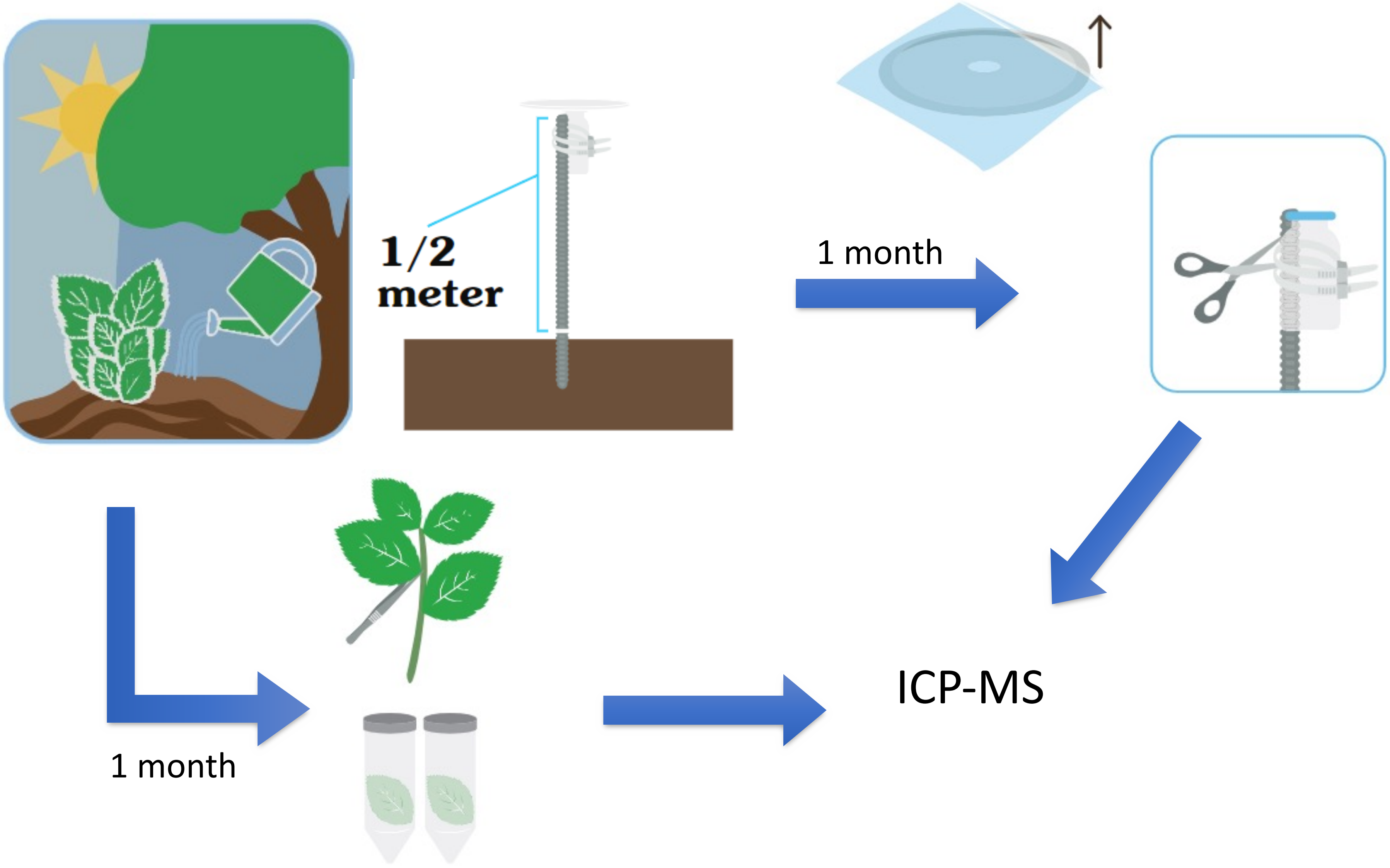
Sampling apparatus (a: frisbee, b: peppermint)



Superior, AZ and layout of surrounding town

Methods – Sampling Process

17	Frisbee
22	Foliar

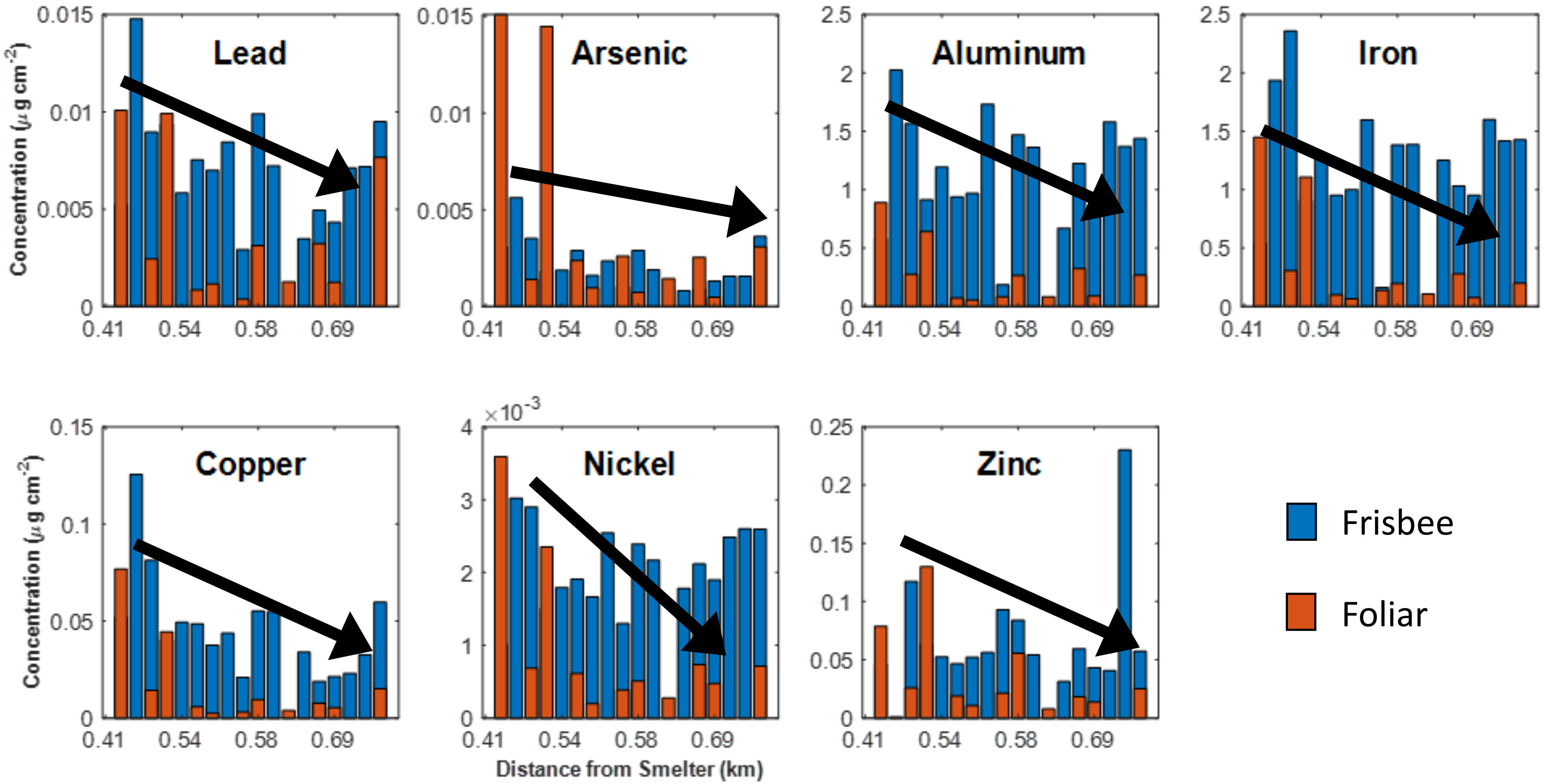


Results

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

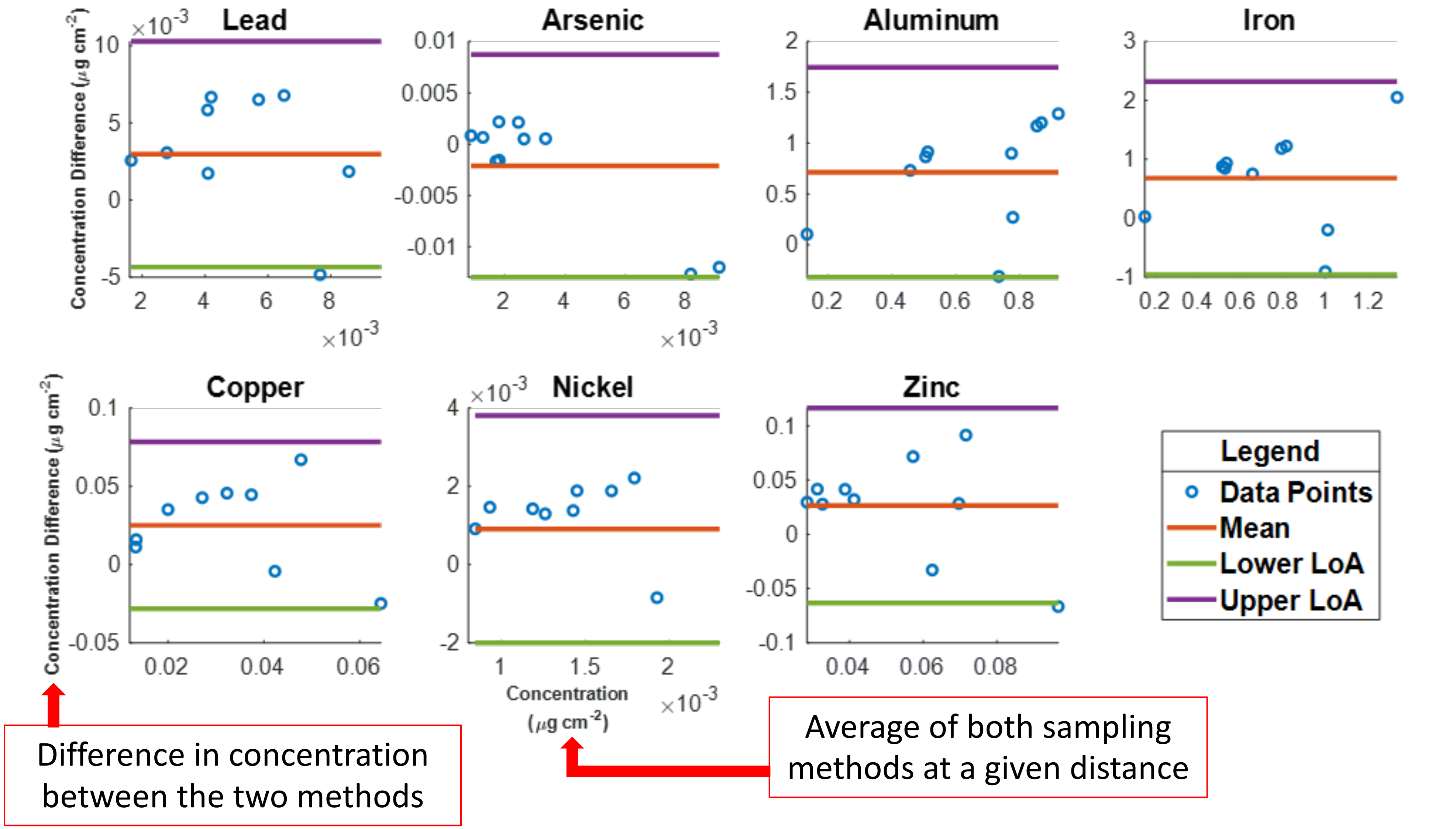
- Frisbee sampled higher concentrations per element per distance, on average
- 51.8 km generally had highest element concentration

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



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

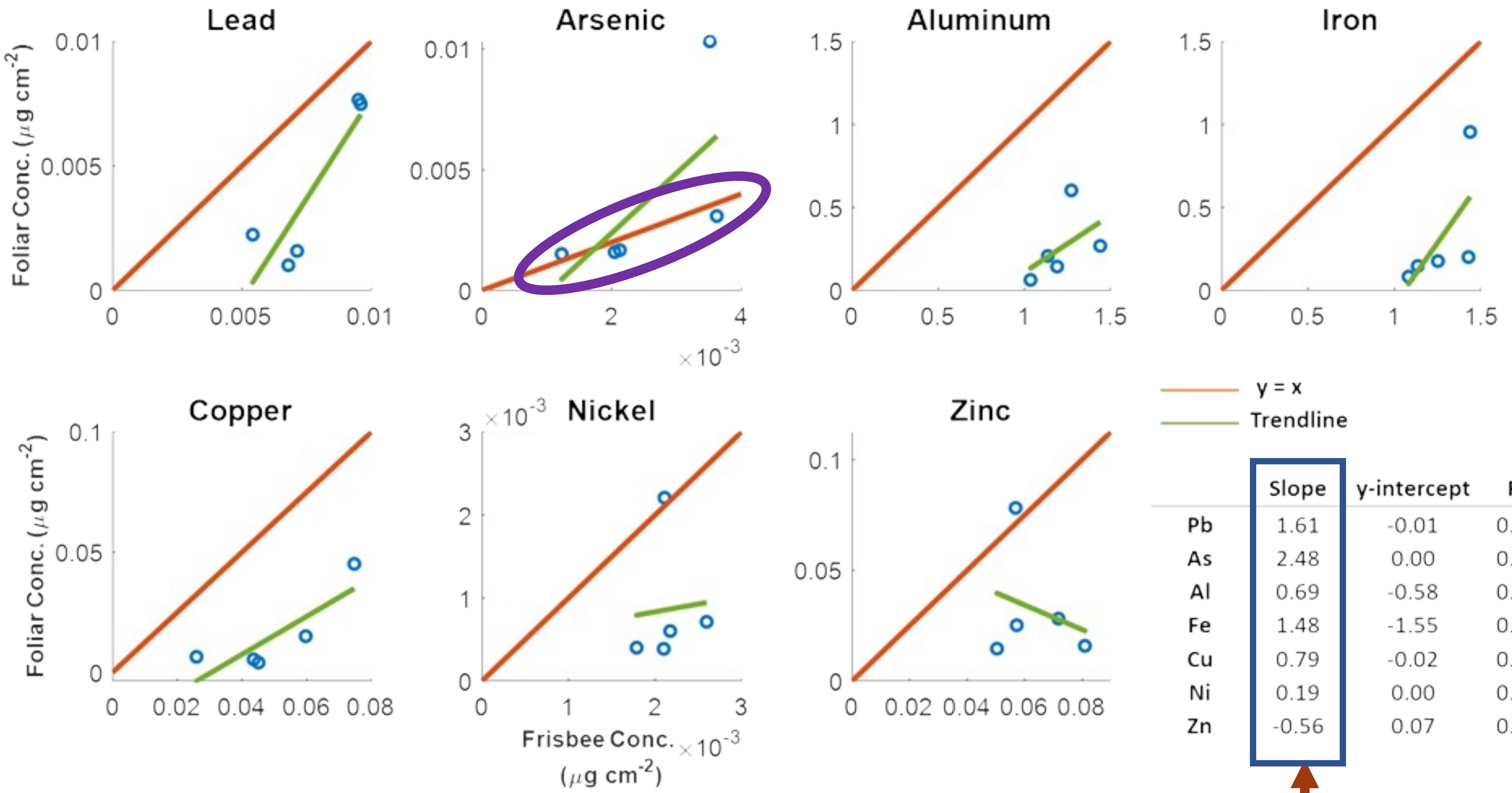
$$EF = \left[\frac{C_{n,sample}}{C_{ref,sample}}\right] / \left[\frac{C_{n,baseline}}{C_{ref,baseline}}\right]$$

(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

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Integrated Environmental Science & Health Risk Laboratory

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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