Urban Gardening and Soil Lead Assessment and Solutions

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Today's Presentation

Assessment of soil Pb and human exposure (bioavailability) in urban soils

<u>Solutions to soils with Pb issues</u>
In situ soil remediation: Use of inexpensive soil amendments to remediate soils (reduce contaminant exposure / risk)

Management practices to reduce exposure to soil Pb

Reuse and Remediation of Vacant Land Soil in Cleveland

Vacant Land in Cleveland is 3,000 acres and expected to increase greatly as new initiatives (i.e., American Recovery and Reinvestment Act) provide funding for demolition of substandard housing.

16,500 properties in Cuyahoga County land bank

Vacant Land reduces value from city neighborhoods

Nationwide Creation of Vacant Urban Land

Vacant Land Reuse Opportunities

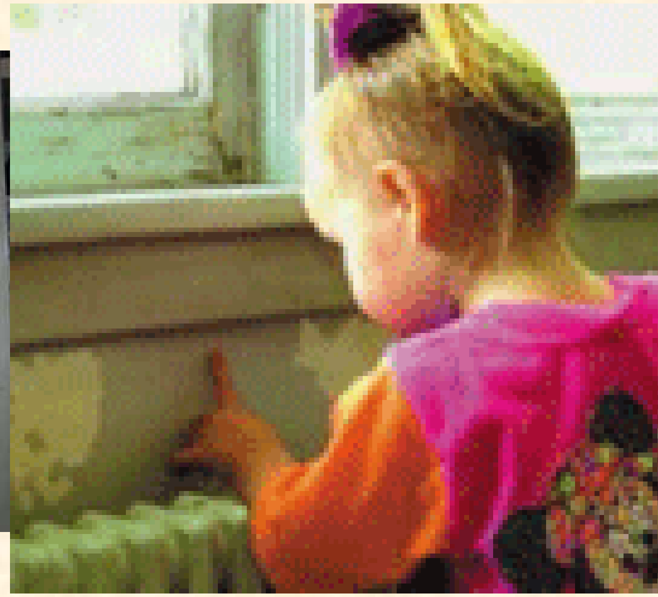
- **Urban agriculture/gardening**

  improve the availability of healthy, fresh foods, improve nutrition and health of residents Community gardens improve the quality of life and social fabric of city neighborhoods

- **Creation of parks, playgrounds and other commons**

Soil Pb Pollution

Pb in paint until 1978



Leaded gasoline

Phased out in 1970s

50% deposited within 100 m of road

other 50% dispersed

Excessive Blood Pb (EBL) in Cuyahoga County

	EBL > 10 μg/dL	EBL > 5 μg/dL
Cuyahoga county	8.5 %	34.6 %
Cleveland	11.0 %	42.2 %

Cuyahoga County Board of Health
Epidemiology and Surveillance Services. Feb 2008

Significant Pb exposure -- indoor (house dust) and outdoor (soil)

Many urban soils have Pb contamination
Effect of distance from the center of Baltimore on Pb concentration in garden soils (1983)

Distance	N	Mean	Med.	90%-ile	Max.	%>500
km		--------mg Pb/kg dry soil--------				
1-50	549	424	124	992	10900	20.9
1-4	90	1020	664	1810	10900	61.1

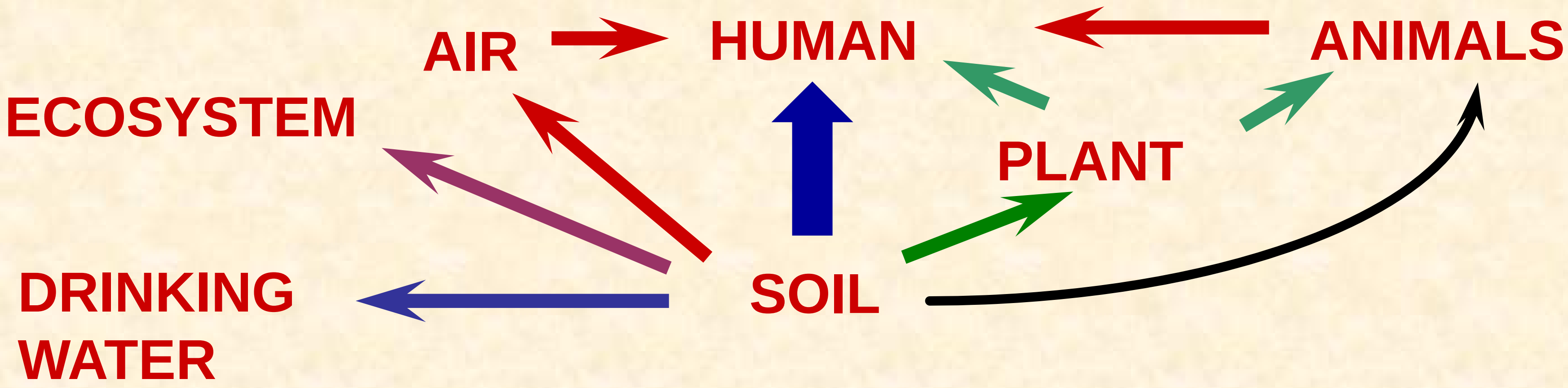
Similar soil Pb historical legacy in many cities

Two possible urban garden sites
Soil Pb Assessment

Can these be used for gardening?

USEPA Risk Assessment Guidance-Human Health

Risk-Based Pathway Analysis



Determine contaminant transmission (mobility, bioavailability) to calculate risk from soil Pb

Soil / contaminant chemistry affects availability, contaminant transmission, and human and ecological risk

Uncontaminated Soils

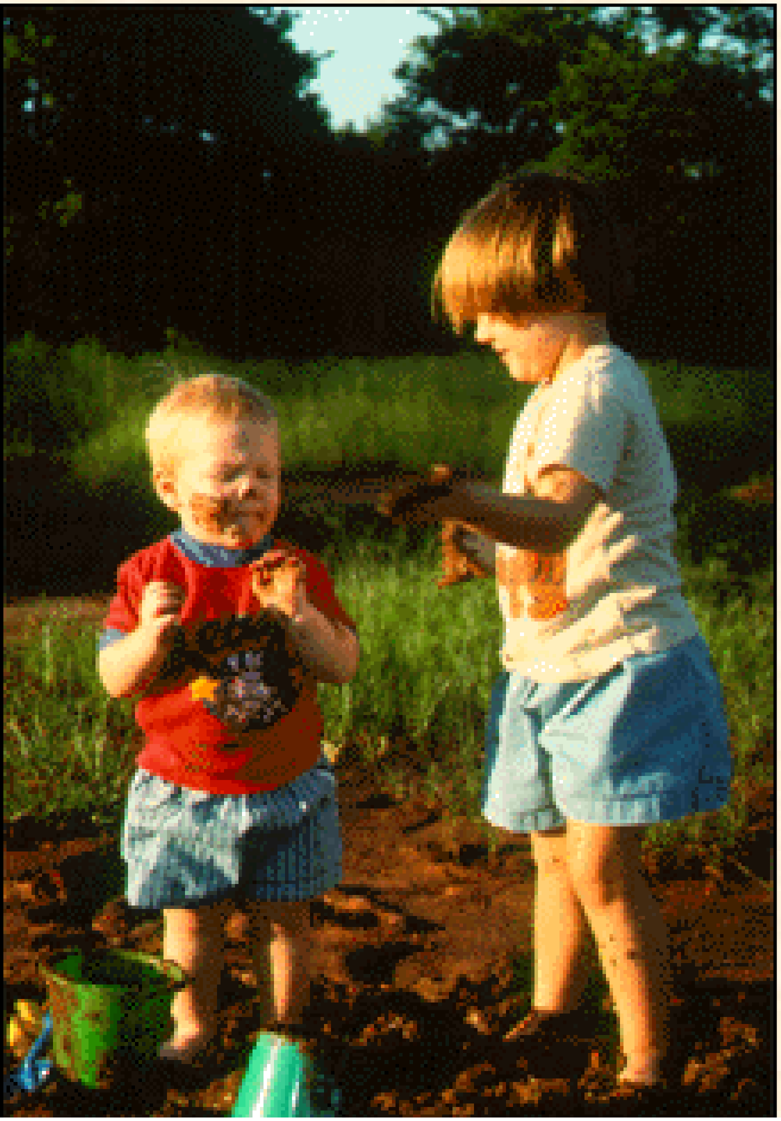
Pb, 2000 mg/kg

Critical Human Exposure Pathways

Soil Pb is insoluble / little phytoavailability

Risk driver for soil Pb in urban gardens is <u>soil ingestion</u> not Pb in the food chain or drinking water

Using Oral Bioavailability to Assess Human Health Risk of the Soil Ingestion Pathway



$$CDI = [Soil\ Pb] \frac{(EF)\,(ED)\,(IR)\,(BIO)}{(BW)\,(AT)}$$

CDI = chronic daily intake of Pb
= Pb absorbed into blood
[Soil Pb] = total soil Pb

EF, ED = exposure frequency / duration
IR = ingestion rate
BIO = Bioavailability of Pb in soil which ranges from 0.0 to 1.0

How do we assess the CDI (risk)?

Measuring Bioavailability Using *In Vivo* Models

accurate bioavailability

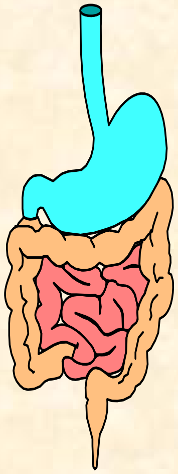
unlikely model

acceptable model for Pb, As, other bioavailability

acceptable model for bioavailability

expensive
ethical issues

In Vitro Gastrointestinal Methods
An Inexpensive, Fast, Accessible Alternative



Simulated human gastrointestinal extraction

Bioaccessible metal = dissolved in gastric and/or intestinal solution; bioaccessible is a conservative measure of bioavailable metal

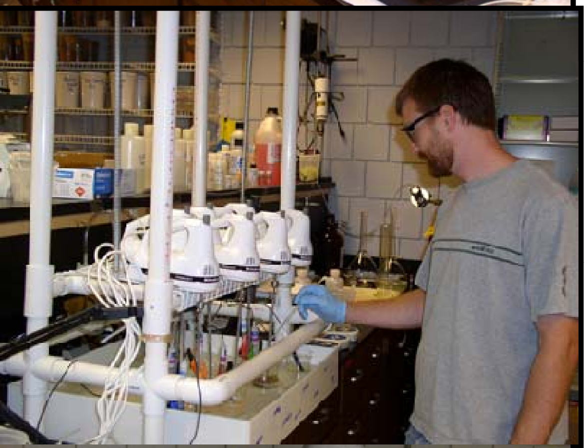
IVG extraction

OSU IVG

$$\% \text{ IVBA} = \left(\frac{\text{In vitro dissolved metal}}{\text{Total soil metal}} \right)$$

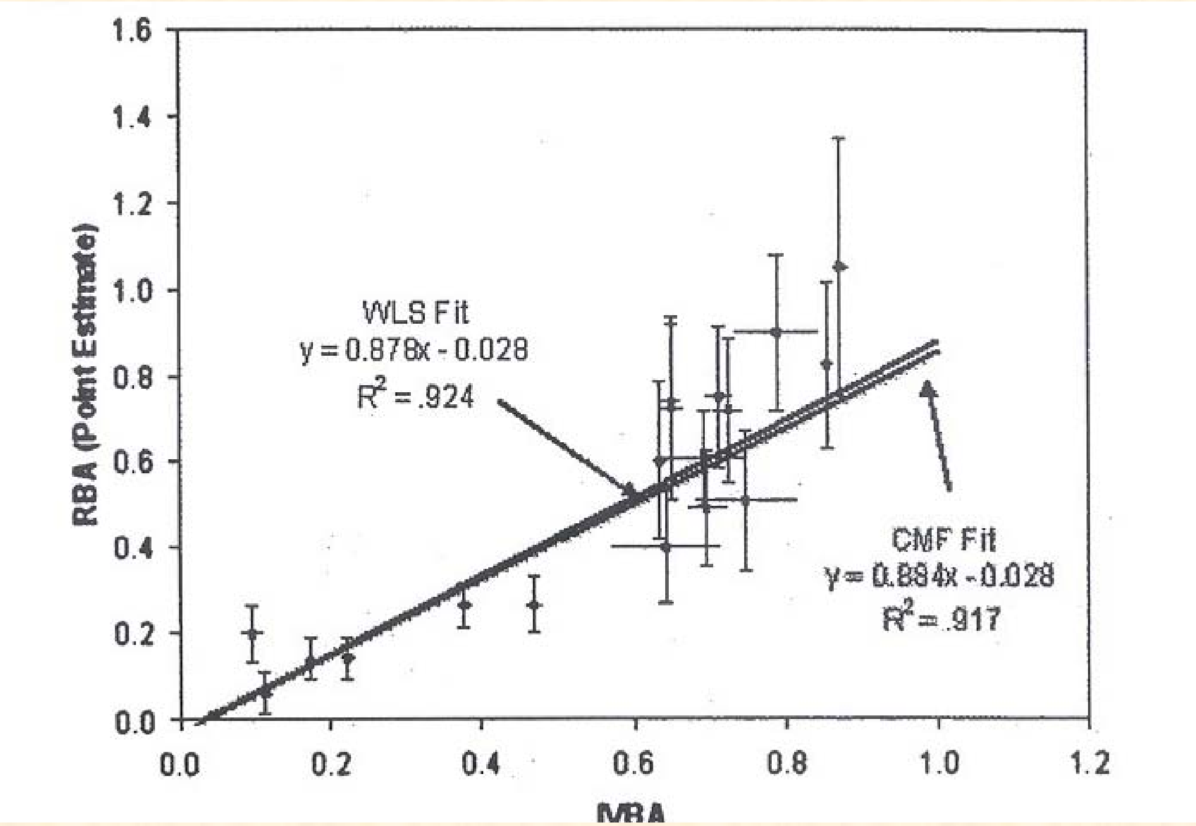
metal analysis by ICP

OSU Soil Chemistry
Metal Bioaccessibility Testing of Soil



We have a very active research program and we offer a variety of IVG soil tests to the public

RBALP *in vitro* gastrointestinal method correlated with swine bioavailable Pb



Drexler and Brattin. 2007.
Human Ecol. Risk Assess. 13:383-401

U.S. EPA, Guidance for Evaluating the Oral Bioavailability of Metals in Soils for Use in Human Health Risk Assessment OSWER 9285.7-80, May 2007; RBALP IVG accepted for Pb, others under consideration for Pb and As.

OSU IVG Research
more active than ever after 10+ yr

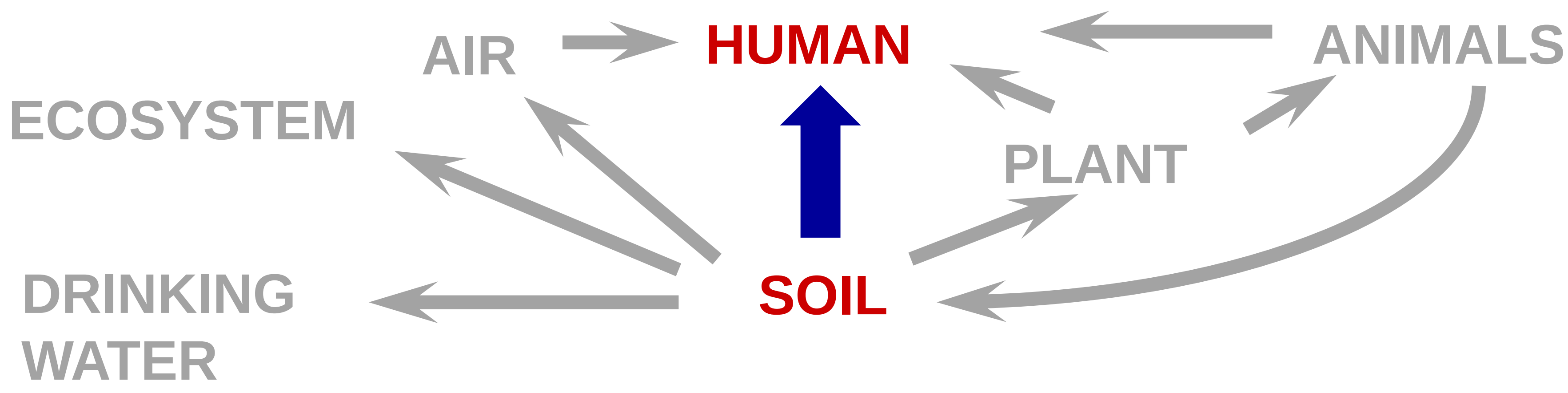
1997

2007

the soil isn’t contaminated

Assessment of Soil Pb in Urban Soil

Risk-Based Pathway Analysis



If risk is unacceptable ➔ cleanup /remedial action required

First, use Soil-Screening levels to evaluate contamination and determine if detailed risk assessment is needed

Soil Assessment of Pb
First -- Measure Total Soil Pb

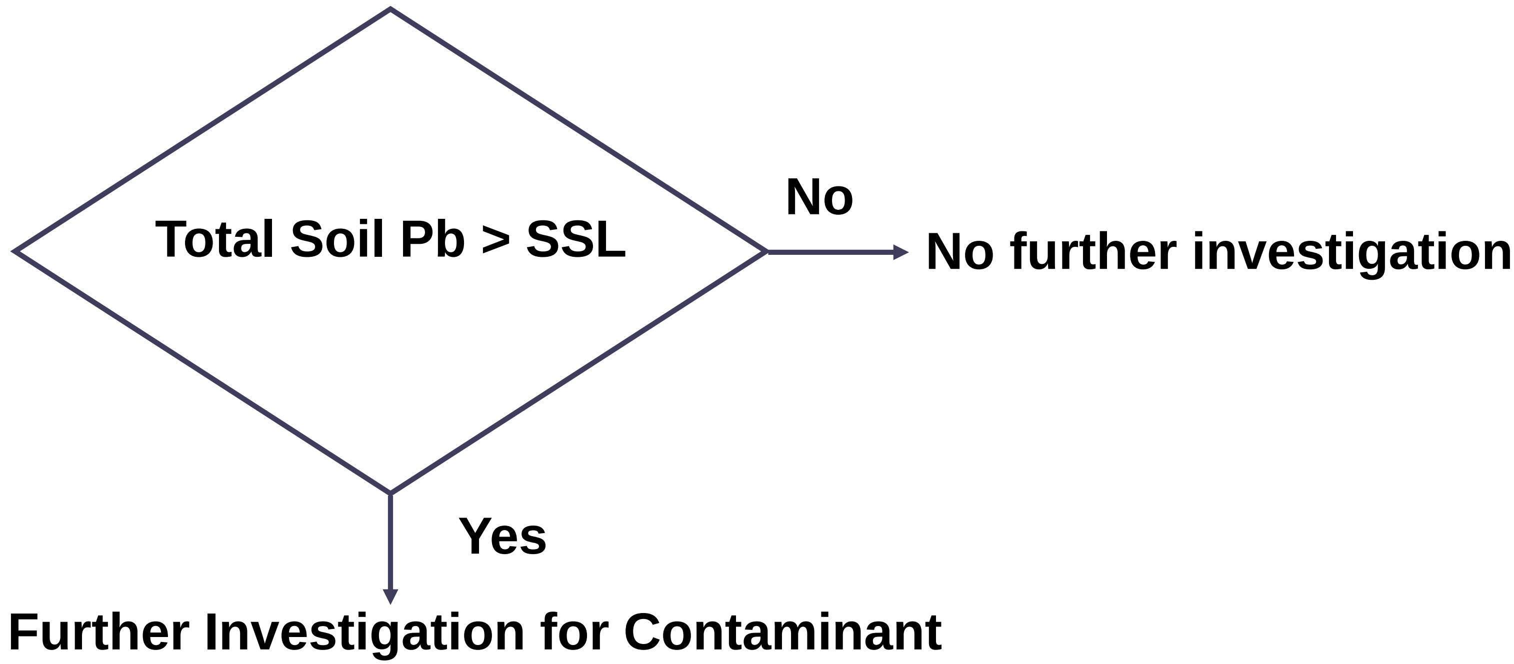
Strong acid digestion used to dissolve soil and release Pb

USEPA Method 3050

USEPA Method 3051, 3051A, 3052

Analysis of dissolved "soil" by inductively coupled plasma atomic emission spectroscopy

Compare your soil Pb to Soil Screening Levels (SSL)



USEPA SSL for Pb is 400 mg/kg (with default assumptions)

200 mg soil ingested/day; 60% relative bioavailability

Ohio EPA Voluntary Action Program

**"This Program was created to give individuals
a way to investigate possible environmental contamination,
clean it up if necessary and receive a promise
from the State of Ohio that no more cleanup is needed."**

http://www.epa.ohio.gov/derr/volunt/volunt.aspx

**Generic direct-contact soil standards: residential land use category
considers soil ingestion, dermal absorption, inhalation of particulate emissions**

Pb VAP soil standard: 400 mg/kg

Two possible urban garden sites

Soil Pb
221 to 391 mg/kg Pb, mean 313

Soil Pb
770 to 900 mg/kg Pb, mean 800

Can these be used for gardening?

How do you reduce risk from exposure to soils > 400 mg/kg Pb?
Soil Ingestion Pathway

$$CDI = [\text{Soil Pb}] \frac{(EF)\,(ED)\,(IR)\,(BIO)}{(BW)\,(AT)}$$

1. Reduce [soil Pb] term - reduce soil Pb
2. Reduce exposure / ingestion of soil, EF, ED, IR
3. Reduce exposure / Pb bioavailability, (bio)

Reducing Soil Pb
Soil Excavation/Landfilling

Excavate top 6”

Fill with new soil
“borrowed soil”

Soil Pb, 800 mg/kg

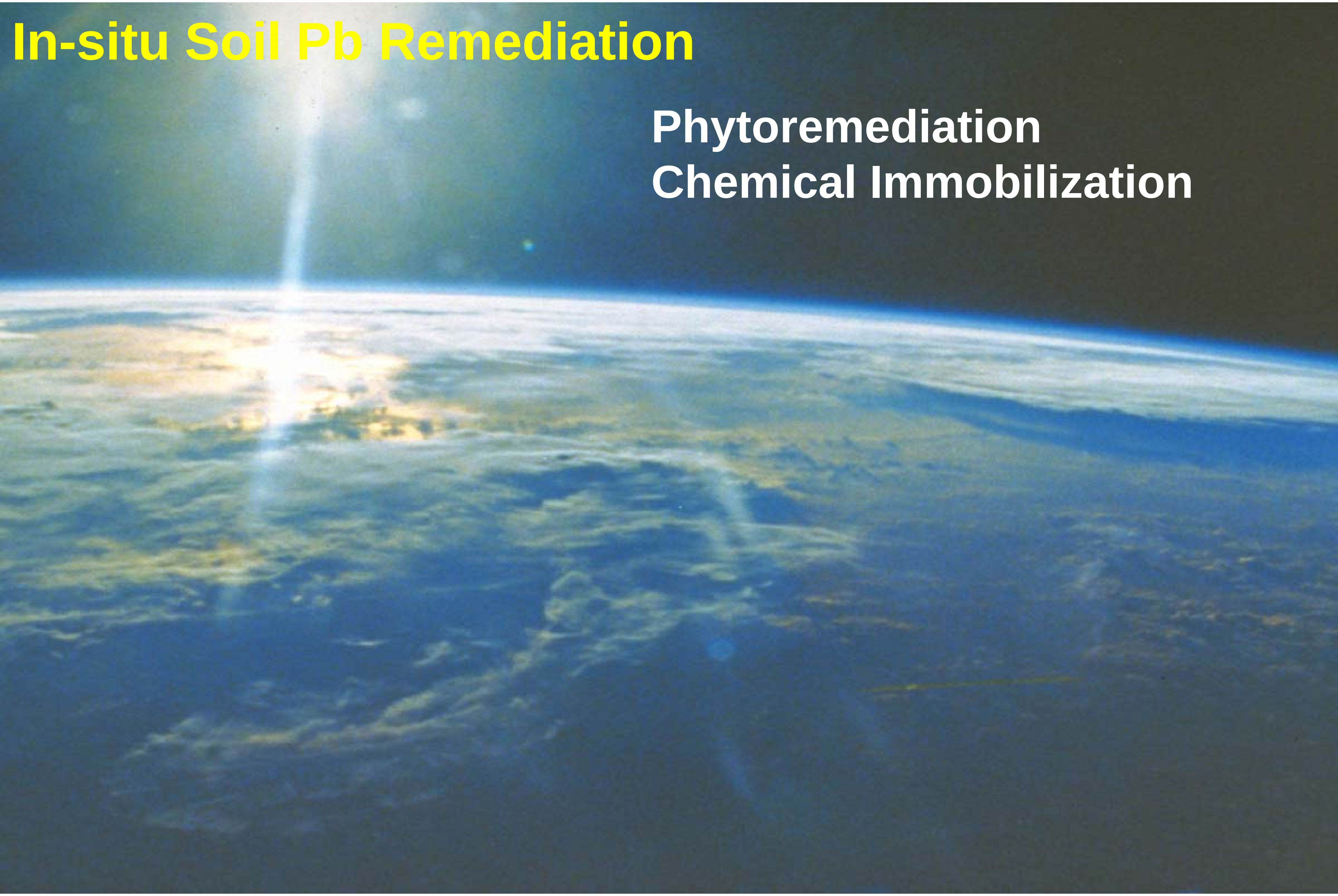
Very Expensive but Contaminant “Gone”
--at least gone from earth surface

$100 to $300/ton
$20,000 to $60,000 / property

Thousands of properties in one city?
$200M?

In-situ Soil Pb Remediation

Phytoremediation
Chemical Immobilization

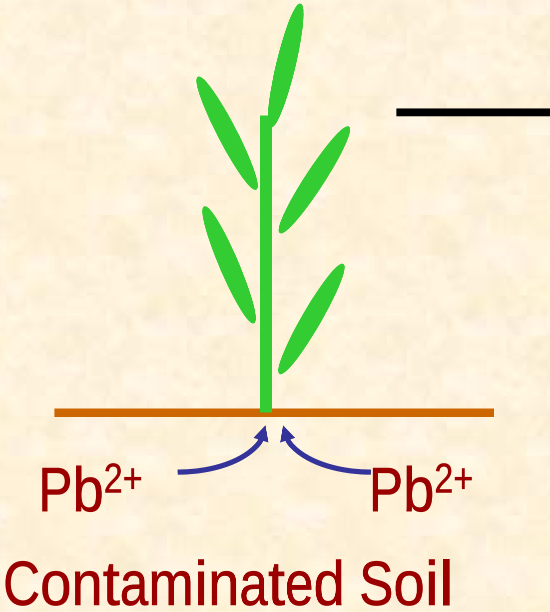


Remove Soil Pb by Phytoremediation

solar-driven metal pumps **green remediation**

Hyperaccumulator plant- more than 1% metal in plant

Phytoextraction



→ **Harvest** → **Beneficial Use**

Biomining: ash plant as ore (Ni)
Mineral feed supplement (Se)

Soil metal contaminant MUST be bioavailable for metal uptake to occur

Limited to contaminants that have some solubility in soil
Pb is very insoluble in soil

Known Metal(loid) hyperaccumulating plants

Table 1. Example plant species which hyperaccumulate elements to over 1% of their shoot dry matter, usually at least 100-fold levels tolerated by crop species.

Element	Plant species	Maximum metal concentration	Location collected	Reference
		mg kg^{-1} dry wt.		
Zn	*Thlaspi caerulescens*†	39 600	Germany	Reeves and Brooks, 1983b
Cd	*Thlaspi caerulescens*	2908	France	Reeves et al., 2001
Cu‡	*Aeolanthus biformifolius*	13 700	Zaire	Brooks et al., 1978
Ni	*Phyllanthus serpentinus*	38 100	New Caledonia	Kersten et al., 1979
Co‡	*Haumaniastrum robertii*	10 200	Zaire	Brooks et al., 1978
Se	*Astragalus racemosus*	14 900	Wyoming	Beath et al., 1937
Mn	*Alyxia rubricaulis*	11 500	New Caledonia	Brooks et al., 1981
As	*Pteris vittata*	22 300	Florida	Ma et al., 2001
Tl	*Biscutella laevigata*	15 200	France	Anderson et al., 1999

† Ingrouille and Smirnoff (1986) summarize consideration of names for *Thlaspi* species; many species and subspecies were named by collectors over many years (Reeves and Brooks, 1983a, 1983b; Reeves, 1988).

‡ Although Cu and Co hyperaccumulation were confirmed in field collected samples, similar concentrations have not been attained in controlled studies.

Chaney et al. 2007. J. Environ. Quality 36:1429-1443.

Alleged phytoremediation of Pb contaminated soils

There isn't a Pb hyperaccumulator plant

Most lead contamination is very insoluble in soil and not available for plant uptake (i.e., phytoextraction)

In 1997, lead contaminated soil was reported to be phytoremediated by Indian mustard (*Brassica juncea*)

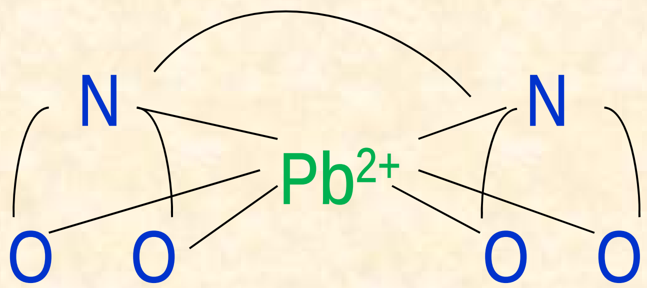
Indian mustard Pb content of >1%, approaching 3%!

News spread around the world!

Chelate-assisted phytoextraction of Pb from soil

Soil-Pb + $EDTA^{4-}$ = Clean soil + $PbEDTA^{2-}$

add chelate solution to soil



$PbEDTA^{2-}$ = Pb^{2+} + $EDTA^{4-}$

Greatly increased
Pb^{2+} dissolved in soil solution

Subsequent studies report large uptake of Pb was due to root membrane injury by EDTA

Chelate-assisted phytoextraction of Pb from soil
very serious problems

Several studies in 2001-2005 period found very little of soil Pb was recovered in the Indian mustard

Mass balance showed >90% of the Pb was unaccounted for -- where did the Pb go?

Hint: EDTA solubilized Pb?

Groundwater contamination of Pb --lysimeters found Large amounts of Pb in water table -- little in plants

Reduce Pb Bioavailability and Exposure
Soil Remediation by *in situ* Soil Amendments

Treat soil to reduce contaminant solubility/availability to ecological and human receptors

Objective is to reduce Pb Oral bioavailability

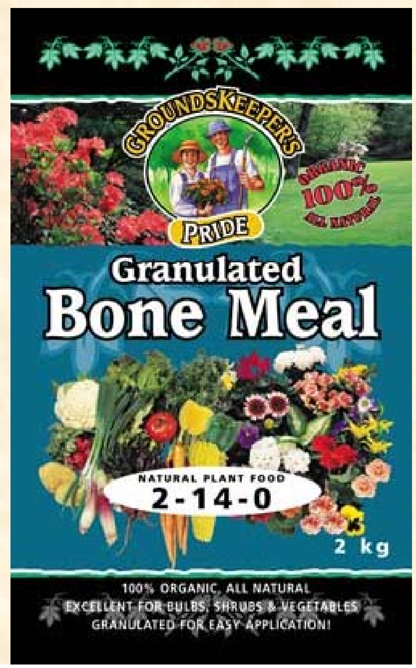
Reduce Pb Bioavailability and Exposure
Soil Remediation by *in situ* Soil Amendments

Phosphates / P Fertilizer

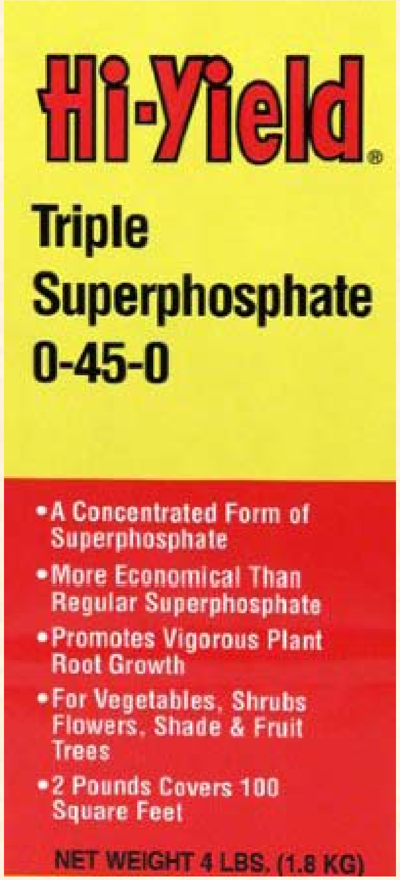
$$Ca_{10}(PO_4)_6(OH)_2 + xPb^{2+} \longrightarrow Ca_{10-x}Pb_x(PO_4)_6(OH)_2 + xCa^{2+}$$

Hydroxyapatite + available Pb

Lead pyromorphite
Low bioavailability



Pb immobilization using phosphorus fertilizer calcium or ammonium phosphates

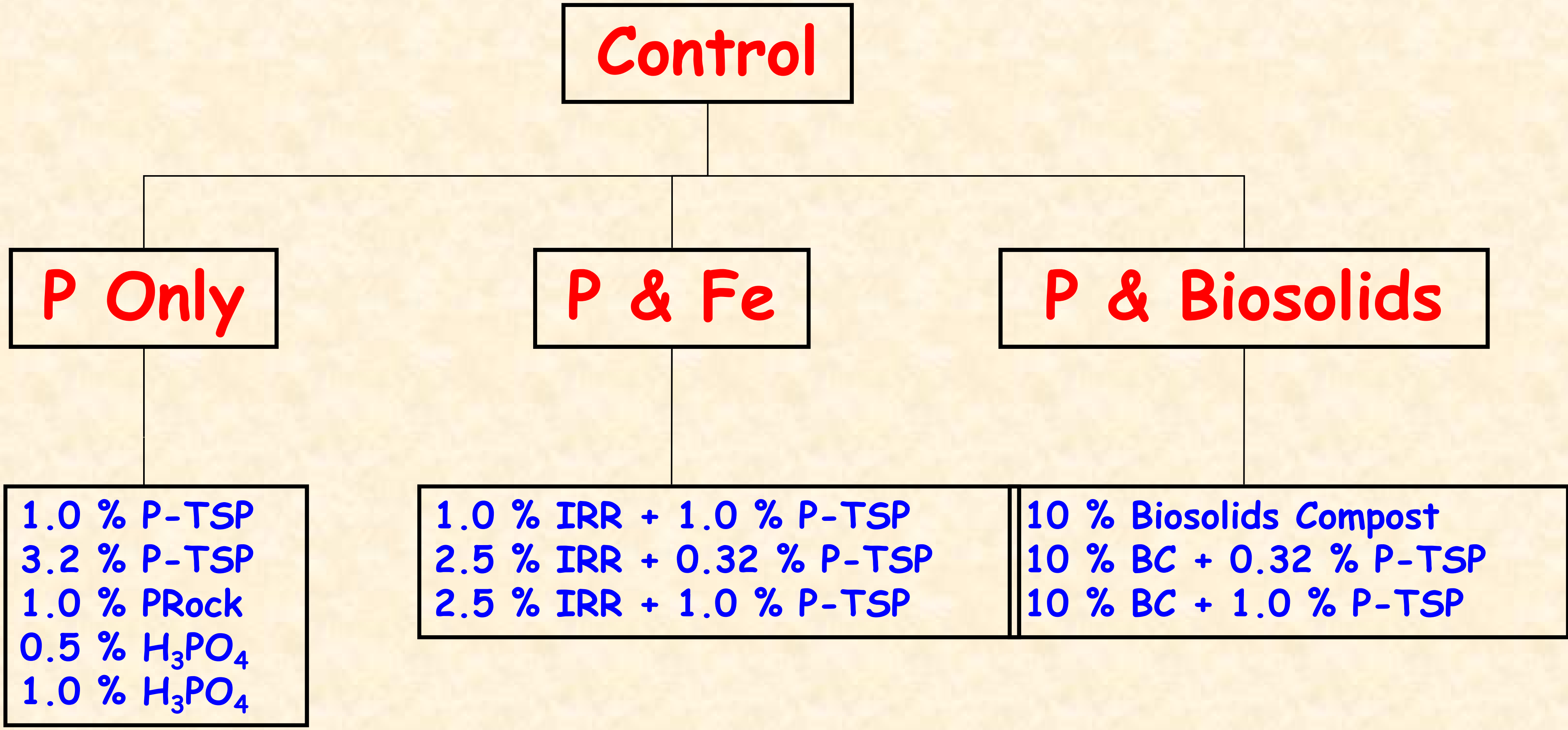


Remediation of Soil Pb at Joplin, Missouri

In-place Inactivation & Natural Ecological Restoration Technologies (IINERT)

Urban soil contaminated with Pb smelter waste

Field Amendments at Joplin



Joplin Soil Feeding Test
Clinical Protocol

- Human volunteers with Pb isotope ratio different from that of the test soils.
- Screening and physical exam.
- Obtain informed consent.
- Three day clinic admission.
- Subject dosed at 250 µg Pb/70 kg BW using soil <250 µm in gelatin capsules.
- Collect blood and urine samples

Phosphate Amendment Reduced Soil Pb Bioavailability to Humans

Joplin Soils -- Results

Group	Age	Weight	Pb Dose	Soil Dose	Bioavailability
	yr	kg	µg	mg	%, Absolute
Untreated	29.6	62.2	238	45.7	42.2 (26.3-51.7)
P-Treated	34.5	72.2	261	61.5	13.1 (10.5-15.8)

70% reduction in Pb bioavailability!

Summary Soil Pb
Assessment / Solutions

VERY HIGH (> 1,500?)
consider another use for soil

HIGH, MEDIUM
1. assess Pb bioavailability to adjust Pb exposure!
2. May need to take action to reduce Pb exposure, cut off exposure / treat to reduce Pb bioavailability, or <u>both</u>

LOW (400 mg/kg) -- don't worry, be happy

Thank you for your attention

More information? Please contact:

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