RUTGERS
THE STATE UNIVERSITY
OF NEW JERSEY

Understanding and Controlling Metal Contamination in Urban Gardens

Ashaki A. Rouff
Associate Professor
Environmental & Sustainable Geochemistry Group
Department of Earth & Environmental Sciences
Rutgers University, Newark, NJ

Outline

- What are soil contaminants?
- Heavy metal contaminants in urban areas.
- How to determine metal contaminants in soils.
- Newark urban gardens as a case study.

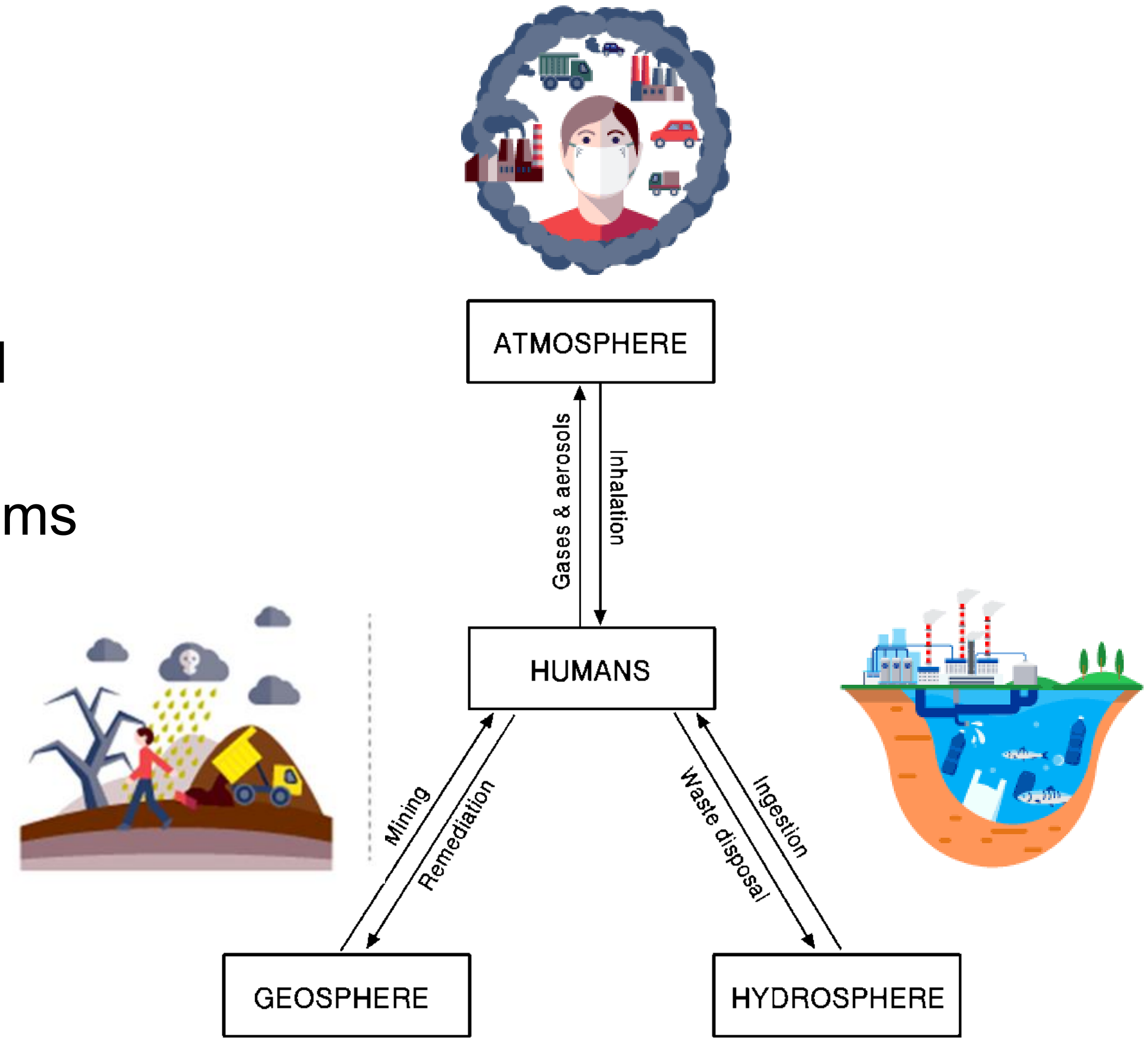
Soil Contaminants

- Contaminant
  - Unwanted substance added to a system
  - Present higher than natural concentrations
  - Changes the natural composition of the system
- Pollutant
  - Contaminant that has a net negative impact on the environmental system
- Toxic Pollutant
  - Pollutant that has a negative impact on biota and/or human health

Soil Contaminants

- (Toxic) Pollutants:
  - Substances identifiable in excess
  - Can be produced by both natural and anthropogenic processes
  - Known to be harmful to living organisms

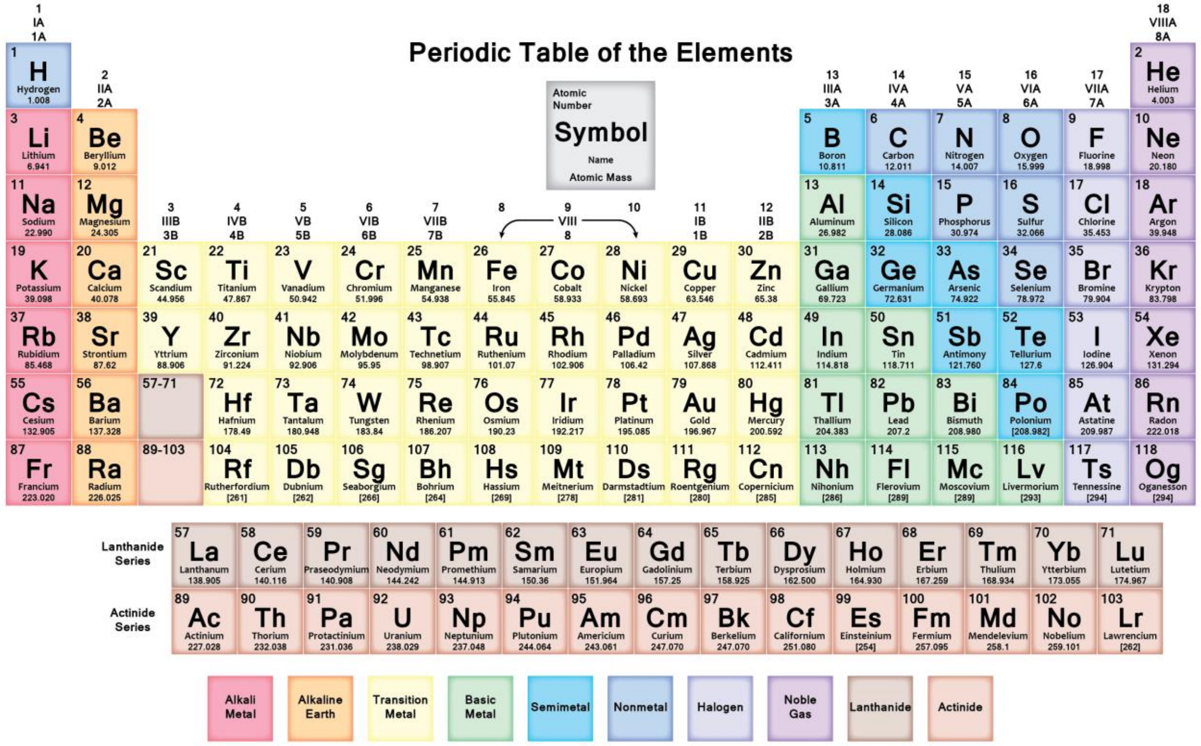
- Include:
  - Pathogens
  - Nutrients
  - Synthetic organic chemicals
  - Heavy metals



RUTGERS

Heavy Metals

- Have a high atomic number, atomic weight and a specific gravity greater than 5.0
- Include
  - Metalloids
  - Transition metals
  - Basic metals
  - Lanthanides
  - Actinides



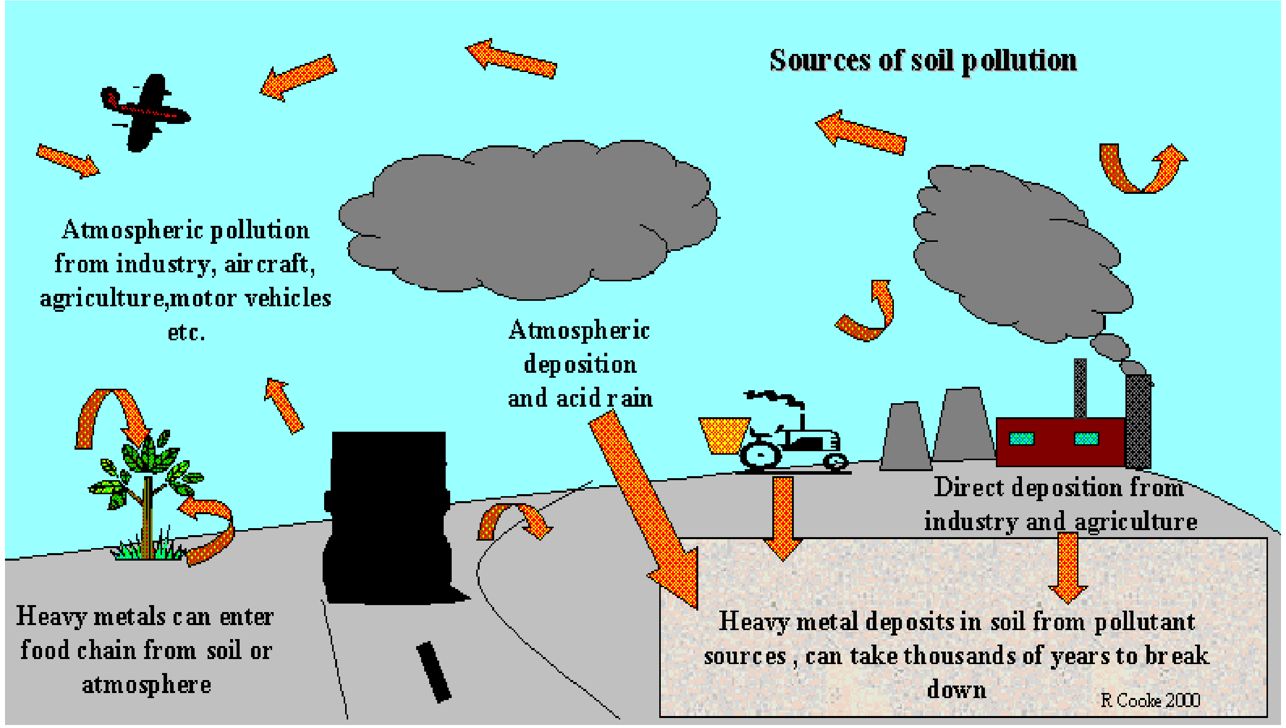
Sources of Heavy Metals in Urban areas

- Transportation
  - Traffic and vehicles emissions
  - Brake and tyre wear
  - Weathering of asphalt and roadside material

- Industrial activities
  - industrial discharge
  - power and desalination plants,
  - fuel combustion

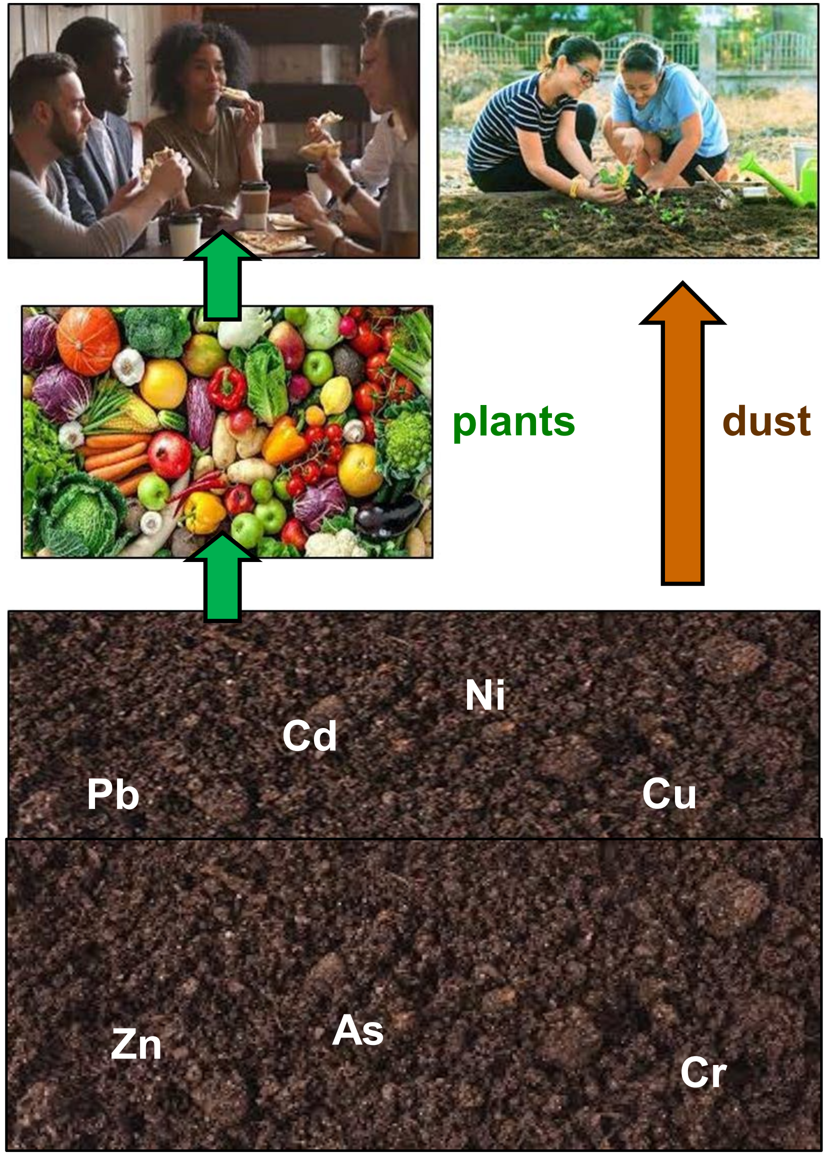
- Household
  - Consumer products
  - Roofing materials
  - Paint

Urban soil quality



arsenic (As)
cadmium (Cd)
chromium (Cr)
copper (Cu),
zinc (Zn)
nickel (Ni)
mercury (Hg)
lead (Pb)

Pollutant transfer pathways



Urban Geochemistry

impact of chemical dispersion of pollutants arising from urbanization on both ecosystem integrity and human health

Which metals? Where are they? What are they bound to?
Are they mobile and/or bioavailable?

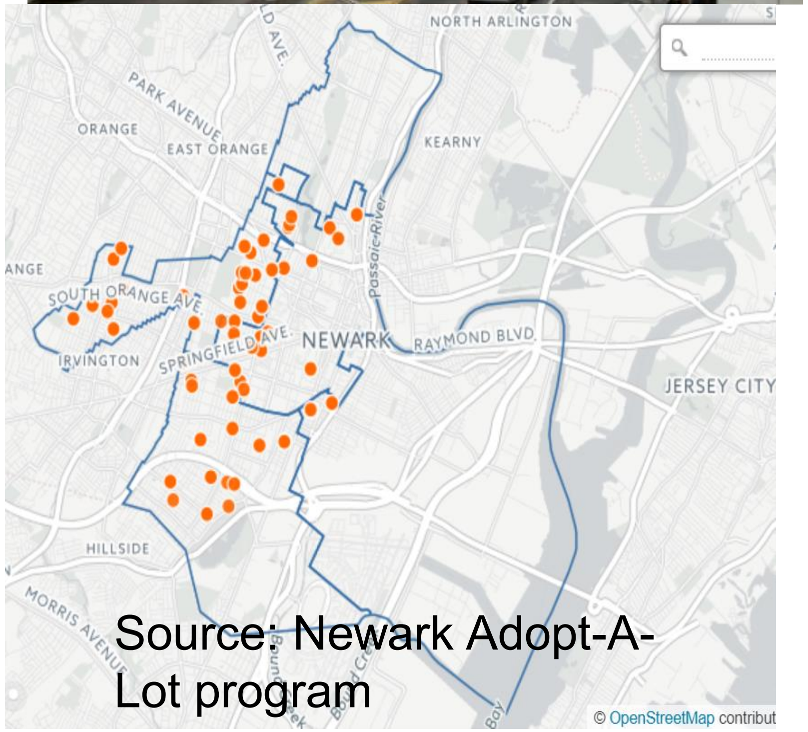
Newark: A Case Study

- Newark is the most populous city in NJ, and is the second largest city of the NYC Metropolitan area – a Megacity

- Major air, shipping, and rail hubs and industry and residences

- Suffers from legacy and current pollution from toxic wastes, manufacturing & industry, transportation; several superfund sites.

- Numerous organizations manage urban farming initiatives that involves local community residents, school children and corporate partners



Source: Newark Adopt-A-Lot program

Soil Quality Standards

Residential Soils	
Contaminant	**mg/kg**
Ag	390
As	19
Cd	78
Co	1,600
Cu	3100
Hg	23
Ni	1600
Pb	400
Se	390
Zn	23,000

- Minimum standards for remediation of residential and non-residential direct contact soils, NJDEP
- Sets levels at which metals may pose a threat to human health via ingestion, dermal and inhalation pathways
- Protects human health but also the environment

Methods to Determine Heavy Metal Contamination

- In-situ analysis
  - Portable X-ray fluorescence analyzer

- Sampling and ex-situ analysis
  - Inductively-coupled optical emission spectrometer

Limits of Detection

XRF LOD for Contaminants in Soil (ppm, mg/kg) for a Standard Reference Material (SRM).

Element	SRM	Element	SRM
Ca	500	Rb	10
Sc	400	Sr	11
Ti	160	Zr	15
V	70	Mo	15
Cr	85	Ag	10
Mn	85	Cd	12
Fe	100	Sn	30
Co	260	Sb	30
Ni	65	Ba	100
Cu	35	Hg	10
Zn	25	Pb	13
As	11	Th	20
Se	20	U	20

ICP-OES LOD with different configurations ug/L

Zn 213.857	0.7	0.2	0.2
Te 214.282	13	15	11
Pt 214.424	11	1.8	1.8
Cd 214.439	0.5	0.1	0.1
Pb 220.353	9.2	2.2	2.2
Bi 223.061	9.1	2.2	2.3
Ir 224.268	7.9	1.7	1.8
Re 227.525	5.6	1.5	1.5
In 230.606	26	5.6	6.0
Ni 231.604	4.5	0.9	0.9
Fe 238.204	1.6	0.2	0.3
Co 238.892	2.7	0.6	0.6
Au 242.794	3.1	1.1	1.2
B 249.772	0.6	0.3	0.3
Si 251.611	4.4	0.9	0.9
Mn 257.610	0.2	0.1	0.1
Lu 261.541	0.2	0.05	0.05
Ta 263.558	5.0	1.5	1.5
Hf 264.141	3.7	0.9	0.8
Cr 267.716	1.1	0.2	0.2

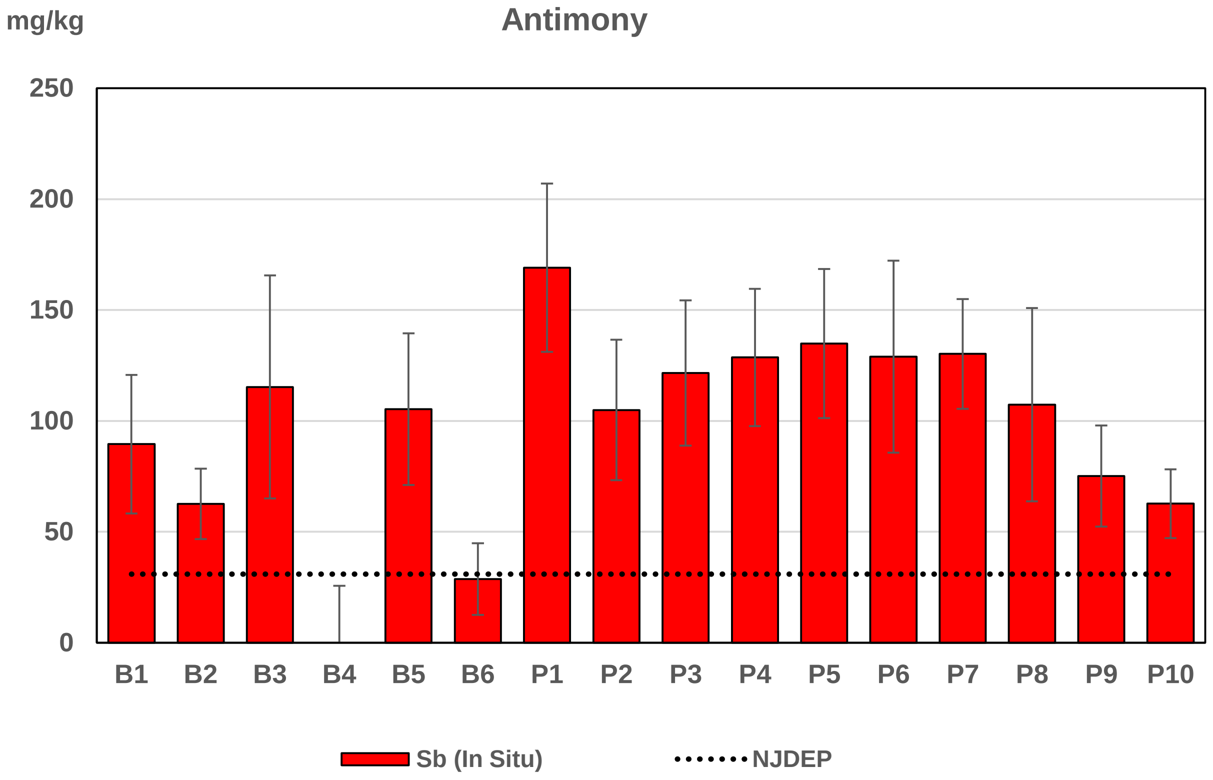
NJDEP Limits

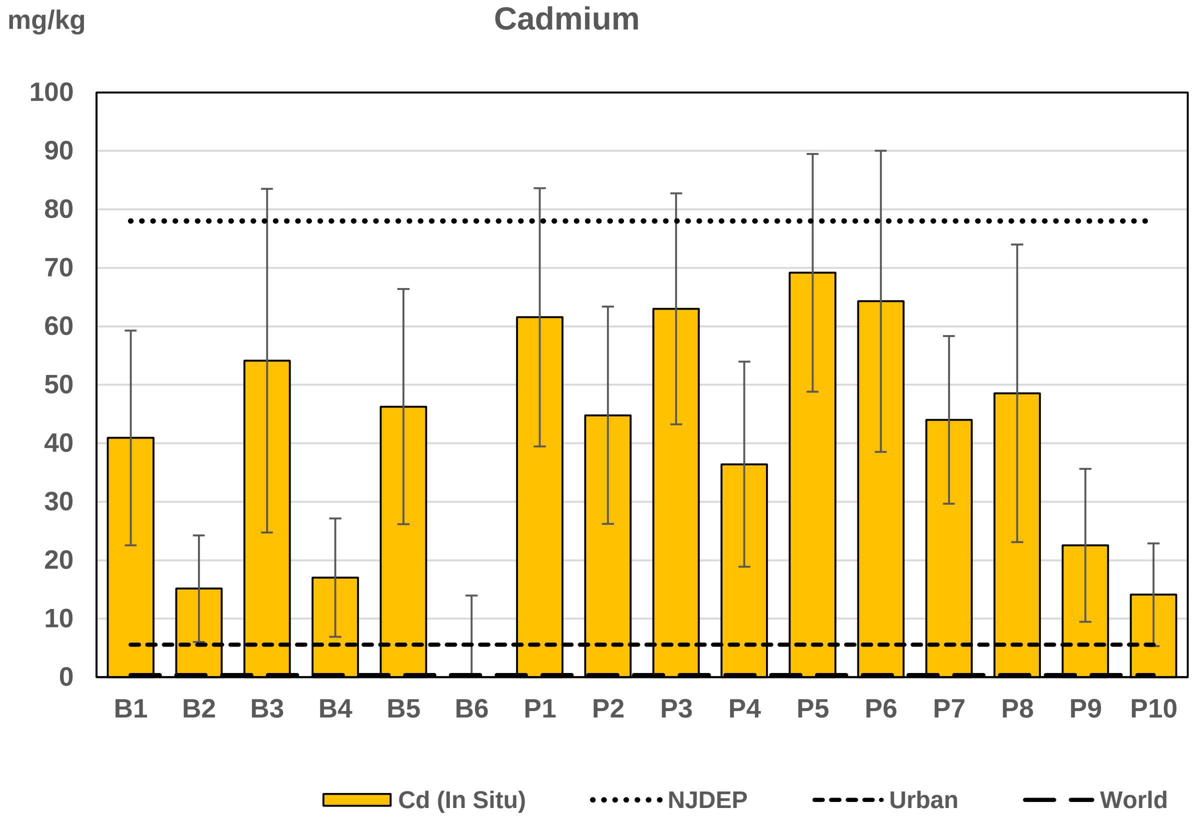
Residential Soils	
Contaminant	**mg/kg**
Ag	390
As	19
Cd	78
Co	1,600
Cu	3100
Hg	23
Ni	1600
Pb	400
Se	390
Zn	23,000

In-Situ XRF for Heavy Metals

- XRF Analysis using EPA Method 6200
- Remove large debris from the soil surface e.g. rocks, pebbles, leaves, vegetation, roots, and concrete.
- Smooth with a stainless-steel trowel and/or compact the soil
- Soil should not be saturated with water ($\leq$ 20%).
- Position the analyzer on the desired analysis spot, ensure the nose of the analyzer is making contact with the soil, and then initiate a reading.
- Sample in a grid, or areas of most concern

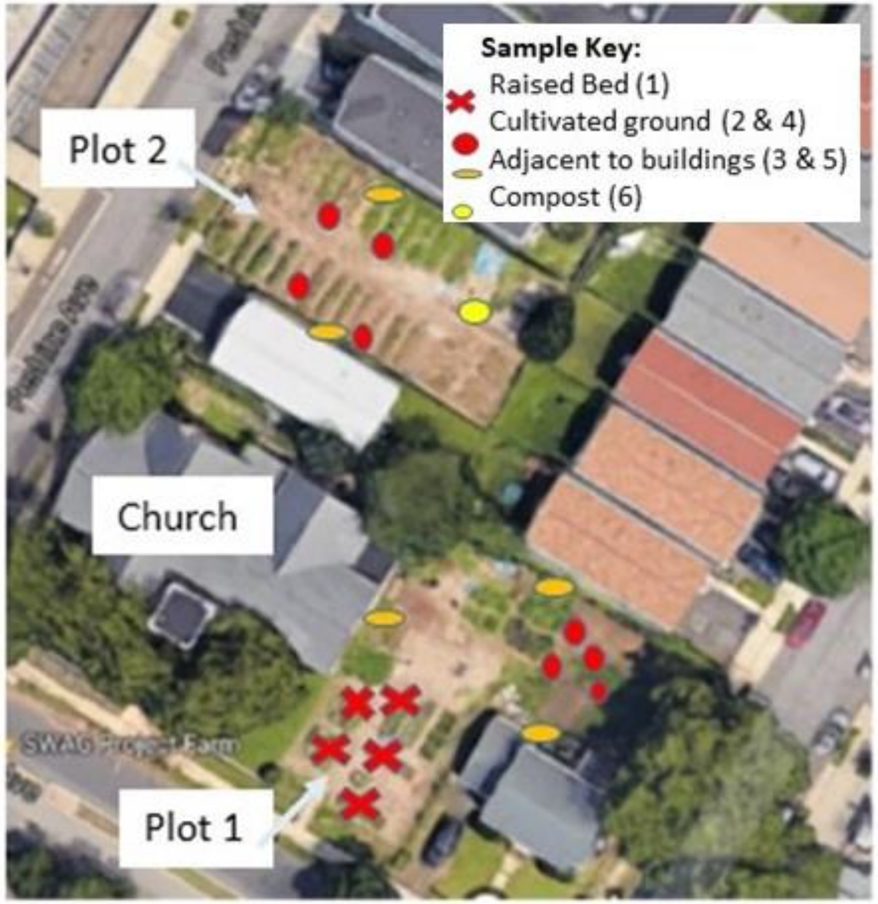
In-Situ XRF for Heavy Metals





Sampling and Ex-Situ Analysis for Heavy Metals

Site 1



Located in the South Ward

Methods

Sampling
- 4 subsamples of soil were collected at 20-30 cm depth
- Subsamples were mixed into a single composite soil sample

Sieving, drying
- Samples were air dried and sieved (2 mm)
- Dried in a muffle furnace at 105 ºC for 24 hours

Total metal extraction
- A portion of dried <2mm fraction was digested with 1 M nitric acid[1](with continuous shaking) for 2 hours
- Extractant was filtered using a 0.45 µm PES syringe filter and stored for analysis

Tessier scheme of extraction

To determine metal associated with the various fractions of soil[2].

Fraction	Description	Mineral/Organic matter association
1	Exchangeable	Hydrated Fe-Mn oxides and humic acids
2	Acid Soluble	Carbonates
3	Reducible	Fe-Mn oxides
4	Oxidizable	Organic matter (humic and fulvic acids)

Fraction	Reagent
1	1 M MgCl2 (pH 7)
2	1 M NaOAc (pH 5)
3	0.04 M NH2OH.HCl (in 25% HOAc)
4	H2O2/HNO3 (pH 2), NH4OAc (3.2 M)

1. Carter, M. R., ed. 1 M HNO_3 Extraction. Soil Sampling and Methods of Analysis, edited by Carter, M. R. Boca Raton, Fl: Lewis Publishers, 1993
2. Tessier, P. G. C. Campbell, and M. Bisson Sequential extraction procedure for the speciation of particulate trace metals, Analytical Chemistry 1979 51 (7), 844- 851

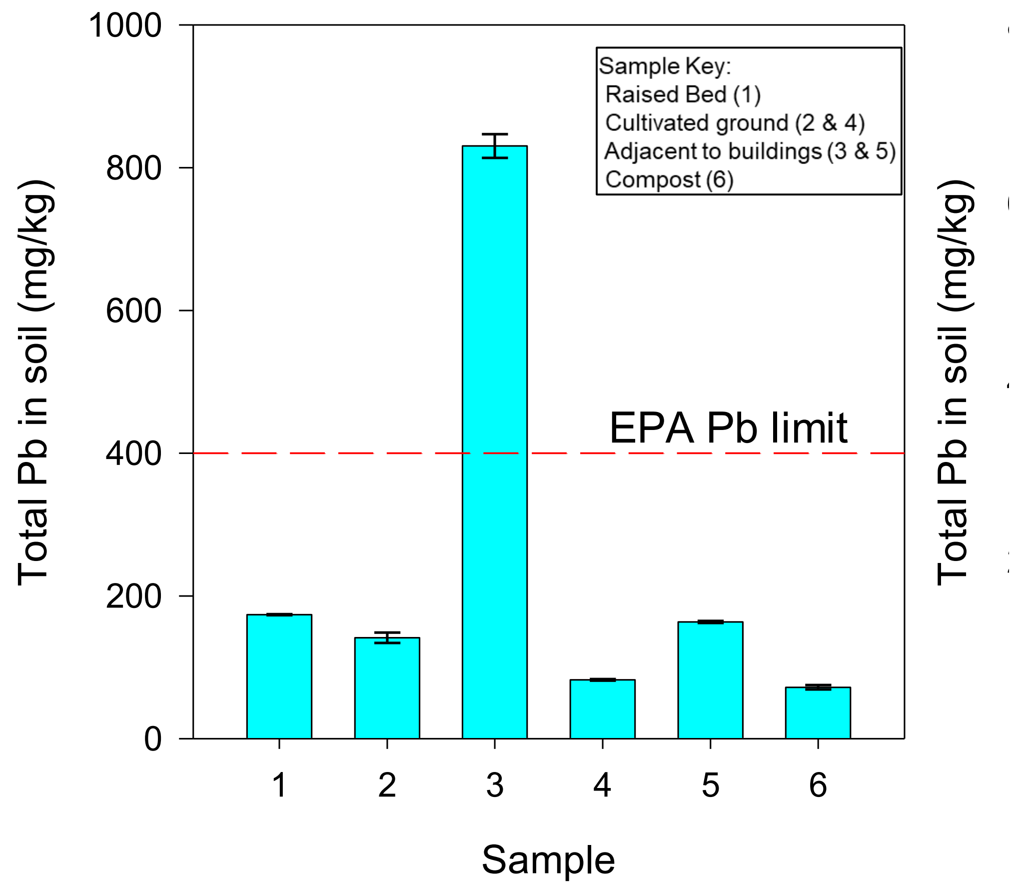
Methods

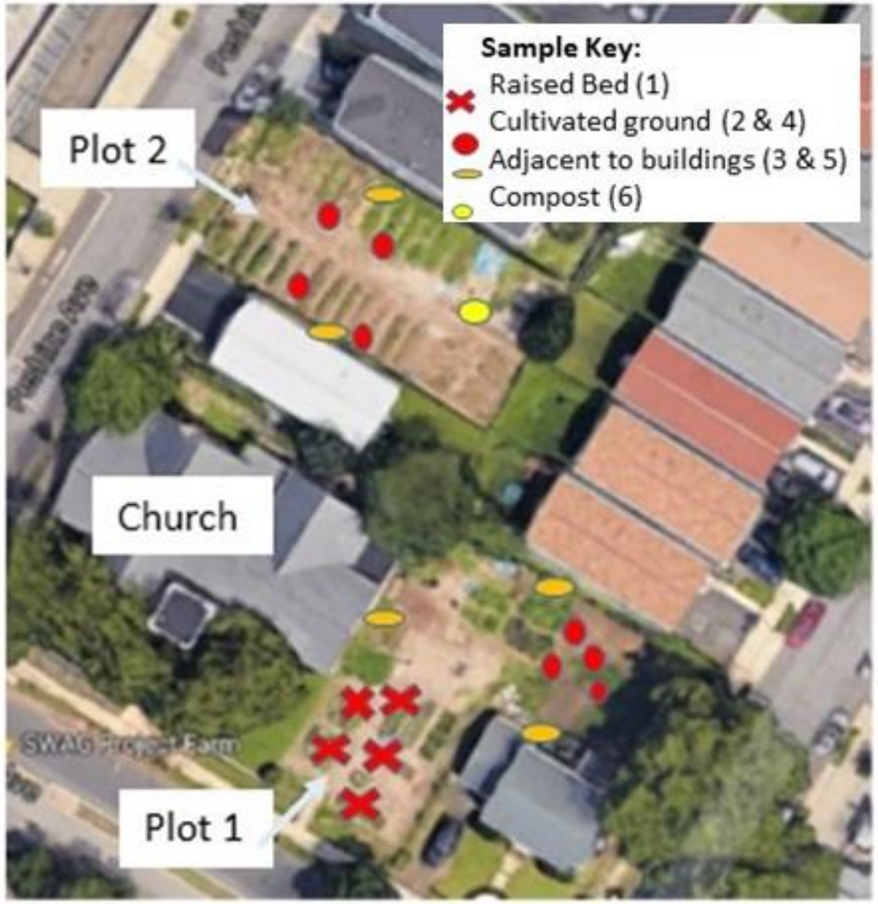
Analysis

- All extractants were analyzed for Pb (also zinc, nickel, copper and cadmium), using an Agilent 5100 SVDV ICP-OES*
- Standards for analysis were prepared in matrices consistent with the samples

RUTGERS

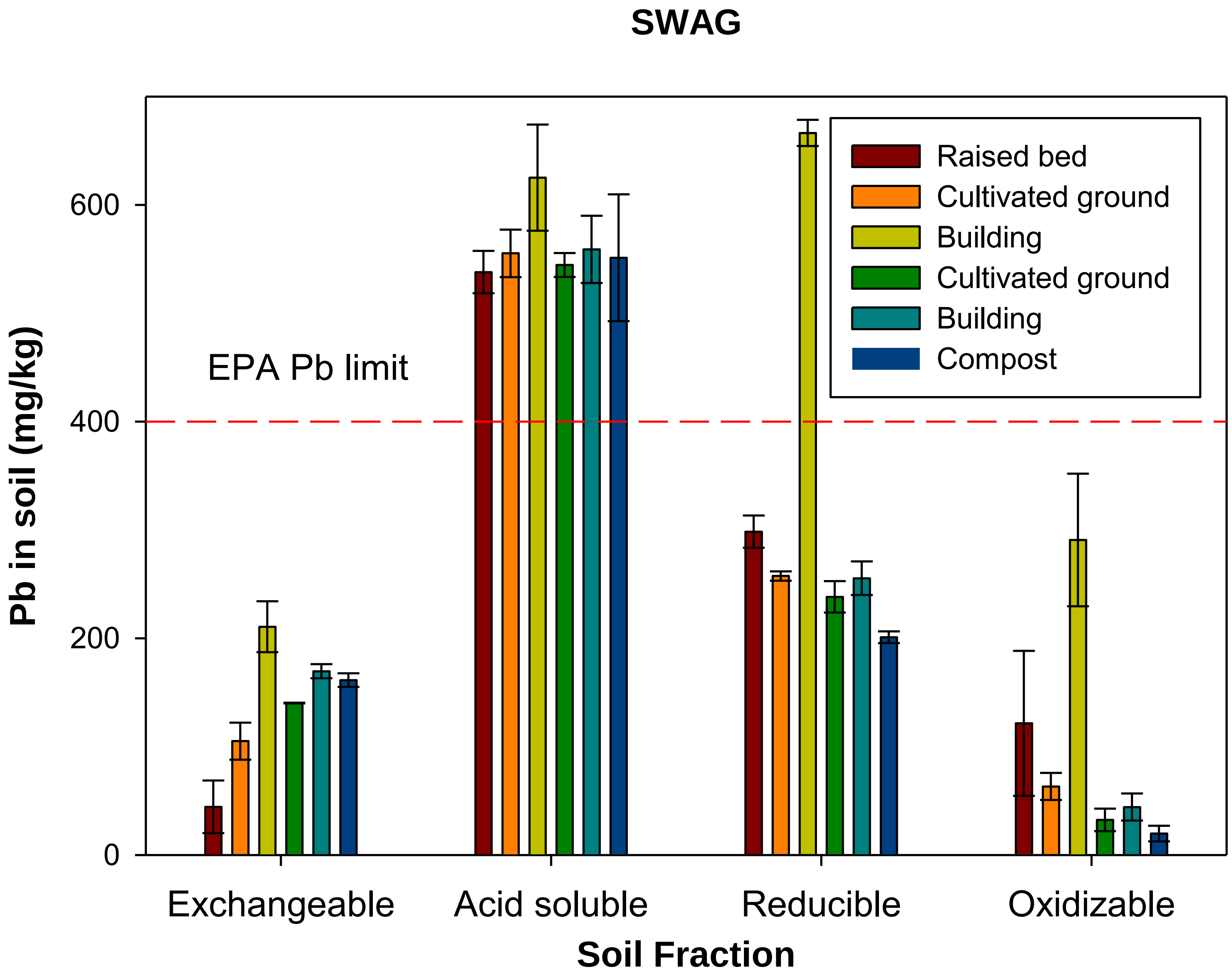
Lead in Bulk Soil





One sample exceeds EPA & NJDEP Pb limit of 400 ppm

Lead in Soil Fractions



- The sample collected near the building has the highest concentration of Pb in all fractions
- In this site, most of the Pb is bound to the acid soluble carbonate minerals, and the reducible fraction
- Metal in carbonate fraction has high mobility and can be released by changes in pH
- The likely source of Pb is from old paint on the building

Summary

- Metals are common pollutants in urban soils as a result of concentrated human activity

- There are known levels at which metals may become toxic to humans and require remediation.

- A combination of in-situ and ex-situ analyses can be combined to determine spatial distribution of metals and mobility.

- Results equip urban farmers with quantitative scientific data regarding the environmental health of their soils, facilitating informed decision making.