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Dynamic modelling of metals in topsoils of UK and Chinese catchments

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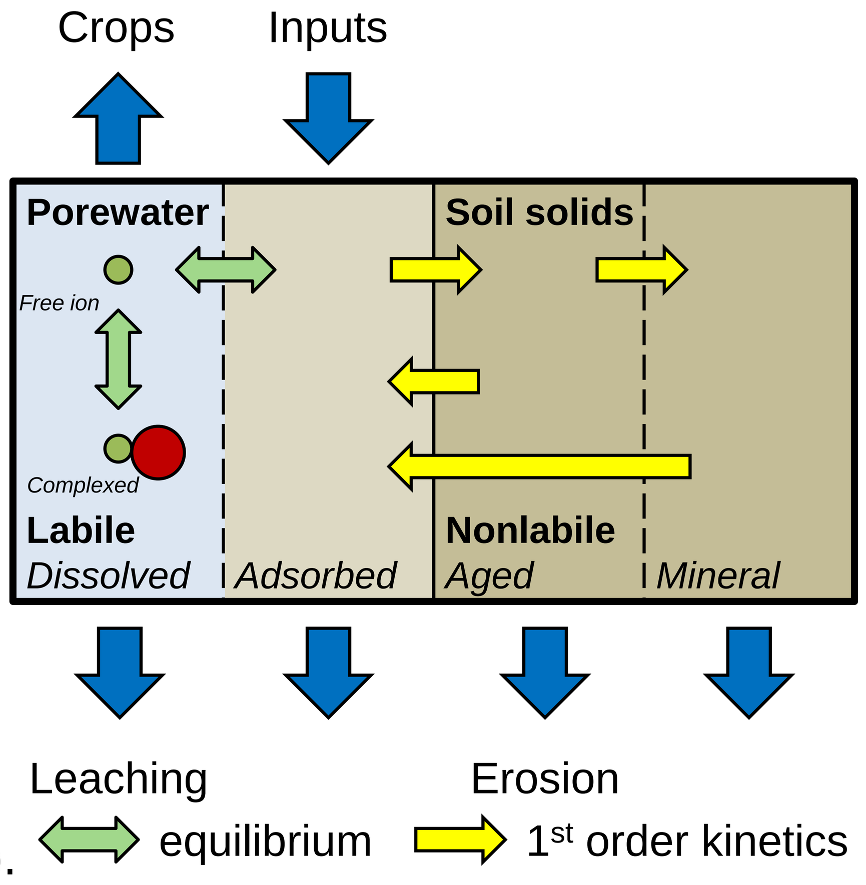
Introduction

- Anthropogenic inputs of metals to topsoils may give rise to negative ecological and human health impacts.
- Prediction of metal concentrations and pools is needed to assess the risks of soil metal enrichment due to anthropogenic activity, e.g. industrial emissions, deliberate or incidental additions of metal to agricultural soils (in fungicides, fertilisers, sewage sludges etc.).
- Dynamic modelling is needed to predict changes in metal concentrations over relevant timescales. The Intermediate Dynamic Model for Metals (IDMM) is such a model.
- This poster presents the structure and parameterisation of the IDMM, and its application to two contrasting scenarios:
  - **Upland soils of the UK** (acid organic soils with high rainfall and runoff).
  - **Agricultural soils of Guanting reservoir, Hebei province, China** (neutral soils with low rainfall and runoff).

The IDMM

- Considers dynamics of labile and nonlabile metal.
- Runs on an annual time step.
- Labile metal chemistry modelled assuming equilibrium.
- 1st order kinetic expressions describe slower transfers among the labile and nonlabile metal pools.
- The model is run from a 'pristine' steady state where natural input and output fluxes balance.
- Soil pH, [DOC] in porewater can be varied over time.
- Can model multiple soil layers; these simulations use a single layer (20-30cm).

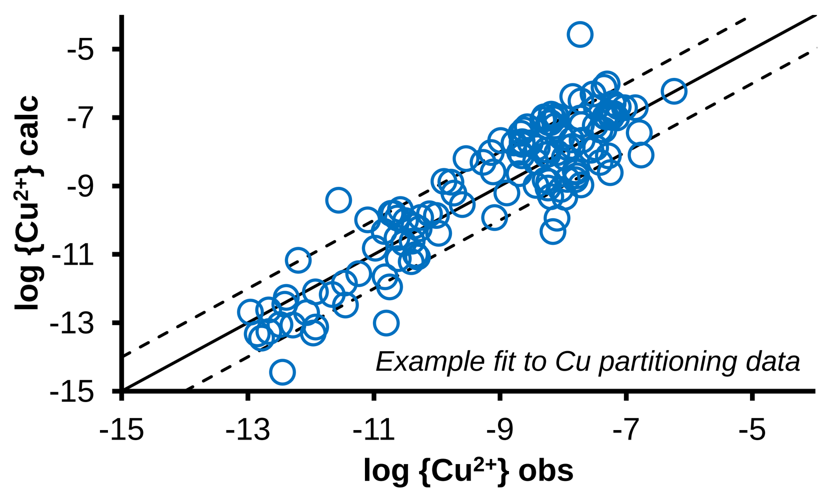


Metal chemistry parameterisation

Equilibrium

Free↔adsorbed: Freundlich type expression [1]

$a_0 + a_1 \cdot \mathrm{pH} + a_2 \cdot \log(\mathrm{SOM}) = \log \{M\}_{ads} - n \cdot \log[M]_{free}$

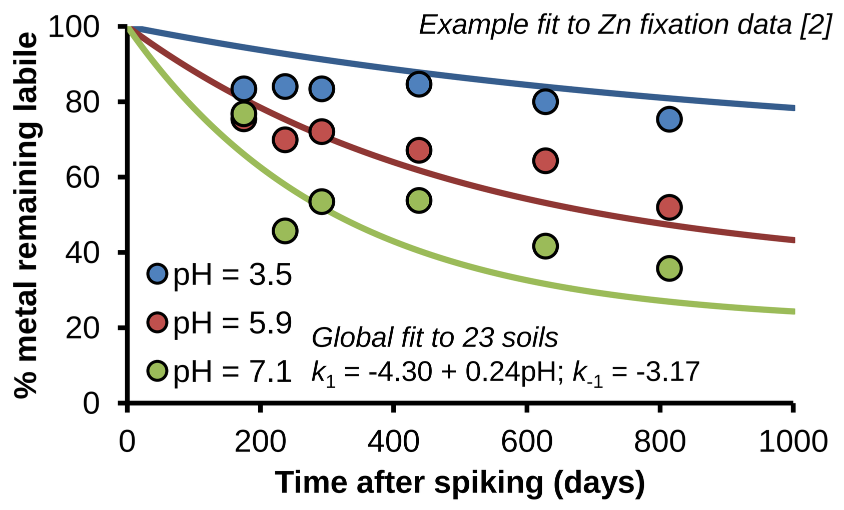


Free↔dissolved: WHAM/Model VI

Kinetics

Labile↔non–labile: 1st order kinetics

$d\{M\}_{lab}/dt = -k_1 \cdot \{M\}_{lab} + k_{-1} \cdot \{M\}_{nonlab}$



Scenarios

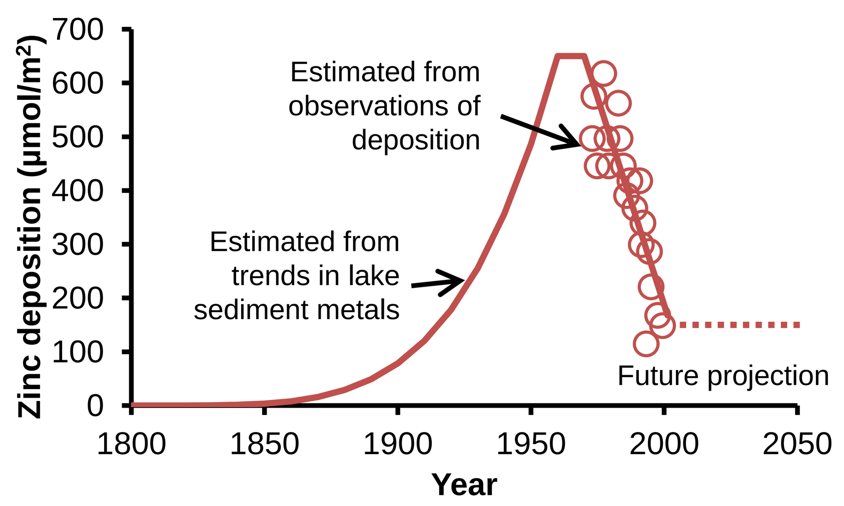
English Lake District [3]	Guanting Reservoir [4]
	
54.4°N, 3.2°W	40.3°N, 115.7°E

	UK	China
Soil layer depth (cm)	22.5	30
Average precipitation (mm/a)	~3000	~425
Average runoff (mm/a)	~2600	~80
Soil pH (present day)	4.9[a]	7.7
Soil organic matter (%)	44	1.84
[DOC] in porewater (mg/dm³)	1.0[b]	1.0[c]
Land use	grazing[d]	arable (maize)[e]

[a] soil pH varied temporally to account for historic soil acidification. 'Pristine' pH = 5.5.
[b] estimated from surface water concentrations.
[c] estimated by fitting.
[d] metal removal by cropping not simulated.
[e] metal removal by cropping simulated assuming constant crop metal concentrations.

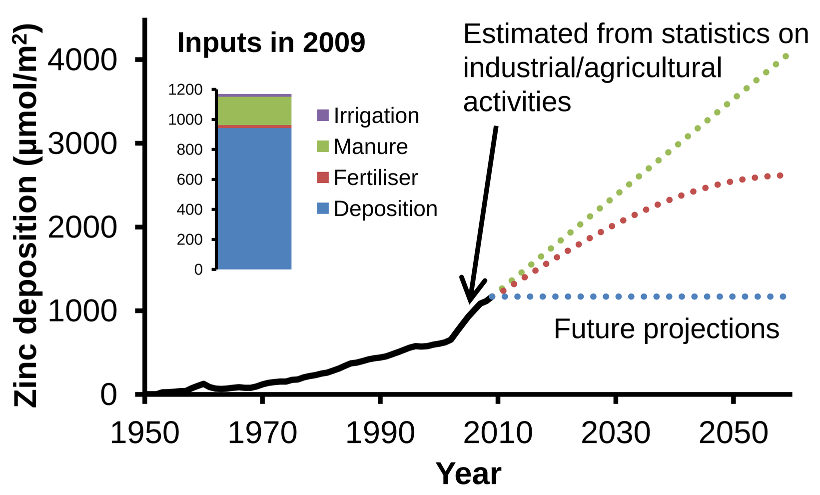
Anthropogenic metal inputs

English Lake District



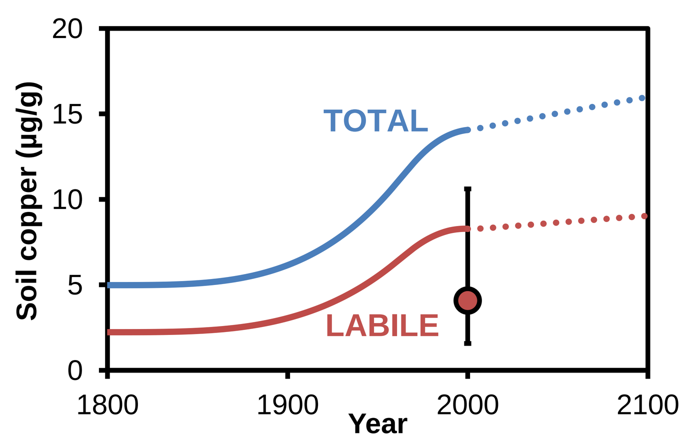
- All inputs assumed to derive from atmospheric deposition.
- Deposition maximum 1960-1970 followed by rapid decline. Future projection assumes no change.

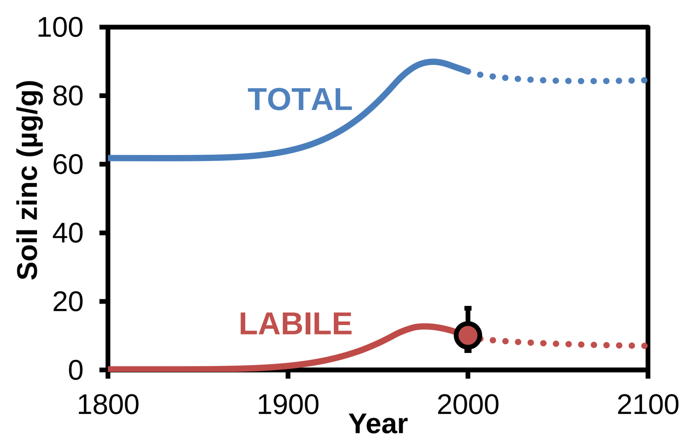
Guanting Reservoir

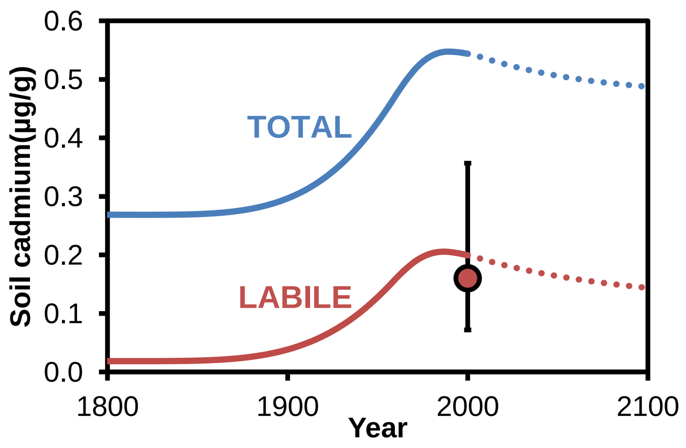


- Inputs from deposition and land use.
- Inputs rise continuously from 1950.
- Atmospheric deposition dominates.
- Three future projections simulated.

Results (UK)

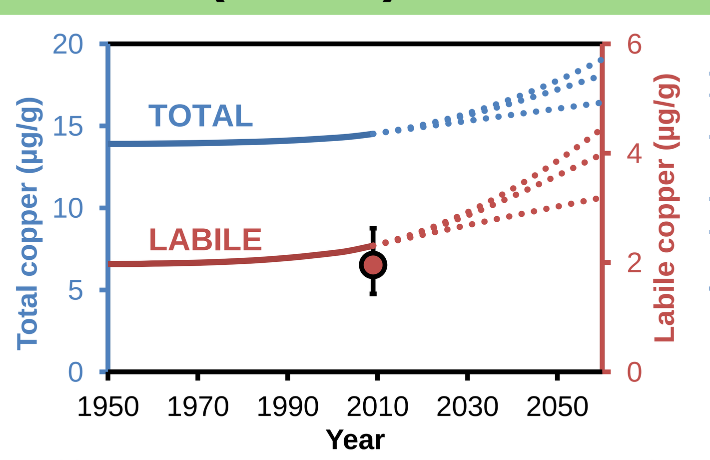


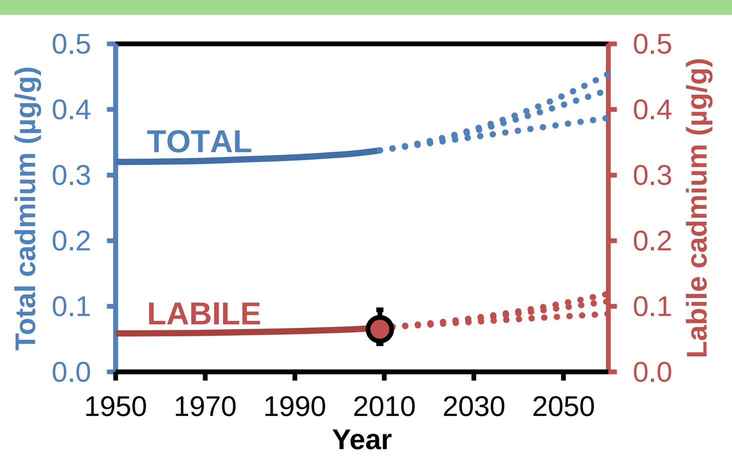


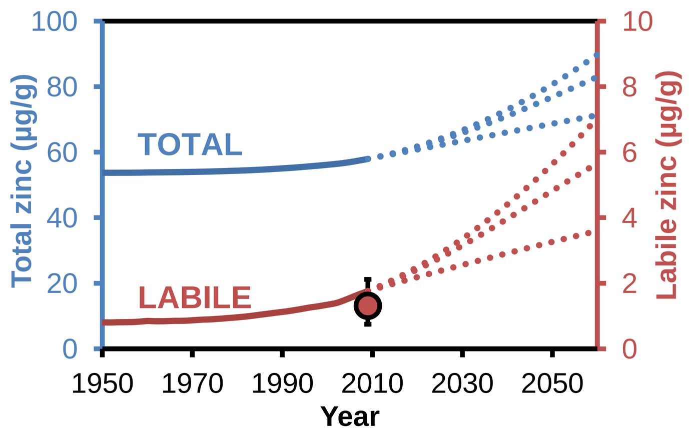


- Reasonable predictions of labile metal concentrations are seen.
- Trends in total metal are computed by fitting to present day concentrations.
- All metals show increases in concentration in response to past deposition. Cd and Zn are predicted to decline in the future. Cu is predicted to continue accumulating.

Results (China)







- Good predictions of labile metal concentrations are seen.
- Fixation is predicted to be important for limiting metal accumulation in labile form.
- Continued accumulation is predicted under all the future projections.
- A drop in inputs of over an order of magnitude is needed to prevent further accumulation.

Conclusions

- The IDMM is a promising tool for assessing changes in soil metal concentrations in response to changing inputs.
- The model has reasonable data requirements, making it ideal for running multiple scenarios, and for application at large scale using spatial data on relevant soil properties.
- Further evaluation of the model is needed, particularly in slightly acidic and circumneutral soils.
- The model has considerable potential for further development:
  - Addition of kinetic fixation models for other metals (e.g. Ni, Pb);
  - Parameterisation for anionic metals/metalloids (e.g. As, Mo);
  - Coupling to surface water models for integrated risk assessment;
  - Parameterisation of crop metal uptake as a function of soil properties;
  - Development of crop uptake submodels allowing prediction of metal concentrations in edible plant parts, for human health risk assessment.

Acknowledgements

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References

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WHY MODEL LONG–TERM METAL DYNAMICS IN SOILS?

BECAUSE WE NEED TO PREDICT THE LONG–TERM RISKS OF METAL ACCUMULATION IN SOILS TO THE ENVIRONMENT AND TO HUMAN HEALTH

NERC SCIENCE OF THE ENVIRONMENT