This is why we are talking about biosolids

What are Biosolids?

Water- 60-80%

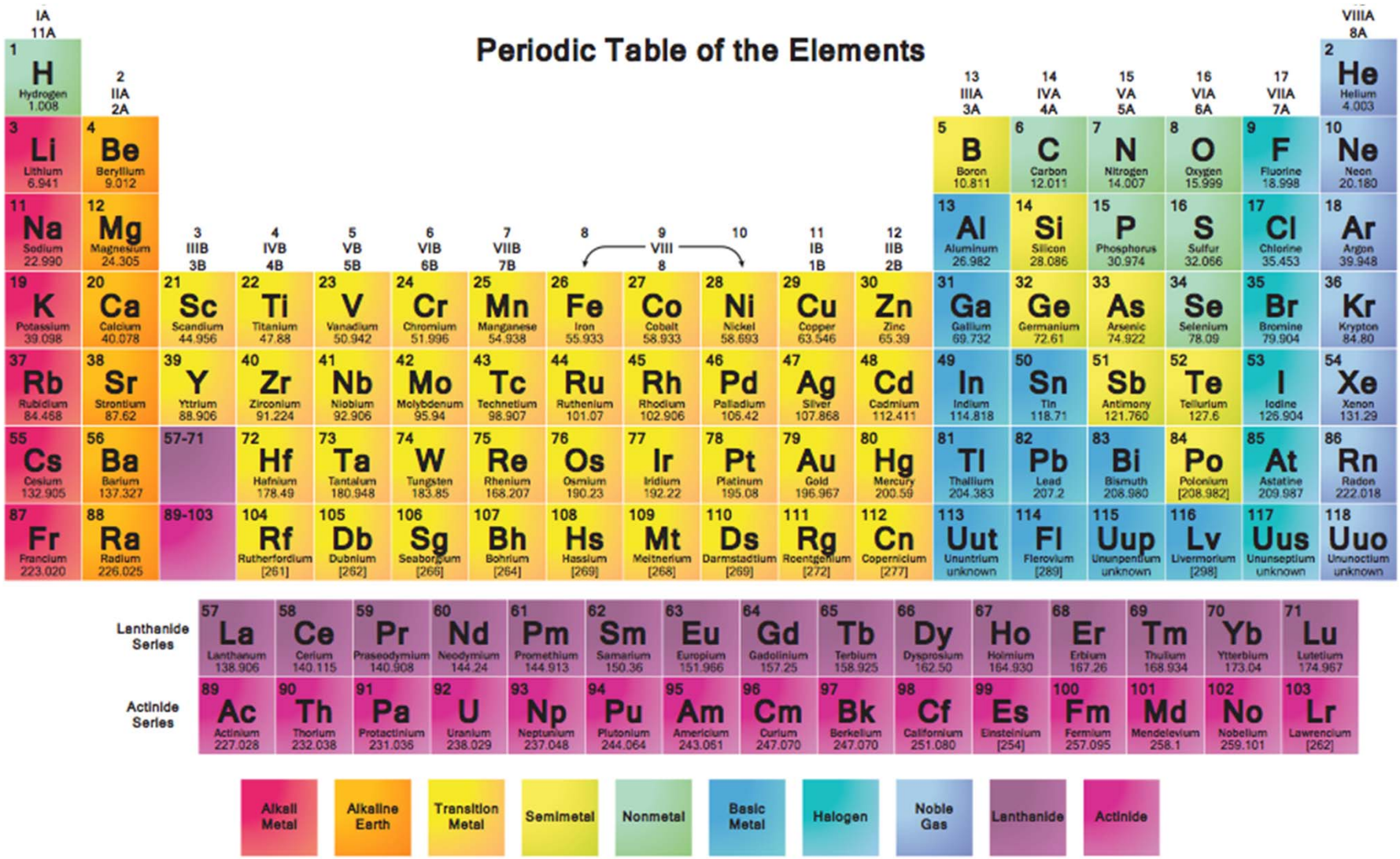
Carbon 4-10% (20-50%)

N 4% (2-7%)

P, S 1 - 3 %

K, Fe, Ca, Cu, Mn, Mg, Zn, B, Co

Biosolids contain just about every element on the periodic table



That's lucky-
What plants need

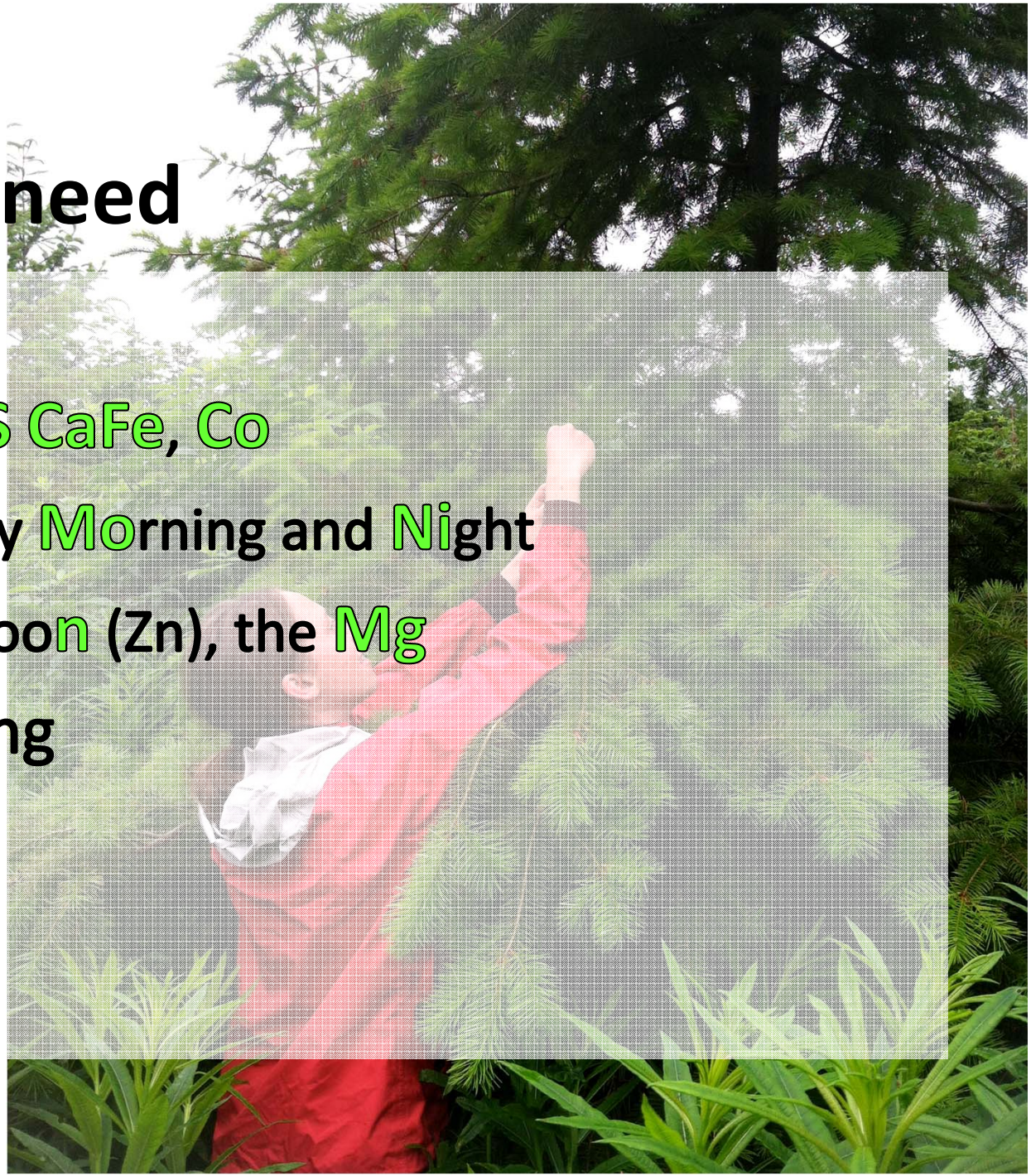
- Nutrients:

  C. B. HOPKiNS CaFe, Co

  Closed Monday Morning and Night

  See You (Cu) Zoon (Zn), the Mg

- 18 and counting



- Many/most of these are necessary plant and animal nutrients
- Some nutrients can be toxic in high enough concentrations (Zn)
- Very few elements are just toxic (As, Pb)

Macro Nutrients

(mg kg^{-1} or ppm)

- N - 25,000 - 40,000
- K - 20,000
- Ca - 5,000
- S - 1,500 - 4,500
- Mg - 3,000
- P - 2,000 - 4,000

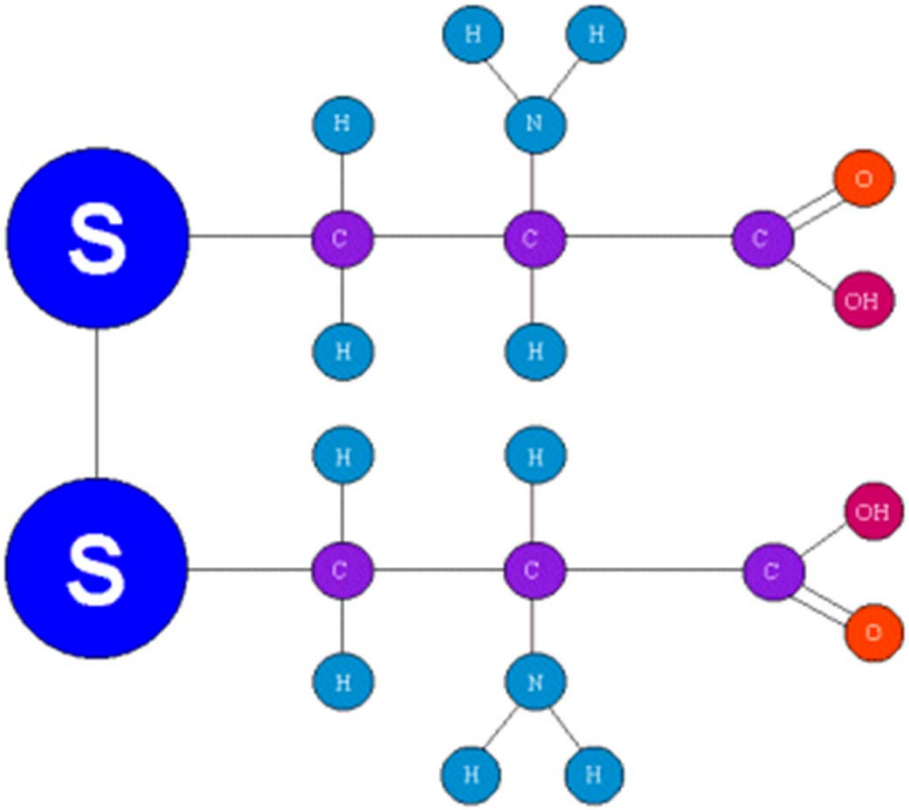
Sulfur in soils

- **Parent materials**
- **Atmospheric deposition**
  - **Coal burning plants**
- **Fertilizers**
  - **Sulfur is often associated with cations that are main fertilizer**

Sulfur deficiency in soybean

Suflur deficiency in wheat

Sulfur- essential in amino acids



Micro Nutrients

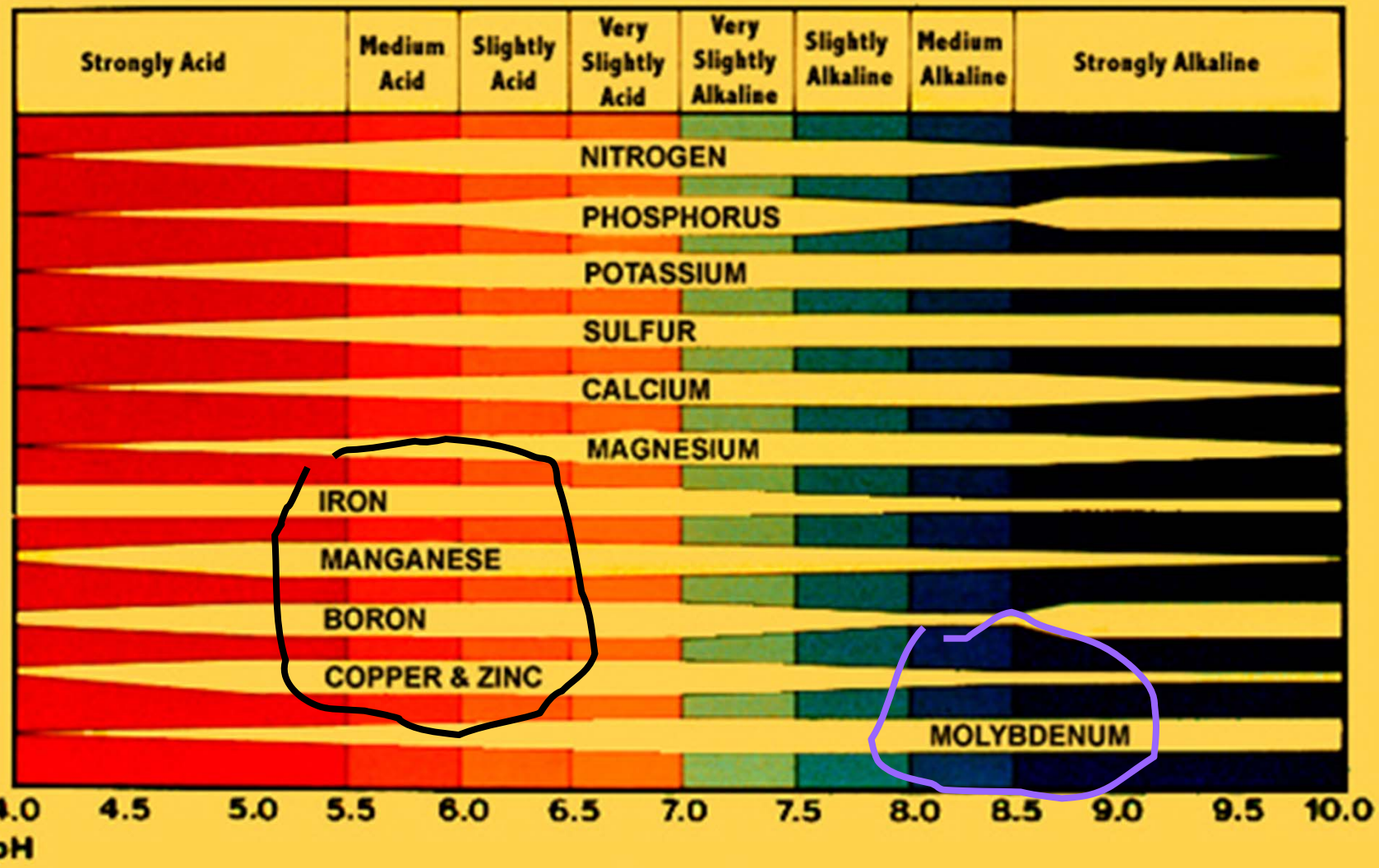
(mg kg^{-1} or ppm)

- **Zn - >20**
- **Mn - >20**
- **Cu - >5**
- **Fe - >50**
- **B - 60**
- **Mo, Co, Ni < 3**

Micronutrients

- Generally necessary in very small amounts
- Generally present in soils in sufficient quantities
- Some are metals, some are anions
- Availability will vary with pH

How Soil pH Affects Availability of Plant Nutrients



Generally

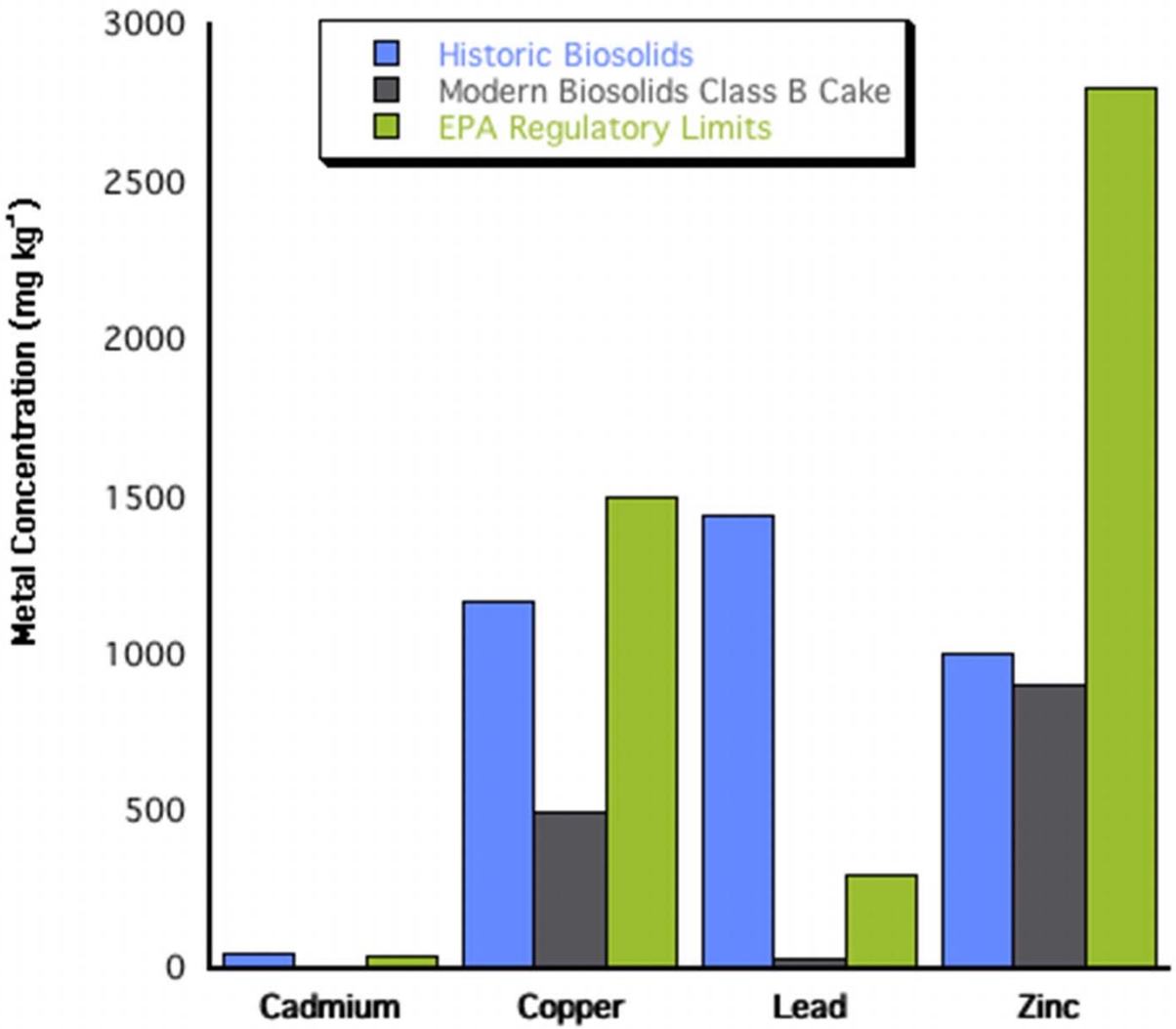
- Micronutrient deficiencies are most common on high pH soils
  - Mn, Fe, Zn
- Or on weathered sandy soils
  - Here parent material contained very small amounts of these nutrients and so they are quickly weathered out of soils

Each has its associated deficiency symptoms

Manganese deficiency

Figure 5. Manganese-deficient celery. Chlorosis of the leaves between the dark veins.

Modern vs. Historic Biosolids



Copper

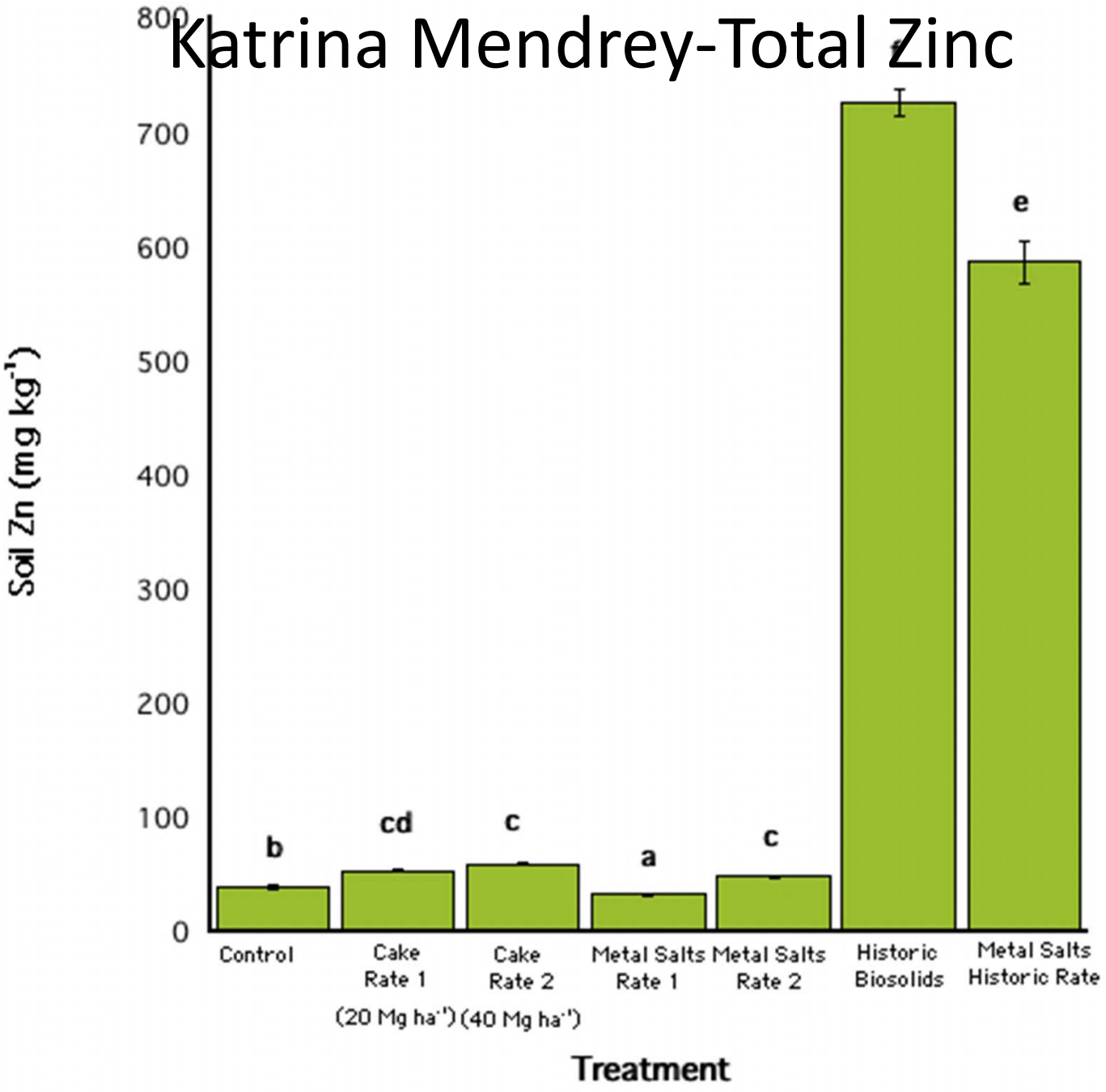
- 503 EQ limit = 1500 ppm
- Biosolids now = 600 ppm
- How much biosolids would you need to apply to reach soil Cu of 1500?

Copper

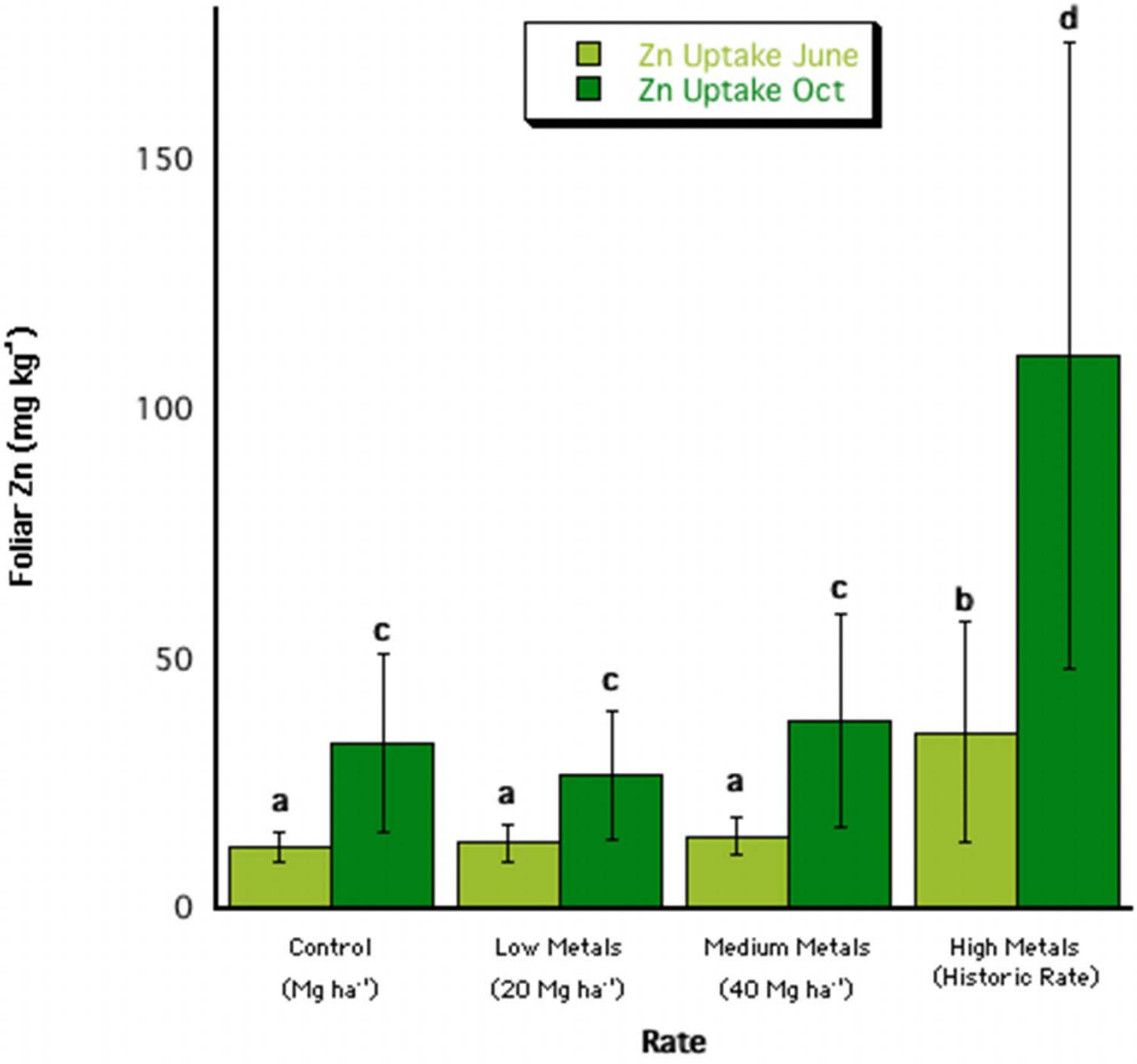
- If you apply biosolids to a soil at 10 tons per acre and the biosolids have 500 ppm Cu- how much have you raised the soil Cu concentration?
  - Assume soil weighs 1000 tons

Katrina- Metal availability to trees

Katrina Mendrey-Total Zinc



Foliar Zinc


Zn Uptake June
Zn Uptake Oct
Foliar Zn (mg kg⁻¹)
150
100
50
0
a
c
a
c
a
c
b
d
Control
(Mg ha⁻¹)
Low Metals
(20 Mg ha⁻¹)
Medium Metals
(40 Mg ha⁻¹)
High Metals
(Historic Rate)
Rate

Which had biosolids?

Lead is one example of a toxic element that is found in biosolids

- This is lead ore- or galena
- The chemical formula for this is PbS (not public television)
- It is about 87% lead

Biosolids from King County contain 15-80 ppm Lead

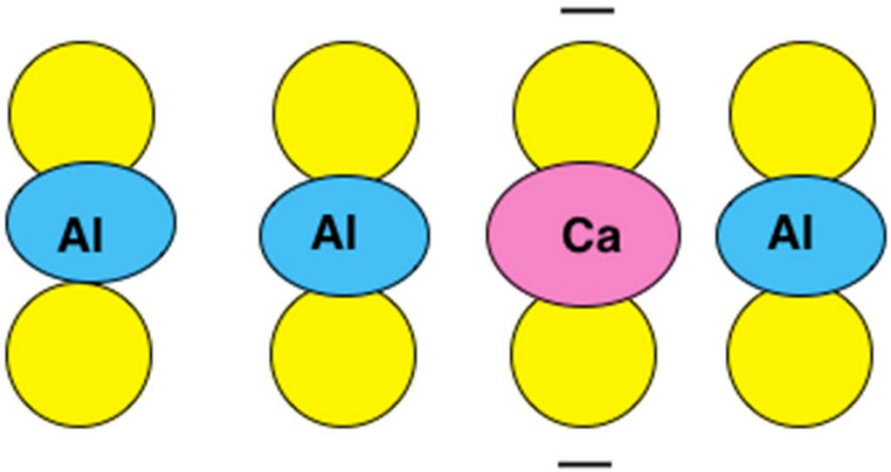
How much is 50 ppm equivalent to?

$ per $10,000?

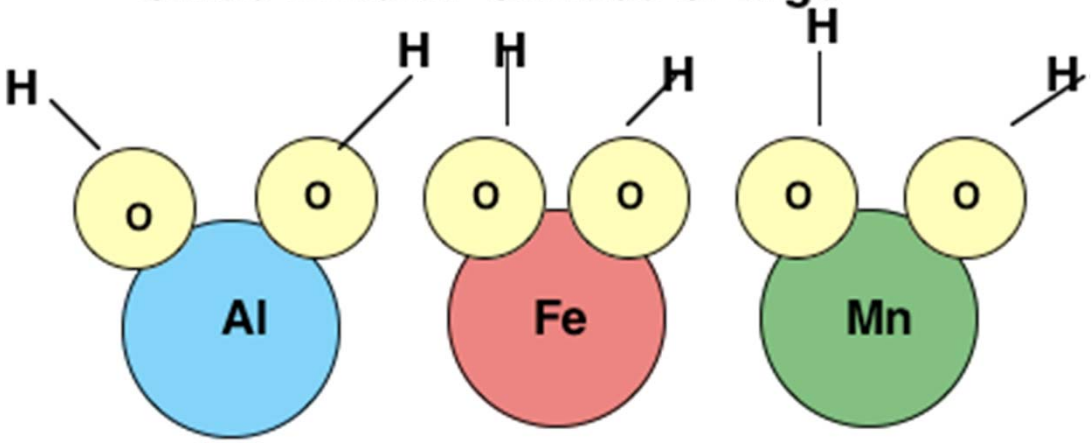
Changes in Lead Availability

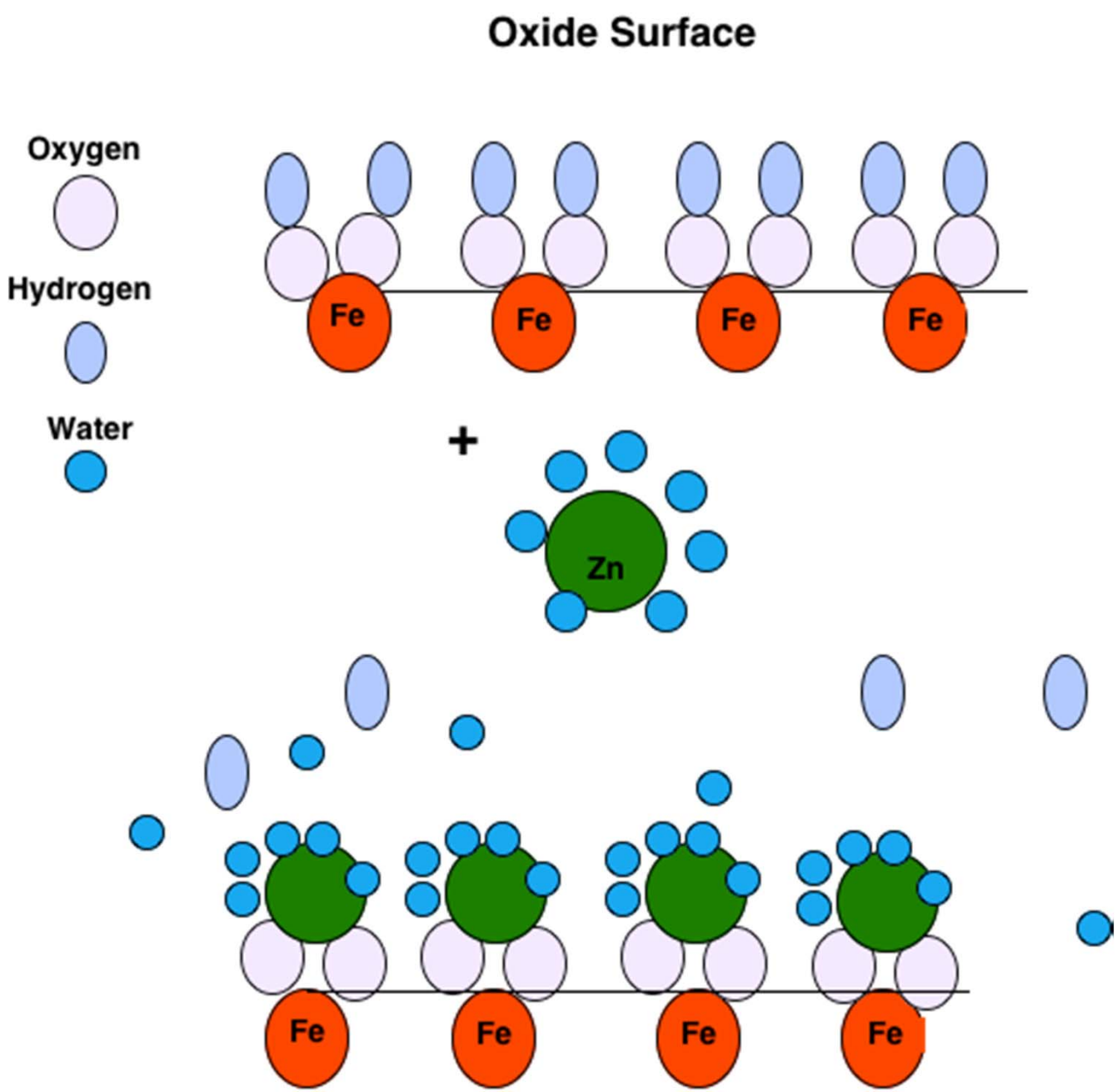
- Pre Compost
  - 1622 mg kg
- Post Compost
  - 595 mg kg

Clay mineral- Isomorphous substitution



Oxide mineral- Surface Charge

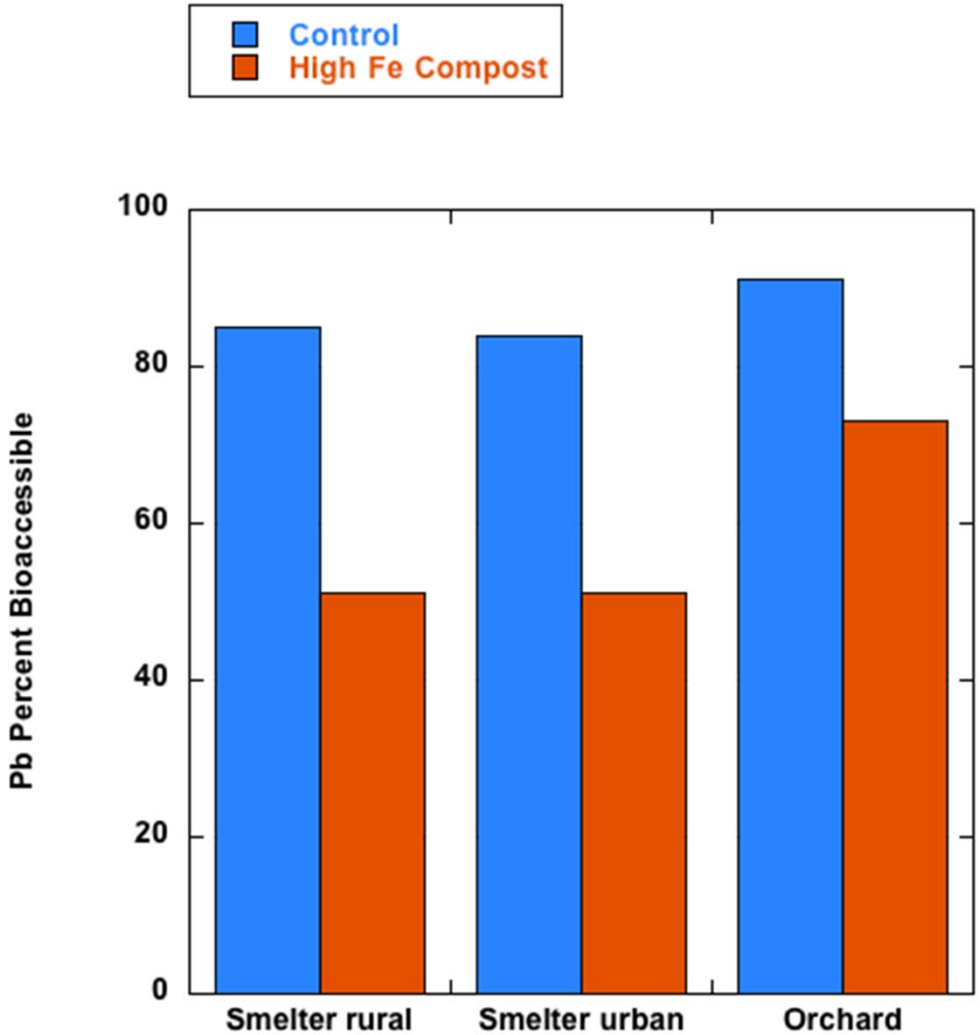



Oxide Surface
Oxygen
Hydrogen
Water
Fe
Fe
Fe
Fe
+
Zn
Fe
Fe
Fe
Fe

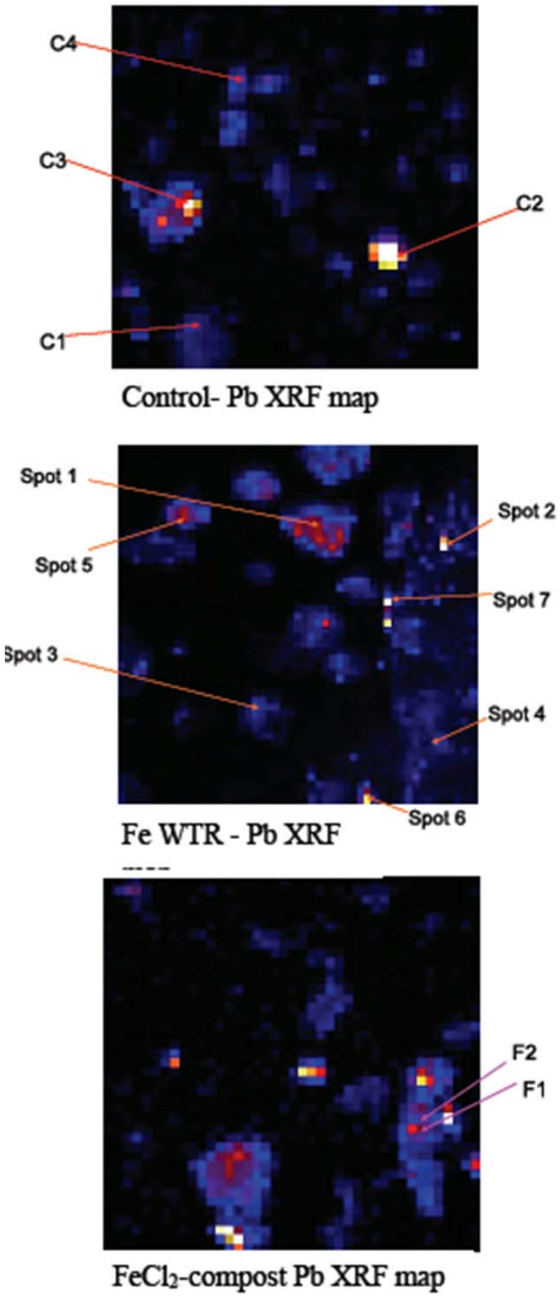
Iron Oxides

Mineral	Surface area $m^2\ g^{-1}$
Kaolinite- crystalline	20
Goethite crystalline	90
Ferrihydrite amorphous	505

How it works



- Fe mechanism for Pb binding
- Able to finally show change in Pb speciation (thanks to Ganga) and get pretty pictures



XAS results - Pb

- Pb in control
  - Anglesite 22%
  - Cerussite 50%
  - Leadhillite 28%
- Fe WTR
  - Fe sorbed Pb 88-100%
  - Pyromorphite 12 - 53%
  - Plumboferrite 53%

Biosolids
Extreme Makeover!

With your host:
Sally Brown

West Page Swamp-
Bunker Hill, ID
Before

West Page Swamp-
Bunker Hill, ID
During- 1998

West Page Swamp-
Bunker Hill, ID
After- 2005- See it shine!

Jasper County, MO
Before

Jasper County, MO
During- 2000

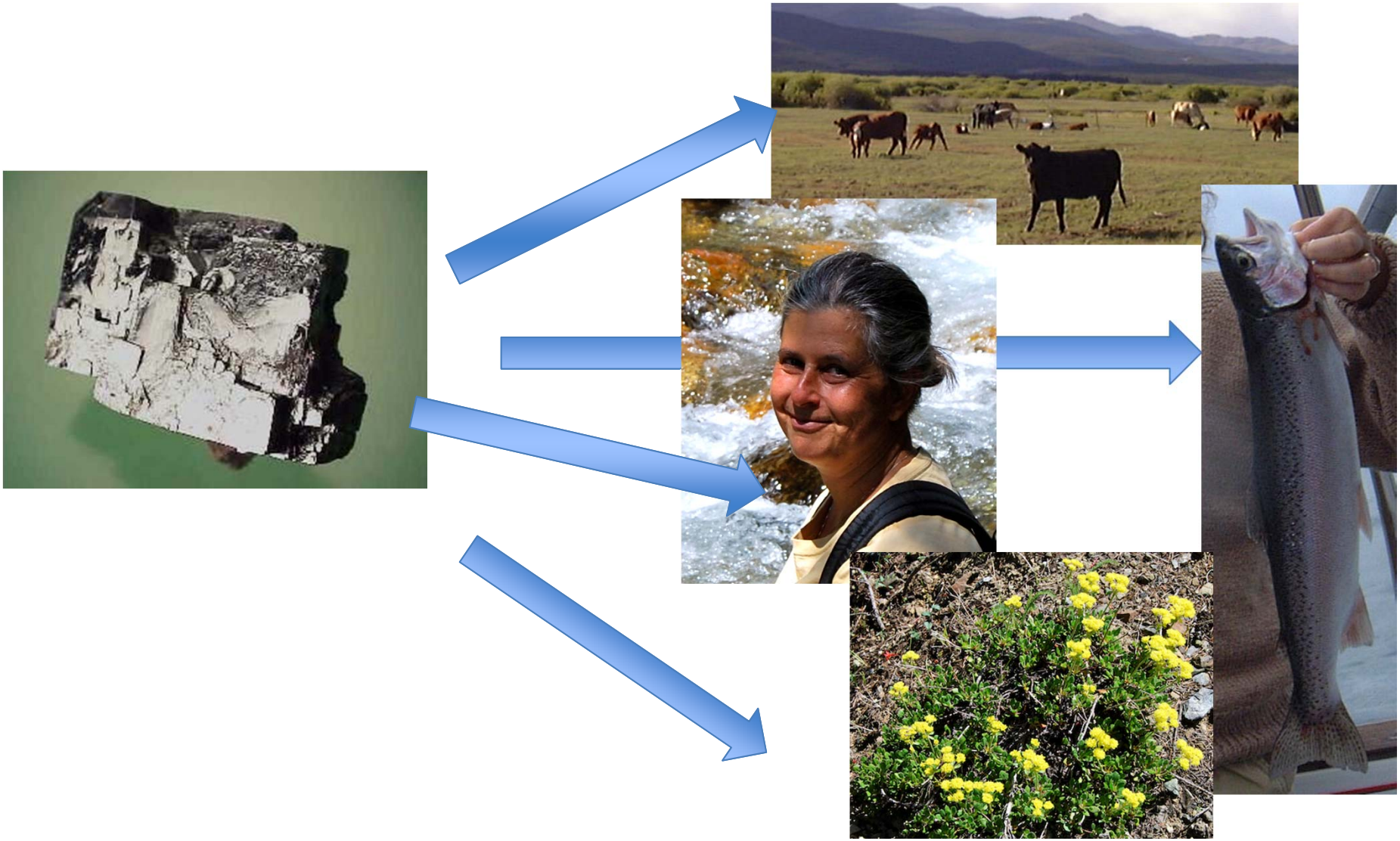
Jasper County, MO
After- 2003 Pretty Nice!

Leadville, CO
Before- 1997

Leadville, CO
During

Leadville, CO
After- 2005- A Stunner!

The risk assessment process for biosolids considered a number of ways that lead and other contaminants in biosolids could cause harm



How do you think that the lead (or other contaminants in the biosolids) could hurt people?

The risk assessment process for biosolids identified pathways that contaminants in biosolids could cause harm and used these to develop metal limits for the biosolids

Also included dust, contaminants to water (surface and ground)

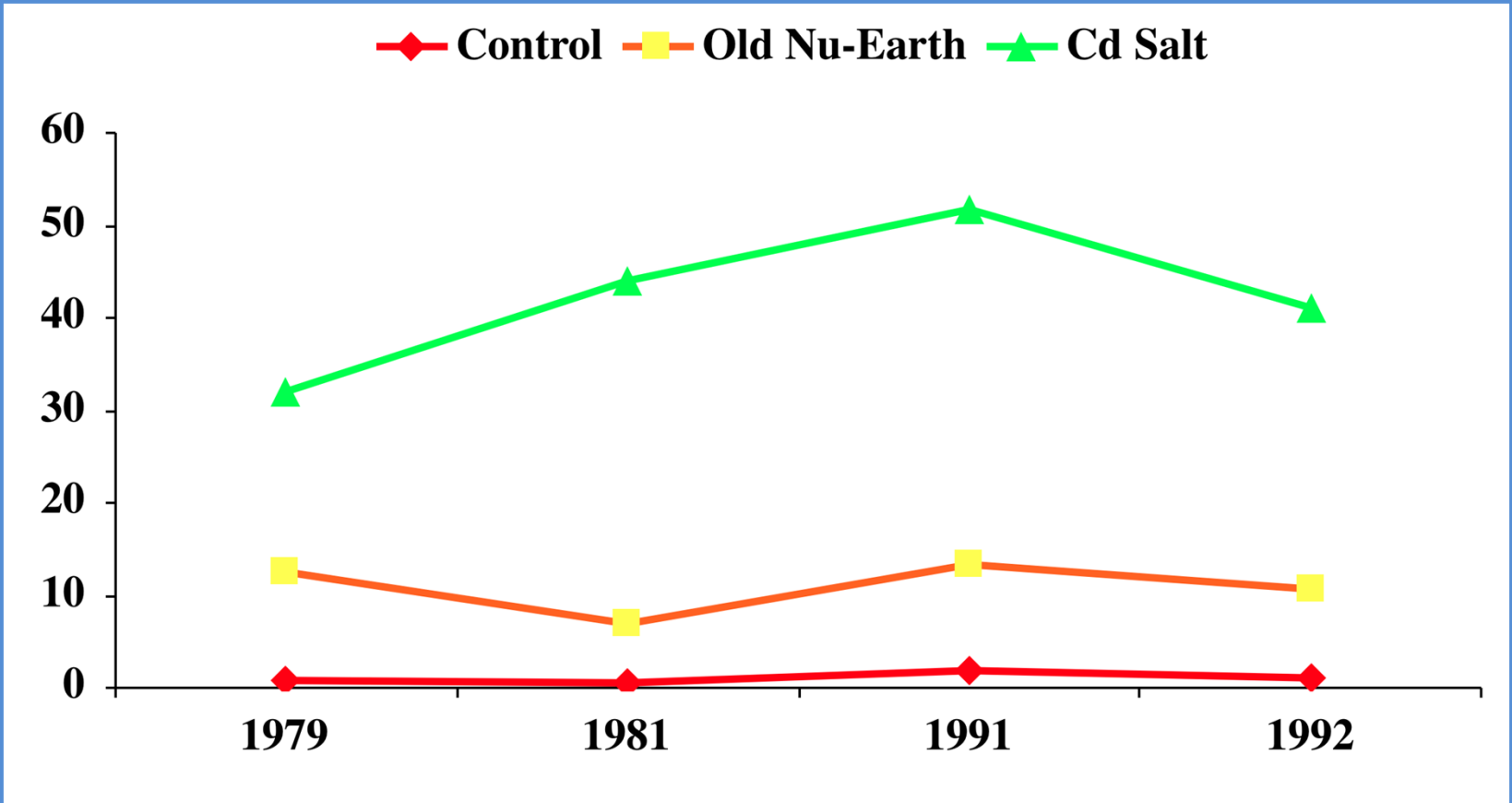
Highly exposed individual (HEI)

- 50% of all garden foods for life
- Soil ingestion of 200 mg soil/day
- 40% of meat from livestock raised on biosolids amended soils
- 100% of water from wells near biosolids amended soils
- For all cases- biosolids applied to make up the soil

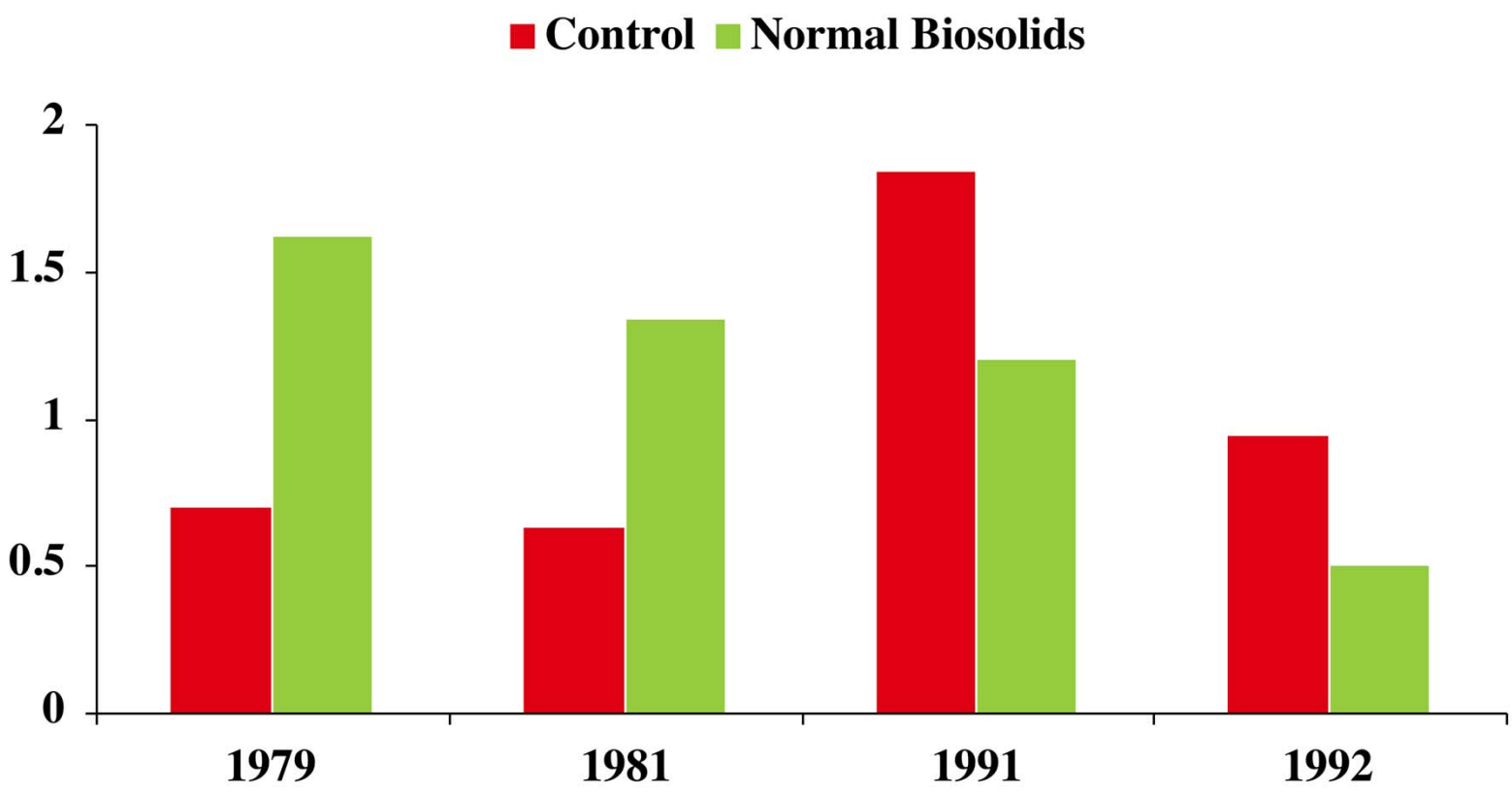
All of the regulatory limits were based on research

Lettuce Cd

Brown et al, 1998



Research: Lettuce Cd



Elements that were considered

- Tolerable:
  - Na, K, Mg, Ca, H, O, N, C, P, Fe, S, Cl, Br, Li, Rb, Sr, Al, Si
- Toxic but very insoluble or very rare:
  - Ti, Hf, Zr, W, Nb, Ta, Re, Ga, La, Os, Rh, Ir, Ru, Ba
- Very toxic and relatively accessible:
  - Be, F, Co, Ni, Cu, Zn, Sn, As, Se, Te, Pd, Ag, Cd, Pt, Ar, Hg, Pb, Sb, Bi

Also considered: dioxins, PCBs, furans, herbicides and pesticides

Final rule- EPA Part 503

9 metals, no organics (carbon based chemicals)

Exceptional Quality limits	King County biosolids
• Arsenic 41	• 3-5.3
• Cadmium 39	• 1-2.3
• Copper 1500	• 370-440
• Lead 300	• 15-88
• Mercury 17	• 0.8-1
• Molybdenum (max 75)	• 8.4-9.4
• Nickel 420	• 13-22
• Selenium 100	• 5-6.4
• Zinc 2800	• 680-870

One consequence of this research: EPA now uses biosolids to cure metal contamination

Coeur d'Alene Wetlands 1998- 2000

1998

2001

I view biosolids

- As a sustainable, safe resource for soils and growers