The Prevalence of Heavy Metals (Arsenic) in Soils around Kuala Lumpur City, Malaysia

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Introduction

Heavy metals are among the principal contaminants in the environment. Beside the natural activities, almost all human activities also have potential contribution to produce heavy metals as side effects. Migration of these contaminants into non-contaminated areas as dust or particulates through the soil and spreading of heavy metals containing sewage sludge are a few examples of events contributing towards contamination of the ecosystems (1). Several methods are already being used to clean up the environment from these kinds of contaminants, but most of them are costly and far away from their optimum performance. The chemical technologies generate large volumetric sludge and increase the costs (2); chemical and thermal methods are both technically difficult and expensive that all of these methods can also degrade the valuable component of soils (3). Conventionally, remediation of heavy-metal-contaminated soils involves either onsite management or excavation and subsequent disposal to a landfill site.

This method of disposal solely shifts the contamination problem elsewhere along with the hazards associated with transportation of contaminated soil and migration of contaminants from landfill into an adjacent environment. Soil washing for removing contaminated soil is an alternative way to excavation and disposal to landfill. This method is very costly and produces a residue rich in heavy metals, which will require further treatment.

Moreover, these physic-chemical technologies used for soil remediation render the land usage as a medium for plant growth, as they remove all biological activities (1). Recent concerns regarding the environmental contamination have initiated the development of appropriate technologies to assess the presence and mobility of metals in soil (4), water, and wastewater. Presently, phyto-remediation has become an effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil. Phyto-remediation is the use of plants to clean up a contamination from soils, sediments, and water. This technology is environmental friendly and potentially cost effective (3).

The aims of this study are to discuss the potentials of recent techniques on absorbent heavy metal-contaminated sites, to provide new knowledge about heavy metals uptake mechanisms in soil and to give some description about the performance of soli uptake heavy metals such as arsenic (As).

Research Question

What is the prevalence of arsenic in the soils around Kuala Lumpur city, Malaysia?

Problem Statement

The soil and agriculture lands in & around the Kuala Lumpur city are at the risk of exposure of heavy metals from untreated agricultural, urban, and industrial effluents. This may results in bio-accumulation of heavy metals in soil and transfer into the underground water which human and animals can consume. Water and its tributaries pass through populated residential areas, towns, industrial and agricultural sites. The analysis of heavy metals that includes arsenic therefore, justified providing precautionary use of the soil, as well as providing a basis to sensitize government authorities such as National Environmental Management Authority (NEMA) towards management of discharge into the soil.

Hypothesis

The Heavy metal contamination with the arsenic remains one of the factors for the solid contamination in the capital city of Kuala Lumpur, Malaysia.

Literature Review

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline, and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (5, 6). Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) [7].

Soils are the major sinks for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation [8], and their total concentration in soils persists for a long time after their introduction [9]. Changes in their chemical forms (speciation) and bioavailability are, however, possible. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants [10]. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems [11–12].

The adequate protection and restoration of soil ecosystems contaminated by heavy metals require their characterization and remediation. Contemporary legislation respecting environmental protection and public health, at both national and international levels, are based on data that characterize chemical properties of environmental phenomena, especially those that reside in our food chain [13]. While soil characterization would provide an insight into heavy metal speciation and bioavailability, attempt at remediation of heavy metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, and environmental and associated health effects (risks) of these heavy metals. Risk assessment is an effective scientific tool which enables decision makers to manage sites so contaminated in a cost-effective manner while preserving public and ecosystem health [14].

Arsenic

Arsenic is a metalloid in group VA and period 4 of the periodic table that occurs in a wide variety of minerals, mainly as As_2O_3, and can be recovered from processing of ores containing mostly Cu, Pb, Zn, Ag and Au. It is also present in ashes from coal combustion. Arsenic has the following properties: atomic number 33, atomic mass 75, density 5.72 $g\,cm^{-3}$, melting point 817°C, and boiling point 613°C, and exhibits fairly complex chemistry and can be present in several oxidation states (−III, 0, III, V) [15]. In aerobic environments, As (V) is dominant, usually in the form of arsenate (AsO_4^{3-}) in various protonation states: H_3AsO_4, $H_2AsO_4^{-}$, $HAsO_4^{2-}$, and AsO_4^{3-}. Arsenate and other anionic forms of arsenic behave as chelates and can precipitate when metal cations are present (16). Metal arsenate complexes are stable only under certain conditions. Arsenic (V) can also co precipitate with or adsorb onto iron ox hydroxides under acidic and moderately reducing conditions. Co precipitates are immobile under these conditions, but arsenic mobility increases as pH increases (15).

Under reducing conditions As (III) dominates, existing as arsenite (AsO_3^{3-}), and its protonated forms H_3AsO_3, $H_2AsO_3^{-}$, and $HAsO_3^{2-}$. Arsenite can absorb or co precipitates with metal sulfides and has a high affinity for other sulfur compounds. Elemental arsenic and arsine, AsH_3, may be present under extreme reducing conditions. Biotransformation (via methylation) of arsenic creates methylated derivatives of arsine, such as dimethyl arsine HAs $(CH_3)_2$ and trimethylarsine As $(CH_3)_3$ which are highly volatile. Since arsenic is often present in anionic form, it does not form complexes with simple anions such as Cl^{-} and SO_4^{2-}. Arsenic speciation also includes organ metallic forms such as methylarsinic acid (CH_3) AsO2H2 and dimethylarsinic acid $(CH_3)_2AsO_2H$. Many as compounds adsorb strongly to soils and are therefore transported only over short distances in groundwater and surface water. Arsenic is associated with skin damage, increased risk of cancer, and problems with circulatory system (17).

Objectives

The objective of this study is:

- To determine the level of heavy metals; viz: arsenic (As) concentration in& around the soils of the capital city Kuala Lumpur, Malaysia.

Methods of Analysis

Location of study sites

Different places around the city (Approximately 4 different places around KL City)

Research design

Soils will be collected and sampled twice (June and July, 2016), and Statistical analysis will be carried out to estimate concentration of Arsenic in those soils according to the techniques mentioned in the table below.

Technologies for remediation of heavy metal-contaminated soils.

Category	Remediation technologies
Isolation	(i) Capping (ii) subsurface barriers.
Immobilization	(i) Solidification/stabilization (ii) vitrification (iii) chemical treatment.
Toxicity and/or mobility reduction	(i) Chemical treatment (ii) permeable treatment walls (iii) biological treatment bioaccumulation, phytoremediation (phytoextraction, phytostabilization, and rhizofiltration), bioleaching, biochemical processes.
Physical separation	
Extraction	(i) Soil washing, pyrometallurgical extraction, in situ soil flushing, and electrokinetic treatment.

Analysis of elements

Elements including lead, nickel, manganese, zinc, cadmium and chromium have been analyzed by various methods which include flame atomic absorption spectrometry(FAAS),graphite furnace absorption spectrometry (GF-AS) and inductively coupled plasma – atomic emission spectroscopy (18,19). Atomic absorption spectrometry is commonly used for it has the advantage of being highly specific, availability and selectivity (20).

Atomic absorption spectroscopy

The technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It requires a standard with known analyte content to establish the relation between the measured and the analyte concentrations and relies on Beer Lambert's law (21, 22).

References

A. Gaur and A. Adholeya, "Prospects of arbuscular mycorrhizal fungi in phytoremediation of heavy metal contaminated soils," Current Science, vol. 86, no. 4, pp. 528–534, 2004.

R. Rakhshaee, M. Giahi, and A. Pourahmad, "Studying effect of cell wall's carboxyl-carboxylate ratio change of Lemna minor to remove heavy metals from aqueous solution," Journal of Hazardous Materials, vol. 163, no. 1, pp. 165–173, 2009. View at Publisher

R. R. Hinchman, M. C. Negri, and E. G. Gatliff, "Phytoremediation: using green plants to clean up contaminated soil, groundwater, and wastewater," Argonne National Laboratory Hinchman, Applied Natural Sciences, Inc, 1995, http://www.treemediation.com/Technical/Phytoremediation_1998.pdf.

Shtangeeva, J. V.-P. Laiho, H. Kahelin, and G. R. Gobran, "Phytoremediation of metal-contaminated soils. Symposia Papers Presented Before the Division of Environmental Chemistry," American Chemical Society, Anaheim, Calif, USA, 2004, http://ersdprojects.science.doe.gov/workshop_pdfs/california_2004/p050.pdf.

S. Khan, Q. Cao, Y. M. Zheng, Y. Z. Huang, and Y. G. Zhu, "Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China," Environmental Pollution, vol. 152, no. 3, pp. 686–692, 2008. View at Publisher

M. K. Zhang, Z. Y. Liu, and H. Wang, "Use of single extraction methods to predict bioavailability of heavy metals in polluted soils to rice," Communications in Soil Science and Plant Analysis, vol. 41, no. 7, pp. 820–831, 2010.

GWRTAC, "Remediation of metals-contaminated soils and groundwater," Tech. Rep. TE-97-01,, GWRTAC, Pittsburgh, Pa, USA, 1997, GWRTAC-E Series.

T. A. Kirpichtchikova, A. Manceau, L. Spadini, F. Panfili, M. A. Marcus, and T. Jacquet, "Speciation and solubility of heavy metals in contaminated soil using X-ray microfluorescence, EXAFS spectroscopy, chemical extraction, and thermodynamic modeling," Geochimica et Cosmochimica Acta, vol. 70, no. 9, pp. 2163–2190, 2006.

D. C. Adriano, Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability and Risks of Metals, Springer, New York, NY, USA, 2nd edition, 2003.

P. Maslin and R. M. Maier, "Rhamnolipid-enhanced mineralization of phenanthrene in organic-metal co-contaminated soils," Bioremediation Journal, vol. 4, no. 4, pp. 295–308, 2000

M. J. McLaughlin, B. A. Zarcinas, D. P. Stevens, and N. Cook, "Soil testing for heavy metals," Communications in Soil Science and Plant Analysis, vol. 31, no. 11–14, pp. 1661–1700, 2000.

M. J. McLaughlin, R. E. Hamon, R. G. McLaren, T. W. Speir, and S. L. Rogers, "Review: a bioavailability-based rationale for controlling metal and metalloid contamination of agricultural land in Australia and New Zealand," Australian Journal of Soil Research, vol. 38, no. 6, pp. 1037–1086, 2000.

W. Ling, Q. Shen, Y. Gao, X. Gu, and Z. Yang, "Use of bentonite to control the release of copper from contaminated soils," Australian Journal of Soil Research, vol. 45, no. 8, pp. 618–623, 2007. View at Publisher

Kabata-Pendias and H. Pendias, Trace Metals in Soils and Plants, CRC Press, Boca Raton, Fla, USA, 2nd edition, 2001.

Q. Zhao and J. J. Kaluarachchi, "Risk assessment at hazardous waste-contaminated sites with variability of population characteristics," Environment International, vol. 28, no. 1-2, pp. 41–53, 2002. View at Publisher

I. Bodek, W. J. Lyman, W. F. Reehl, and D. H. Rosenblatt, in Environmental Inorganic Chemistry: Properties, Processes and Estimation Methods, Pergamon Press, Elmsford, NY, USA, 1988.

A. Scragg, Environmental Biotechnology, Oxford University Press, Oxford, UK, 2nd edition, 2006

Aceto, M., Abollino, O., Bruzzoniti, M.C., Mentasti, E., Sarzanini, C., Malandrino, M. (2002) Food Additives and Contaminants, 19:126.

Bingol, D. and Akcay, M. (2005) Determination of trace elements in fly ash samples by AAS after applying different digestion procedure. Journal of Quantitative Spectroscopy and Radiative Transfer, 101:146-150.

Christian, G.D. (2005) Analytical Chemistry. 6th Ed John Wiley and Sons. pp 474-478.

García, R. and A. P. Báez (2012) Atomic Absorption Spectrometry (AAS), Atomic Absorption Spectroscopy, Muhammad Akhyar Farrukh (Ed.), http://www.intechopen.com/books/atomic-absorption-spectroscopy/atomic-absorption-spectrometry-aas-.Accessed on 19th December 2012.

Skoog, D.A., West, D.M., Holler, F.J. and Crouch, S.R.(2005) Fundamentals of Analytical Chemistry. Publisher, Chemistry: David Harries, 8th Ed, pp 720-723.