www.ijemr.net ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Volume-8, Issue-6, December 2018

International Journal of Engineering and Management Research

Page Number: 171-175

DOI: doi.org/10.31033/ijemr.8.6.16

Soil Remediation Technologies for Heavy Metals – A Review

Eva Lailatun Nisa Fatdillah[1] and Nur Irfah Mohd Pauzi[2]

[1]Student, Civil Engineering Department, College of Engineering, Universiti Tenaga, Nasional, Putrajaya Campus, KM7, Jalan IKRAM-UNITEN, 43009 Kajang, Selangor, MALAYSIA

[2]Senior Lecturer, Civil Engineering Department, College of Engineering, Universiti Tenaga, Nasional, Putrajaya Campus, KM7, Jalan IKRAM-UNITEN, 43009 Kajang, Selangor, MALAYSIA

[2]Corresponding Author: irfah@uniten.edu.my

ABSTRACT

Soil is a very vital necessity to the ecosystem and human population. Due to the urbanization and industrialization, the quality and the fertility of soil is deteriorating. This has been a huge concern among countries to discover the suitable yet effective solution to remediate the soil as the contaminated soil may introduce unhealthy and unsafe environment to society. One of the common pollutants in soils are heavy metals and it is very challenging to remediate as it is not biodegradable materials. Remediation methods for metals can be classified to two categories; in-situ remediation and ex-situ remediation. Studies show that chemical remediation the most effective methods used. Chemical remediation and biological remediation are also another two available options. Chemical remediation methods can be categorized into four; chemical leaching, chemical fixation, electrokinetic remediation and vitrify technology. Biological remediation includes phytoremediation, bioremediation and the combination of the remediation are one of the most cost effective methods that can be implemented especially in poor and middle income countries as it involves natures such as plants and animals in the process.

Keywords-- Soil Remediation, Contaminated Soil, Heavy Metals, Chemical Remediation, Biological Remediation

I. INTRODUCTION

Soil pollution is no longer a new issue but a concern in this industrialization and urbanization era. Due to the increasing of population, the land use demand is also growing and soil pollution is not only affecting it but also the value property of the neighborhood. In addition, contaminated site introduce unhealthy and unsafe environment towards society. According to Department of Environment Malaysia, contaminated land is a site which substance occur at above natural occurring metal level and can poses or likely poses immediate harm or long-term hazard towards society or environment while remediation is any action to eliminate, reduce, control or mitigate the risk of contaminated soil and groundwater.

The objectives for this paper is to review the current methods and technologies in heavy metals contaminated site for remediation purposes. (Wood, 2001) stated that generally there are three wide categories of methods of remediation; engineering approaches, technical approaches and hydraulic measures and natural attenuation. Engineering approaches includes landfill where it is an engineered design to isolate the contaminants from harming the environment. It is very systematic where it is designed to manage leachate of Municipal Solid Waste (MSW) and not polluting the soil. Technical approaches involves physical techniques, biological techniques, and stabilization of the soils. Hydraulic approaches consist methods in controlling groundwater flow to control the contaminants discharge while natural attenuation is a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater according to Environmental Protection Agency (EPA).

For decades, soil contamination and its remediation have been subject to research and study. Remediation in this context is the methods to reduce or to extract if possible the contaminants from the soil and recover the soil to its original state; not-polluted soil. The utility of any one soil remediation technique invariably depends on the nature of contamination and the level of risks posed by the contaminants (D. Kofi, 1996). For sites that contaminated by heavy metals, the challenge to remediate these kind of soils are due to the chronicity,

stealthiness and irreversibility (Wang, Li, & Wang, 2013). In Malaysia, the contamination soil is one of a major concern due to the increasing the number of land such as industrial sites, motor workshops, petrol stations, fuel depots, railway yards, landfills and ex-mining land. Generally, children is the highest risk group in the urban population exposed to heavy metal risk due to the higher adsorption rate of heavy metal of children as their accidental ingestion of particles soil particles from hand-to-mouth activities (Yuswir et al., 2015).

In Malaysia, the contaminated sites management and control falls under the Department of Environment. Before reporting the contaminated land to the authority, risk assessment and site screening are need to be done to investigate the risk of contamination. The assessment are divided into 3 steps; initial assessment, detailed assessment and risk assessment. Initial assessment is usually includes desk study, interview, and site visit. Detailed assessment is a subsurface investigation which involving the soil and the groundwater activities such as soil boring, groundwater well installation and soil and groundwater sampling to identify if the subsurface environment is affected. Risk assessment is a process where estimation of the potential impact to the ecosystem and human population under a specific set of conditions.

Throughout years of research and study, the best and suitable methods to remediate the contaminated site is yet to be found. It is challenging as each method usually only applicable to extract or reduce one pollutant while this particular site is commonly contaminated by more than one contaminant (Stoianet., al,, 2018). On the other side, for poor and middle income countries, some better methods and technologies are quite costly and not economical to be implemented. It is quite worrisome as recent study found that more than 2000 locations in these 47 countries are affected and exposed to toxic chemicals (Ludlow & Roux, 2012). In Malaysia, these kind of environmental issues are very complex and challenging due to the degree of cleaner technology used, competency of handling these issues, old issues are not properly address and the related regulations are not updated.

Figure 1 shows the site assessment and management process for soil contamination. The process has two phase which is phase 1 – initial assessment, phase II – detailed assessment and finally risk assessment. The initial assessment involve the desktop study, site reconnaissance, develop the conceptual site model and design site investigation. Furthermore, the detailed assessment will involve the data quality, safety and health, field measurement, data interpretation and reporting. Finally, the risk assessment evaluation will be done at the site. The hazard is identified, the toxicity assessment, exposure assessment and risk characterization based on the contaminated area.

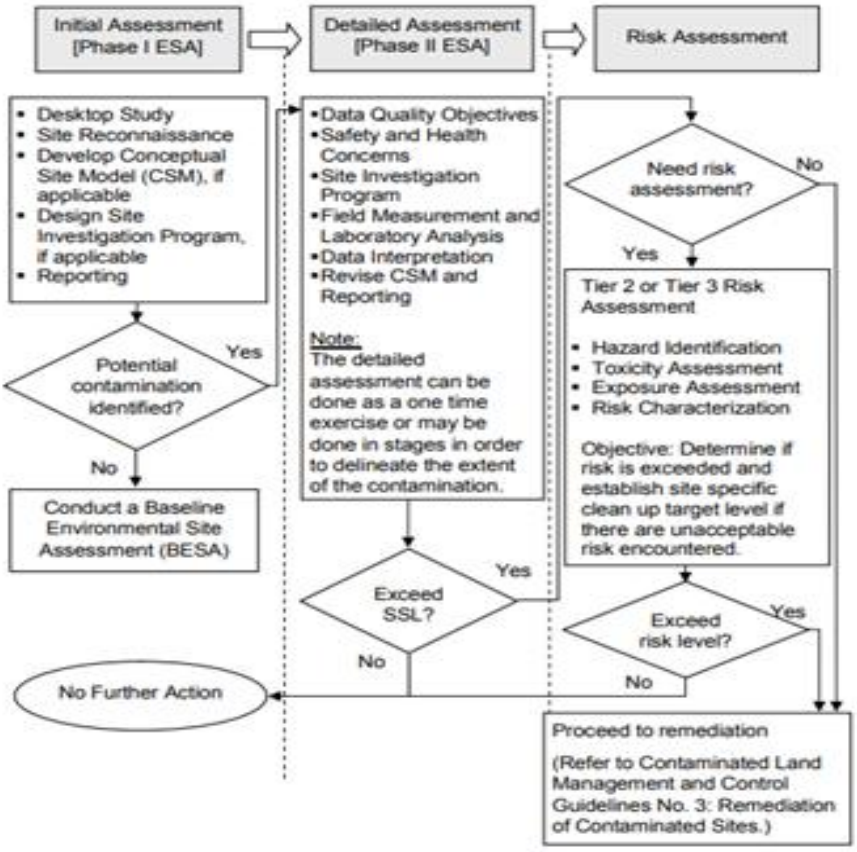

Figure 1: Site assessment and management process

II. HEAVY METALS CONTAMINATED SOIL

It is important to remediate soil contaminated by heavy metal as it poses threat to soil quality, environment, animals and society. The remediation process for heavy metal contaminant is a huge concern as it is not biodegradable and to discover the best method that cost effective is challenging. The soil pH, properties of metals, redox conditions, soil chemistry, organic matter content, clay content, cation exchange capacity and soluble ligands in the surrounding fluid play each roles in affecting the behavior of heavy metals in the soil.

Remediation methods can be classified to two categories; in-situ remediation and ex-situ remediation. In-situ technique referring to contaminated soil is not taken out and still stay at the place when the remediation process take place. Ex-situ techniques need excavation of soil then treat it or simply dispose it. Soil that involves in ex-situ technique can be handle on site or transported off-site. Study shows that chemical method of remediation is the most effective in removing of pollutant from the soil.

Soil replacement and thermal desorption are the common physical remediation used in recovering contaminated soil by heavy metal (Yao et. al., 2012). Soil replacing can be defined as replacing or partly replacing the contaminated soil with the clean soil to dilute the concentration of pollutant and increase the soil fertility and at the same time remediating the soil. Thermal desorption is putting the contaminated soil in the steam, infrared radiation, microwave up to the high temperature to make the pollutant volatile.

Most common chemical remediation methods can be categorized into four; chemical leaching, chemical fixation, electrokinetic remediation and vitrify technology. (Yao et al., 2012) summarized that chemical leaching is a process where contaminated soil is washed by fresh water, other liquids or gas that can help in leaching the pollutant from the soil so that the heavy metals in soil is transferred from soil to liquid phase through the ion exchange, precipitation , adsorption and leachate before recovered from it. Usually high concentration of HCl is used as its effectiveness in removing the pollutants however the higher concentration of acid in the soil is destructing and altering the physical, chemical and biological structure of the soil that can lead to nutrient loss in the soil.

The process of chemical fixation is the process where the soil is added by reagents or any materials into the contaminated soil and using them with heavy metals to form insoluble or hardly movable, low toxic matters, thus decreasing the migration of heavy metals to water, plant and other environmental media and achieving the remediation of the soil ((Yao et al., 2012 ; Zhao et al., 2004). In the same paper, it summarized that electrokinetic remediation is a process where voltage is applied at the two sides of soil then forming electric field gradient where the pollutant will was carried to two poles treatment room via elctromigration and treated further. The author also discussed the vitrify technology where it is one of the methods to remediate the soils by heating it at the temperature range from 1400-2000°C for the organic matters volatilize and decompose.

In addition, biological remediation that includes phytoremediation, bioremediation and the combination of the remediation can be applied to remove the heavy metals pollutants in soils. Bioremediation is a process where biological organisms are used to clean polluted soils. In phytoremediation, the process applied the usage of vegetation for in-situ treatments where the ideas is to emerging green approach by maximizing the natural ability of the plants such as plant roots can extend towards water table, while establishing a dense root mass that consume large quantities of water and stabilize contaminants to reduce leachablity(Ludlow & Roux, 2012). (Ranieri et. al., 2016) stated that;

"In particular, metal hyperaccumulation in different species is investigated with the aim of determining the mechanisms associated with the accumulation and detoxification of heavy metals and using these macrophytes and their rhizomes, roots, stems, and leaves for the decontamination of polluted sites"

(Wang et al., 2013) suggested EDTA washing technique to remove lead that polluting the soil. The study conducted by experimenting the soil with variety concentration of EDTA from 0 to 0.15mol/L. The results showed the increasing EDTA concentration introduce the reduction of cohesive value, 50% of leachate and content of illite, albite in the soil. It is also showed rising in number of internal angle of soil, and the content of quartz in soil. It is stated that the reduction of cohesive value and increasing of internal angle value are due to the arrangement of directionality of soil is weakened, the decreasing clay mineral and cincinal schistose.

(Fabbricino et. al., 2018) summarized the investigation of the application of ethylenediamine-N,N'-disuccinic acid (EDDS) as a washing solution for Pb-contaminated site. The author discussed thedifferent molar concentrations of the washing solutions and the efficiencies of varying solid/liquid ratio are tested at different pH values. The results shows that the contaminants are almost completely removed the mobile fraction of the metal bound to the soil particles where the extraction shows greater efficiency when the pH values are close to neutrality. Table 1 shows the summarization of remediation methods.

Table 1: Summarization of Remediation Methods

Method	Descriptions
Soil replacement	Replacement of the contaminated soil with the non-contaminated soil Two ways of technique; soil spading and importing new soil Reduce exposure and the risk of the contaminated sites to the environment High cost as use high labor work Suitable for severely contaminated small area
Soil Isolation	Separating contaminated soil from the non-contaminated soil Require a follow up remediation measure after isolation Prevent the contaminant to polluting the groundwater
Vitrification	Stabilization method that involving the usage of extremely high temperature In-situ vitrification able to treat mixed soil waste Complex process that cost highly and required lots of energy
Electrokinetic remediation	Process of transferring a low density electric current, ion and small particle charges between the electrode that imbedded in the soil
Phytoremediation	Categorized into phytoextraction, phytofiltration, phytostabilization, and phytovolatization Applying the usage of plants to extract pollutants and reduce it mobility in the soil Environmental friendly and cost effective method
Soil washing	Contaminated soil is washed by fresh water, other liquids or gas that can help in leaching the pollutant from the soil Removed contaminant completely from the soil Potentially altering the physical, chemical and biological structure of the soil
Chemical fixation	Process where the soil is added by reagents or any materials into the contaminated soil Reagents; organic and inorganic amendment

III. CONCLUSIONS

Remediation process for metals contaminated land is very challenging due to the chronicity, stealthiest and irreversibility of the metals. However, the remediation is still need to be carried out to reduce or to remove potential risk that can harm environment and society. The objective for this paper is to review the technologies and methods to remediate heavy metals contaminated soils.

Studies proves that chemical remediation is the most effective method to reduce contaminants in the soil. It shows that using high concentration of HCl as reagent to remediate heavy metals contaminated soil can reduce contaminant effectively but this method can destroy the physical, biological and chemical structure of the soil and altering it.

Biological remediation that includes phytoremediation and bioremediation is the most cost effective methods and easy to applied as it is maximize the ability of nature such as plants and animal to help in reduce the contaminants. Study shows vermin-remediation that use the natural earthworm can increase the biological, physical and chemical structure of the soil.

ACKNOWLEDGEMENT

The author would like to thank the Universiti Tenaga Nasional for supporting this research under bold grant with the number

UNITEN/RMC/10289176/B/9/2017/58 risk assessment prediction of settlement at open dumping area using Monte Carlo simulation.

REFERENCES

[1] Fabbricino, M., Ferraro, A., Luongo, V., Pontoni, L., & Race, M. (2018). Soil washing optimization, recycling of the solution, and ecotoxicity assessment for the remediation of pb-contaminated sites using EDDS. *Sustainability*, *10*(3), 636. https://doi.org/10.3390/su10030636

[2] Istrate, I., Cocârță, D., Wu, Z., & Stoian, M. (2018). Minimizing the health risks from hydrocarbon contaminated soils by using electric field-based treatment for soil remediation. *Sustainability*, *10*(1), 253. https://doi.org/10.3390/su10010253

[3] Ludlow, A., & Roux, P. (2012). Innovative technologies for sustainable environmental remediation in poor and middle income countries. *Journal of Health and Pollution*, *2*(3), 1-4.

[4] Ranieri, E., Bombardelli, F., Gikas, P., & Chiaia, B. (2016). Soil pollution prevention and remediation. *Applied and Environmental Soil Science*, *2016*, 1–2. https://doi.org/10.1155/2016/9415175

[5] Wang, P., Li, J., & Wang, H. (2013). Engineering properties of heavy metal contaminated soil affected by EDTA Washing. *EJGE*. Available at: http://www.ejge.com/2013/Ppr2013.354alr.pdf.

[6] Wood, P. (2001). Remediation methods for contaminated sites. *In Assessment and Reclamation of Contaminated Land*. Retrieved from http://dx.doi.org/10.1680/clair.25950.0003

[7] Yao, Z., Li, J., Xie, H., & Yu, C. (2012). Review on remediation technologies of soil contaminated by heavy metals. *Procedia Environmental Sciences*, *16*, 722–729. https://doi.org/10.1016/j.proenv.2012.10.099

[8] Yuswir, N. S., Praveena, S. M., Aris, A. Z., Syed Ismail, S. N., de Burbure, C., & Hashim, Z. (2015). Heavy metal contamination in urban surface soil of klang district (Malaysia). *Soil and Sediment Contamination: An International Journal*, *24*(8), 865–881. https://doi.org/10.1080/15320383.2015.1064090