BENCHMARKING HEAVY METAL CONTAMINATION FOR BROWNFIELD IN MALAYSIA

AIK HENG, LEE
Senior R & D Director,
Institute Alam Sekitar Malaysia

HAMID NIKRAZ
Professor & Chairman, Department of Civil Engineering,
Curtin University of Technology

YUNG TSE HUNG
Professor, Department of Civil Engineering,
Cleveland State University

Malaysia has over 10,000 brownfield sites which have yet to be registered. In fact there is limited information and controls on soil and groundwater contamination from these brownfield sites. In this study, four brownfield sites were examined in terms of the soil and groundwater quality to benchmark the heavy metal contents to be used as indicators of soil and groundwater contamination and to derive suggested benchmarking reference for remedial action to be taken. It also described briefly the possible remediation techniques to clean up the heavy metals in brownfield sites and the need for registration of brownfield sites towards sustainable development.

Keywords: Brownfield, soil quality, groundwater quality, heavy metal contamination and remediation.

1. Introduction

Due to urbanization and increasing land values there is a dire need to ensure that potential land is strategized for development purposes. Potential of redeveloping brownfields has prompted the need to have proper management strategies that can identify, document and catologue these brownfields to assist decision makers and planning agencies to make appropriate decisions so that environmental risks can be minimized for brownfields to be redeveloped.

Currently, in Malaysia there is no full listing and registration for brownfield sites and also there are no standards for soil and groundwater quality [1]. The brownfield sites may contain low contaminants such as debris to highly hazardous substance such as heavy metals, volatile organic substances, radioactive material and others that may contain in the ground due to man activities.

It is estimated there are over 10,000 brownfield sites exist in Malaysia. Some of these sites are developed, abandoned and some with potentials for redevelopment. Brownfields are analogue to contaminated sites that have been used for industrial, commercial, warehousing or other purposes that may be contaminated due to the presence of hazardous substances, pollutants or contaminants and usually existing in areas occupied by industrial activities, waste dumping, petrol and oil storage. The site of the brownfield sites varies from small premises to larger ones depending on the nature and type of activities at site.

The contaminants encountered at brownfields generally include heavy metals such as As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn, VOC such as benzene, toluene and SVOC such as PAH and others.

Heavy metals cannot be chemically degraded and can affect all groups of organism and ecosystem processes [2-6] which are generally originating not only from industrial activities but also agriculture activities such as fertilizer application [7]. Heavy metals therefore are good indicators for contamination of brownfield sites.

The geology in Malaysia generally consists of granite, sedimentary rocks, shale, sandstone and limestone whereby heavy metals are also grounded in natural form. Heavy metals however can be introduced further to the land through fertilizer application, soil remediation and can cause contamination as well. On top of these activities, heavy metals are further introduced by other man activities namely industrial activities.

This study was therefore conducted with the aim to determine available heavy metals found in brownfields so as to benchmark the baseline with typical agriculture soil so relevant benchmarking references of heavy metal contamination can be established for remedial action to be taken.

2. Materials and method

2.1. *Soil and groundwater sampling*

Twenty soil samples obtained from four brownfield sites in Malaysia were evaluated to assess the range of heavy metals in the soil and groundwater at the brownfield sites. The four brownfield sites as depicted in Table 1 involve namely (i) Site 1 that is an industrial land in proximity to heavy manufacturing industries; (ii) Site 2 that is a site in proximity to motor vehicle repairs; (iii) Site 3 that is a site in proximity to high technology industrial activities; and (iv) Site 4 that is a site in close proximity to sanitary landfill.

Table 1. Description of brownfield sites

Brownfield Site	Number of Samples	Type of Activity	Surrounding Land Use
Site 1	3	Heavy Industry	Heavy industrial activities
Site 2	9	Mechanical Workshop	Industrial, housing, warehousing
Site 3	2	High Technology Industry	High technology industrial activities
Site 4	6	Sanitary Landfill	Agriculture, landfill

Both test pits and borehole drilling were used in the sampling program. Soil samples were also taken from each test pit for classification of the soil profile. Soil samples collected during sampling were placed in pre-cleaned jars, sealed and labeled prior sending to laboratory for analytical purposes.

Groundwater wells were established in each test pit and left for 24 hours to ensure stability of the groundwater levels before measuring the groundwater levels. The monitoring wells were purged by removing one full well volumes of water. Groundwater samples were obtained with use of a bailer. The groundwater were then collected in 1000 ml bottles, labeled and sealed prior sending to laboratory for analytical purposes.

2.2. *Analysis*

The soil and groundwater samples were sent to laboratory for analysis. All samples were preserved according to the analytical requirement. The testing methods used are in accordance to APHA (American Public Health Association) 19th Edition 1995 as shown in Table 2.

Table 2 : Testing methods and parameters tested

Parameters Tested	Testing Method
As	APHA 3114C – Continuous Hydride Generation
Cd	APHA 3111B
Co	APHA 3111B
Cr	APHA 3111B
Cu	APHA 3111B
Hg	APHA 3112B – Cold Vapor Atomic Absorption Spectrometric
Ni	APHA 3111B
Pb	APHA 3111B
Zn	APHA 3111B

Note : APHA – American Public Health Association, 19th Edition 1995

The analytical results obtained from the soil and groundwater sampling programs were analyzed and compared to the selected references for soil and groundwater.

By way of this analogue, the significance of the heavy metal contamination in the soil and groundwater at the brownfield sites can be quantified with the relevant references.

3. Results and discussions

3.1. *Heavy metals in soil*

Table 3 provides a summary of the heavy metal concentrations found at the brownfield sites. The results were also compared with the soil investigation level published by the Ministry of Agriculture and the Dutch Reference Values. Fig. 1 provides a comparison of the heavy metal contents at the four brownfield sites.

Table 3 : Summary of soil analysis (mg/kg)

Heavy Metals	Site 1	Site 2	Site 3	Site 4	Malaysia Reference *	Dutch Reference	
						S Value **	I Value ***
As	0.03	0.1	0.43-0.63	0.26-1.13	60	29	55
Cd	0.03-0.08	0.03	0.87-22.25	NA	0.3	0.8	12
Co	0.63-0.85	NA	1.35-2.56	NA	10	9	240
Cr	0.003	0.05-3.1	1.28-23.36	12.26-29.21	60	100	380
Cu	0.36-0.70	3.8-11.7	0.97-13.10	0.1-6.6	50	36	190
Hg	0.01	0.01	0.70	0.7	0.35	0.3	10
Ni	0.005	1.3-10.7	1.0-2.91	NA	45	35	210
Pb	0.26-0.29	12.1-46.5	0.10-10.56	3.31-11.29	65	85	530
Zn	NA	12.4-96.2	NA	NA	95	140	720

Note : Values indicate range detected at each site
* Soil investigation level published by Ministry of Agriculture Malaysia
** S Values (Target Values) – Below this value regard as being multi functional and land suitable for all usage
*** I Values (Intervention Values) - Above these values the soil is regard as a 'serious case of pollution' and some form of measures are to be adopted
NA – Not Available
NR – No Recommendation

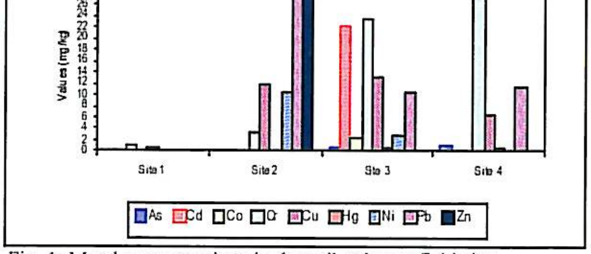

Fig. 1: Metal concentrations in the soil at brownfield sites

As values ranging from 0.03 to 0.63 mg/kg were detected at the brownfield sites. The values were within the Malaysian reference as well as within the Dutch reference.

Cd values ranging from 0.03 to 22.25 mg/kg were detected at the brownfield sites. Cd values at site 1, site 2 and site 4 were within the Malaysian reference as well as the Dutch reference. Cd values at site 3 however exceeded these references.

Co values ranging from 0.63 to 2.56 mg/kg were detected at the brownfield sites. The values were within the Malaysian reference and the Dutch reference.

Cr values ranging from 0.003 to 29.21 mg/kg were detected at these sites which were within the two references used for comparison purposes.

Cu values ranging from 0.1 to 13.10 mg/kg were detected at these brownfield sites which were also within the references used for comparison purposes.

Hg values ranging from 0.01 to 0.7 mg/kg were detected at the brownfield sites. Hg values at site 3 and site 4 exceeded the Malaysian reference. Hg levels at these sites were also detected to be above the Dutch S Values and below the Dutch I Values for intervention purposes.

Ni values ranging from 0.005 to 10.7 mg/kg were detected at the brownfield sites which were within the Malaysian reference and the Dutch reference.

Pb values ranging from 0.10 to 46.5 mg/kg were detected at the brownfield sites which were within the Malaysian reference and the Dutch reference.

Lastly, Zn of 12.4 to 96.2 mg/kg were detected at site 2 which were detected to be above the Malaysian reference and the Dutch reference.

In the summary based on the analysis conducted, the heavy metal concentrations detected at the brownfield site can be used as a good indicator to assess the level of contamination of the brownfield sites. The study to compare the extend of the heavy metal contamination can be used to benchmark heavy metal contamination for remedial actions.

3.2. *Heavy metals in groundwater*

Table 4 provides a summary of the groundwater analysis at the four brownfield sites while Fig. 2 depicts the metal concentrations in the groundwater at the brownfield sites. Comparisons with the NDWQ (National Drinking Water Quality) and the Dutch reference values were also made.

Table 4 : Summary of groundwater analysis (mg/l)

Heavy Metals	Site 1	Site 2	Site 3	Site 4	Malaysia Reference *	Dutch Reference	
						S Value **	I Value ***
As	0.3	0.01	0.001-0.005	0.001-0.006	0.05	0.01	0.06
Cd	0.2	0.003	0.006	0.003	0.005	0.0004	0.006
Co	0.2-3.67	NA	0.002	NA	NR	0.006	0.03
Cr	0.3	0.01	0.001-0.063	0.01-0.7	0.05	0.001	0.03
Cu	1.36-2.39	0.01	0.001	0.01-0.34	1	0.015	0.075
Hg	1	0.01	0.001	0.001-0.006	0.001	0.00005	0.0003
Ni	0.5	NA	0.001-0.003	NA	NR	0.015	0.003
Pb	2.0	0.03	0.148-0.196	0.09-0.21	0.1	0.015	0.075
Zn	NA	0.38-0.51	NA	NA	1.5	0.065	0.7

Note : Values indicate range detected at each site

* National Drinking Water Quality, Ministry of Health Malaysia

** S Values (Target Values) – Below this value regard as being multi functional and land suitable for all usage

*** I Values (Intervention Values) - Above these values the soil is regard as a 'serious case of pollution' and some form of measures are to be adopted

NA – Not Available

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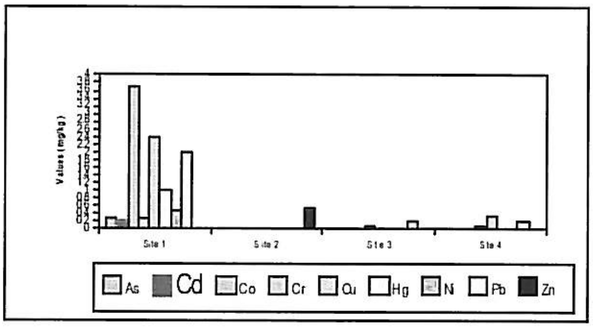

Fig. 2 : Metal concentrations in groundwater at brownfield sites

As values ranging from 0.001 to 0.3 mg/l were detected at the brownfield sites. As values at site 1 were above the NDWQ as well as above the Dutch S Values.

Cd values ranging from 0.003 to 0.2 mg/l were detected in the groundwater at these brownfield sites. Cd values at site 1 were detected to be above the selected reference while Cd values at site 3 were above the Dutch S Values.

Co values ranging from 0.002 to 3.67 mg/l were detected in the groundwater samples. Co values at site 1 were detected above the Dutch I Values.

Cr values ranging from 0.001 to 0.3 mg/l were detected in the groundwater samples. Cr values at site 1 were detected above the NDWQ and Dutch Reference while Cr values at site 2 were found to be above the Dutch S Values. At site 4, Cr values were above the NDWQ and Dutch I values.

Cu values ranging from 0.001 to 2.39 mg/l were detected in the groundwater samples. Cu values at site 1 were above the selected references while at site 3 Cu values were above the Dutch I for intervention purposes.

Hg values ranging from 0.001 to 1 mg/l were detected in the groundwater samples. Hg values at site 1 were detected above the selected while Hg values at site 2 and site 3 were above the Dutch S Values. Hg values at site 4 were above the Dutch S Values.

Ni values ranging from 0.001 to 0.5 mg/l were detected in the groundwater samples. Ni values at site 1 were above the Dutch I Values for intervention purposes.

Pb values ranging from 0.03 to 2.0 mg/l were detected in the groundwater samples. Site 1, site 2 and site 3 showed Pb values in the groundwater to be above the NDWQ and Dutch I values for intervention.

Zn values ranging from 0.38 to 0.51 mg/l were detected in the groundwater samples which were found to be above the Dutch S Values.

Thus, from the above analysis, it can be summarized that the heavy metals detected in the groundwater are good indicators to be used to assess the level of contamination in the brownfield sites.

3.3. *Benchmarking reference of heavy metal contamination for brownfield*

A suggested reference was derived from the study to provide a benchmark for remedial actions required to be taken as shown in Table 5.

Table 5 : Suggested reference for benchmarking heavy metal contamination in brownfield for remedial action to be taken

Heavy Metals	Value In Soil (mg/kg)	Value In Groundwater (mg/l)
As	5	0.05
Cd	10	0.005
Co	5	0.1
Cr	30	0.05
Cu	20	1.0
Hg	0.3	0.002
Ni	20	0.002
Pb	50	0.2
Zn	95	1.5

This provides as an alternative reference value for benchmarking soil and groundwater contamination in brownfields which had exposed to contaminants such as industrial pollutant or leaching of metal ions from nearby sources.

3.4. *Remediation for heavy metal contamination*

Various considerations are to be given after evaluating the contaminants found above the suggested reference derived. Nevertheless, a consistent and common framework is required to address the issues. For this purpose a hierarchy of remedial actions is proposed so that the brownfield site can be redeveloped for other purposes. The remedial techniques involve onsite treatment or offsite treatment as depicted in Fig. 3.

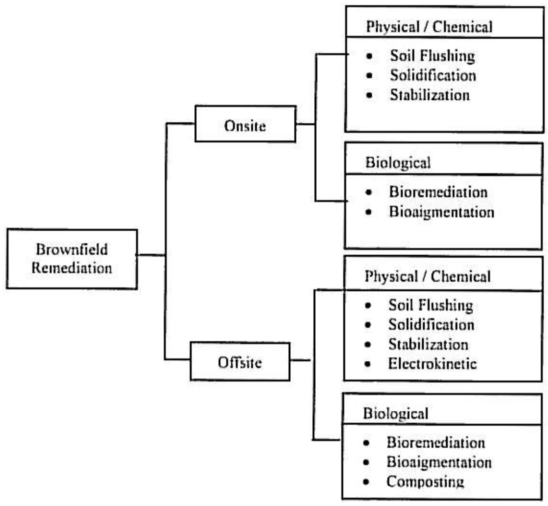

Fig. 3 : Remediation for heavy metal contamination in brownfield

The remediation techniques include physical chemical treatment involving soil flushing and solidification method applicable depending on the heavy metal contaminants found at site. Biological treatment involving bioremediation and bioaugmentation whereby heavy metals are removed by use of microorganism.

4. Conclusions

The study aims to derive reference for benchmarking heavy metals at brownfield sites which serves as a good indicator for heavy metal contamination for the brownfield sites.

Further studies however are to conducted for the brownfield sites as a move towards registration of the brownfield as an additional approach towards sustainable development in Malaysia.

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