UNIVERSITI PUTRA MALAYSIA

AVAILABILITY AND PHYTOREMEDIATION OF ZINC AND COPPER IN TWO MALAYSIAN SOILS TREATED WITH SEWAGE SLUDGE

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By

AISHAH RAMADAN MOHAMED BINADAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To the soul of my father "may Allah forgive him and grant him his highest paradise".
To my beloved mother and my siblings with love and eternal appreciation.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Professor Shamshuddin Jusop, PhD
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The disposal of municipal sewage sludge face serious challenges. Currently, over 3.2 $\times 10^6$ metric tons of domestic sewage sludge in Malaysia are in need of safe disposal. Phytoremediation provides an efficient soil remediation solution since it uses plants to remove contaminants. A glasshouse experiment were conducted to assess the potential of four plant species (*Jatropha curcas, Hibiscus cannabinus, Acacia mangium* and *Syzigium cumini*) to the phytoremediation of excess Zn and Cu in Oxisol and in Ultisol amended by different rates of sewage sludge: 0, 5 and 10% v/v.

The results showed that the addition of 10% e sludge enhanced the nutritional status of the Oxisol and Ultisol, shown by the increase in soil pH from 5.36$\pm$0.01 to 5.84$\pm$0.02 in the Oxisol, and from 4.77$\pm$0.02 to 5.37$\pm$0.01 in the Ultisol, the CEC increased from 8.00$\pm$0.57 to 9.39$\pm$0.01 $cmol_c\ kg^{-1}$ in Oxisol and from 10.33$\pm$0.01 to 11.22$\pm$0.06 $cmol_c\ kg^{-1}$, available P increased from 10.70$\pm$0.05 mg kg^{-1} to 24.00$\pm$0.02 mg kg^{-1}, in Oxisol and from10.90 $\pm$0.05 mg kg^{-1} to 26.80$\pm$0.01 mg kg^{-1} in Ultisol.

Among the four plants examined, it was found that *J. curcas* and *H. cannabinus* were capable of accumulating more Zn and Cu than those of the *A. mangium* and *S. cumini,* which was shown by their high translocation factor (TF>1). *H. cannabinus* had the highest TF value of Zn (2.43$\pm$0.02), while *J. curcas* had the highest TF value of Cu (1.52$\pm$0.02).

Fractionation of metals showed that the Zn and Cu existed in the residual form, while the sludge application into the soils tended to shift the forms of Zn and Cu away from residual fraction to water soluble and exchangeable fractions that might be more available for plant uptake.

A leaching study was conducted to determine movement of Zn and Cu in the tested soils. The results showed that the application of 10% sewage sludge seemed to increase the concentration of Zn and Cu in the leachates of the soils, the maximum concentration of Zn in the leachates from the Ultisol was 82.35 ±0.45 mg L^{-1} which was higher than that of the Oxisol 62.91 ±0.25 mg L^{-1}. For Cu, it was 8.69 ±0.15 mg L^{-1} in the leachates of the Ultisol which was lower than that of the Oxisol of 11.67 ±0.05 mg L^{-1}. The downward movement of Zn and Cu in the soil columns after the leaching process was different among the metals, whereby Zn had a lower concentration (1.12 ±0.03 mg kg^{-1}) compared that to Cu (5.6 ±0.07 mg kg^{-1}) in the both soils, especially for the 0-5 cm layer.

The results adsorption study showed that the sewage sludge application had significant effect on the processes of adsorption-desorption of Zn and Cu. This is shown by the systematic change of the distribution coefficients (K_d). Comparison between K_d values for both soils indicated the following selectivity of metals: Cu (K_d= 3.42) > Zn (K_d=2.82). It is clear that Zn adsorption was lower than that of Cu. The adsorption isotherms of Zn and Cu of both soils were well fitted to linear Freundlich and Langmuir equations (R^2 = 0.96 - 0.99).

This study suggests that sewage sludge possessed the ability to improve the fertility of highly weathered soils. However, the presence of Zn and Cu is a negative side effect of using sewage sludge. The excess Zn and Cu in treated soils can be successfully removed by phytoremediators, such as *J. curcas* and *H. cannabinus*.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KETERSEDIAAN DAN FITOREMEDIASI ZINK DAN KUPRUM DALAM DUA JENIS TANAH MALAYSIA YANG DIRAWAT DENGAN SISA KUMBAHAN

Oleh

AISHAH RAMADAN MOHAMED BINADAM

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Pengerusi : Profesor Shamshuddin Jusop, PhD
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Pelupusan sisa kumbahan adalah suatu proses yang amat mencabar. Di Malaysia, lebih 3.2 juta tan metrik sisa kumbahan domestik perlu dilupuskan dengan selamat. Fitoremediasi merupakan suatu penyelesaian untuk pemulihan tanah yang efisien kerana ianya menggunakan tumbuhan untuk mengelurkan bahan pencemaran dari tanah. Satu kajian rumah kaca telah dijalankan bertujuan menilai potensi empat spesies tumbuhan (*Jatropha curcas*, *Hibiscus cannabinus*, *Acacia mangium* and *Syzigium cumini*) untuk fitoremediasi kandungan Zn dan Cu yang berlebihan dalam tanah Oxisol dan Ultisol yang diletakkan dengan sisa kumbahan pada kadar yang berbeza, iaitu pada kepekatan 0, 5 dan 10% i.p./ i.p.

Hasil kajian mendapati tanah Oxisol dan Ultisol yang rawat dengan sisa kumbahan pada kadar 10% menunjukkan peningkatan dari segi nutrisi tanah berdasarkan kenaikan pH dari 5.36±0.01 ke 5.84±0.02 dalam tanah Oxisol dan dari 4.77±0.02 ke 5.37±0.01 dalam tanah Ultisol. Nilai CEC tanah meningkat dari 8.00±0.57 ke 9.39±0.01 $cmol_c$ kg^{-1} dalam tanah oxisol dan dari 10.33±0.01 ke 11.22±0.06 $cmol_c$ kg^{-1} dalam tanh Ultisol. Ketersediaan P juga meningkat dari 10.70±0.05 mg kg^{-1} ke 24.00±0.02 mg kg^{-1} dalam tanah Oxisol dan dari 10.90 ±0.05 mg kg^{-1} ke 26.80±0.01 mg kg^{-1} dalam tanah Ultisol.

Di antara empat jenis tumbuhan yang dikaji, didapati pokok *J. curcas* dan *H. cannabinus* menunjukkan keupayaan mengumpulkan lebih banyak Zn dan Cu berbanding dengan pokok *A. mangium* dan *S. cumini*, berdasarkan kepada faktor translokasi yang tinggi (TF>1). Pokok *H. cannabinus* menunjukkan nilai TF yang paling tinggi untuk Zn (2.42±0.02), manakala *J. curcas* pula menunjukkan nilai TF yang paling tinggi untuk Cu (1.52±0.02).

Kajian komposisi logam menunjukkan Zn dan Cu wujud dalam bentuk mendakan, manakala aplikasi sisa kumbahan pada tanah menyebabkan kecenderungan penukaran Zn dan Cu daripada bentuk mendakan ke bentuk yang larut air dan dalam keadaan boleh ditukarganti dan lebih tersedia untuk tumbuhan.

Suatu kajian larutlesap telah dijalankan untuk melihat pergerakan Zn dan Cu dalam tanah yang diuji. Hasil kajian menunjukkan aplikasi sisa kumbahan pada kepekatan 10% meningkatkan kandungan Zn dan Cu dalam hasil larutlesap. Kepekatan maksimum Zn dalam hasil larutlesap tanah Ultisol adalah sebanyak 82.35 ±0.45 mg L^{-1} dan lebih tinggi berbanding kepekatan dalam tanah Oxisol iaitu sebanyak 62.91 ±0.25 mg L^{-1}. Manakala untuk Cu pula, kepekatan dalam hasil larutlesap tanah Ultisol adalah 8.69 ±0.15 mg L^{-1} iaitu lebih rendah berbanding tanah Oxisol sebanyak 11.67 ±0.05 mg L^{-1}. Pergerakan Zn dan Cu menuruni kolum tanah hasil dari proses larutlesap adalah berbeza. Kepekatan Zn adalah lebih rendah (1.12 ±0.03 mg kg^{-1}) berbanding kepekatan Cu (5.6 ±0.07 mg kg^{-1}) untuk kedua-dua jenis tanah terutamanya pada lapisan 0-5 sm.

Keputusan kajian jerapan menunjukkan aplikasi sisa kumbahan memberikan kesan yang ketara dalam proses jerapan dan pembebasan Zn dan Cu dalam tanah. Ini dibuktikan oleh perubahan yang sistematik dalam nilai pembolehubah taburan (K_d). Perbandingan antara nilai K_d untuk kedua-dua jenis tanah menunjukkan urutan pilihan logam seperti berikut: Cu (K_d= 3.42)> Zn (K_d=2.82). Jerapan Zn adalah jelas lebih rendah berbanding Cu. Isoterma jerapan untuk Zn dan Cu dalam kedua-dua jenis tanah adalah sangat menepati persamaan linear Freundlich dan Langmuir (R^2 = 0.96 - 0.99).

Kajian ini menunjukkan bahawa sisa kumbahan mempunyai keupayaan untuk meningkatkan kesuburan tanah yang terluluhawa, walaupun kehadiran Zn dan Cu merupakan kesan sampingan yang negatif dari penggunaan bahan ini. Namun, kandungan Zn dan Cu yang berlebihan dalam tanah ini boleh hapuskan melalui fitoremediasi oleh pokok *J. curcas* dan *H. cannabinus*.

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I certify that a Thesis Examination Committee has met on 21 July 2017 to conduct the final examination of Aishah Ramadan Mohamed Binadam on her thesis entitled "Availability and Phytoremediation of Zinc and Copper in Two Malaysian Soils Treated with Sewage Sludge" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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LIST OF ABBREVIATIONS, UNITS AND SYMBOLS

Å	Angstrom
AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of variance
BCF	Bio-concentration factor
BD	Bulk density
Ca	Calcium
CEC	Cation Exchange Capacity
cm	Centimeter
F1	Water soluble fraction of heavy metal
F2	Extractable fraction of heavy metal
F3	Carbonate Fraction of heavy metal
F4	Fe-Mn Oxides Fraction of heavy metal
F5	Organic Fraction of heavy metal
F6	Residual Fraction of heavy metal
ICP	inductively coupled plasma spectrometry
IWK	Indah Water Konsortium
L	liter
Mg	Magnesium
mg kg^{-1}	Milligram per kilogram
OM	Organic matter
PCA	Principal Component Analysis
PCV	Polyvinyl chloride
PET	polyethylene terephthalate container
SAS	Statistical Analysis System
TC	Total Carbon
TF	Transfer factor
TN	Total Nitrogen
XRD	X-ray Diffraction

CHAPTER 1

INTRODUCTION

1.1 General overview

The accruing benefits from sludge recycling generated from sewage treatment of municipal wastewater cannot be neglected because this sewage sludge has become a subject of research in different fields in recent years. A growing number of environmentalist scientists are becoming interestingly over the importance of sewage sludge recycling which is of great concern for environmental such as soil pollution. However, due to the increasing costs of chemical fertilizers; recycling sewage sludge as a fertilizer is economical option.

Increased population, a consequence of economic development and rapid urbanization has led to the production of huge amounts of sewage sludge around the world, which brings about considerable stresses on the environment and accumulation of various kinds of biological and chemical pollutants, especially on soils (Adriano, 2013). Sewage sludge has been used as an amendment to soil improvement conditions. The application of sewage sludge to tropical soils is one of the proposed methods of maintaining soil characteristics. It is also an alternative for the disposal of waste products. Sewage sludge has the potential to enhance soil productivity because it contains high organic matter (30 to 56%) and plant nutrients. Malaysian domestic sewage sludge is acidic in nature (pH 3.92 to 6.43) and it has variable chemical composition (nitrogen (N), phosphorus (P), calcium (Ca), potassium (K) and magnesium (Mg)) and heavy metals with higher concentrations of zinc (153 to 7012 mg kg^{-1}) and copper (63 to 732 mg kg^{-1}). However, environmental issues concerning contamination are increasing in heavy metals in soil which is derived from applying sewage sludge to soils (Indah Water Konsorttium, 2014). The disposal of sewage sludge from wastewater treatment plants is a problem of concern due to the challenges in disposal and the cost of disposal. However, in Malaysia, issues concerning the disposal of sewage sludge owing to the limited number of facilities of sewage sludge treatment have given rise to environmental pollution (Indah Water Konsorttium, 2014).

In the 21st century, pollution control has turned out to be a big challenge because of a spectacular growth in contaminants caused from activities of human (Larue et al., 2010). Pollution of forest and agricultural soils is probably to continue and has become comparatively widespread already. Heavy metals, organic and inorganic pollutants are accumulating in soils from different resources such as transport, agricultural activities, industrial and sewage sludge (Salomons and Stigliani, 2012).

Higher costs of chemical fertilizers, higher prices of alternate disposal besides stricter guidelines on discharge of sewage sludge into water procedures have increased in application of sewage sludge in production of crop. Some studies have addressed the risks and benefits of agricultural usage of sewage sludge (Alvarenga et al., 2015).

Sewage sludge could improve the physio-chemical conditions of soil. But the most important discussion in using sewage sludge is the increase in heavy metals. Applying sewage sludge to soils must be limited by heavy metals presence as well as other pollutants (Fang et al., 2016). Soil application of sewage sludge is widely recommended in numerous countries due to its environmental advantage and economic benefits, obtained by the purposeful use of sewage sludge (Wu et al., 2012). In fact, there is limited information in the long-term impacts of sewage sludge on the structural and chemical properties of soils in the wet tropics lands (Nogueirol et al., 2013).

However, concerns were brought up on the fact that excessive and repeated addition of sewage sludge could lead to detrimental environmental risks, particularly in soils toxic metals pollution (Wu et al., 2012). It has also been claimed that heavy metal on soils has been increased due to applying sewage sludge and this would possibly present risk to humans, animals and plants (Bondarczuk et al., 2016). Most commonly found heavy metals in sewage sludge are zinc (Zn), copper (Cu), lead (Pb), nickel (Ni) and cadmium (Cd). Zinc and Cu must be carefully checked and controlled because when the sewage sludge is applied to soil.

Zinc and copper gained more attention because of their high concentrations in sewage sludge (7012 and 732 mg kg^{-1} for Zn and Cu respectively). Consequently, we chose to study Zn and Cu, which are essential to plants when in low concentrations, but toxic when in high concentrations. Yet Zn and Cu have a contrasting behavior in soils, with Cu typically found less mobile than Zn (Mehes-Smith et al., 2014).

High concentrations of heavy metals in soil lead to phytotoxic effect and led to bad development on vegetation (Wuana and Okieimen, 2011; Adriano, 2013). However, recognizing the chemical forms in which the metals are preserved in soil helps to predict their mobility to water sources (Rosazlin et al., 2006).

Consequently, remediation of soil polluted by heavy metals is needed in imperative to scale down the related hazards, create the soil obtainable for agricultural production, and improve food safety. So far different conventional remediation methods have been employed for the purpose of remediation soils. Efforts presented by various academics to clean up polluted soils are either too costly or not ecofriendly, where different type of conventional remediation methods have been used in earlier decades but limited methods have been applied successfully in practice. Presently, there is phenomenal attention in the methods of phytoremediation (Öztürk, 2016).

Phytoremediation is one of the unique methods of the remedial hopes for environment. The achievement of phytoremediation can be contingent in a high precision on the selection of the plants, agriculture conditions, land adjustments, and heavy metals movements which is soil and climate specific (Hernandez-Allica et al., 2008). Plant species grown in contaminated soils have the ability to uptake heavy metals in ions form soil solution and stored in different parts of the plant such as leaves, stems, fruits, seeds, and roots (Tangahu et al., 2011). Plants readily assimilated metals through their roots in dissolve water and ionic forms (Bohra et al., 2015).

Soil pollution has become a major source of concern and has posed serious environmental problems within the last few years in many developed nations. Sewage sludge is one of the major sources of enrichment of heavy metals. It contains heavy metals such as Zn and Cu. Phytoremediation offers environmental friendly method to treat the polluted soil. It offers opportunities to use the biomass of plant for environmental benefits. Hence, this study is crucial in examining the ability of woody plants species as Zn and Cu accumulators for remediating Oxisol and Ultisol.

1.2 Justification

Sewage sludge applications onto soils offer multiple benefits and adverse environmental consequences. Variety pollutants, including heavy metals, are eventually transported to the environment. Thus, soil contaminants need to be cleaned up to improve environmental safety. This study was conducted to quantify the response of weathered highly soils to an increase in pollution due to sewage sludge application and to assess the ability of phytoremediation technology in remediating two Malaysian soils treated with sewage sludge.

1.3 The Objectives

This study was aimed to evaluate the efficacy of selected woody plants (*Jatropha curcas, Hibiscus cannabinus, Acacia mangium* and *syzigium cumini*) as Zn and Cu accumulators in contaminated soils .

Considering the previous background, the specific objectives of the present study were:

i. To screen the ability of four woody plants species as heavy metals accumulators in Oxisol and Ultisol amended with sewage sludge;
ii. To elucidate the potential of two selected plants species to remediate heavy metal contaminated soils which have been treated with sewage, and to determine the availability and relative distribution of various forms of the metals in the sewage sludge and treated soils;
iii. To investigate the influence of sewage sludge on the leaching and downward movement characteristics of Zn and Cu; and
iv. To assess the adsorption and desorption of Zn and Cu for soils having different rates of sewage sludge.

REFERENCES

Abbas, A. H., Ibrahim, A. B. A., Nor, M. F. M. and Aris, M. S. 2011. Characterization of Malaysian domestic sewage sludge for conversion into fuels for energy recovery plants. *National Postgraduate Conference (NPC), 2011*. Date of Conference*:* 19-20 Sept. 2011. Page(s): 1 – 4 Print ISBN: 978-1-4577-1882-3.INSPEC Accession Number: 12495082.Conference Location: Kuala Lumpur. Digital Object Identifier: 10.1109/ Nat PC.2011.6136402.

Abdulla, R., Chan, E. S. and Ravindra, P. 2011. Biodiesel production from *Jatropha curcas*: a critical review. *Critical Reviews in Biotechnology*. 31(1): 53–64.

Abhilash, P. C., Srivastava, P., Jamil, S. and Singh, N. 2011. Revisited *Jatropha curcas* as an oil plant of multiple benefits: critical research needs and prospects for the future. *Environmental Science and Pollution Research*.18(1): 127-131.

Adams, N., Carroll, D., Madalinski, K., Rock, S., Wilson, T. and Pivetz, P. 2000. Introduction to Phytoremediation. Report EPA/600/R-99/107. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Adriano, D. C. 2013. Trace elements in the terrestrial environment, Springer Science and Business Media.

Ahmad, T., Ahmad, K. and Alam, M. 2016. Sustainable management of water treatment sludge through 3 'R'concept. *Journal of Cleaner Production*. 124: 1–13.

Ahmadpour, P., Ahmadpour, F., Mahmud, T. M. M., Abdu, A., Soleimani, M. and Tayefeh, F. H., 2014a. Phytoremediation of heavy metals: A green technology. *Heavy Metal Contamination of Water and Soil: Analysis, Assessment, and Remediation Strategies*, p.249.

Ahmadpour, P., Soleimani, M., Ahmadpour, F. and Abdu, A. 2014 b: Evaluation of Copper Bioaccumulation and Translocation in *Jatropha curcas* Grown in a Contaminated Soil. *International Journal of Phytoremediation* . 16(5): 454-468.

Ahmed, G., Miah, M. A., Anawar, H. M., Chowdhury, D. A. and Ahmad, J. U. 2012. Influence of multi-industrial activities on trace metal contamination: an approach towards surface water body in the vicinity of Dhaka Export.Processing Zone (DEPZ). *Environmental monitoring and assessment*. 184(7): 4181-4190.

Akan, J. C., Abdulrahman, F. I., Sodipo, O. A. and Lange, A. G. 2010. Physicochemical Parameters in Soil and Vegetable Samples from Gongulon Agricultural Site, Maiduguri- Borno State, Nigeria. *Journal of American Science*. 6 (12):78-87.

Ali, H., Khan, E. and Sajad, M. A. 2013. Phytoremediation of heavy metals-concepts and applications. *Chemosphere*. 91(7): 869-881.

Alloway, R.T.1990. Heavy metals in soils. Blaikie and John Wiley and Sons Inc.: New York.

Almeida, A. A. F. D., Valle, R. R., Mielke, M. S. and Gomes, F. P. 2007. Tolerance and prospection of phytoremediator woody species of Cd, Pb, Cu and Cr. *Brazilian Journal of Plant Physiology*, 19(2): 83-98.

Alumaa, P., Kirso, U., Petersell, V. and Steinnes, E. 2002. Sorption of toxic heavy metals to soil. *International Journal of Hygiene and Environmental Health*. 204(5-6): 375-376.

Alvarenga, P., Mourinha, C., Farto, M., Santos, T., Palma, P., Sengo, J., Morais, M.C. and Cunha-Queda, C. 2015. Sewage sludge, compost and other representative organic wastes as agricultural soil amendments: Benefits versus limiting factors. *Waste Management*. 40:44-52.

Anamika, S and Fulekar, M. H. 2012. Phytoremediation of Heavy Metals by *Brassica juncea* in Aquatic and Terrestrial. Environment .*Environmental Pollution* . 21: 153-169.

Anda, M., Shamshuddin, J., Fauziah, C. I. and Omar, S.S. 2008. Mineralogy and factors controlling charge development of three Oxisols developed from different parent materials. *Geoderma.* 143(1):153-167.

Anderson, J.M. and Ingram, J.S.I. 1993. Tropical Soil Biology and Fertility. A Handbook of Methods, 2 Edn., pp: 221.CAB International, Wallingford U.K.

Angin, I. and Yaghanoglu, A. V. 2011. Effects of sewage sludge application on some physical and chemical properties of a soil affected by wind erosion. *Journal of Agricultural Science and Technology*. 13: 757-768

Anjum, N. A., Pereira, M. E., Ahmad, I., Duarte, A. C. and Umar, S. 2012. Phytotechnologies: Remediation of environmental contaminants .CRC press Taylor and Francis Group.

Anten, N. P. 2004. Optimal photosynthetic characteristics of individual plants in vegetation stands and implications for species coexistence. *Annals of Botany*.95(3): 495-506.

Antoniadis, V. and Golia, E. E. 2015. Adsorption of Cu and Zn in low organic matter-soils as influenced by soil properties and by the degree of soil weathering *Chemosphere*. 138: 364–369.

Arbaoui, S., Evlard, A., Mhamdi, M. E.W., Campanella, B., Paul, R. and Bettaieb, T. 2013. Potential of kenaf (*Hibiscus cannabinus* L.) and corn (*Zea mays* L.) for phytoremediation of dredging sludge contaminated by trace metals. *Biodegradation*. 24(4):563-567.

Ariyakanon, N. and Winapanich, B. 2006. Phytoremediation of Copper Contaminated Soil by *Brassica juncea* (L.) Czern and *Bidens alba* (L.) DC. var. radiate. *J. Sci. Res. Chula.Univ.* 31: 49-56.

Ashori, A., Harun, J., Raverty, W. D. and Yusoff, M. N. M. 2006. Chemical and morphological characteristics of Malaysian cultivated kenaf (*Hibiscus cannabinus*) fiber. *Polymer-Plastics Technology and Engineering*. 45(1):131-134.

ASTM. 2000. Standard test methods for moisture, ash, and organic matter of peat and other organic soils. Method D 2974-00. American Society for Testing and Materials. West Conshohocken, PA.

Ayyanar M, Subash-Babu P 2012. Syzygium cumini (L.) Skeels: A review of its phytochemical constituents and traditional uses. Asian *Pacific Journal of Tropica*l *Medicine* .2: 240- 246.

Ayyanar, M. and Subash-Babu P. 2012. *Syzygium cumini (L.)* Skeels: a review of its phytochemical constituents and traditional uses. *Asian Pacific Journal of Tropical Biomedicine*. 2(3): 240-246.

Azizi, A. B., Lim, M. P. M., Noor, Z. M. and Abdullah, N. 2013. Vermiremoval of heavy metal in sewage sludge by utilising Lumbricus rubellus. *Ecotoxicology and environmental safety*. 90:13-20.

Bada, S. B. and Kalejaiye, S. T. 2010. Response of Kenaf (*Hibiscus cannabinus* L.) grown in different soil textures and lead concentration. *Research Journal of Agriculture and Biological Sciences*. 6(5): 659-664.

Badr, N., Fawzy, M. and Al-Qahtani, K. M. 2012. Phytoremediation: an economical solution to heavy-metal-polluted soil and evaluation of plant removal ability. *World Applied Sciences Journal*. 16(9): 1292-1301.

Bech, J., Duran, P., Roca, N., Poma, W., Sánchez, I., Barceló, J., Boluda, R., Roca-Pérez, L. and Poschenrieder, C. 2012. Shoot accumulation of several trace elements in native plant species from contaminated soils in the Peruvian Andes. *Journal of Geochemical Exploration*. 113:106-111.

Bech, J., Roca, N., Tume, P., Ramos-Miras, J., Gil, C. and Boluda, R., 2016. Screening for new accumulator plants in potential hazards elements polluted soil surrounding Peruvian mine tailings. *Catena*. 31:136:66-73.

Behbahaninia, A. , Mirbagheri, S. A., Khorasani, N., Nouri, J. and Javid, A. H. 2009. Heavy metal contamination of municipal effluent in soil and plants. *Journal of Food Agriculture and Environment.*7 (3-4): 851-856.

Benavides, M. P., Gallego, S. M. and Tomaro, M. L. 2005. Cadmium toxicity in plants. *Brazilian Journal of Plant Physiology*. 17(1):21-34.

Benoit, V. A., Paola, A. C. and Jerald, L. S. 2010. Phytoremediation of Polychlorinated Biphenyls: New Trends and Promises. *Environmental science and technology*. 44 (8):2767–2776.

Bettiol, W. and Ghini, R. 2011. Impacts of Sewage Sludge in Tropical Soil: A Case Study in Brazil. *Hindawi Publishing Corporation.Applied and Environmental Soil Science*.6:1-11.

Bhogal, A., Nicholson, F. A., Chambers, B. J. and Shepherd, M. A. 2003. Effects of past sewage sludge additions on heavy metals availability in light textured soils: implications for crop yields and metal uptakes. *Environmental pollution*. 121(3): 413-423.

Blake, G. R. and Hartge. K. H. 1986. Bulk Density, in A. Klute, ed., Methods of Soil Analysis, Part I. Physical and Mineralogical Methods: *Agronomy Monograph* (2nd ed.), pp. 363-375. Soil Science Society of America, Inc.Publisher

Bohn, H. L., Strawn, D. G. and O'Connor, G .A. 2015. Soil chemistry. John Wiley and Sons.

Bohra, A., Sahrawat, K. L., Kumar, S., Joshi, R., Parihar, A. K., Singh, U. and Singh, N. P. 2015. Genetics-and genomics-based interventions for nutritional enhancement of grain legume crops: status and outlook. *Journal of applied genetics*.56(2): 151-161.

Bohra, A., Sanadhya, D. and Chauhan, R. 2015. Heavy Metal Toxicity and Tolerance in Plants with Special Reference to Cadmium: A Review. *The Journal of Plant Science Research*. 31(1): 51-74.

Bolan, N., Kunhikrishnan, A., Thangarajan, R., Kumpiene, J., Park, J., Makino, T., Kirkham, M. B. and Scheckel, K. 2014. Remediation of heavy metal (loid) s contaminated soils–To mobilize or to immobilize?. *Journal of Hazardous Materials*. 266:141-166.

Bondarczuk, K., Markowicz, A. and Piotrowska-Seget, Z. 2016. The urgent need for risk assessment on the antibiotic resistance spread via sewage sludge land application. *Environment international*. 87:49-55.

Bourioug, M., Alaoui-Sossé, L., Laffray, X., Raouf, N., Benbrahim, M., Badot, P. M. and Alaoui-Sossé B. 2014. Evaluation of Sewage Sludge Effects on Soil Properties, Plant Growth, Mineral Nutrition State, and Heavy Metal Distribution in European Larch Seedlings (*Larix decidua*). *Arabian Journal for Science and Engineering*. 39(7): 5325-5335.

Brady, N.C. and Weil, R. R. 2008. Soil water: Characteristics and behavior. In: Brady NC, Weil RR (eds) The nature and properties of soils. pp 177–21. Prentice Hall, New Jersey.

Bray, R. H. and Kurtz, L. T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Journal of Soil Science*. 59: 39-45.

Brooks, R. R., Lee, J., Reeves, R. D. and Jaffrre, T. 1977. Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. *Journal of Geochemical Exploration*. 7: 49–57.

Buccolieri, A., Buccolieri, G., Dell'Atti, A., Strisciullo, G. and Gagliano Candela, R. 2010. Monitoring of total and bioavailable heavy metals concentration in agricultural soils. *Environmental monitoring and assessment*. 168(1-4): 547-560.

Cambier, P., Pot, V., Mercier, V., Michaud, A., Benoit, P., Revallier, A. and Houot, S., 2014. Impact of long-term organic residue recycling in agriculture on soil solution composition and trace metal leaching in soils. *Science of the Total Environment*. 499:560-573.

Canning-Clode, J., Fofonoff, P., Riedel, G. F., Torchin, M., Ruiz, G. M. 2011. The effects of copper pollution on fouling assemblage diversity: a tropical-temperate comparison. *PloS one*. 6(3): p.e18026.

Cantinho, P., Matos, M., Trancoso, M. A. and dos Santos, M. C. 2016. Behaviour and fate of metals in urban wastewater treatment plants: a review. *International Journal of Environmental Science and Technology*. 13(1): 359-386.

Caporale, A. G. and Violante, A. 2015. Chemical Processes Affecting the Mobility of Heavy Metals and Metalloids in Soil Environments. *Current Pollution Reports*, pp.1-13.

Cerqueira, B., Arenas-Lago, D., Andrade, M. L. and Vega, F. A. 2015. Validation of TOF-SIMS and FE-SEM/EDS Techniques Combined with Sorption and Desorption Experiments to Check Competitive and Individual Pb^{2+} and Cd^{2+} Association with Components of B Soil Horizons. *PLoS one*. 10(4): e0123977.

Chaney, R. L., Angle, J. S., Broadhurst, C. L., Peters, C. A., Tappero, R.V. and Sparks, D.L. 2007. Improved understanding of hyperaccumulation yields commercial phytoextraction and phytomining technologies. *Journal of Environmental Quality*. 36(5): 1429-4143.

Chlopecka, A., Bacon, J.R., Wilson, M.J. and Kay, J. 1996. Forms of cadmium, lead, and zinc in contaminated soils from Southwest Poland. *Journal of Environmental Quality*. 25(1): 69-79.

Ciadamidaro, L., Madejón, E., Puschenreiter, M. and Madejón, P. 2013. Growth of Populus alba and its influence on soil trace element availability. *Science of the Total Environment*. 454: 337-347.

Clemente, R., Walker, D.J., Roig, A. and Bernal, P. 2003. Heavy metal bioavailability in a soil affected by mineral sulphides contamination following the mine spillage at Aznalcóllar (Spain). *Biodegradation.* 14(3): 199–205.

Contin, M., Olga Malev , O. , Izosimova , A. and De Nobili, M . 2015. Flocculation of sewage sludge with $FeCl_3$ modifies the bioavailability of potentially toxic elements when added to different soils. *Ecological Engineering*. 81: 278–288.

Corseuil, H. X. and Moreno, F. N. 2001. Phytoremediation potential of willow trees for aquifers contaminated with ethanol-blended gasoline. *Water Research* 35 (12): 3013-3017.

Costa, J. S. D., Albarracín, V.H. and Abate, C. M., 2011. Responses of environmental Amycolatopsis strains to copper stress. *Ecotoxicology and environmental safety*. 74(7):2020-2028.

Crisóstomo, J. A., Freitas, H. and Rodríguez-Echeverría, S. 2007. Relative growth rates of three woody legumes: implications in the process of ecological invasion. *Web Ecology*. 7(1): 22-26.

Csavina, J., Field, J., Taylor, M.P., Gao, S., Landázuri, A., Betterton, E.A. and Sáez, A. E. 2012. A review on the importance of metals and metalloids in atmospheric dust and aerosol from mining operations. *Journal of Science of the Total Environment*. 1(433): 58–73.

Dada, A. O., Olalekan, A. P., Olatunya, A. M. and DADA, O. 2012. Langmuir, Freundlich, Temkin and Dubinin–Radushkevich Isotherms Studies of Equilibrium Sorption of Zn^{2+} Unto Phosphoric Acid Modified Rice Husk. *IOSR Journal of Applied Chemistry.* 3: 2278-5736.

Dayang, S. N. and Fauziah, I. C. 2013. Soil factors influencing heavy metal concentrations in medicinal plants. *Pertanika Journal of Tropical Agricultural Science.* 36 (2): 161-177.

Desta, M. B. 2013. Batch sorption experiments: Langmuir and Freundlich isotherm studies for the adsorption of textile metal ions onto Teff Straw (Eragrostis tef) agricultural waste. *Journal of thermodynamics*. 17: 2013.

Dhillon, K. S., Dhillon, S.K. and Thind, H. S. 2008. Evaluation of different agroforestry tree species for their suitability in the phytoremediation of seleniferous soils. *Soil use and management*. 24(2): 208-216.

Dietz, A. C. and Schnoor, J. L. 2001. Advances in phytoremediation. *Environ Health Perspect*. 109: 163–168.

Dinh, N., Vu, D.T., Mulligan, D. and Nguyen, A.V. 2015. Accumulation and distribution of zinc in the leaves and roots of the hyperaccumulator Noccaea caerulescens. *Environmental and Experimental Botany*. 110: 85-95.

Doumett, S., Lamperi, L., Checchini, L., Azzarello, E., Mugnai, S., Mancuso, S. Petruzzelli, G. and Del Bubba , M. 2008. Heavy metal distribution between contaminated soil and *Paulownia tomentosa*, in a pilot-scale assisted phytoremediation study: Influence of different complexing agents. *Chemosphere*. 72(10): 1481–1490.

EPA. 2000. Introduction to phytoremediation, Washington: U.S. Environmental, Office of Research and United States Environmental Protection Agency, Washington, DC, February 2000. 104

Ettler, V. 2016. Soil contamination near non-ferrous metal smelters: A review. *Applied Geochemistry*. 64:.56-74.

Fadiran, A.O., Ababu, T.T. and Mtshali, J.S. 2014. Assessment of mobility and bioavailability of heavy metals in sewage sludge from Swaziland through speciation analysis. *American Journal of Environmental Protection*. 3(4): 198-208.

Fang, W., Wei, Y. and Liu, J. 2016. Comparative characterization of sewage sludge compost and soil: Heavy metal leaching characteristics. *Journal of hazardous materials*. 310:1-10.

Fischerova, Z., Tlustos, P., Szakova, J. and Sichorova K. 2006. A comparison of phytoremediation capability of selected plant species for given trace elements. *Environmental Pollution*. 144(1): 93-100.

Fonseca, B., Figueiredo, H., Rodrigues, J., Queiroz, A. and Tavares, T. 2011. Mobility of Cr, Pb, Cd, Cu and Zn in a loamy sand soil: A comparative study. *Geoderma*. 164: 232–237.

Fritsch, C., Giraudoux, P., Coeurdassier, M., Douay, F., Raoul, F., Pruvot, C., Waterlot, C., de Vaufleury A. and Scheifler, R. 2010. Spatial distribution of metals in smelter impacted soils of woody habitats: influence of landscape and soil properties, and risk for wildlife. *Chemosphere.* 81: 141–155.

Gall, J. E., Boyd, R. S. and Rajakaruna, N .2015. Transfer of heavy metals through terrestrial food webs: a review. *Environmental monitoring and assessment*. 187(4):1-21.

Gerringa, L.J.A., de Baar, H.J.W., Nolting, R.F. and Paucot, H. 2001. The influence of salinity on the solubility of Zn and Cd sulphides in the Scheldt estuary. *Journal of Sea Research*. 46(3): 201-211.

Ghosh, M. and Singh, S.P. 2005. A review on phytoremediation of heavy metals and utilization of its byproducts . *Applied ecology and environmental research*. 3(1):1-18.

Girotto, E., Ceretta, C. A., Rossato, L. V., Farias, J. G., Tiecher, T. L., De Conti, L. and Nicoloso, F. T. 2013. Triggered antioxidant defense mechanism in maize grown in soil with accumulation of Cu and Zn due to intensive application of pig slurry. *Ecotoxicology and environmental safety*.93: 145-155.

Gonzalez, D., Almendros, P. and Alvarez, J. M. 2015. Mobility in soil and availability to triticale plants of copper fertilisers. *Soil Research*. 53(4): 412-422.

Goolsby, E. W. and Mason, C. M. 2015. Toward a more physiologically and evolutionarily relevant definition of metal hyperaccumulation in plants. *Frontiers in plant science*. 6: 33

Greenberg, B. M. 2006. .Development and field tests of a multi-process phytoremediation system for decontamination of soils. *Canadian Reclamation.* 1: 27 – 29.

Greipsson, S., Tay, C., Whatley, A. and Deocampo, D. M. 2013. Sharp decline in lead contamination in topsoil away from a smelter and lead migration in Ultisol. *World Environment*. 3(3): 102-107.

Grossman, R.B. and Reinsch, T.G. 2002. Bulk density and linear extensibility. Methods of Soil Analysis: Part 4 Physical Methods . pp.201-228. SSSA Book Series.

Guerra, P., Ahumada, I. and Carrasco, A. 2007. Effect of biosolid incorporation to mollisol soils on Cr, Cu, Ni, Pb, and Zn fractionation, and relationship with their bioavailability. *Chemosphere*. 68(11): 2021-2027.

Hadad, H. R., Maine, M. A. and Bonetto, C. A. 2006. Macrophyte growth in a pilot-scale constructed wetland for industrial wastewater treatment. *Chemosphere*. 63(10): 1744-1753.

Hameed, B. H. and Daud, F. B. M. 2008. Adsorption studies of basic dye on activated carbon derived from agricultural waste: Hevea brasiliensis seed coat. *Chemical Engineering Journal*, 139(1):48-55.

Hazelton P, Murphy B .2007. Interpreting Soil Test Results What Do All the Numbers Mean?. Csiro Publishing .

Hernández, T., Garcia, E. and García, C., 2015. A strategy for marginal semiarid degraded soil restoration: A sole addition of compost at a high rate. A five-year field experiment. *Soil Biology and Biochemistry*. 89:61-71.

Hernandez-Allica, Becerril, J. and Garbisu, C. 2008. Assessment of the phytoextraction potential of high biomass crop plants. *Environmental Pollution*. 152(1): 32-40.

Herzel, H., Krüger, O., Hermann, L. and Adam, C. 2016. Sewage sludge ash—A promising secondary phosphorus source for fertilizer production. *Science of the Total Environment*. 542: 1136-1143.

Hongbo, S., Liye, C., Gang, X., Kun, Y., Lihua, Z. and Junna, S., 2011. Progress in phytoremediating heavy-metal contaminated soils. In Detoxification of Heavy Metals .pp. 73-90.Springer Berlin Heidelberg.

Hossain, M. D., Hanafi, M. M., Jol, H. and Jamal, T. 2011. Dry matter and nutrient partitioning of kenaf (*Hibiscus cannabinus* L.) varieties grown on sandy bris soil. *Australian Journal of Crop Science*. 5(6): 654-659.

Houghton, J., Thompson, K. and Rees, M. 2013. Does seed mass drive the differences in relative growth rate between growth forms?. *The Royal Society's flagship biological research journal*. (280): 1762. 20130921.

Huang, B., Lia, Z., Huang,J. Guo, L., Nie, X., Wanga, Y. Zhanga, Y. and Zeng, G. 2014. Adsorption characteristics of Cu and Zn onto various size fractions of aggregates from red paddy soil. *Journal of Hazardous Materials*. 264(15) 176–183.

Illera, V., Walter, I., Souza, P. and Cala, V., 2000. Short-term effects of biosolid and municipal solid waste applications on heavy metals distribution in a degraded soil under a semi-arid environment. *Journal of Science of the Total Environment*. (255): 29-44.

Indah Water Konsortium Retieved 22 March 2014 from Http://www.iwk.com,my/v/customer/sludge-treatment.

Indah Water Konsortium Sdn Bhd .1997. A potty history of sewage sludge and its treatment. (Pamphlet).

Integrated Taxonomic Information System (ITIS) 2016 www.itis.gov Http:// www.itis.gov/.

Jadia, C. D. and Fulekar, M. H. 2009. Phytoremediation of heavy metals: Recent techniques. *African journal of biotechnology*. 8(6):921-928.

Jamil, S., Abhilash, P.C., Singh, N. and Sharma, P. N. 2009. *Jatropha curcas*: a potential crop for phytoremediation of coal fly ash..*Journal of hazardous materials*. 172(1): 269-275.

Ji, P., Sun, T., Song, Y., Ackland, M.L. and Liu, Y. 2011. Strategies for enhancing the phytoremediation of cadmium-contaminated agricultural soils by Solanum nigrum L. *Environmental pollution*. 159(3):762-768.

Jing, Y. D., He, Z. L. and Yang, X. E. 2007. Role of soil rhizobacteria in phytoremediation of heavy metal contaminated soils. *Journal of Zhejiang University Science B*. 8(3):192-207.

Joseph, S. M., Ababu ,T. T. and Amos, O. F .2014. Characterization of Sewage Sludge Generated fromWastewater Treatment Plants in Swaziland in Relation to Agricultural Uses. *Resources and Environment.* 4(4): 190-199.

Justin, V., Majid, N. M., Islam, M.M., Abdu, A.2011.Assessment of heavy metal uptake and translocation in *Acacia mangium* for phytoremediation of cadmium-contaminated soil. *Journal of food, Agriculture and Environment.* 9(2): 588-592.

Kabata-Pendias A. 2001. Trace elements in soils and plants. Third Edition, CRC Press, NY.

Kabata-Pendias, A. and Pendias, A. 1992 . Trace elements, soils and plants. CRC press Inc., Boca Raton, Fl.

Karam, A., Khiari, L., Breton, B. and Jaouich, A. 2016. Zinc Sorption by Six Agricultural Soils Amended with Municipal Biosolids. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering.* 10(29): 2016.

Keller, C., McGrath, S. P. and Dunham, S. J. 2002. Trace metal leaching through a soil grassland system after sewage sludge application. *Journal of Environmental Quality*. 31(5): 1550-1560.

Kettler, T. A., Doran, J. W. and Gilbert, T. L. 2001. Simplified method for soil particle-size determination to accompany soil-quality analyses. *Soil Science Society of America Journal*. 65(3):.849-852.

Khan, S., Wang, N., Reid, B.J., Freddo, A. and Cai, C. 2013. Reduced bioaccumulation of PAHs by Lactuca satuva L. grown in contaminated soil amended with sewage sludge and sewage sludge derived biochar. *Environmental pollution*. 175: 64-68.

Khatri, B. and Pathak, B. 2013. Estimation Of Heavy Metals By ICP- Mass Spectroscopy In Different Plant Samples From Bathinda And Suratgarh Thermal Power Stations, India. *International Journal of Scientific and Engineering Research*. 4(1):518-522.

Kokyo, O., Tao, L., Hongyan, C., Xuefeng, H., Chiquan, H., Lijun, Y. and Onemochi, S. 2013. Development of Profitable Phytoremediation of Contaminated Soils with Biofuel Crops. *Journal of Environmental Protection*. 4: 58-64.

Kramer, U., Talke, I. N. and Hanikenne, M. 2007: Transition metal transport. *FEBS letters.* 581(12):2263–2272.

Kubátová, P., Hejcman, M., Szákova, J., Vondráčková, S. and Tlustoš, P., 2016. Effects of Sewage Sludge Application on Biomass Production and Concentrations of Cd, Pb and Zn in Shoots of Salix and Populus Clones: Improvement of Phytoremediation Efficiency in Contaminated Soils. *BioEnergy Research*..1-11.

Kumar, N., Bauddh, K, Kumar,,S. Dwivedia, N. Singha, D..P. and Barmanb S.C. 2013. Accumulation of metals in weed species grown on the soil contaminated with industrial waste and their phytoremediation potential. *Ecological Engineering*. 61 : 491–495.

Kumari, A., Lal, B. and Rai, U.N., 2016. Assessment of native plant species for phytoremediation of heavy metals growing in the vicinity of NTPC sites, Kahalgaon, India. *International journal of phytoremediation*. 18(6): 592-597.

Lambers, H., Raven, J.A., Shaver, G. R. and Smith, S.E .2008. Plant nutrient-acquisition strategies change with soil age. *Trends in Ecology and Evolution*. 23(2): 95-103.

Larue, C., Nathalie K., Runying Wang, and Jean-Philippe M.2010. Depollution potential of three macrophytes: exudated, wall-bound and intracellular peroxidase activities plus intracellular phenol concentrations. *Bioresource technology* .101(20): 7951-7957.

Lavelle, P. and Spain, A. V. 2013 .Soil ecology. kluwer academic publishers . New York, boston, dordrecht, london, moscow. *EBook* .

Li, M. S., Luo, Y.P. and Su, Z.Y. 2007. Heavy metal concentrations in soils and plant accumulation in a restored manganese mine land in Guangxi, South China. *Environmental Pollution*. 147: 168-175.

Li, X., Liu, L., Wang, Y., Luo, G., Chen, X., Yang, X., Hall, M.H., Guo, R., Wang, H., Cui, J. and He, X., 2013. Heavy metal contamination of urban soil in an old industrial city (Shenyang) in Northeast China. *Geoderma*, 192:50-58.

Li, Y. and Cai, Y. 2015. Mobility of toxic metals in sediments: assessing methods and controlling factors. *Journal of Environmental Sciences.*31:203-205.

Liang, J., Chen, C., Song, X., Han, Y. and Liang, Z. 2011. Assessment of heavy metal pollution in soil and plants from Dunhua sewage irrigation area. *International Journal of Electrochemical Science.* 6:5314-5324.

Liang, J., Yang, Z., Tang, L., Xu, Y., Wang, S. and Chen, F. 2012. Growth Performance and Tolerance Responses of Jatropha (*Jatropha curcas*) Seedling Subjected to Isolated or Combined Cadmium and Lead Stresses. *International Journal of Agriculture and Biology*. 14(6):861-869.

Lindemann, W. C. and Cardenas, M .1984. Nitrogen mineralization potential and nitrogen transformations of sludge-amended soil. *Soil Science Society of America Journal*. *48*(5):1072-1077.

Lindsay, W. L.1972. Inorganic phase equilibria of micronutrients in soils. In Micronutrients in Agriculture, ed. Mortvdt J.J., Gioradano P.M. and Lindsay W.L. pp. 41-57.

Linguaa, G., Todeschinia, V., Grimaldib,M. Baldantonib D., Protob, A., Cicatellib, A., Biondic, S. Torrigianid, P. and Castiglione, S. 2014. Polyaspartate, a biodegradable chelant that improves the phytoremediation potential of poplar in a highly metal-contaminated agricultural soil. *Journal of Environmental Management*. 132 : 9-15.

Lukman, S., Essa, M.H., Mu'azu, N.D., Bukhari, A. and Basheer, C. 2013. Adsorption and Desorption of Heavy Metals onto Natural Clay Material: Influence of Initial pH. *Journal of Environmental Science and Technology* .6 (1):1-15.

Luo, J., Qi, S., Peng, L. and Wang, J. 2015. Phytoremediation efficiency of Cd by Eucalyptus globulus transplanted from polluted and unpolluted sites. *International journal of phytoremediation.* 18(4): 308-314.

Ma, L.Q. and Dong, Y. 2004. Effects of incubation on solubility and mobility of trace metals in two contaminated soils. *Environmental Pollution*. 130(3):.301-307.

Madrid, F., Liphadzi, M. S. and Kirkham, M. B. 2003. Heavy metal displacement in chelate-irrigated soil during phytoremediation. *Journal of Hydrology*. 272(1–4): 107–119.

Maestri, E., Marmiroli, M., Visioli, G. and Marmiroli, N. 2010. Metal tolerance and hyperaccumulation: costs and trade-offs between traits and environment. *Environmental and Experimental Botany*. 68(1):.1-13.

Mahar, A., Wang, P., Ali, A., Awasthi, M.K., Lahori, A.H., Wang, Q., Li, R. and Zhang, Z. 2016. Challenges and opportunities in the phytoremediation of heavy metals contaminated soils: A review. *Ecotoxicology and Environmental safety*. 126: 111-121.

Maiti, S. K., Kumar, A. and Ahirwal, J. 2015. Bioaccumulation of metals in timber and edible fruit trees growing on reclaimed coal mine overburden dumps. *International Journal of Mining, Reclamation and Environment*. 7:1-14.

Majid, N. M., Islam, M. M. and Mathew, L. 2012.Heavy metal uptake and translocation by mangium (*Acacia mangium*) from sewage sludge contaminated soil. *Australian Journal of Crop Science.* 6(8): 1228-1235.

Makra, L. 2014. Anthropogenic Air Pollution in Ancient Times. *History of Toxicology and Environmental Health: Toxicology in Antiquity* .2: 21.

Malaysia Meteorological Department (MMD) 2013. http://www.met.gov.my/

Malik, S., Almeida, E. B. and de Andrade Paes, A. M. 2016. *Syzygium cumini* (L.) Skeels: Cardiometabolic Properties and Potential Tissue Culture-Based Improvement of Secondary Metabolites Production. *Transgenesis and Secondary Metabolism.* 1-20.

Marchiol, L. , Assolari, S., Sacco, P. and Zerbi G .2004. Phytoextraction of heavy metals by canola (*Brassica napus*) and radish (*Raphanus sativus*) grown on multicontaminated soil. *Environmental Pollution*. 132(1): 21-27.

Margu į E., Iglesias, M., Camps, F., Sala, L. and Hidalgo, M. 2015. Long-term use of biosolids as organic fertilizers in agricultural soils: potentially toxic elements occurrence and mobility. *Environmental Science and Pollution Research*. 5:1-11.

Mark, E. H. 2013. Effects of Heavy Metals and Metalloids on Soil Organisms. *Heavy Metals in Soils Environmental Pollution.* 22: 141-160.

Martini, I.P. and Chesworth, W. 2013. Weathering, soils and paleosols (Vol. 2). Elsevier.

Mastretta C., Barac T., Vangronsveld J., Newman L., Taghavi, S. and Van der lelie, D. 2006. Endophytic bacteria and their potential application to improve the phytoremediation of contaminated environments. *Biotechnology and genetic engineering reviews*. 23(1): 175-188.

Masvodza, D. R., Dzomba, P., Mhandu, F. and Masamha, B. 2013. Heavy Metal Content in *Acacia saligna* and *Acacia polyacantha* on Slime Dams: Implications for Phytoremediation. *American Journal of Experimental Agriculture, 3*(4):871-883.

Mateo-Sagasta, J., Raschid-Sally, L. and Thebo, A. 2015. Global Wastewater and Sludge Production, Treatment and Use. In Wastewater (pp. 15-38). Springer Netherlands.

Materac, M., Wyrwicka, A. and Sobiecka, E. 2015 Phytoremediation techniques in wastewater treatment. *Environmental Biotechnology*. 11 (1): 10-13.

Mbila, M. O., Thompson, M. L. Mbagwu., J. S. C. and Laird, D. A. 2001. Distribution and movement of sludge derived trace metals in selected Nigerian soil. *Journal of Environmental Quality*. 30(5): 1667-1674.

McGrath, S.P. and Zhao F-J. 2003. Phytoextraction of metals and metalloids from contaminated soils. *Current Opinion in Biotechnology*. 14: 277-282.

Mehes-Smith, M., Nkongolo, K. K., Narendrula, R., Cholewa, E. 2014. Mobility of heavy metals in plants and soil: a case study from a mining region in Canada. *American Journal of Environmental Sciences*. 9: 483-493.

Melo, L. C. A. , Puga A. P. , Coscione, A. R., Beesley, L., Abreu, A,.C. and Otávio, A. 2016. Sorption and desorption of cadmium and zinc in two tropical soils amended with sugarcane-straw-derived biochar. *Journal of Soils and Sediments.* 16 (1): 226-234.

Memon, A.R. and Schroder, P. 2009. Implications of metal accumulation mechanisms to phytoremediation. *Environmental Science and Pollution Research*. 16(2):162-175.

Milinovic J., Vidal M., Lacorte S. and Rigol A. 2014. Leaching of heavy metals and alkylphenolic compounds from fresh and dried sewage sludge. *Environmental Science and Pollution Research*. 21(3): 2009-2017.

Moore, A.D., Alva, A.K., Collins, H.P. and Boydston, R.A. 2010. Mineralization of nitrogen from biofuel by-products and animal manures amended to a sandy soil. *Communications in soil science and plant analysis*. 41(11): 1315-1326.

Moreira, C. S., Casagrande, J.C., Alleoni, L.R.F., de Camargo, O.A. and Berton, R. S. 2008. Nickel adsorption in two Oxisols and an Alfisol as affected by pH, nature of the electrolyte, and ionic strength of soil solution. *Journal of Soils and Sediments*. 8 (6): 442-451.

Naveen, B. P., Sivapullaiah, P.V. and Sitharam, T.G. 2014. Characteristics of a municipal solid waste landfill leachate. Proceedings of Indian Geotechnical Conference IGC-2014. December 18-20, 2014, Kakinada, India.

Nazir, A., Malik, R.N., Ajaib, M., Khan, N. and Siddiqui, M.F. 2011. Hyper accumulators of heavy metals of industrial areas of Islamabad and Rawalpindi Pakistan. *J. Bot*. 43(4): 1925-1933.

Niu, Z. X., Sun, L. N., Sun, T. H., Li, Y. S. and Wang, H. 2007. Evaluation of phytoextracting cadmium and lead by sunflower, ricinus, alfalfa and mustard in hydroponic culture. *Journal of environmental sciences*. 19(8): 961-967.

Nogueira, T.A.R., Franco, A., He, Z., Braga, V.S., Firme, L.P. and Abreu-Junior, C.H. 2013. Short-term usage of sewage sludge as organic fertilizer to sugarcane in a tropical soil bears little threat of heavy metal contamination. *Journal of environmental management*. 114:168-177.

Nogueirol, R.C., De Melo, W. J. and Alleoni, L. R. F. 2013. Testing extractants for Cu, Fe, Mn, and Zn in tropical soils treated with sewage sludge for 13 consecutive years. *Water, Air, and Soil Pollution*. 224(5): 1-13.

Nouri, J., Khorasani, N., Lorestani, B., Karami, M., Hassani, A.H. and Yousefi, N. 2009. Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential. *Environmental Earth Sciences*.59(2):315-323.

OECD, O. T.2000. adsorption-desorption using a batch equilibrium method. Guidelines for the Testing of Chemicals, 1-45.

Oh, K., Cao, T., Li, T. and Cheng, H. 2014. Study on application of phytoremediation technology in management and remediation of contaminated soils. *Journal of Clean Energy Technologies*. *2*(3): 216-220.

Ok, Y. S., Kim, S.C., Kim, D.K., Skousen, J.G., Lee, J.S., Cheong, Y.W., Kim, S.J. and Yang, J.E. 2011. Ameliorants to immobilize Cd in rice paddy soils contaminated by abandoned metal mines in Korea. *Environmental geochemistry and health*. 33(1): 23-30.

Öztürk, M., Ashraf, M., Aksoy, A., Ahmad, M.S.A. and Hakeem, K.R. 2016. Plants, Pollutants and Remediation. *Springer*.

Page, A. L., Chang, A. C., and Adriano, D. C.1988. Land application of municipal sewage sludge, guidelines-trace elements. In Proc. 2nd Int. Symp. Land Application Sewage Sludge.

Pant, P. P. and Tripathi, A. K. 2012. Effect of Lead and Cadmium on morphological parameters of *Syzygium Cumini* Linn seedling. *Indian Journal of Science*. 1(1): 29-31.

Paz-Alberto, A.M. and Sigua, G.C. 2013. Phytoremediation: a green technology to remove environmental pollutants. *American Journal of Climate Change*. 2(1):29110-29116.

Pérez, D.V., De Alcantara, B., Rona, S. G., Polidoro, J. C. and Bettiol, W. 2011. Chemical changes in an Oxisol cultivated with maize (Zea mays, L.) after six years disposal of sewage sludge. *International Journal of Environmental Engineering*. 4(3-4):352-371.

Pilon-Smits, E. 2005. Phytoremediation. *Annual Review of Plant Biology*. 56 : 15–39.

Prasad, M. N. V. 2007. Phytoremediation in India. *Phytoremediation: Methods and Reviews*.23:435-454.

Pulford, I. D. and Dickinson, N. M. 2005. Phytoremediation technologies using trees. In: Trace elements in the environment (*Prasad MNV, Saiwan KS, Naidu R eds*). pp. 375-395.Taylor and Francis, CRC Press, New York, USA.

Pulford, I. D. and Watson, C. 2003. Phytoremediation of heavy metal-contaminated land by trees - A review. *Environment International.* 29: 529-540.

Rajoo, K. S, Arifin, A., Singh, D. K., Abdul-Hamid, H. Shamshuddin J. and Wong, W. Z. 2013. Heavy Metal uptake and translocation by *dipterocarpus verrucosus* from sewage sludge contaminated soil. *American Journal of Environmental Science.* 9 (3): 259-268.

Rascio, N. and Navari-Izzo, F. 2011. Heavy metal hyperaccumulating plants: How and why do they do it? And what makes them so interesting? *Plant Science.* 180(2):169-181.

Rascio, N. and F. Navari-Izzo. 2010. Heavy metal hyperaccumulating plants: How and why do they do it? And what makes them so interesting? *Plant Science.* 2:169-181.

Rosazlin, A., Fauziah, C. I., Rosenani, A. B. and Zauyah, S. 2006. Domestic sewage sludge application on an acid tropical soil, part II: Heavy metals uptake by maize and accumulation in the soil. *Malaysian Journal of Soil Science*. 10:35–52.

Rosazlin, A., Fauziah, C.I., Rosenani, A.B. and Zauyah, S. 2007. Domestic Sewage Sludge Application to an Acid Tropical Soil: Part III. Fractionation Study of Heavy Metals in Sewage Sludge and Soils Applied with Sewage Sludge. *Malaysian Journal of Soil Science*. 11 : 81-95 .

Rosenani, A. B., Kala, D.R. and Fauziah, C. I. 2004. Charactriztion of Malaysian sewage sludge and nitrogen mineralization in three soil treated with sewage sludge. *SuperSoil 2004: 3th Australian New Zealand Soils Conference,5-9 December 2004,University of Sydney, Australia*. Published on DROM. www.regional.org.au/au/asssi/

Saikh, H., Varadachari, C. and Ghosh, K .1998.Effects of deforestation and cultivation on soil CEC and contents of exchangeable bases: A case study in Simlipal National Park, India. *Plant and Soil*. 204(2):175-181.

Sakakibara, M., Ohmori, Y., Ha, N.T.H., Sano, S. and Sera, K. 2011. Phytoremediation of heavy metal‐contaminated water and sediment by Eleocharis acicularis. *CLEAN–Soil, Air, Water*. 39(8): 735-741.

Salas, F. M., Chino, M., Goto, S. , Igarashi, T., Masujima, H. and Kumazawa, K. 1998. Forms and distribution of heavy metals in soils long term applied with sewage sludge. *Journal of the International Society for Southeast Asian Agricultural Sciences*. 4: 64-98.

Samolada, M.C. and Zabaniotou, A. A. 2014. Comparative assessment of municipal sewage sludge incineration, gasification and pyrolysis for a sustainable sludge-to-energy management in Greece. *Waste management*.34(2):411-420.

Sanghamitra, K., Rao, P.P. and Naidu, G.R.K., 2011. Heavy metal tolerance of weed species and their accumulations by phytoextraction. *Indian Journal of Science and Technology*. 4(3):285-290.

Schwitzguébel, J.P. 2004. Potential of phytoremediation, an emerging green technology: European trends and outlook. *Proceedings-Indian National Science Academy Part B*. 70(1): 131-152.

Serna, W.E. and Pomeras, E. M .1992. Use of sewage sludge in crop production. AY-240. Purdue University Cooperative Extension Service West Lafayette, Ind.

Shaheen, S .M, Shams, M. S., Ibrahim, S. M., Elbehiry, F.A., Antoniadis, V. and Hooda, P. 2014. Stabilization of sewage sludge by using various by-products: Effects on soil properties, biomass production, and bioavailability of copper and zinc. *Water, Air and Soil Pollut*. 225(7):1-13.

Shaheen, S. M., Derbalah, A. S. and Moghanm, F. S. 2012. Removal of heavy metals from aqueous solution by zeolite in competitive sorption system. *International Journal of Environmental Science and Development*.3(4): 362.

Shaheen, S. M., Tsadilas, C. D. and Rinklebe, J. 2013. A review of the distribution coefficients of trace elements in soils: influence of sorption system, element characteristics, and soil colloidal properties. *Advances in colloid and interface science*. 201:43-56.

Shaheen, S. M., Tsadilas, C. D., Rupp, H., Rinklebe, J. and Meissner, R. 2015. Distribution coefficients of cadmium and zinc in different soils in mono-metal and competitive sorption systems. *Journal of Plant Nutrition and Soil Science*. 178(4):671-681.

Shamshuddin , J. 2011. Methods in Soil Mineralogy. Universiti Putra Malaysia Press.

Shamshuddin, J. and Anda, M. 2012. Enhancing the Productivity of Ultisols and Oxisols in Malaysia using Basalt and/or Compost. *Pedologist*. 12: 382-391.

Shamshuddin, J. and Fauziah, C. I. 2010. Weathered Tropic Soils: The Ultisolis and Oxisols .Universiti Putra Press.

Sharma, S., Singh, B. and Manchanda, V. K. 2015. Phytoremediation: role of terrestrial plants and aquatic macrophytes in the remediation of radionuclides and heavy metal contaminated soil and water. *Environmental Science and Pollution Research*. 22(2):946-962.

Sheoran, V., Sheoran, A.S. and Poonia, P. 2009. Phytomining: a review. *Minerals Engineering*. 22(12): 1007-1019.

Sheppard, S., Long, J., Sanipelli, B. and Sohlenius, G. 2009. Solid/liquid partition coefficients (Kd) for selected soils and sediments at Forsmark and Laxemar-Simpevarp. Svensk kärnbränslehantering (SKB). R-09-27, Stockholm, Sweden, Report.

Sherene, T. 2010. Mobility and transport of heavy metals in polluted soil environment. *Biological Forum -An International Journal*.2(2): 112-121.

Shi, Z., Allen, H. E., Di Toro, D. M., Lee, S. Z. and Harsh, J. B. 2013. Predicting PbII adsorption on soils: the roles of soil organic matter, cation competition and iron (hydr) oxides. *Environmental Chemistry*. 10(6): 465-474.

Siedlecka, A. 2014. Some aspects of interactions between heavy metals and plant mineral nutrients. *Acta Societatis Botanicorum Poloniae*, 64(3):265-272.

Singh, R.P. and Agrawal, M .2007. Effects of sewage sludge amendment on heavy metal accumulation and consequent responses of *Beta vulgaris* plants. *Chemosphere*.67: 2229–2240.

Singh, S. N. and Tripathi, R. D. 2007. Environmental Bioremediation Technologies. Springer Science and Business Media.

Soil Survey Staff .2014. Keys to Soil Taxonomy. United States Department of Agriculture Natural Resources Conservation Service, 12nd ed. pp735–741.

Sommers, L. E. 1977. Chemical composition of sewage sludge and analysis of their potential use as fertilizers. *Journal of Environmental Quality*. 6(2): 225-232.

Srinivasan, P., Sarmah, A.K., Smernik, R., Das, O., Farid, M. and Gao, W. 2015. A feasibility study of agricultural and sewage biomass as biochar, bioenergy and biocomposite feedstock: Production, characterization and potential applications. *Science of the Total Environment*. 512:495-505.

Stern, B. R.. 2010. Essentiality and toxicity in copper health risk assessment: overview, update and regulatory considerations. *Journal of Toxicology and Environmental Health, Part A*. 73(2-3): 114-127.

Sun, Y. B., Zhou, Q. X., An, J., 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(1): 106-112.

Sundström, R., Åström, M. and österholm, P. 2002. Comparison of the metal content in acid sulfate soil runoff and industrial effluents in Finland. *Journal of Environmental science and technology*. 36(20): 4269-4272.

Surriya, O., Sarah, S. S., Waqar, K. and Gul Kazi, A. 2014. Phytoremediation of soils: prospects and challenges (pp. 1-1). Academic Press: London.

Surriya, S. S. S., Waqar, K., and Kazi, A. G. (2014). Phytoremediation of soils: prospects and challenges. Soil Remediation and Plants: Prospects and Challenges, 29:1.

Tangahu, B.V., Sheikh Abdullah, S.R., Basri, H., Idris, M., Anuar, N. and Mukhlisin, M. 2011. A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *International Journal of Chemical Engineering*. 16:1-31.

Tessens, E. and Shamshuddin, J. 1983. Quantitative Relationships between Mineralogy and Properties of Tropical Soils. UPM Press, Serdang.

Tessier A.P., Campbell G.C. and Biosson M. 1979. Sequential extraction procedure for different soil clay fractions and goethite. *Geoderma*. 34: 17-35.

Thakur, S., Singh, L., Ab Wahid, Z., Siddiqui, M.F., Atnaw, S.M. and Din, M.F.M., 2016. Plant-driven removal of heavy metals from soil: uptake, translocation, tolerance mechanism, challenges, and future perspectives. *Environmental monitoring and assessment*. 188(4): 1-11.

Thomasi, S. S. Fernandes, R. B. A., Fontes, R. L. F. and Jordão, C. P. 2015. Sequential extraction of copper, nickel, zinc, lead and cadmium from Brazilian Oxysols: metal leaching and metal distribution in soil fractions. *International Journal of Environmental Studies*. 72(1): 41-55.

Tomar, P., Mandal, R. and Yadav, N., 2015. Plant: A Natural Purifier of Environment. *MR International Journal of Engineering and Technology*. 7(2):50-55.

Trannin, I.C.D.B., Siqueira, J.O. and Moreira, F.M. D.S. 2005. Agronomic assessment of an industrial biosolid for corn crop. *Pesquisa Agropecuária Brasileira*.40(3): 261-269.

Twohig, E. and Kelley, E. 2015. Wastewater Treatment Sludge and Septage Management In Vermont. http://www.watershedmanagement.vt.gov/

Udom, B. E., Mbagwu, J. S. C., Adesodun, J. K. and Agbim, N. N. 2004. Distributions of zinc, copper, cadmium and lead in a tropical ultisol after long-term disposal of sewage sludge. *Journal of Environment International*. 30(4):467-470.

USEPA. 1994). A plain Guide to the EPA Part 503 Biosolids Rule. EPA/832/R-93/003, Washington, DC.

Usman, A. R .A. and Mohamed, H. M. 2009. Effect of microbial inoculation and EDTA on the uptake and translocation of heavy metal by corn and sunflower. *Chemosphere.* 76: 893-899.

Usman, K., Khan, S., Ghulam, S., Khan, M. U., Khan, N., Khan, M. A. and Khalil, S. K. 2012. Sewage sludge: an important biological resource for sustainable agriculture and its environmental implications. *American Journal of Plant Sciences*. 3(12):1708.

Vaitkutė, D., Baltrėnaitė, E., Booth, C.A. and Fullen, M.A. 2010. Does sewage sludge amendment to soil enhance the development of Silver birch and Scots pine. *Hungarian geographical bulletin*. 59(4): 393-410.

Van der Perk, M., 2013. Soil and water contamination. CRC Press.

van Schaik, J. W. J., Kleja, D. B. and Gustafsson, J. P. 2010. Acid-base and copper-binding properties of three organic matter fractions isolated from a forest floor soil solution. *Journal of Geochimica et Cosmochimica acta*. 74(4):1391-406.

Vangronsveld, J., Herzig, R., Weyens, N., Boulet, J., Adriaensen, K., Ruttens, A., Thewys, T., Vassilev, A., Meers, E., Nehnevajova, E. and van der Lelie, D. 2009. Phytoremediation of contaminated soils and groundwater: lessons from the field. *Environmental Science and Pollution Research*. 16(7): 765-794.

Vega, F. A., Covelo, E. F.and Andrade, M. L.2006. Competitive sorption and desorption of heavy metals in mine soils: Influence of mine soil characteristics. *Journal of Colloid and Interface Science.* 298: 582–592.

Violante, A., V. Cozzolino, V., L. Perelomov, Caporale1, A.G. and Pigna , J. M. 2010. Mobility and bioavailability of heavy metals and metalloids in soil environments. *Journal of soil science and plant nutrition*. 10 (3): 268-292.

Violante, A., Huang, P.M. and Gadd, G.M. 2008. Biophysico-chemical processes of heavy metals and metalloids in soil environments. Book Review. Environ. Eng. Manage. J, 7, pp.163-166. Wiley, Chichester.

Wang, S. and Mulligan, C. N. 2013. Effects of three low-molecular-weight organic acids (LMWOAs) and pH on the mobilization of arsenic and heavy metals (Cu, Pb, and Zn) from mine tailings. *Journal of Environmental geochemistry and health*. 35(1): 111-118.

Wei ,C.Y. and Chen, T.B. 2006. Arsenic accumulation by two brake ferns growing on an arsenic mine and their potential in phytoremediation .*Chemosphere*. 63(6):1048-1053.

WHO. 2007. Joint FAO/WHO Expert standards program codex Alimentation Commission. Geneva, Switzerland.

Willscher, S., Mirgorodsky, D., Jablonski, L., Ollivier, D., Merten, D., Büchel, G., Wittig, J. and Werner, P. 2013. Field scale phytoremediation experiments on a heavy metal and uranium contaminated site, and further utilization of the plant residue. *Hydrometallurgy* 131: 46–53.

Willscher, S., Wittig, J., Bergmann, H., Büchel, G., Merten, D. and Werner, P., 2009, September. Phytoremediation as an alternative way for the treatment of large, low heavy metal contaminated sites: application at a former uranium mining area. *In Advanced Materials Research*. 71: 705-708.

Wilson, B. and Pyatt, F.B. 2007. Heavy metal bioaccumulation by the important food plant, *Olea europaea* L., in an ancient metalliferous polluted area of Cyprus. *Bulletin of environmental contamination and toxicology*.78(5): 390-394.

Woodbury, P. B. 1993. Potential effects of heavy metals in municipal solid waste composts on plants and the environment. *Biomass and Bioenergy*. 3: 239-259.

Wu, F., Yang, W., Zhang,J. and Zhou, L.2009.Cadmium accumulation and growth response of a poplar (Poplus deltoids x Pupulus nigra) in cadmium contaminated purple soil and alluvial soil. *Journal Hazard Material.*1: 1-6.

Wu, G., Wu, J.Y. and Shao, H.B. 2012. Hazardous heavy metal distribution in Dahuofang Catchment, Fushun, Liaoning, an important industry city in China: a case study. *CLEAN–Soil, Air, Water*.40(12): 1372-1375.

Wua, G., Kanga, H., Zhangc, X., Shaob, H., Chuc L. and Ruand C.2010. A critical review on the bio-removal of hazardous heavy metals from contaminated soils. *Journal of Hazardous Materials*. 174:1-8 .

Wuana, R .A. and Okieimen, F.E. 2011. Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. *ISRN Ecology*. 1: 1–20.

Wuana, R. A. and Mbasugh, P. A. 2013. Response of roselle (*Hibiscus sabdariffa*) to heavy metals contamination in soils with different organic fertilisations. *Chemistry and Ecology*. 29(5): 437-447.

Wuana, R.A., Okieimen, F.E. and Vesuwe, R.N. 2015. Mixed contaminant interactions in soil: Implications for bioavailability, risk assessment and remediation. *African Journal of Environmental Science and Technology*.8(12): 691-706.

Yang, Z. Q. and Kimura, M. 1995. Solubility fractionation of Zn, Cu, and Cd in soils applied with sewage sludge and their potential availability to plant. *Journal of Environmental Sciences*. 8 (4): 369-378.

Yoon, J., Cao, X., Zhou, Q. and Ma, L.Q. 2006. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. *Science of the total environment*. 368(2): 456-464.

Zahedifar, M., Karimian, N. and Yasrebi, J. 2012. Influence of applied zinc and organic matter on zinc desorption kinetics in calcareous soils. *Archives of Agronomy and Soil Science*. 58 (2): 169-178.

Zarcinas, B.A., Fauziah, C. I., McLaughlin, M. J. and Cozens, G .2004. Heavy metals in soils and crops in Southeast Asia. 1. Peninsular Malaysia. *Environmental Geochemistry and Health*. 26(4):343-357.

Zauyah, S. C., Juliana, B., Noorhafizah, R., Fauziah, C.I. and Rosenami, A. B. 2004. Concentration and speciation of heavy metals in some cultivated and uncultivated utisols and inceptisols in peninsular Malaysia. *Proceeding of the Supersoil 3rd Australian New Zealand Soils Conference*, University of Syndey, Australia.

Zeng, Z. Z., Lei, X. J., Gou, J. F., Gao, D. X., Wang, H. C. and Nan, Z. R. 2015. Leaching-induced migration and compositional form change of Cu, Zn, and Cd from sludge to loess. *Toxicological and Environmental Chemistry*. 97(3-4):439-453.

Zhang, J., Wang, S., Feng, Z., and Wang, Q. 2009. Stability of soil organic carbon changes in successive rotations of Chinese fir (Cunninghamia lanceolata (Lamb.) Hook) plantations. *Journal of Environmental Sciences*, 21(3): 352-359.

Zhang, S. W., Hu, S. B., Xiao, X., Chen, Y. L. and Wang, X. L., 2009. Phytoremediation of cadmium pollution in soil by oilseed rape. *Acta Agriculturae Boreal-Occidentalis Sinica*. 18(4): 197–201.

Zheng, S. A., Zheng, X. and Chen, C. 2012. Leaching behavior of heavy metals and transformation of their speciation in polluted soil receiving simulated acid rain. *PloS one*.7(11): e49664.

Zhi, W. and Ji, G. 2012. Constructed wetlands, 1991–2011: a review of research development, current trends, and future directions. *Science of the Total Environment*. 441:19-27.