

New solutions to soil pollution and distribution, bioavailability and management of heavy metals



THE ASIAN ECONOMY HAS BEEN GROWING FAST IN RECENT DECADES, and environmental stresses are building up rapidly along the way. Most alarming is the increasing contamination of heavy metals in soils due to rapid industrialization, urbanization and intensive agriculture in the region. Soil, which is the landscape for the ecosystem and the basic resource for food production, is now threatened by 'soil pollution,' which has no obvious warning signs, and so has been growing unnoticed in many fields in Asian countries.

Along with industrial expansion, arable lands have been gradually degraded or contaminated with heavy metals and organic pollutants in most Asian countries. In the past two decades, this trend became more evident, significantly aggravating the quality of soils and crops as the concentration of pollutants continue to increase. Consequently, this brings about great risks to human health and the deterioration of environmental quality.

There is also a growing public concern in the region over the detection of heavy metal uptake by crops which affect food quality and safety. With the opening up of the rice market, changing land use from paddy soils into non-waterlogged cropping system has posed some problems on soil properties and soil systems. Some irrigation water for rice production in the region are contaminated by illegal discharges of waste from industrial parks or livestock wastewater and has affected the paddy soil qualities and food safety by heavy metals.

The concern over soil contamination stems primarily from health risks, both of direct contact and from secondary contamination of water supplies. In some developed countries where the extent of contaminated land is most well known, having a legal framework to identify and deal with this environmental problem has become a requisite. This however may well be just the tip of the iceberg, with developing countries very likely to be the next generation of new soil contamination cases.

Soil pollution trends in Asia

FFTC collaborated with the East and Southeast Asian Federation of Soil Sciences (ESAFS) in the conduct of the 8th ESAFS Conference held in Tsukuba, Japan in October 2007. About 300 soil scientists in east and southeast Asian countries attended the conference, where FFTC sponsored a special session to bring into the mainstream recent trends and issues on *New Solutions to Soil Pollution and Distribution, Bioavailability and Management of Heavy Metals*. The special session was intended to collect reliable data and useful information to develop methodologies to rehabilitate arable lands that have been gradually degraded or contaminated with heavy metals and organic pollutants in most Asian countries, toward the promotion of safe food production in the region.

In Taiwan, more than 90 percent of potential contaminated areas of rural soils are produced by wastewater. The government's biggest challenge was the Cd pollution in brown rice in 1988. More than 300 ha of rural soils in central Taiwan were also found to be contaminated by multiple elements (Cu, Cr, Ni, Pb, and Zn) discharged from wastewater of illegal plants in the area. In Japan, a soil survey of heavy metals by its environment agency yielded Cu, Zn, Cd, Pb, Cr, Mn, Ni, and As in arable land and forest soil in 1978-1982. Soil samples were collected from 687 sites, and the results obtained from this survey were used to determine the natural abundance level of heavy metals in cultivated soils in the country. In Korea, an extensive monitoring project of heavy metals distribution in soils and crops was conducted in the last few years, revealing concentrations of Cd, Cu, Pb and Zn in paddy soils mostly below the threshold levels of arable land pollution, but without an evident anthropogenic source of contaminants.



Closed mine as source of heavy metal contamination in paddy soil in Korea.

In eastern Asia, a complete database of soil-crop inventory of heavy metals have been developed in the last two decades. From national monitoring and study programs, the relationships between heavy metals concentration in rice and other crops, as well as heavy metals concentration in soils to evaluate food safety have been established.

The recent widespread awareness of the extent of soil pollution and its health risks has led most developed countries in the region to establish guidelines and strict rules on legal liability for soil contamination. In 2000, Taiwan's Environmental Protection Administration (EPA) declared the Soil and Groundwater Pollution and Remediation Act, as well as the regulation of most inorganic and organic pollutants for rural soils and non-rural soils including industrial parks. In 2003, the Soil Contamination Countermeasure Law was enforced in Japan to protect public health and establish measures to prevent human health hazard caused by the contaminated soil.

Strategies for monitoring and remediation

Many soil remediation techniques have been developed and applied in the field scale of

contaminated sites of rural soils, including excavation, attenuation by mixing, chemical stabilization, soil washing, phytoremediation, and thermal desorption. The most popular remediation techniques used in Asia, as well as new strategies for monitoring of soil quality and food safety for human health, are as follows:

Dilution technique. If the heavy metal concentration is lower in the subsurface soil than that in the surface soil, deep plowing and consequently mixing the two layers can significantly decrease the metal levels to meet pollutant regulation.

Chemical stabilization or chemical washing techniques. This technique involves the application of chemical amendments to decrease the mobility or solubility of metals in the contaminated paddy soil and thus decrease the metal uptake of plants.

Phytoremediation. This consists of depolluting contaminated soils with plants able to contain, degrade or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants, from the media that contain them.

New aspects and strategies of soil remediation. Some fundamental principles in the

development of remediation strategies in developed countries include: precautionary principle; risk-based philosophy for identifying, prioritizing and assessing the need for remedial action; necessity to prevent future pollution; and 'polluter pays' principle, with a mechanism for helping innocent landowners.

Threat to food quality and safety

Food safety is a basic need for any population, yet people hear warnings of hidden dangers on the dining table — of unsafe rice and poisoned vegetables. Via the food chain, harmful substances from the soils find their way into the crops and into humans, where they can cause a variety of illnesses. Hence, soil pollution is now receiving the kind of attention once only accorded to air and water pollution

Rice is the staple food in most Asian countries, but many paddy soils are now contaminated by illegal discharges of waste water from local factories. Results from field studies in Taiwan showed that rice variety and soil Cd concentration are major factors affecting edible rice safety, with the Indica type rice absorbing significantly more Cd from contaminated soil than Japonica type. In Korea, previous studies have shown that metal contents in rice grown nearby abandoned mines are higher than those in unpolluted areas. Among various anthropogenic sources for soil pollution, heavy metals from mining activities are known to be the major contributors to accumulated metals in crops in the country. In China, an estimated 12 million tons of grain are contaminated by heavy metals every year, causing direct losses of 20 billion yuan (US\$2.57 billion).

Of all the elements, the most important to consider in terms of food-chain contamination are arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb) and selenium (Se). The propensity for plants to accumulate and translocate these contaminants to edible and harvested parts depends largely on soil and climatic factors, plant genotype and agronomic management.

Excessive human intake of Cd is of concern as this element accumulates over a lifetime in the body, with impairment of kidney function being the main adverse effect. Cadmium inputs to soil in fertilizer, biosolids, soil amendments, and atmospheric deposition often exceed outputs in crops and drainage waters, so that Cd concentrations in many agricultural soils are slowly increasing. However, evidence for increases in Cd concentrations in crops over time is contentious, as is the evidence for human health problems due to low-level Cd contamination of the food chain. Adverse health effects due to Cd intake have been manifested only in situations of gross soil contamination, with a predominantly rice-based diet, where soil-plant and plant-human transfer of Cd would have been enhanced.



Photos courtesy of H.Y. Guo, TARI, Taiwan ROC.



Field sampling of rice for heavy metals detection: (from left) field sample collection; plant tissue cutting for treatment; fresh sample treatment.



**Soil chemical conditioner/
reversing
remediation
technology for Cd-
contaminated paddy
soil in Korea.**

Recommendations and future prospects

Rapid urbanization and industrialization makes soil pollution an inevitable problem and a big challenge to scientists and environmental policy makers. For healthy and sustainable future generations, the soil resource should be protected against a slow and insidious poisoning by heavy metals released from mining, industrial, and agricultural activities. While there are lots of available literatures on soil pollution, the guidelines established by individual

countries worldwide to control the pollution of agricultural soils are not consistent and standardized. This points to the complexity of heavy metal behavior in agro-environmental system, the various climatic, geologic, and hydrological conditions in different countries, and the political and nonscientific factors affecting the establishment of regulations.

Site-specific and health-based risk assessments are deemed to be the most reliable

**Participants of the ESAFS
conference during the field
observation tour in Shizuoka
and Aichi prefectures, Japan.**



and practical approaches in resolving the problem of soil pollution. More scientific evidence from case-specific research, especially from long-term field trials involving all kinds of key conditions and factors are necessary to understand the bioavailability of heavy metals in various soil types after long periods of time and to provide reliable parameters for health-based risk assessments.

Lastly, the collection of reliable data on heavy metal concentrations in soils and crops in various Asian countries must be given utmost importance. From this database, a variety of useful information and methodologies can be developed toward achieving the ultimate goal of providing safe and quality foods to the people of the region.

8th East and Southeast Asia Federation of Soil Science Societies (ESAFS) Conference: Special Session on "New solutions to Soil Pollution and Distribution, Bioavailability and Management of Heavy Metals"

Held at the Tsukuba International Conference Hall, Tsukuba, Japan, October 22-26, 2007

No. of participants: about 300 soil scientists from east and southeast Asian countries

No. of FFTC-sponsored participants/papers presented: 9 (from Korea, Japan, Malaysia, Philippines, Taiwan ROC, Thailand)

Co-sponsors: National Institute for Agro-Environmental Sciences (NIAES), Japan; East and Southeast Asia Federation of Soil Science Societies (ESAFS), Japan

List of FFTC-sponsored papers

1. New aspects of collaborative research on the soil pollution, food safety and soil remediation techniques in Asia
- Zueng-Sang Chen, National Taiwan University (NTU), Taiwan ROC
2. Heavy metal pollution, risk assessment and remediation in paddy soil environment: research experiences and perspectives in Korea
- Jae E. Yang, Kangwon National University, Korea
3. Heavy metal pollution of soil and a new approach to its remediation: research experiences in Japan
- Tomoyuki Makino, NIAES, Japan
4. Development of soil-crop inventory on heavy metals in Japan
- Makoto Nakai, NIAES, Japan
5. Bioavailability and safety issues of heavy metals in paddy soil-rice continuum in Korea
- Won-Il Kim, National Institute of Agricultural Science and Technology (NIAS), RDA, Korea
6. Prediction of heavy metals uptake by different rice species in paddy soils near contaminated sites of Taiwan
- Horng-Yuh Guo, Agricultural Research Institute (ARI), Taiwan ROC
7. A review on heavy metals contamination of crops and agriculture soils of peninsular Malaysia
- Zulkefli Malik, Malaysian Agricultural Research and Development Institute (MARDI), Malaysia
8. Cadmium contamination in paddy soil and rice grain in Mae Tao Creek, Thailand
- Orathai Sukreeyapongse, Land Development Department, Thailand
9. Heavy metals monitoring initiatives in Camarines Sur, Philippines
- Fe B. Perlas, Camarines Sur State Agricultural College, Philippines

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