Hemp (*Cannabis sativa* L.) as a phytoremediator

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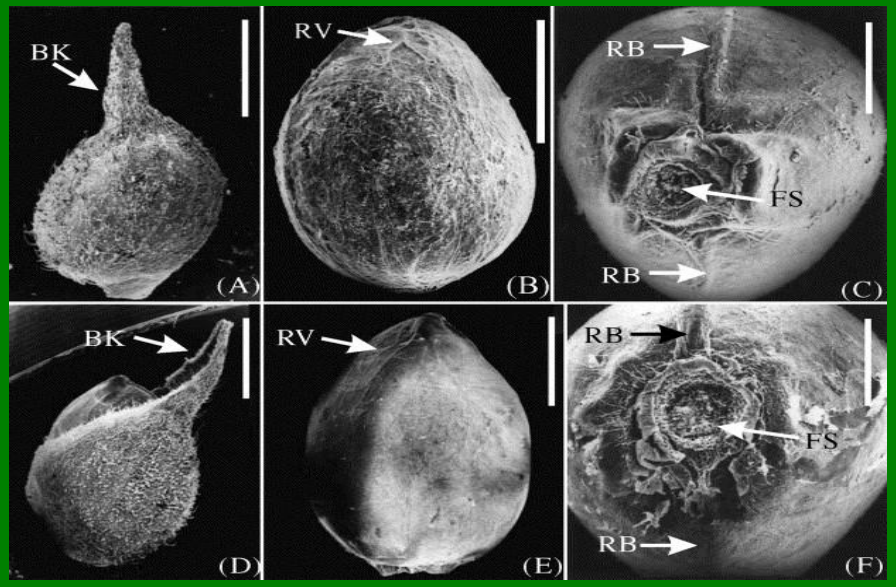
Outline

- What is hemp
- Heavy metal phytoextraction
- Radiocesium phytoextraction
- Current project in Colorado

What is hemp?

- *Cannabis sativa* L.
  - First named by Carolus Linneaus in 1753
  - Native to central Asia
  - In the family Cannabacea
    - Other members include *Humulus* and *Celtis*

- Has been used for 10,000 years, one of first cultivated plants.
  - Industrial hemp vs. drug hemp
    - .5-1% THC content vs. 3- 20% THC content.
    - THC present in trichomes of flowers, industrial hemp varieties grown for fiber and oil



(Jiang et al, 2006)

Why use hemp as a phytoremediator?

- High biomass which is unaffected by pollutants
  - Root can grow up to 8 feet below ground
  - Low growing cost
- Quick growing season
  - full maturation in 180 days
- Good accumulator from air and soil
- Contaminated products can be used for industrial purposes
  - Biodiesel fuels, industrial lubricants and varnishes, insulation, construction materials, paper, clothing, food and plasticized or composited materials for a variety of uses



Using hemp for biofuels on cadmium polluted agricultural land

- Yi et al. (2010) examined feasibility for converting *C. sativa* into biodiesel.
  - They successfully converted the oil from seeds while meeting ASTM standards (American Society for Testing Materials)
  - The only drawback was that oxidation stability was poor, necessitating additives for industrial level production.
- Much of the land around the world is polluted with Cadmium
  - Burning of fossil fuels, human sludge, pesticides from the 1950s and 60s
- Shi and Cai (2009) did a study on fuel plants and Cadmium uptake
  - Used hemp, flax, castor, peanut, sunflower, cotton , soybean and rapeseed
  - Biomass of hemp not effected and BFC (cadmium in plant/cadmium initial in soil) was quite high.

Treatments (mg/kg)	Cd content (μg/g)		BCF (%)	
	Roots	Shoot	Roots	Shoot
A. hypogaea				
50	616.9 ± 24.8b	97.4 ± 5.6c	1234 ± 50b	195 ± 11a
100	2013.7 ± 67.6a	157.7 ± 3.0b	2014 ± 68a	158 ± 3b
200	2124.5 ± 52.1a	177.4 ± 5.2a	1062 ± 26b	89 ± 3c
B. rapa				
50	682.3 ± 16.3c	235.6 ± 0.9c	1365 ± 33a	471 ± 2a
100	899.6 ± 30.0b	266.3 ± 8.1b	900 ± 30b	266 ± 8b
200	993.4 ± 38.7a	287.7 ± 5.4a	497 ± 19c	144 ± 3c
C. sativa				
50	1549.7 ± 101.4c	56.7 ± 6.4c	3099 ± 203a	113 ± 13a
100	2349.0 ± 114.3b	82.9 ± 2.7b	2349 ± 114b	83 ± 3b
200	4052.8 ± 225.6a	101.5 ± 8.0a	2026 ± 112b	51 ± 4c
C. tinctorius				
50	616.3 ± 18.4c	191.4 ± 4.1b	1232 ± 36a	382 ± 11a
100	838.2 ± 9.6b	231.8 ± 9.6a	838 ± 9b	231 ± 10b
200	1076.6 ± 29.9a	256.9 ± 11.5a	538 ± 14c	128 ± 6c
G. max				
50	458.7 ± 9.9b	26.8 ± 1.0c	917 ± 20a	54 ± 2a
100	618.6 ± 8.0a	34.7 ± 0.7b	619 ± 8b	35 ± 1b
200	614.3 ± 27.2a	68.9 ± 2.3a	307 ± 14c	34 ± 1b
H. annuus				
50	341.5 ± 1.5b	88.1 ± 4.1b	683 ± 3a	176 ± 8a
100	374.7 ± 2.4c	105.5 ± 4.9c	375 ± 3b	106 ± 5b
200	408.3 ± 5.4d	146.8 ± 0.7d	204 ± 3c	74 ± 4c
L. usitatissimum				
50	203 ± 10b	109 ± 5b	405 ± 20a	218 ± 11a
100	293 ± 5ab	144 ± 7b	293 ± 5b	144 ± 7b
200	372 ± 78a	231 ± 36a	186 ± 39c	115 ± 18b
R. communis				
50	341.4 ± 2.1b	14.7 ± 1.9b	683 ± 4b	25 ± 7a
100	386.0 ± 4.6b	28.0 ± 4.0b	386 ± 5c	24 ± 7a
200	2517.9 ± 178.7a	59.8 ± 7.5a	1259 ± 89a	30 ± 4a

Means in the same column for each crop followed by the same letter are not significantly different at $P<0.05$ based on LSD test.

Hemp and heavy metal accumulation

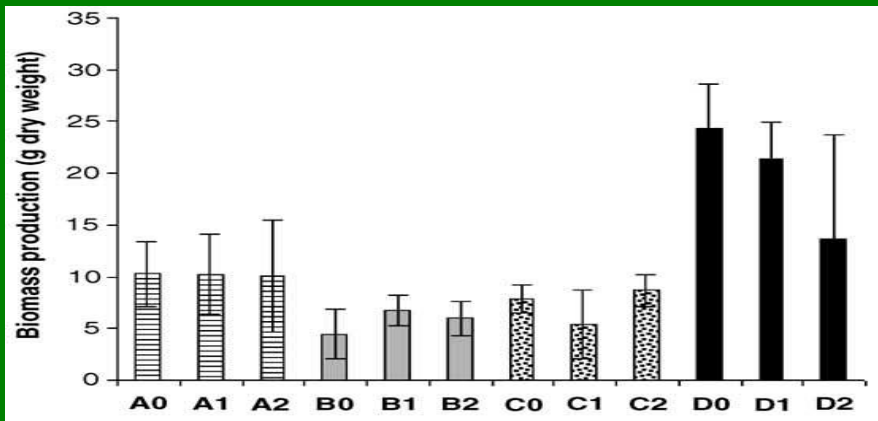
- Broader look at heavy metal uptake
  - Linger et al (2001) look at nickel, cadmium, and lead in seeds, leaves, fibers and hurds
  - Highest in leaves; Ni>Pb>Cd in all parts
  - Fiber content was not affected

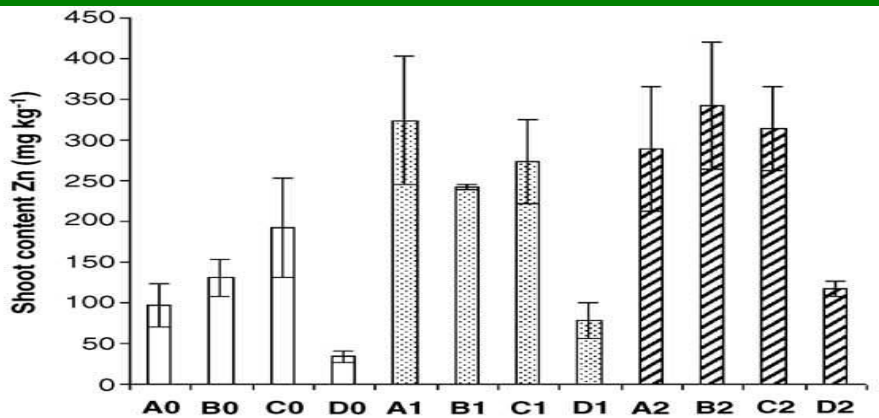
Table 1
Heavy metal contents of the hemp samples

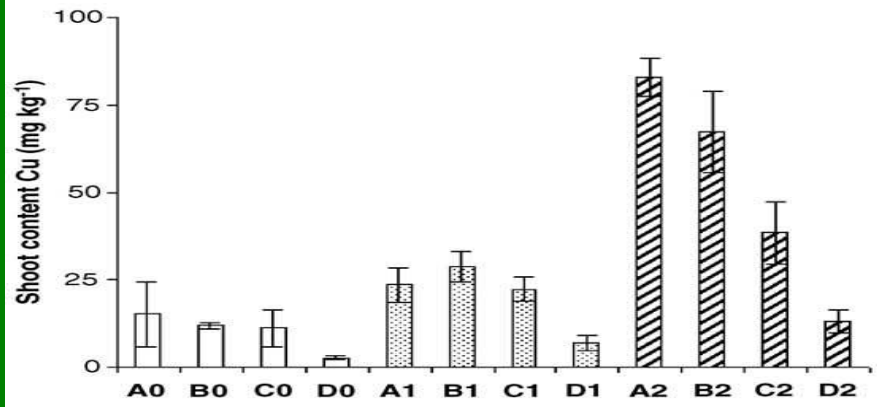
Sample	Weight (g)	Residue (%)	Cd content		Pb content		Ni content	
			ppm	Average	ppm	Average	ppm	Average
Hurds	1.732	2.6	0.78		2.60		12.96	
Hurds	1.973	2.6	0.76	0.8	2.94	2.8	9.99	11.5
Fibres	1.537	3.5	0.85		3.97		7.42	
Fibres	1.575	3.3	0.79	0.8	3.78	3.9	6.32	6.9
Leaves	1.485	23.3	3.94		23.20		63.83	
Leaves	2.058	23.5	2.96	3.5	21.65	22.4	63.46	63.6
Seeds	0.757	6.0	1.19		1.98		33.24	
Seeds	0.829	6.4	1.03	1.1	1.69	1.8	24.79	29.0

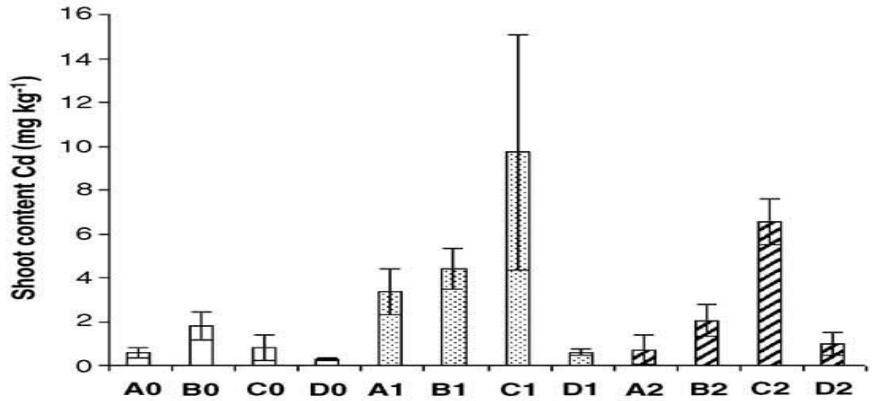
Using chelators

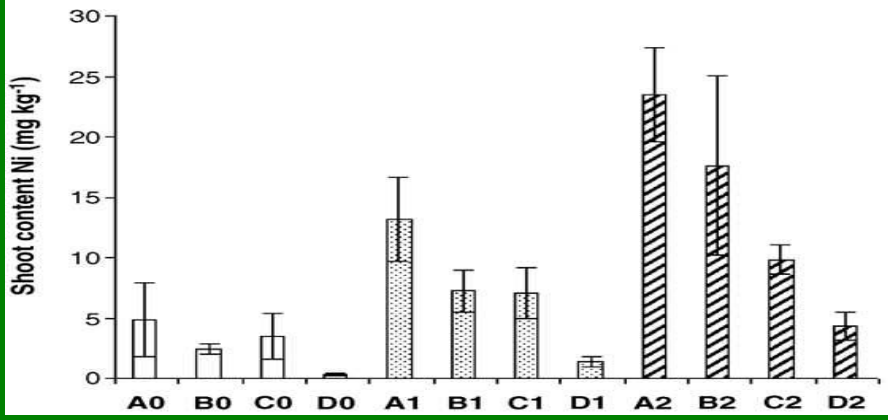
- Another study chose to examine the effects of EDTS vs. EDDS for increased phytoremediation potential in the shoots
  - The biomass for treatments with the chelators did not change
  - Nickel and Copper were improved with EDDS, whereas Cadmium and Zinc were more improved with EDTS

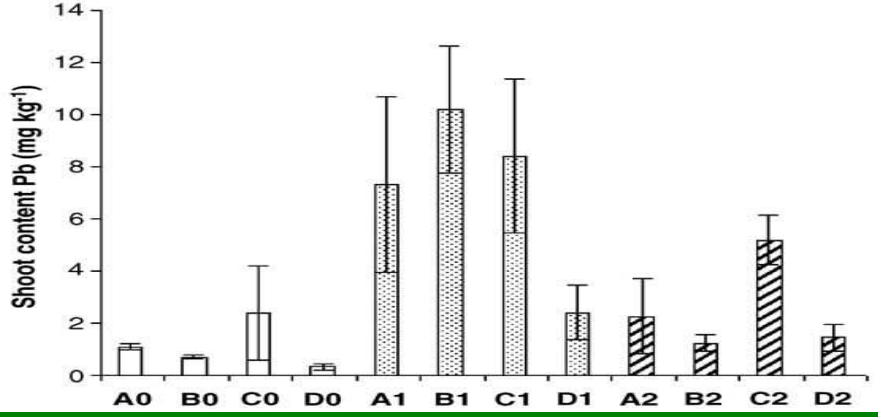

Biomass production (g dry weight)
0
5
10
15
20
25
30
35
A0 A1 A2 B0 B1 B2 C0 C1 C2 D0 D1 D2


Shoot content Zn (mg kg-1)
0
50
100
150
200
250
300
350
400
450
A0 B0 C0 D0 A1 B1 C1 D1 A2 B2 C2 D2


Shoot content Cu (mg kg-1)
0
25
50
75
100
A0 B0 C0 D0 A1 B1 C1 D1 A2 B2 C2 D2

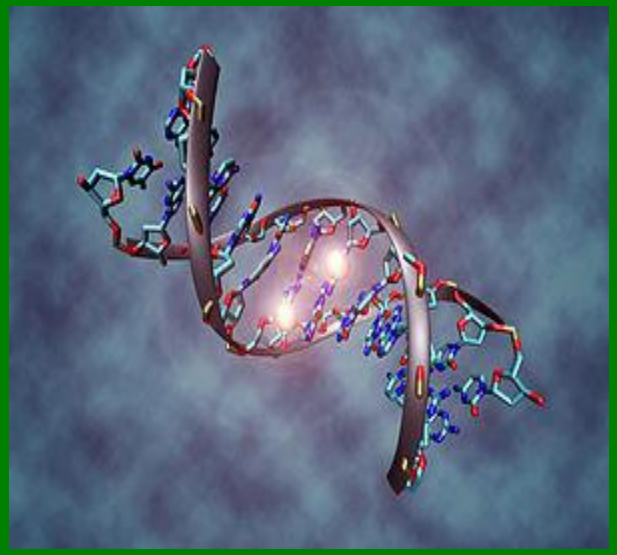

Shoot content Cd (mg kg-1)
0
2
4
6
8
10
12
14
16
A0 B0 C0 D0 A1 B1 C1 D1 A2 B2 C2 D2


Shoot content Ni (mg kg-1)
0
5
10
15
20
25
30
A0 B0 C0 D0 A1 B1 C1 D1 A2 B2 C2 D2


Shoot content Pb (mg kg-1)
0
2
4
6
8
10
12
14
A0 B0 C0 D0 A1 B1 C1 D1 A2 B2 C2 D2

DNA methylation

- There is some evidence that one of the mechanisms that allows for metal tolerance is due to the methylation of DNA
- When compared to a *Trifolium repens*, a metal sensitive plant, the presence of 5-methylcytosine is much greater on root DNA
- After heavy metal treatments of Nickel, Cadmium and Cromium, both plants showed hypomethylation, indicacating that DNA methylation is a defense mechanism to metal tolerance, possibly to prevent structural damage



Hemp and cesium accumulation

- A study done in 2005 by Vandenhove and Hees tested hemps ability to uptake of radiocesium.
  - Sandy soils used to emulate Chernobyl conditions
  - Used a lysimeter and pots in greenhouse.

- Soil was contaminated with approx. 326 kBq/kg in pots and 13.0 kBq/kg in the lysimeter and harvested after 186/136 days.

- Chernobyl accident was contaminated at 1480 kBq/m^2

Table 4
Maximal ^{137}Cs soil contamination levels in function of end use of product and observed transfer factors

	Flax TF ($\times 10^{-3}$ m^2 kg^{-1})	Use	Decontamination factor	Limit Bq kg^{-1}	Max soil cont. kBq m^{-2}
Stem fibre	0.06	Fibre	>100	740[a]	12 300
Stem fibre	0.06	Building material: boards, chips, fibre board	>100	1850[a]	31 000
Stem	3	Biofuel	1	740[a]	247
Seeds	0.5	Oil	*10*–50	185	*3700*[c]
Seeds	0.5	Flour	*1.3*–2[b]	370	*962*
	Hemp ($\times 10^{-3}$ m^2 kg^{-1})				
Stem fibre	1	Fibre	1	740[a]	740
Stem fibre	1	Building material: boards, chips, fibre board	1	1850[a]	1850
Stem	0.7	Biofuel	1	740[a]	1057
Stem	0.7	Litter	1	1850[a]	2643
Seeds	3	Oil	*10*–50	185	*610*
Seeds	3	Flour	*1.3*–2[b]	370	*160*

Disadvantages of using hemp as a phytoremediator

- Hemp is not the most efficient phytoremdiator
- While demand for hemp products is high, legal issues can inhibit or slow project
- Introduction of a possible noxious weed

Phytoremediation with hemp in Colorado

- Jason Lauve and the Industrial Hemp Remediation Project in Lafayette, Colorado

Future research

- Organics uptake using hemp
- Plant mechanisms for heavy metal uptake
- Ways to enhance heavy metal uptake

Conclusions

- Hemp can be used for a variety of industrial products such as building materials, biofuels, insulation, textiles and paper products.

- Hemp is a good phytoremediator potential for heavy metals and radioactive cesium due to the possibility of using the phytoextracted material in industrial products

Quiz questions

- Name two uses for industrial hemp.
- Name one type of pollutant is hemp can phytomremediate.

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Quiz answers

- Many answers for # 1: textiles and paper, biofuels, food and industrial grade oils, building materials.
- #2: I talked about Cesium, Cd, Ni, Zinc, Lead, Cu
- Xxxxxxxxxxx