Ecotoxicity of heavy metals in soil

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Critical pathways for metals in soil (generic cases)

• Cd, Pb: exposure to humans

• Zn, Cu, Ni: toxicity to soil dwelling organisms (plants, microbes, invertebrates, wildlife)

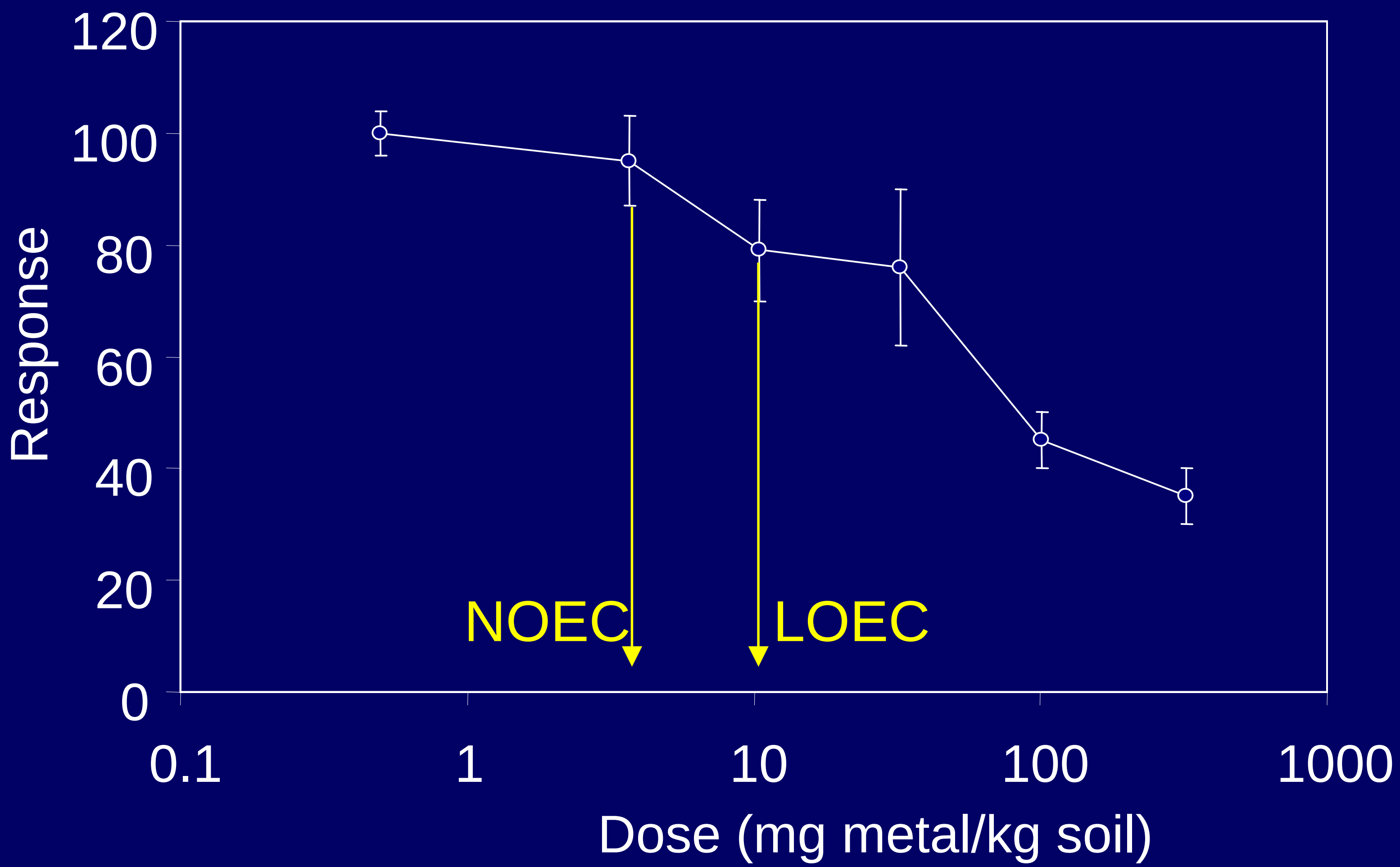
↓

<u>ecotoxicity</u> should be assessed to

•regulate Zn, Cu and Ni emissions (e.g. sludge, critical loads, fertilisers)

•assess success of remediation in soils contaminated by Zn, Cu and Ni

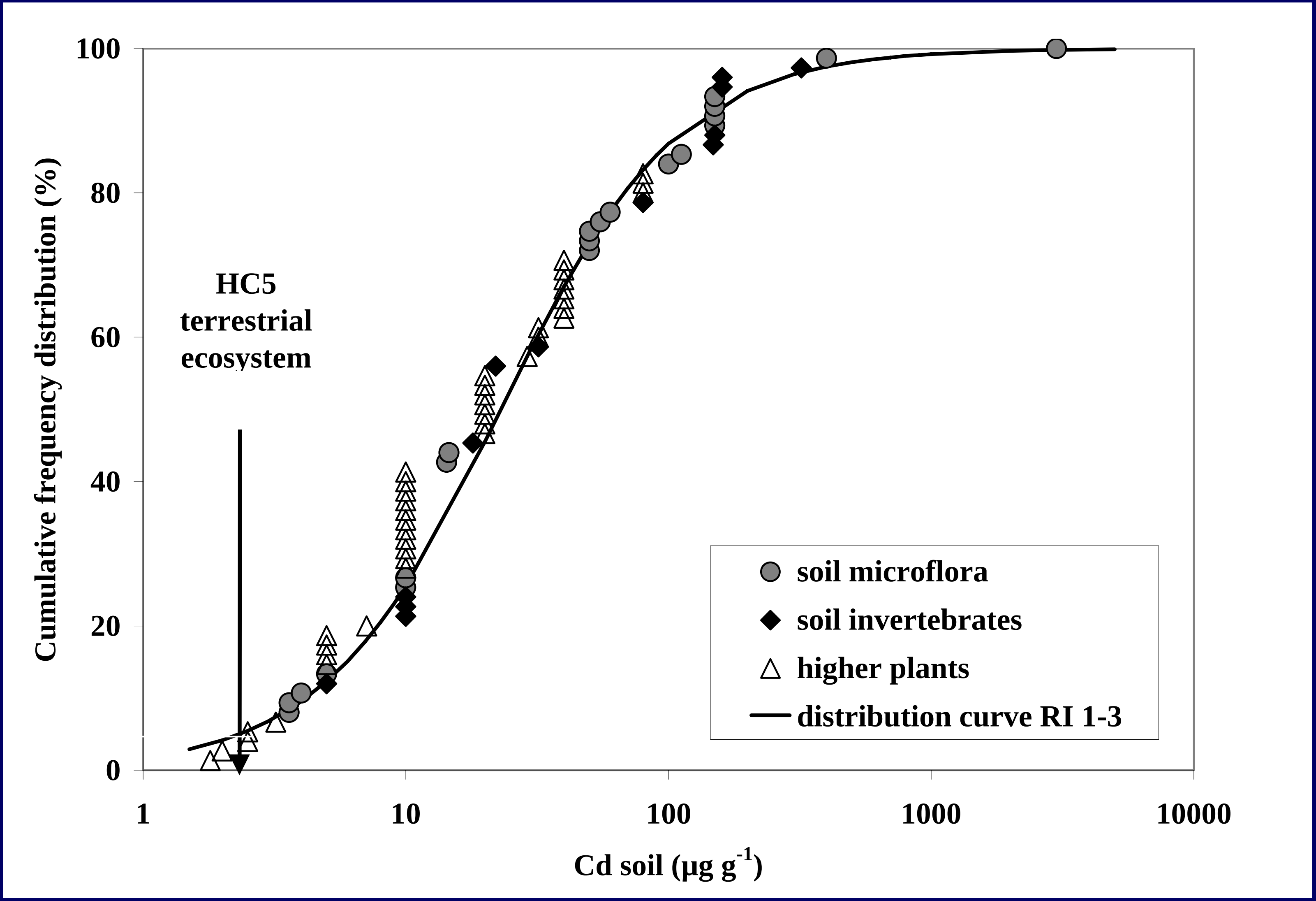
Conventual ecotoxicity approach: dose-response studies with metal salt spiked soils in the laboratory



NOEC: highest conc. with no effect (n.s.) or ≤ 10 % Inh.

LOEC: >10 % Inh. (if sign.) or >20 % Inh. (if no stats. avail.)

The convential derivation of the ‘generic’ Predicted No Effect Concentration in soil is the 5th percentile of NOEC values of different species, the so-called HC5 of the Species Sensitivity Distribution



The HC_5, derived from laboratory NOEC values is within range of geological background values

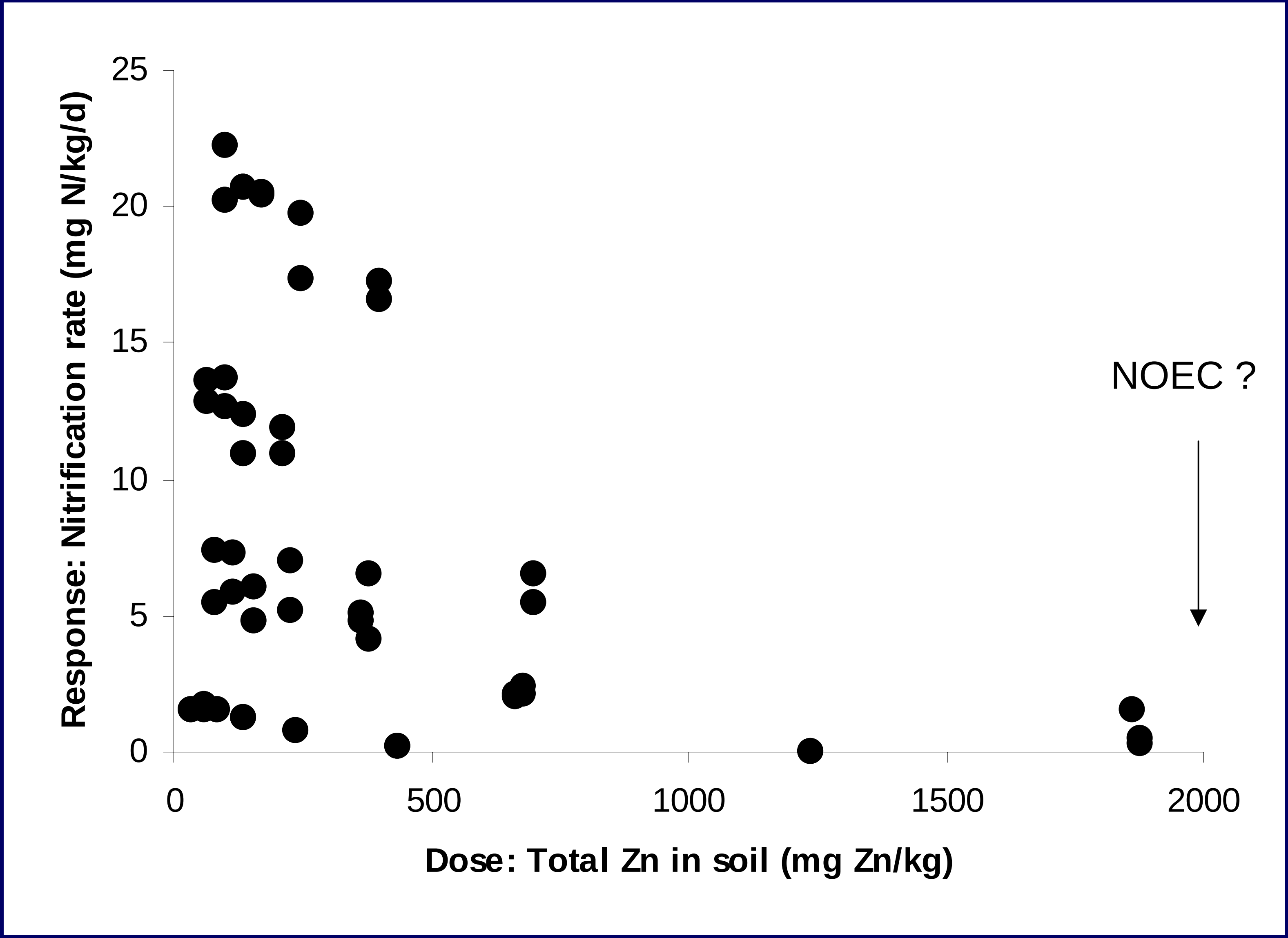
Examples

	HC_5	range of geological background
Ni	10 mg/kg	1-100 mg/kg
Cu	21 mg/kg	2-50 mg/kg
Zn	27 mg/kg (added)	5-150 mg/kg

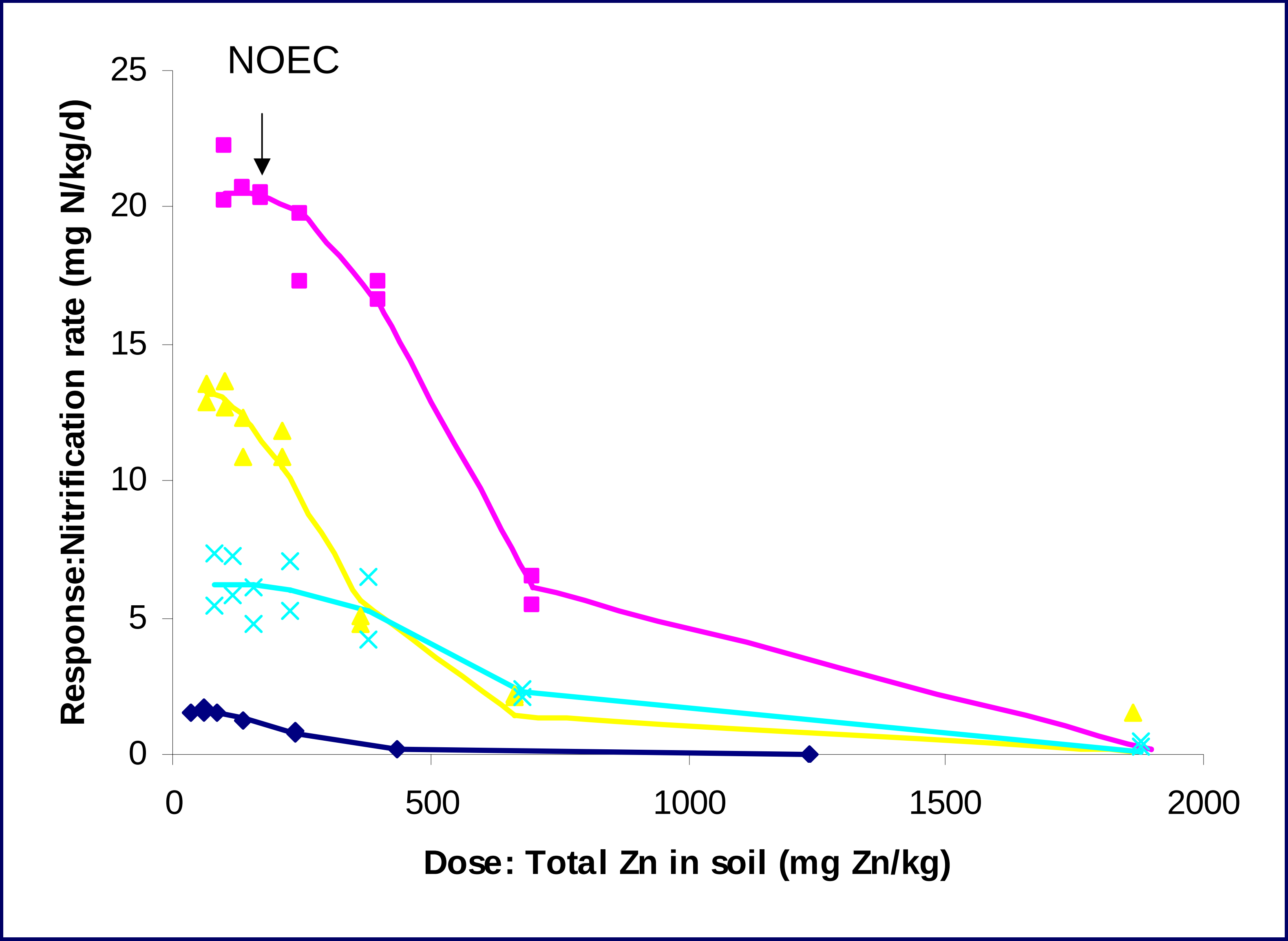
Is the metal dose at background near or above toxicity thresholds?
Do soil properties (texture, %OM, pH) matter?

- does metal speciation affects the…effective <u>dose</u>?
- do soil properties also affect the biological <u>response?</u>

The biological response (soil nitrification potential) is weakly related to soil contamination when combining data of different Zn contaminated soils

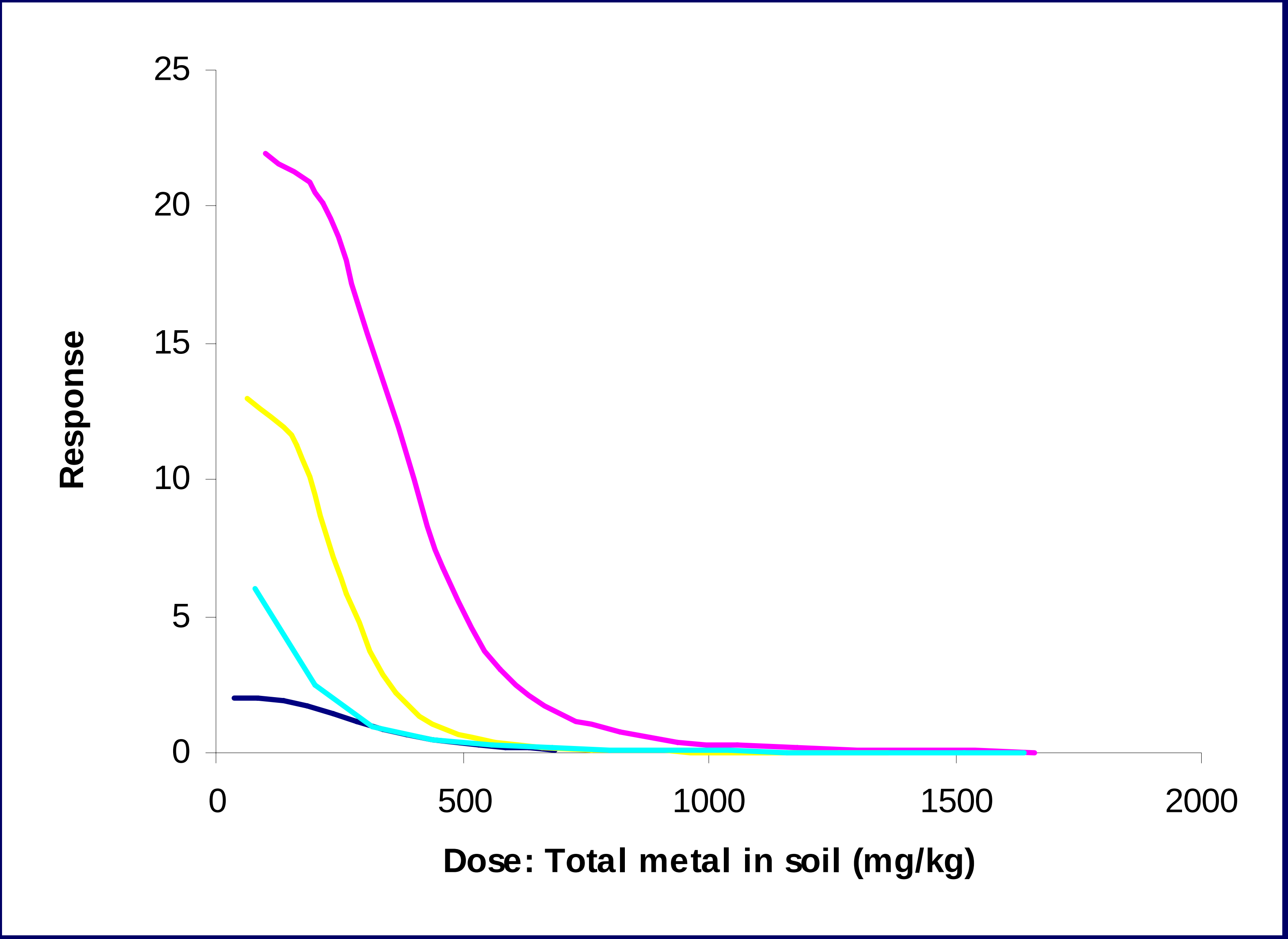


Same data revisited: (soil nitrification potential) is sensitive to added Zn WHEN COMPARED TO CORRESPONDING CONTROL

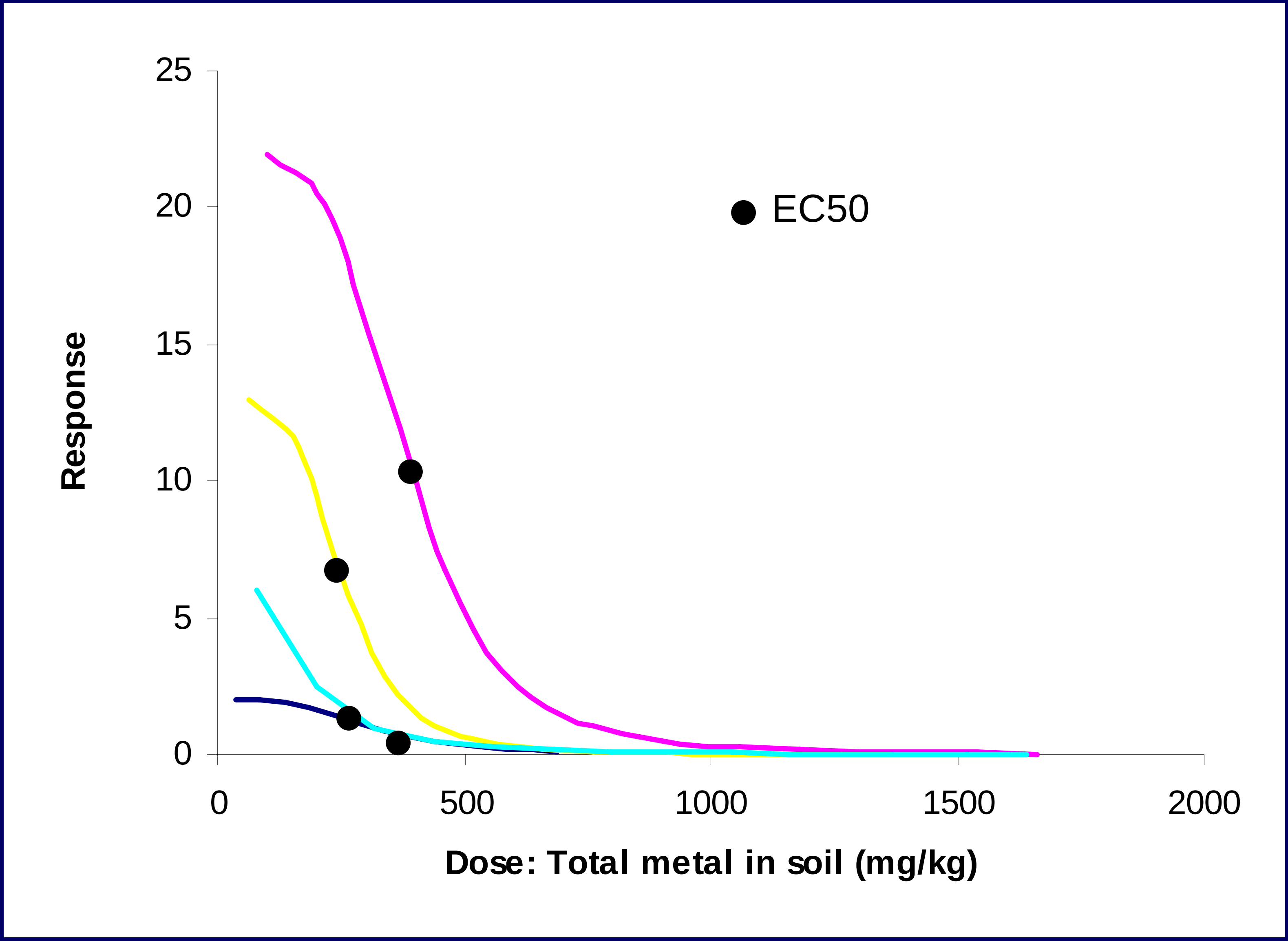


Soil properties control the biological response:

1. Because they affect the control <u>response</u>: ecotoxicity threshold can only be determined if an appropriate control is found



Soil properties control the biological response:
2. Because they affect the effective dose (e.g. EC50 vary among soils)

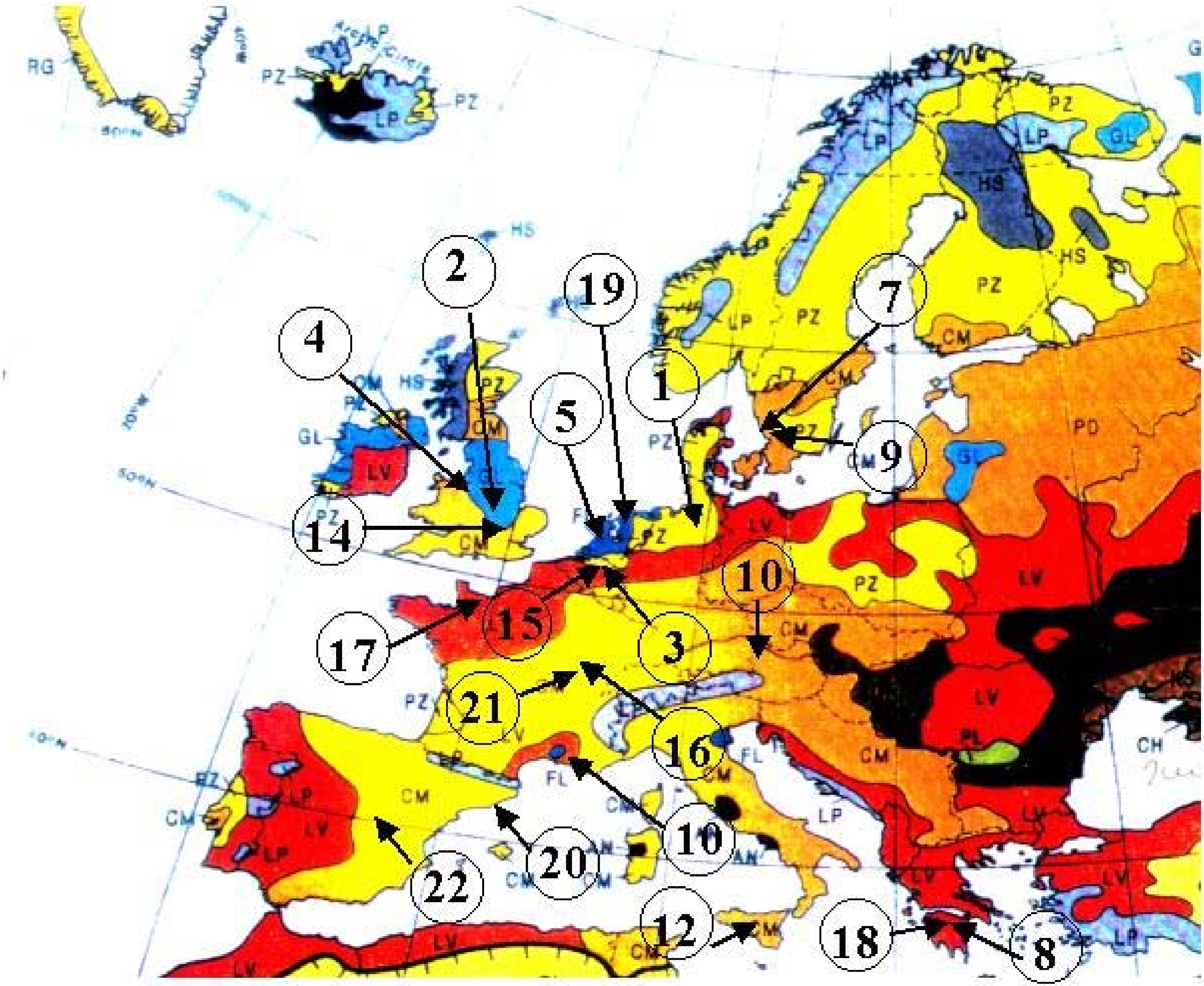


Research questions:

(a) what is the role of soil properties on the sensitivity to added metals, e.g. what controls the EC50, does speciation explain the ‘effective dose’?

(b) are metal salt spiked soils a model for metal contamination in the field, i.e. how to express the effective dose in the field?

Starting hypothesis: solubility controls toxicity, solubility increases with decreasing soil pH, hence we expect that EC50 decrease as pH decreases



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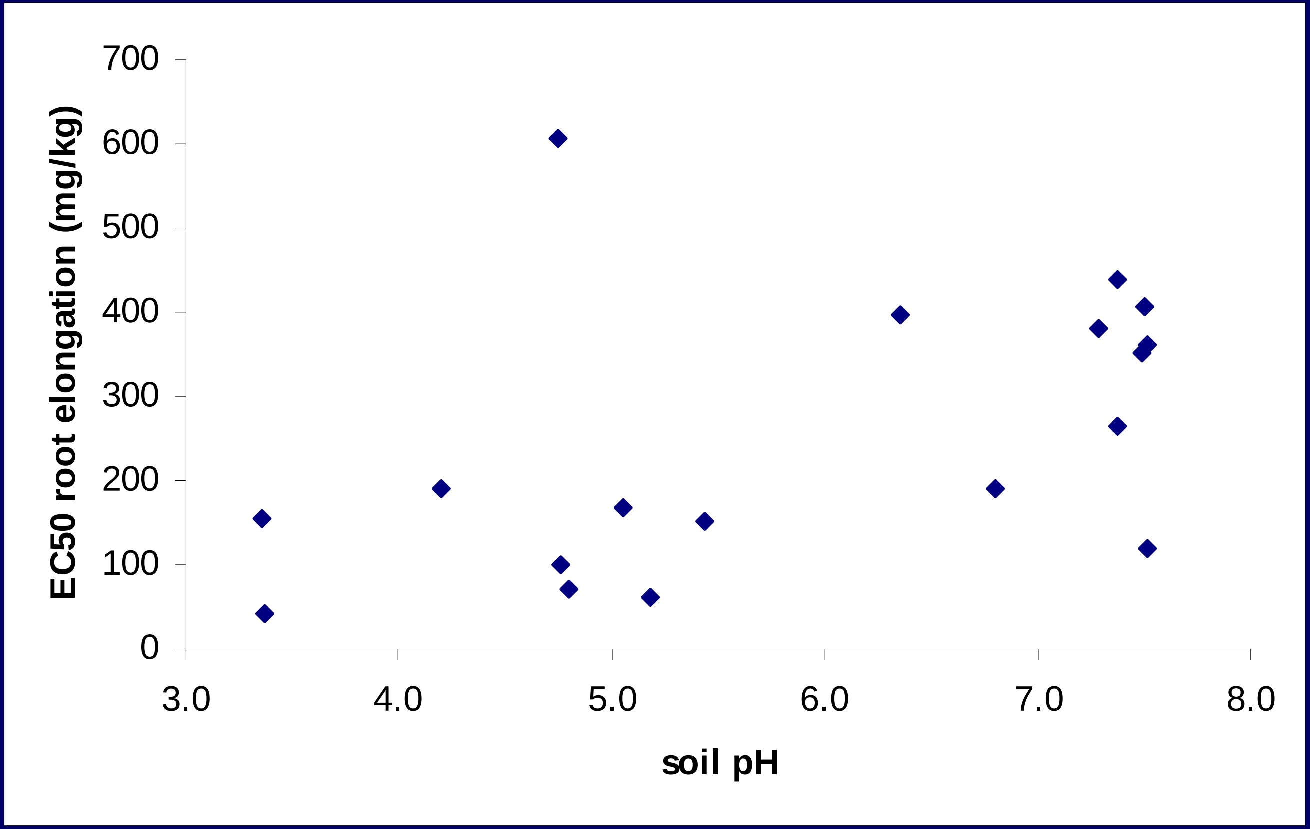
Soil properties (n=19)

pH ($CaCl_2$, 0.01M)	3.0-7.5
%OC	0.4-23
CEC (at soil pH, $cmol_c$/kg)	2-36
Cu total (mg/kg)	2-88
%$CaCO_3$	0-47

Soil classes: Cambisol, Fluvisol, Histosol, Leptosol, Luvisol, Podzol, Regosol

19 soils, EC50 ranges 38-605 mg Cu/kg

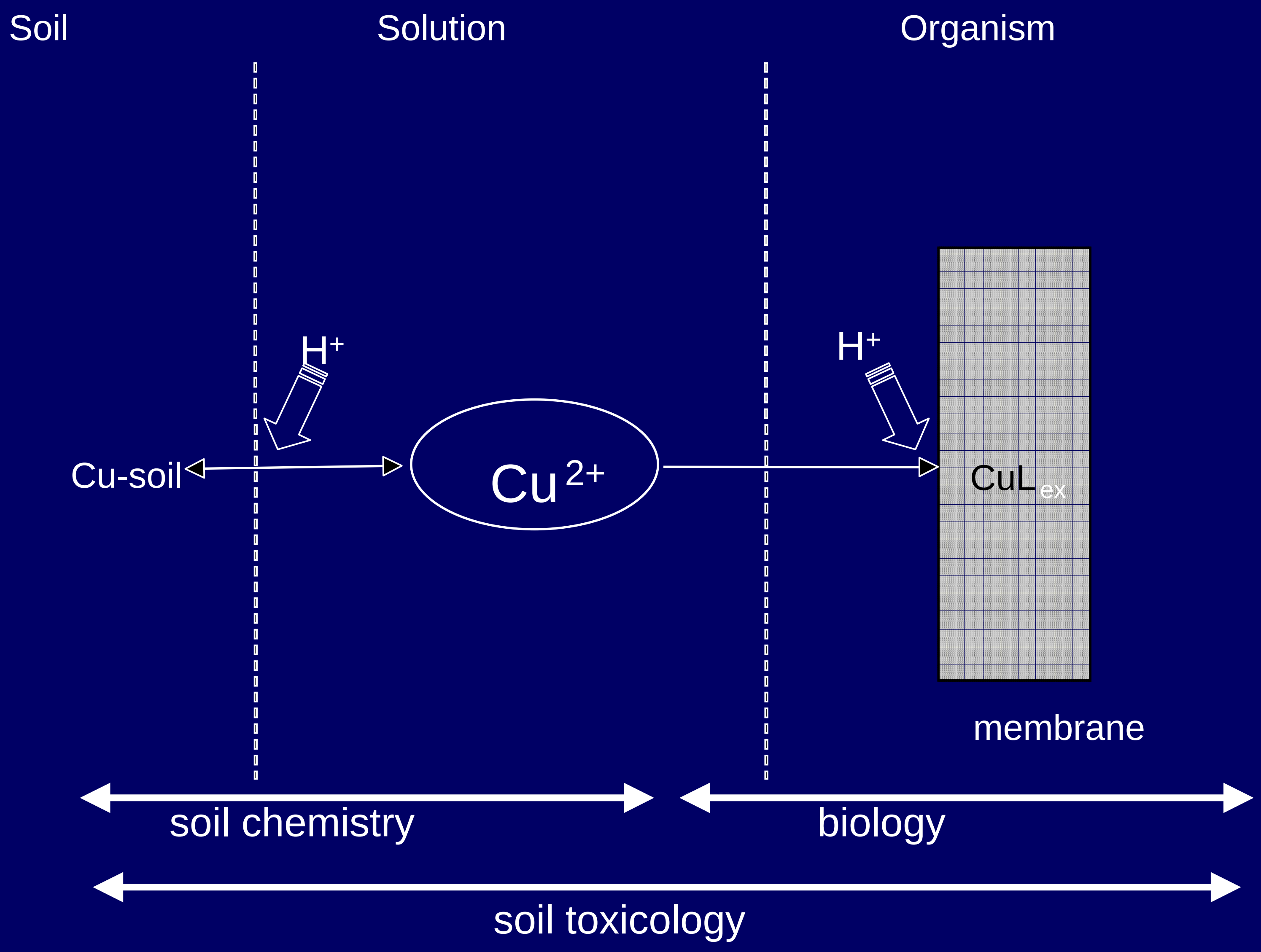


Correlation between EC50 and pH is very weak

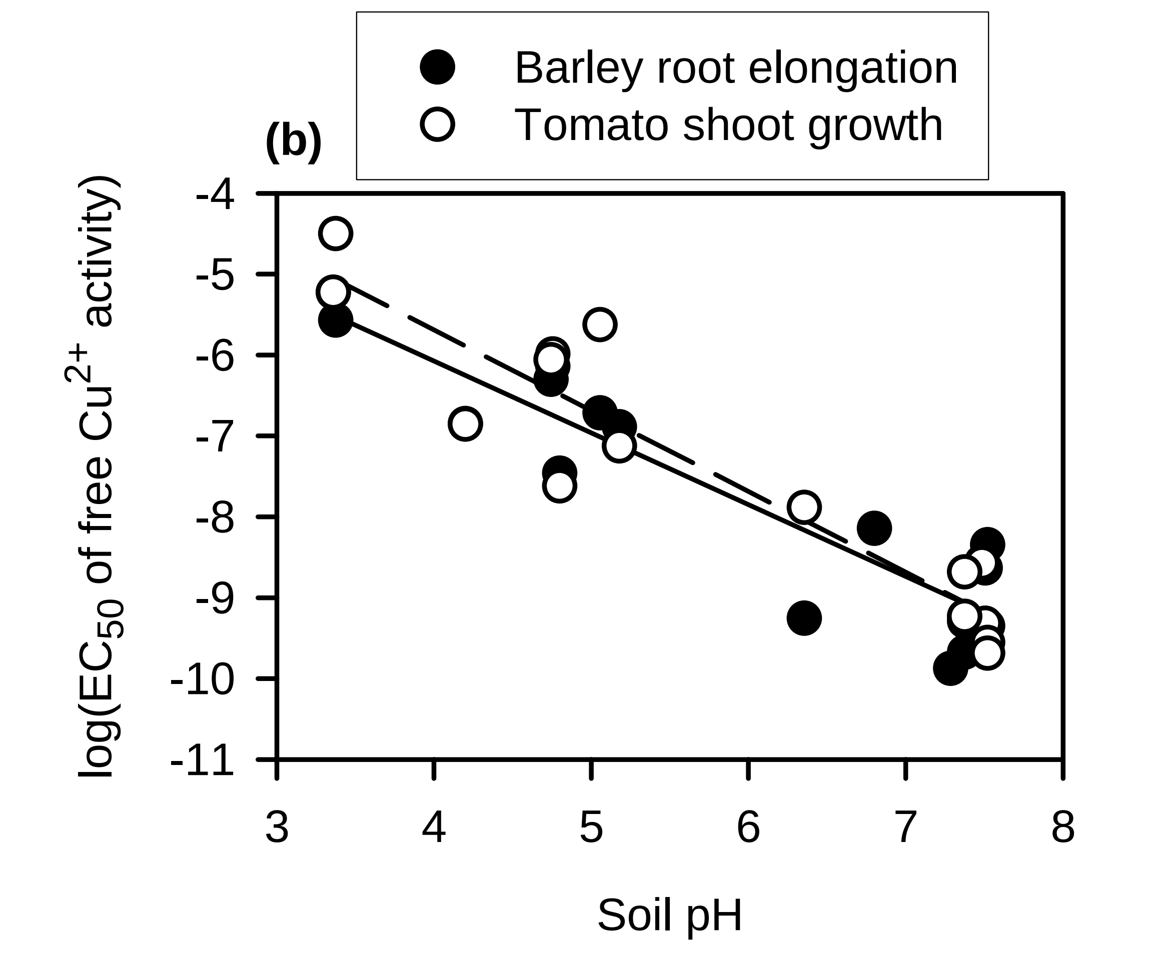
Root elongation toxicity thresholds: total Cu is more consistent than soluble Cu or free ion activity

		Minimum	Maximum	x-fold variation
Total soil Cu (mg/kg)	EC50	38	605	**16**
Soil solution Cu (mg/L)	EC50	0.02	1.29	**61**
Free Cu^{2+} (M)	EC50	1.3×10^{-10}	5.9×10^{-5}	**4×10^{4}**

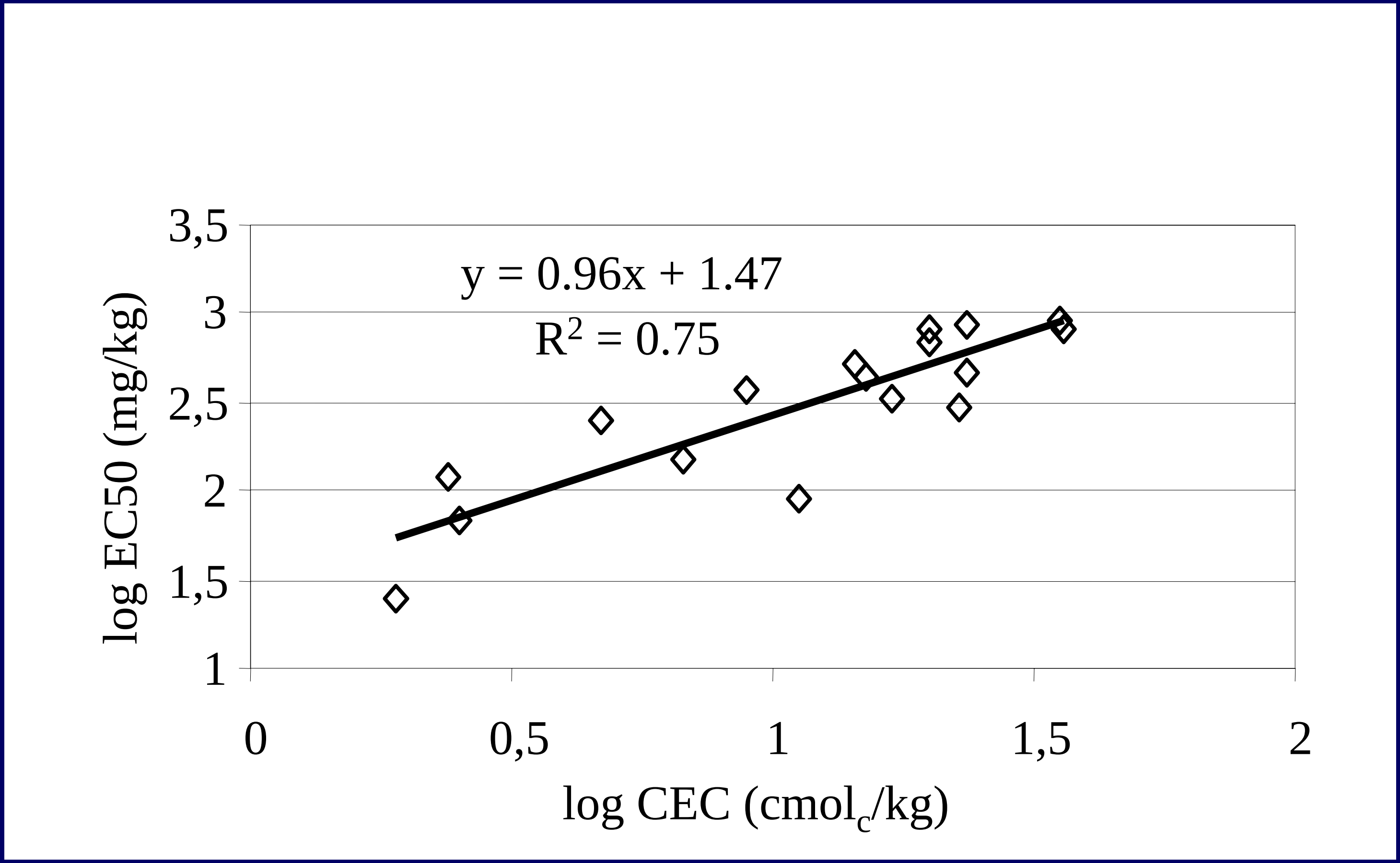
predictive model of bioavailability and toxicity of copper in soils



H^+ protects Cu^{2+} toxicity to plants.



CEC (at soil pH) explains total Cu toxicity. Example: growth of tomato seedling



CEC	EC50 (mg/kg)	EC50 (cmolc/kg)	EC50 (%of CEC)
5	140	0.4	**9**
10	270	0.9	**9**
20	400	1.3	**8**

Answer to question 1: does speciation explains the ‘effective dose’?

In case of Cu toxicity to plants: neither solubility, nor free ion activity but the *relative amount of Cu in the CEC* (at soil pH) is fairly consistent among soils, i.e. about 8% of CEC occupied by Cu yields EC50 for tomato

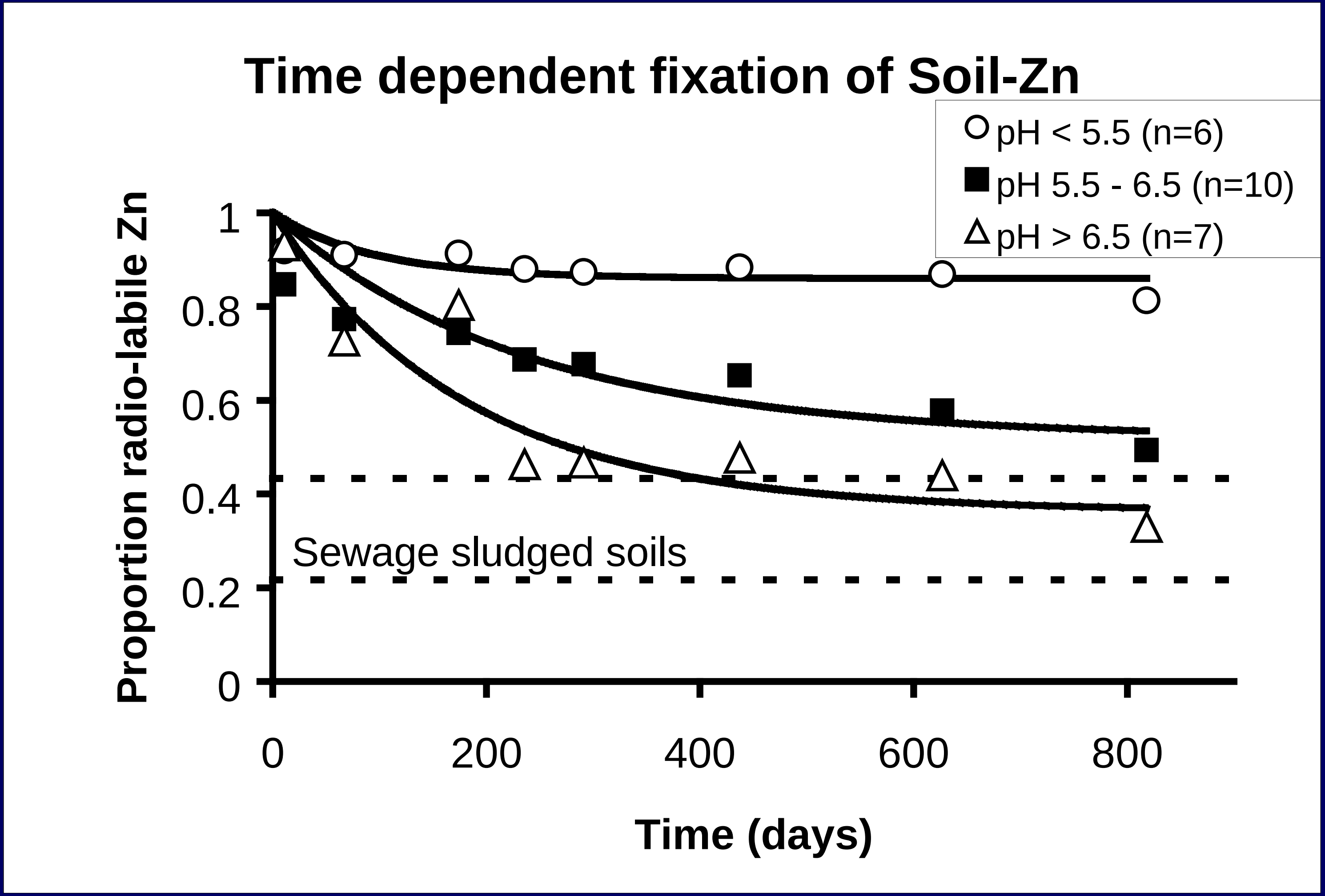
CEC (at soil pH): depending on %OM, % clay and pH

Can we generalise for other assays and other metals?

YES: CEC consistently explains toxicity to plants, earthworms and springtails for Cu, Zn and Ni; slope sometimes somewhat lower than 1.0 (i.e. not always proportionality between EC50 and CEC)

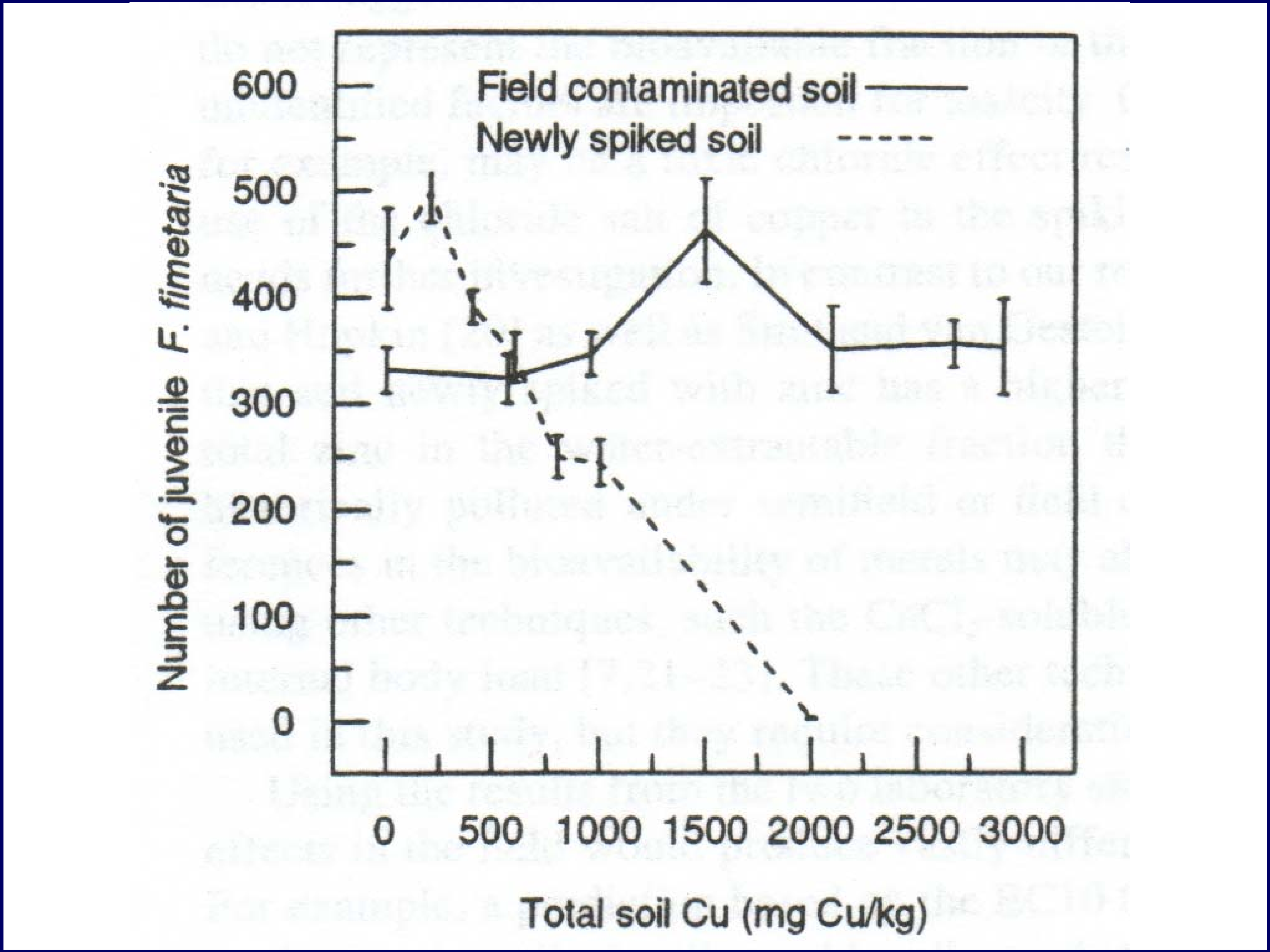
NO: thresholds for <u>microbial populations</u> are affected by other properties (background metal, pH)…more complex because populations are different among soils

Part B: toxicity in salt spiked soils versus that in field contaminated soils



Tye et al., 2003

Toxicity of Cu in freshly spiked soils exceeds that in field contaminated soils

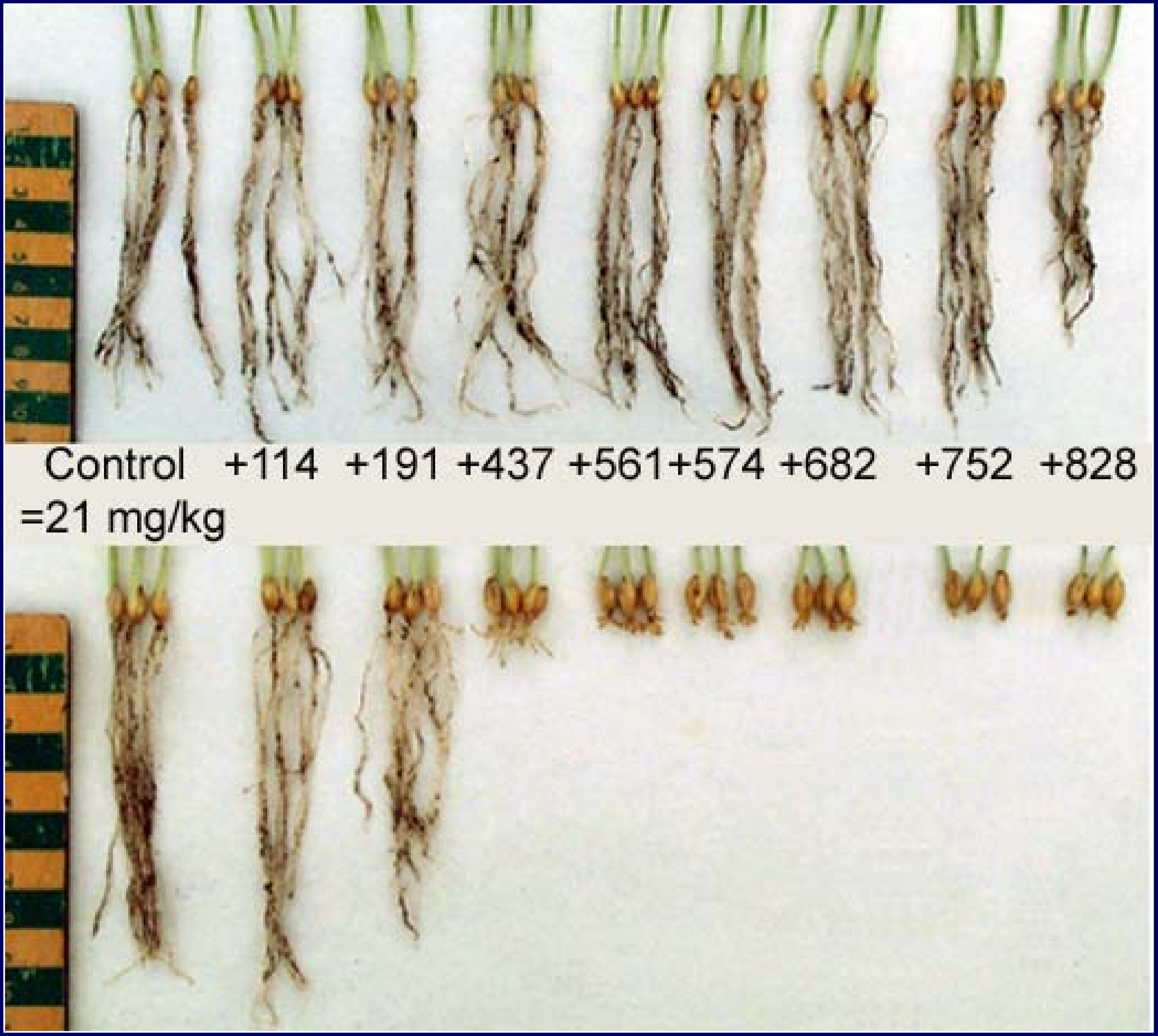


Scott-Fordsmand et al. 2000

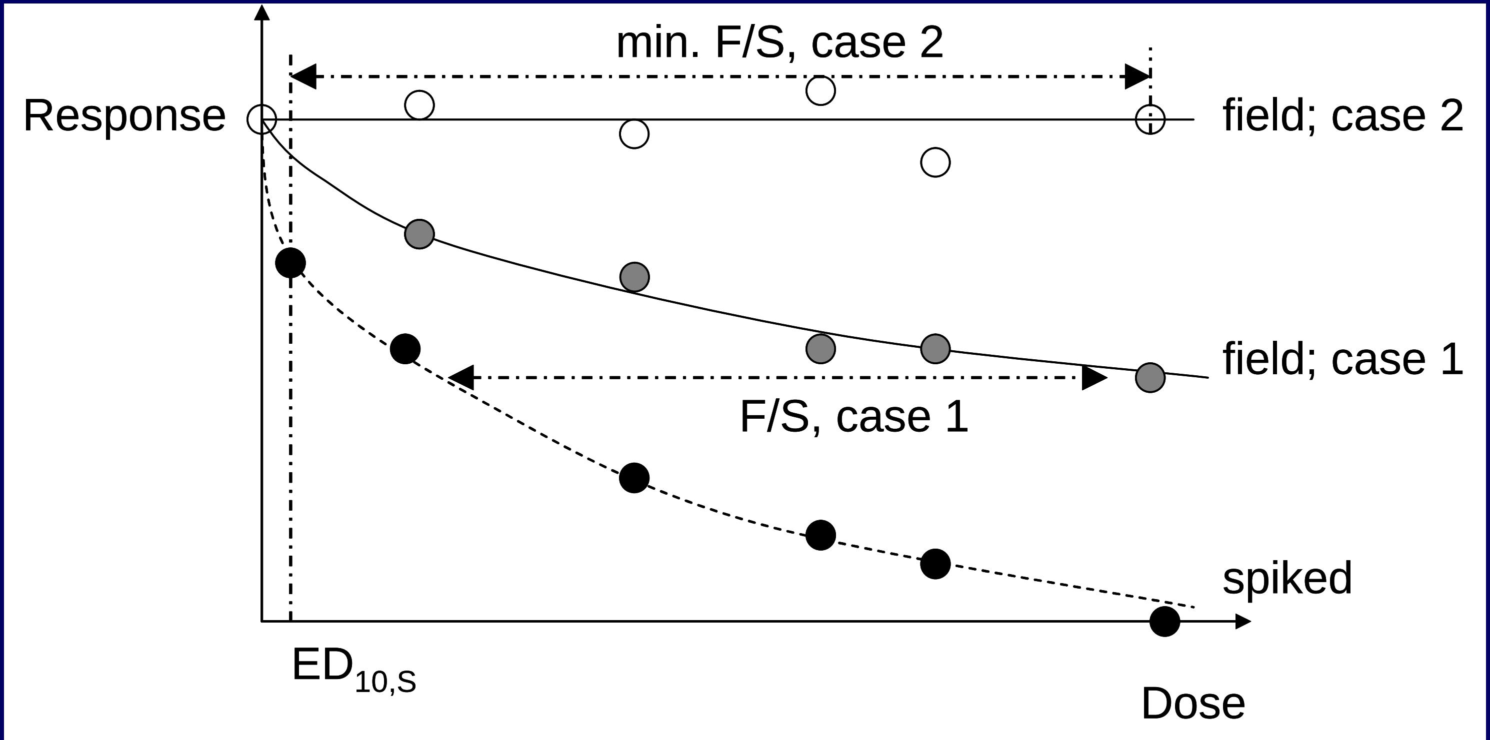
Toxicity of Cu in freshly spiked soils exceeds that in field contaminated soils

Field transect

Fresh spike

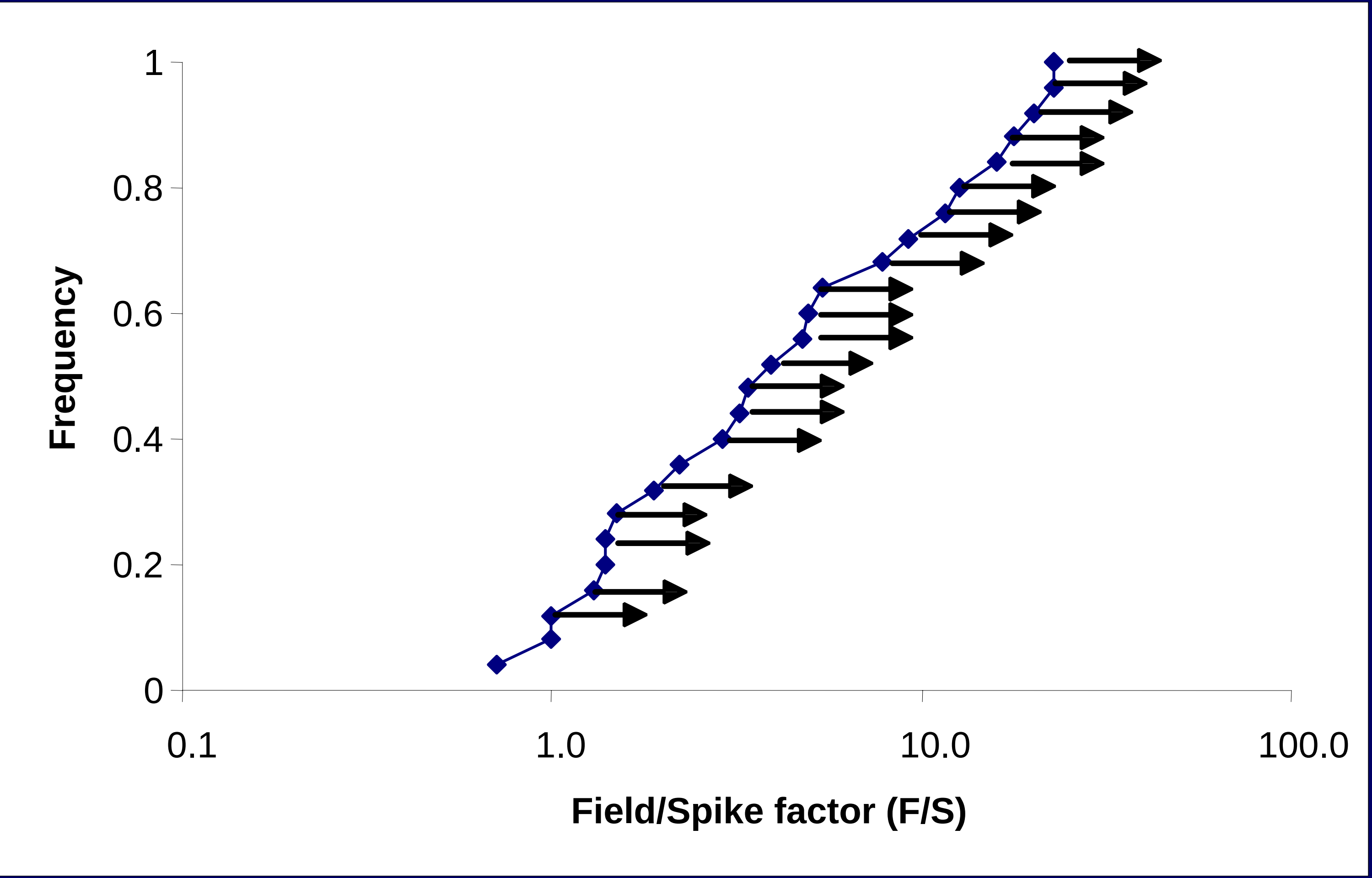


III.B Empirical factors (F/S= Field/Spike factors) to correct for the differences in toxicity

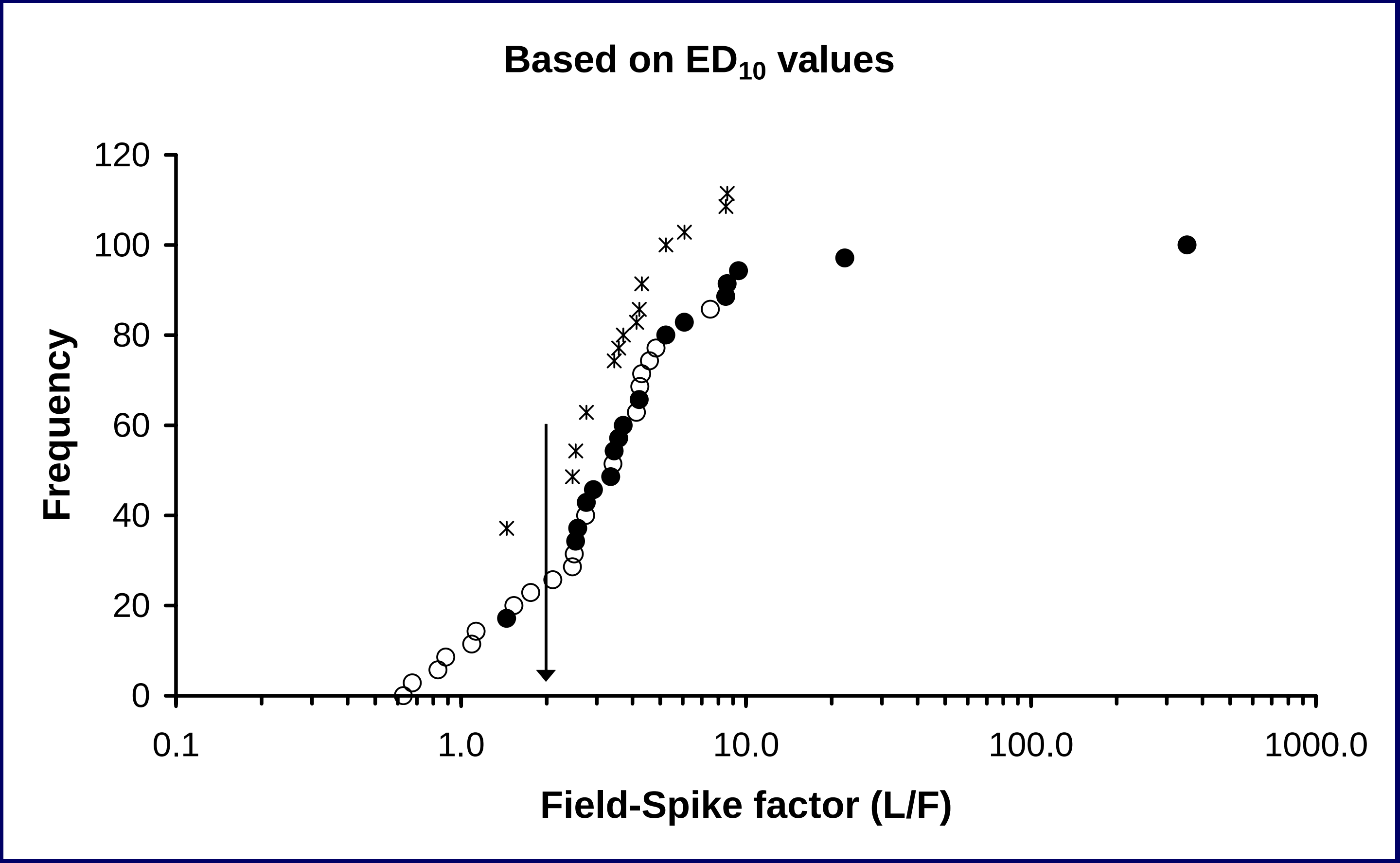


$F/S = ED_{x,field} / ED_{x,spiked}$

Example for Zn: ED10 ratios of 3 transects and 6 assays



Example for Cu: ED10 ratios of 4 transects, 3 experimentally aged soils and 7 assays



(closed symbols: unbounded values)

Conclusions

1. Soil properties affect the biological response, ecotoxicity threshold can only be determined if an appropriate control is found. Toxicity is a change in response, relative to a reference. Confounding factors in dose-response relationships in the environment are the rule, not the exception.

2. Solubility based thresholds are generally poorer predictors of toxicity than total based predictors; relative concentration of metal in the CEC (at soil pH) appears to unify thresholds.

3. Weight of evidence that toxicity in metal salt spiked soils >> in field contaminated soil at equivalent total metal; speciation can merge curves (not shown here).

Dziekuje !