International Institute for Environmental Studies
国际环境科学中心

Soil Contamination and Remediation
Live E-lecture Series
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Content Outline
Part 1 – Introductory Lectures

L1 (w/c 06/03) Bioavailability of Metals in Contaminated Soils (Sauvé/Montréal)

L2 (w/c 13/03) Background concentrations of trace metals in soils (Ma/Florida)

L3 (w/c 20/03) Characterisation of Cr(VI)-Contaminated Urban Soils (Graham/UoE)

L4 (w/c 27/03) Antimony behaviour in shooting range soils (Schulin/ETH)

Part 2 – Contaminant Remediation – Case Studies

L5 (03/04) Remediation Methods for high-pH Cr(VI)-Contaminated Soils (Graham/UoE)

L6 (10/04) Earthworm-enhanced Remediation of Soil with Organic Contaminants (Ji/Nanjing)

L7 (17/04) Remediation of Mercury-contaminated Farming Soils (Zhong/Nanjing)

L8 (24/04) Phytoremediation of As-contaminated soils (Ma/Florida)

Part 3 – Environmental Risk Assessment and Regulation

L9 (w/c 01/05) Principles and practise of terrestrial ecotoxicology (Oliver/Keele)

L10 (w/c 08/05) Terrestrial ecotoxicology for chemical risk assessment (Oliver/Keele)

L11 (w/c 15/05) Case studies for retroactive and proactive soil risk assessments (Watmough/Trent)

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Synopses

Lecture 1: Chemical Speciation, Fractionation and Bioavailability of Metals in Contaminated Soils (Sébastien Sauvé / Montréal)

Metals in contaminated soils are for the most part bound to the solids and hence only a small fraction of the total metal content is potentially bioavailable for uptake or biological effects. The first step in determining bioavailability is to study what factors control the fractionation of metals between the solid and liquid phase. Mineral equilibrium calculations can inform on the solubility of some minerals but in most situations, sorption will be controlling soil solution concentration below what would be expected from mineral equilibrium. Solid-liquid distribution coefficients (Kd) can then be used to predict partitioning among the liquid and solid fractions. It is clear that soil solution pH, soil organic matter and soil texture will greatly influence this distribution.

Furthermore, a major portion of the metals occurring within the solution will be bound to dissolved organic matter and thus potentially of a lower bioavailability. The measurements and modelling of the chemical speciation of metals in soil solution is therefore key to the understanding of their fate and potential ecotoxicological impacts. This chemical speciation must be considered through measurements or modelling and its implications must somehow be considered within soil quality criteria derivation.

Lecture 2: Background concentrations of trace metals in soils (Lena Ma / Florida)

Arsenic contamination in soils is of great environmental concern due to its toxic effects as a carcinogen. There are thousands of arsenic-contaminated soils in worldwide due to widespread use of arsenic in the past. Based on the current guideline, soils can be cleaned to their natural background arsenic concentrations in soils. However, there is neither a scientific protocol available for determining arsenic background concentrations nor a good database to be used as a reference for such a purpose. Thus, a comprehensive study was conducted to determine the background concentrations of arsenic in Florida surface soils using 450, geographically and pedogenically representative, and chemically and physically characterized, soil samples. Arsenic concentrations in Florida soils varied not only with soil types but also with digestion methods. They were much lower compared to soils in the US and world, ranging from 0.1 to 50.6 mg kg^{-1} with a geometric mean concentration of 0.42 mg kg^{-1}. It is thus very important to obtain valid background arsenic concentrations for cost-effectively cleaning up arsenic contaminated soils.

Reference: Chen, M., L.Q. Ma and W. Harris. 1999. Baseline concentrations of 15 trace elements in Florida surface soils. J. Environ. Qual. 28:1173-1181

Lecture 3: Characterisation of Cr(VI)-Contaminated Urban Soils (Margaret Graham / University of Edinburgh)

- Why did Cr(VI) continue to leach from contaminated site more than 40 years after closure of the chemical factory?
- We will answer this question by considering the history of a major chrome producing site in Glasgow (Scotland) and then exploring the use of XRPD, SEM-EDX and XRF to characterise the chemical and physical forms of chromium present in the industrial wastes

Suggested Reading:

Hillier et al., Sci. Total Environ., 2003, 308, 195-210

Hillier et al., Environ. Sci. Technol., 2007, 41, 1921-1927

Farmer et al., ASCE Geotech. Spec. Pubn. No. 177, 2008, 740-747

Lecture 4: Antimony behaviour in shooting range soils (Schulin/ETH)

Switzerland has around 2000 active shooting ranges plus some military practicing grounds in the mountains, where soil contamination with antimony has raised public concern after autho¬rities became aware of potential problems for the environment and human health some years ago. In a series of microcosm, pot, column and field lysimeter experiments, we investigated the behaviour of antimony in selected shooting range soils and potential risks, with particular emphasis on the effects of water-logging, which is a common problem in Swiss grassland soils. The lecture will focus on the results of these investigations.

Suggested Reading:

Hockmann, K. and R. Schulin, Leaching of antimony from contaminated soils. In: H. M. Selim (ed.), Competitive Sorption and Transport of Heavy Metals in Soils and Geological Media, CRC Press, 2013, pp. 119-145

Hockmann et al., Journal of Hazardous Materials, 2014, 275, 215-221

Hockmann et al., Environ¬mental Chemistry, 2014, 11, 624-631

Hockmann et al., Chemosphere, 2015, 13, 536-543

Lecture 5: Earthworm-enhanced Remediation of Soil with Organic Contaminants (Rong Ji / Nanjing University)

Bioavailability and microbial activity are two of the determinants for degradation of organic contaminants in soil. Via their feeding activity, earthworms, especially the geophagous earthworms, have great impacts on soil physicochemical and biological properties, and therefore stimulate the dissipation of contaminants in soil by enhancing both degradation and bound-residue-formation of the contaminants.

Suggested reading:

Hickman, ZA; Reid, BJ. Earthworm assisted bioremediation of organic contaminants. *Environ. Int.* 2008, 34, 1072-1081.

Shan, J; Brune, A; Ji, R. Selective digestion of the proteinaceous component of humic substances by the geophagous earthworms *Metaphire guillelmi* and *Amynthas corrugatus*. *Soil Biol. Biochem.* 2010, 42, 1455-1462.

Lecture 6: Remediation of Mercury-contaminated Farming Soils (Huan Zhong/ Nanjing University)

Recent studies reveal that consumption of contaminated rice could be an important pathway of human exposure to methylmercury, posing a health risk to human beings. Therefore, it would be of great importance to remediate Hg-contaminated farming soils. Immobilization and phytoextraction of Hg are two common ways to remediate the Hg-contaminated soils, and theories and examples are provided in this lecture.

Suggested reading:

Wang Y-J, Dang F, Evans D, Zhong H*, Zhao J-T, Zhou D-M. Mechanistic understanding of MeHg-Se antagonism in soil-rice systems: the key role of antagonism in soil. Scientific Reports. DOI 10.1038/srep19477. 2016.

Shu R, Wang Y-J, Zhong H*. Biochar amendment reduced methylmercury accumulation in rice plants. Journal of Hazardous Materials 313: 1–8. 2016.

Lecture 7: Developing a Remediation Method for high-pH Cr(VI)-Contaminated Soils (Graham/ University of Edinburgh)

- How do you remediate Cr(VI) in contaminated soils which have high pH, low moisture content, low water permeability?
- We will review the options for remediation of Cr(VI)-contaminated soils
- We will then consider the reasons why "off-the-shelf" methods did not work before looking at the steps required to develop and apply a "fit-for-purpose" remediation strategy

Suggested Reading:

Geelhoed et al., Environ. Sci. Technol., 2003, 37, 3206-3213

Graham et al., Sci. Total Environ., 2006, 364, 32-44.

Lecture 8: Phytoremediation of As-contaminated soils (Ma/ Florida)

Arsenic is of great environmental concern due to its extensive contamination and carcinogenic toxicity. Anthropogenic activities have resulted in numerous arsenic contaminated sites worldwide. The arsenic hyperaccumulator *Pteris vittata* L. (Chinese Brake fern) has many desirable attributes for use in phytoremediation of arsenic-contaminated soils (Ma et al., 2001). Pilot-scale field demonstration shows that the plant was effective in removing arsenic from the soil (14%) after two seasons. The plant's abilities to produce large quantities of root exudates (to solubilize soil arsenic), to produce large root biomass (>fronds), to effectively translocate arsenic to the fronds (up to 95%), to reduce arsenic from arsenate-AsV to arsenite-AsIII (up to 100% arsenite) in the fronds, and to keep high concentration of P in the roots have all contributed to its capability to hyperaccumulate arsenic, making it a good candidate for use in phytoremediation of arsenic contaminated sites.

Reference: Ma, L.Q., K.M. Komar, C. Tu, W. Zhang, and Y. Cai. 2001. A fern that hyperaccumulates arsenic. Nature. 409: 579.

Lecture 9: Principles and practise of terrestrial ecotoxicology (Ian Oliver / Keele University)

Terrestrial ecotoxicology seeks to determine what levels of contaminants cause harm to organisms in soil systems. The lecture will introduce the principles that underpin the discipline and will cover the typical assays employed, organisms tested, and quantification of toxicity endpoints (toxicity metrics).

Suggested Reading:

Smolders, E., Buekers, J., Oliver, I. and McLaughlin, M. J. (2004). Soil properties affecting toxicity of zinc to soil microbial properties in laboratory-spiked and field-contaminated soils. Environmental Toxicology and Chemistry, 23, 2633-2640.

Van Gestel, C. A. M. (2012) Soil ecotoxicology: state of the art and future directions. Zookeys, *275-296.*

Lecture 10: Terrestrial ecotoxicology for chemical risk assessment (Oliver / Keele)

Once generated, terrestrial ecotoxicology data can be employed to derive concentrations that will be unlikely to cause harm to soil dwelling organisms (i.e. Predicted No Effect Concentrations, or PNECS). PNECs enable risk assessment of the concentrations observed at contaminated sites. The derivation of these PNECS requires rigorous compilation, evaluation and combination of data from different soils and for different organisms in order to ensure that the derived values are protective for all.

Suggested reading:

Smolders, E., Oorts, K., Sprang, P. V., Schoeters, I., Janssen, C. R., McGrath, S. P. and McLaughlin, M. J. (2009). Toxicity of trace metals in soil as affected by soil type and aging after contamination: using calibrated bioavailability models to set ecological soil standards. Environmental Toxicology and Chemistry, 28, *1633-1642.*

Lecture 11: Case studies for retroactive and proactive soil risk assessments (Watmough/Trent)