KSEA-KBRC International Symposium

Heavy Metal Remediation in Agricultural Ecosystems

Bioavailability-based Soil Management Technology for Safer Food Crop Production

Date & Time
November 15 (Thu), 2012 at 13:00 ~ 18:00

Venue
Digital Media Center (Seo Am Kwan) 1st floor
Kangwon National University, Chuncheon, Korea

Organized by
The Korean Society of Environmental Agriculture
The Korea Biochar Research Center, Kangwon National University
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Dar-Yuan Lee (National Taiwan University)

Immobilizer assisted management of metal contaminated agricultural soils for safer food production
Kwon-Rae Kim (Gyeongnam National University of Science and Technology)
It is our pleasure to invite outstanding scientists for the International Symposium on “Heavy Metal Remediation in Agricultural Ecosystems” organized by the Korean Society of Environmental Agriculture.

This symposium invited the world leading scientists from five countries including Japan, Korea, Netherlands, Taiwan and the United States to promote the heavy metal remediation in agricultural ecosystems.

Heavy metals have been known as sources inducing the contamination or disturbance of surrounding ecosystems. As you all know, the releasing heavy metals into agricultural ecosystems can be accumulated into plant tissues by uptake, thereby directly affecting human health. Thus, many attempts to reduce the contamination of heavy metals are being progressed worldwide.

The goals of this International Symposium on “Heavy Metal Remediation in Agricultural Ecosystems” are to discuss about the newly announced technologies for heavy metal remediation in agricultural ecosystems and to suggest the environmentally-friendly strategies of heavy metal control for managing or improving our surrounding ecosystems.

Finally, this symposium is planned to provide the world’s leading experts to share their valuable insights with colleagues for the research and development of heavy metal remediation technology in Korea.

Thank you so much.

November 15, 2012
Soon Gang Yun
President
The Korean Society of Environment Agriculture
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<tr>
<th>Time</th>
<th>Topics</th>
<th>Chairs</th>
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<td>12:00~13:00</td>
<td>Registration</td>
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<td>13:00~13:10</td>
<td>Opening Ceremony</td>
<td>Soon Gang Yun President, The Korean Society of Environmental Agriculture, Korea</td>
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<tr>
<td>13:10~13:40</td>
<td>The power and limitations of synchrotron X-rays in agro-environmental research</td>
<td>Dean L. Hesterberg Professor, North Carolina State University, USA</td>
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<td>13:40~14:10</td>
<td>Soil characteristics and soil management affecting the metal bioavailability and food safety of heavy metal contaminated soils in Taiwan</td>
<td>Jae E. Yang Professor, Kangwon National University, Korea</td>
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<td>14:10~14:35</td>
<td>Soil washing for rice paddy soils contaminated with cadmium</td>
<td>Tomoyuki Makino Senior Researcher, National Institute for Agro-Environmental Sciences, Japan</td>
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<td>14:35~14:55</td>
<td>Effective regulation of heavy metal uptake of crop plants using amendments in arable soil</td>
<td>Chang Oh Hong Professor, Pusan National University, Korea</td>
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<td>15:25~15:50</td>
<td>Soil characteristics and soil management affecting the metal bioavailability and food safety of heavy metal contaminated soils in Taiwan</td>
<td>Jeong-Gyu Kim Professor, Korea University, Korea</td>
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<td>16:20~16:40</td>
<td>Current issues on the heavy metal contamination of agricultural fields and agro-food in Korea</td>
<td>Won-Il Kim Senior Researcher, National Academy of Agricultural Science, Korea</td>
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<td>17:05~17:35</td>
<td>Arsenic sequestration in iron plaque and its effect on As uptake by paddy rice grown in soils with high contents of As, iron oxides, and organic matter</td>
<td>Dar-Yuan Lee Distinguished Professor, National Taiwan University, Taiwan</td>
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<td>17:35~18:00</td>
<td>Immobilizer-assisted management of the metal contaminated agricultural soils for safer food production</td>
<td>Kwon-Rae Kim Professor, Gyeongnam National University of Science and Technology, Korea</td>
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Geochemical reactivity in soil as a tool to derive local and national soil standards for crop protection
Abstract

Geochemical reactivity in soil as a tool to derive local and national soil standards for crop protection

Paul Römkens, Guo, Horng-Yuh, Sonia Rodrigues

Paul Römkens (Alterra, Wageningen-UR, the Netherlands, paul.romkens@wur.nl), Guo, Horng-Yuh (TARI, Taichung, Taiwan) & Sonia Rodrigues (University of Aveiro, Portugal)

Levels of various metallic contaminants in soil have increased due to emission from industry, agriculture and traffic. Especially near urban and/or industrialized areas in both developed and developing countries levels of metals like lead (Pb), cadmium (Cd) or mercury (Hg) have increased to such an extent that the transfer from soil to crop can lead to levels in crops that can pose risks for both human and animal health. To protect both humans and animals from excess exposure to such elements soil quality criteria are needed that consider both the chemical availability in the soil as well as the potential transfer to crops and (drinking) water. Till now most soil standards do not consider either the geochemical differences between soils as reflected by differences in soil type nor the uptake by important food and feed crops. Here we propose a set of soil extracts that are able to describe the potential and actual availability of metals in soil. The results from these extracts can be used to link the levels of metals in the soil to that in the water and food crops. Based on such data models are calibrated and used to derive meaningful protection standards. Examples presented include improved local standards for lead in urban gardens across the EU and improved soil quality guidelines for rice (paddy).

The major advantage of the set of extracts proposed here is that they are easy to perform and results from various studies in both the EU and Asia seem to indicate a generic validity of the model concept for metals including Cd, Pb, and Hg. This can facilitate the harmonization of the derivation of soil standards in various parts of the world.
Geochemical reactivity in soil as a tool to derive local and national soil standards for crop protection

Paul Römkens, Alterra WUR, the Netherlands
Guo, Horng-Yuh, TARI, Taichung, Taiwan
Sonia Rodrigues, University of Aveiro, Portugal

Outline

- Why “reactivity” in risk assessment?
- The concept: data – methods – models
- Applications, from local to (inter)national scale
Reactivity – Availability & Risk Assessment

Main concept:

- Total metal content is not related to risk
- Risk in this concept includes uptake by crops/organisms, leaching to water, and human exposure
- A combination of single chemical extracts can mimic potential and actual availability
- Models can be calibrated using such extract data
- Such models can serve as tool to derive improved soil standards

I. Reactivity: the concept

TOTAL Metal Content in Soil

Inert or non-reactive pool

Reactive Pool

Available Pool
I. Reactivity: its meaning

- Inert or non-reactive pool
  - Crystal matrix (clays/minerals)
  - Chemically not reactive
  - Biologically not available

- Reactive Pool
  - Adsorbed (clay/SOM/Fe-Al)/precipitates
  - Chemically reactive/bioaccessible
  - Biologically potentially available

- Available Pool
  - In solution
  - Chemically very reactive
  - Biologically available (speciation!)

I. Reactivity: how to measure it?

- Inert or non-reactive pool

- Reactive Pool
  - Strong acid: HF (Aqua Regia)
  - Dilute acid: 0.1 M HCl, 0.43 M HNO₃
  - Salt: 0.01 M CaCl₂

- Available Pool
I. Reactivity: how to model it?

- From Partition Models to Mechanistic Modelling

I. Application of partition model

Transfer functions for solid-solution partitioning of cadmium, copper, nickel, lead and zinc in soils: derivation of relationships for free metal ion activities and validation with independent data

I. Application of partition & mechanistic model

Evaluation of the performance and limitations of empirical partition-relations and process based multi-interface models to predict trace element solubility in soils

I. Application of concept of reactivity

HNO$_3$ based reactivity for Cd, Pb and Zn paddy soils $\approx$ Dutch soils!
I. Application of concept of reactivity

- Reactivity (0.43 M HNO₃) can be directly linked to human oral bioaccessibility (SBET-glycine test)

II. Derivation of Soil Quality Standards

Key: link between reactivity in soil and targets to be protected

- Uptake model → Food quality criteria
- Acceptable levels in soil
- Soil – water Transfer model → Water quality criteria
II. Derivation of Soil Quality Standards

- Further input (for agriculture) include ao:
  - Feedings patterns
  - Soil properties (nationwide): surface and profile
  - Critical limits in food & fodder, (drinking) water, ecosystem health etc

(Local)/Regional Standards

Dark = more critical!
III. Standards for Food Quality

- Impact of industrialization/urbanization on quality of food
  - Quality of home grown food in urban areas
  - Food chain modeling of metals: from stable to table
  - Derivation of sound soil guidelines considering differences in availability
  - Farm management guidelines to improve crop quality

III. Standards for Food Quality: Urban agriculture

It looks clean......
III. Standards for Food Quality: Urban agriculture

- Step 1: monitoring of quality of home grown food in urban areas:

- Celery, basil
- Rubarb
- Carrot, beet, lettuce, parsley
- Potato, zucchini, bean, onion, fruit
III. Standards for Food Quality: Urban agriculture

- Step 2. model derivation and Improved Risk Assessment

IV. Food chain modeling of metals: from stable to table

Peat areas ("Toemaak")

Kempen (industrial)

Limburg (geogenous/industrial)
IV. Food chain modeling of metals: from stable to table

- Kidney food quality standards are exceeded (human consumption)
IV. Food chain modeling of metals: from stable to table

Intake by cows

Accumulation in organs: experimental

Accumulation in organs: field
IV. Food chain modeling of metals: from stable to table

Predicted Cadmium levels in kidneys of cows (6 yr)

Conclusion: Cd quality standards organ meat are not met

- Exposure assessment of entire population

pH 4.5 – 2 ppm Cd in soil

NL - average
Food Safety Issues: Rice

Asia: rice fields next to industry/highway/cities
Is it safe to eat and sell the rice?

But its not all bad: The best Asian Food!
Or: use concept of geochemical reactivity

- Approach
  - Determine reactivity and availability
  - Derive relationship between availability and uptake
  - Use soil-solution-plant model to improve soil standards
  - Use soil-solution-plant model to design land management and farming options

Model development: soil to rice transfer model for Cd

Model:
\[ Cd_{\text{rice}} = f(\text{pH}, \text{CEC}, Cd) \]

Or
\[ Cd_{\text{rice}} = f(\text{Cd & Zn in 0.01 M CaCl}_2) \]
Model development

- Interesting observations:
  - Cadmium uptake is related to CaCl₂ extractable Cd
  - Uptake is related to availability under aerobic conditions
  - Water management can be used as a tool to reduce Cd uptake
  - Uptake by root by Indica (accumulator) and Japonica (normal) is similar, internal transport in plant is different
  - Soil management will have a similar effect on both species

Results: proposed new national Monitoring Values

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Note that the current standard is 5 which means it is not protective for most soils!
### Farmers options to deal with pollution

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<tr>
<th>Management options</th>
<th>Cd-soil</th>
<th>Soil management options</th>
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<tbody>
<tr>
<td>Change rice cultivar (0.5 – 2 ppm)</td>
<td>0.5</td>
<td>Manage the soil (liming)</td>
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<td>Change type of crop (&gt; 2-3 ppm)</td>
<td>1</td>
<td>Washing with iron(II)chlorine</td>
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<td>Change land use (&gt; 3 ppm)</td>
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<td>Water management (period of drainage)</td>
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<td>5</td>
<td>Use crops to remove metals from soil (extraction)</td>
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<td>Deep plowing</td>
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<td>Clean soil (acid washing, replace by clean soil)</td>
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### Acknowledgements

- Chih-Min Chiang, TARI – ROC
- Prof. Eduarda Pereira, Univ. Aveiro
- René Rietra, Alterra
- Bert-Jan Groenenberg, Alterra
- Jihyog Yoo, RDA Korea
- Piet Otte & Frank Swartjes RIVM
- And many others......