Contaminated Land Remediation Technologies: Current Usage And Applicability In Malaysia

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Contaminated lands are often the blight of concerted industrial activities in highly developed and industrialized countries. Unfortunately, Malaysia is not unaffected by this issue and thus requires intervention in terms of tightening of legislation regarding contaminated land as well as application of established remediation technologies. Since redevelopment of such sites are already earmarked under the 9th Malaysia Plan, it is reckoned that the next step for related stakeholders is to focus on local customization or creation of cost-effective and effectual contaminated land remediation technologies. As applications of these technologies are still in their infancy in Malaysia, familiarity of such technologies is lacking among pertinent stakeholders. Therefore, this paper aims to provide an overview of the types of contaminated land remediation technologies with regards to their current usage and applicability in the Malaysian context. Technologies such as soil vapour extraction, bio-remediation, containment, solidification/ stabilization, excavation and phyto-remediation are described. It is suggested that a long-term strategy be established to ensure more expertise and technologies with regards to contaminated land remediation will be locally available. All agencies, either public or private should invest in the training of their personnel so that a pool of local experts can be made available in the near future.

The presence of contaminated land has been the subject of concern in most developed countries for at least two decades, especially countries that are experiencing scarcity of uncontaminated land (greenfields) for development. Even though the predicament of contaminated land in Malaysia is not thought to be as widespread as that found in industrialized countries, the problem nevertheless exists and demands intervention. Many of the older industrial areas in Malaysia have large patches of contaminated land including petrol stations, waste disposal sites and ex-mining sites. Land contamination in Malaysia is generally attributed to:

(a) Indiscriminate dumping of wastes;
(b) Leaking of underground petroleum storage tanks;
(c) Improper and illegal storage of fuel and chemicals within industrial premises;
(d) Years of gradual accumulation of chemicals within industrial premises.

Utilization of established technologies for land remediation in Malaysia is rather limited as compared to developed countries. These technologies are mostly being utilized on a trial basis in order to facilitate local remediation engineers to evaluate the technical and economic feasibility of local application. However, with the imminent creation of a National Register for contaminated sites and formulation of comprehensive policies on redevelopment of such sites earmarked under the 9th Malaysia Plan, these technologies will be essential in assisting sustainable development initiatives in the country. Hitherto, the majority of engineers and environmental experts in Malaysia are unaware of the existence of such technologies and this may hamper efforts in redevelopment of contaminated sites. As such, the aim of this paper is to provide an overview of the types of contaminated land remediation technologies with regards to their current usage and applicability in the Malaysian context.

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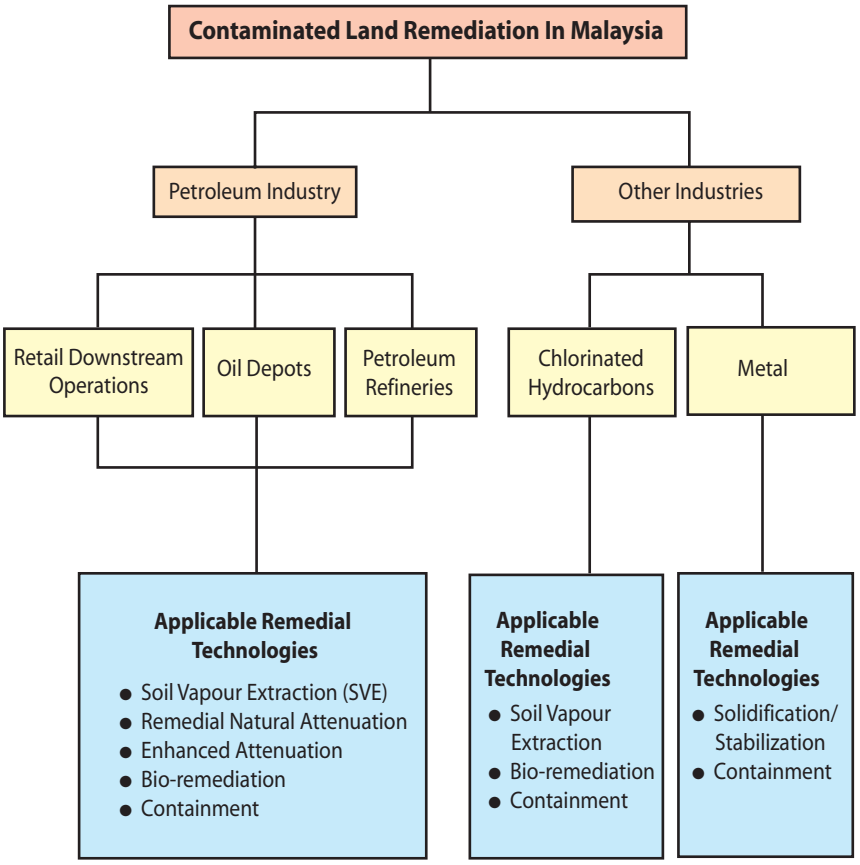

Figure 1: Contaminated land remediation technologies in Malaysia

The Need For Contaminated Land Remediation Technologies In Malaysia

Demand for contaminated land remediation technologies in Malaysia is low compared to developed countries due to the exorbitant costs of carrying out remediation and the lack of legislation to obligate culprits to bear the remediation costs. Large-scale contaminated land remediation is primarily conducted on a voluntary basis and not regulatory driven, albeit some organisations would find it necessary to fulfill property lease or purchasing requirements by carrying out remediation activities (*Leong and Ng, 2001*). Therefore, cost still plays a major factor for industries that are willing to acquire the services of environmental firms in order to clean up contamination located within their premises. Other external circumstances that cause the need for contaminated land remediation in Malaysia include property value depreciation, negative public perception and requirement from third parties such as potential buyers of the property (*Lee, 2001*).

Description Of Remediation Technologies

The selection of remediation technology for cleaning up of a particular contaminated land is dependent upon various factors such as local soil conditions, hydro-geological conditions and the types of contaminants. Most established remediation technologies do not necessitate localized customization.

The predominant industry that frequently conducts contaminated land remediation in Malaysia is the petroleum-based industry. Locations such as retail downstream operations (petrol kiosks), oil depots and petroleum refineries are examples of petroleum-based premises that generally require contaminated land remediation. This may be attributed to the fact that the petroleum-based industry is managed by established multi-national corporations that incorporate efficient and well-organized environmental management systems in their routine operations. As a result, these systems, which are standard corporate requirements, compel the corporations to carry out clean-up activities of contaminated sites within their premises. Conversely, other industries such as metal plating, paper and textile in Malaysia are generally managed by small and medium enterprises (SMEs) which generally ignore contaminated spots within their premises due to their supposedly meagre profits to cover the high costs of remediation.

Figure 1 shows the list of contaminated land remediation technologies normally used in Malaysia. These technologies include soil vapour extraction, bio-remediation; remedial natural attenuation, containment, solidification and stabilization, contaminated soil excavation and phytoremediation. Subsequent sections provide a brief description of these technologies and their applicability in Malaysia

- **Soil Vapour Extraction**

Soil vapour extraction (SVE) removes harmful chemicals, in the form of vapours, from the soil above the water table. These chemicals are usually organic compounds which are easily volatilized (VOCs). The vapours are extracted (removed) from the ground by applying a vacuum to pull the vapours out (*USEPA, 2001*). This technology is depicted in *Figure 2*. In most local clean up projects involving organics (especially if groundwater contamination is a concern), remediation is usually conducted by means of SVE and coupled with above ground pump-and-treat (P&T) systems that incorporate small-scale wastewater treatment systems to facilitate and expedite the clean up process. Local application of SVE is very suitable due to constant warm temperature ($30^0 \pm 5^0$C) in the country throughout the year that facilitates

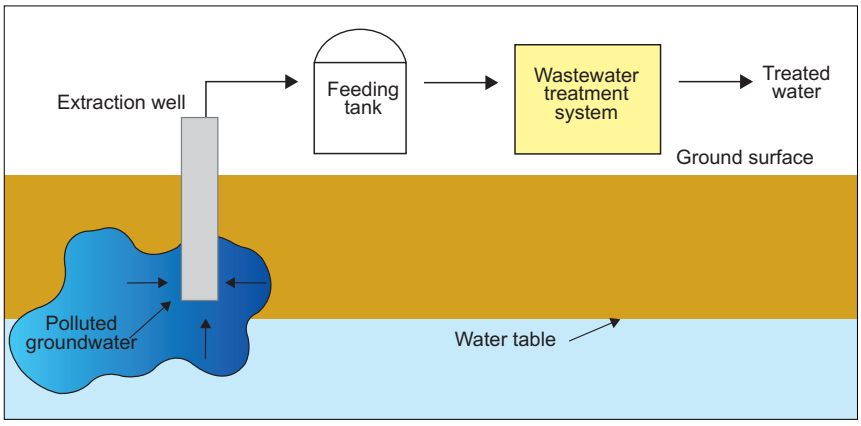

Figure 2: Soil vapour extraction (Adapted from USEPA, 2001)

rapid evapouration of organic-based chemicals under vacuum within contaminated soil matrix.

- **Bio-remediation And Remedial Natural Attenuation**

Bio-remediation allows natural processes to clean up harmful organic chemicals in the environment. Microbes that are present in soil and groundwater degrade certain harmful chemicals, such as those found in gasoline and oil spills. When microbes completely digest these chemicals, they change them into water and harmless gases such as carbon dioxide (*USEPA, 2001*). Bio-remediation can be conducted *in-situ* or *ex-situ*. The most significant parameters affecting bio-remediation are temperature, concentration of nutrients/fertilizers and concentration of oxygen (aeration). In Malaysia, laboratory-scale treatability studies must be carried out prior to actual clean-up. A diagram illustrating the mechanisms in bio-remediation is shown in *Figure 3*.

Natural attenuation relies on natural processes to clean up or attenuate pollution in soil and groundwater *in-situ*. Natural attenuation occurs at most polluted sites. However, the right conditions must exist to clean sites properly. If not, cleanup will not be quick enough or complete enough (*USEPA, 2001*). The supplementary engagement of experts to monitor or test these conditions to ensure natural attenuation is working is called monitored natural attenuation (MNA). In recent years, there have been requests for natural attenuation to be part of contaminated soil remediation strategies in Malaysia. This method is still novel and generally conducted subsequent to a primary clean-up activity where monitoring of soil conditions is initiated.

- **Containment**

This is the simplest remediation method currently used in Malaysia. It is employed if there are no potential environmental and/or public health threats posed by the sub-surface contaminants. This method merely involves paving the entire contaminated site with concrete to prevent public contact, with no effort on contaminant source removal. Additional steps involve placing a cover over contaminated material such as wastes buried at a landfill to stop rainwater from seeping through the wastes and carrying pollution into groundwater, lakes or rivers.

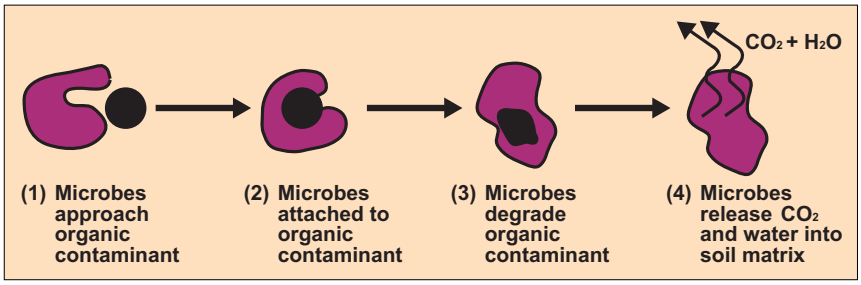

Figure 3: Mechanisms of bioremediation (Adapted from USEPA, 2001)

- **Solidification/Stabilization**

Solidification/Stabilization (S/S) technology uses physical and chemical processes to produce chemically stable solids with improved contaminant containment and handling characteristics (*USACE, 1995*). Solidification refers to a process whereby wastes in the form of sludges or soils, are solidified to produce free-standing and monolithic masses with enhanced physical integrity (*Cheng, 1991; USACE, 1995*). Stabilization is a chemical alteration technique of reducing the mobility and solubility of contaminants in wastes or soil (*Conner 1990; Vipulanandan and Wang, 1997*). S/S is best utilized for soil heavily contaminated with metals and can be utilized either *in-situ* or *ex-situ*. *In-situ* S/S operations, schematically shown in *Figure 4*, usually consist of augers to mix clean-up materials and metal contaminated soils with addition of water. The clean-up materials usually consist of chemical binders such as cement or lime (CaO) and other pozzolanic materials. S/S is the Best Demonstrated Available Technology (BDAT) in the US for remediation of metal contaminated soils due to its high effectiveness in stabilizing metals. This technology is also highly adaptable to Malaysian weather as high humidity permits high cementitious hydration of mixed slurry, rendering high compressive strength of the treated soils.

- **Contaminated Soil Excavation**

This is the conventional method used by the local authority (especially

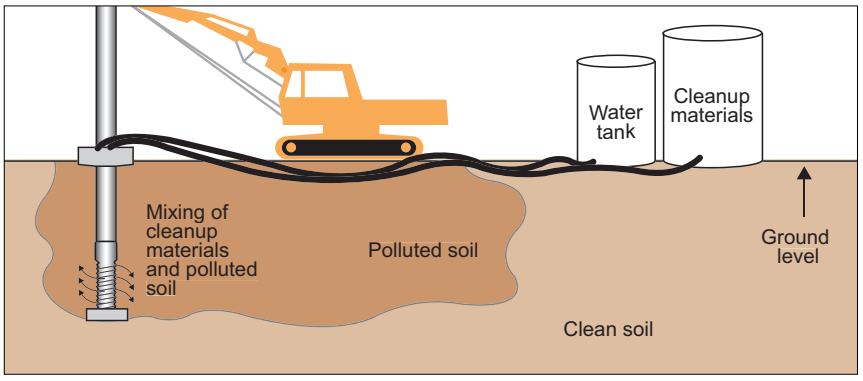

Figure 4: In-Situ solidification/stabilization of contaminated soil (USEPA, 2001)

the Department of Environment) to remove the direct threat of contaminated soil on groundwater caused by illegal dumping of scheduled wastes. The excavated contaminant is subsequently treated *ex-situ* at a treatment facility. Although this method is usually fast and cost-effective, alternative clean-up technologies are being considered as excavation is not viable for clean-up of soils contaminated at depths of more than five metres.

- **Phyto-remediation**

This method utilizes plants to accumulate heavy metals or organics in contaminated soils. It consists of two mechanisms, namely, phyto-extraction involving uptake of contaminants by plants and phyto-stabilization, where excretion of components from plants decrease soil pH and form metal complexes. The use of phyto-remediation for extraction of contaminants from soils is almost non-existent in Malaysia and is mainly limited to bench-scale research in academic institutions. However, this technology presents itself as an attractive remediation option as it increases the aesthetic values of the contaminated site and requires less equipment and labour than any other remediation methods.

Conclusions & Recommendations

Expertise and land remediation technologies are currently available in the global market. In the short term, Malaysia can rely on the pool of available experts and technologies in the global market. However, Malaysia must consider a long-term strategy to ensure expertise and technologies will be available locally. All agencies, either public or private should invest in the training of their personnel so that a pool of local experts can be made available in the near future. Various training institutions in the country should also provide training programmes, courses, seminars by bringing in experts from developed countries, especially from the US, or by tapping into the pool of experts from multi-national companies based in Malaysia. Contaminated soil remediation technologies, while still in their infancy in Malaysia in terms of market potential and applicability, should be viewed as important commodities especially since the Government plans to tighten legislations and policies regarding contaminated land remediation and due diligence matters. BEM

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