Pollution Control in Wetland Soil and Water around the Globe

Jörg Rinklebe

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Environmental Pollution is one of the most pressing issues of human mankind

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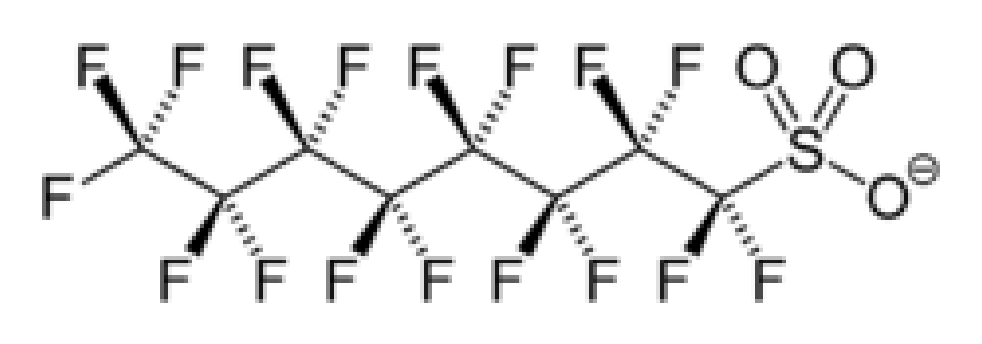
Soil- and Groundwater-Management

Poly- and per-fluoroalkyl substances (PFAS)

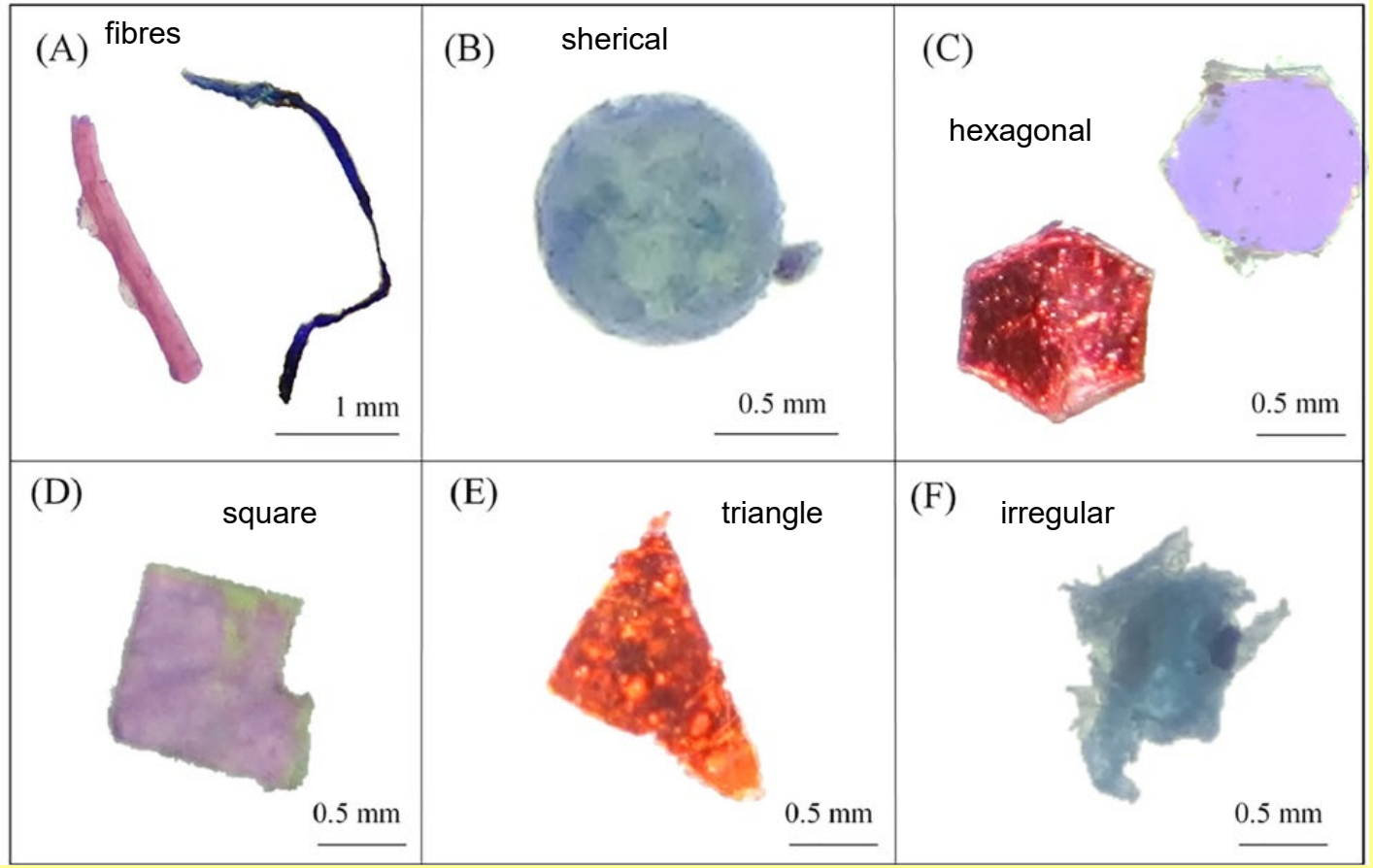
Perfluoroktansulfonat (PFOS)



Möhnequelle bei Brilon

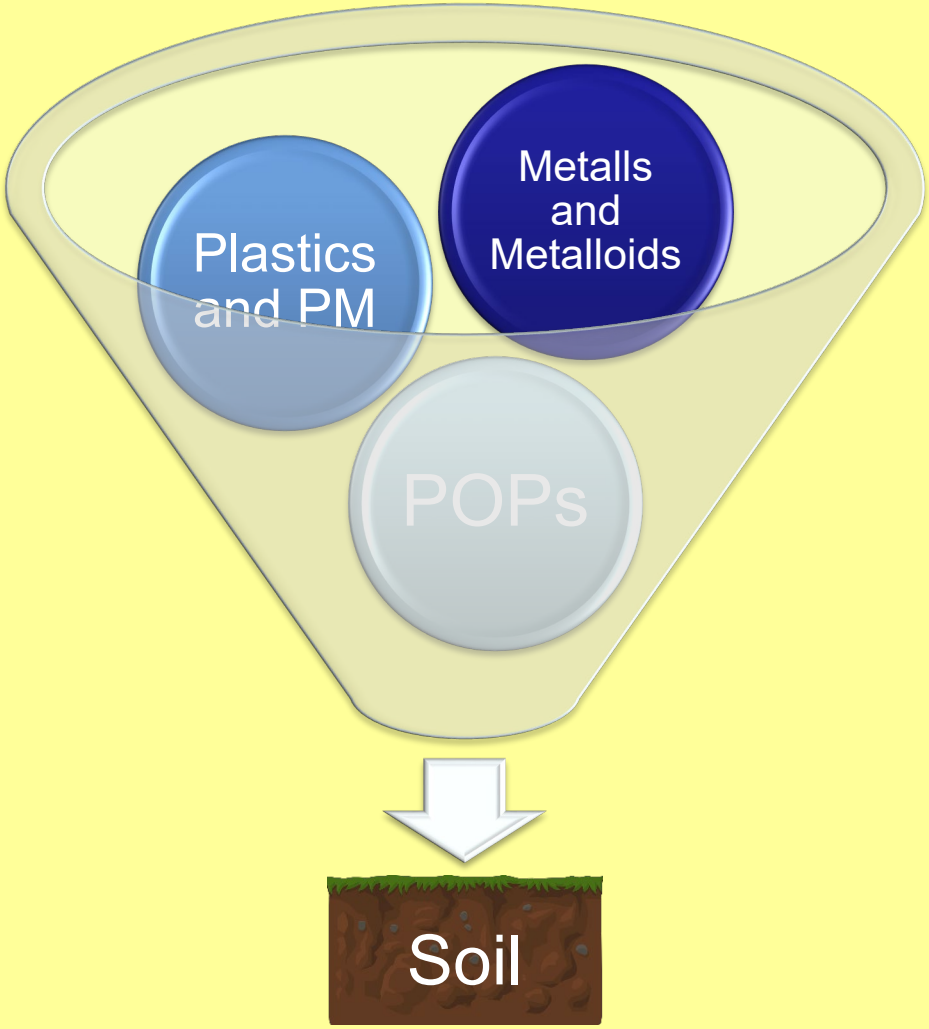
Sonne, C., Bank, M.S., Jenssen, B.M., Cieseielski, T.M., **Rinklebe, J.,** Lam, S.S., Hansen, M., Bossi, R., Gustavson, K., Dietz, R. (2023). PFAS pollution threatens ecosystems worldwide. ***Science***, 379. DOI: 10.1126/science.adh0934

Particulate plastics in the environment



Bradney, L., Wijesekara, H., Palansooriya, K.N., Obadamudalige, N., Bolan, N.S., Ok, Y.S., **Rinklebe, J.,** Kim, K.-H., Kirkham, M.B. (2019). Particulate plastics as a vector for toxic trace-element uptake by aquatic and terrestrial organisms and human health risk. **Environment International**. 131. 104937.

Cocktail of Contaminants



Important reviews

Bolan, N. …. **Rinklebe**, J. (**2021**) Remediation of poly- and perfluoroalkyl substances (PFAS) contaminated soils – To mobilize or to immobilize or to degrade? **Journal of Hazardous Materials** 401, 123892.

Khan, S…. **Rinklebe**, J. (2021): Global soil pollution by toxic elements: Current status and future perspectives on the risk assessment and remediation strategies – A review, **Journal of Hazardous Materials** 417, 126039 18.

Kumar, M., ….. **Rinklebe**, J. (2021): Remediation of soils and sediments polluted with polycyclic aromatic hydrocarbons: To immobilize, mobilize, or degrade? **Journal of Hazardous Materials** 420, 126534 24.

Sarkar, B., … **Rinklebe**, J., Ok, Y. S. (2021): Challenges and opportunities in sustainable management of microplastics and nanoplastics in the environment. **Environmental Research**, 112179

Natasha, N., …. **Rinklebe**, J. (2021): Influence of biochar on trace element uptake, toxicity and detoxification in plants and associated health risks: A critical review. **Critical Reviews in Environmental Science and Technology**, DOI: 10.1080/10643389.2021.1894064

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Soil Pollution and Sustainable Development Goals

SDG15: Life on land
Soil pollution and loss:
- threaten the health of plant and animals
- reduce soil biodiversity

SDG13: Climate action
Soil pollution and loss:
- reduce soil carbon storage potential
- result in deforestation to obtain new farmland

SDG12: Responsible consumption and production
Soil pollution and loss:
- make sustainable production in agriculture difficult

SDG11: Sustainable city and communities
Soil pollution and loss:
- results in derelict land, environmental displacement, and iniquitous exposure patterns

SDG1: No poverty
Soil pollution and loss:
- reduce crop yield and income, which in turn jeopardizes health, and reduces cognitive and health potential

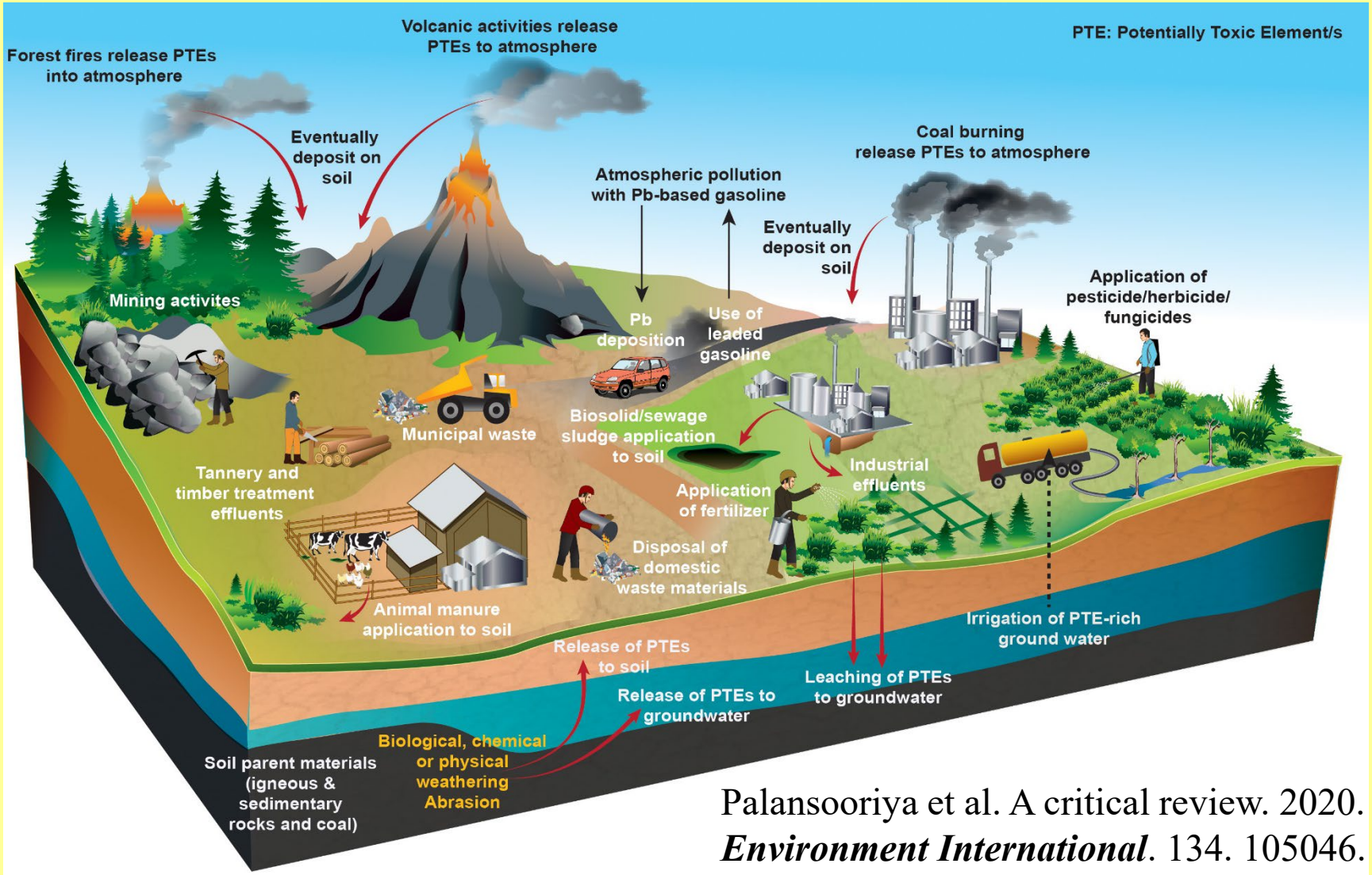
SDG2: Zero hunger
Soil pollution and loss:
- less food is produced per unit land
- limit the available land for growing crops

SDG3: Good health and well-being
Soil pollution:
- with lead reduces children's IQ
- with cadmium causes kidney dysfunction, bone disease and cancers
- with mercury causes neurological damage

SDG6: Clean water and sanitation
Soil pollution:
- pollutes groundwater
- enters drinking water sources via surface runoff

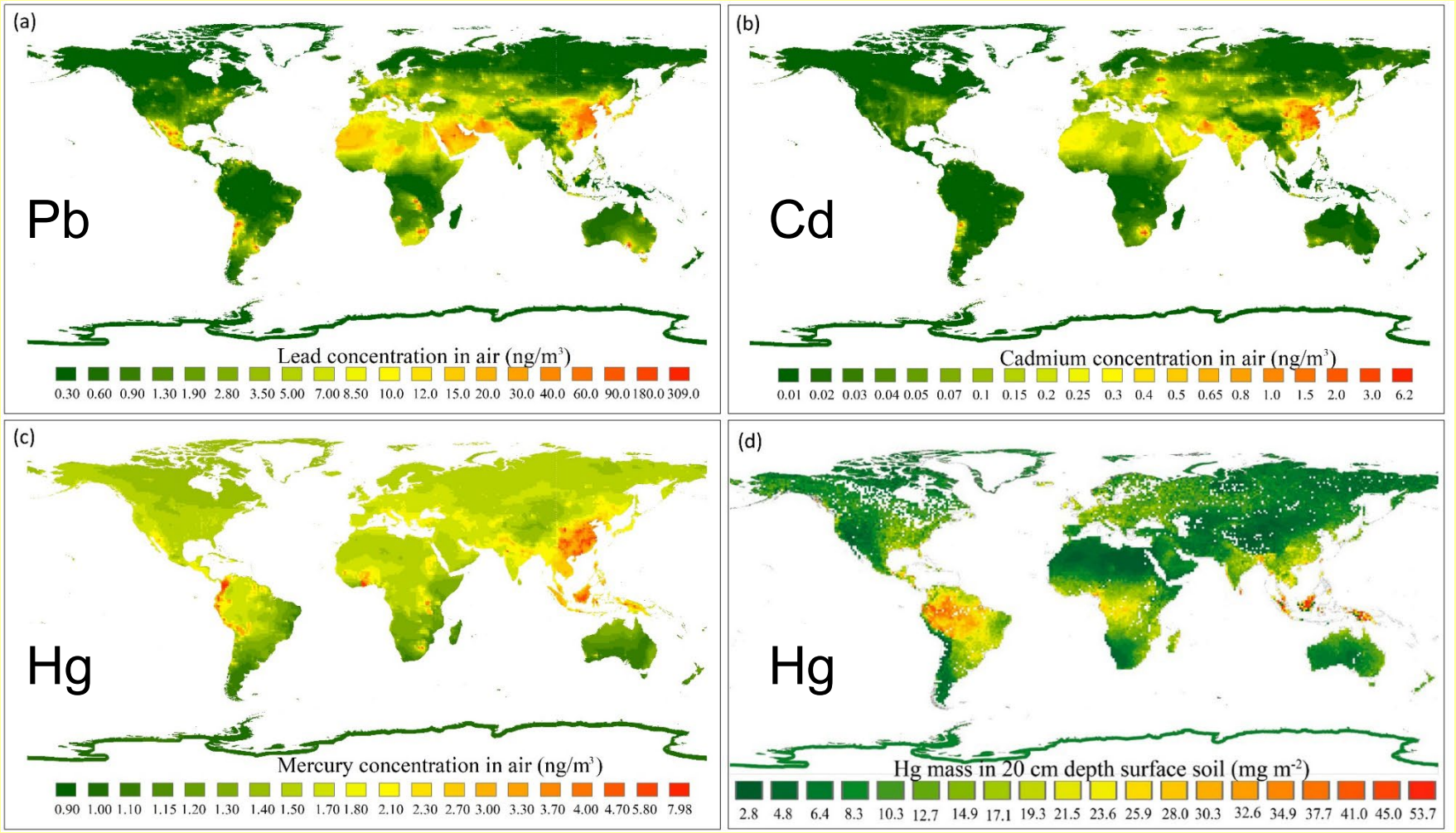
Hou, D., O'Connor, D., Igalavithana, A.D., Alessi, D.S., Luo, J., Tsang, D.C.W., Sparks, D.L., Yamauchi, Y., **Rinklebe, J., Ok, Y.S.** (2020): Metal contamination and bioremediation of agricultural soils for food safety and sustainability. **Nature Reviews. Earth & Environment.** 1. 366–381.

Sources and Cycle of Toxic Elements in Ecosystems



Palansooriya et al. A critical review. 2020. ***Environment International***. 134. 105046.

Spatial distribution of heavy metals



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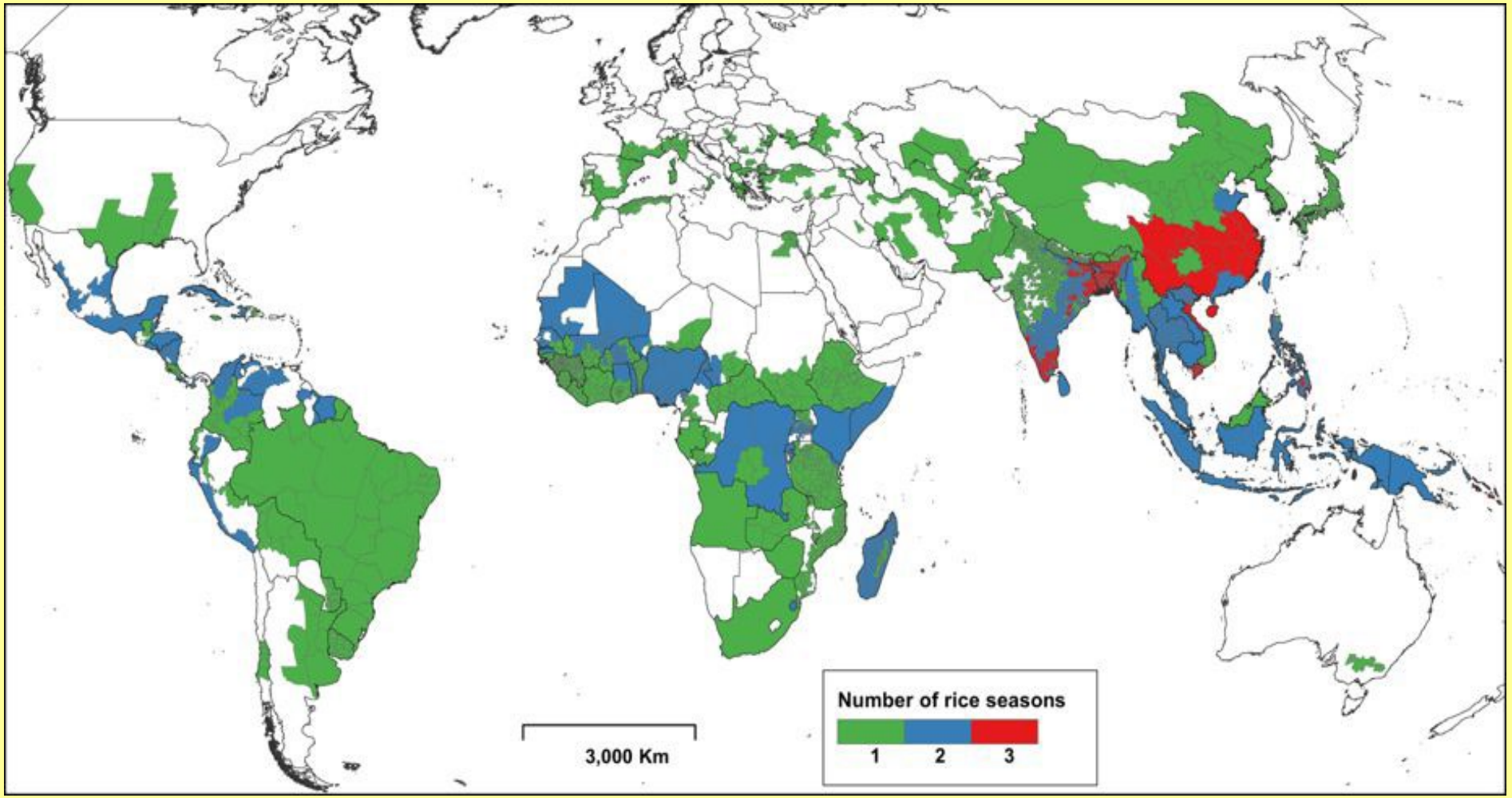
Main rice production regions, and the number of rice-growing seasons



Laborte et al., 2017, Scientific Data 4, 170074

Natural dynamic redox conditions: Paddy and floodplain soils

Wetlands

Wetlands can serve as sinks, sources, and transformers of pollutions and nutrients, and as such they can have a significant impact on water quality and ecosystem productivity in riverine and coastal zones.

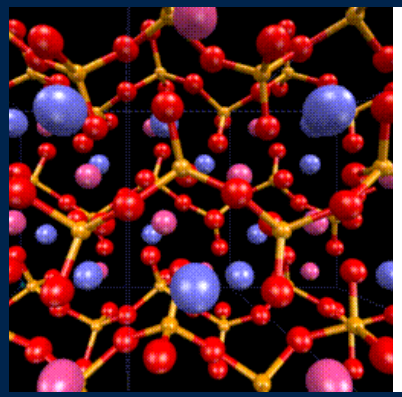
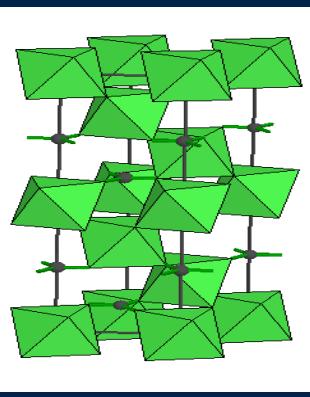
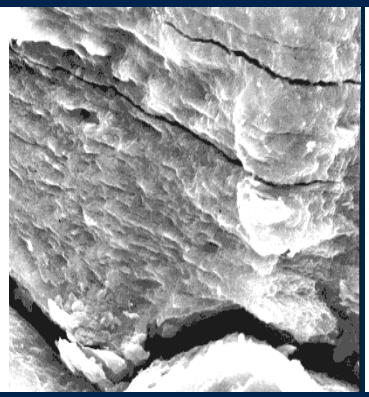
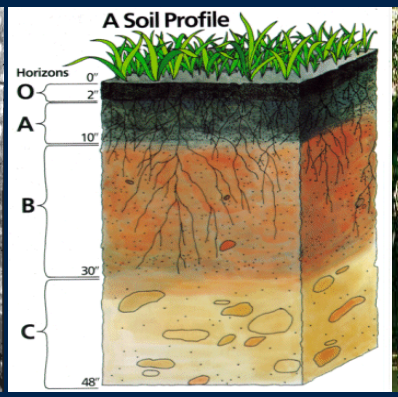
Problem

- **Wetland soils are often highly polluted with toxic elements**
- **Mobilization and Transfer in**
  - **groundwater**
  - **plants**
  - **food chain**
- **Potential risk**

Evaluation of metal mobility & risk assessment

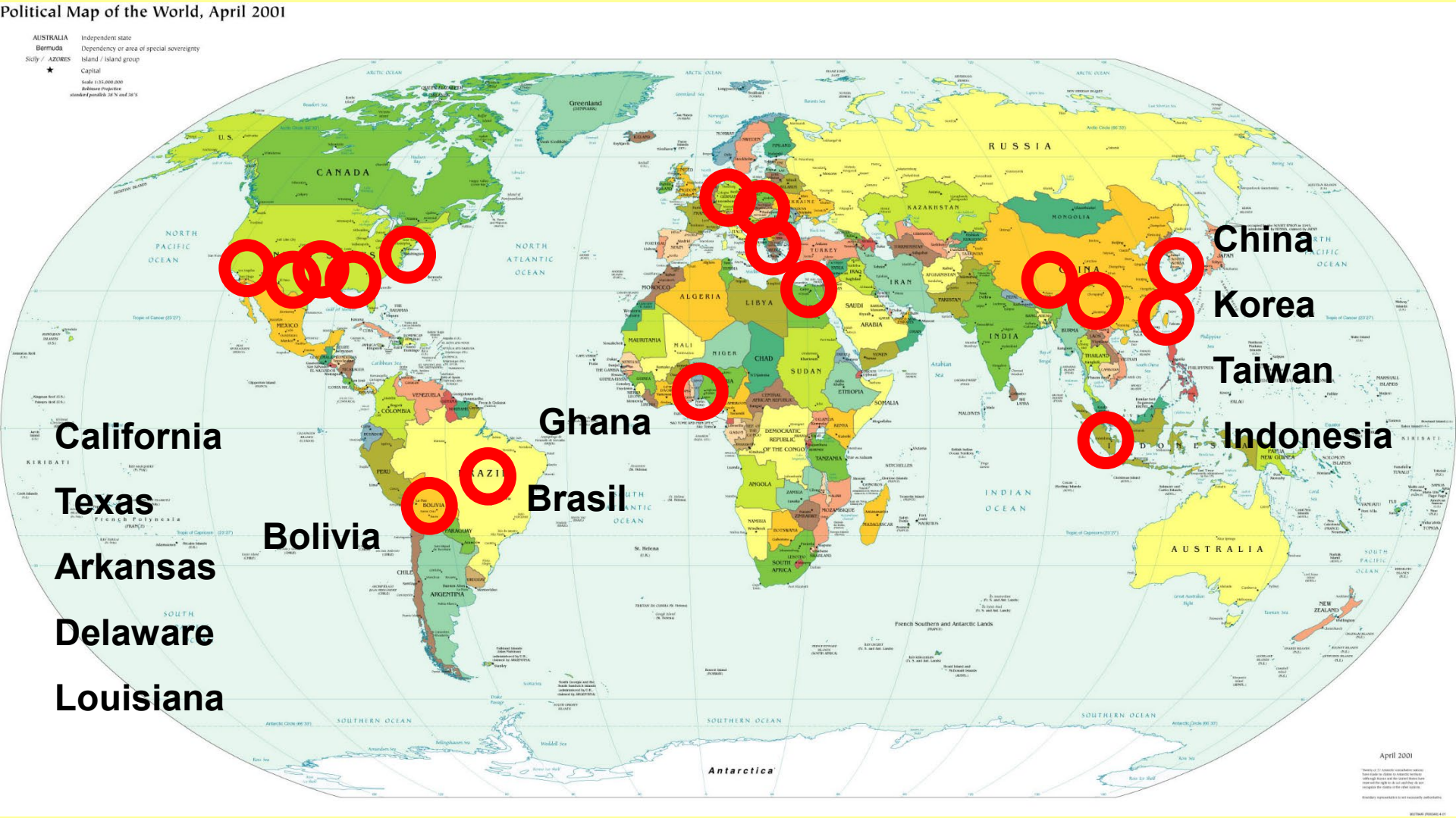
- Quantifying the concentrations of trace metals
- Determine forms of bounding
- Field monitoring of trace metals
- Laboratory experiments

A Range of Scales

Atomic	Molecular	Microscopic	Macroscopic	Field
				
• XRF • XPS • XAS *Requires synchrotron radiation.*	• XRD • TGA • FTIR • DRS	• Enhanced Visual Analysis: 1. SEM 2. TEM 3. AFM	• Field Plots • Equilibrium Studies • Kinetic Studies • Extractions	• Visual/ Intuitive Insight • Field Plots

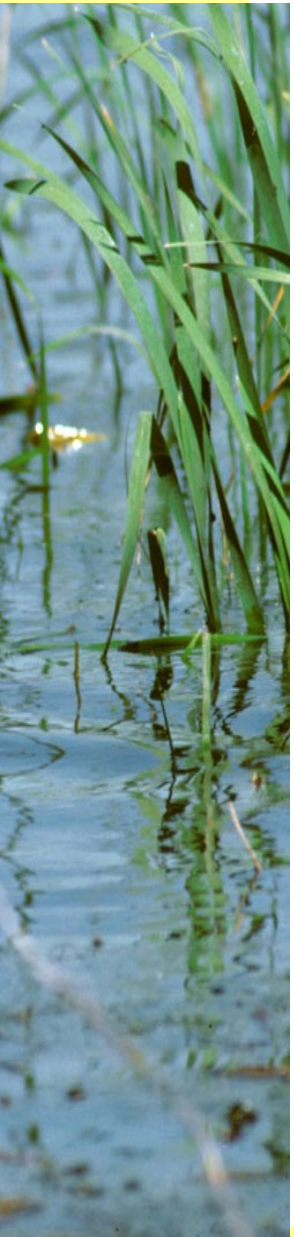
Adaptation of Bertsch and Hunter, 1996.

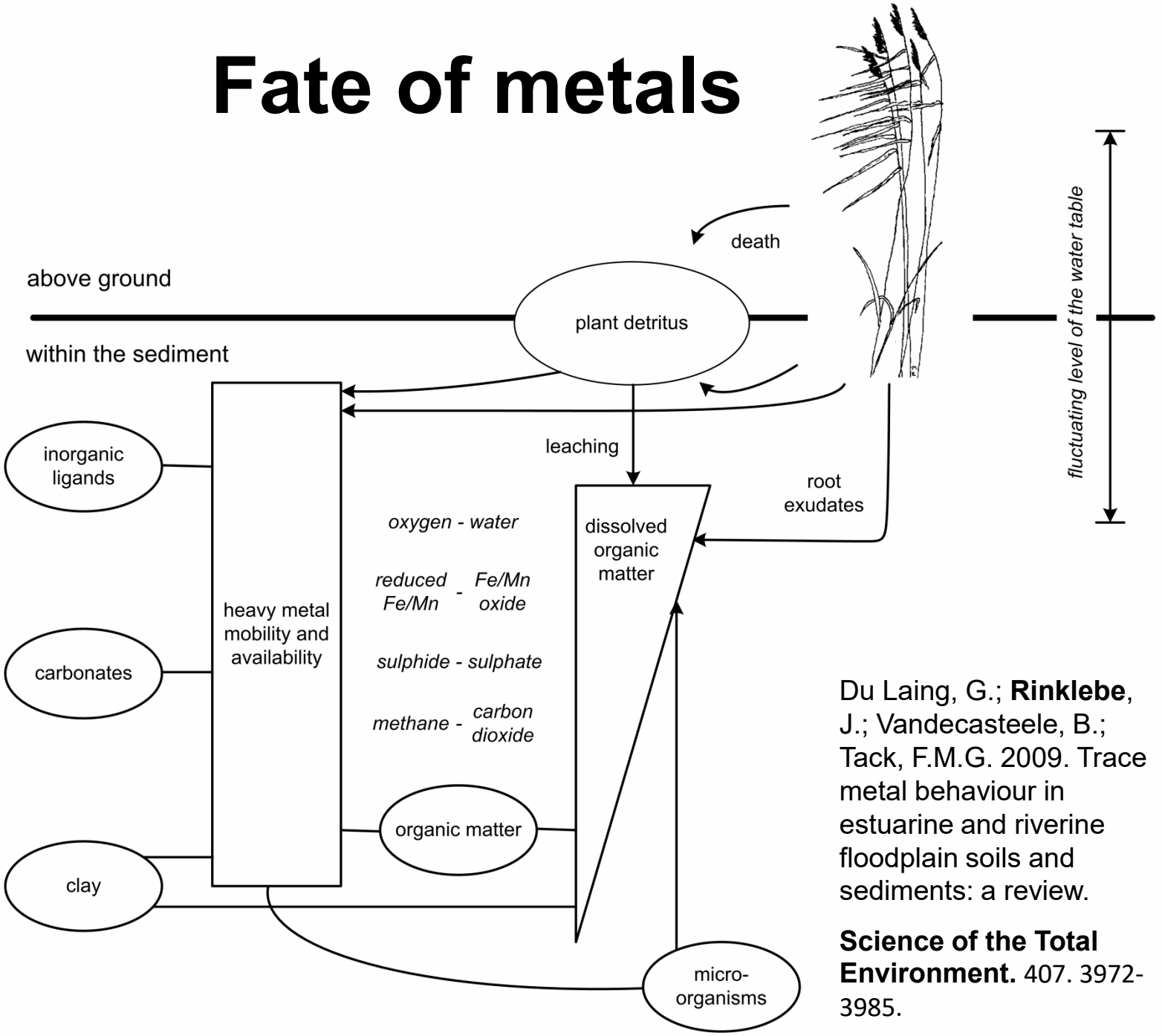
Study areas



http://www.mygeo.info/karten.html

Fate of metals

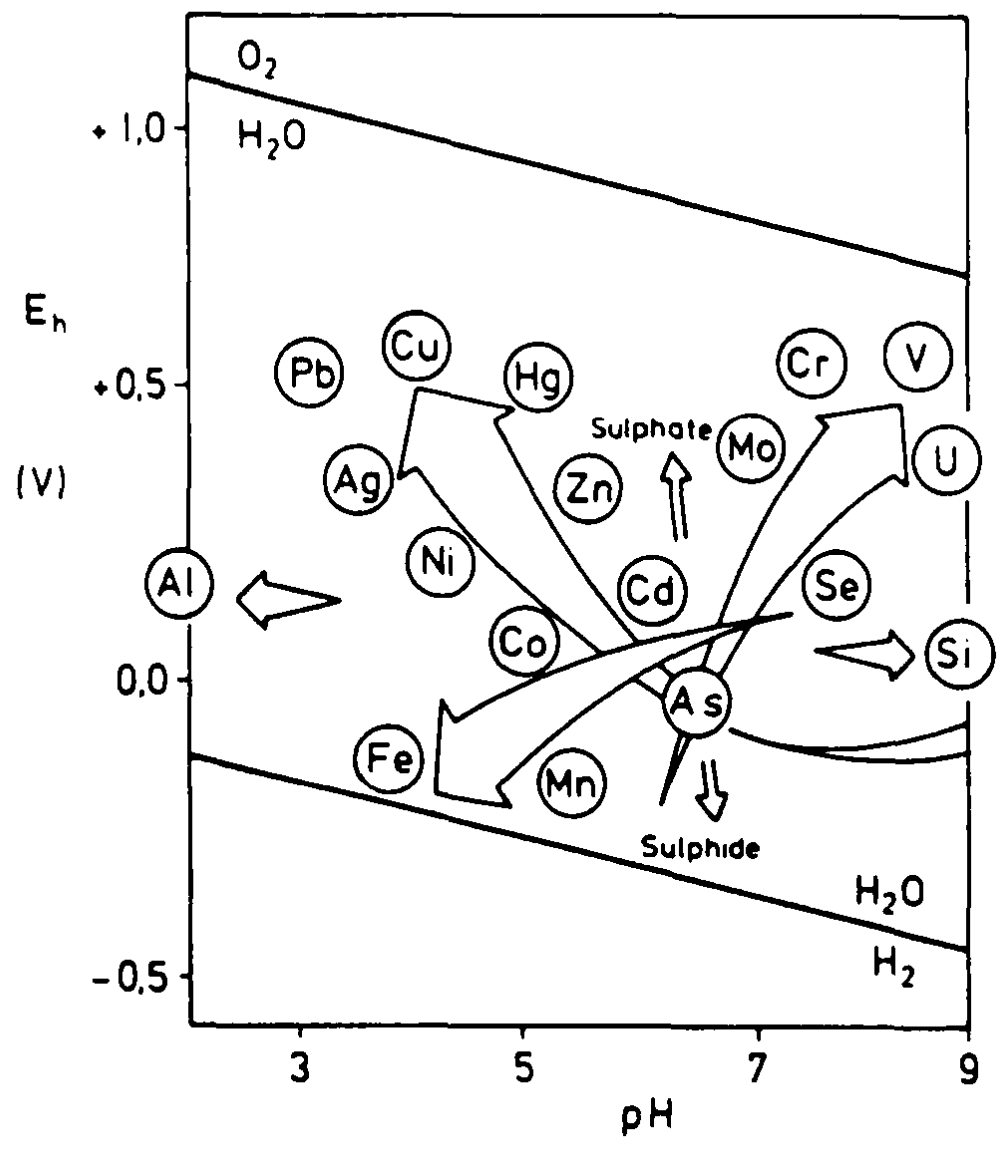




Du Laing, G.; **Rinklebe**, J.; Vandecasteele, B.; Tack, F.M.G. 2009. Trace metal behaviour in estuarine and riverine floodplain soils and sediments: a review.

Science of the Total Environment. 407. 3972-3985.

Metals vs. pH / E_H



Förstner, U. (1993): Int. J. Environ. Anal. Chem. 51, 5-23.

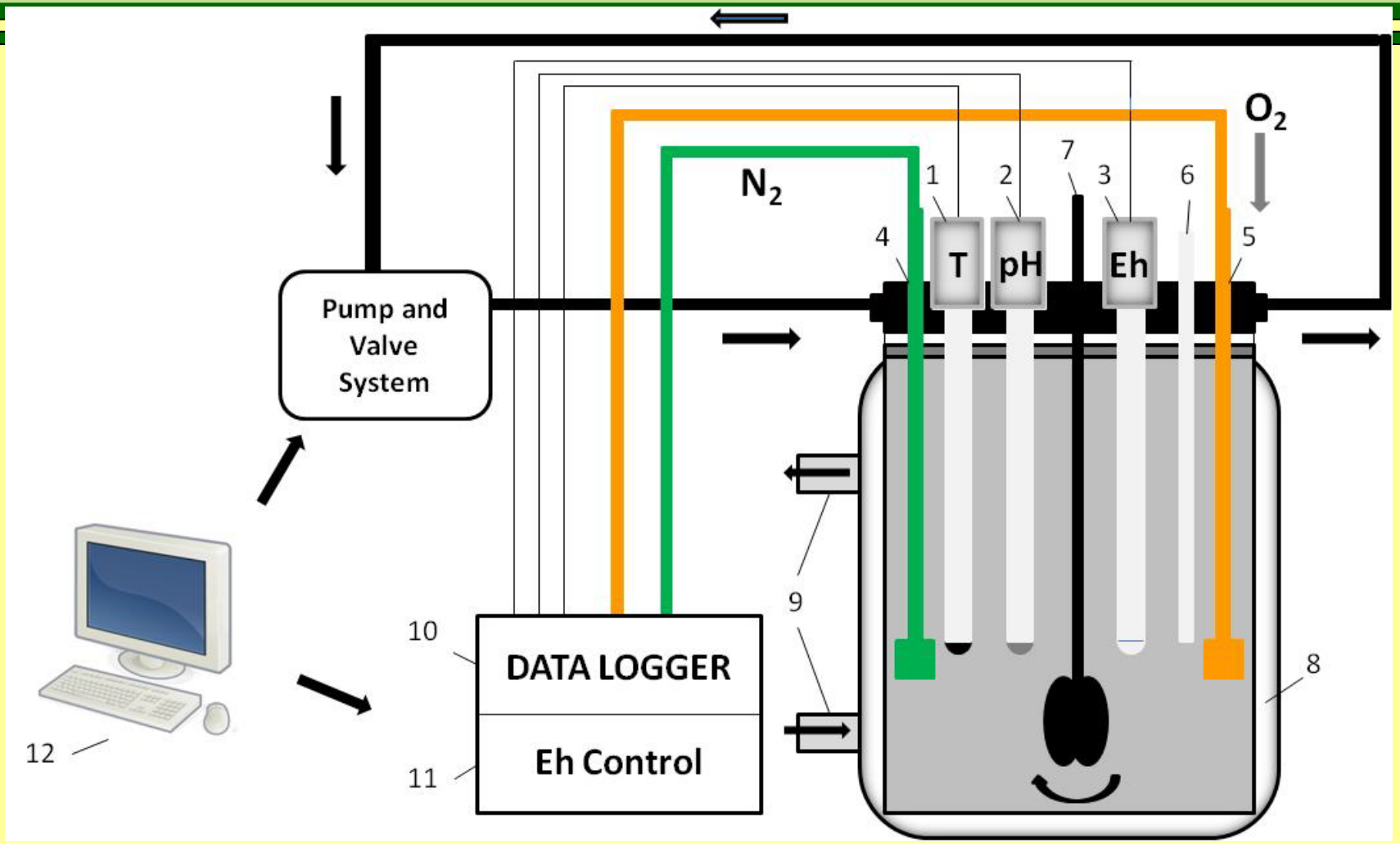
Challenge

- Environmental conditions are changing continuously
- Forcast of mobilization of toxic compounds into the environment
- Mimic changing environmental conditions

Dynamic redox conditions

Using an automatic biogeochemical microcosm system which enables to control redoxpotential (E_H) (or pH) systematically and to set pre-definite redox windows over a wide range.

Biogeochemical microcosms



Yu, K.; Böhme, F.; **Rinklebe**, J.; Neue, H.-U.; DeLaune, R.D. (2007). Major Biogeochemical Processes in Soils. **Soil Science Society of America Journal** 71. 1406-1417.

Yu, K., and J. **Rinklebe**. (2011). Advancement in soil microcosm apparatus for biogeochemical research. **Ecological Engineering** 37: 2071-2075.

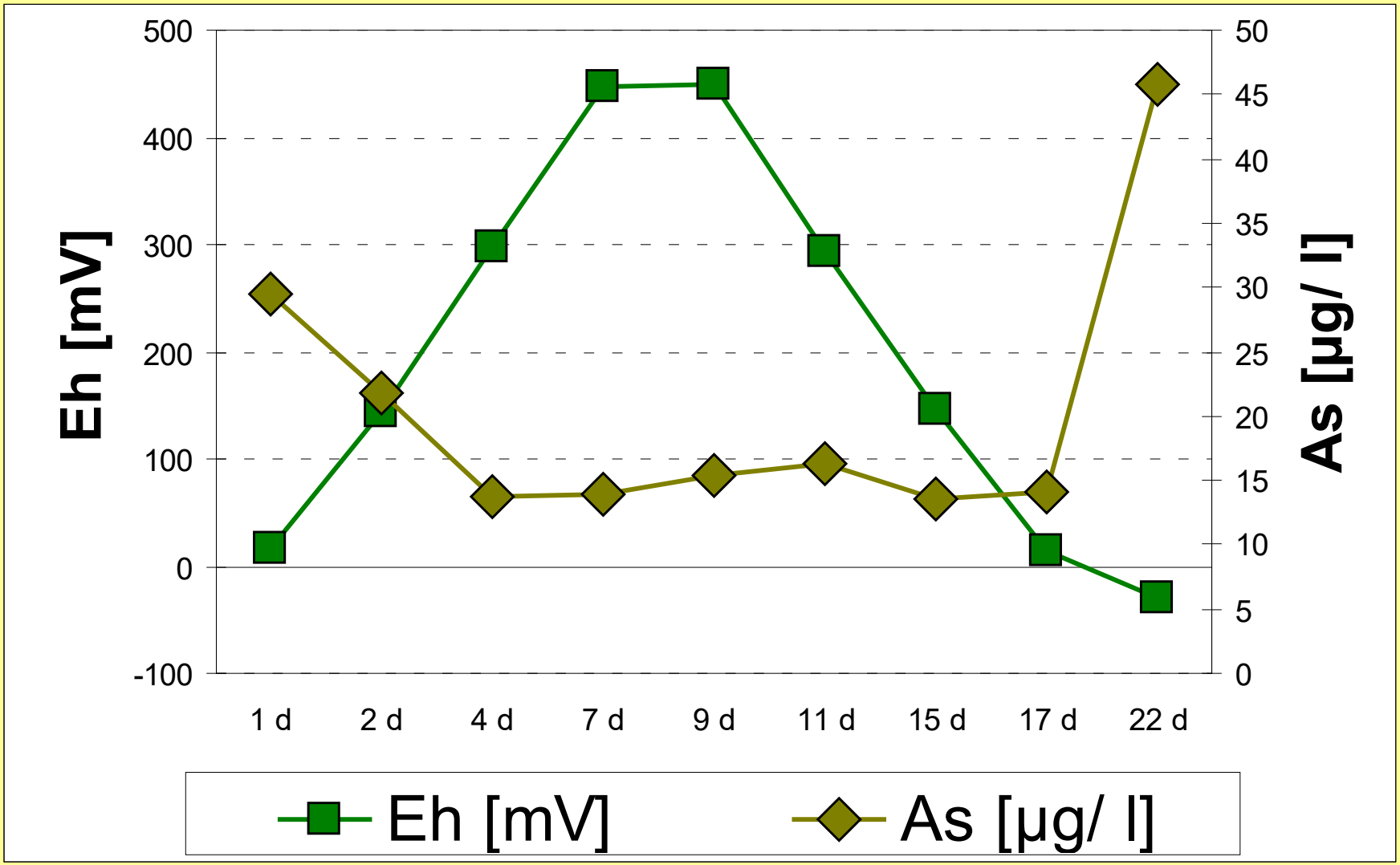
Biogeochemical microcosm

Yu, K.; Böhme, F.; **Rinklebe, J.;** Neue, H.-U.; DeLaune, R.D. (2007): Major Biogeochemical Processes in Soils. **Soil Science Society of America Journal** 71. 1406-1417.

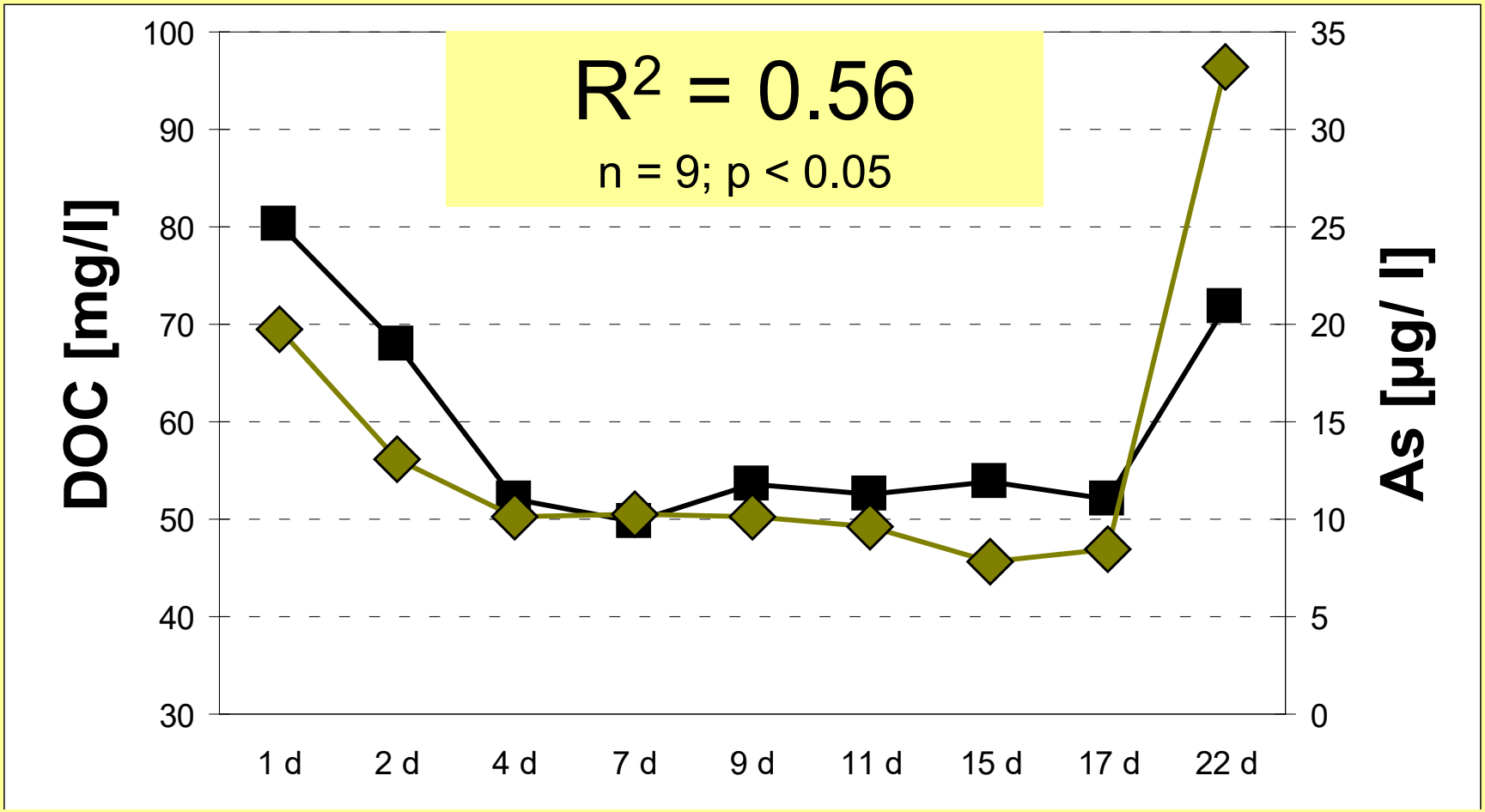
Yu, K.; **Rinklebe, J.** (2011): Advancement in soil microcosm apparatus for biogeochemical research. **Ecological Engineering.**

Biogeochemical microcosms

E_H vs. As
Experiment in the lab

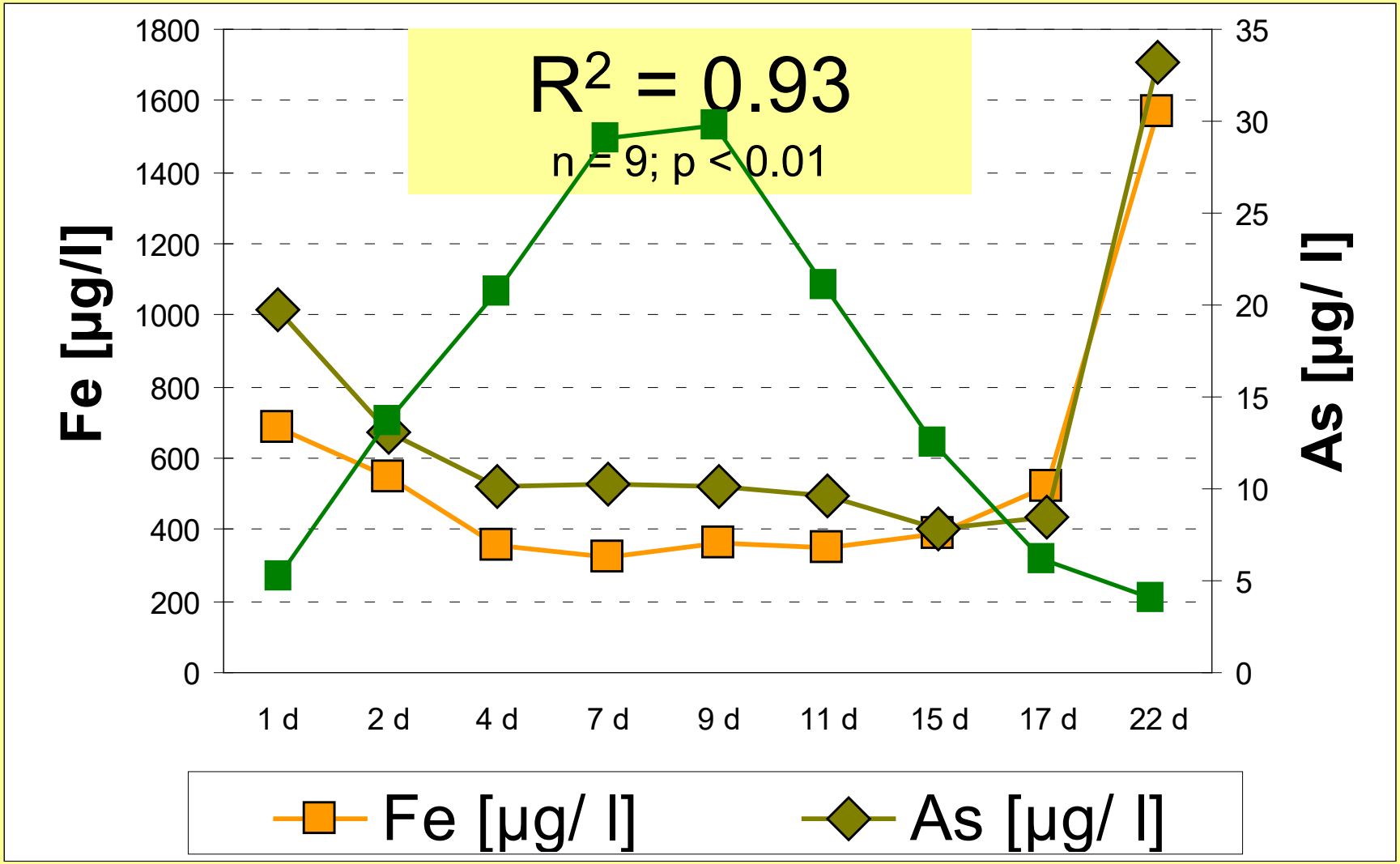


DOC vs. As Experiment in the lab

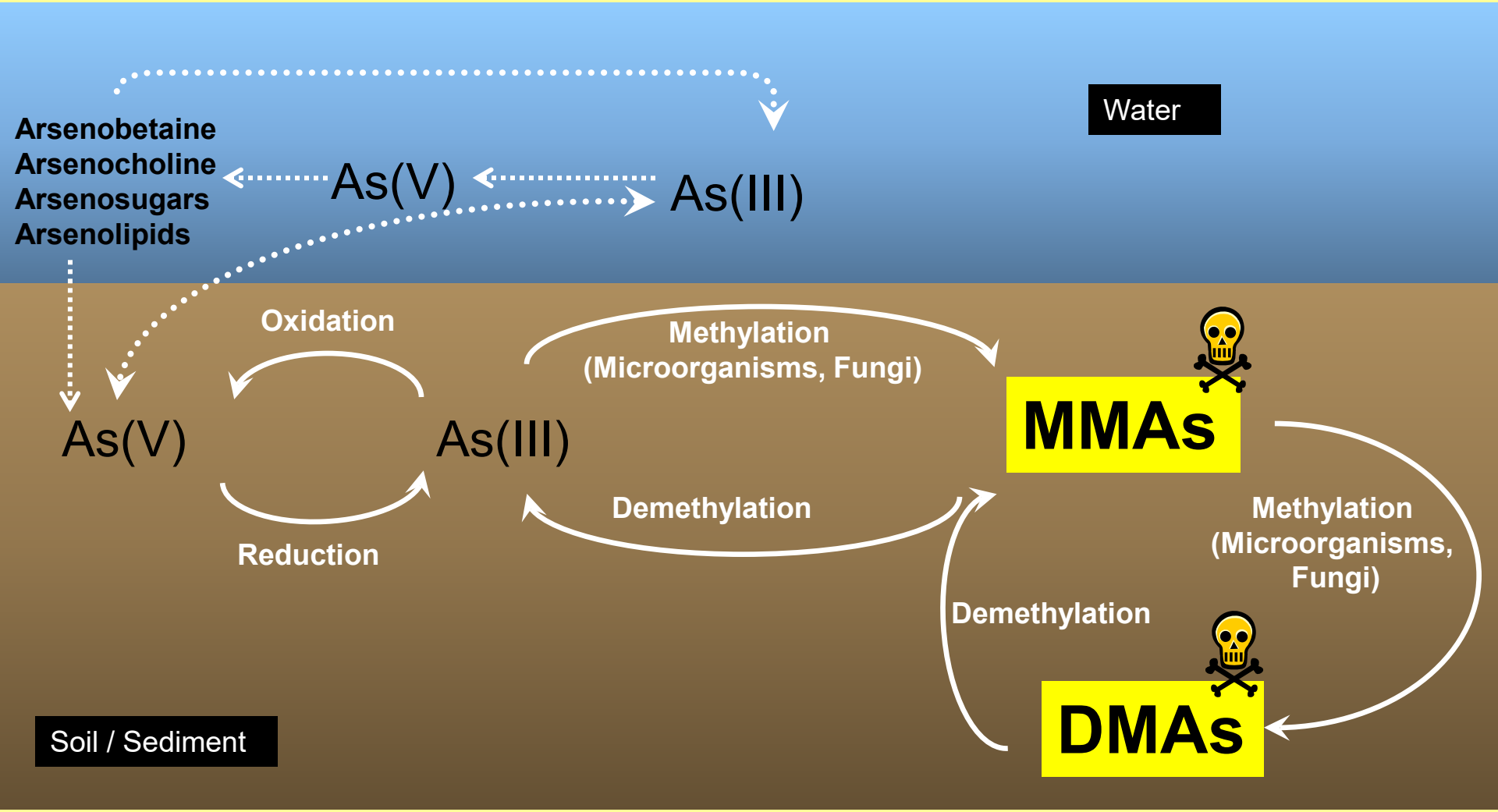


Yu, K.; Böhme, F.; **Rinklebe, J.;** Neue, H.-U.; DeLaune, R.D. (2007): Major Biogeochemical Processes in Soils. **Soil Science Society of America Journal** 71. 1406-1417.

Fe vs. As
Experiment in the lab

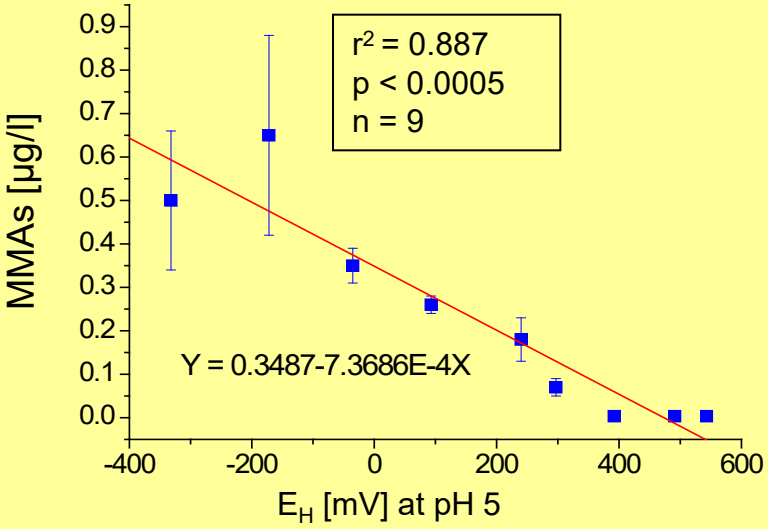


Arsenic in the environment

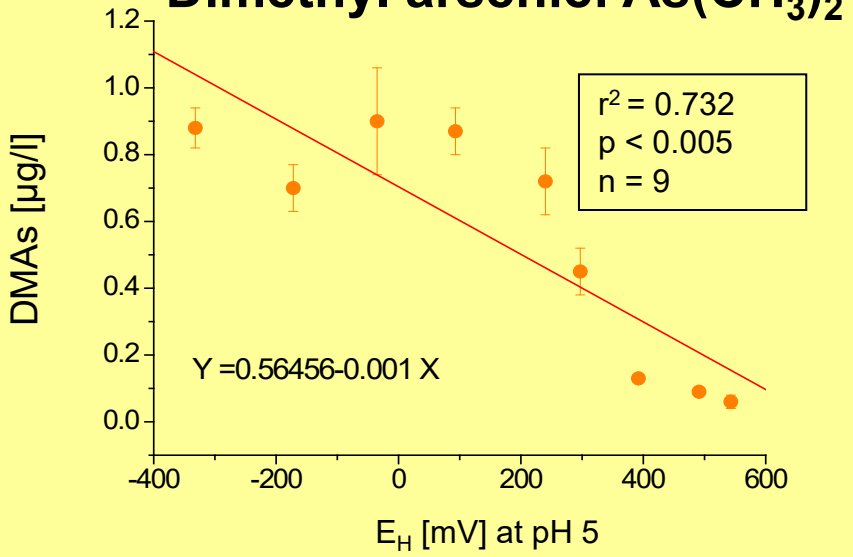


E_H vs. As

Monomethyl arsenic: $AsCH_3$

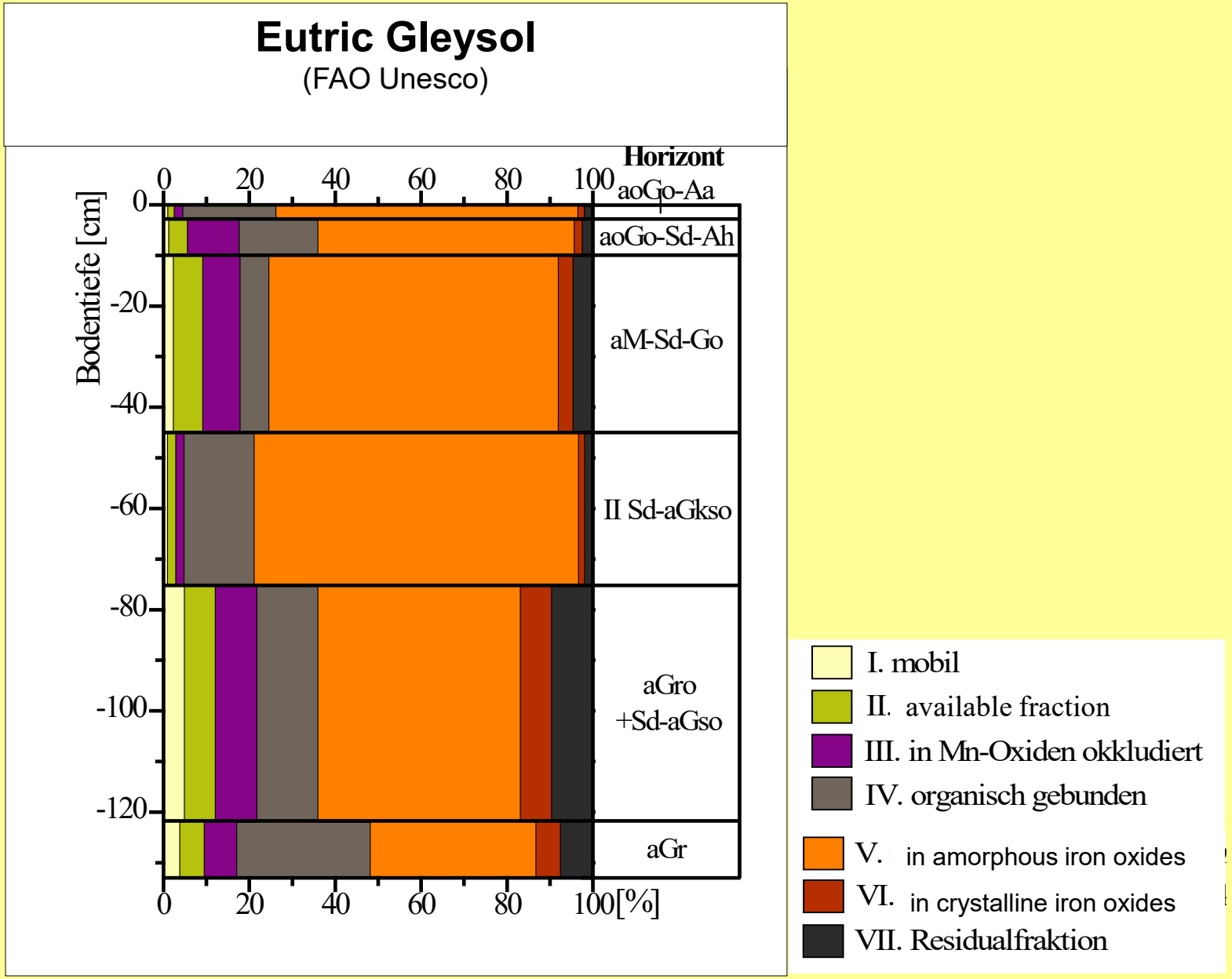


Dimethyl arsenic: $As(CH_3)_2$



Frohne, T.; **Rinklebe, J.**; Diaz-Bone, R.; Du Laing, G. (2011): Controlled variation of redox conditions in a floodplain soil: impact on metal mobilisation and biomethylation of arsenic and antimony. **Geoderma**. 160. 414-424.

Arsenic forms of Bounding



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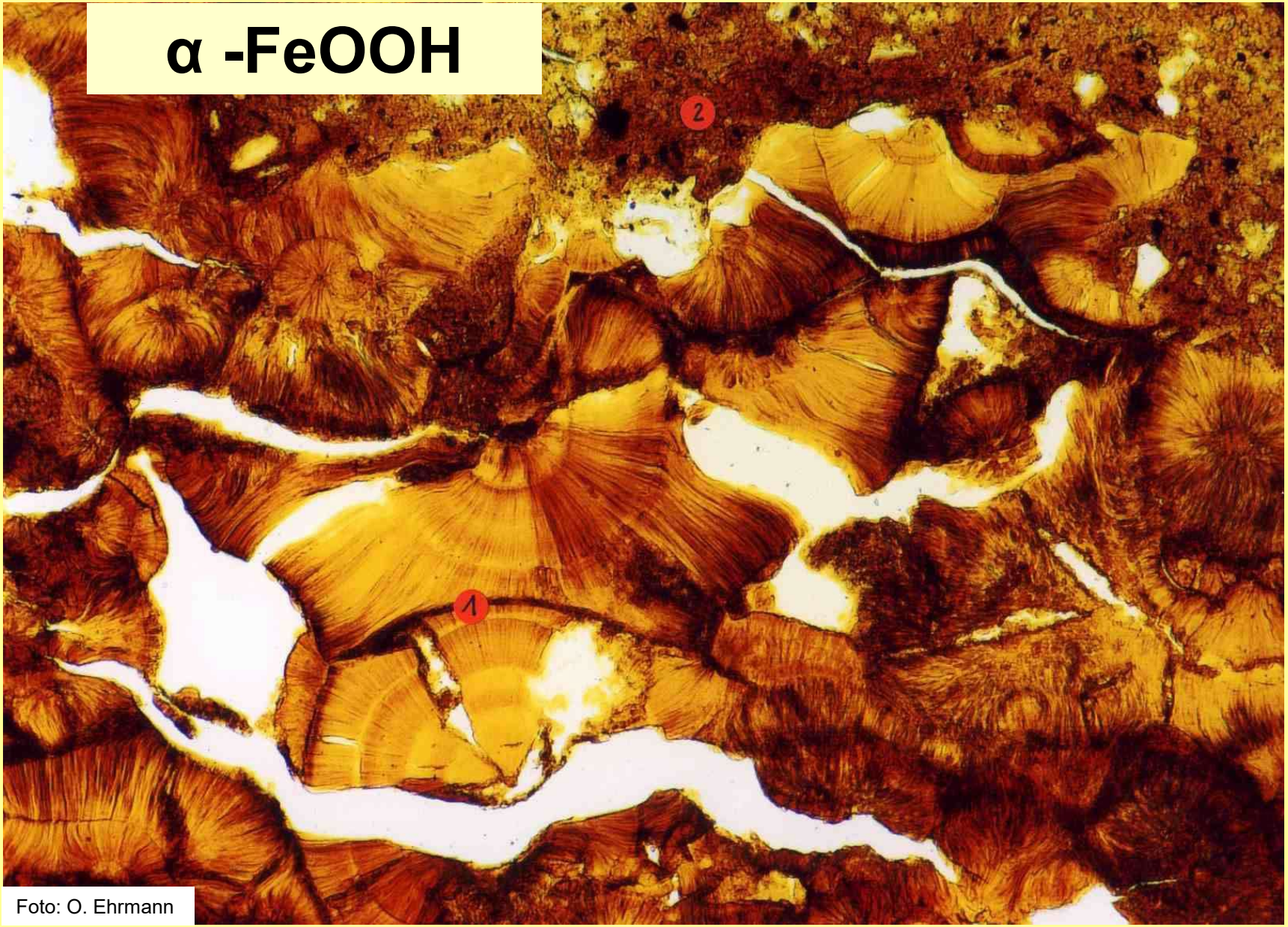

Eutric Gleysol (55-59 cm)

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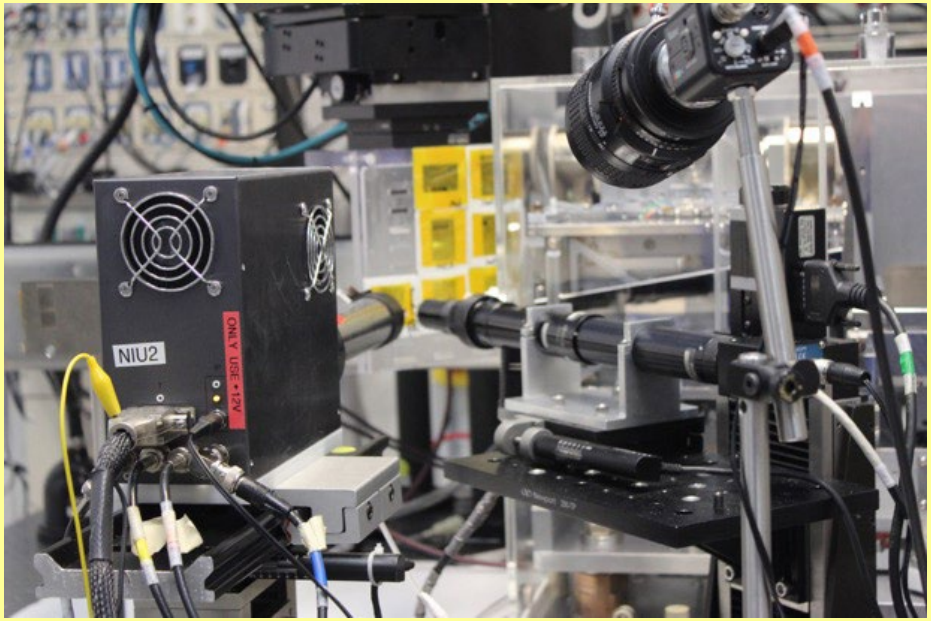
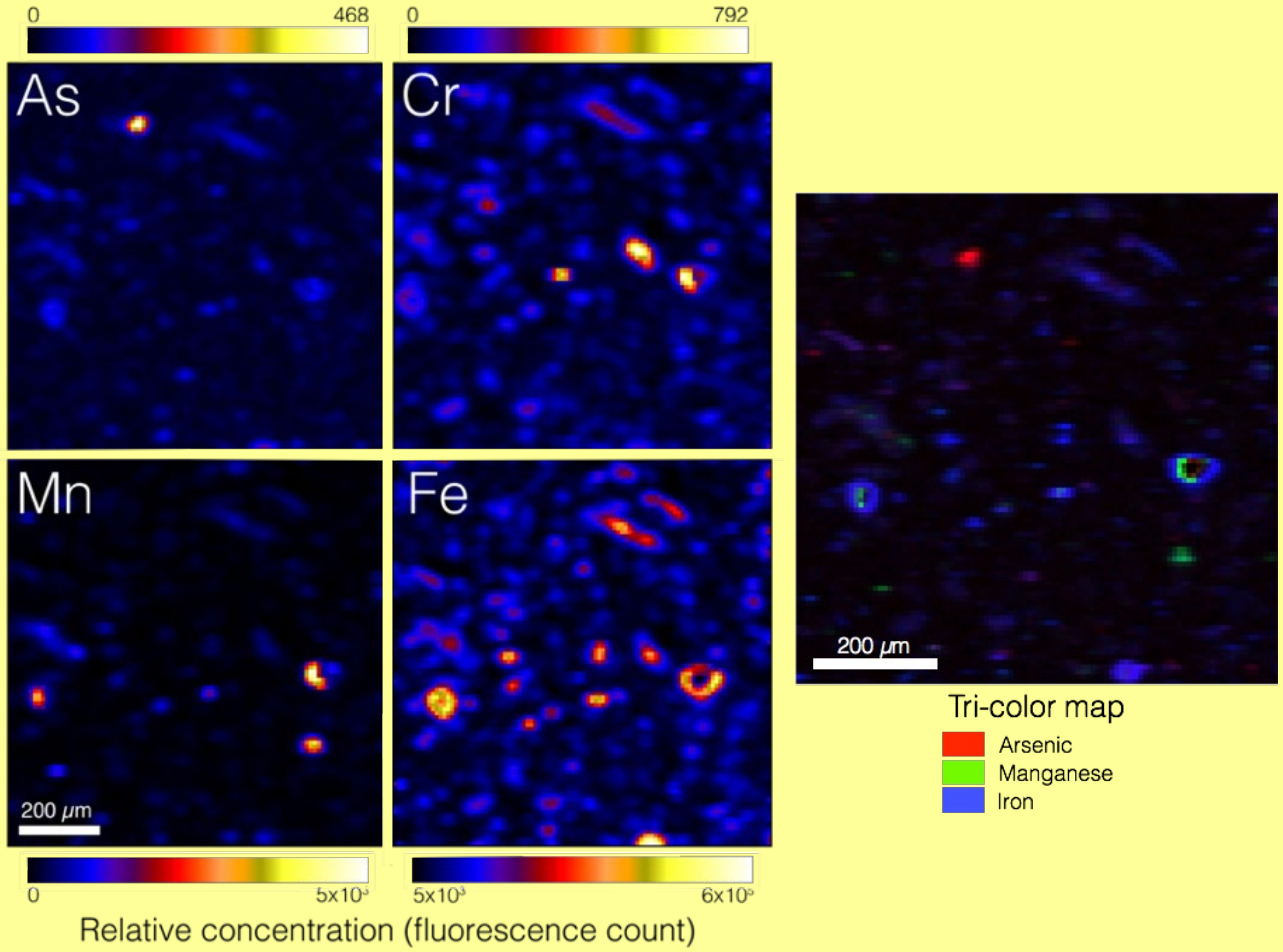
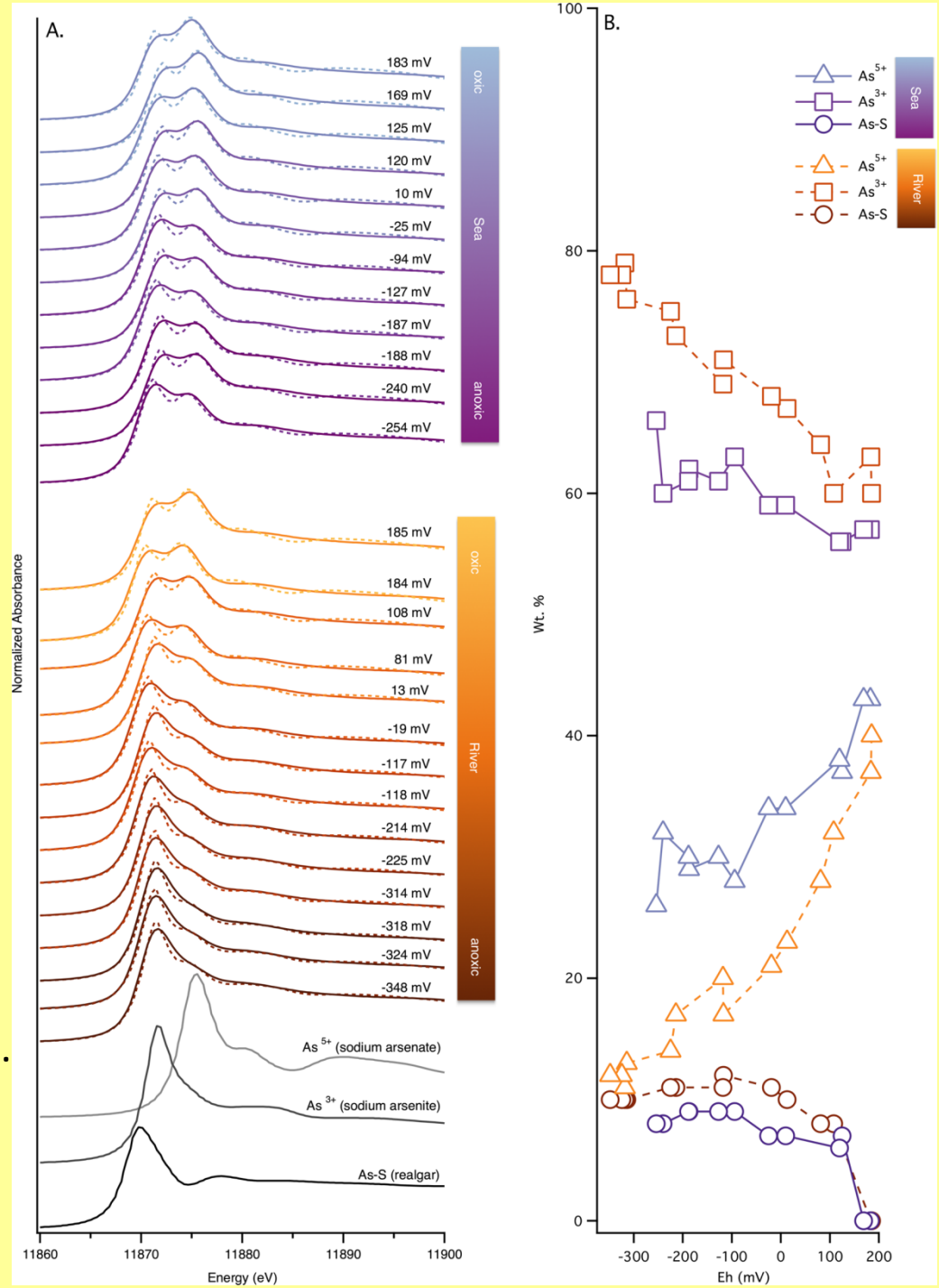
X-ray Absorption Near Edge Structure (XANES) Spectroscopy “fingerprinting”



μ-SXRF Map of As-contaminated wetland soil and tri-color map showing elemental colocation of As, Cr, Fe, and Mn.



LeMonte, J.J.; Stuckey, J.W.; Tappero, R.; **Rinklebe, J.**; Sparks, D.L. (**2017**): Sea level rise induced arsenic release from historically contaminated coastal soils. **Environmental Science and Technology.** 51. 5913-5922.



Arsenic XANES for sea water and river water inundations scenarios across designated Eh windows following 72 h equilibration time at that Eh. Data are represented by the solid lines and fits obtained by linear combination fitting are dotted lines.

LeMonte, J.J.; Stuckey, J.W.; Tappero, R.; **Rinklebe, J.**; Sparks, D.L. (**2017**): **ES&T.** 51. 5913-5922.

The biogeochemical microcosm system

allows mechanistically studies of pollution control processes in soils, sediments, and waters

- **kinetics and dynamics of trace elements and other harmful substances**
- **amendments of various substances (e.g. biochar, organoclay, carbonates) to decrease the mobilization of pollutions**

The biogeochemical microcosm system

- is capable to assess the mobilization of hazardous materials released into the environment and

- provides a wide range of applications in environmental science and technologies

Key papers

Du Laing, G.; **Rinklebe**, J.; Vandecasteele, B.; Tack, F.M.G. (**2009**): Trace metal behaviour in estuarine and riverine floodplain soils and sediments: **a review**. **Science of the Total Environment.** 407. 3972-3985.

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Challenges for future research

- **Dynamics and kinetics of trace elements and their speciation under changing E_H conditions**
- **Spatial and temporal resolution**
- **Linking microbial and chemical processes in flooded soils & sediments**

Guidelines for authorities

- No belittlement
- No panicmongering
- Objective & transparent politics of information's
- Continuous monitoring
- Substantial research

Important reviews

Hou, D.…**Rinklebe, J., Ok, Y.S.** (2020): Metal contamination and bioremediation of agricultural soils for food safety and sustainability. **Nature Reviews. Earth & Environment.** 1. 366–381.

Palansooriya, K.N.…. **Rinklebe**, J., Ok, Y.S. (2020): Soil amendments for immobilization of potentially toxic elements in contaminated soils: A critical review. **Environment International**. 134. 105046.

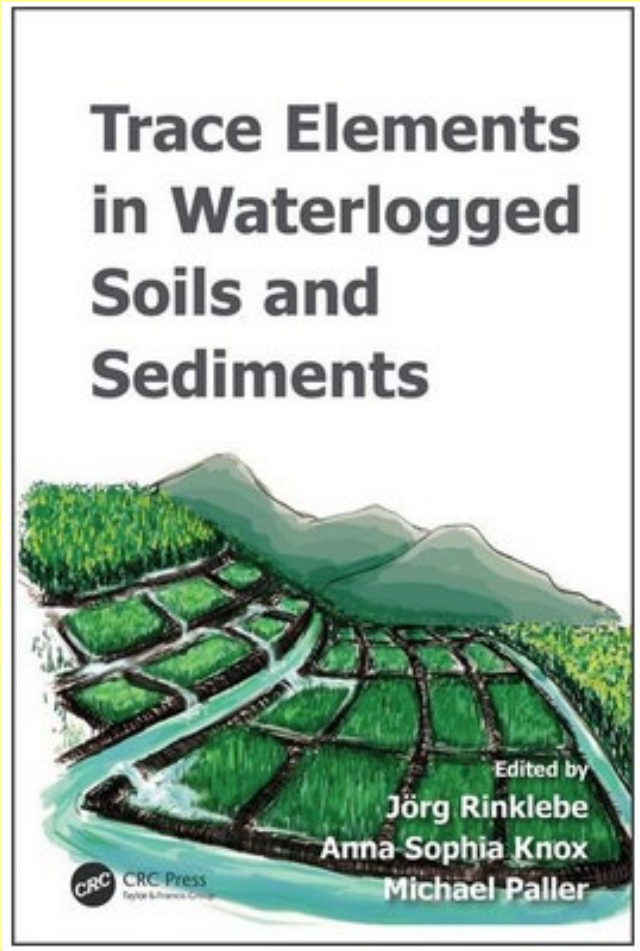
Shaheen, S.M.; … **Rinklebe, J.** (2019): Wood-based biochar for removal of potentially toxic elements (PTEs) in water and wastewater: A critical review. **International Materials Reviews.** 64(4). 216-247.

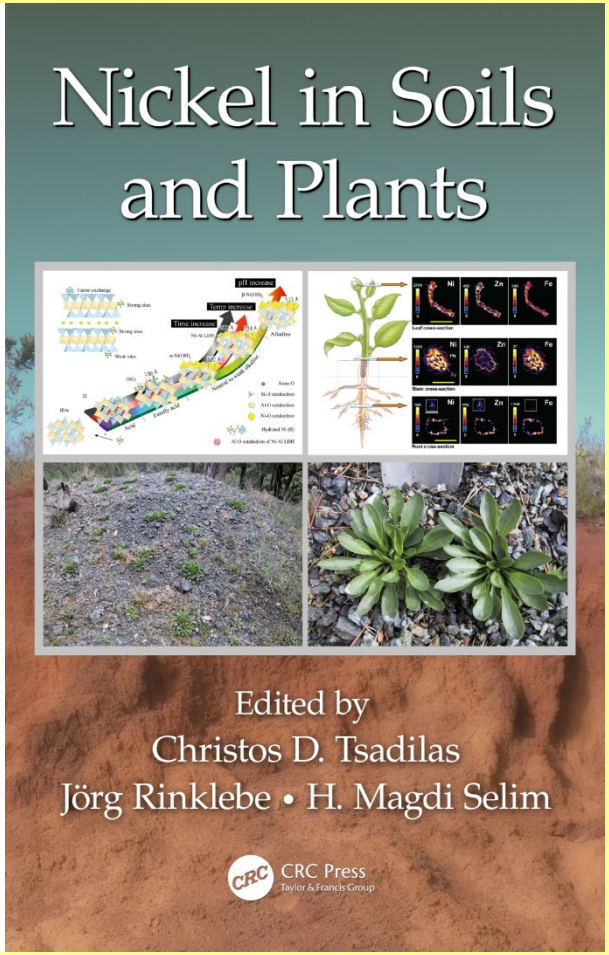
Antoniadis,.. **Rinklebe** (2019): A critical prospective analysis of the potential toxicity of trace element regulation limits in soils worldwide: Are they protective concerning health risk assessment? – A review. **Environment International**. 127. 819-847.

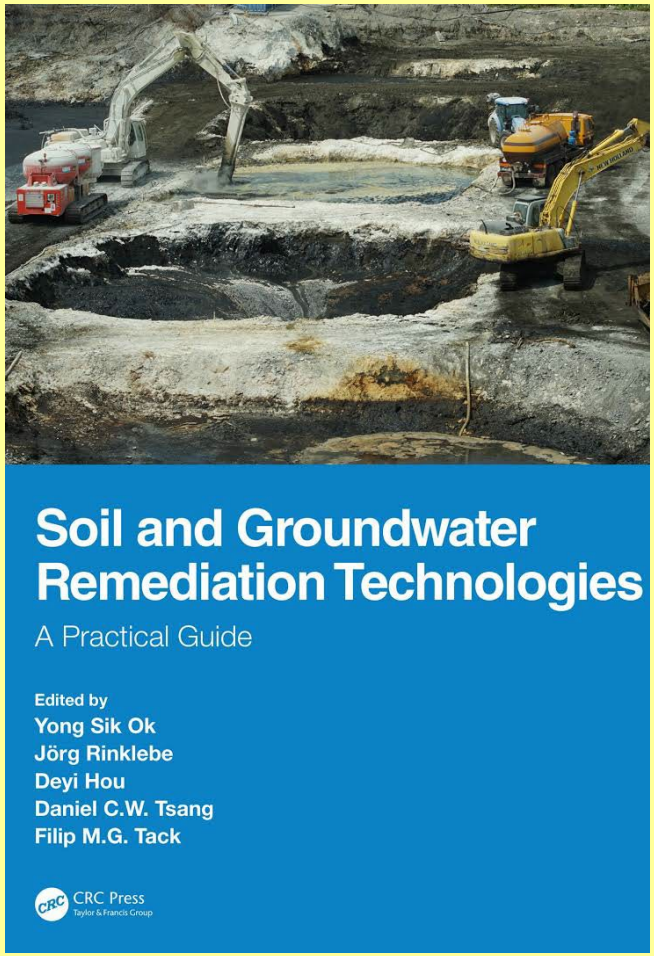
Antoniadis, V……. **Rinklebe, J.** (2017): Trace elements in the soil-plant interface: Phytoavailability, translocation, and phytoremediation–A Review. **Earth-Science Reviews**. 171. 621-645.

Beckers, F.; **Rinklebe, J.** (2017): Cycling of Mercury in the Environment: Sources, Fate, and Human Health Implications - A Review. **Critical Reviews in Environmental Science and Technology.** 47(9). 693-794.

Books


Trace Elements in Waterlogged Soils and Sediments
Edited by
Jörg Rinklebe
Anna Sophia Knox
Michael Paller
CRC Press


Nickel in Soils and Plants
Edited by
Christos D. Tsadilas
Jörg Rinklebe • H. Magdi Selim
CRC Press
Taylor & Francis Group


Soil and Groundwater Remediation Technologies
A Practical Guide
Edited by
Yong Sik Ok
Jörg Rinklebe
Deyi Hou
Daniel C.W. Tsang
Filip M.G. Tack
CRC Press
Taylor & Francis Group

Books

Just released!