Minimizing human exposure to contaminants in urban soils

Ganga Hettiarachchi

Department of Agronomy

Kansas State University

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Project: Gardening Initiatives at Brownfields Sites Research Approach

Efficacy of soil amendments in reducing food-chain transfer (leafy, root, and fruiting vegetables)

- By measuring plant contaminant concentrations following kitchen-style washing, a laboratory cleaning procedure, or peeling

Efficacy of soil amendments in reducing direct exposure risk

- By measuring bioaccessibility of soil contaminants
- By contaminant speciation

Experimental design: Randomized complete block with a split-plot arrangement

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Example Site 1: Kansas city, MO

Size ~ 42m x 37m

Silt loam (Sand-4%, Silt-75%, Clay-21%)

The site was screened *in situ*, every ~6 m for trace elements using x-ray fluorescence spectrometer

↓

Moderately elevated Pb

Soils were also tested for chlordane

Attanayake et al., 2014. J. Environ. Qual. *Vol. 43 No. 2, p. 475-487*

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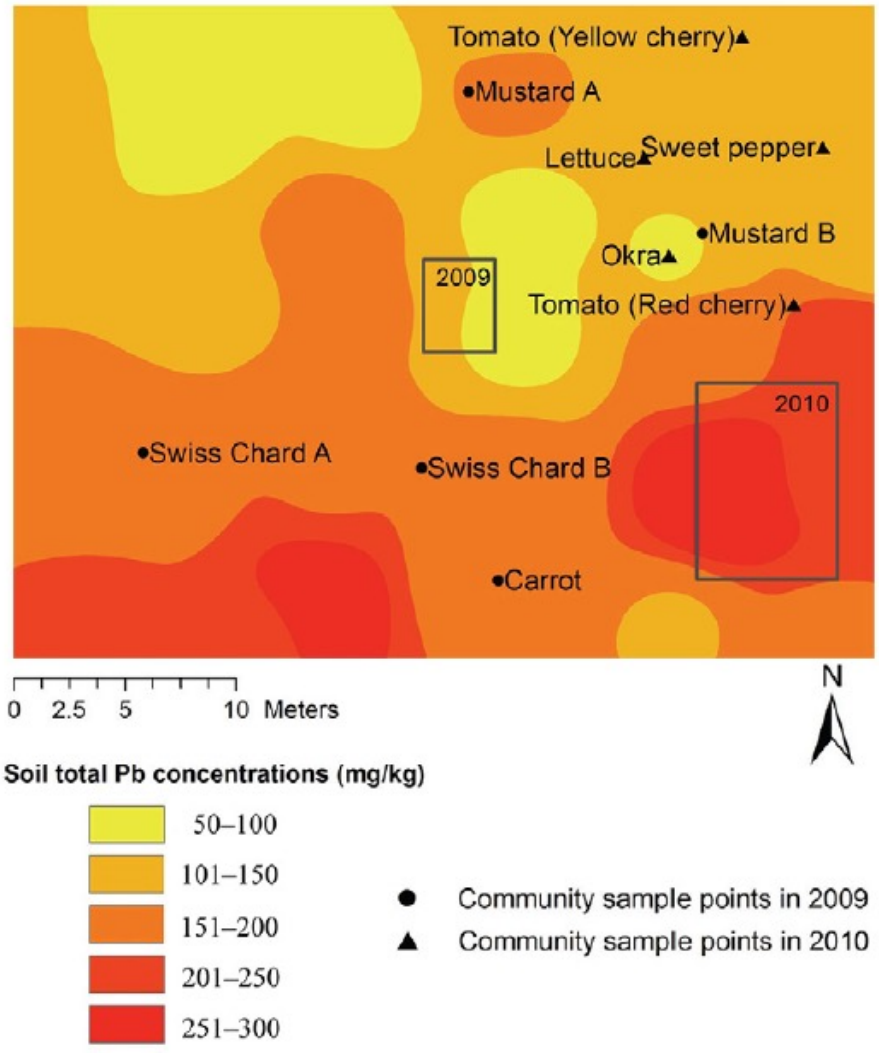

Distribution of soil total Pb concentrations

**Laboratory conformation analysis-Using EPA 3051 method

Chlordane - n.d.
DDT- 0.04 mg/kg to1.3 mg/kg
DDE - only detected in two of the submitted samples (0.03, 0.04 mg/kg)

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Selected Soil Properties

Sample ID	pH	Mehlich-3 P	Ext. K	NH_4-N	NO_3-N	OM
		---------- mg/kg ----------				%
9S	6.6	130	624	53.6	73.2	3.9
9D	6.6	93	455	9.6	35.1	3.4
21S	7.2	116	417	11.8	22.7	3.0
21D	7.2	123	221	9.3	15.0	3.1
26S	7.8	57	255	8.3	4.3	1.5
26D	7.6	80	260	8.2	2.2	1.1
39S	6.9	154	488	15.0	24.2	4.7
39D	6.9	149	334	9.6	13.3	3.3

S = 0-15 cm
D = 15-30 cm

Texture: Silt loam with 21% clay

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Test plot-2010

April 2010.

Treatments:
No compost and compost @28 kg/m^2
Crops:
Swiss Chard
Carrots
Tomato

June 2010.

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Contaminant Dilution through Compost Addition

Kansas City, MO

Plot #	Total Soil Pb (mg/kg)	
	Prior to Compost Addition	After Compost Addition
1	289	203
2	255	120
5	253	146
8	186	114
Average	246	146

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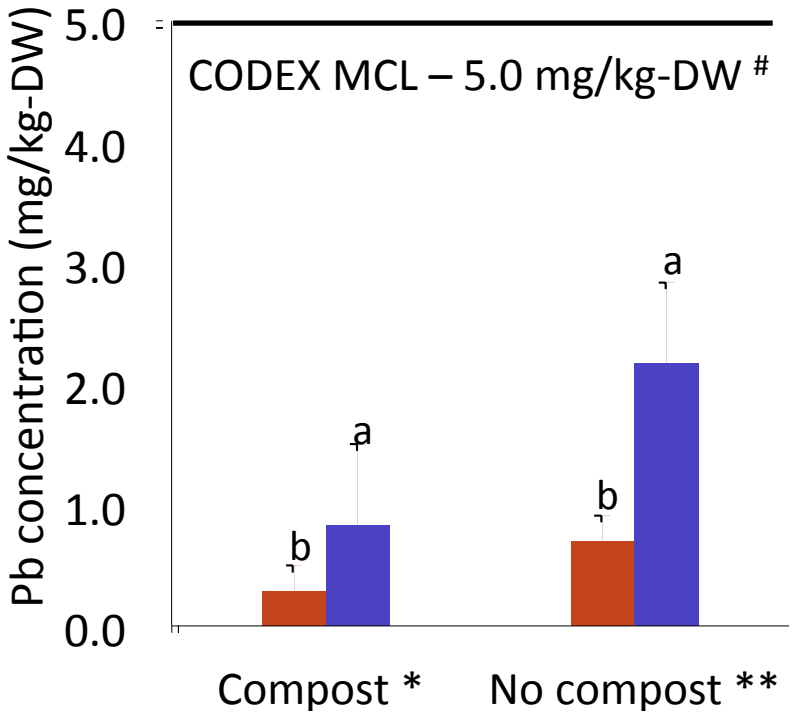
Lead Concentration in Swiss Chard



Lab cleaned

Kitchen cleaned

Compost – ↓ 59 %

Lab cleaning- ↓ ~ 67 %

Treatment	Soil Pb (mg/kg)
No compost	128-348
Compost	101-256

p<0.05 (split plot design, 4 blocks)

*,** between two categories a, b- within a category

CODEX MCL (FAO/WHO) - 0.3 mg/kg fresh wt. basis (94% moisture)

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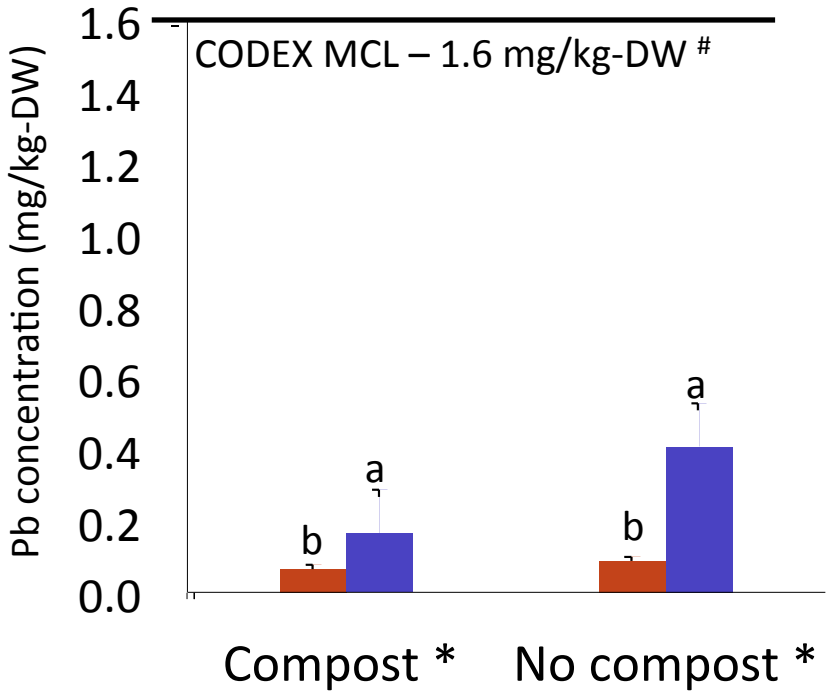
Lead Concentration in Tomato



Lab cleaned

kitchen cleaned

Lab cleaning- ~ 61-78%

Treatment	Soil Pb (mg/kg)
No compost	143-271
Compost	122-193

p<0.05 (split plot design, 4 blocks)

*,** between two categories a, b- within a category

CODEX (FAO, WHO) - 0.1 mg/kg fresh wt. (94% moisture)

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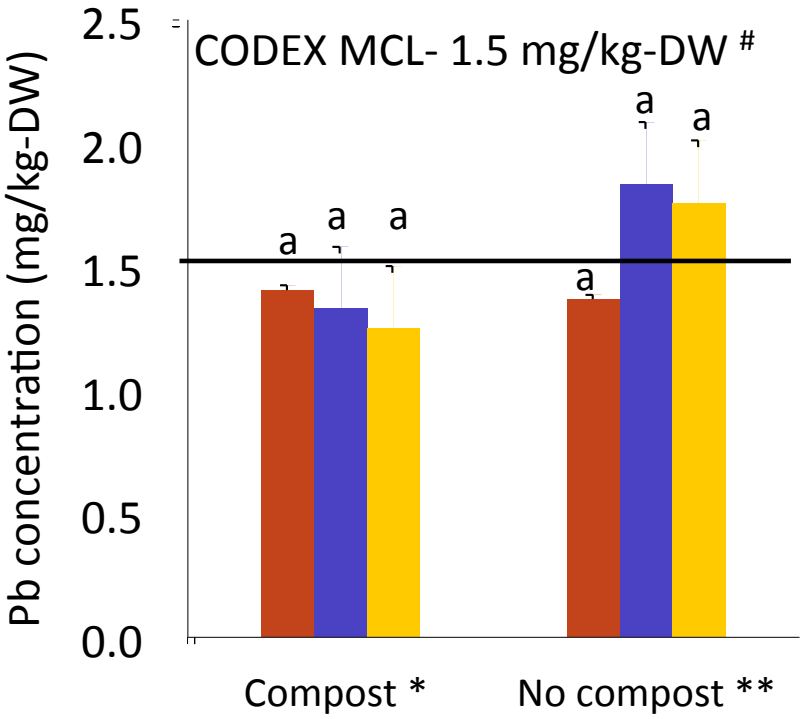
Lead Concentration in Carrot



Lab cleaned
Kitchen cleaned
Peeled

Compost- ~ 20 %

Treatment	Soil Pb (mg/kg)
No compost	154-388
Compost	119-161

p<0.05 (split plot design, 4 blocks)

*,** between two categories a, b- within a category

CODEX (FAO, WHO) - 0.1 mg/kg fresh wt. (93% moisture)

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Physiologically Based Extraction Test-PBET Results

- ***Testing gastrointestinal dissolution of soil Pb***

Treatment	Initial at pH 2.5		End of the season at pH 2.5	
	PBET (mg/kg)	PBET* %	PBET (mg/kg)	PBET* %
No Compost	14.1 ± 4.8	5.6 ± 0.9**	12.8 ± 5.1	5.1 ± 0.5***
Compost	7.4 ± 1.4	3.9 ± 0.4**	8.5 ± 1.8	3.9 ± 0.5***

* PBET Pb as a percentage of soil total Pb

** Values in the same columns were significantly different at $p<0.15$

*** Values in the same were significantly different at $p<0.1$

NIST 2711a: PBET Pb 35.2%

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Physiologically Based Extraction Test-PBET Results

Testing gastrointestinal dissolution of soil Pb

Treatment	Initial at pH 1.5		End of the season at pH 1.5	
	PBET (mg/kg)	PBET* %	PBET (mg/kg)	PBET* %
No Compost	78.7 ± 19.5	32.9 ± 2.3**	84.4 ± 27.5	35.4 ± 1.5***
Compost	53.9 ± 6.8	29.0 ± 1.0**	56.7 ± 5.7	26.7± 0.8***

* PBET Pb as a percentage of soil total Pb

** Values in the same columns were significantly different at $p<0.1$

*** Values in the same were significantly different at $p<0.0.05$

NIST 2711a: PBET Pb 78.9%

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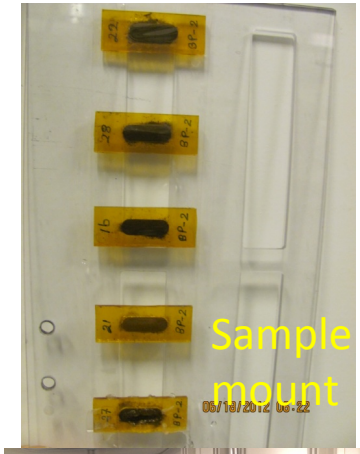
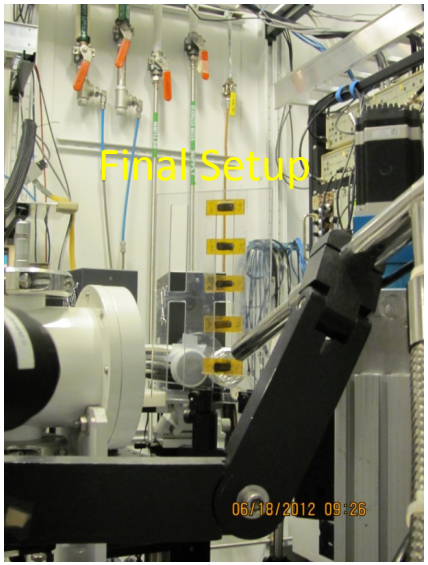
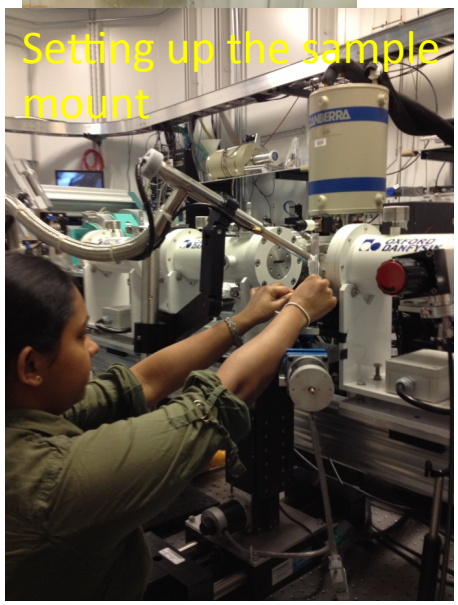
Hutch


Sample mount

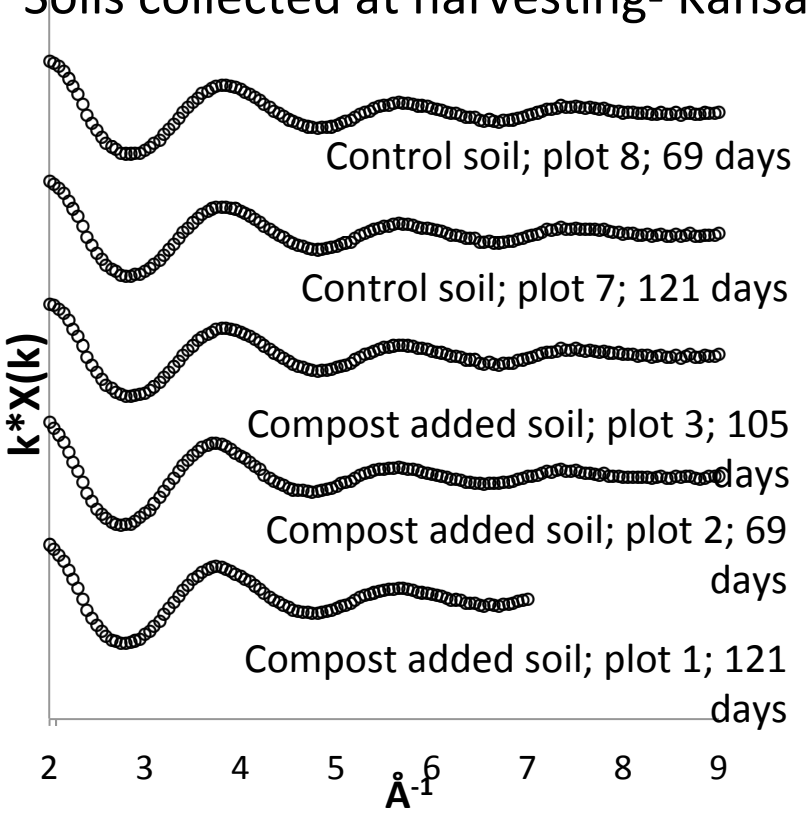




Speciation of soil Pb: Advanced Light Source, ANL, Argonne, IL

Pb L-edge x-ray absorption fine structure (XAFS) spectroscopy

Soils collected at harvesting- Kansas City site



95 % Pb-Fe
5 % Pb-Org

96 % Pb-Fe
8 % Pb-Org

96 % Pb-Fe
4 % Pb-Org

64 % Pb-Fe
36 % Pb-Org

74 % Pb-Fe
26 % Pb-Org

Pb-Fe: Pb bound to ferrihydrite; Pb-Org: Pb bound to humic acid

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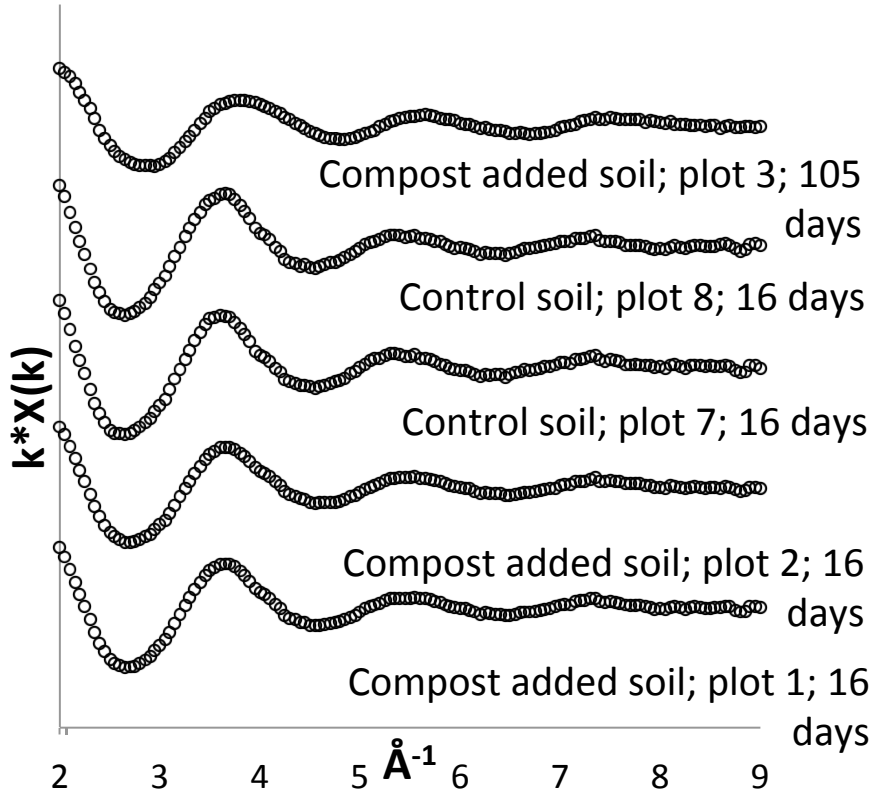
Pb XAFS- PBET soil residues



90 % Pb-Fe
10 % HP

93 % Pb-Org
7 % HP

83 % Pb-Org
17 % HP

37 % Pb-Fe
53 % Pb-Org
10% HP

24 % Pb-Fe
67 % Pb-Org
9 % HP

Pb-Fe: Pb bound to ferrihydrite; Pb-Org: Pb bound to humic acid; HP: hydroxypyromorphite

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Example Site 2: Philadelphia, PA

Testing plants and soils- A couple of sites in Philadelphia with very high Pb concentrations (> 1000 mg/kg)

Partnering with EPA region 3 and the Greensgrow Philadelphia

GREENSGROW FARMS
GROWERS OF FOOD, FLOWERS AND NEIGHBORHOODS

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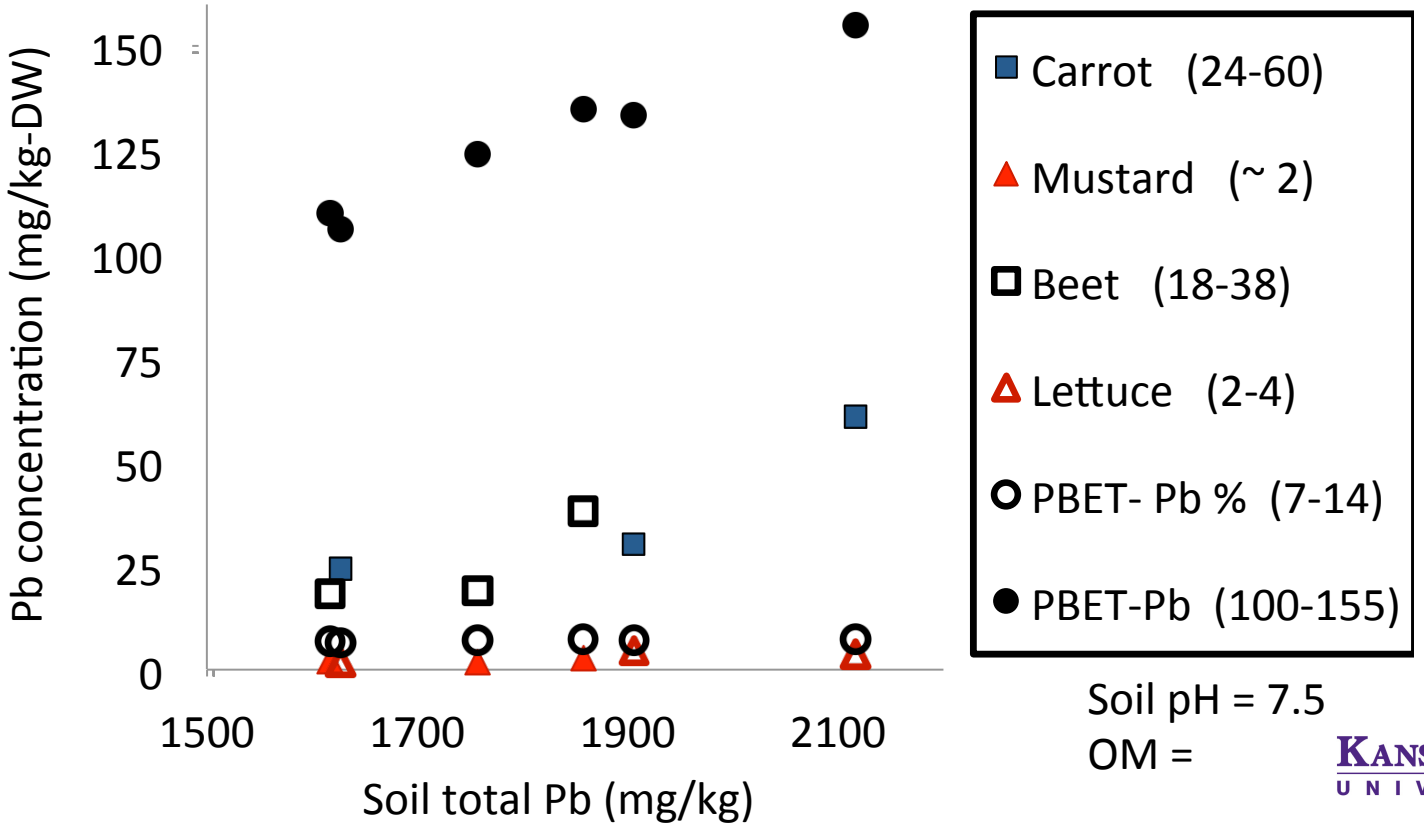
Philadelphia- high Pb soil
Example site 2



Soil pH = 7.5

OM =

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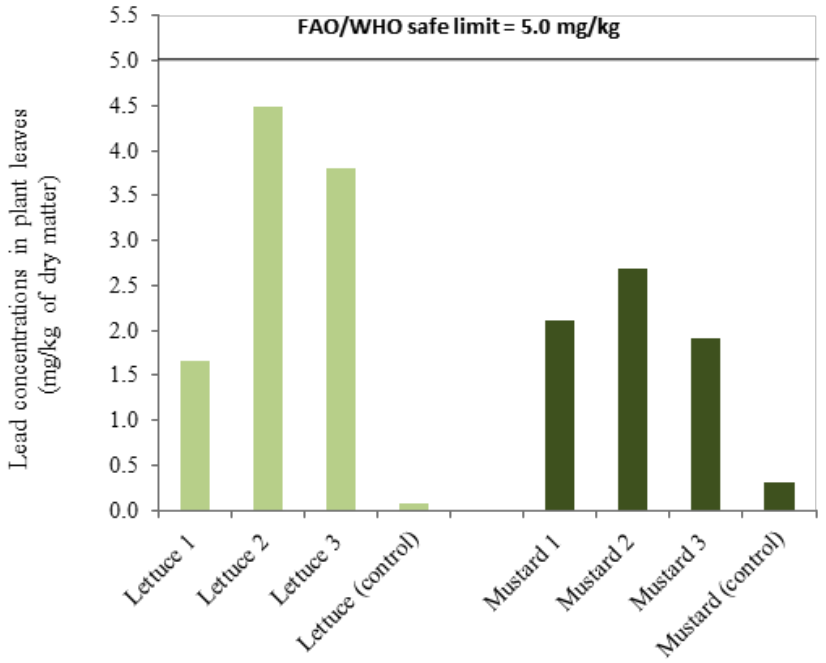
Philadelphia- 2011 data

Sample Location	Lead concentrations in soils (mg/kg)
L 1	1627
L 2	1906
L 3	2117
M 1	1618
M 2	1858
M 3	1757
Average	1814
L control	3.59
M control	2.66



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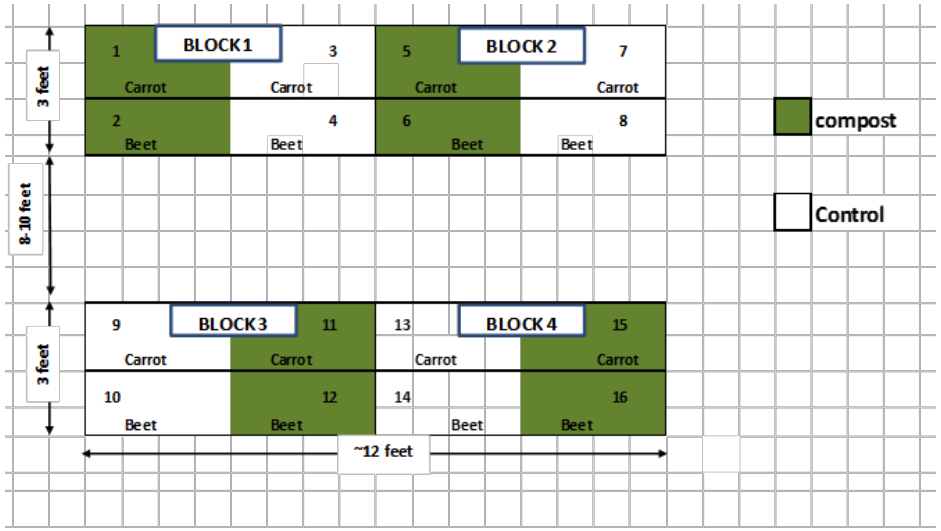
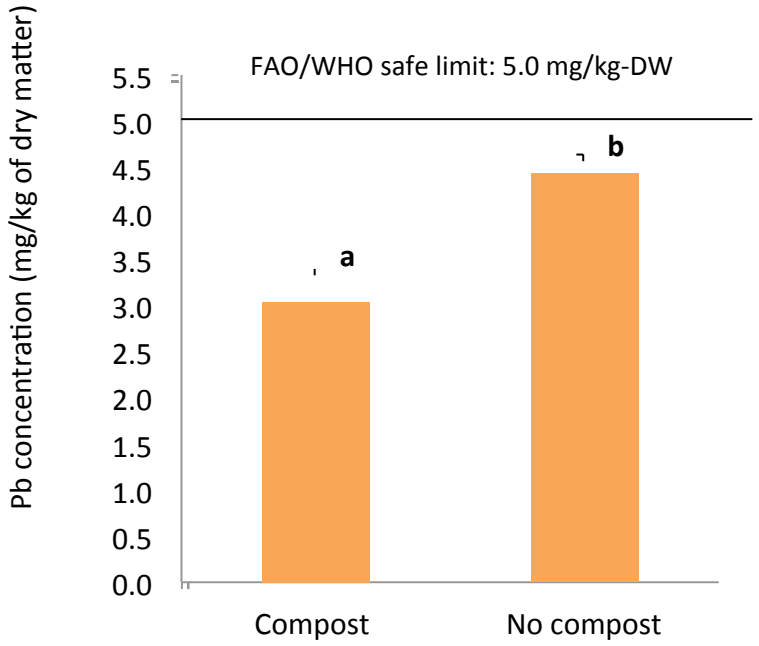
Philadelphia test plots- 2012



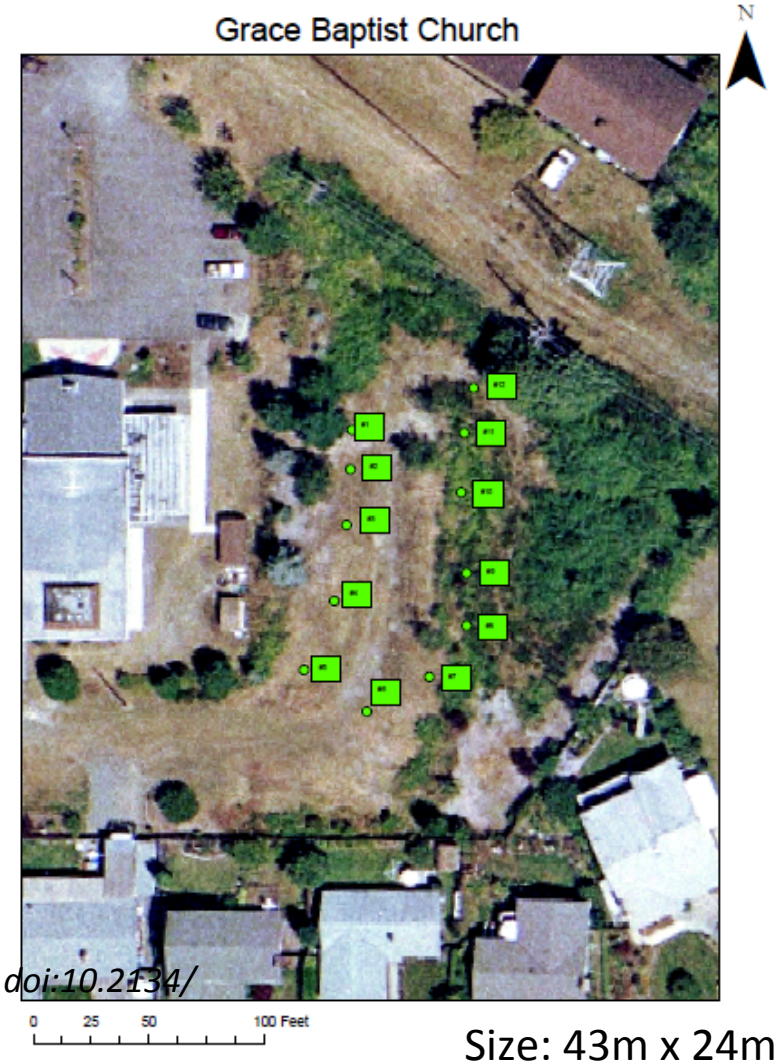
Soil Pb concentrations > 1300 mg/kg



Tacoma, WA Example Site 3

Element	Concentration in soil (mg/kg)
As	17- 162
Pb	17- 427

Texture: Sandy loam
Soil pH: 5.6 (soil: water)



Size: 43m x 24m

Ref.: Defoe P.P., G.M. Hettiarachchi, C. Benedict, S. Martin. 2014. J. Environ. Qual. doi:10.2134/jeq2014.03.0099

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Test plots-Tacoma, WA- 2010

Low to medium available N, P and K in soils

<u>Treatments</u>:

No compost and compost @ ~28 kg/m^2

<u>Crops</u>:

Lettuce, Carrots

Tomato

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Tacoma, WA- Test plots

Dolomite+ Tagro added

Control

Further dilution of contaminants through enhanced growth

Lead uptake by tested vegetable types was similar
Arsenic uptake was minimal

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Summary

- The pathway from contaminated soil to plant to human is insignificant
- The potential exposure pathway of concern is direct exposure of humans to contaminated soils
- Bioaccessibilities of Pb and As in tested urban soils were low
- Compost additions help reducing contaminant concentration in vegetables and also, bioaccessible Pb and As to humans
- Pb speciation in soils was dominated by Pb sorbed to Fe oxy(hydr)oxide and to soil organic C (Pb-Org)
- The fraction of Pb-Org was high in soils with high organic C and increased with time after application of compost in the field
- Scorodite-like As^{v} species (Fe arsenate- like) were the most dominant in As species in tested soils

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Contributors

- Graduate students- Chammi Attanayake, Phillip Defoe, Janelle Price, Ashley Harms, Jay Weeks
- Co-PI Sabine Martin and other Investigators (DeAnn Presley, Gary Pierzynski, Blasé Leven, Larry Erickson, Rhonda Janke)

Collaborators

- Jake Wagner (UMKC); Chris Benedict (WSU); Kristen McIvor (UW); Ginny Roberts (Purdue Extension); Chris Harrell (Lazarus LLC), Monica Palomo & her group (Cal Poly); Deon Van der Merwe (KSU); E. Santos (KSU); J. Tatarko (KSU)
- Mary Seaton Corboy and Nathan Hasler-Brooks (Greensgrow Philadelphia Project); Nathan Michael Szuberla & Karen Wolkins (Toledo Botanical Gardens)
- City brownfields offices, EPA Region 3, 5, and 7

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Kansas State University

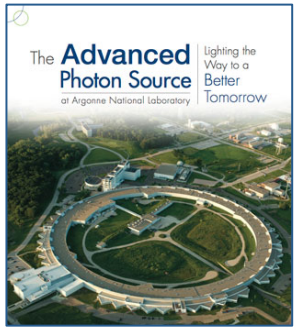
Washington State University

Cal Poly Pomona

Seattle P-Patch

Seattle Department of Neighborhoods

United States Environmental Protection Agency



Seal of the City of Toledo — Laborare Est Orare — January 7, 1837

UMKC University of Missouri Kansas City

Purdue Extension Marion County — Making a Difference

keep Indianapolis beautiful INC.

Indianapolis — Gregory A. Ballard, Mayor

Indianapolis Brownfield Redevelopment Program

Toledo Grows

Toledo Botanical Garden

Greensgrow Farms — Growers of Food, Flowers and Neighborhoods