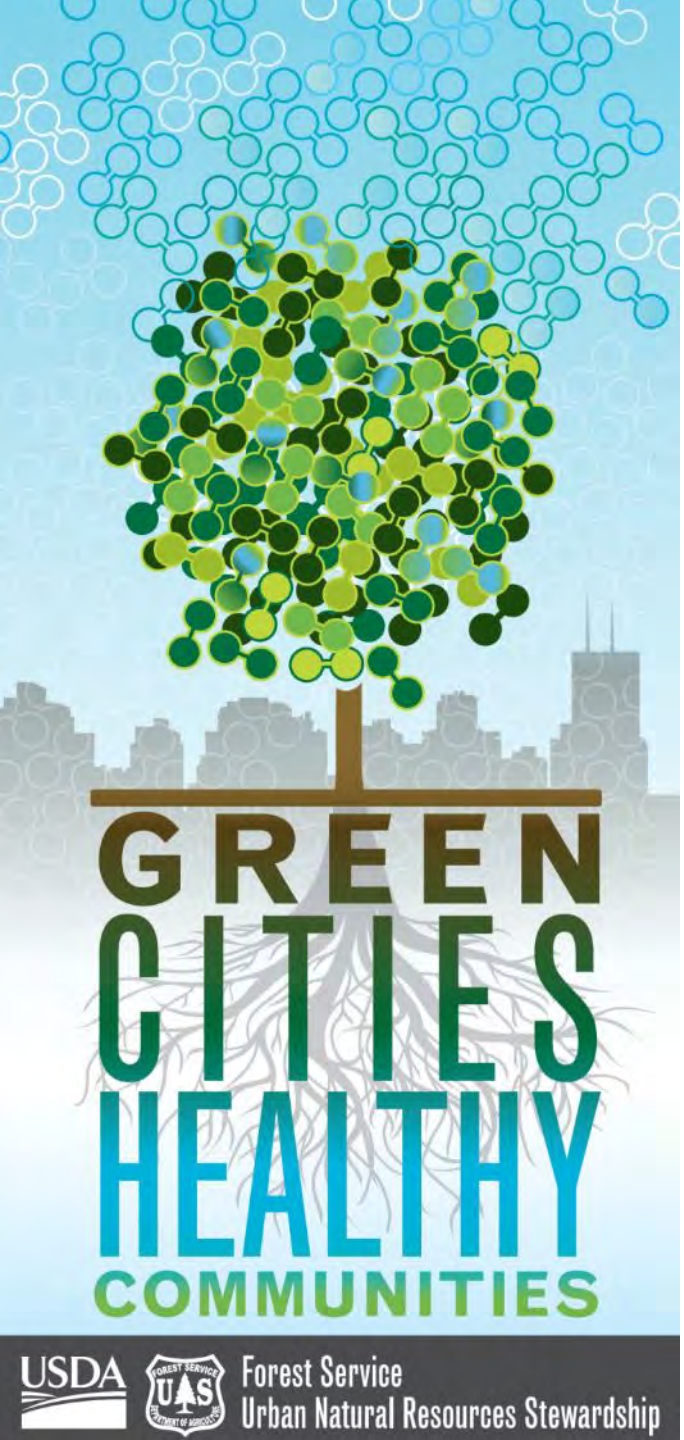

USDA Forest Service

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webinar series

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Using moss to detect air pollution in Portland, Oregon: Details of a groundbreaking study

Rob Mangold

Director, Pacific Northwest Research Station
USDA Forest Service
Portland, OR

Sarah Jovan

Research Ecologist
USDA Forest Service
Portland, OR

Julie Wroble

Toxicologist
US Environmental Protection Agency, Region 10
Seattle, WA

Katie McClintock

Air Enforcement Officer
US Environmental Protection Agency, Region 10
Seattle, WA

Using Moss to Detect Air Pollution in Portland

Sarah Jovan[1], Geoffrey Donovan[1], Demetrios Gatziolis[1], Igor Burstyn[2], Yvonne L. Michael[2], Michael C. Amacher[3], Vicente Monleon[1]

[1]U.S. Forest Service, PNW Research Station, Portland, OR.
[2]Drexel University, Dornsife School of Public Health, Philadelphia, PA.
[3]U.S. Forest Service, Logan Forestry Sciences Lab, Logan, UT.

THE
MOSSBUSTERS
Who ya gonna call?
(425) 772-7055
Roof Cleaning
Gutter Cleaning
Pressure Washing
Moss Removal & Treatment

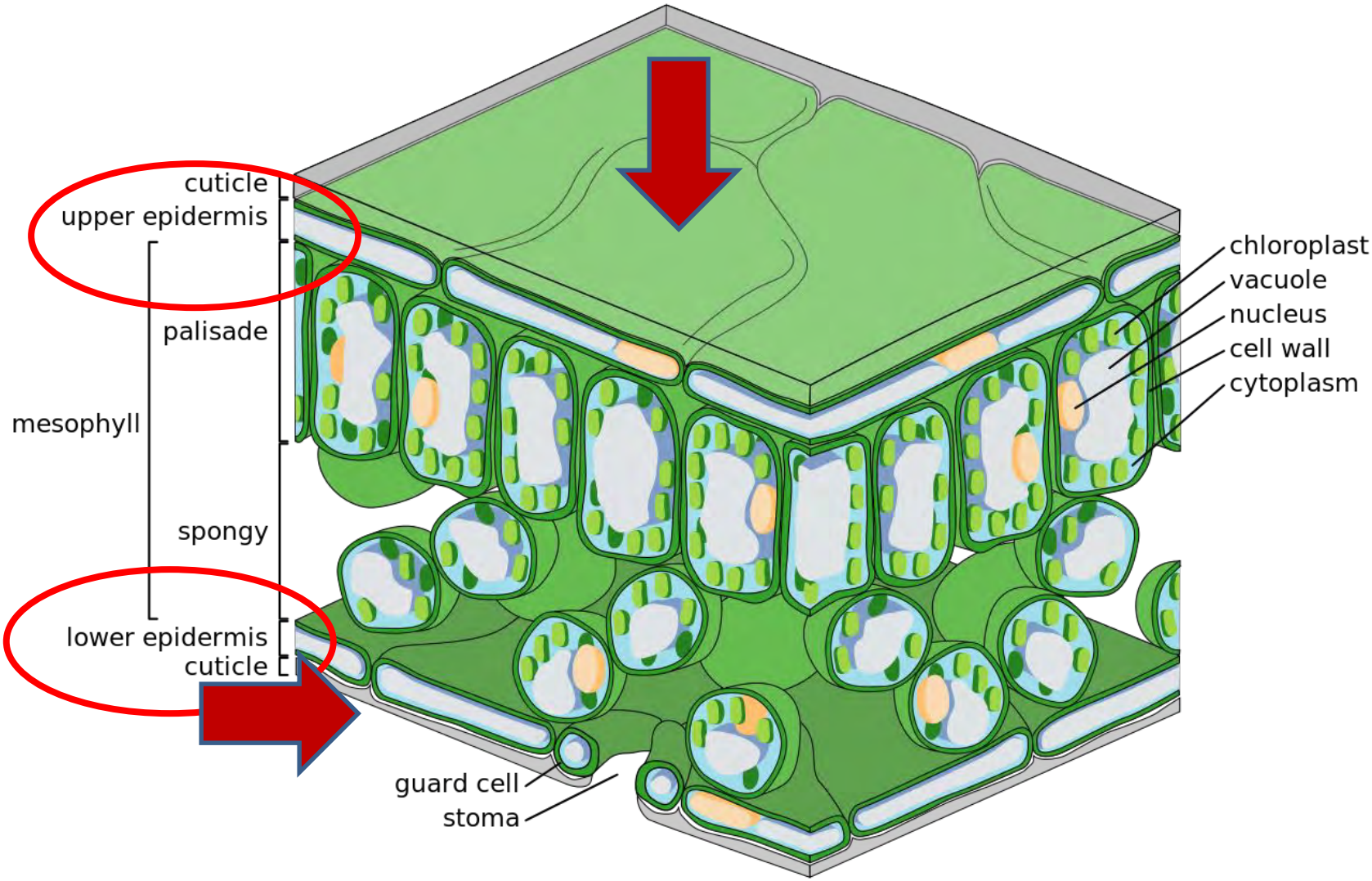
What is a moss?

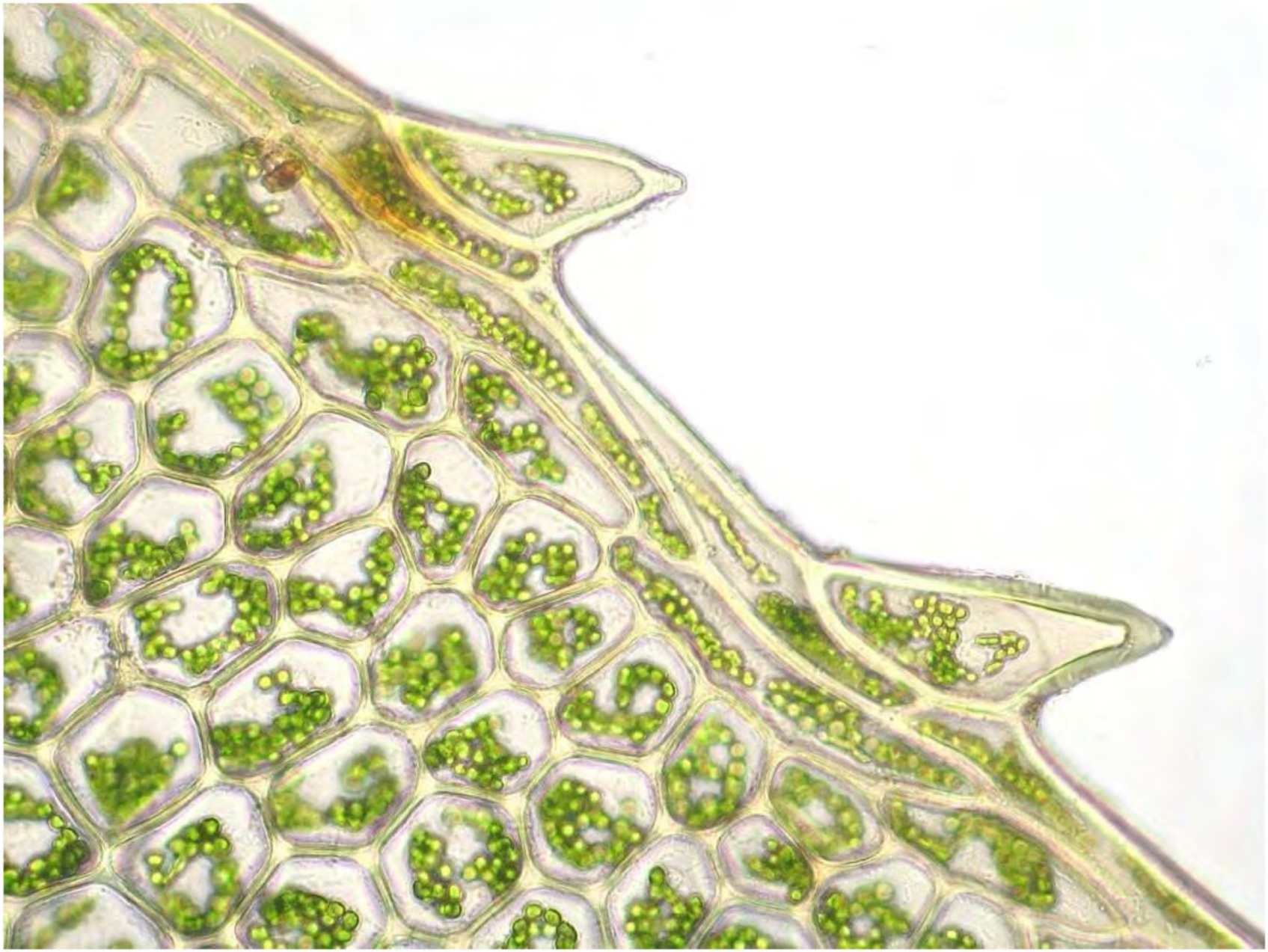
Definition: taxonomic division *Bryopsida*

small, non vascular plants

the oldest plant lineage…

Vascular plant leaf in cross-section





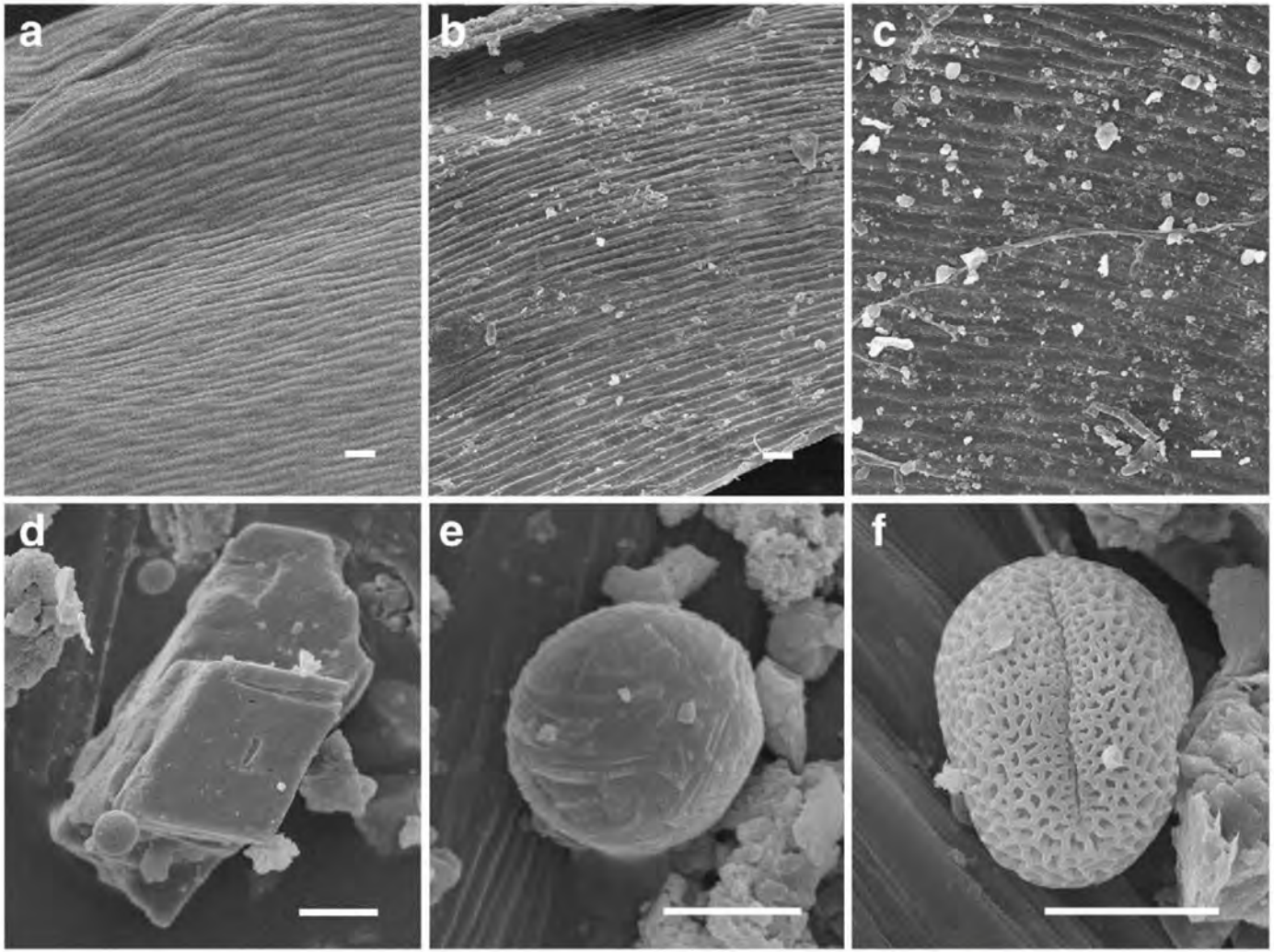
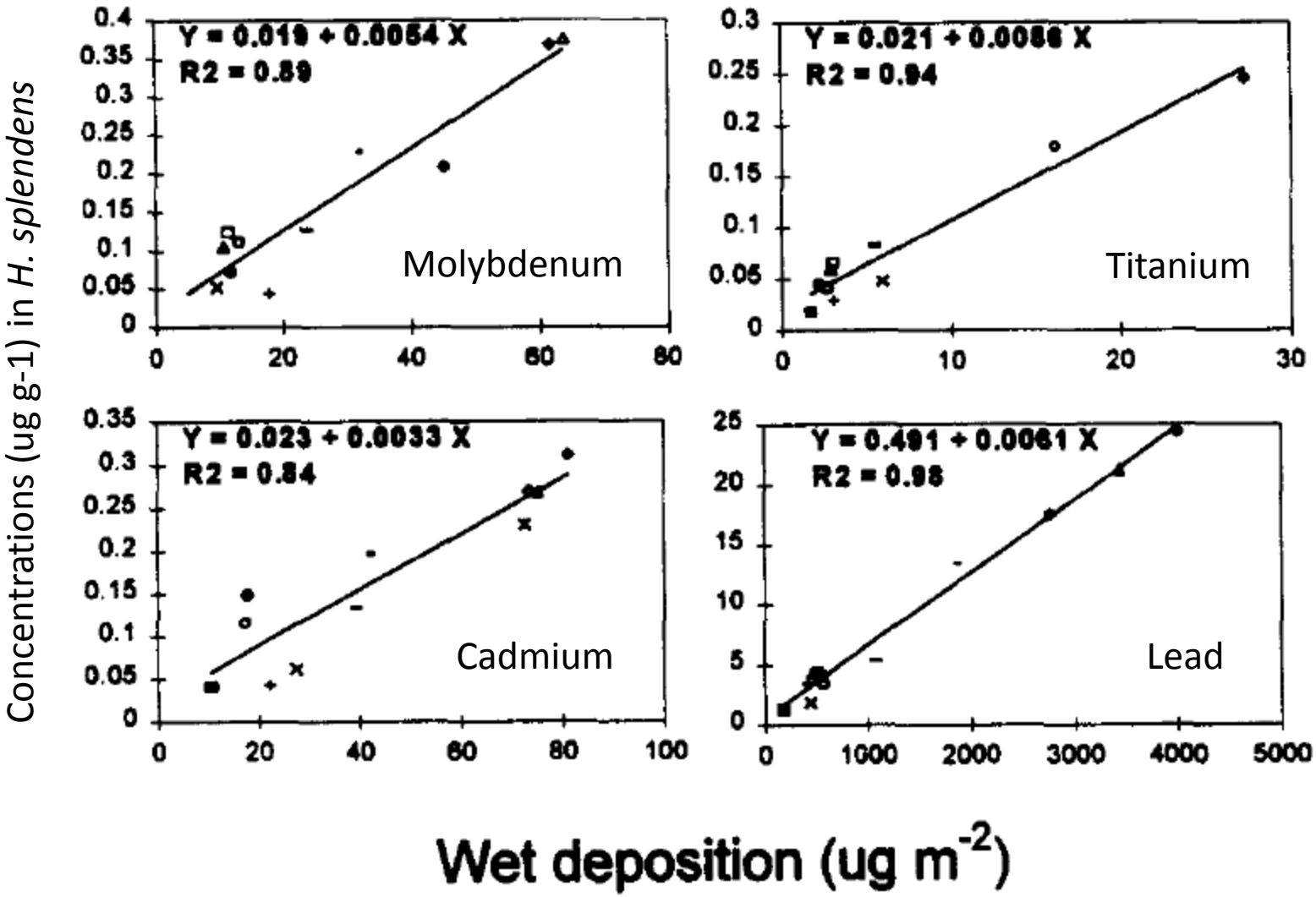


Fig. 5. SEM micrographs of moss leaflets before (a) and after exposure (b,c) in the green (b) and roadside (c) site pair nr. 9 of Fig. 1, and enlargement of particulate matter (d,e) and pollen grain (f). Bar = 10 μm (a–d, f); 3 μm (e).

Tretiach et al. 2011. Science of the Total Env. 409: 822-830



Berg and Steinnes 1997: Env Poll 98: 61-71

Unknowns…

- For some metals, not much is known about relationships to atmospheric concentrations.
- What other environmental factors (e.g. rainfall intensity, precipitation pH) affect metals in moss?
- What timeframe does the moss represent? (our best guess is 1 - 3 years)

Why use bioindicators?

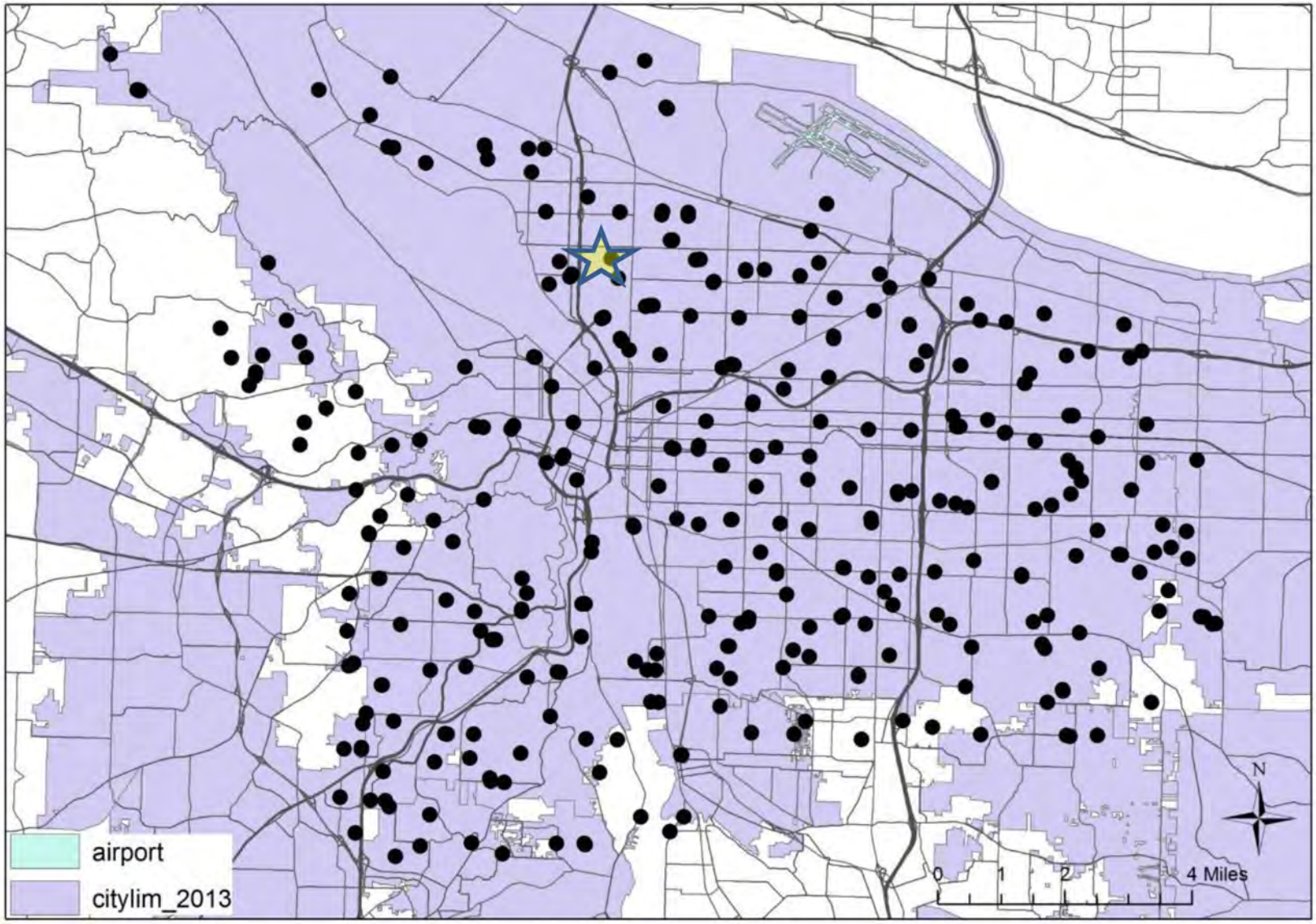
Expense per site

Air Q active instruments: ~$40K annually to measure metals

Moss: ~$150 per site

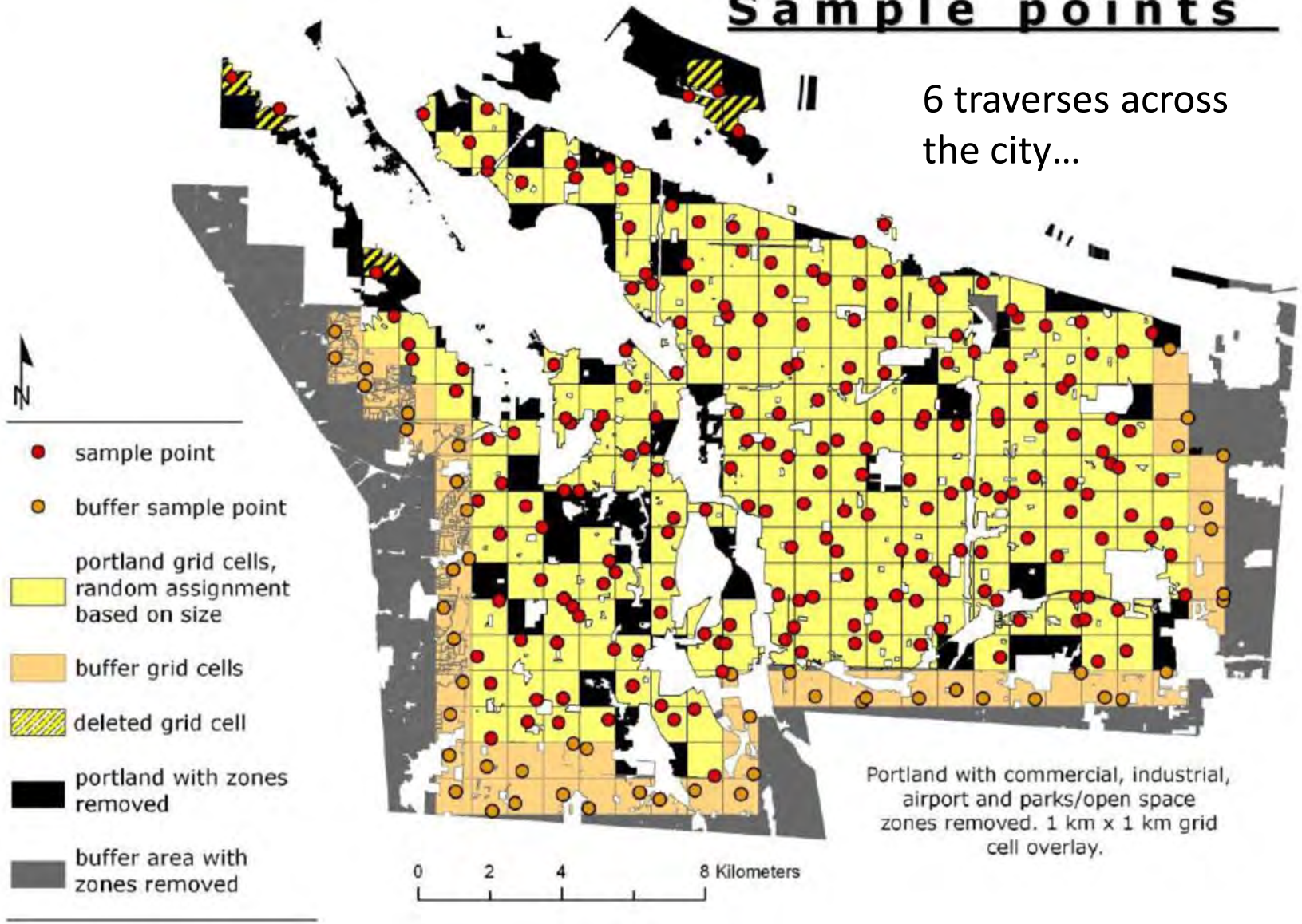
Moss samples = 346 in 2013

Air quality monitors = 1



Sample points

6 traverses across the city…

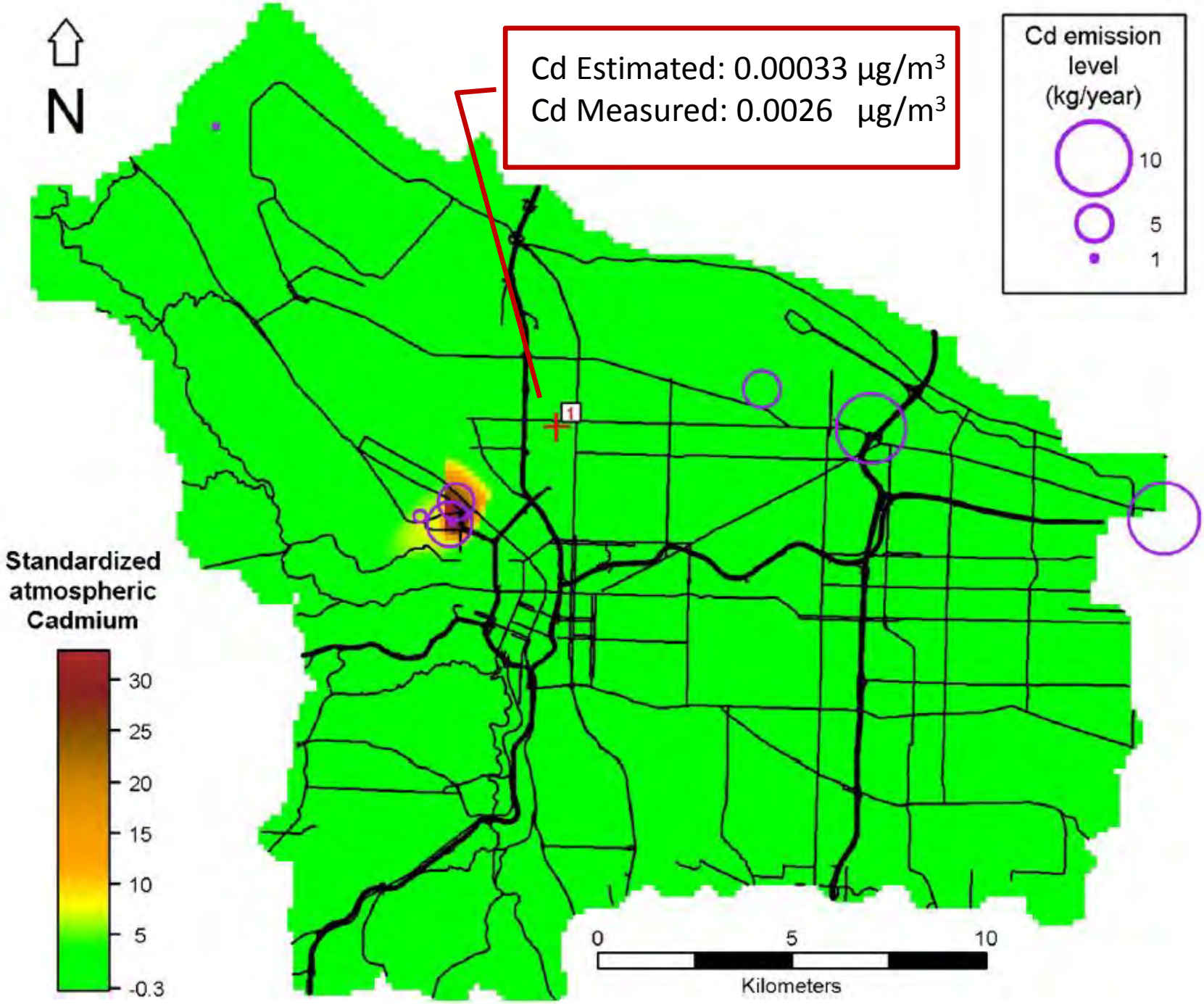


Portland with commercial, industrial, airport and parks/open space zones removed. 1 km x 1 km grid cell overlay.

Orthotrichum lyellii

U.S. distribution: AK, CA, ID, OR, WA

Analysis by ICP-OES:
Al, As, B, Ba, Ca, Cd,
Co, Cr, Cu, Fe, K, Mg,
Mn, Mo, Na, Ni, P,
Pb, S, Se, Si, Sr, Zn


N
Cd Estimated: 0.00033 µg/m3
Cd Measured: 0.0026 µg/m3
Cd emission level (kg/year)
10
5
1
1
Standardized atmospheric Cadmium
30
25
20
15
10
5
-0.3
0
5
10
Kilometers

Cadmium (Cd):

- Lung cancer
- Prostate cancer
- Kidney disease
- Learning difficulties in children
- For more info, see ATSDR Cas ID# 7440-43-9

Spatial modeling

- Built a spatial linear model of Ln(Cd) in moss using an exponential covariance structure
  - Backwards, step-wise model selection
  - Models estimated using restricted maximum likelihood (SAS 9.4 MIXED)
- Used final model to estimate Cd on a 50m grid across the city

Covariates

- Tree genus
- Weather (precipitation, temperature)
- Density of roads (IDW, 500m buffer)
- Tree canopy cover (IDW, 500m buffer)

Covariates

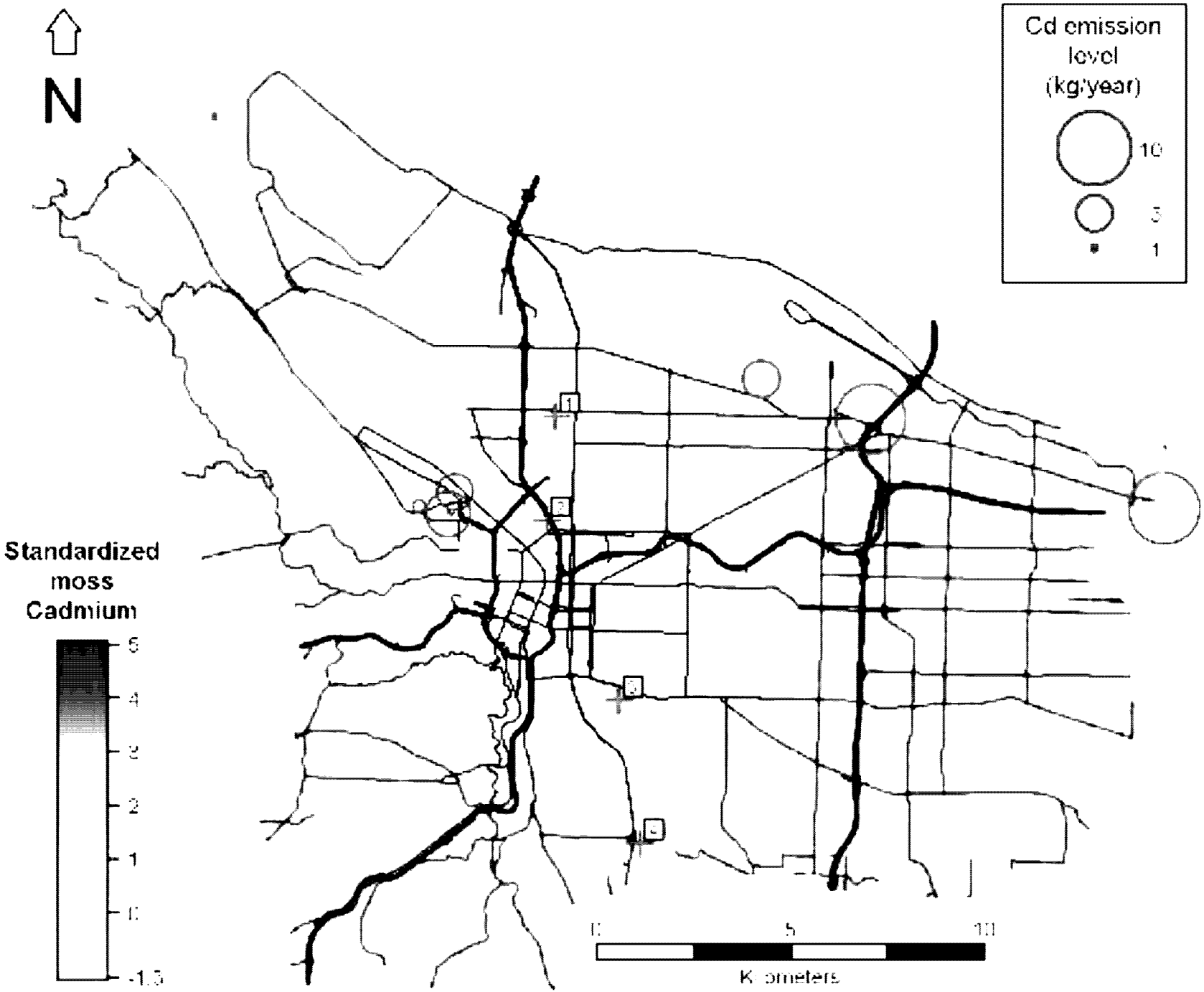
- Distance to permitted Cd emitters

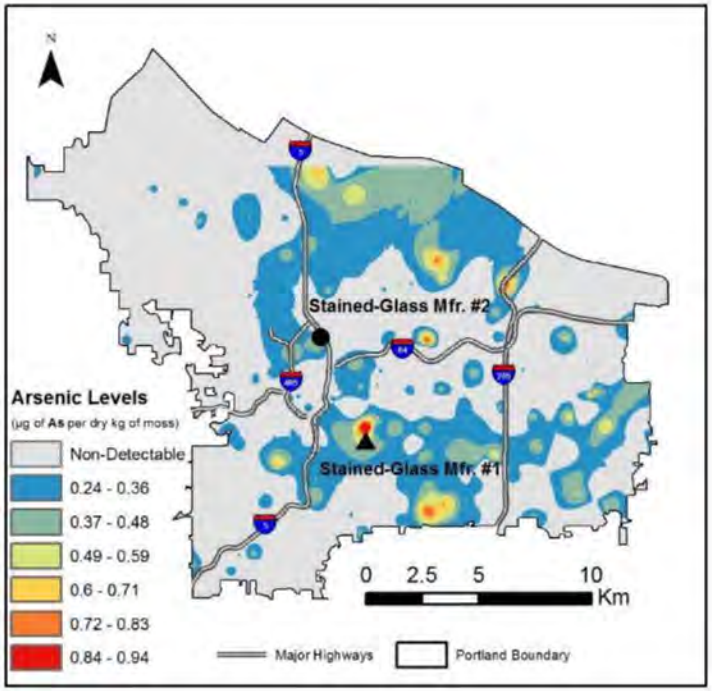
Covariates

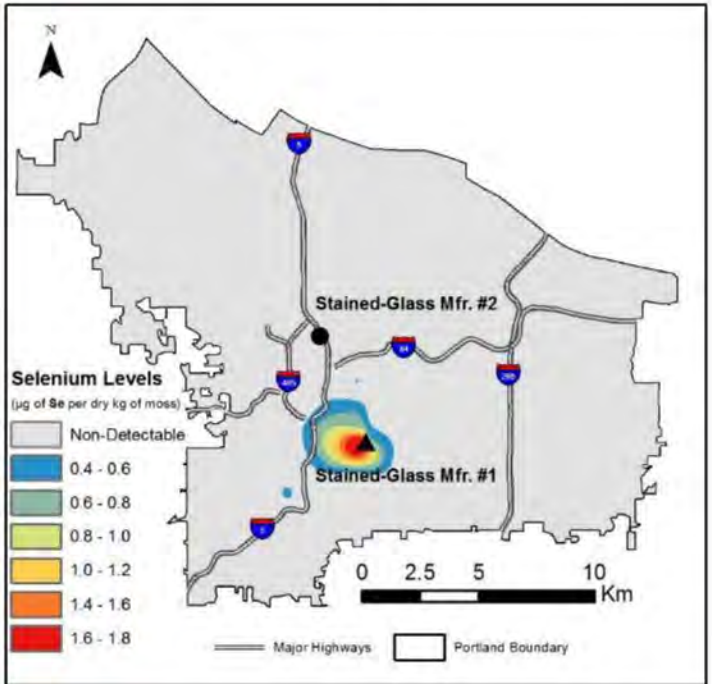
- **Distances to 2 unpermitted glass factories**

Covariates

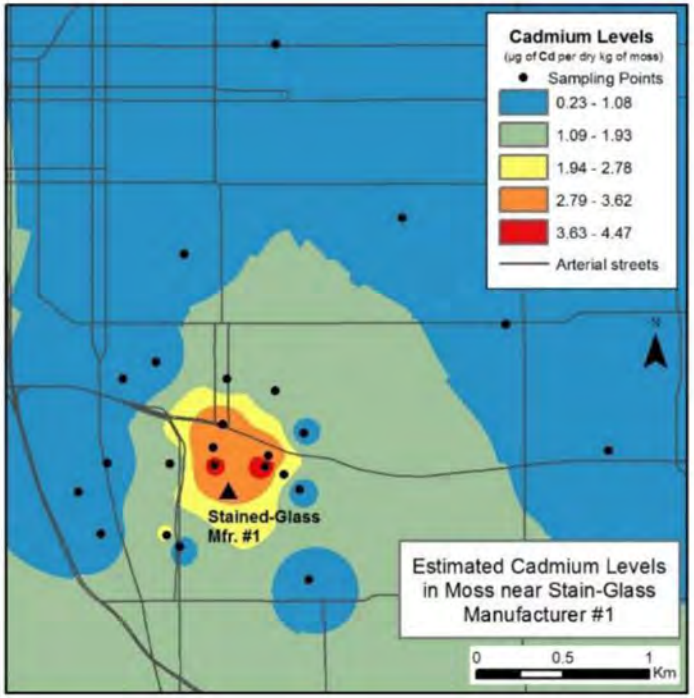
- **Distance to Washington border**
- **Percent industrial land** (500m)
- **Percent residential land** (500m)

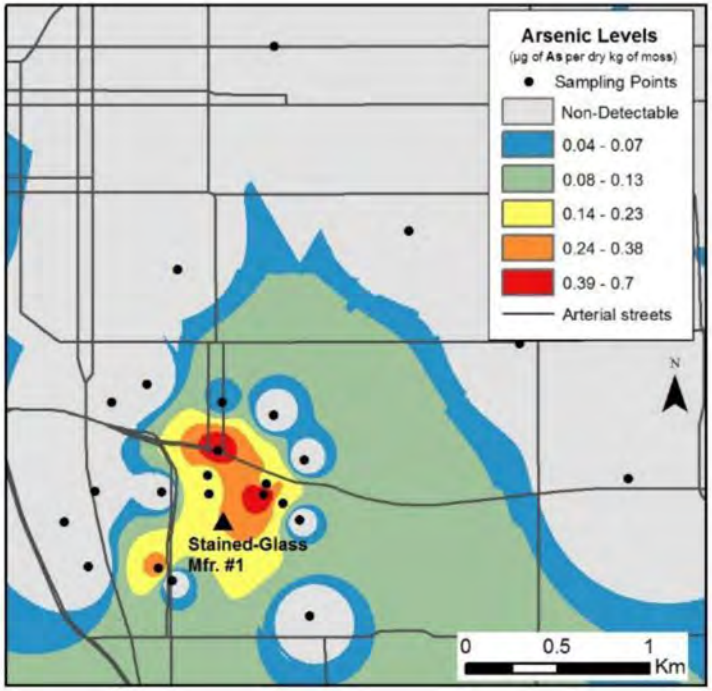

N
Cd emission level (kg/year)
10
5
1
Standardized moss Cadmium
5
4
3
2
1
0
-1.5
1
2
3
4
0
5
10
Kilometers

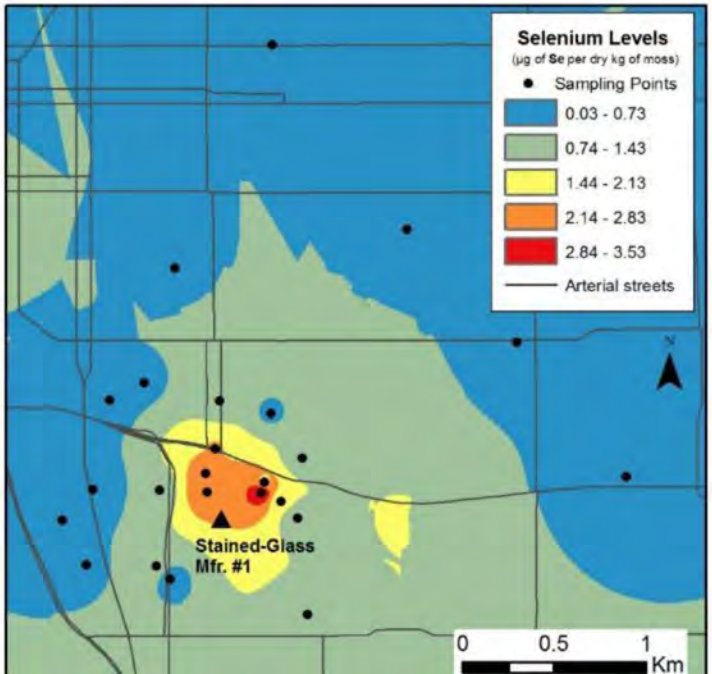

N
Stained-Glass Mfr. #2
Stained-Glass Mfr. #1
Arsenic Levels
(µg of As per dry kg of moss)
Non-Detectable
0.24 - 0.36
0.37 - 0.48
0.49 - 0.59
0.6 - 0.71
0.72 - 0.83
0.84 - 0.94
0 2.5 5 10
Km
Major Highways
Portland Boundary

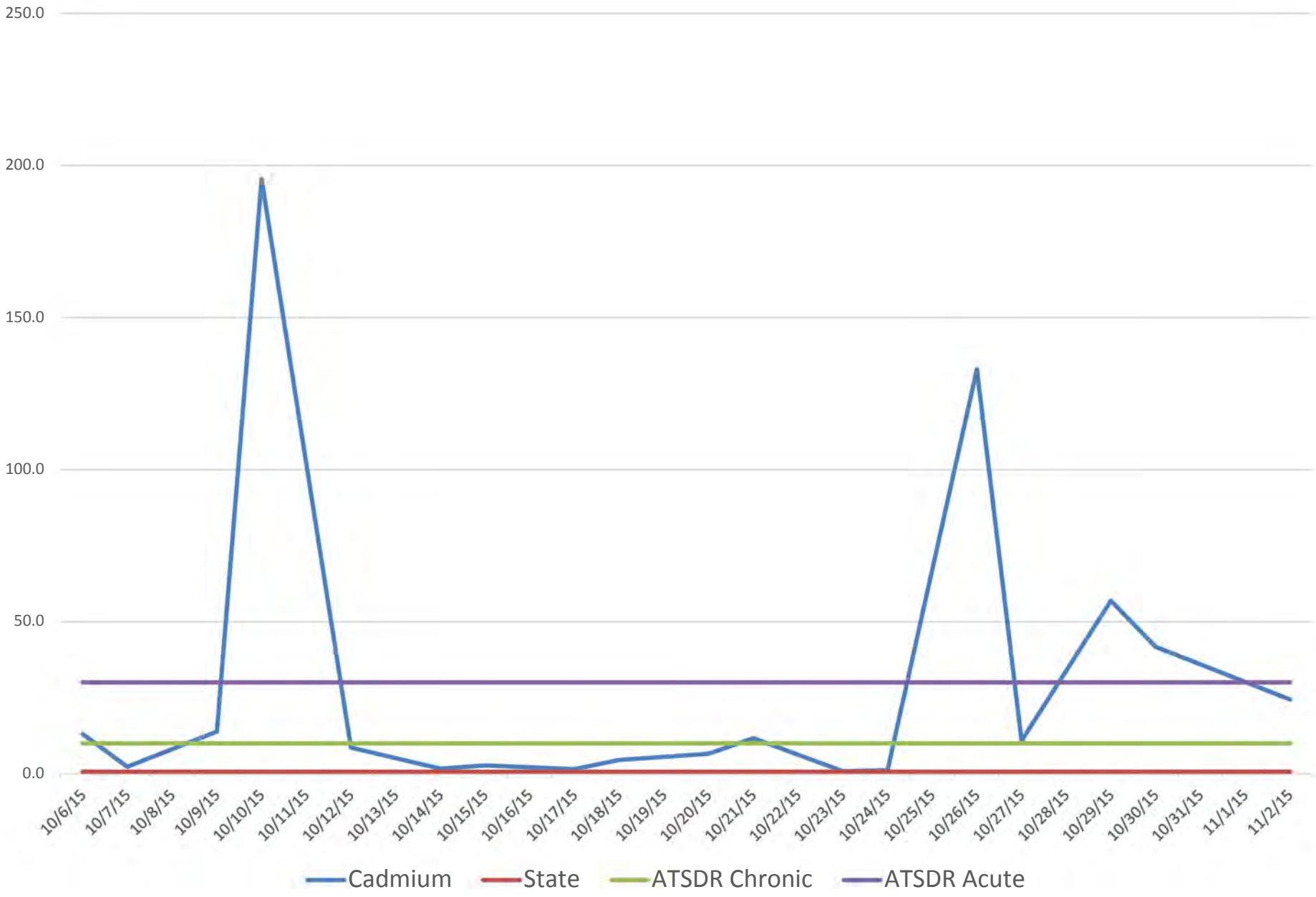

N
Stained-Glass Mfr. #2
Stained-Glass Mfr. #1
Selenium Levels
(µg of Se per dry kg of moss)
Non-Detectable
0.4 - 0.6
0.6 - 0.8
0.8 - 1.0
1.0 - 1.2
1.4 - 1.6
1.6 - 1.8
0 2.5 5 10
Km
Major Highways
Portland Boundary

- Informed DEQ of findings
- Oct 2015: DEQ monitored air near the facility
- Oct 2015: we sampled 25 additional sites in the area with the help of a PSU Urban Ecology class


Cadmium Levels
(µg of Cd per dry kg of moss)
Sampling Points
0.23 - 1.08
1.09 - 1.93
1.94 - 2.78
2.79 - 3.62
3.63 - 4.47
Arterial streets
N
Stained-Glass Mfr. #1
Estimated Cadmium Levels in Moss near Stain-Glass Manufacturer #1
0
0.5
1
Km


Arsenic Levels
(µg of As per dry kg of moss)
Sampling Points
Non-Detectable
0.04 - 0.07
0.08 - 0.13
0.14 - 0.23
0.24 - 0.38
0.39 - 0.7
Arterial streets
N
Stained-Glass Mfr. #1
0
0.5
1
Km


Selenium Levels
(µg of Se per dry kg of moss)
Sampling Points
0.03 - 0.73
0.74 - 1.43
1.44 - 2.13
2.14 - 2.83
2.84 - 3.53
Arterial streets
N
Stained-Glass Mfr. #1
0
0.5
1
Km


250.0
200.0
150.0
100.0
50.0
0.0
10/6/15
10/7/15
10/8/15
10/9/15
10/10/15
10/11/15
10/12/15
10/13/15
10/14/15
10/15/15
10/16/15
10/17/15
10/18/15
10/19/15
10/20/15
10/21/15
10/22/15
10/23/15
10/24/15
10/25/15
10/26/15
10/27/15
10/28/15
10/29/15
10/30/15
10/31/15
11/1/15
11/2/15
Cadmium
State
ATSDR Chronic
ATSDR Acute

Area of concern

Cleveland HS

Winterhaven
K-8

Moss (and lichens) are a valuable screening tool for prioritizing the location of air monitoring instruments

Considerations for future studies

- Finding a suitable bio-indicator - requires scouting
- Unfavorable conditions include: Dry, desert-like climate, high SO_2

- Alternatives: "moss bags" with *Sphagnum,* bromeliads, other moss & lichen transplants, tree bark

Sphagnum moss bag

Additional applications

- Other pollutants can be measured: e.g. nitrogen, sulfur, mercury, PAHs, PCBs, dioxins and furans, PDBEs, some pesticides, herbicides, radionuclides

- Isotope ratios in moss/lichen: can help differentiate between emissions sources (natural vs mobile vs different types of industrial)

Next steps:

- Publishing remaining metals data this summer
- Reciprocal transplant/calibration study with Portland State University
- Cincinnati, summer 2017
- **Other priorities/suggestions??**

Thanks!