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IMPACT OF SOIL CONTAMINATION ON FEED AND FOOD SUPPLY CHAINS: FIELD DATA AND MODEL APPLICATION

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OUTLINE

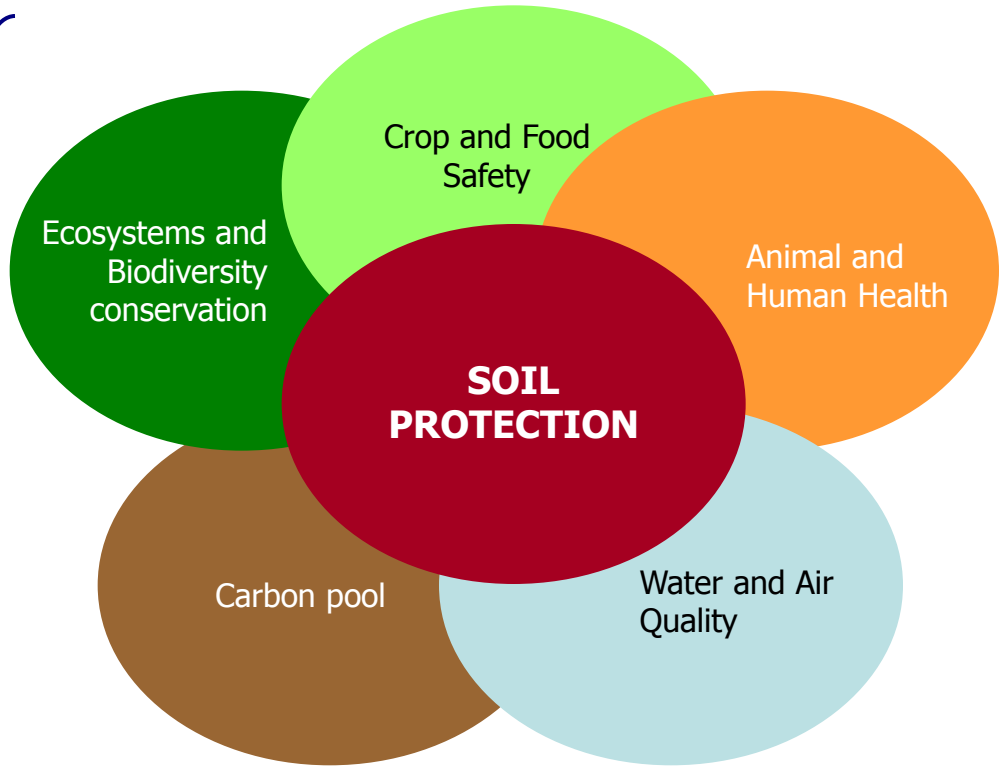
- Introduction
- Objectives/ Scope
- Results
- Conclusions

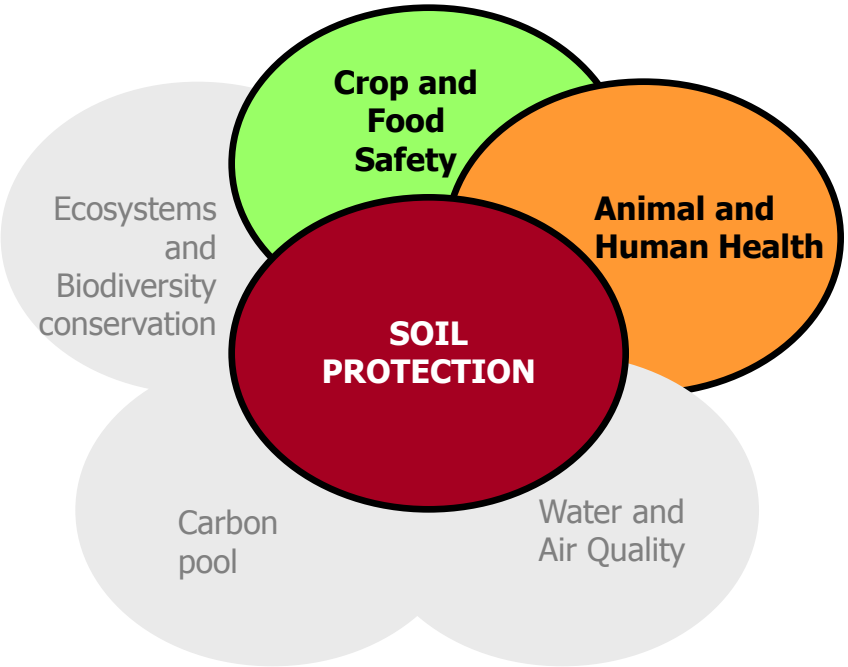
Challenges to the Scientific Community:

- Demonstrate importance of soil protection

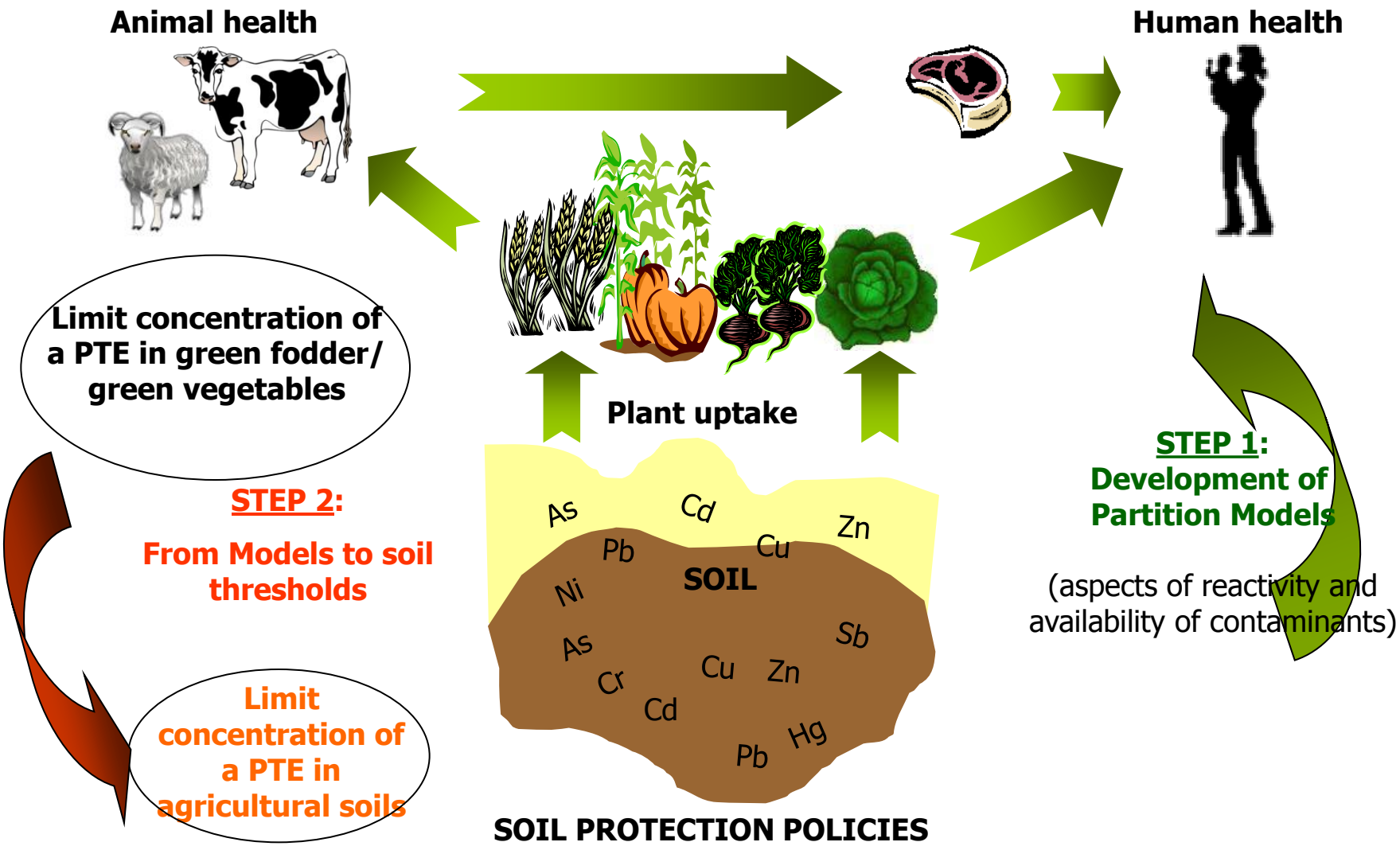
COMMON AMONG ALL EUROPEAN COUNTRIES/ TRANSBOUNDARY:

Potential for harmonization of scientific aspects towards a EU regulatory framework

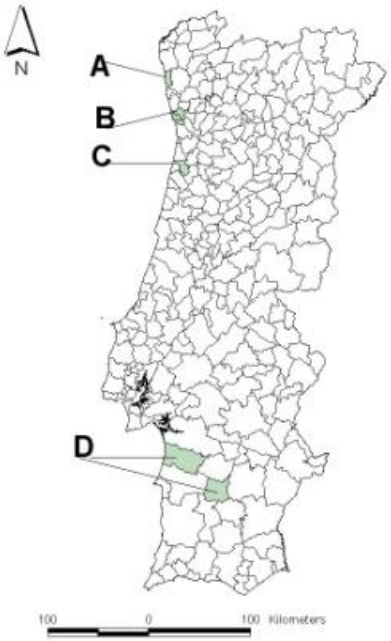



Crop and Food Safety
Animal and Human Health
SOIL PROTECTION
Ecosystems and Biodiversity conservation
Carbon pool
Water and Air Quality

PORTUGAL


Animal health
Human health
Limit concentration of a PTE in green fodder/ green vegetables
Plant uptake
STEP 1: Development of Partition Models
(aspects of reactivity and availability of contaminants)
STEP 2: From Models to soil thresholds
Limit concentration of a PTE in agricultural soils
As
Cd
Zn
Pb
Cu
Ni
SOIL
Sb
As
Cr
Cu
Zn
Cd
Hg
Pb
SOIL PROTECTION POLICIES

Field studies in Portugal



Area A: **Rural - Agriculture**
Area B: **Urban - Agriculture**
Area C: **Estarreja Chemical Complex - Agriculture**
Area D: **Lousal, Caveira and Aljustrel mines - Agriculture**

✓ **215 soil samples**

✓ **208 plant samples:** Ryegrass (*Lolium perenne*); Italian ryegrass (*Lolium multiflorum*); Orchard grass (*Dactilis glomerata*); Rye (*Secale cereale*); Collard greens (*Brassica oleracea*); and Mustard greens (*Brassica Juncea*).

PTE's analysed: Hg, As, Cd, Cu, Pb, Zn, Cr, Ni, Co, Mn, Fe, Al, U, Ba, B, Mo, Li, Sb, Se, Be

Soil properties: pH, OrgC %, Clay %, Amorphous Fe and Al oxides, DOC ($CaCl_2$ extracts)

Soil analysis: extraction with *aqua regia* (ICP-MS analysis); Pyrolysis-AAS (for Hg); extraction with 0.43 M HNO_3 and 0.01 M $CaCl_2$

Total pools of PTEs (mg kg^{-1} d.w.)

Total [Hg]: 0.013-98 mg kg^{-1} median: 0.34 mg kg^{-1}

aqua regia

- **[Cd]: 0.10-3.7 mg kg^{-1}** median: 0.40 mg kg^{-1}
- **[Zn]: 17-1,194 mg kg^{-1}** median: 137 mg kg^{-1}
- **[Cu]: 7.4-7,635 mg kg^{-1}** median: 80 mg kg^{-1}
- **[Pb]: 10-11,546 mg kg^{-1}** median: 58 mg kg^{-1}
- **[As]: 6.3-2,189 mg kg^{-1}** median: 54 mg kg^{-1}
- **[Ni]: 4.5-45 mg kg^{-1}** median: 16 mg kg^{-1}
- **[Co]: 0.50-49 mg kg^{-1}** median: 8 mg kg^{-1}
- **[Ba]: 16-599 mg kg^{-1}** median: 62 mg kg^{-1}
- **[Sb]: 0.10-220 mg kg^{-1}** median: 1.4 mg kg^{-1}
- **[U]: 0.20-13 mg kg^{-1}** median: 1.4 mg kg^{-1}
- **[Mo]: 0.50-1.6 mg kg^{-1}** median: 0.90 mg kg^{-1}
- **[Be]: 0.20-1.5 mg kg^{-1}** median: 0.50 mg kg^{-1}
- **[Cr]: 2.0-70 mg kg^{-1}** median: 17 mg kg^{-1}
- **[Se]: 0.50-19 mg kg^{-1}** median: 1.2 mg kg^{-1}

Origin:

Geogenic

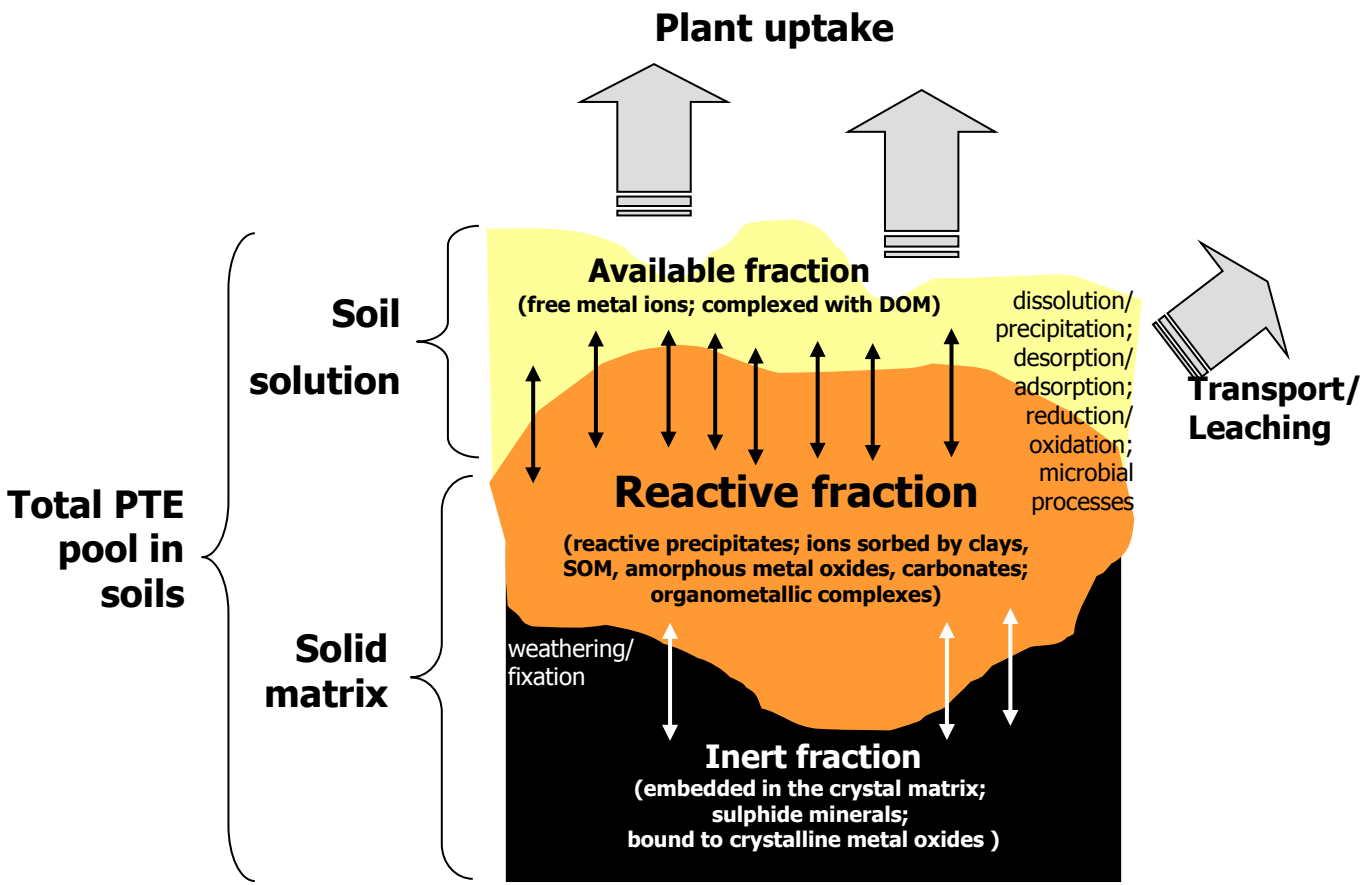
Ni, Cr, Co, U, Al, Mn, Fe

Anthropogenic

(urban, industrial, mining)

Cd, Zn, Ba, Hg, Cu, Pb, As, Se, Sb, Mo

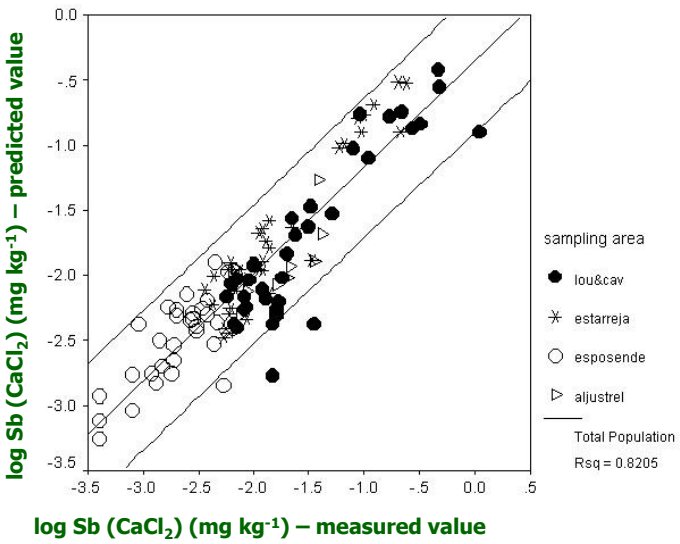
What happens when there is soil contamination??
Fate of potentially toxic elements in soils



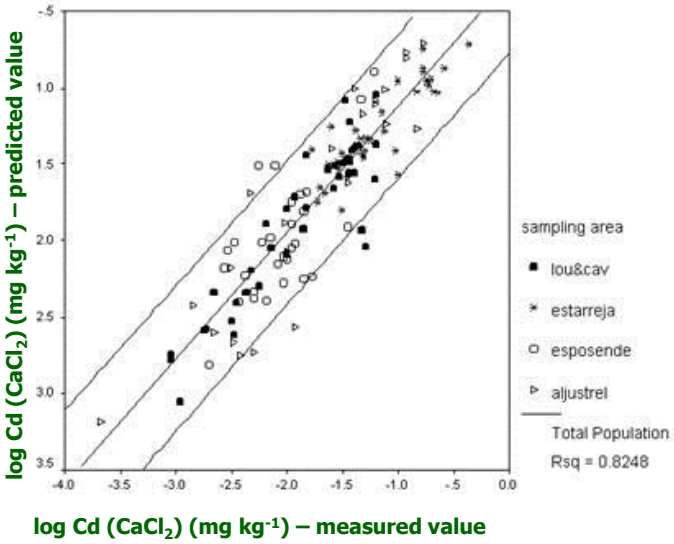
Rodrigues *et al.*,Chemosphere 2010a

Examples calibration of the soil ⇔ soil solution models

Sb



Cd



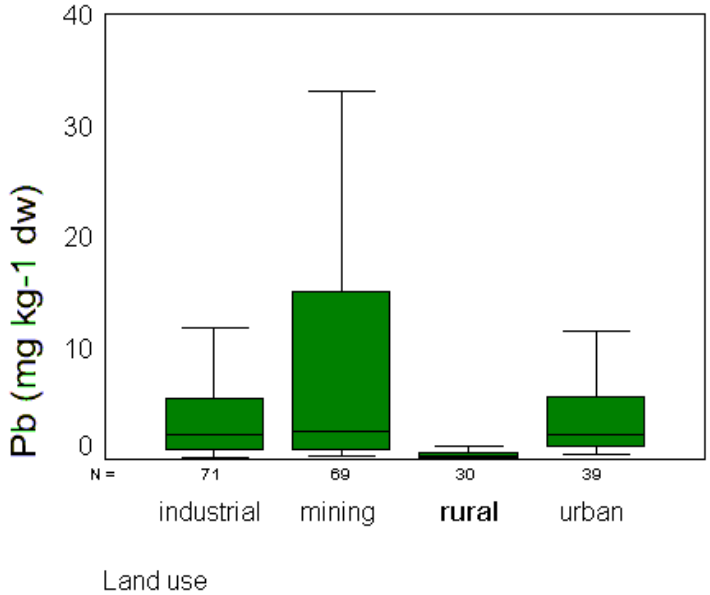
$$\log[\mathbf{Sb}_{\mathbf{available}}] = -1.0 - 0.75\times\log[\text{Org C}] + 0.65\times\log[\text{clay}] + 1.0*\log[\mathbf{Sb}_{\mathbf{reactive}}]$$

$$\log[\mathbf{Cd}_{\mathbf{available}}] = 2.0 - 0.44\times\text{pH} - 0.78\times\log[\text{Org C}] - 0.63\times\log[\text{Al}] + 1.1\times\log[\mathbf{Cd}_{\mathbf{reactive}}]$$

Rodrigues *et al.*,Chemosphere 2010b

What about crops ???

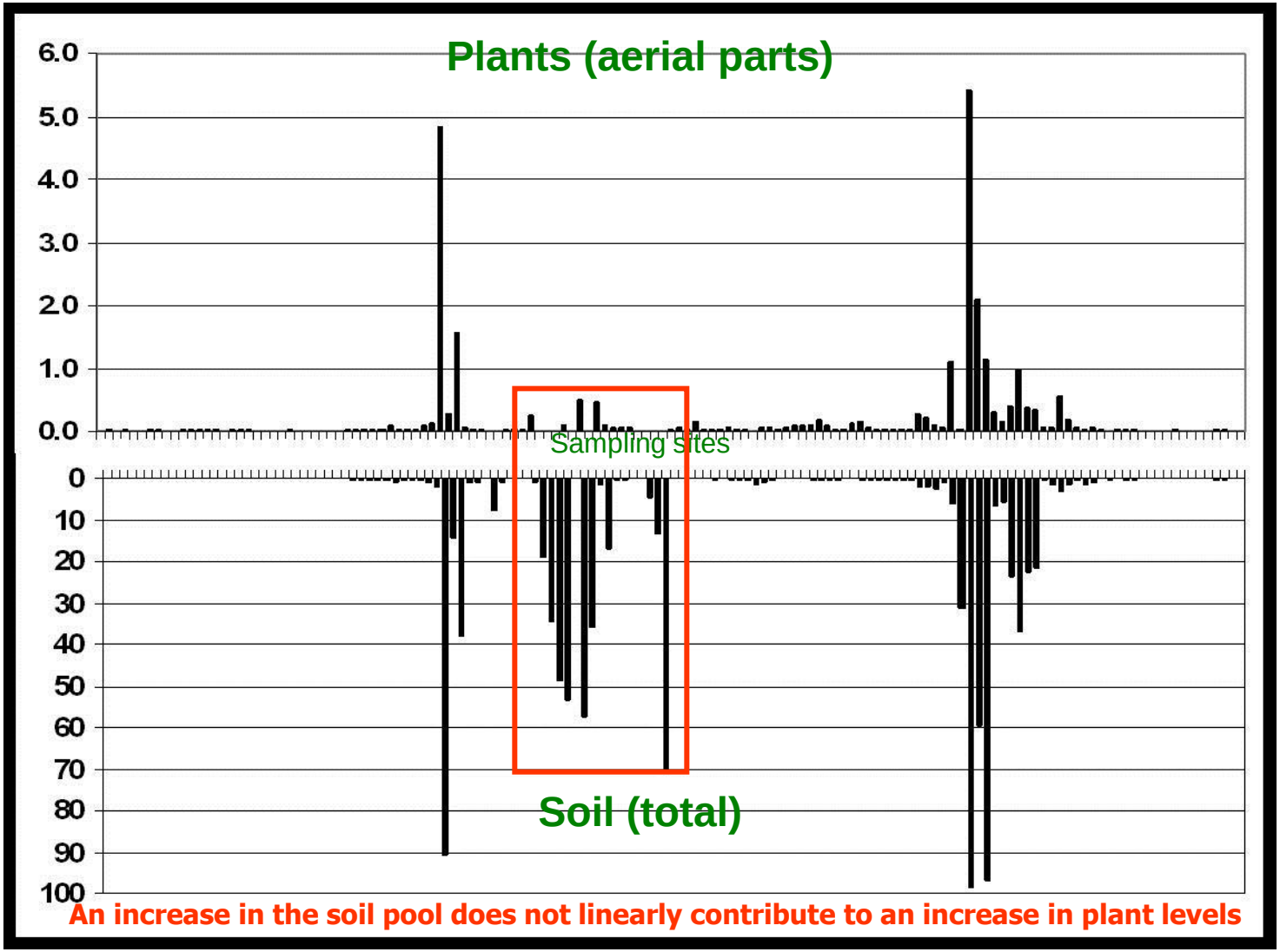
Example: Pb in crops from different areas



Contaminant levels in food crops generally remained below food safety limits.

Levels of Hg, Pb, As, Cu, Cd and Zn in feed products from industrial and mining sites exceeded current EU feeding stuff limits.

Hg (mg kg^{-1})



An increase in the soil pool does not linearly contribute to an increase in plant levels

Freundlich-type empirical function to link PTE in soil to levels in crops:

$$[PTE]_{plant} = a \cdot [PTE]_{soil}^{b}$$

Or after log transformation:

$$\log[PTE]_{plant} = \log(a) + b \cdot \log[PTE]_{soil}$$

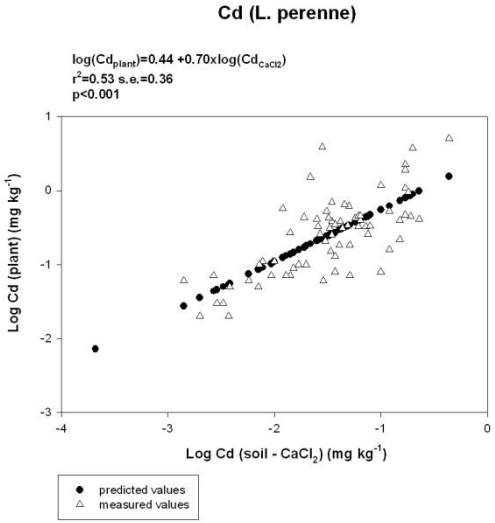
Coefficients derived from regression analysis

(Kraus *et al.*, 2002; Römkens *et al.*, 2009)

a) $$\log[PTE]_{plant} = \log(a) + b \bullet \log[PTE]_{soil(available)}$$

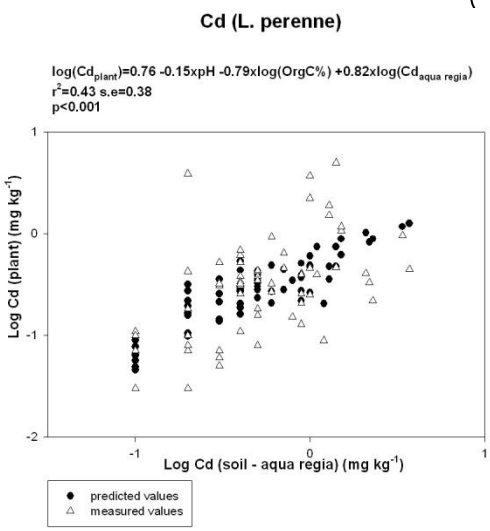
Soil available pool

(0.01 M $CaCl_2$ extraction)



b) $$\log[PTE]_{plant} = \log(a') + (c...n) \bullet \log[soil\_properties] + b \bullet \log[PTE]_{soil(total)}$$

Soil properties and total pool



Summary of results on estimation of plant contents of PTE's

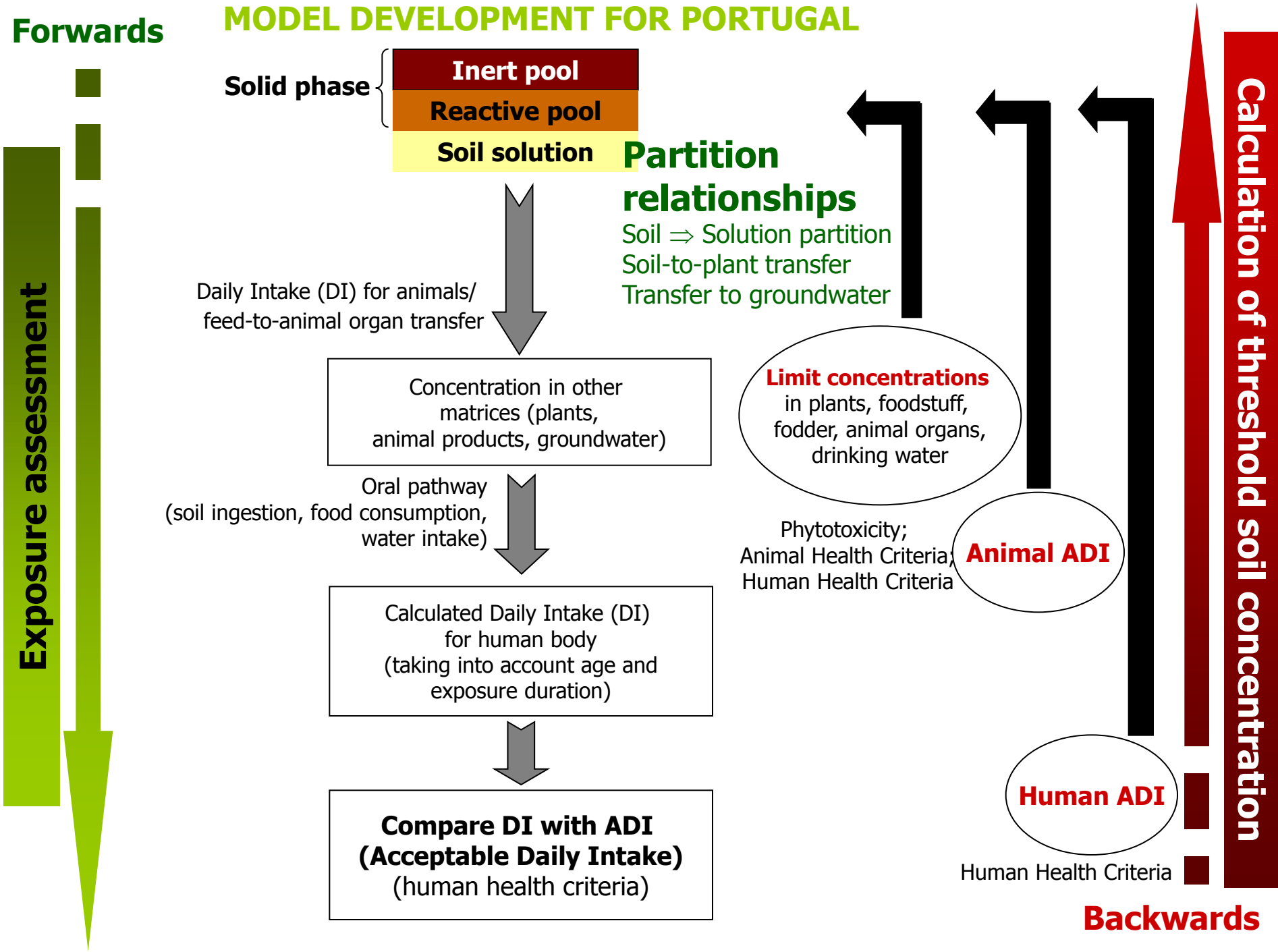
✓ Both empirical SPT models and the 0.01 M $CaCl_2$ extraction explained between 40 and 90 % of the variation of Cd, Zn, Pb, Cu, Hg, As, Sb and Ba in feed crops.

✓ Organic carbon and pH were the main variables explaining levels of elements in ryegrass.

✓For Hg and Pb, Al_{ox} played a significant role.

✓For Cr, Se, Mo and B no significant relationship was found.

MODEL DEVELOPMENT FOR PORTUGAL



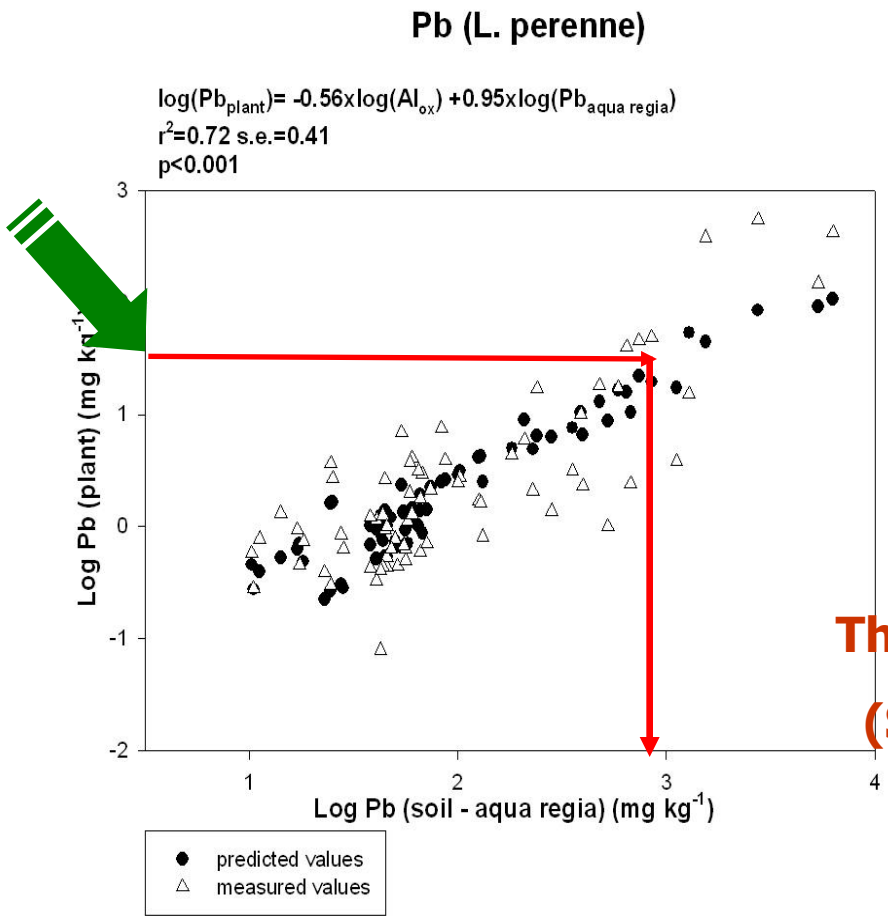
Calculation of threshold soil concentrations for Lead

Use of calibrated empirical models

EC Limit in feedstuff

+

Soil properties



Threshold value in soil

(Soil quality criteria)

Soil quality criteria for Cd and Pb (green fodder production)

This study

	Limit soil concentrations (total*) (mg kg^{-1} d.w.)					
	Cd			Pb		
	pH=4; Org C=3%	pH=5; Org C=3%	pH=6; Org C=3%	Al_{ox}=50 mmol kg^{-1}	Al_{ox}=100 mmol kg^{-1}	Al_{ox}=150 mmol kg^{-1}
Green fodder production (*Lolium perenne*)	2.1	3.1	4.8	411	618	789
	Limit soil concentrations (available **) (mg kg^{-1} d.w.)					
	Cd			Pb		
Green fodder production (*Lolium perenne*)	0.3			71		

Soil properties

* soil total concentrations = *aqua regia* extraction

** soil available concentrations = 0.01 M $CaCl_2$ extraction

Legislation in different countries

Soil quality criteria other countries (soil total concentrations, mg kg^{-1} d.w.) (source: Carlon, 2007)		
	Cd	Pb
Portugal (agricultural soils amended with sewage sludge)	1 (pH<5.5) 3 (5.5<pH<7.0) 4 (pH>7.0)	50 (pH<5.5) 300 (5.5<pH<7.0) 450 (pH>7.0)
UK (soil guideline values: allotments) (based on a sandy loam soil with 6% organic matter content)	1.8	n.a.
the Netherlands (generic target values - intervention values) (standard soil 10 %OM; 25 % clay)	0.8 - 12	85 - 530
Flanders, Belgium (clean-up values; agricultural areas)	2	200

- **Comparable to ranges from other countries**

Results: Calculation of soil threshold concentrations on the basis of soil ⇒ crop relationships

CONCLUSIONS

✓ There are **soil contamination problems** in Portugal in urban, industrial and mining areas

✓ There is transfer of contaminants along the **terrestrial foodchain**

✓ Soil contamination contributes to increase **exposure** of animals and humans to potentially toxic elements

✓ **Partition functions** that link PTE's reactivity and chemical availability with crop quality are promising to assess animal or human exposure to soil contaminants

✓ Can be used to derive and/or improve **soil threshold concentrations** for a large array of PTE's.

⇒ **substantial increase in the accuracy of risk assessment**

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Approach including improved partition functions:

- Generic applicability!
- Conceptual basis of a harmonized strategy for management of contaminated sites across Europe: soil – feed - food safety – animal health – human exposure issues

Future research:

- Other plants/ crops
- For some elements (e.g. Cr) no soil-to-plant relationship exists:

  re-consider the approach?
- improvement of plant – animal relationships

  data lacking!

Acknowledgments

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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Thank you for your attention!