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

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Dust Workshop
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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

from Arizona Geological Survey, 2015
Motivation

• 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

1/2 meter

1 month

ICP-MS

1 month

<table>
<thead>
<tr>
<th></th>
<th>Frisbee</th>
<th>Foliar</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Results

<table>
<thead>
<tr>
<th>Distance (km from smelter)</th>
<th>Frisbee (µg cm(^{-2}))</th>
<th>Foliar (µg cm(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pb</td>
<td>As</td>
</tr>
<tr>
<td>0.4 - 0.79</td>
<td>0.010</td>
<td>0.004</td>
</tr>
<tr>
<td>0.8 - 0.99</td>
<td>0.007</td>
<td>0.002</td>
</tr>
<tr>
<td>1 - 1.49</td>
<td>0.007</td>
<td>0.002</td>
</tr>
<tr>
<td>1.5 - 2.0</td>
<td>0.005</td>
<td>0.001</td>
</tr>
<tr>
<td>51.8</td>
<td>0.009</td>
<td>0.004</td>
</tr>
</tbody>
</table>

- 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
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

<table>
<thead>
<tr>
<th>Number of points</th>
<th>Pb</th>
<th>As</th>
<th>Al</th>
<th>Cu</th>
<th>Ni</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance (km)</strong></td>
<td>Frisbee</td>
<td>Foliar</td>
<td>Frisbee</td>
<td>Foliar</td>
<td>Frisbee</td>
<td>Foliar</td>
</tr>
<tr>
<td>0.4 - 0.79</td>
<td>4</td>
<td>6</td>
<td>25.0</td>
<td>23.4</td>
<td>30.8</td>
<td>101.2</td>
</tr>
<tr>
<td>0.8 - 0.99</td>
<td>3</td>
<td>4</td>
<td>20.6</td>
<td>40.5</td>
<td>20.7</td>
<td>200.5</td>
</tr>
<tr>
<td>1 - 1.49</td>
<td>4</td>
<td>6</td>
<td>28.3</td>
<td>31.9</td>
<td>28.6</td>
<td>122.9</td>
</tr>
<tr>
<td>1.5 - 2.0</td>
<td>5</td>
<td>4</td>
<td>13.8</td>
<td>44.9</td>
<td>10.1</td>
<td>80.8</td>
</tr>
<tr>
<td>51.8</td>
<td>1</td>
<td>2</td>
<td>21.2</td>
<td>110.7</td>
<td>25.9</td>
<td>165.5</td>
</tr>
</tbody>
</table>

- 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)

\[ EF = \frac{C_{n,\text{sample}}}{C_{n,\text{baseline}}} / \frac{C_{\text{ref, sample}}}{C_{\text{ref, baseline}}} \]

(Goldschmidt, 1937)
• Most slopes close to 1 – indicating agreement between methods
• Outlier was kept in dataset because it represented samples closest to former smelter
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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National Institute of Environmental Health Sciences
Your Environment. Your Health.

gardenroots
A Citizen Science Garden Project