2010 Taipei International Conference on the Investigation, Remediation and Management of Soil and Groundwater Contaminated Sites

Preface

Year 2010 is the tenth anniversary of the “Soil and Groundwater Pollution Remediation Act” promulgation in Taiwan. To celebrate this great achievement, Taiwan Association of Soil and Groundwater Environmental Protection, and Environment Protection Administration R.O.C., organized this conference for academic exchange and advanced concepts and technologies promotion, in the field of soil and groundwater remediation and management.

This conference proceeding is contributed by many distinguished specialists from different countries, including the United States, Canada, the United Kingdom, Australia, Japan, Korea, China, and Taiwan.

We would like to thank all the authors and participants who dedicated their enthusiasm, time and expertise, and that renders this conference successful.

Chen Wuing Liu

Chen-Wuing Liu,
Chairman of TASGEP

Table of Content

OPENING GENERAL SESSION

SESSION A - AGRICULTURAL LAND CONTAMINATION

SESSION B - ADVANCED REMEDIATION TECHNOLOGY

SESSION C - SUSTAINABLE MANAGEMENT OF SOIL, GROUNDWATER, AND SEDIMENTS

SESSION D - BROWNFIELD MANAGEMENT AND HEALTH RISK ASSESSMENT

Current Status and Future Policies of Managing Contaminated Soil and Groundwater in Taiwan

Hung-Teh, Tsai[1]

1.The Executive Secretary of EPA Soil and Groundwater Pollution Remediation Fund Management Board

Keywords: Soil and Groundwater Pollution, Administrative policy

Prevention of water, air, solid waste and hazardous material contamination had been the priority in environmental protection in Taiwan. With the development of the economy, the living condition in Taiwan had been deteriorating. Being the ultimate receptor in the environment, soil and groundwater pollution problem had started to gain notice. As a result, Soil and Groundwater Pollution Remediation Act (SGPRA) was enacted in February 2, 2000. Since then, soil and groundwater contamination investigation and remediation work had officially been put into actions.

During the initial phase, all the emphasis was on revising SGPRA and other related administrative policies, improving the collection of Soil and Groundwater Pollution Remediation Fees process, speeding up the investigation of high contamination potential sites, promulgating contaminated site management and remediation, publishing remediation technology guidelines, strengthen professional abilities. The execution of contamination management was first targeted on farmlands, gas stations and large storage tanks with at least 10-year old, abandoned factories, illegal dumping sites, military facilities, landfill sites, and operating factories which manufacturing process involved with lead and/or chlorinated compounds. Within the last 10 years, 2465 contaminated sites with a total area of 1423.8 hectares had been discovered. Out of which, 1615 sites (454.3 hectares) had been corrected and the rest of the 850 sites (969.5 hectares) are still in the process of being corrected. On average, 274 contaminated sites have been discovered and 179 contaminated sites had been delisted each year. Current status of contaminated sites in Taiwan is summarized in the following table.

Table Summary of Current Status of Contaminated Sites in Taiwan

Site Status	Total Discovered Sites		Sites Being Corrected		Sites Need to Be Corrected	
Site Type	**Number**	**Area (Hectare)**	**Number**	**Area (Hectare)**	**Number**	**Area (Hectare)**
Farmland	2,099	476.5	1,509	356.0	590	120.6
Gas Station	129	21.4	39	8.1	90	13.3
Storage Tanks	15	211.9	5	34.0	10	177.9
Factories	162	615.6	53	51.9	109	563.6
Illegal Dumping Sites	17	16.6	1	3.0	16	13.6
Other	43	81.9	8	1.3	35	80.5
Subtotal	2,465	1,423.8	1,615	454.3	850	969.5

After 10 years of conducting soil and groundwater pollution remediation, future policies and structures on contaminated site management are shown below.

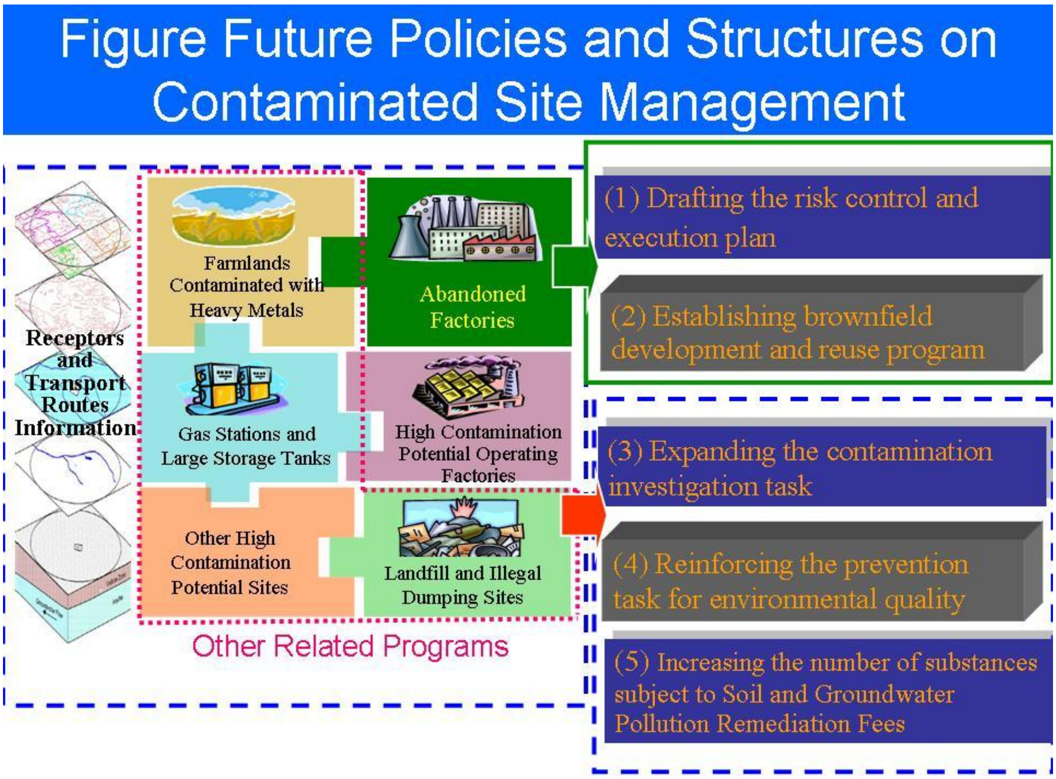


Figure Future Policies and Structures on Contaminated Site Management

Overall, it includes the following:

1. **Drafting the risk control and execution plan:** Following the trends of other advanced countries, the concept of risk assessment will be introduced into the SGPRA. Local and site-specific parameters, tier-assessment process, review and approval process, risk management, risk communication, public

involvement, expert agent system will be established. In addition, results from all the studies and sources will be combined to establish an environmental risk assessment and management system in order to reach the goal of sustainable land use.

2. **Establishing brownfield redevelopment and reuse program:** Brownfield redevelopment and reuse program and other related loaning, incentive, or subsidizing supplementary programs will be established in order to attract private investors/developers to conduct contaminated site cleanup and remediation. This will increase the local employment rate, land usage and government tax income. It also serves the purpose of contamination remediation, local development and protection of environment and human health. Currently, two contaminated sites located in Ruifang (瑞芳), Taipei County and Dapingding (大坪頂), Kaohsiung County have been selected as brownfield redevelopment and reuse demonstration sites.

3. **Expanding the contamination investigation task:** It is expecting to complete the preliminary contamination investigation for all the abandoned factories, illegal dumping sites and gas stations in the country within four years. The investigation also will be conducted at high contamination potential sites, including factories in operations, airports, and military facilities.

4. **Reinforcing the prevention task for environmental quality:** Sediment qualities will be monitored and controlled. The obligation of environmental quality management will be spreading to the management levels of all industries. A color-coded warning/management system will be implemented for all industrial districts. Voluntary soil investigation actions and environmental insurance program will be promulgated. At the mean time, geographic information system (GIS) database will be highly utilized to develop a country-wide land contamination risk map. This does not only serve the purpose of contamination prevention, it also can serve as the basis of future land management.

5. **Increasing the number of substances subject to Soil and Groundwater Pollution Remediation Fees:** Coal, iron and other waste material will be included and subject to Soil and Groundwater Pollution Remediation Fees in order to improve current fee collection situation. The Soil and Groundwater Pollution Fund is anticipated to grow up to 30 billion

Taiwanese Dollars in 15 years and this fund will be used for future site investigation and remediation activities.

Since soil, groundwater and sediment remediation work is extensive, we’ll continue to learn and pass on our valuable experiences. Furthermore, we anticipate to reach the goal of ensuring sustainable land and groundwater use, improving our living environment and protecting human health.

Regulation of Brownfield Sites in the UK Using a Sustainable Risk Based Approach

J D, Atkinson[1]

1.Environment Agency, Orchard House, Addington, Kent, UK, ME19 5SH

Keywords: Brownfield; regulation; risk assessment; sustainable

Regulation of Brownfield sites has had a rapidly changing history over the past 20 years. Initial response to some significant contaminated sites led to legislation and regulations in the USA and Europe, that addressed clean-up based on standards that were related to empirical standards, current analytical techniques or external drivers from other process regulation. However this soon led to difficulties in countries who took the early steps, for instance the initial Dutch approach of cleaning up contamination to a clean standard for any type of land after use was soon found to be extremely costly and unsustainable. Dutch standards (1) were subsequently amended for historic contamination. (See Appendix A for weblink to Dutch guide on soils[1]). The approach adopted in the UK is based on standards related to proposed after use. This risk based approach has been further developed in the UK as remediation activities have moved on from the traditional dig and dump approach to more innovative technologies off-site, or on-site and in-situ treatments. The European Union(EU) Landfill Directive (2) effectively banned direct dig and dump, requiring pre-treatment of all wastes. (see Appendix A weblink[2])This coupled with technology development has led to remediation techniques for treating contaminated materials either in off-site locations with subsequent landfill disposal or on-site on large dedicated areas as a more cost-effective approach. An early large scale example of this approach was adopted for the London 2012 Olympics site.

Initially in the UK national regulations based on the first EU Waste Framework Directive (3) made many of the early in-situ applications or off-site treatment somewhat difficult and bureaucratic. However taking a Modern Regulation view and working with the Remediation Industry to develop a more effective approach to remediation, has allowed further technology development alongside protocols and regulations that are more sustainable in their application.

Risk-based Regulation stands or falls on a clear understanding of the site history, proposed site use and environmental setting. Developing a clear Conceptual Site Model (CSM), alongside a clear understanding of relevant standards, specific site requirements and certainty of use is critical. This allows the application of the most suitable package of treatment options to address site risks posed to the wider environment or human health, while remaining sustainable in the context of wider potential environmental impacts and remaining cost-effective. Remediation options appraisal must now look at the wider environmental impacts of particular techniques, for instance, the carbon footprint of miles travelled to disposal facilities as opposed to re-use of materials on-site following suitable treatment. This approach has led to the requirement to develop further the initial regulatory framework available to cover these remediation activities and facilities.

Excavated contaminated materials from historically contaminated sites or sites impacted by pollution incidents are considered wastes in most instances, under the EU Waste Framework Directive, therefore the subsequent treatment falls under the Environmental Permitting regime. Initially this meant the site had to designated as a waste site and permitted accordingly with the associated fees and charges required by this regime. This was deemed unacceptable by the construction and development industry because of concerns related to property blight and the additional charges and time delays imposed by the regime. A more flexible system was sought using mobile waste plant permits, which allowed the treatment activity to be permitted for a short period on any particular site. Once complete the plant was removed from the site and the permitted activity closed out. Providing the wider context of clean-up standards was set by the planning permission for the site development, this approach seemed to work well. Initially all plant was regulated under separate permits, meaning an operator had to hold several licences for kit deployed at different project sites. Subsequent experience in the regulatory framework allowed amendment of this to cover the operator under one permit and the actual use of plant and equipment was then covered by a deployment form for each individual project site. This cut down permit costs and gave a more standardised approach to the permit. The use of a conceptual site model approach for the treatment activities also allowed a risk based approach to be taken to the level of monitoring for emissions required at one site. This could be detailed in the deployment form. (see appendix A for weblink[3] to guidance).

This “lighter touch” regulatory approach has now been taken further by the development of a Code of Practice for the re-use of excavated contaminated materials that are deemed suitable for a particular site, without using the context of waste permits. This code of Practice, developed with Industry and under the steerage of the UK NGO; Contaminated Land: Applications in Real Environments (CLAiRE), (see Appendix A for weblink[4]), has allowed the UK Environment Agency to further reduce the regulatory burden on business, a key concept in the UK, while still ensuring environmental protection. This risk based approach is now accepted as best practice across the UK, especially important in these financially constrained times.

The wider context of environmental impacts has led to an increasingly closer assessment of the carbon accounting of remediation and although the primary focus remains the clean-up of contamination to reduce the environmental and human health impacts of Brownfield sites, the wider environmental costs must be determined as part of the cost calculations. This alongside the standards set for clean-up under the Planning regime in the UK, aligned to a clear understanding of the Conceptual Site Model for any particular site, has allowed for a clearer, focussed, sustainable approach to remediation. This approach backed by a modern regulation system, which works with industry to face up to the challenges posed by historic contamination, allows the most cost-effective approach to be taken on any specific Brownfield site. This wider context has been recognised by the Brownfield Briefing Remediation Innovation Awards in 2010 by a new award “Best low carbon remediation technique”. (see Appendix A for weblink[5])

The key message is to be risk based and flexible in allowing innovation in both technology and regulation to allow for cost-effective and sustainable remediation of contaminated sites.

References

1.Dutch Standards – Dutch Soil Protection Act 1987

2.Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste

3.Council Directive 75/442/EEC of 15 July 1975 Waste Framework Directive

Appendix A:

1. http://international.vrom.nl/docs/internationaal/Into%20Dutch%20Soils.pdf
2. http://ec.europa.eu/environment/waste/index.htm
3. http://www.environment-agency.gov.uk/business/topics/permitting/36112.aspx
4. http://www.claire.co.uk/index.php?option=com_content&view=article&id=210&Itemid=82
5. http://www.brownfieldbriefing.com/home

Soil Contamination and Soil Management: Bioavailability as the Key to Soil Quality Standards for Agriculture

P.F.A.M. Römkens[1], H.Y. Guo[2] and C.M. Chiang[3]

1.Alterra, Wageningen UR. PO Box 47, 6700 AA Wageningen, the Netherlands, Paul.Romkens@wur.nl

2.TARI - Taiwan Agricultural Research Institute, Wufong, Taichung 41301 Taiwan, HYGuo@tari.gov.tw

3.TARI - Taiwan Agricultural Research Institute, Wufong, Taichung 41301 Taiwan, CMChiang@tari.gov.tw

Keywords: soil pollution, risk assessment, soil standards, bioavailability, rice, cadmium

Soil pollution has an increasing impact on human health and environmental quality. Increased emissions from industry, traffic ánd agriculture during the last decades to soil and water have resulted in increased contaminant levels in soils and surface waters. Especially in industrialized areas near urban areas, this has resulted in a clear increase of substances like cadmium (Cd), lead (Pb), and organic contaminants including PAH's in soil including soils used for agriculture. Research across Asia as well as urbanized areas in Europe like the Netherlands, the UK and Germany has confirmed that the quality of food is affected by this increase in contaminant levels in soil (Römkens et al., 2009). Due to uptake of contaminants from soil by crops, exposure of both human beings and animals raised for consumption has increased. This transfer pathway from soil into (food and fodder) crops and animal products thus significantly contributes to the exposure of people (Franz et al., 2008).

To limit exposure to contaminants through intake of food, quality standards for arable crops are in place. In most countries WHO standards are used as a guideline for baseline quality of food. Despite the fact that such guidelines exist, there is an apparent gap between food quality standards and soil testing levels. Research performed in Taiwan as well as the Netherlands for example demonstrates that although the soil meets the criteria for Cd in soil, the crops grown on such fields does not meet the standards for food (Römkens et al., 2009) as is illustrated in figure 1 for rice grown in paddy fields in Central Taiwan.

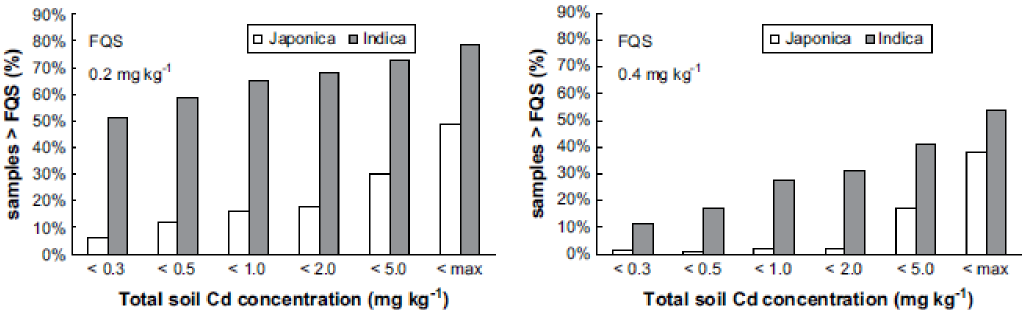


Figure 1.1 Percentage of samples where Cd concentration in rice grains exceeds the food quality standard of 0.2 mg kg $^{-1}$ (left) or 0.4 mg kg $^{-1}$ (right) at a certain Cd content in soil (X-axis). *Source: Römkens et al. (2009)*

Data in figure 1.1 show that up to 75%of all samples collected from soils that contained less than 5 mg kg^{-1} Cd (current limit for soils in Taiwan) exceed the 0.2 mg kg^{-1} food quality standard. This clearly shows that soil standards based on the total metal content are not able to safeguard the quality of food. Such observations have been made in the Netherlands as well which shows that this issue is not limited to specific soils or climatic regions. One of the solutions that are currently studied or even applied (NL, UK) is to consider the (bio)availability of contaminants in soil and use scientific concepts to derive better soil quality standards (Brand et al., 2009). Obviously soil standards to be used in the field should be rather easy to apply or measure which clearly limits the use of complicated methodologies or extraction techniques. Nevertheless it is imperative to consider several important soil properties that control the availability of contaminants since the uptake pattern of metals like Cd is very different in different types of soil (for example sandy soil vs. clay soils).

Current research in various countries in the EU and Asia have shown that for Cd, rather uniform predictive models can be derived that are able to predict the availability of Cd in soil ánd uptake by crops (e.g. Simmons et al., 2008; François et al., 2009; Rodriguez et al., 2010).

Obviously such approaches always have to consider climatic and geographical aspects that affect the soil to plant transfer pathway. Using the recently develop soil to plant transfer models using data from Taiwan (Römkens et al., 2009) that consider differences in soil type and soil pH, improved standards for Japonica and Indica cultivars were derived as is shown in table 1.1

Table 1.1 Overview of soil standards (in mg kg^{-1}) based on soil type and pH. In the calculations a food quality standard of 0.4 mg kg^{-1} for Cd in rice grains was used.

	Japonica		Indica	
pH	5	7	5	7
Sandy soil	1	3	0.5	1.5
Clay soil	2	5	0.5	2

The approach used here is similar to the one used at present in the Netherlands and Germany to derive target levels for arable soils. One of the major consequences is that one single standard for all soils as has been used before is not recommended. Differences between soils on one hand and cultivars (Japonica versus Indica) on the other are such that one single standard cannot account for such differences. A potential solution for this is to use the minimum level as a *reference* (or target) soil quality level. For the rice cultivars tested here, this would be equivalent to 0.5 mg kg^{-1}. If the soil Cd content remains below this level, all cultivars can be used safely and no further testing is needed. If the soil does not meet this criterion, a second testing level is needed based on soil properties (pH and CEC) to determine which cultivars can be used safely. As such this tiered approach has been introduced in the new Dutch regulatory framework as well and allows for a step-by-step assessment of soil quality. Since Taiwan has an excellent soil monitoring network, this secondary level information is available in most areas.

References

Brand, E., Peijnenburg, W. Groenenberg, J.E. Vink, J. Lijzen, J. ten Hulscher, D., Jonker, C. Römkens P.F.A.M. and Roex, E. (2009). Towards implementation of bioavailability mesaurements in the Dutch regulatory framework. RIVM report 711701084/2009, RIVM, Bilthoven, the Netherlands, 80 pp.

François, M., Grant, C., Lambert, R. and Sauvé, S. (2009). Prediction of cadmium and zinc concentration in wheat grain from soils affected by the application of phosphate fertilizers varying in Cd concentration. *Nutr Cycl Agroecosyst* **83**:125–133.

Franz, E., Römkens, P.F.A.M., van Raamsdonk, V and van der Fels-Klerx, I. (2008) A chain modeling approach to estimate the impact of soil cadmium pollution on human dietary exposure. *J. Food Prot.*, **71**(12):2504-2513.

Rodrigues, S.M., Henriques, B. Ferreira da Silva, E. Pereira, M.E. Duarte, A.C. and Römkens, P.F.A.M. (2010). Evaluation of an approach for the characterization of reactive and available pools of twenty potentially toxic elements in soils: Part I – The role of key soil properties in the variation of contaminants' reactivity. *Chemosphere*, doi:10.1016/j.chemosphere.2010.07.026.d

Römkens, P.F.A.M, Koopmans, G.F., Guo, H.Y., Chu, C.L., Liu, T.S. and C.F. Chiang (2009) Prediction of Cadmium uptake by brown rice and derivation of soil–plant transfer models to improve soil protection guidelines. *Environ. Pol.*, 157:2435–2444

Simmons, R.W., Noble, A.D., Pongsakul, P., Sukreeyapongse, O., and Chinabut, N. (2008) Analysis of field-moist Cd contaminated paddy soils during rice grain fill allows reliable prediction of grain Cd levels. *Plant and Soil* **302**, 125-137

The Long Term Monitoring of Heavy Metal Concentrations in Farmland Soils and Its Use for Farmland Management

K. Kohyama[1]

1.Natural Resources Inventory Center, National Institute for Agro-Environmental Sciences, Tsukuba 305-8604 Japan, kohyama@affrc.go.jp

Keywords: soil monitoring; farmland management; heavy metals

In Japan, soil survey in farmland (Soil survey program for the maintenance of farmland fertility) has been done in late 1970s and made 1:50,000 soil maps were compiled. Farmland was evaluated based on the soil properties to improve its productivity. While “Impediment”, which includes physical impediment such as existence of gravel layer and existence of harmful substances such as heavy metal pollution, is one of the factors to evaluate the land, heavy metal pollution was not reflected to the evaluation because they were not be analyzed in this program. After that, the Monitoring survey program for soil conditions started and the soil changes were monitored every 5 years in about 20,000 sites. In this program, heavy metal status (total contents and HCl soluble contents) was analyzed and information concerning heavy metals has been accumulated. The information showed periodical change of heavy metal concentration in the regions, the agricultural land uses and the soil types and became basal data of heavy metals status in farmland. The detail of monitoring data of heavy metals was not published for some reason except some prefectural governments. In this paper, two topics, that is, periodical changes of heavy metals in land use types and soil types in Japan and some management problems in viewpoint of periodical changes in Gunma prefecture, are introduced.

Periodical change of heavy metal concentration (Cu, Cd, Zn, As and Pb) in Japanese farmland soils

Total and acid soluble heavy metal concentrations in about 3,500 sites per one survey period were measured in the Monitoring survey program for soil conditions in four survey periods. These data were averaged by survey periods, land uses and soil types and were analyzed. Acid soluble Cd concentration ranged 0.2-0.4 mg kg^{-1} and the values were nearly same in survey periods, land uses and soil types. On the contrary, acid soluble Cu, Zn and As concentrations in orchard were higher than other land use (paddy, upland and grassland) (Figure 1). Periodical changes in land uses and soil types were not clear.

Periodical change of heavy metal concentration (Cu, Cd, Zn and As) in Gunma prefecture

Gunma prefecture is located in northern Kanto region and a several areas were polluted by copper and zinc mines. In the Monitoring survey program for soil conditions, Gunma prefecture measured total and acid soluble Cu, Cd, As and Zn and tallied in regions, crops and soil types. As a result, they found that acid soluble Cu, Zn in devil's tongue field and acid soluble Zn in orchard were higher than other crop fields and it was caused by application of Bordeaux mixture. To prevent from excess accumulation of Cu and Zn in the fields, they showed the new technique to decrease Bordeaux mixture application in devil's tongue cultivation or application standard for sewage sludge and composts in farmland.

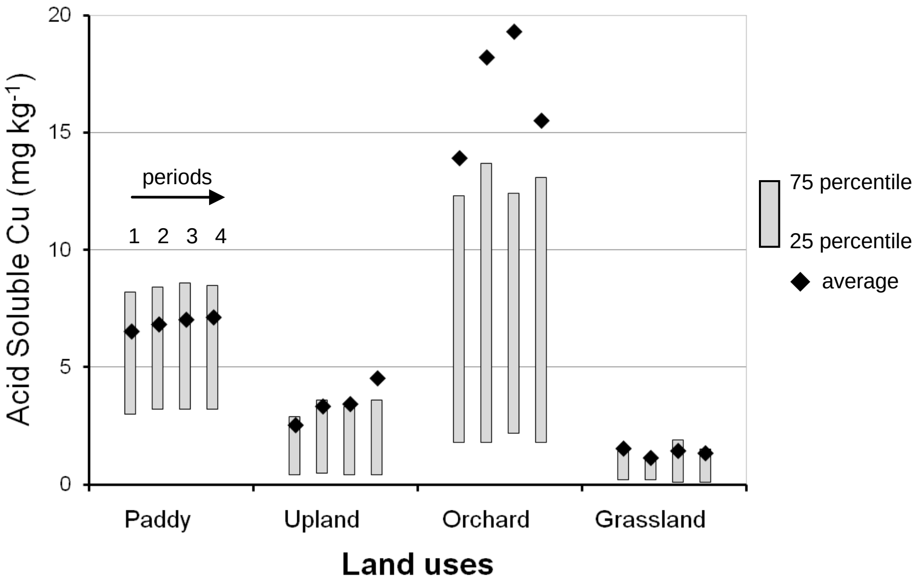


Figure 1 Periodical changes in land uses in acid soluble Cu (Agricultural Production Bureau 2008)

Reference

Agricultural Production Bureau (2008), Report for Soil Conservation Survey Program, 476-485, Ministry of Agriculture, Forestry and Fisheries (in Japanese)

Kanuma, N, Sunaga F, Saruta M and Minegishi S (2005), Concentration of Heavy Metals in Tillage Soil of Gunma Prefecture for Last Twenty years, Gunma Agric Tech Center Res. Rep, **2**, 137-144 (in Japanese with English summary)

Ebihara, T, Yamada M, Saito K and Honma M (1991), Heavy Metal Concentration in Arable Lands, Gunma Agric. Res. A, **8**, 53-62 (in Japanese with English summary)

Monitoring and Management Strategies of Agricultural Land Contamination in Korea

J.E. Yang[1], J.H. Hur[1], Y.S. Ok[1], D.J. Kim[2] and Y.H. Park[3]

1.Dept. of Biological Environment, Kangwon National University, Chuncheon 200-701, Korea (yangjay@kangwon.ac.kr)

2.Soil & Groundwater Management Division, Ministry of Environment, Gwacheon 427-729, Korea (kimdjin@korea.kr)

3.Korea Environment Institute, Seoul 122-040, Korea (yhpark@kei.re.kr)

Keywords: Soil contamination, contaminants, heavy metals, remediation, monitoring, management

This paper reviews the policies on the agricultural land contamination, monitoring of soil contamination and soil remediation technologies being practiced in Korea. In Korea, soil contamination and management are controlled by the Soil Environment Conservation Act (SECA) which was promulgated in 1995 and revised several times to protect the soil from hazardous materials. Under the act from 2009, a total of 21 soil contaminants including trace elements and organics are designated as soil contaminants (Table 1). Compared to the previous standards, metal extraction method was changed from dilute acid extraction (0.1M HCl) to total extraction (aqua regia). Also soils are further divided into three categories for an efficient pollution management. The soils in the industrial facilities such as gasoline production, hazardous chemicals production and pipeline etc are included for the special control.

Among heavy metals, Pb and Cd are set for standards for the mostly consuming agricultural products in Korea: Pb (mg/kg): cabbage, spinach (<0.3); rice, corn, soybean (<0.2); sweet potato, potato, onion, radish, carrot, garlic, leek (<0.1). Cd (mg/kg): rice, cabbage, spinach (<0.2); corn, soybean, red bean, sweet potato, potato, radish, carrot, garlic, (<0.1); leek, green onion (<0.05).

Under the SECA, the nationwide soil monitoring system is operating at 1,521 sites, of which 388 soils (25.5% of total) are related to agriculture, to determine concentrations of soil contaminants over years. In agricultural lands, heavy metal concentrations have mostly been monitored but both metals and organic contaminants have been monitored in industrial lands. In most of the agricultural lands, concentrations of contaminants have been lower than the criteria but those in industrial and abandoned mine areas have exceeded the standards. Table 2 shows the soil monitoring results for selected contaminants in average. All of monitoring results are archived in the Soil and Groundwater Information System (SGIS) and available for public via on-line service (http://sgis.nier.go.kr).

Table 1 Pollution criteria of soil contaminants designated by the SECA.

Contaminants	Threshold of Danger Level (mg/kg)			Corrective Action Level (mg/kg)		
	Region I*	Region II	Region III	Region I	Region II	Region III
Cd	4	10	60	12	30	180
Cu	150	500	2,000	450	1,500	6,000
As	25	50	200	75	150	600
Hg	4	10	20	12	30	60
Pb	200	400	700	600	1,200	2,100
Cr^{6+}	5	15	40	15	45	120
Zn	300	600	2,000	900	1,800	5,000
Ni	100	200	500	300	600	1,500
B	400	400	800	800	800	2,000
Org. P	10	10	30	-	-	-
PCB	1	4	12	3	12	36
CN	2	2	120	5	5	300
Phenol	4	4	20	10	10	50
Benzene	1	1	3	3	3	9
Toluene	20	20	60	60	60	180
Ethylbenzene	50	50	340	150	150	1,020
Xylene	15	15	45	45	45	135
TPH	500	800	2,000	2,000	2,400	6,000
TCE	8	8	40	24	24	120
PCE	4	4	25	12	12	75
Benzo(a)pyrene	0.7	2	7	2	6	21

*Regions I, II and III: agricultural, recreational and industrial soils, respectively.
Heavy metal concentrations are based on total (aqua regia) extraction.

Table 2 Average concentrations (mg/kg) of selected contaminants in monitoring sites.

Year	Total sites	Cd	Cu	As	Hg	Pb	Cr^{6+}	CN	TPH
2004	1,500	0.09	4.38	0.05	0.04	5.85	0.00	0.01	9.74
2008	1,521	0.05	3.52	0.24	0.04	4.02	0.01	0.00	16.45

The Korea Ministry of Environment (MOE) sets the remediation guideline of the contaminated soil for VOCs, SVOCs, fuels and inorganics. Remediation technologies are classified based on pollution location (unsaturated and saturated zone), excavation (in-situ and ex-situ) and principles (chemical, biological and thermal). During 2000-2006, total 434 sites were remediated with 796 remedial methods being applied, of which in-situ and ex-situ were composed of 83.3% and 16.7%, respectively. The remedial technologies being applied to the contaminated fields were in the orders of soil vapor extraction (29.6%), bioventing (27.8%), landfarming (11.2%), soil flushing (9.1%), bioslurping (7.2%), others (soil washing, air sparging, thermal desorption etc) (5.8%), chemical oxidation/reduction (4.2%), chemical extraction (2.6%) and bioremediation (2.5%). These methods are for the contaminated soils by organic contaminants such as fuels and toxic chemicals.

Soil contaminations by heavy metals in agricultural lands in Korea are mostly restricted to the abandoned/closed mines and heavy industrial areas. Due to economic and practical reasons, the remediation technologies being developed for example in the US superfund sites have not practiced in the contaminated paddy and upland fields. Thus, soil engineering practices such as soil cover, dressing, reversing of layers and removal of contaminated soil layer have been extensively used. Along with these methods, chemical amendments such as lime, steel slags, coal ash, minerals (dolomite, zeolite), composts, zero-valent iron etc. have been used to remediate the contaminated paddy and upland soils. At present through several field trials, the combined technologies of physical, chemical, phytoremediation and microbial stabilization are being developed in the metal contaminated paddy fields. These results will be introduced in the conference.

References

Ahmad, M., Lim, J.E., Yang, J.E. and Ok, Y.S. (2009) Effects of natural and calcined oyster shell on Cd and Ob immobilization in the contaminated soil. Proceedings of the 9th International Conference of ESAFS, 79-80.

Korea Ministry of Environment (2007) Guideline of the contaminated soil remediation. pp.214.

Yang, J.E., Ok, Y.S., Kim, W.I. and Lee, J.S. (2007) Heavy metal pollution, risk assessment and remediation in paddy soil environment: Research experiences and perspectives in Korea. Proceedings of the 8th conference of ESAFS. 44-49.

Identification of Hyperaccumulating Weed Species in Unpolluted Sites: Theory and Confirmation

Qixing Zhou [1, 2, *] and Shuhe Wei [2]

1.Key Laboratory of Pollution Processes and Environmental Criteria (Ministry of Education), College of Environmental Science and Engineering, Nankai University, Tianjin 300071, China

2.Key Laboratory of Terrestrial Ecological Process, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China

Keywords: hyperaccumulator; phytoremediation, weed species, unpolluted site

Phytoextraction mainly using hyperaccumulators to remove heavy metals from contaminated soils holds some promises for commercial development (Chaney et al., 1997). The four standards of screening out hyperaccumulating plants include: (1) strong accumulation capability, namely, the critical concentration in the shoots of a hyperaccumulator of As, Pb, Cu, Ni, and Co should be higher than 1,000 mg kg^{-1} dry mass, and Zn and Mn are 10,000 mg kg^{-1}, Au is 1.0 mg kg^{-1}, and Cd is 100 mg kg^{-1}, respectively, 100 folds higher than that in common plants (Baker and Brooks, 1989); (2) translocation capability, the translocation factor (TF, the concentration ratio of heavy metals in shoots to those in roots) > 1.0, namely, the concentration of a metal in the shoots of a plant should be higher than that in the roots (Chaney et al., 1997; Ma et al., 2001); (3) enrichment capability, enrichment factor (EF, the concentration ratio of a metal in a plant to that in soil) > 1.0 (Wei and Zhou, 2004; Wei et al., 2005a); and (4) tolerance capability, a hyperaccumulator should have high tolerance to the toxicity of heavy metals, and its biomass or growth under pollution stress is not decreased significantly (Wei et al., 2004; 2005b).

Though many hyperaccumulators have been documented, especially found in polluted sites, screening out more hypeaccmulators is still the key step of phytoextraction and phytoremediation. Weed species can survive under adverse conditions, which may improve their absorbing capacity to water and fertilizers. Thus, there is a possibility to identify hyperaccumulators from weed

---

[*] Corresponding author. Tel: +86-22-23507800, fax: +86-22-23501117; E-mail: Zhouqx@nankai.edu.cn; Zhouqx523@yahoo.com

species even though in unpolluted sites.

Using the pot-culture experiment spiked with 10 mg Cd kg^{-1}, we determined the characteristics of 20 weed species collected from an unpolluted site of Shenyang, China. The results showed that only the EFs and TFs of *Conyza canadensis* and *Solanum nigrum* were higher than 1.0 (Table 1). The other 18 weed species did not displayed basic Cd-hyperaccumulative characteristics. However, the further Cd concentration gradient experiment should be conducted to validate whether *C. canadensis* and *S. nigrum* were real Cd-hyperaccumulators while the concentration of Cd spiked to plot-culture soils is not very high.

Table 1 Accumulative characteristics of weed species grown in Cd contaminated soil (mg kg^{-1})*

Plant	Tissue	Cd	EF	Plant	Tissue	Cd	EF	Plant	Tissue	Cd	EF
Portulaca oleracea	Root	92.82	9.24	*Conyza canadensis*	Root	9.04	0.91	*Humulus scandens*	Root	15.78	1.56
	Shoot	13.99	1.39		Shoot	18.82	1.89		Shoot	4.78	0.47
Solanum nigrum	Root	27.76	2.76	*Cirsium pendulum*	Root	3.58	0.35	*Plantago asiatica*	Root	7.66	0.76
	Shoot	31.80	3.17		Shoot	9.22	0.91		Shoot	3.22	0.32
Chenopodium album	Root	9.61	0.95	*Rumex maritimus*	Root	8.13	0.81	*Plantago depressa*	Root	14.08	1.39
	Shoot	5.33	0.53		Shoot	1.51	0.15		Shoot	0.70	0.07
Potentilla paradoxa	Root	34.87	3.46	*Polygonum lapathifolium*	Root	31.92	3.3	*Metaplexis japonica*	Root	9.48	0.93
	Shoot	8.43	0.84		Shoot	7.83	0.81		Shoot	2.28	0.22
Oenothera biennis	Root	1.43	0.14	*Lepidium apetalum*	Root	9.70	0.96	*Xanthium sibiricum*	Root	17.70	1.75
	Shoot	0.30	0.03		Shoot	3.36	0.33		Shoot	4.24	0.42
Ranunculus chinensis	Root	23.08	2.30	*Commelina communis*	Root	5.41	0.53	*Acalypha australis*	Root	9.01	0.89
	Shoot	2.58	0.26		Shoot	0.64	0.06		Shoot	1.23	0.12
Amaranthus retroflexus	Root	12.07	1.20	*Perilla frutescens*	Root	8.45	0.83				
	Shoot	6.51	0.65		Shoot	0.31	0.03				

* Partial data were published by Wei and Zhou, 2004.

In order to confirm the validity and reliability of the pot-culture experiment, we further collected and investigated some samples of the same 23 weed species from Cd/Pb/Zn contaminated soils surrounding a Pb/Zn mining area. The results showed that all collected plants had same accumulation characteristics of Cd, such as EFs and TFs. Particularly, the concentration of Cd in the two plants was higher than 100 mg kg^{-1} what a Cd-hyperaccumulator should own. When the characteristics of these weed species accumulating Cd under pot-culture conditions were compared with those in Cd/Pb/Zn contaminated soils, the results indicated in the pot-culture experiment could basically reflect the real status in natural polluted environment.

In treatments Cd spiked with 25 and 50 mg kg^{-1}, the concentration of Cd in the stems and leaves of *S. nigrum* exceeded its critical level, up to 103.8 and 124.6 mg/kg, and 135.5 and 194.3 mg kg^{-1}, respectively (Table 3). The shoot EF values for Cd were 2.68 and 1.12, respectively, all EFs > 1.0. Furthermore, Cd accumulation in shoots was higher than that in roots, *i.e*. TF > 1.0. Thus, *S. nigrum* growing in soils artificially spiked with 25 and 50 mg kg^{-1} Cd exhibited the properties of a Cd hyperaccumulator (Baker and Brooks, 1989; Chaney *et al*., 1997). However, the concentration of Cd in stems and leaves of *C. canadensis* was lower than 100 mg kg^{-1} in all individual treatments, even though the EF value was also higher than 1.0 (Table 3). Therefore, this species cannot be considered as a Cd hyperaccumulator. It should be a Cd accumulator (Baker and Brooks, 1989; Chaney *et al*., 1997).

In the past years, most reported hyperaccumulators were identified through the sample-analyzing method in polluted sites (Visoottiviseth et al., 2002; Yang et al., 2005; Doumett et al., 2008; Sasmaz and Sasmaz, 2009). However, the botanic populations growing in polluted sites especially around metal-mining areas are often climax population whose dominant species are usually fern, shrubbery or arbor. Some disappeared indigenous plants with hyperaccumulative function, and pioneer species and middle species in community-succession processes would be overlooked,.while the sampling analysis method is used to identify hyperaccumulators from various types of plants. Noticeably, some hyperaccumulators may result from the long-term adaptation of normal plants in far-flung natural history; the other hyperaccumulators can be attributed to the mutation and short-term evolvement of accumulative genes under stress of polluted environment (Sun et al. 2008; 2009). Besides, there are some uncertain factors in the identification of plant species (Sun et al., 2010). For instance, a plant species that has been identified by a botanist is still difficult to distinguish and collect them for a researcher with other scientific background, thus resulting in an inexactitude record (Wei and Zhou, 2004; Wei et al., 2009). The results validated in this research that some hyperaccumulators can be identified from plants collected from unpolluted sites.

Table 2 Cd-accumulative characteristics of plants grown in Pb/Zn mining areas (mg kg^{-1})

Plant	Tissue	Cd	EF	Plant	Tissue	Cd	EF	Plant	Tissue	Cd	EF
P. oleracea	Root	1.52	3.53	*C. Canadensis* 1	Root	15.4	1.31	*C. Canadensis* 2	Root	3.03	1.88
	Shoot	0.28	0.65		Shoot	17.84	1.51		Shoot	3.52	2.18
C. Canadensis	Root	0.78	1.81	*C. pendulum*	Root	9.37	0.32	*H. scandens*	Root	0.41	0.16
	Shoot	1.01	2.35		Shoot	12.32	0.42		Shoot	0.34	0.14
C. album	Root	1.73	0.93	*R. maritimus*	Root	0.09	0.09	*P. asiatica*	Root	3.67	0.21
	Shoot	0.73	0.39		Shoot	0.21	0.21		Shoot	3.45	0.19
P. paradoxa	Root	4.46	0.38	*P. lapathifolium*	Root	0.41	0.11	*P. depressa*	Root	5.25	0.45
	Shoot	3.34	0.28		Shoot	0.23	0.06		Shoot	4.14	0.35
O. biennis	Root	0.88	0.05	*L. apetalum*	Root	1.06	0.25	*M. japonica*	Root	0.26	0.11
	Shoot	0.71	0.04		Shoot	0.57	0.14		Shoot	0.12	0.04
R. chinensis	Root	44.48	1.38	*C. communis*	Root	1.62	0.62	*X. sibiricum*	Root	9.25	0.56
	Shoot	5.65	0.17		Shoot	0.38	0.14		Shoot	5.06	0.31
A. retroflexus	Root	1.53	0.88	*P. frutescens*	Root	2.01	1.37	*Acalypha australis*	Root	4.12	0.80
	Shoot	0.72	0.42		Shoot	0.54	0.37		Shoot	0.85	0.16
S. nigrum 1	Root	2.11	0.87	*S. nigrum* 2	Root	95.12	3.46	*S. nigrum* 3	Root	264.38	2.37
	Shoot	5.07	2.09		Shoot	120.05	4.36		Shoot	385.25	3.45

* Partial data were published by Wei et al., 2004.

Table 3 The accumulation of Cd in *S. nigrum* and *C. canadensis* under experimental conditions (mg kg^{-1})

Plant	Treatment (mg kg^{-1})	Root	Stem	Leaf	Inflorescence	Shoot	EF	TF
S. nigrum	CK	0.1	0.4	0.5	0.2	0.3	1.00	3.00
	10	28.8	61.5	75.5	11.2	36.6	3.63	1.27
	25	59.9	103.8	124.6	23.7	67.3	2.68	1.12
	50	97.4	135.5	194.3	33.3	101.1	2.02	1.04
C. canadensis	CK	0.1	0.2	0.4	0.2	0.2	1.00	2.00
	10	13.9	29.7	44.5	18.0	27.8	2.81	2.00
	25	46.6	50.2	59.7	21.1	47.5	1.92	1.02
	50	79.0	77.9	93.4	47.5	70.4	1.39	0.89

* Partial data were published by Wei et al., 2009.

References

Baker, A.J.M. and Brooks, R.R. (1989) Terrestrial higher plants which hyperaccumulate metallic elements- a review of their distribution, ecology and phytochemistry. *Biorecovery* 1: 81-126.

Chaney, R.L., Malik, M. and Li, Y.M. (1997) Phytoremediation of soil metals. *Curr. Opin. Biotech.* 8: 279-284.

Doumett, S., Lamperi, L., Checchini, L., Azzarello, E., Mugnai, S., Mancuso, S., Petruzzelli, G. and Bubba M.D. (2008) Heavy metal distribution between contaminated soil and *Paulownia tomentosa*, in a pilot-scale assisted phytoremediation study: Influence of different complexing agents. *Chemosphere*, 72: 1481-1490.

Ma, L.Q., Komar, K.M., Tu, C., Zhang W.H., Cai, Y. and Kennelley, E.D. (2001) A fern that hyperaccumulates arsenic. *Nature* 409: 579.

Sasmaz, A. and Sasmaz, M. (2009) The phytoremediation potential for strontium of indigenous plants growing in a mining area. *Environmental and Experimental Botany*, 67: 139-144.

Sun, R.L., Jin, C.X. and Zhou, Q.X. (2010) Characteristics of cadmium accumulation and tolerance in a new-found cadmium hyperaccumulator *Rorippa globosa* (Turcz.) Thell. *Plant Growth Regulation*, 61: 67-74.

Sun, Y.B., Zhou, Q.X. and Diao, C.Y. (2008) Effects of cadmium and arsenic on growth and metal accumulation of Cd-hyperaccumulator *Solanum nigrum* L. *Bioresource Technology*, 99: 1103-1110.

Sun, Y.B., Zhou, Q.X., Liu, W.T. and Liu, R. (2009) Chelator-enhanced phytoextraction of heavy metals from contaminated soil irrigated by industrial wastewater with the hyperaccumulator plant (*Sedum alfredii* Hance). *Geoderma*, 150: 106-112.

Visoottiviseth, P., Francesconi, K. and Sridokchan, W. (2002) The potential of Thai indigenous plant species for the phytoremediation of arsenic contaminated land. *Environ. Pollut.* 118: 453.

Wei, S.H. and Zhou, Q.X. (2004) Identification of weed species with hyperaccumulative characteristics of heavy metals. *Progr. Natural Sci.* 14: 495-503.

Wei, S.H., Zhou, Q.X. and Wang, X. (2005a) Cadmium-hyperaccumulator *Solanum nigrum* L. and its accumulating characteristics. *Environ. Sci.* 26: 167-171, in Chinese.

Wei, S.H., Zhou, Q.X. Wang, X. and Cao, W. (2004) Hyperaccumulative characteristics of some weeds distributed round a Pb-Zn mining site. *Techniq. Equipm. Environm. Pollut. Contr.* 5: 33-39, in Chinese.

Wei, S.H., Zhou, Q.X., Wang, X., Zhang, K.S., Guo, G.L. and Ma, L.Q. (2005) A newly-discovered Cd-hyperaccumulator *Solanum nigrum* L. *Chin. Sci. Bullet.* 50: 33-38.

Wei, S.H., Zhou, Q.X., Saha, U.K., Xiao, H., Hu, Y.H. and Ren, L.P. (2009) Identification of a Cd accumulator *Conyza canadensis*. *J. Hazard. Materi.* 263: 32-35.

Yang, X.E., Feng, Y., He, Z.L. and Stoffella, P.J. (2005) Molecular mechanisms of heavy metal hyperaccumulation and phytoremediation. *Journal of Trace Elements in Medicine and Biology*, 18: 339-353.

Arsenic and Cadmium Contamination in Paddy Soils and Crops in Japan and Effects of Water Management on Arsenic and Cadmium Content in Rice Grain

T. Arao[1], A. Kawasaki[2], K. Baba[3], S. Matsumoto[4] and Y. Maejima[5]

1.National Institute for Agro-Environmental Sciences, Kannondai 3-1-3, Tsukuba, Ibaraki, 305-8604, Japan, arao@affrc.go.jp

2.National Institute for Agro-Environmental Sciences, Kannondai 3-1-3, Tsukuba, Ibaraki, 305-8604, Japan, akawa@affrc.go.jp

3.National Institute for Agro-Environmental Sciences, Kannondai 3-1-3, Tsukuba, Ibaraki, 305-8604, Japan, kojibaba@affrc.go.jp

4.Shimane University, 2059 Kamihonjomachi, Matsue, Shimane, 690-1102, Japan, smatsu@life.shimane-u.ac.jp

5.National Institute for Agro-Environmental Sciences, Kannondai 3-1-3, Tsukuba, Ibaraki, 305-8604, Japan, ymaeji@affrc.go.jp

Keywords: Arsenic; Cadmium; Codex Alimentarius Commission; JECFA; Pot experiments; PTWI; rice

After the first metal mine in Japan began operating in the early 8th century, metal mining became an established industry between the late 16th and early 17th centuries. However, it was not until the Meiji Era (1868–1912) when Japanese metal mines started to be run as modern businesses. Among various metals mined, there was a remarkable increase in the demand for copper (Cu) and zinc (Zn) as raw materials for general and military industries, and so the production outputs of mines increased dramatically. After the end of World War II, further demand for metals was driven by rapid economic growth in the 1960s. During this historical process, various hazardous metals were released into the environment, causing extensive soil contamination by toxic metals such as arsenic (As) and cadmium (Cd).

As is a carcinogen and the intake of inorganic As in rice is a significant risk factor for cancer in populations for which rice is a staple foodstuff. For inorganic As, a provisional tolerable weekly intake (PTWI) of 15 μg kg^{-1} body weight was established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). The Committee withdrew this PTWI at its 72nd meeting. Inorganic As causes cancer of the lung, urinary tract, and skin, and a range of adverse effects have been reported at exposures lower than those reviewed by the JECFA. Therefore, the EFSA CONTAM Panel concluded that the JECFA PTWI of 15 μg kg^{-1} body weight is no longer appropriate.

The Ministry of Agriculture, Forestry, and Fisheries of Japan analyzed the As contents of staple crops in Japan and found that As concentrations in brown rice ranged from 0.04 to 0.33 mg kg^{-1}, with an average value of 0.16 mg kg^{-1} (n = 199). Rice is therefore a major source of dietary intake of inorganic As in the Japanese population. Contamination by As occurs to a greater extent in paddy rice than in other upland crops because anaerobic conditions in paddy soil lead to As mobilization and thus enhanced. Iran had previously submitted a proposal to CODEX Committee on Contaminants in foods (CCCF) for new work on an ML for arsenic in rice. The CCCF decided to establish an electronic WG led by China to develop a discussion paper on the feasibility of establishing MLs for arsenic in rice for next year's meeting.

Although Cd is not an essential element for plants, some crops transport Cd absorbed by the roots up to the edible parts. In 1968, the relationship between Cd contamination and *itai-itai* disease was pointed out, and the Ministry of Health and Welfare revised the standards for foods and additives on the basis of the Food Sanitation Law in 1970 to regulate the Cd content in brown rice to less than 1.0 mg kg^{-1}. Recently, PTMI for Cd of 25 μg kg^{-1} bodyweight per month has been established by JECFA (2010). The weekly intake of Cd from foods in Japan in 2001 was estimated to be 4.1μg kg^{-1} body weight, and about half the Cd intake from foods was from rice. A maximum concentration of 0.4 mg kg^{-1} for Cd in white rice grain has been adopted by the Codex Alimentarius Commission. Rice is a staple crop in Asia, and is the principal source of dietary intake of Cd in the Japanese population; therefore, minimizing the intake of Cd from rice is an important health issue.

Flooding of paddy fields is effective in reducing grain levels of Cd; however, anaerobic conditions in paddy soil lead to As mobilization and, therefore, As uptake by rice could increase (Koyama, 1975, Inahara et al., 2007, Kyuma, 2004).

In the 1970s and 1980s, the mechanism of As damage to paddy rice and countermeasures for paddy rice fields were clarified by Koyama et al (1975) and Yamane (1989). Koyama et al (1975) conducted experiments with paddy rice grown in pots of As-contaminated soils and found a significant negative correlation between the yields of brown rice and the levels of 1 M HCl soluble

As in the soil. The Japanese criterion for As pollution of paddy fields was set at 15 mg kg^{-1} of 1 M HCl soluble As so that the rice yield was not reduced by more than 10%.

A part of paddy field is contaminated with As and Cd which mainly derived from waste water from mine. In 1971, “Agricultural Land Soil Contamination Prevention Law” regulated for Cd: 1mg kg^{-1} in brown rice, Cu: 125mg kg^{-1} in soil and As: 15mg kg^{-1} in soil. There were 6,945 ha of paddy soils contaminated with Cd and 6,104 ha have been already completed by soil dressing. There were 391 ha of paddy soils contaminated with As and 324 ha have been already completed by soil dressing.

Pot experiments, with three replications each, were performed in 2008. Wagner pots (1/5000 a) were filled with 3 kg of two kinds of soil collected from the plow layer of paddy fields. Soil A contained 0.56 mg kg^{-1} Cd, and 25 mg kg^{-1} As. Soil B contained 0.66 mg kg^{-1} Cd, and 48 mg kg^{-1} As. Seven water-management treatments were examined in the experiment: treatment 1 involved flooding throughout the entire growth period; treatment 2, flooding from transplanting to three weeks after heading; treatment 3, flooding from transplanting to heading; treatment 4, flooding from transplanting to three weeks before heading and from heading to three weeks after heading; treatment 5: flooding from transplanting to three weeks before heading; treatment 6, flooding from transplanting for two weeks and then from three weeks before heading to three weeks after heading; and treatment 7, flooding from transplanting for two weeks (Arao et al, 2009).

In both the soils, rice from the continuous flooding treatment 1 had the lowest Cd concentration and the highest As concentration in grain (Table 1). Rice from treatment 5 had the highest Cd concentration in grain in soil A, and rice from treatments 5 and 7 had higher Cd concentrations in grain than rice from other treatments in soil B; rice grains from treatments 5 and 7 also had the lowest As concentration in both. The As concentrations in grain were significantly different between treatment 1 and treatment 2 in both soils.

In both soils, rice grain from treatment 6, where flooded condition existed between 3 weeks before heading and 3 weeks after heading, had a higher concentration of As and a lower concentration of Cd than rice grain from treatments 3, 4, 5, and 7. Rice grain from treatment 4 had a 59–62% lower Cd concentration than that from treatment 3 in both soils; however, the As concentrations in the rice grains were not significantly different between treatments 3 and 4 in both soils.

Table 1 Effects of water management on As speciation and Cd concentration in grain and straw.

	grain				straw			
	Soil A		Soil B		Soil A		Soil B	
	As	Cd	As	Cd	As	Cd	As	Cd
Water management	mg kg^{-1}				mg kg^{-1}			
1	0.95 ± 0.044 a	0.005 ± 0.001 a	1.7 ± 0.118 a	0.010 ± 0.003 a	27.3 ± 0.66 b	0.02 ± 0.004 a	26.2 ± 0.85 a	0.03 ± 0.004 a
2	0.92 ± 0.029 a	0.016 ± 0.002 a	1.7 ± 0.077 a	0.046 ± 0.011 b	29.5 ± 0.29 a	0.14 ± 0.014 a	26.7 ± 0.27 a	0.22 ± 0.054 a
3	0.30 ± 0.020 c	0.36 ± 0.003 d	0.59 ± 0.014 c	0.27 ± 0.012 d	15.9 ± 0.59 d	1.4 ± 0.043 d	17.0 ± 0.76 c	1.3 ± 0.093 c
4	0.36 ± 0.007 c	0.21 ± 0.018 b	0.60 ± 0.037 c	0.16 ± 0.011 c	11.7 ± 0.70 e	1.1 ± 0.10 c	18.1 ± 0.57 c	0.85 ± 0.097 b
5	0.11 ± 0.026 d	0.41 ± 0.034 e	0.17 ± 0.030 d	0.34 ± 0.020 e	1.8 ± 0.09 f	2.0 ± 0.14 e	5.0 ± 0.18 d	1.3 ± 0.051 c
6	0.55 ± 0.006 b	0.066 ± 0.006 a	1.26 ± 0.044 b	0.063 ± 0.006 b	18.4 ± 0.84 c	0.66 ± 0.12 b	23.2 ± 0.64 b	0.57 ± 0.013 b
7	0.10 ± 0.014 d	0.28 ± 0.021 c	0.14 ± 0.027 d	0.38 ± 0.011 e	1.1 ± 0.53 f	1.4 ± 0.10 d	0.9 ± 0.22 e	2.4 ± 0.24 d

The same letters are not significant at the 5% level.

References

Arao, T., S. Ishikawa, M. Murakami, K. Abe, Y. Maejima and T. Makino (2010) Heavy metal contamination of agricultural soil and countermeasures in Japan, *Paddy and Water Environment*, **8**, 247 – 257

Arao T., A Kawasaki, K Baba, S Mori, S Matsumoto (2009) Effects of water management on cadmium and arsenic accumulation and dimethylarsinic acid concentrations in Japanese rice, *Environ. Sci. Tech*., **43**(24), 9361-9367

Inahara M, Ogawa Y, Azuma H (2007) Effect of alkalinity application on cadmium uptake by lowland rice under different water managements. *Jpn. J. Soil Sci. Plant Nutr*. **78**, 253–260 (in Japanese with English abstract).

JECFA (2010) Seventy-third meeting SUMMARY AND CONCLUSIONS, http://www.fao.org/ag/agn/agns/jecfa/JECFA73%20Summary%20Report%20Final.pdf

Koyama T (1975) Arsenic in soil–plant system. *Jpn. J. Soil Sci. Manure* 46, pp. 491–502 (in Japanese).

Kyuma K (2004) Soils polluted with hazardous elements. In ‘Paddy Soil Science’ pp 241-254. (Kyoto Univ. Press: Kyoto, Japan)

Takahashi Y, Minamikawa R, Hattori KH, Kurishima K, Kihou N, Yuita K (2004) Arsenic behavior in paddy fields during the cycle of flooded and non-flooded periods. *Environ. Sci. Technol*. **38**, 1038–1044.

Yamane, T. et al (1976) Mechanism of rice plant injury in arsenic contaminated paddy soils and its preventive measures: I. Influence of arsenite and arsenate in growth media on the nutrient uptake, growth and yield of rice plant. *Bull. Shimane. Agr. Exp.* **14**, 1–17 (in Japanese with English abstract)

Yamane, T. (1989) The mechanisms and countermeasures of arsenic toxicity to rice plant. *Bull. Shimane. Agr. Exper.*, **24**, 1-95 (in Japanese with English abstract)

Lessons Learnt During Bioremediation of Over 150 Sites Contaminated with Chlorinated Aliphatic Hydrocarbons in Japan

P. C. Shrihari[1], P. S. Reddy[2] and S. Maeda[3]

1.EcoCycle Corporation, 694-2, Akada, Toyama, 939-8064, Japan

2.EcoCycle Corporation, 694-2, Akada, Toyama, 939-8064, Japan, psreddy@ecocycle.co.jp

3.EcoCycle Corporation, 694-2, Akada, Toyama, 939-8064, Japan

Key words: Chlorinated hydrocarbons; bioremediation, *In-situ*

In-situ bioremediation was successfully applied over 150 sites contaminated with chlorinated aliphatic hydrocarbons in Japan. The sites included active manufacturing facilities, illegal dumping sites and former industrial facilities. The overburden areas were ranging from few hundred m^2 to tens of acres in size with the contamination concentrations up to a few hundred mg/L. Proper site investigation for obtaining data on contamination (sources, types, extent, co-contaminants etc.) and hydrogeology were found to be more critical than just knowing the microbiology of the site, for designing site specific bioremediation. Depending on the site conditions (hydrogeology, site usage, contamination concentration, etc.) various injection methods (gravity injection, direct push, fracturing etc.) were followed to deliver biostimulants into the ground. Interpreting the post injection monitoring parameters on the parent and daughter compounds, geochemistry and microbiology helped read the progress and direction of site remediation process. The paper also covers various trouble shootings (biofouling, byproduct gas emission etc.) during bioremediation process.

Bioremediation of Contaminated Sites Using Microorganisms: Blessing or Curse

Ji-Dong Gu[1]

1.Laboratory of Environmental Microbiology and Toxicology, School of Biological Sciences, The University of Hong Kong, Hong Kong SAR

Keywords: biodegradation; environmental remediation; microorganisms; biodiversity

Microorganisms are known for their involvement in transformation and detoxification of a wide range of environmental pollutants including both inorganic and organic ones. Convincing scientific results have been demonstrated for effectiveness of microorganisms in bioremediation in laboratory systems, but in comparison *in situ* remediation of contaminated sites have been achieved only with some limited success. Such results are examples of our lack of understanding of microorganisms living in the complex natural ecosystem and their interactions with both the different species and also the physical non-living components, e.g., surfaces. Because of these, we still face major challenges in our inability to manipulate, far from a comprehensive understanding of microorganisms for the benefit and well-being of our society. I would like to use several examples to illustrate my arguments here.

Microorganisms living in culture flasks and pure culture are very different from those in the natural environment including the contaminated sites because majority of them forms association with physical surfaces, so called biofilm (Fig. 1). Such a protective mechanism is very beneficial to a community of microorganisms and it has an important role in effective bioremediation and application of microorganisms for various purposes. At the same time, very little information is available on the microbial physiology and biochemistry when dealing with those on surfaces. In addition to the appearance of biofilm, microbial metabolic network is also an area lacking detailed information.

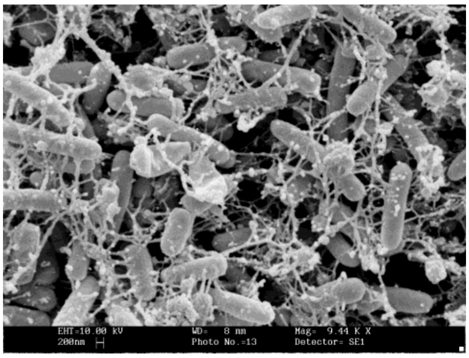


Figure 1. Scanning electron micrograph showing enrichment culture of different bacteria on surface with intracellular expolymeric materials

Microorganisms, living in the complex microbial world, possess an intricate biochemical network of interaction far from the reach of our current knowledge. For simple chemicals with environmental toxicological relevance, e.g., dimethly phthalate, dimethyl terephthalate and dimethyl isophtahel, transformation and degradation of them follow a common biochemical pathway, initially very similar - ester bond hydrolysis, but the involvement of microorganisms in each of the initial 2-hydrolytical reaction steps can be varied to the extent by two different microorganisms, *Klebsiella oxytoca* and *Methylobacterium mesophilicum* (Fig. 2). This shows the high selectivity of biochemical enzyme from the respective microorganism involved for each of the two step of degradation. At the same time, it is also feasible that microorganisms use this mechanism to promote and preserve a higher diversity of microbial community.

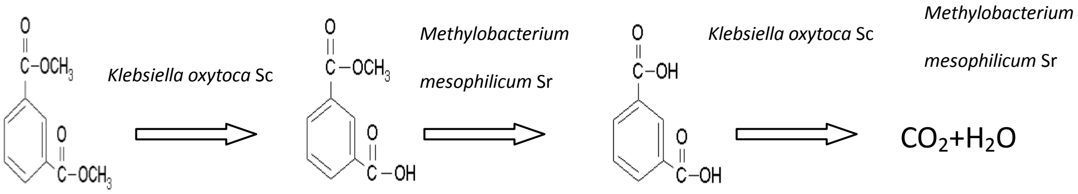


Figure 2. Proposed biochemical pathway for biodegradation of dimethyl isophthalate (DMI) by *Klebsiella oxytoca* Sc forming monomethyl isophthalate (MMI) and by *Methylobacterium mesophilicum* Sr forming isophthalic acid (IPA)

Because natural ecosystem is much more complex consisting of both inorganic, organic constituents and biota, promoting microbial activity *in situ* needs knowledge and better understanding of microbial physiology and biochemistry so that bioremediation by inoculation of effective microorganisms may achieve some success as planned. Without the prior understanding, implementation of bioremediation is simply ‘to feel the elephant by the blinds’.

References

Li, J., and J.-D. Gu (2007) Complete degradation of dimethyl isophthalate requires the biochemical cooperation between *Klebsiella oxytoca* Sc and *Methylobacterium mesophilicum* Sr isolated from wetland sediment. *Sci. Total Environ.***380**: 181–187.

Yu, X., and J.-D. Gu (2007) Accumulation and distribution of trivalent chromium and effects on metabolism of the hybrid willow *Salix matsudana Koidz* × *alba* L. *Arch. Environ. Contam. Toxicol.* **52**: 503–511.

Gu, J.-D. (2009) Corrosion, Microbial. Pages 259–269. *In*: M. Schaechter (ed.), *Encyclopedia of Microbiology* (3rd ed.), Elsevier, U.K.

Mitchell, R., and J.-D. Gu (eds.) (2010) *Environmental Microbiology* (2nd ed.), Wiley-Blackwell, Hoboken, New Jersey. 363 pp.

Bioremediation of Toxic Metals and POPs Contaminated Soils

Y. M. Luo[1]

1.Soil and Environment Bioremediation Research Centre, CAS Key Laboratory of Soil Environment and Pollution Remediation, Institute of Soil Science, Chinese Academy of Sciences (CAS), Nanjing, China 210008, ymluo@issas.ac.cn

Keywords: Bioremediation; contaminated soil; phyotremediation; POPs; toxic metals

During last ten years biotechnology integrating phytoremediation with microbial remediation has been developed for cleanup and restoration of polluted farmland soil. Some native hyperaccumulator plants such as *Sedum plumbizincicola* (Cd/Zn hyperaccumulator) and *Pteris vittata* (As hyperaccumulator) were applied for field-scale phytoextraction of toxic metals from contaminated agricultural soils. The plants with large and deep root system like *Vetiveria zizanioide and with bioenergy capacity like Sorghum,* maize, and *Miscanthus sinensis,* were used for phytostablisation, biofuel production, carbon sequestration and conservation of polluted land and mining tailings. The clover and alfalfa plants having nitrogen fixation were transplanted for phytodegradation of persistent organic pollutants such as pesticides, PAHs and PCBs in soils. Enhanced phytoremediation technologies, for examples chelate-induced phytoextraction and microorganism-inoculated rhizoremediation, have been demonstrated in the field. Intercropping system by using both crop and hyperacculmulator plant was developed for agricultural production while phytoremediation. Techniques for post harvest, treatment and utilization of remedying plants were also developed in different ways for various purposes. More attention has been paid to phyto-/microbial remediation of organic pollutants. It is needed to better understand the underlying processes and to further develop, optimize, demonstrate and commercialize biotechnologies. It is still required to implement soil remediation regulation, soil environmental standards and risk assessment for opening the potential market of sustainable and green environmental technologies in China.

This paper mainly introduces recent research and development in phytoremediation and microbial remediation and their potential application for remediation of toxic metal and/or POPs polluted soil in China.

Reference

Luo, Y.M. (2009). Current Research and Development in Soil Remediation Technologies. Progress in Chemistry, **21**(2-3), 558-565.

Accelerated Site Cleanup Using a Sulfate-Enhanced *In Situ* Remediation Strategy

G.M. Birk[1], S.L. Knox[2], and M.C. Yeh[3]

1. EOS Remediation, LLC, 1101 Nowell Road, Raleigh, NC 27607, U.S.A., Phone: +1.919.873.2204, gbirk@eosremediation.com

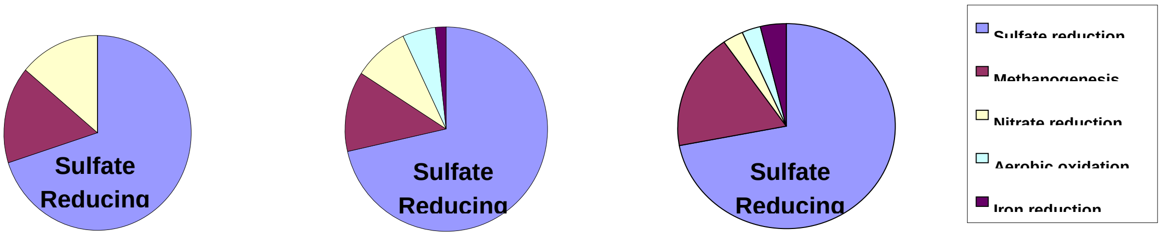
2. EOS Remediation, LLC, 1101 Nowell Road, Raleigh, NC 27607, U.S.A., Phone: +1.919.873.2204, sknox@eosremediation.com

3. EOS Remediation, LLC, Yatsu 6-22-7-805, Narashino City, Chiba 275-0026, Japan, Phone: +81.90.9858.1344, mei.yeh@eosremediation.com

Keywords: anaerobic bioremediation; sulfate-enhanced bioremediation; petroleum hydrocarbons; BTEX; MTBE; sulfate; hydrocarbon; petroleum; contamination; groundwater

Soil and groundwater clean-up is critical to sustainable business practices across many industries. The conventional wisdom for remediation of aquifers contaminated with petroleum hydrocarbons (PHCs) is to add oxygen. A paradigm shift in the remediation of petroleum hydrocarbons has occurred that employees a sulfate-enhanced *in situ* remediation strategy.

It was once thought that aromatic hydrocarbons do not biodegrade under anaerobic conditions. However, the importance of naturally occurring anaerobic oxidation processes in the biodegradation of PHCs is now firmly established and is considered the dominant driving force in natural attenuation of PHCs in the subsurface. Sulfate reduction and methanogenesis appear to be the dominant natural degradation processes at most sites (Wiedemeier et al., 1999). A recent British Petroleum/EPA study (Kolhatkar et al., 2000) has concluded that most hydrocarbon plumes are anaerobic and depleted of sulfate. Other studies such as Wilson et al. (2002) showed that of these natural anaerobic processes, sulfate reduction accounts for most of the degradation. Cuthbertson et al. (2006) presented case studies that demonstrated the benefits of adding electron acceptors such as **EAS™** (U.S. Patent # 7,138,060) to stimulate the biodegradation of petroleum contaminants in groundwater under field conditions at various sites.



Wiedemeier, T.H et al. at 38 Sites EPA-BP Study at 74 Sites AFCEE Study at 42 Sites

Figure 1. Sulfate-Utilizing Microbes Dominant Process at Most Sites

The availability of electron acceptors controls the rate of *in situ* biodegradation. In the presence of petroleum hydrocarbons, terminal electron acceptors are depleted at a rate significantly higher than can be naturally replenished, thus inhibiting biological degradation. The introduction of additional electron acceptors to the subsurface can accelerate the rate of biological degradation (Cuthbertson et al., 2009).

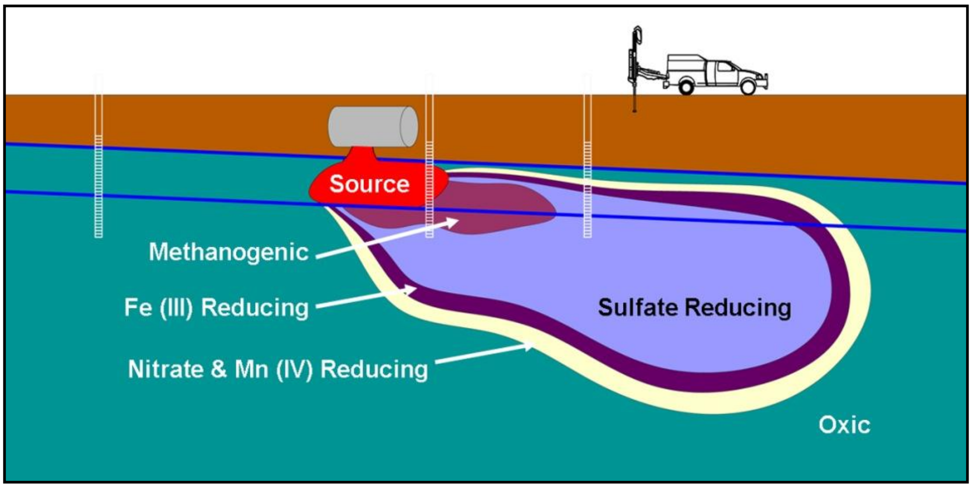


Figure 2. Typical Hydrocarbon-Impacted Aquifer (Most dissolved hydrocarbon plumes are depleted of “electron acceptors” - DO, nitrate, sulfate, iron, etc.

Based on a solid body of published scientific evidence, adding electron acceptors such as **EAS™** to groundwater will aid in increased degradation. **EAS™** addition will stimulate biodegradation by providing a soluble, readily available electron acceptor. In the presence of elevated sulfate (SO_4^{-2}), anaerobic groundwater bacteria use the PHCs for carbon and energy while mineralizing the hydrocarbons to carbon dioxide (CO_2) and water (H_2O). The following chemical equation illustrates this concept for the biodegradation of toluene (C_7H_8) under sulfate reducing condition where “B” represents bacterial metabolism.

$$C_7H_8 \ + \ 4.5SO_4^{-2} \ + \ 3H_20 \xrightarrow[B]{} 7HCO_3 \ + \ 4.5HS^- \ + \ 2.5H^+$$

This reaction results in complete degradation of the PHCs (e.g., Benzene, Ethylbenzene, Toluene and Xylenes). Ongoing project results indicate that the **EAS™** technology can cost-effectively turn land once deemed unusable into productive real estate. In addition, SO_4^{-2} reduction consumes protons increasing the pH and enhancing methanogenesis. At pH of approximately 6.8 and higher, hydrogen sulfide (H_2S) does not form easily. Most of the sulfide is bound as bisulfide (HS^-) and it stays dissociated from H^+ ions.

References

Cuthbertson, J, Kaestner, J, and Bruce, L 2006. “Use of High Concentration Magnesium Sulfate Solution to Remediate Petroleum Impacted Groundwater”, paper presented at the 22nd Annual International Conference on Soils, Sediments & Water, Amherst, MA, 17-19 October

Cuthbertson, J, and Schumacher, M 2008. “Full Scale Implementation of Sulfate Enhanced Biodegradation to Remediate Petroleum Impacted Groundwater”, *Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy, Vol. 14 [2009]*

Kolhatkar, R and Wilson, J 2000. “Evaluating Natural Biodegradation of MTBE at multiple UST sites”, paper presented at NGWA/API Petroleum Hydrocarbons and Organic Chemicals in Groundwater, Houston, 15-17 November, pp. 32-49

Wiedemeier, T, Rifai, H, Newell, C and Wilson, J 1999, Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface, John Wiley & Sons, Inc. New York

Wilson, J and Kolhatkar, R 2002, ‘Role of Natural Attenuation in the Life Cycle of MTBE Plumes’, Journal of Environmental Engineering, Vol. 128, No. 9, pp. 876-882

In-situ Chemical Oxidation of a Tetrachlorethene Plume in Groundwater

W.E. Pickens[1] and R.P. Hultgren[1]

1. MWH Americas, Inc., Denver, Colorado, william.e.pickens@mwhglobal.com, ryan.hultgren@mwhglobal.com.

Keywords: in-situ chemical oxidation; tetrachloroethene; PCE; sodium permanganate.

MWH conducted an investigation and corrective action pilot studies at a former chemical distribution facility located in Denver, Colorado. Chlorinated solvents, pesticides, and herbicides were formerly handled at the facility between approximately 1973 and 2001. The investigation was conducted under the jurisdiction of the Colorado Department of Public Health and Environment, Resource Conservation and Recovery Act (RCRA) Corrective Action Program.

The first phase of the investigation entailed the installation and sampling of 42 soil borings and 28 multi-depth groundwater monitoring wells at, and adjacent to, the facility to assess the horizontal and vertical extent of impacts. The geology beneath the site consists of approximately 25 meters of interbedded alluvial sands and clay, which overlie shale bedrock. Groundwater beneath the site is unconfined and the water table occurs at a depth of approximately 13 meters below ground surface (bgs).

A tetrachloroethene (PCE) plume was identified in groundwater that extends approximately 0.7 kilometers down-gradient from the facility. PCE concentrations in groundwater were detected at levels up to 6,700 micrograms per liter (ug/L). The groundwater standard is 5 ug/L. Based on data collected from vertically nested monitoring wells, PCE impacts were found to be concentrated in the upper portion of the alluvial aquifer. Oxygen-reduction potential (ORP) measurements in groundwater indicated general oxidizing conditions within the aquifer. No significant levels of PCE break-down products were detected in groundwater. This is likely due to the general oxidizing conditions in the aquifer, plus the fact that no ready source of carbon was available to facilitate reductive dechlorination (Pankow, 1996).

The second phase of the investigation was focused on delineating the locations of contaminant mass within the source area at the site. A truck-mounted rig with a membrane interface probe (MIP) and a conductivity probe were utilized as part of the second phase investigation.The MIP/conductivity evaluation demonstrated that the bulk of the PCE mass was concentrated within the upper 3 meters of the saturated zone. Clay interbeds within the upper portion of the aquifer prevented significant vertical migration of the contaminant from occurring.

Based on the investigation findings, in-situ oxidation was identified as the most viable remedial technique. Further, it was determined that an oxidant that was long-lasting and not too aggressive would be best at this site in order to allow for more residence time in the aquifer and more diffusion into low permeability interbeds. Based on these criteria, sodium permanganate and sodium persulfate were selected for further evaluation. Initially, a bench-scale study of soil oxidant demand was performed. Then the effectiveness of each of the chemical oxidants was evaluated. The bench-scale study results indicated a relatively low soil oxidant demand (0.8 grams per kilogram) in soils from the site. In addition, it was determined that sodium permanganate had the highest oxidant capacity of the two chemical oxidants selected for testing.

The in-situ chemical oxidation (ISCO) pilot test at the site consisted of three key components: the injection of sodium permanganate at four locations, installation of confirmation soil borings immediately after the injections to assess the subsurface oxidant migration pathways, and a groundwater monitoring program to analyze the injection radius of influence and the effects on groundwater chemistry over time. Four percent (%) by weight (wt/wt) sodium permanganate was injected into the subsurface with a direct-push rig at four, on-site locations within the source zone. Oxidant was injected down the inside of the rod and into the formation at 0.3 meter intervals between approximately 12 and 16 meters bgs. Approximately 22,100 liters of oxidant were injected into the first location (INJ-1), and approximately 21,200 liters of oxidant were injected into each of the remaining three locations (INJ-2, INJ-3, and INJ-4). A groundwater monitoring program, which consisted of collecting groundwater samples for field and laboratory parameter analyses, was continued for 24 months after the ISCO injections.

Within the first 3 months of monitoring after the ISCO injections were performed, permanganate was observed (purple coloration and elevated ORP) in eleven monitoring wells within approximately 22 meters of the injection locations. Permanganate was observed to persist in five of the monitoring wells through 24 months of post-ISCO injection monitoring. The apparent concentration of permanganate observed in the monitoring wells (as a function of color intensity) has decreased over time. The continued presence of permanganate in the groundwater over time indicates that additional oxidant capacity is present. This will allow oxidant to diffuse into lower permeability clay interbeds and destroy contaminant mass in these zones over time.

PCE concentrations in groundwater were reduced between 50 and 100% (by weight) as of the 15 month post-ISCO groundwater sampling event in 11 of the 12 wells sampled. Groundwater samples collected 24 months after the completion of the ISCO injections also showed significant reductions in PCE concentrations in the majority of the monitoring wells within 22 meters downgradient of the injection locations. However, samples from four wells within the source area began to show increases in concentrations after 15 months, indicating possible rebound in these areas.

The ISCO pilot study demonstrated that this technology was highly successful in removing contaminant mass over a large area of the site. An additional injection event will be conducted in order to treat portions of the source area where rebound was observed.

References

Pankow, James F., and Cherry, John A., 1996, Dense Chlorinated Solvents and Other DNAPLs in Groundwater, 286-290. Waterloo Press.

Three Decades of Study and Experience: Understanding the Behavior of Non-aqueous Phase Liquids in Heterogeneous Porous Media- What Have We Learned to Solve Real-World Problems?

T.H. Illangasekare[1]

1.Center for Experimental Study of Subsurface Environmental Processes (CESEP), Division of Environmental Science and Engineering, Colorado School of Mines, Golden , CO 80401, USA, **tissa@mines.edu**.

Keywords: Subsurface Contamination; organic waste; non aqueous phase liquids (NAPLs); remediation; modeling; intermediate scale testing.

Remediation of aquifers contaminated with chemicals that are in the form of Non-aqueous Phase Liquids (NAPLs) still remains a challenge. Most organic solvents and waste products such as coal tar and wood treating agents those sink below the water table because of their densities higher than water are referred to as DNAPLs. The DNAPLs after reaching the saturated zone behaves unstably, resulting in fingering and preferential flow contributing to complex entrapment architecture with zones of ganglia and pools. Low solubilities result in the entrapped DNAPL remaining as a separate phase for long periods of time, thus making them long–term sources of contamination. Also, in some hydrolgeologic settings, dissolved mass emanating from these sources diffuses into low permeability materials and rebounds after the NAPL source has depleted, thus contributing plume longevity and downgradient risk. Remediation is costly and poses significant technical challenges. The technical challenges of remediation of NAPL contaminated sites are associated with the complex entrapment architecture that is difficult to characterize and locating zones where mass rebound occurs. The author and co-workers have been involved research investigating a number of fundamental issues related to mass flux generation from DNAPL source zones. The basic scientific knowledge generated in these studies resulted in the development of numerical models, up-scaling methods and site characterization methods that were validated in the laboratory. This presentation focuses on the key findings and lessons learned from this research to help develop strategies to solve real world contamination problems.

Field data is often incomplete, costly to obtain, and inadequate to obtain complete insights to fundamental processes, and validate developed models and tools. Intermediate scale testing offers the ability to study, under controlled conditions, complicated processes in heterogeneous subsurface at different scales. The approach used in this study combines multi-scale experiments with numerical modeling efforts, augmented with field data. As subsurface heterogeneity contributes to morphologies of DNAPL entrapment (pools and ganglia) and architecture, a primary emphasis was placed on the effects of variability of soil properties at all scales of interest. Mass transfer under both natural conditions and the source zone subjected to remedial action were studied and quantified. The physical, chemical and biological transformations associated with surfactant-enhanced dissolution, in situ chemical oxidation, thermal treatment, source zone bio-remediation and nano iron treatment were studied.

The results of this research were used answer the following questions that lead to practical problem solution: (1) What are the impacts of mass removal form source zone on plume? (2) At sites with significant low permeability soils, can complete source zone mass removal reduce down-gradient risk? (3) Can NAPL source zone be adequately characterized? (4) What treatment techniques are effective? (5) Can dissolved mass flux be predicted?

(a) NAPL behavior: In the unsaturated zone the NAPLs tends to get preferentially entrapped in low permeability sandy soils due to high capillary suction. Whereas, once the DNAPLs penetrate the water table, they preferentially move through high permeability soils and get entrapped as ganglia or form pools. Due to capillary barrier effects, the DNAPL will not enter low permeability soils, but any discontinuities such as fractures or root casts may transmit the DNAPL through these soil formations. In general, DNAPLs get distributed sparsely as fingers, pools and immobilized zones of ganglia. Hence, the exact locations where the DNAPLs are present in source zones are difficult to determine through soil coring methods.

(b) Mass flux: Mass flux is controlled by a combination of factors that include heterogeneity, groundwater flow and entrapment morphology and architecture. The heterogeneity in combination with the sparsity of DNAPL mass distribution result in mixing of mass generated at DNAPL sources and water flowing through unaffected aquifer zones. As it is difficult to determine DNAPL sources, prediction of total mass flux generation based on DNAPL source zone characteristics is not feasible. The up-scaling method that was developed to use laboratory scale mass transfer rate coefficients to predict mass transfer in field system gave good results. However, practical application of the method requires characterization data that is not readily available at field sites.

(c) Stagnant zone mass flux: Under certain site conditions, a fraction of dissolved mass can diffuse into low permeability zones and rebounds when the DNAPL source is fully exhausted. However, a combination of factors contributes to how significant this mass refund is in determining the longevity of the dissolved plume. Our research results show that as the plume migrates, a large fraction of the dissolved mass gets stored close to the DNAPL source. After the dissolved mass started spreading, the surface area of the low permeability interfaces and their orientation (texture architecture) will determine how much mass is stored through matrix diffusion. Also, as the plume migrates, the lowered concentrations reduce the diffuse mass flux gradients, this reducing mass storage. A practical conclusion is that, to determine how significant the matrix mass storage and its contribution to plume longevity, many site-specific factors have to be evaluated, before concluding the plume longevity is solely due to mass rebound from stagnant zones.

(d) Site characterization: Two non-intrusive source zone characterization methods were investigated. The primary motivation was that traditional coring methods fail when the DNAPL is sparingly distributed and any sampling methods that are intrusive have the potential to mobilize DNAPLs that are in pools. The first method using partitioning tracers failed to estimate the entrapped mass when the source zone had lower ganglia to pool ratio. The method also failed when used to estimate treatment effectiveness after remediation due to strong tracer-chemical interaction (e.g. ISCO). Use of mass flux date to determine parameters of the entrapment architecture showed potential, but practical application will require multi-level samplers that are costly to install. Methods to develop optimal ways to place these sampling wells to determine DNAPL entrapment architecture are needed. Monitoring technologies based on new sensing technologies and wireless sensor networks are in progress.

(e) Source mass removal: The research where different cleanup technologies were evaluated for their ability to remove source zone mass in general showed that it is possible to reduce downgradient plume concentrations through source zone mass reduction, but it is not feasible to remove adequate mass to bring the concentrations to drinking water standards. Source zone bioactivity during bio remediation was able to increase the mass dissolution by few factors, but the rates were still not high enough to remove significant source mass. ISCO using permanganates oxidized a significant fraction of DNAPL mass but the source zone conditions changed drastically as a result of pore clogging that affected post-treatment mass transfer. Injected nano iron into the source lost its reactivity fast requiring continuous injection, making it impractical. Determining the optimal location to inject nano iron cost effectively to treat the dissolved mass emanating from source still remains a challenge.

Comparison of Chlorinated Volatile Organics Concentrations in Shallow Groundwater at Two Areas with Different Vadose Zone Sediments

G.C. Wang[1], H.H. Chen[2], J.T. He[3]

1.School of Water Resources and Environment Sciences, China University of Geosciences, Beijing, China, wanggc@cugb.edu.cn

2.School of Water Resources and Environment Sciences, China University of Geosciences, Beijing, China, chenhh@cugb.edu.cn

3.School of Water Resources and Environment Sciences, China University of Geosciences, Beijing, China, jthe@cugb.edu.cn

Keywords: Chlorinated Volatile Organics; Shallow groundwater; Vadose zone; Sorption

As a part of regional groundwater quality investigation and assessment, an investigation on the chlorinated volatile organics (VOCs) in groundwater has been conducted at two areas, North and Southeast China respectively. Totally 186 and 36 sets of shallow groundwater samples were collected from wells for chlorinated VOCs analysis at the two areas respectively. The results show that the spatial distribution of higher concentration points is consistent with the distribution of industrial zones at the both areas, suggesting that industrial activities could be main sources of chlorinated VOCs in groundwater. The detection probabilities of chlorinated VOC components are from 30.6% to 100% and the concentration of chlorinated VOC components from 0.05 μg/L to 13.91 μg/L at the area A, Southeast China. The detection probabilities range from 25.27% to 57.53% and the concentration from 0.07μg/L to 956.6 μg/L at the area B, North China. Comparatively, the detection probabilities are higher but the concentrations are lower at the area A than those at the area B.

A preliminary investigation on the vadose zone sediments was carried out in an attempt to explore the differences above. The vadose zone of the area A mainly comprises silt clay of river, lakes and delta sedimentary facies，while the vadose zone of the area B is mainly composed of medium to coarse-grained sands and gravel. The results of soil samples analysis show that the portion of clay particles (smaller than 0.075 mm) in soils accounts for 98% at the area A and 1.56-13.71% at the area B. The content of organic matters in soils is 0.72-12.2% at the area A and 0.14-0.25% at the area B, respectively. Both contents of clay particles and organic matters in soils at the area A are higher than those at the area B (Table 1). It indicates that soils at the area A have stronger sorption capacity than those at the area B. A lab soil sorption analysis shows that the sorption contents of organic contaminants in soils at the area A can reach several hundreds even thousands mg/kg. This confirms that soils at the area A have stronger sorption capacity. Thus, more organic contaminants in infiltration water in the vadose zone will be sequestrated into soils at the area A.

It is well known that the retardation transfer of organic contaminants often results from the sorption. The retardation factor, which is used to express the characteristics of retardation transfer, was estimated in the investigation. The results show that the retardation factors for chlorinated VOC components range from 2.29 to 13.21 at the area A and from 1.75 to 2.57 at the area B. Obviously, it indicates that soils at the area A has stronger capacity to retard contaminants transfer than those at the area B.

Table 1 The Vadose zone sediments at the two areas

Area	Lithology of vadose zone	Depth of Groundwater level (m)	Clay particle (%)	Organic matter (%)
Area A	silt clay	2-5	>98	0.72-12.2
Area B	medium to coarse sands, gravel	14.32-19.97	1.56-13.71	0.14-0.25

The analysis above shows that the vadose zone sediments play an important role in the transferring of organic contaminants into groundwater from the surface sources. At the area where soils comprising higher portions of clay particles and organic matters, more organic contaminants could be adsorbed on the soils and the concentrations of contaminants in groundwater could be lower accordingly, vice versa. This could enhance the understanding of the behaviors of organic contaminants in soils and groundwater and has implication for strategy-making of investigation of organic contaminants in regional scale.

References

Jiang, T.H., Chen, H.H., Liu, F., Liu, L.C. (2006) Primary study of contamination preventing abilities of vadose to organic contamination in shallow groundwater in some area of Tai Lake drainage area. In: *Collection of Coastal Geo-Environmental and Urban Development*, China Geological Survey (eds), Beijing, 2005: 313-321.

Jiang, T.H., Cheng, D.H., Han, B., Cui, X.H. (2006) Estimation of natural attenuation rate of chlorinate solvents contamination in shallow groundwater. *Earth Sciences Frontiers* 13(1): 140-144.

Chen, H.H., Jiang, T.H., Liu, F., Liu, L.C.. (2005) Organic contamination characteristics of shallow groundwater in a study area of the Taihu Lake basin, Jiangsu, China. *Geological Bulletin of China* 24(8), 735-739.

Importance of Using Small-Scaled Technology for Site Characterization

C. S. Chen[1], Y. T. Lin[1], Y.C. Sie[1]

1.Graduate Institute of Applied Geology, National Central University, Johngli, Taoyuan

Keywords: site investigation; heterogeneity; local scale; aquifer contamination

Any aquifer is composed of different geological materials that have different ability of transmitting groundwater and solutes. Heterogeneity is referred to as the spatial variation of hydraulic conductivity K(x, y, z), which significantly affects groundwater and solute movement in aquifers. Site remediation starts with site investigation, where suitable technologies are used to understand aquifer heterogeneity, types of contaminants, distributions of contaminants, and other relevant information. Site investigation cannot be overemphasized because information and data acquired at this stage is instrumental to the subsequent design of remedial measures. Many in-situ remediation measures fail to clean up the sites or fall short of the expectation is primarily due to insufficient knowledge of aquifer heterogeneity and inadequate understanding of contaminant distributions. Both deficiencies can be largely overcome by using small-scaled aquifer characterization techniques and groundwater sampling methods that are prone to yield three-dimensional descriptions of aquifer heterogeneity and contaminant distributions.

It is well understood that in an aquifer the low-K zones, relative to high-K zones, play a key role in affecting the transport behavior of either the dissolved phase or the liquid phase of nonaqueous phase liquids (NAPLs). Thus an appropriate hydraulic test for site investigation should be able to differentiate the high-K and low-K zones. In this regard, the pumping test, popular for characterizing aquifer hydraulic properties for groundwater exploitation, is unsuitable for site investigation because it is designed to evaluate transmissivity (T); the transmissibility of groundwater through the whole aquifer thickness and for an extent approximated by the radius of influence. As a large-volume, vertically averaged parameter, transmissivity contains no information on local variation of K across aquifer thickness. On the other hand, using the conventional water-volume approach (purging 3~5 times of well water volume before sampling) for groundwater sampling usually yields groundwater samples that the concentration levels are diluted. To avoid dilution and to acquire more complete pictures of site contamination, it needs sampling techniques that sample smaller volumes that can quantify "point-wise" groundwater quality. These small scaled groundwater sampling techniques include, e.g., micropurge, double-packer, MIP with the direct push machine, and others.

Relative to pumping test, the slug test is a smaller-scaled hydraulic test that evaluates K of the geological materials surrounding the test well. From the practical viewpoint, slug test is superior to pumping test in a contaminated site because it withdraws little or no groundwater, causes minor change of the groundwater flow, and gives rise to minor alteration of concentration distribution. However, there is also concern of the scale issue for slug test. The way the slug test is conducted determines the sample volume for which the K value estimated represents. The sample volume is related to the test screen length of a slug test. The conventional way takes advantage of the full well screen, and the sample volume comprises materials surrounding the whole screen length. The K value obtained is thus a vertically averaged one and fails to reflect vertical variation of K. The modern way of conducting the slug test; however, aims to identify the depth-specific K by limiting the test screen length to a small portion of the well screen. The shorter the test section, the higher resolution of K(z), and the more detailed understanding of the site hydrogeology. One popular way of conducting such a slug test is the multilevel slug test (MLST). It uses a double-packer setup to divide the well screen into a number of smaller test sections (25 cm to 80cm or so) and each test section is located at different depth. At each depth a depth-specific slug test is performed and the K value of that depth evaluated. Conducting a series of the depth-specific slug test in a well allows us to determine the vertical variation of K(z) around the test well. As a site normally has many wells, the multiple well MLST will give a three-dimensional illustration of the K(x, y, z) field.

In a sandy aquifer we conducted MLST in 20 wells, and the results allow us to determine the three-dimensional K field. In Figure 1, the K variations only at five different depths are displayed. The patterns of K distribution are very irregular; typical for natural conditions. Another advantage of the MLST technique is the ability of multilevel sampling. That is, we can take groundwater samples of different depths corresponding to the locations of each test section. As shown in Figure 2, benzene concentrations at five different depths are highly irregular in both the horizontal and vertical directions. Information in Figures 1 and 2 are useful for the design of remediation plan, which includes a combination of different remedial techniques at different locations.

In a semi-consolidated formation, we conducted a full screen slug test in a well. The K value obtained is about 10^{-8} m/sec, indicating that the formation is rather impermeable with little ability to transport contaminants. However, the MLST in the same well reveals that most of the formation is indeed rather impermeable with K values from 10^{-7}~10^{-8} m/sec, except at a depth where the K value is as high as 10^{-5} m/sec. Careful examination of the core samples of this well indicates that the higher K is due to micro fissures, which are absent at other depths. This higher K layer forms a solute pathway. These field cases manifest the importance of using small-scaled investigation techniques to characterize the site hydrogeology and contamination distribution.

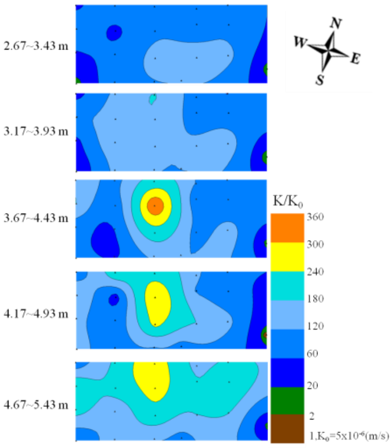


Figure 1 The K fields at five depths in a sandy aquifer determined by MLST.

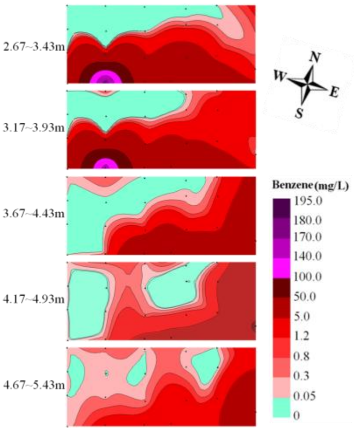


Figure 2 The distributions of benzene at five depths in a sandy aquifer by multilevel sampling.

Challenges and Successes in Managing Contaminated Sites in Canada

Faramarz Bogzaran[1]

1.B.Sc., QEP, RMCCM.Fluid Energy Recovery Corp.2077 Haywood Ave.,West Vancouver, BCV6V 1X2, Canada

Over the past 15 years, several of the Canadian provinces and territories have amended or changed their contaminated site regulations resulting in a well-defined set of rules and targets to clean up contaminated sites. However, several obstacles have adversely impacted the progress of cleaning contaminated sites; some of the key obstacles are; inconsistent or variable regulatory process from one province to another, stringent clean up standards, different levels of government involved in cleaning high profile sites and the cutbacks by the private sector in environmental expenditures due to the recession. Other challenges include;

- Lack of cohesive site prioritization practices
- Recession and post recession impact on proper funding for site clean up
- Short site remediation season due to cold climate in the northern regions of the country
- NIMBY syndrome
- Remedial technology application in urban centers
- Private sector annual expenditures in site remediation and reclamation varies from one company to another
- Property values continue to be the key driver in cleaning up the Brownfield sites in urban centers
- Cheap landfill disposal costs continue to prevent application of innovative remedial technologies
- Disparity between annual environmental budget vs. actual expenditures as well as lack of proper reserves for environmental liabilities by the private sector

The federal government introduced its Federal Contaminated Site Action Pan Program (FCSAP) in 2005. This accelerated funding program is part of The Canadian Economic Action Plan designed to clean up the federal contaminated sites while creating employment opportunities during and post recession.

Many of the urban centers faced a significant reduction in Brownfield development over the past two years due to reduction in construction activities and a significant drop in property values and sales. The private sector expenditures in managing contaminated sites decreased during the recession while the government of Canada increased its spending in managing its environmental liabilities to stimulate the economy and increase employment.

Since the beginning of 2010 there has been an increase in construction activities in major cities in Canada leading to more optimism that some of the major Brownfield projects will resume as more capital become available to the land developers.

Some of the key successes over the past 10 years include;

- FCSAP program launch leading to federal contaminated site clean ups throughout the country
- Streamlining federal government procurement process to select and award contracts to the consultants and remedial contractors resulting in a more timely process to mitigate environmental liability owned by the federal government
- Well-defined contaminated site regulations, although it may be stringent, in some of the provinces have led to the clean up and de-listing of many private sector properties and lowering of corporate environmental liabilities
- The private sector initiatives to site prioritization practice has resulted in mitigating the highest priority sites impacting groundwater and nearest receptors
- More acceptance by the private sector in selecting innovative technologies in managing their contaminated sites
- More spending on actual site remediation and clean up than continued assessment
- A risk-based standards have been developed to manage and mitigate the environmental liabilities in a cost effective and scientifically-proven manner

The author will expand on the challenges and the successes in the contaminated site management by providing data, reports and detailed analysis of environmental expenditures in Canada.

Advances in Contaminated Sediment Remediation from the Lower Fox River OU1 Project

G.R. Eykholt[1], D.M. Roznowski[2], and W.A. Hartman[3]

1. Foth Infrastructure & Environment, LLC, 1402 Pankratz St., Suite 300, Madison WI 53704, USA

2. Foth Infrastructure & Environment, LLC, 2737 S. Ridge Road, Green Bay, WI 54307, USA

3. GW Partners, W7881 Oakcrest Dr, Hortonville, WI 54944 USA

Keywords: contaminated sediments; modeling; PCBs; dredging; sediment cap; dredge residuals; sediment dewatering

The Lower Fox River Operable Unit 1 (OU1) Project, a large contaminated sediment remediation project in Wisconsin, has been successfully completed over the period of 2004 to 2009. OU1 is the portion of the Lower Fox River in Little Lake Butte des Morts, near Menasha and Neenah, Wisconsin. Remediation in OU1 included dredging of 371,600 cubic yards (284,100 m^3) of sediment over an area of 257 acres (104 Ha), placement of an armored cap over 114 acres (46.1 Ha), sand cover over 107 acres (43.3 Ha), and residual (post-dredge) sand cover over 37 acres (15.0 Ha). Dredged sediment was dewatered and more than 359,000 tons (326,000 metric tons) of dewatered sediment were hauled to landfills. An onsite water treatment facility treated decant water to meet applicable discharge standards, prior to discharge back to the river. River cleanup goals and objectives were met, including the objectives to reduce contaminant concentrations in the river to levels protective of human health and the environment. Recent accounting of the project costs totaled approximately $88.5 million (US), excluding design and long term monitoring costs. Earlier estimated costs for the project, incorporating an all dredge remedial alternative, were as high as $140 million.

The Lower Fox River flows north for 39 miles, beginning at the outlet of Lake Winnebago and terminating at the river's mouth into the bay of Green Bay. It is the most industrialized river in Wisconsin. The river has experienced water quality problems since the early 1900s, and polychlorinated biphenyls (PCBs) were discovered in the river in the 1970s. The Record of Decision (ROD) for the project was issued in 2002 by the Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency, requiring that sediments with PCB concentrations above 1 mg/kg be addressed. Prior to dredging, PCB concentrations in sediment were typically below 5 mg/kg, however, some areas had PCB concentrations exceeding 50 mg/kg. Approximately 1% of the sediment exceeded regulatory standards (TSCA) for hazardous wastes, and sediments dredged from these areas were segmented, dewatered, and hauled to a hazardous waste landfill.

As of August, 2010, the recovery of OU1 is being monitored and other downstream reaches of the Lower Fox River (Operable Units 2 to 5) are under various stages of remediation. Residual sampling of OU1 and a certification process has verified that the surface weighted average PCB concentration for OU1 is below the target concentration of 0.25 mg/kg. Water column PCB concentrations have also shown significant improvement, while fish tissue PCB monitoring has just begun and levels are expected to dissipate more gradually.

Elements of this successful sediment remediation project included: a successful partnership of the clients, project team and regulatory community; several stages of river and sediment characterization; modeling of the extent of contamination and sediment characteristics in three dimensions; a high level of strategic thinking that used updated summaries of modeling and sampling data to build confidence in the model and data characteristics for the project; dredging with high precision and productivity; a detailed cap design and placement strategy; environmental monitoring with background controls and feedback to dredging and capping operations, and; a variety of quality assurance and quality control measures. The project was actively coordinated by the client (GW Partners) and carried out with regular oversight from the client, client consultants, and a regulatory agencies oversight team.

As mentioned above, project success occurred, in part, due to a higher level of strategic thinking, which included sharing multiple model iterations between the client and the regulatory agencies. Additional modeling measures, beyond delineation of the sediment depth of contamination, and mathematically rigorous post-processing of the model’s three-dimensional mesh, was used to provide an extensive list of sediment characteristics which could then be expressed to GIS. Through GIS, the data were effectively visualized, managed and queried for strategic decisions, leading to the development of an optimized remedy for the project. The optimized remedy, which included capping and sand cover, in addition to dredging, saved nearly 40 percent in overall remedial action cost.

The success of the OU1 project is relevant to other sediment remediation projects involving dredging, capping, and residuals management. It is especially relevant to larger, multi-year projects where incremental savings for particular remedies can add up to significant overall cost reductions. The presentation will emphasize the importance of modeling and data systems which can be used to answer key questions raised during project planning and review. In addition, areas of improvement that were recognized during active remediation will be discussed.

"Waste to Resource": An Overview of Assessment and Technology in Sediment Remediation

Dr. D. W. Moore[1] and Dr. B. J. Mastin[1]

1.Weston Solutions, Inc., 2433 Impala Dr. Carlsbad, CA 92010

Key Words: Sediment; Remediation; Trends; Strategies

Over the years a number of organizations (USEPA, USACE, RTDF, SMWG, SEDNET) have evaluated a variety of remediation technologies and approaches for contaminated sediments. These approaches can be broadly categorized into contaminant destruction (thermal, chemical, bioremediation), physical separation/stripping (soil washing, phytoremediation), sequestration (amendment and stabilization, vitrification), isolation (capping, excavation/dredging and landfill placement), and monitored natural attenuation (eliminating sources and tracking natural recovery). Factors affecting remedy selection include but are not limited to identification of contamination source(s), extent and magnitude of contamination, contaminant form(s), proximity to sensitive receptor(s) and habitat(s), stability of the site, cost, engineering feasibility, societal/cultural concerns, as well as risk/uncertainty associated with implementation of selected remedies (efficiency and permanence of the selected solution).

Beginning in the 1970's, emphasis at many sediment remediation sites was on removal and for permanent confinement and/or entombment. The USACE led a large research program focused on physical isolation of contaminants through *in-situ* capping and confined disposal facilities (CDFs) (USACE 1987). As our ability to evaluate and understand potential ecological and human health risks improved, an emphasis was placed on development of conceptual site models for purposes of understanding exposure pathways and identifying receptors of concern to inform remedy selection. In the 1980's and 1990's there were a number of research efforts focused on *ex-situ* technologies using chemical, electro-chemical, thermal and/or other physical treatments to destroy, separate, and/or isolate sediment-associated contaminants (Averett et al., 1990; Stern et al, 2000).Problems encountered with some of these technologies included robustness, scale-ability, and costs.

Development of new technologies (geotextiles, resins, GAC, etc.) has facilitated development of innovative approaches for *in-situ* treatment focused on isolation and sequestration. Bioremediation became more attractive with the advent of new tools to isolate, grow, and even enhance (via genetic engineering) microbial, fungal, and plant species to accumulate and/or destroy certain contaminants. Issues with bioremediation revolved around limitations for *in-situ* application, the temporal/spatial scale required for treatment as well as the potential for ongoing exposure during treatment.

In the early 2000's, the USEPA Office of Solid Waste and Emergency Response (OSWER) published their "Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites" (USEPA 2002). This eleven step process outlined an integrative approach to guide remedial project managers in development, selection and implementation of appropriate remedies for contaminated sediment sites. It emphasized the importance of having a well developed site conceptual model and the application of risk-based decision making in remedy selection and design to minimize short-term exposure while ensuring long-term protection. It also provided for monitoring during and after sediment remediation to document effectiveness. Subsequently, OSWER published a more comprehensive guidance document entitled, "Contaminated Sediment Remediation Guidance for Hazardous Waste Sites" (USEPA 2005). As the concept of sustainability emerged and gained momentum OSWER developed an additional guidance for reducing the environmental footprint of remediation activities with the publication of "Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites" (USEPA 2008). Accompanying this movement toward more sustainable practices, there has been a shift in thinking toward greater consideration of the geospatial context and ecosystem services as part of the remedy selection process. In 2009, the EPA Scientific Advisory Board published, "Valuing the Protection of Ecological Systems and Services", followed by a draft white paper (Slack, 2010), "The Incorporation of an Ecosystem Service Assessment into the Remediation of Contaminated Sites" promoting consideration of questions such as: How does the affected site function in context of the larger ecosystem in which it resides?; How will various selected remedies alter that function?; Can remedies be selected and implemented in such a way as to preserve or even enhance that function?

This presentation will provide an overview of current technologies and strategies through several relevant case studies, preview emerging principles and concepts relating to sediment remediation, and outline criteria for site-specific remedy selection. Every site is exceptional, including but not limited to hydrodynamics, sediment characterization, contaminant mixture and extent, potential receptors, exposure pathways, and overall environmental conditions. In order to choose and validate a potential remedy(s), a comprehensive feasibility process should be outlined and employed to rationalize relevant options for each and every site. Once a viable remedy(s) is identified, further goodness-of-fit evaluations (including cost, environmental footprint, associated risks and liabilities, potential environmental and occupational exposures, and long-term success) are performed to refine overall remedy selection and expected performance (i.e., efficiency and effectiveness).

References

Averett, D.E., B.D. Perry, E.J. Torre, and J.A. Miller. 1990. Review of Removal, Containment, and Treatment Technologies for Remediation of Contaminated Sediments in the Great Lakes, Miscellaneous Paper EL-90-25. U.S. Army Corps of Engineers Waterways Experiment Station, prepared for U.S. Environmental Protection Agency - Great Lakes National Program Office, Chicago, IL.

Slack, S. 2010. Draft White Paper: The Incoporation of Ecosystem Service Assessment into the Remediation of Contaminated Sites. Prepared for USEPA Office of Solid Waste and Emergency Response, Office of Superfund Remediation and Technology Innovation. www.clu-in.org.

Stern, E.A., J.L. Lodge, K.W. Jones, N.L. Clesceri, H. Feng, and W.S. Douglas. 2000. Decontamination and Beneficial Use of Dredged Materials.

USACE. 1987. Confined Disposal of Dredged Materials. Engineer Manual 1110-2-5027. U.S. Army Corps of Engineers, Washington, DC.

U.S. EPA. 2002. Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites.

U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. OSWER Directive 9285.6-08. February.

USEPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. Office of Solid Waste sand Emergency Response. EPA-540-R-05-012 OSWER 9355.0-85. http://www.epa.gov/superfund/resources/sediment/guidance.htm.

USEPA. 2008.Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites Office of Solid Waste and Emergency Response. EPA 542-R-08-002 http://cluin.org/greenremediation.

–

Brownfield Remediation and Its Regulation – Rhodes Peninsula

J. C. Coffey[1], T. M. Manning[1] and S.E.Yu[1]

1.Department of Environment, Climate Change and Water, New South Wales, Australia.

john.coffey@environment.nsw.gov.au

Keywords: Brownfield; remediation; Rhodes Peninsula and Homebush Bay

The remediation and redevelopment of Rhodes Peninsula (Peninsula) and Homebush Bay in Sydney, Australia has been one of the most contentious and complex remediation projects in New South Wales, and embodies most of the key elements of Brownfields redevelopment. The triggers for the remediation and redevelopment of the Peninsula are many and include: the local decline and changing mix of industrial activities; recognition of the site contamination and the need for its regulation and remediation; the change in community expectations for use of the area, and development and population pressures within the city.

What was seen as isolated, low value, industrial land, surrounded by swamps and contaminated with dioxins is now seen as high value, prime waterfront land, well serviced by public parks, transport, retail services and with local employment opportunities. A suite of regulatory tools and actions was necessary to realise the area's potential for development.

The remediation and redevelopment at Rhodes Peninsula has been guided and driven by a number of regulatory and planning tools. Those include:

- The *Contaminated Land Management Act 1997 (New South Wales)*[1] which compels polluters and owners of significantly contaminated land to notify the government and provides powers to hold polluters and land owners accountable for remediating the land. The preparation of numerous guidance documents and regulations for site assessment and remediation has been a critical part of the implementation of this Act. Another crucial aspect of the legislation has been the creation of a Contaminated Site Auditor scheme, accrediting appropriately qualified and experienced consultants to review and approve site remediation plans and verify their implementation.

- The *Protection of the Environment Operations Act 1997 (New South Wales)*[2] provides the regulatory framework to control discharges to air and water, levels of noise and waste management by industrial activities, including site remediation, to protect both the environment and the community during the remediation works.
- The *National Protocol for Approval/Licensing of Commercial-Scale Facilities for the Treatment/Disposal of Schedule X Wastes 1994* a protocol developed to manage intractable wastes and now assists in *Australia's Implementation Plan* for *the Stockholm Convention on Persistent Organic Pollutants*[3]. Further details on this are provided in the *National Strategy for the Management of Scheduled Wastes*[4]. This protocol was used to assess and approve the use of thermal treatment technology to destroy the chlorinated organic (including dioxins) compounds present in the soil.
- The *Sydney Regional Environmental Plan No 29-Rhodes Peninsula*[5]*,* a planning directive, which enabled high density residential, commercial and retail development on the Peninsula, adding potential value to the land that required remediation and thereby underwriting the commercial viability of the high cost remediation works.

These regulatory tools have both driven and provided a framework for this Brownfields redevelopment. The industries, pollutants and remediation technologies used on the 45 hectare Peninsula were:

Industry	**Principal Pollutant(s)**	**Remediation strategy/technology**
Paint	Lead	Soil washing trialled but unsuccessful. Contaminated soil excavated, stabilised and relocated off-site to a secure licensed storage (monocell).
Organic Chemicals	Phthalates and a wide range of other organic compounds	On site bioremediation and extraction
Herbicides, pesticides, preservatives etc	Organo-chlorines Total petroleum hydrocarbons (TPH) Benzene Chlorobenzenes Dioxins and Furans	Direct fired soil thermal treatment. For one site, only the most highly contaminated soil was treated, with strategic on-site re-use of other untreated soil, based on criteria derived from site specific human health and ecological risk assessment. On another site all soil thermally treated.

In addition, two sediment remediation projects within Homebush Bay were carried out. An area of 8 hectares heavily impacted by chlorinated organics and dioxins had the top 0.5 metres of sediments removed and thermally treated. The area was backfilled with clean crushed rock placed over a layer of geotextile. Another 0.4 hectares of sediments contaminated with lead was excavated to a depth of 0.3 metres and backfilled with clean crushed rock over geotextile.

Major regulatory and environmental challenges for the projects included:

- Reviewing and finally approving the complex *Human Health and Environmental Risk Assessments* for the various sites and the matrix of site specific soil re-use criteria for one site.
- Assessing, licensing and monitoring the use of two direct fired soil thermal treatment plants, used for the first time in Australia on chlorinated organics, including high concentrations of dioxins.
- The development, issuing and enforcement of Environmental Protection Licences incorporating a complex suite of environmental monitoring requirements. These included monitoring of on and off-site air quality including volatile and semi volatile organic compounds (VOCs and SVOCs) and dust, emissions from the thermal treatment plants, site water treatment and discharges, noise, and water quality in the bay during the sediment remediation.

The key outcomes of this Brownfields project are:

- Thermal treatment used to successfully destroy contaminants, including dioxins, in 270,000 tonnes of soil with only one exceedance of the limit of 0.1 ng/m^3 WHO TEQ for dioxins in the thermal plant discharge stack during full scale treatment operations. Three further exceedances occurred during trials to re-comply.
- Disturbance of the local community was minimised, with the exception of two periods of high odour during excavation of soil with the highest concentrations of chlorinated organics.
- An estimated 90% of contaminated soil treated and re-used or managed on-site with only 10% going off-site.
- A reduction of an estimated 50% in the average concentration of dioxins in Homebush Bay, the principal source of dioxins in Sydney Harbour.
- Minimal disturbance to the rest of Sydney Harbour during the sediment remediation works.

- Extensive and effective community engagement and communication over 10 years that informed the community about the projects and sought their input to some of the key decisions, in particular about thermal treatment of soil.
- Remediation of the 45 hectare Peninsula and parts of Homebush Bay at a cost of US$160 M, paving the way for development valued at US$2,500 M, including 5,000 apartments plus retail and commercial space.

References

1.Contaminated Land Management Act 1997, policy and regulation
http://www.environment.nsw.gov.au/clm/

2.Protection of the Environment Operations Act 1997 and environment protection licensing
http://www.environment.nsw.gov.au/licensing/

3.*Australia's Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants*
http://www.environment.gov.au/settlements/publications/chemicals/pubs/stockholm-nip.pdf

4.National Strategy for the Management of Scheduled Wastes
http://www.environment.gov.au/settlements/publications/chemicals/scheduled-waste/strategy-1992/index.html

5.Sydney Regional Environmental Plan No 29-Rhodes *Peninsula*
http://www.austlii.edu.au/au/legis/nsw/consol_reg/srepn29p539/

Brownfield Management and Health Risk Assessment in the U.S.

S.S. Que Hee[1]

1.Department of Environmental Health Sciences and UCLA Center for Occupational and Environmental Health, School of Public Health, University of California at Los Angeles, 650 Charles Young Jr Drive South, Los Angeles California 90095-1772 Phone: (310)206-7388; Fax:(310)794-2106; E-Mail: squehee@ucla.edu

Keywords:

More than 450,000 brownfields exist in the United States of America. A brownfield is defined as a real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Brownfield management and health assessment in the United States is regulated under the Small Business Liability Relief and Brownfields Revitalization Act (“Brownfields Law”, P.O. 107-118) under the oversight of the United States Environmental Protection Agency (U.S. EPA)..

The law authorizes assessment and cleanup grants that may measure human health and ecological effects from contaminants and pollution from environmental stressors such as hazardous substances, and authorizes public health interventions but not research. Brownfields redevelopment and reuse, and long-term management and stewardship, are also funded. Examining site access patterns to determine the potential for exposures or site hazards that pose safety concerns is also funded.

Public health interventions may involve:

- Mapping site features that may affect exposures such as site proximity to drinking water wells or surface water bodies
- Monitoring health as part of community-wide inventory activities
- Collecting or linking baseline health and environmental measures to inform redevelopment planning options

- Monitoring air, nearby play areas, surrounding soils or surface or ground waters during cleanup, reuse or as part of long term management and stewardship to ensure protection of public health and the environment.

If the stressors are unknown, then research into their identities and quantifications may be necessary. Once the stressors are known risk assessment may then be conducted to achieve control and prevention of current and future effects.

Risk assessment involves:

- Using a scientific process
- Finding the inherent toxicity of the stressor
- Estimating how much of a stressor should be present in an environmental medium for a specified risk now and in the future (e.g., soil, water, air)
- Estimating how much contact (exposure) a person or ecological receptor should have with the contaminated environmental medium for a specified risk now and in the future

Chemical carcinogens in mixtures determine the lowest concentrations of the original exposing mixture to be achieved in the present U.S. EPA risk assessment methodology. In general the list of contaminants, pollutants, or hazardous substances is reduced to those chemicals that are carcinogens or that are potent toxics of high concentrations to act as sentinel or indicator chemicals relative to any known guidelines values. Exposure assessment is then conducted for these indicator chemicals including determination of exposure scenarios, determination of factors associated with each scenario (e.g., exposure frequency, exposure duration, life expectancy, inhalation rate, etc.), collection of data to support each factor, estimation of exposure concentrations, and accounting of contaminant-specific intakes for all exposure routes. Exposure scenarios are usually based on standard US exposure assessment considerations modified as appropriate to reflect unique site conditions. The scenarios usually represent anticipated conditions for projected future land use patterns (i.e., industrial or recreational). Thus, evaluated future receptors usually include an industrial worker, a recreational user, a child user, and the elderly user. Exposure factor values are usually selected to estimate RME circumstances, defined as the highest degree of exposure that is reasonably expected to occur at a site as well as worst case scenarios. The hazardous indices of the combined chemical indicators for these exposure assessment situations are then calculated and compared.

Risk-based preliminary remedial goals (RBPRGs) are also generally calculated using any action or regulatory guidelines or background data as appropriate instead of observed concentrations or guestimated ones. Once the degree of cleanup is estimated, and the known remediation methods evaluated, the potential cost can be calculated to assess remediation feasibility.

The presentation features some representative case studies with carcinogens and non-carcinogens in different exposure assessment scenarios to illustrate the differences in approach to multimedia human health risk assessment, and will touch on how the risk assessment of mixtures can be approached in a multimedia world for remediation and nonremediation purposes.

Generic and Advanced Human Health Risk Assessment for Brownfield Regeneration

C Paul Nathanail[1]

1.University of Nottingham, Nottingham NG7 2RD UK & Land Quality Management Ltd, UK,
paul@lqm.co.uk

Keywords: brownfield, contaminated land, human health, risk assessment

As economies develop and make the transition from heavy manufacturing to specialist manufacturing or services that require less land. Former industrial land can be abandoned as an urban area expands and formerly undeveloped land is built on (CABERNET, 2006; Nathanail, 2010a,b). However land is in limited supply and an ever expanding urban area is sowing the seeds of future problems. Successful cities are characterised by plenty of human-to-human interaction. Even in these days of push-email, mobile phones and video conferencing, much business, entertainment, innovation and retail is done face to face. Reusing former industrial sites is essential if travel times are contained and interaction opportunities encouraged. However many historic industrial activities resulted in chemical contamination of soil and groundwater.

Such contamination can harm human health – especially if the new users of the land are more susceptible than the workers in the former industry. As urban areas grow, there is a need for more housing, schools, playgrounds: children are smaller and more vulnerable to exposure to contaminants. It is essential that redeveloped brownfield sites are rendered safe and fit for the next intended use.

Ensuring land is fit for use begins with a thorough understanding of the history of the site and its geo-environmental setting (Nathanail et al. 2007).This understanding arises from a thorough desk study and site inspection that then inform the development of a conceptual model that allows a qualitative risk assessment to be carried out (Nathanail & Nathanail, 2010).

Sites where evidence indicates previous activities may have resulted in contamination require quantitative risk assessment and such assessment requires site specific analysis of soil and water chemistry and ground characterisation. Simple, generic quantitative risk assessment involves comparing site contaminant concentrations with relevant generic soil standards. Substantial exceedance of such standards triggers remediation to reduce the risk site contamination poses to human health. Lower levels of exceedance require more specialist risk assessment to evaluate the need or otherwise for what is usually expensive and often time consuming remediation. Specialist risk assessment removes conservative assumptions in generic assessment criteria and develops a more detailed understanding of a site but at the expense of extra site investigation and monitoring so is not something to be embarked upon lightly.

Generic assessment criteria can speed up, simplify and reduce the cost of risk assessment (Nathanail et al. 2009). As such, they need to be widely applicable and hence must represent soil contaminant concentrations that are definitely safe and pose minimal or no risk to human health. They are generated once, often by government agencies or other reputable organisations, and are widely accepted by regulators and adopted by risk assessors. They need to reflect local soil conditions and climate as well as the characteristics, diet and behaviour of the people, often the children, who will be on the site. As such each country or part of a country needs to develop its own generic criteria; it cannot and should not simply import criteria from another country. However the approach, software and many of the input parameters used in other countries may be adopted and then adapted to local conditions (Cheng & Nathanail 2009).

Specialist, detailed quantitative risk assessment is more time consuming and costly but can demonstrate that remediation is not needed and so it should only be undertaken where it is likely to deliver more benefits than moving straight to remediation. Site specific estimates of contaminant bioavailability based on sequential extraction tests that mimic the human digestive system are widely used to refine assessment criteria. Our understanding of contaminant uptake by plants grown for food in gardens is poor so site specific measurements of such uptake are an even more sophisticated refinement of the assessment criteria.

Risk assessment is used in many countries around the world to estimate and then evaluate the risk posed by contamination in soil or groundwater. It can help demonstrate a brownfield site is fit for its intended use despite the presence of some contamination. It can also help inform remediation clean up targets where remediation is necessary and involves source removal, destruction or reduction rather than pathway interruption.

Current thinking of how to remove unacceptable risks involves considering how the remediation can be integrated with other ground engineering required by the project to deliver more sustainable solutions. Sustainable remediation may be a useful context in some legal regimes, such as Part 2A of the UK Environmental Protection Act 1990. For brownfield regeneration remediation should aim to contribute to sustainable redevelopment. Action undertaken for remediation purposes may also provide underground space, the opportunity to install ground source heat pumps, the opportunity to improve geotechnical properties or to construct means of attenuating the effect of peak rainfall events. However a thorough risk assessment is and will remain a component of sustainable urban land reuse (Nathanail in prep.).

References

CABERNET. 2006. *Sustainable Brownfield Regeneration: CABERNET Network Report*. Millar, K., Grimski, D, Ferber, U. & Nathanail, C.P. http://www.cabernet.org.uk/resourcefs/427.pdf accessed on 8 August 2010

Cheng, Y. & Nathanail, C.P. 2009. Generic Assessment Criteria for human health risk assessment of potentially contaminated land in China, *Science of the Total Environment*, 408:324–339 DOI:10.1016/J.SCITOTENV.2009.09.021

Nathanail, C.P. 2009a. The role of engineering geology in risk-based land contamination management for tomorrow’s cities. In: M.G. Culshaw, H.J. Reeves, I. Jefferson & T.W. Spink (eds) *Engineering Geology for Tomorrow’s Cities*. Engineering Geology Special Publication 22: 149–158. Geological Society of London, Bath doi: 10.1144/EGSP22.11.

Nathanail, C.P. in prep. The Tenth Glossop Lecture: *Engineering geology of sustainable, risk based land quality management*. (email paul@lqm.co.uk for publication details).

Nathanail, C.P. 2010a. Sustainable Brownfield Regeneration. In: Swartjes, F.A. (ed.) *Dealing with Contaminated Sites: From Theory Towards Practical Application*. Springer, Dordrecht.

Nathanail, C.P. 2010b. Risk based contaminated land management and engineering geology. In: *Proceedings of the 11th Congress of the IAEG: Extended Abstracts volume*, pp 540-546. ISBN 978-0-908960-54-5

Nathanail, C. P, McCaffrey, C, Ashmore, M, Cheng, Y, Gillet, A, Ogden, R, & Scott, D. 2009. *The LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment* (2nd edition). Nottingham: Land Quality Press.

Nathanail, J. F., & Nathanail, C. P. 2010. Conceptual site models for potentially contaminated sites. In: *Proceedings of the 11th Congress of the IAEG: Extended Abstracts volume*, pp 536-539. ISBN 978-0-908960-54-5

Nathanail, J. F., Bardos, P. & Nathanail, C. P. 2007. *Contaminated Land Management Ready Reference*, 2nd edn. EPP Publications & Land Quality Press, Nottingham.

Integration of Brownfield Management and Human Health Risk Assessment in SGPRA

S.S. Hung[1], C. Huang[2]

1.Soil and Groundwater Remediation Fund Management Board, Environmental Protection Administration,
Executive Yuan, Taipei, Taiwan, R.O.C.
2.Environmental Engineering Research Center, Sinotech Engineering Consultants, Inc., Taipei, Taiwan, R.O.C.

Keywords: brownfield; risk assessment; contaminated site management

Regulatory Basis

The land contamination has become a major environmental issue in Taiwan since 1990's. The Legislative Yuan granted the Soil and Groundwater Pollution Remediation Act (SGPRA) in 2000 to address the concerns regarding the subsurface contamination. In the body of the act, human health risk assessment and contaminated land reuse (or brownfield) have been integrated to proactively offer a legal pathway for sustainable land use.

The design of the SGPRA exhibits a dual-threshold contaminated site management characteristic. The Control Site (CS) is defined as the contamination requires proper containment and pollution control actions while the Remediation Site (RS) is considered as a site exhibits serious impacts to human health and environment. In terms of remediation action, RS is required to design and to implement a comprehensive remediation action so that the impact to human health results from the contamination can be mitigated. In general, the Control Standard is the remediation goal for all contaminated sites to be delisted from either the CS or the RS. However, a risk-based remediation goal can be proposed by the responsible parties if there are technical impracticability conditions or land redevelopment plans to follow. Therefore, a direct link between risk assessment and contaminated land redevelopment has been created within the SGPRA.

The Site Management Framework

To management contaminated site in a sustainable prospective, a framework with risk-based management concept is established. The framework is shown in Figure 1. The figure illustrates the contaminated site is categorized into two classes based on the severity of risk posed according to the contaminated site conditions. For RS, the responsible parties may propose a risk-based remediation goal based on the results of risk assessment for future land use. A risk management and remediation program then is designed. At this phase, if the land is intended for redevelopment, the redevelopment plan should be submitted with the remediation program to the authority for review. Therefore, the rationale of the remediation program can be realized and the suitability of future monitoring program for the site after the redevelopment plan can be overseen.

Within the framework, the linkage between contaminated land redevelopment and risk assessment is conceptually established (the grayed blocks in the figure). Also, the brownfield is actually well integrated with the comprehensive contaminated site management. The advantage of the integration is that the contaminated site can be managed within one consistent framework. To governmental agencies, the interagency responsibility can be clearly defined and the interactions among different laws and regulations can be synchronized.

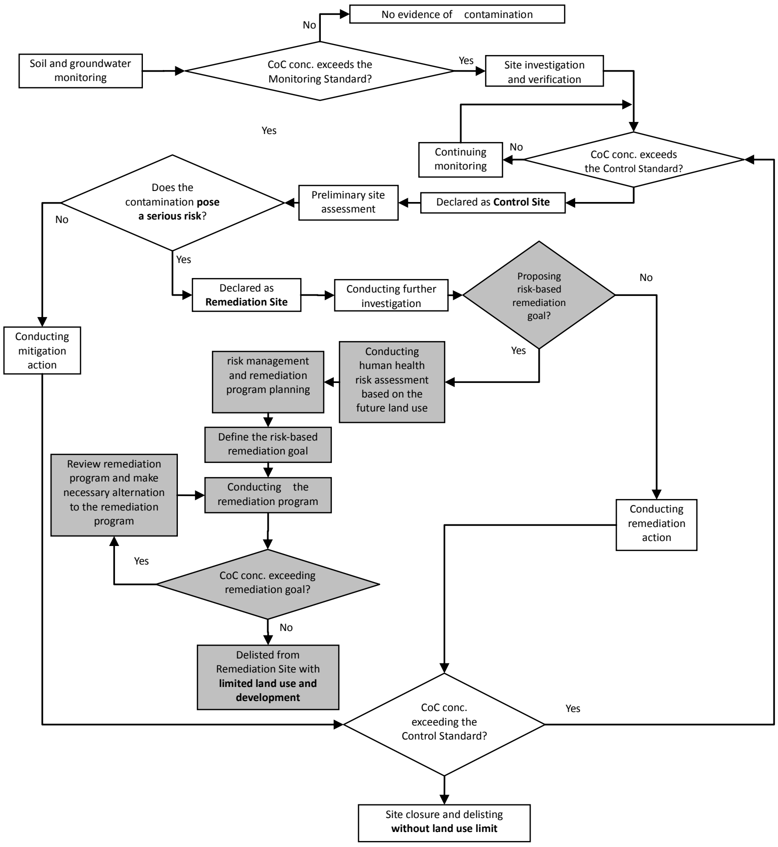


Figure 1 The contaminated site management framework in the SGPRA.

The Challenges of the Brownfield Management

The SGPRA has defined the responsibility of authority in protecting and remediating the subsurface environment so that the people can have a safe environment without risks resulted from subsurface contamination. Additionally, any land is an asset to a country and the government has the responsibility to preserve the asset for the people. It is a duty of leadership to save for the generations to come. The brownfield program can lead to sustainable land uses and become the core of the asset conservation.

With the legal foundation, there are challenges that should be considered in a proactive way. The site management should be considered as a land life cycle management. The technical solutions, risk-based management methodology, and administrative measures will have to be integrated to revitalize the value of the contaminated land. The brownfield program needs to have causes to attract the responsible parties and stakeholders to engage. Thus, a reasonable incentive program has to be in place. However, the incentive program might involve taxation, finance, and responsibility reduction/mitigation that the realization of complete brownfield program can be time consuming. Nevertheless, the contaminated land use is beneficial to people as well as administrative entity and the realization can be accelerated through proper regulation designs and policy decisions.

References

Tsai, H.T., Huang, C., Hung, S.S., Chung, Y.J.. (2010) Sustainable Use of Contaminated Land in Taiwan -Building A Risk Assessment Foundation and Lessons Learned. *In proceedings of EcoBalance 2010*, Tokyo, Japan. (in press).

Hung, S.S. (2010) A Study on Administration and Responsibility of Contaminated Land Reuse, Master Thesis, College of Law, Cheng-Chih University, Taipei, Taiwan, R.O.C.

An-Shun Remediation Site Monitoring Management and the Residental Healthcare

Hwang Jen Chang[1]

1.Enviromental Protection Bureau of Tainan City, Tainan 701, Taiwan, chiefman@mail.tnepb.gov.tw

Keywords: An-Shun Remediation Site、soil、dioxin、mercury、control strategies

The Tainan An-shun plant was produced chlorine and alkali from 1938. Resulting in serious soil pollution and affect the health of residents, and it has been found the pollution when road building in 2003. In 2004, EPA was officially announced the site as "soil remediation site ", the Tainan City Government would take emergency response and health care for the surrounding residents, including residents of life care, health care, terminated the fish farms and pollution control response. After the polluters were in the ruling in 2007, the CDPC began the remediation works. The duration of remediation is from 2009 to 2024, the Tainan City Government would implement comprehensive monitoring operation, supervision and management includes environmental management of the daily inspection, a regular basis to project inspection, monitoring and verification of remediation of environmental quality results in order to grasp the rectification work completed on schedule, to avoid secondary pollution produced, and the ongoing health care work to residents.

Site Management and Redevelopment Experience in the United Kingdom

D W Laidler[1]

1.CL:AIRE – Contaminated Land Applications in Real Environments, 7thFloor, 1 Great Cumberland Place London, WIH 7AL, UK. dwlaidler@btinternet.com

Keywords: brownfield, contaminated land, human health, risk assessment

The role of consultation in the formulation of policy, legislation and its regulation has a longstanding tradition in the UK. For the UK's land management community, participation in the structure of our emerging contaminated land regime arose in the mid 1990's (1). This was coupled with awareness of an accelerating programme of national guidance to provide the technical tools to support the regime's implementation. Our UK government also published its policy principles to form the underpinning framework of managing contaminated land which have remained relevant to the present day. It confirmed its commitment to sustainable development and the polluter pays principle with its first priority to prevent or minimise further pollution of land. It identified the "suitable for use" approach as the basis for the control and treatment of existing contamination where remedial action would only be required where contamination posed unacceptable actual or potential risks to health or the environment, having taken account of the actual or intended use of the site and also where appropriate and cost effective means were available (2). As such, the government aimed to ensure that cost burdens in managing land would be proportionate, manageable and economically sustainable (1).

Broadly coinciding with this period of policy and legislative development, the UK saw a growing impetus in the application of in-situ and ex-situ remediation technologies. For knowledgeable land holders with potential exposure to liability arising from the risks that contamination could pose to human health or the environment there were real concerns at that time that their sites were often little more than testing grounds for the onward development and refinement of the applied technologies. Whilst high quality research and development was being undertaken at laboratory bench scale, there was a view of a significant gap before translation could occur into full scale application on sites. Particularly to problem holders, this gap was a key constraining feature on the level of confidence that full scale remediation technology on real sites and in real conditions would indeed perform as intended.

Industry's response was to provide a vision. Initially advanced to the major problem holders it achieved wider support involving all other sectors – regulators, technical specialists, design consultants, academics, researchers and technology providers. That vision was for a new body to champion this confidence gap by managing and coordinating a network of defined contaminated test sites which could be matched to potential remedial technologies at field scale and thereby provide the basis for assessing their ultimate effectiveness in addressing risks to human health and the environment (3). Importantly, one of its specific aims was objectivity in that results would be made available for dissemination irrespective of whether outcomes were achieved or fell short of expectations. The vision also enabled the facility to demonstrate technology performance by adding further lines of evidence and thereby improve confidence.

This new body was launched in 1999 as CL:AIRE – Contaminated Land Applications in Real Environments. Fundamental to the overall objective of establishing a reputation for authoritative, high quality dissemination was CL:AIRE's Technology and Research Group, or TRG. Comprising high level experts representing a wide range of interested sectors, it was charged with overseeing projects from initial proposal through to the eventual dissemination of results, a support structure that continues to the present day.

For the UK land community, its growing experience over the last decade in site redevelopment and managing land contamination has inevitably lead to the learning of lessons in efficiencies and approaches and as a result an appetite to address shortfalls or gaps in practice. Drawing on the springboard provided by the quality of its early projects, CL:AIRE's activities have not only continued in its site based projects, but have grown to embrace other areas where it acts as driver and coordinator behind significant initiatives that represent UK good practice as well as a consolidating a role in international networks. Typical of its growing coverage is CL:AIRE's participation in projects to help develop and disseminate good practice and understanding of risks to human health.

Statistical assessment of analytical results has been an area of uncertainty with certain UK practitioners. To help improve both confidence in data handling and consistency of approach, focussed supporting guidance has been developed (4).

Collaborative exercises have been undertaken by separate groups which when combined provide a comprehensive body of generic assessment criteria (GAC) to assist human health risk assessment from soils. CL:AIRE's role has involved coordination and dissemination of one of the collaborative groups (5).

Interest groups involved with land development and regeneration have realised the benefits to be gained from the appropriate and sustainable reuse of excavated site materials. A cross industry group convened under CL:AIRE's coordination has collaborated to develop an innovative Code of Practice covering technical processes and reporting together with a framework setting parameters for the conduct of practitioners in the context of the role of the regulator (6).

CL:AIRE acts as secretariat for the UK's Sustainable Remediation Forum - SuRF (UK) (7), an initiative that is now reporting on embedding sustainability criteria into site management and remediation decision-making. The implications on human health resulting from the application of remedial activities or of the risks that may arise from undertaking the activities are typical headings the framework will embrace

UK organisations continue to develop thinking in advancing skills and competences, focussed on helping build on foundations in already achieved through postgraduate training, the initiatives of professional bodies with provisions for accreditation (8) and related efforts to advance technical capability frameworks for Brownfield practitioners. CL:AIRE has recently assumed a specific role in the UK, in gaining awarding body status that provides the authority, where demand exists, to set qualifications in contaminated land practice.

The key message borne from experience of UK practice is that collaborative participation from all sectors serves to contribute to a robust and proportionate land management framework. Added benefits can be gained through a respected and active body that has capacity to coordinate, contribute and drive forward initiatives that provide added confidence to current practice and processes.

References

1. Defra. 2006. Environmental Protection Act 1990: Part 2A Contaminated Land. Circular 01/2006
2. DoE and Welsh Office. 1994. Framework for Contaminated Land. Outcome of the Government's Policy Review and Conclusions from the Consultation Paper-Paying for our Past.
3. Bardos P, Johnson S, Laidler D. 1997. Field Scale Sites for the Research, Development and Demonstration of Technologies for the Management of Contaminated Land -CONSEPT Feasibility Study (Confidential) 1997.
4. CL:AIRE/ CIEH. 2008. Guidance on Comparing Soil Contamination Data with a Critical Concentration.
5. CL:AIRE / AGS /EIC. 2010. Soil Generic Assessment Criteria for Human Health Risk Assessment.
6. CL:AIRE. 2008. Definition of Waste: Development Industry Code of Practice.
7. SuRF (UK). 2010. A Framework for Assessing the Sustainability of Soil and Groundwater Remediation.
8. http://www.silc.org.uk/