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HEAVY METAL DISTRIBUTION, MOBILITY AND RISK ASSESSMENT IN SURFACE SEDIMENT OF SUNGAI PULOH IN SELANGOR, MALAYSIA

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By

USMAN SADIQ ABUBAKAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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DEDICATION

This work is dedicated to Almighty Allah (SWT) and to my lovely parent, Alhaji Abubakar Sadiq Jagindi and Hajiya Hauwa'u Abubakar for their love, support, resilience, patience and understanding.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Syaizwan Zahmir Zulkifli, PhD
Faculty : Science

Sungai Puloh is a mangrove swamp area plagued with industrial, agricultural and other commercial activities and has a direct small link to the straits of Malacca. It is surrounded by industries including steel and paint manufacturing companies, car repair shops etc. Heavy metals (HMs) are environmental pollutants whose sources are both natural and anthropogenic. Heavy metals bioavailability and mobility is affected by physical, chemical and biological factors among which are organic matter and sediment characteristics. Organic matter and particle size distribution play a significant role in the fate of HM in the sediment, and consequently the river. The aims and objectives therefore, are to investigate the concentration of some selected HMs (Cu, Zn, Ni, Cd and Pb) in the surface sediment of Sg. Puloh, determine organic matter content and particle size distribution as well as assess the degree of HM contamination/risk by means of pollution indices evaluation namely: risk assessment code (RAC), geoaccumulation Index (I_{geo}), contamination factor (CF) and pollution load index (PLI). Sequential extraction technique SET and Aqua regia digestion were performed using Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer 800) for heavy metal concentration. Loss on ignition and pipette method of analyses were employed for the determination of organic matter content and particle size respectively. SPSS statistical package version 22 was used to determine correlation, significance or otherwise of heavy metals concentration. Heavy metals concentrations for Cu, Zn, Ni, Cd and Pb were found between 83.05-202.34, 405.39-755.04, 114.67-226.90, 0.53-3.06 and 95.19-225.47 μg/g respectively. Grain size analysis revealed clay in the sediment at between 52.89-60.16, silt 25.38-35.99 and sand 4.68-14.42%. Organic matter content ranged between 38.45-46.90%. Correlation between grain size and total metal concentration revealed was significant for Cd, Cu, and Ni ($r = 0.657^*$, $r = 0.705^*$ and $r = 0.682^*$) respectively. Kruskal Wallis' nonparametric test revealed significant difference in heavy metals concentrations ($P < 0.01$, $P < 0.05$). Risk

assessment code RAC showed medium (RAC= 11-30) to very high risk (RAC > 50) with Pb posing the highest risk. Geoaccumulation index, Cd highest in S5 (I_{geo}) = 3 while Cu lowest (I_{geo})= 0.2 in S2. Contamination factor (CF), Zn and Pb highest, Ni and Cu lowest. Pollution load index showed values greater than 1 (PLI > 1), indicating high level of pollution. Sediment of Sg. Puloh has high contamination of HM and the source are both from natural and anthropogenic. The presence of heavy metals in the residual fraction confirms that some of the heavy metals come from natural source. From the result obtained, it can be concluded that Sg. Puloh is highly polluted. All the stations have shown high level of heavy metal concentration from both natural and anthropogenic sources, high organic matter content from a sediment that is characteristically clay. Pollution indices have also indicated high contamination, especially in S5, S3 and S4. This can be attributed to the cited industries nearby, agriculture and other activities.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

TABURAN, MOBILITI DAN PENILAIAN RISIKO LOGAM BERAT DALAM SEDIMEN PERMUKAAN DI SUNGAI PULOH, SELANGOR, MALAYSIA

Oleh

USMAN SADIQ ABUBAKAR

Februari 2018

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Sungai Puloh adalah sebuah paya bakau yang telah diancam oleh pelbagai aktiviti industri, pertanian dan komersial lain serta mempunyai sebuah hubungan terus dengan Selat Melaka. Ia dikelilingi oleh kawasan industri seperti syarikat logam dan pembuatan, bengkel pembaikan kereta dsb. Logam berat (HMs) adalah bahan pencemar alam sekitar yang berasal dari sumber semulajadi dan antropogenik. Bioketersediaan dan mobility logam berat adalah dipengaruhi oleh factor-faktor fizikal, kimia dan biologi, yang merangkumi bahan organik dan ciri-ciri sedimen. Taburan bahan organik dan saiz butiran memainkan fungsi yang ketara kepada ketentuan HMs dalam sedimen dan seterusnya kepada sungai. Oleh itu, objektif kajian ini adalah untuk menyelidik kepekatan HMs terpilih (Cu, Zn, Ni, Cd dan Pb) dalam sedimen permukaan Sungai Puloh, menentukan kandungan bahan organik dan saiz butiran, serta tahap pencemaran/risiko HMs dari sudut penilaian indeks pencemaran yang termasuk: tata penilaian risiko (RAC), indeks geopengumpulan (I_{geo}), faktor pencemaran (CF) dan indeks beban pencemaran (PLI). Teknik pengekstrakan berjujukan SET dan pencernaan akua regia telah digunakan untuk mencerna sampel. Sebuah spektrofotometer serapan atom (AAS) (PerkinElmer AAnalyst 800) telah digunakan untuk menentukan kepekatan logam berat. Kehilangan akibat pencucuhan dan kaedah pipet telah digunakan untuk menentukan kandungan jirim organik dan saiz butiran. Pakej statistic SPSS versi 22 telah digunakan bagi menentukan kolerasi, keertian atau sebaliknya bagi logam berat dengan beberapa parameter. Kepekatan logam berat Cu, Zn, Ni, cd dan Pb telah didapati antara 83.05-202.34, 405.39-755.04, 114.67-226.90, 0.53-3.06 and 95.19-225.47 µg/g. Analisis saiz butiran menunjukkan bahawa liat dalam sedimen adalah antara 52.89-60.16, kelodak 25.38-35.99 and pasir 4.68-14.42 µg/g. Kandungan jirim organik pula berjulat antara 38.45-46.90%. Kolerasi antara saiz butiran dan jumlah kepekatan logam Cd, Cu dan Ni telah ditunjukkan signifikan ($r = 0.657^*$, $r = 0.705^*$ and $r = 0.682^*$). Ujian Kuruskal Wallis

tanpa parameter menunjukkan perbezaan beerti dalam kepekatan logam berat ($P < 0.01$, $P < 0.05$). tata penilaian risiko RAC menunjukkan sederhana (RAC = 11 – 30) hingga risiko sangat tinggi (RAC > 50) dengan Pb memberikan risiko tertinggi. Bagi indeks geopengumpulan, Cd adalah tertinggi di S5 (I_{geo}) = 3, manakala Cu paling rendah (I_{geo}) = 0.2 di S2. Bagi faktor pencemaran (CF), Zn dan Pb adalah tertinggi, Ni dan Cu adalah terendah. Indeks beban pencemaran pula menunjukkan nilai melebihi 1 (PLI > 1), yang menunjukkan pencemaran peringkat tinggi. Sedimen Sg Puloh mempunyai pencemaran HM yang tinggi dan sumber adalah dari kedua-dua semulajadi dan antropogenik. Kehadiran logam berat di peringkat baki membuktikan bahawa sebahagian logam berat berasal dari sumber semulajadi. Daripada keputusan yang dieprolehi, Sg. Puloh boleh disimpulkan mengalami pencemaran yang tinggi. Semua stesen menunjukkan kepekatan logam berat yang tinggi bagi kedua-dua sumber semulajadi dan antropogenik, kandungan jrim organik yang tinggi bagi sedimen berjenis liat. Indeks-indeks pencemaran juga menunjukkan pencemaran yang tinggi, terutamanya di S5, S3 dan S4. Ini adalah disebabkan kehadiran aktiviti-aktivti industri, pertanian dan lain-lain berhampiran kawasan tersebut.

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I certify that a Thesis Examination Committee has met on 9 February 2018 to conduct the final examination of Usman Sadiq Abubakar on his thesis entitled "Heavy Metal Distribution, Mobility and Risk Assessment in Surface Sediment of Sungai Puloh in Selangor, Malaysia" 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 Master of Science.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AMD	Acid Mines Drainage
ANOVA	Analysis Of Variance
ATSDR	Agency for Toxic Substances and Disease Registry
B_n	Background value of metals
CF	Contamination Factor
C_n	Concentration of a metal
Co	Company
CNS	Central Nervous System
DDW	Double Distilled Water
DNA	Deoxyribonucleic Acid
dw	Dry Weight
EFLE	Easily and freely leachable or exchangeable
EPA	Environmental Protection Agency
FEDRIP	Federal Research in Progress
F	Fraction
g/cm3	Gram Per Centimiters Cube
GPS	Global Positioning System
I_{geo}	Geoaccumulation Index
IZA	International Zinc Association
Km2	Kilometer Square
LOI	Loss on Ignition
Ltd	Limited
M_A	Mass of burnt sample (Ash)
M_D	Mass of Dry sample

M_O	Mass of organic matter
M_{PDS}	Mass of Porcelain and Dry Sample
Mg/Kg	Miligram per Kilogram
n	Number
NB	Note Before
NEM	Northeast Monsoon
OM	Organic Matter
PCA	Principal Component Analysis
PC	Principal Component
PLI	Pollution Load Index
PNS	Peripheral Nervous System
RAC	Risk Assessment Code
S	Sites
SE	Standard Error
SET	Sequential Extraction Technique
Sg	Sungai
SPSS	Statistical Package for Social Sciences
SWM	Southwest Monsoon
UPM	Universiti Putra Malaysia
USDI	United State Department of Interior
^0C	Degree Celsius
µ	Micro
%	Percentage

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Malaysia is a tropical rainforest region and traditionally, agricultural-based country but transformed gradually into a multi-sector economy, especially in the direction of electrical and electronic appliances industries. It is rich in natural resources, given its significant land mass of mangroves which are highly complex, diverse and productive. It geographically lies above the equator between 2° and 8° N and it is divided into West and East by South China Sea with total land area of 329,350 km^2. West Malaysia has a land mass of 131,573 km^2 with characteristically extensive coastal plains topographically. Generally, the temperature of west Malaysia ranges from 23-31 °C and rainfall throughout the year with high humidity. The heaviest rain being experienced around October to December. The coastal nature of the region has made it prone to environmental pollution.

Coastal environments have been identified as reservoirs of waste materials especially in sediment, coming from both anthropogenic and natural source (Song, Choi, Lee, & Jang, 2014). It is also very rich in natural resources and diverse economic activities (Looi, Aris, Wan Johari, Yusoff, & Hashim, 2013). The coastal marine sediment is composed of a mixture of complex organic compounds whose origins are terrestrial and marine sources. Coastal zones are known for its capacity to trap reasonable amount of organic matter from both anthropogenic as well as natural sources through the activities of physical, chemical and biological phenomena (Gao, Chen, & Bay, 2012). A considerable portion of the coastal area is made up of mangrove, with a sediment generally consisting of sandy and muddy deposit and also plays a major role in the overall fluxes of heavy metals in coastal systems as source of metals and/or sink (Sakellari, Plavšić, Karavoltsos, Dassenakis, & Scoullos, 2011; Song et al., 2014). Mangroves are specific intertidal ecosystems covering between 160,000 and 200,000 km^2 along more than 70 percent of tropical and subtropical coastline (Marchand, Allenbach, & Lallier-Vergès, 2011). It comprises of close to 80 percent species worldwide from around 20 families of vascular plants. It is one of the most productive ecosystems with high level of biodiversity (Marchand et al., 2011).

Heavy metals pollution in Malaysia has been on the increase in recent times as a result of activities of many kinds, arising from urban development, agricultural activities, intense industrial as well as water transportation (Khodami, Surif, W.O., & Daryanabard, 2017). Heavy metals are characteristically toxic in high concentration, persistent and non-biodegradable with the tendencies of bioaccumulation and biomagnification in the environment (Lim, Choi, Shin, Jeong, & Jung, 2013). Most of these activities are far more intense in the west coast of Peninsular Malaysia with over 60% of the total Malaysian population living in this area, coupled with the fact that

most developmental projects as well as industrialization are being carried out. It is therefore imperative to investigate the distribution and the degree of heavy metal pollution as this will help in providing desired information for bioavailability, transportation and accumulation of pollutants which in turn will help with information required for coast utilization and supervision (Armynot du Châtelet, Bout-Roumazeilles, Riboulleau, & Trentesaux, 2009; Hu et al., 2013). Several activities have prompted interest and needs to embark on intense environment assessment along the west coast of Peninsula Malaysia. This may include but not limited to the following characteristics: (1) dense population more than any other region in Malaysia, (2) It is the most industrialized area, (3) It has many flowing rivers within, and (4) The straits of Malacca, which is said to be one of the most important shipping lane in the world, is also part of the west coast of Malaysia (Yap, Ismail, Tan, & Omar, 2002a).

Industrial/manufacturing activities have no doubt large implications toward natural environment. It enhances development, creating wealth and generally improving on the life of people. However, it usually comes with serious ramifications, resulting to environmental degradation. Interactions between manufacturing activities and natural environment create enormous unfavourable environmental condition due to inevitable release of pollutants (Nagajyoti, Lee, & Sreekanth, 2010).

Sungai Puloh is a small town located not far from Klang. Like Klang, Sungai Puloh also has a few industries cited and numerous human activities, ranging from car and motorcycle workshops, agriculture and several other small and medium scale businesses. There is also the problem of land clearing for municipal development. Sungai Puloh is in mangrove area and the river runs from communities and meanders through the mangrove, down to the strait of Malacca. This river receives wastes due to the human activities and most likely natural given that it is a mangrove area. It is therefore imperative that its pollution status is known and closely monitored.

1.2 Problem Statement

Human and industrial activities are very common in and around Sungai Puloh area with attendant wastes generation that may, in high level, pose a great risk to biota. Heavy metal pollution occurs via waste generation through industrial, agricultural as well as other human activities, like municipal wastes deposition. Mangrove environments are known to be characteristically rich in biodiversity and therefore prone to human and natural activities. These activities usually result in waste generation and potentially pollute the environment. Organic matter is one of the wastes components that associates highly with heavy metals. Other sediment characteristics, example grain size equally influence the distribution and transport of heavy metals within the water system. This river is important because of its strategic location, providing an avenue for fishing and other farming activities. However, possible contamination from the surrounding industries, workshop also, excessive fertilizer and pesticides application could contaminate the fish and other aquatic organisms carried

and deposited into the river. This could ultimately affect human since human consumes the fish that are likely contaminated from the river.

1.3 Aim and Objectives

1. To investigate heavy metal concentration in Sungai Puloh, Selangor
2. To determine the impact of anthropogenic activities and potential mobility of heavy metals in the sediment of Sungai Puloh by estimating the level of organic matter and particle size on the distribution and mobility
3. To assess the risks pose by heavy metals to the biota in the area through risk assessment code (RAC), contamination factor (CF), Geoaccumulation Index and Pollution load index (PLI)

REFERENCES

Abd El-Azim, H. & El-Moselhy, K. M. (2005). Determination and partitioning of metals in sediments along the Suez Canal by sequential extraction. Journal of Marine Systems, 56(3–4), 363–374.

Abdullah, M. H., Sidi, J. & Aris, A. Z. (2007). Heavy Metals (Cd , Cu , Cr , Pb and Zn) in Meretrix meretrix Roding , Water and Sediments from Estuaries in Sabah , North Borneo Aim and Purpose of the Research, *2*(3), 69–74.

Abdullah, N. A., Azhar, N., Shazili, M., Samsul, R., Abdullah, L. I. & Sokiman, S. (2015). Sediment Heavy Metals Distribution in Relation to Grain Size at Johor Port : East Coast Peninsular Malaysia, *1*, 31–40.

Abollino, O., Malandrino, M., Giacomino, A. & Mentasti, E. (2011). The role of chemometrics in single and sequential extraction assays: a review: part I. Extraction procedures, uni- and bivariate techniques and multivariate variable reduction techniques for pattern recognition. Analytica Chimica Acta, 688(2), 104–121.

Agah, H., Bastami, K. D. & Fumani, N. S. (2016). Ecological risk , source and preliminary assessment of metals in the surface sediments of Chabahar Bay , Oman Sea. MPB, 107(1), 383–388.

Ahmad, A. K., Mushrifah, I. & Shuhaimi-Othman, M. (2009). Water quality and heavy metal concentrations in dediment of Sungai Kelantan, Kelantan, Malaysia: A baseline study. Sains Malaysiana, 38(4), 435–442.

Ahmad, I., Badri, M. A. & Ramlan, M. N. (1993). The background levels of heavy metal concentration in sediments of the west coast of Peninsular Malaysia.

Al Akeel, K. (2013). Empirical investigation of water pollution control through use of *Phragmites australis,* a thesis submitted for the degree of Doctor of Philosophy.

Alloway, B. (1995). Heavy Metals in Soils Trace Metals and Metalloids in Soils and Their Bioavailability. Heavy Metals in Soils: trace metals and metalloids in soils and their bioavailability.

Anderson, T. J., Barrett, G. W., Clark, C. S., Elia, V. J. & Majeti, V. A. (1982). Metal Concentrations in Tissues of Meadow Voles from Sewage Sludge-Treated Fields1. Journal of Environment Quality, 11(2), 272.

Ansari, T.M., Marr, I.L. and Tariq, N. (2004). Heavy metals in marine pollution perspective-A Mini Review. Journal of Applied Sciences.

Arain, M. B., Kazi, T. G., Jamali, M. K., Baig, J. A., Afridi, H. I., Jalbani, N. & Sarfraz, R. A. (2009). Comparison of Different Extraction Approaches for Heavy Metal Partitioning in Sediment Samples. Pedosphere, 19(4), 476–485.

Armynot du Châtelet, É., Bout-Roumazeilles, V., Riboulleau, A. & Trentesaux, A. (2009). Sediment (grain size and clay mineralogy) and organic matter quality control on living benthic foraminifera. Revue de Micropaléontologie, 52(1), 75–84.

Bacon, J. R. & Davidson, C. M. (2008). Is there a future for sequential chemical extraction ? (2), 25–46.

Badri, M. A. & Aston, S. R. (1983). Observations on heavy metal geochemical associations in polluted and non-polluted estuarine sediments. Environmental Pollution Series B: Chemical and Physical, 6(3), 181–193.

Baralkiewicz, D, Siepak, J. (1999). Chromium, Nickel and Cobalt in Environmental Samples and Existing Legal Norms. Polish Journal of Environmental Studies, 8(4), 201–208. Retrieved from

Barillé-Boyer, A. L., Barillé, L., Massé, H., Razet, D. & Héral, M. (2003). Correction for particulate organic matter as estimated by loss on ignition in estuarine ecosystems. Estuarine, Coastal and Shelf Science, 58(1), 147–153.

Bernard, A. (2008). Cadmium & its adverse effects on human health. The Indian Journal of Medical Research, 128(4), 557–564.

Billah, M., Hena, A., Kamal, M., Hanafi, M., Idris, B., Ismail, J. Bin, & Bhuiyan, K. A. (2014). Zoology and Ecology Cu , Zn , Fe , and Mn in mangrove ecosystems. Zoology and Ecology, 24(4), 37–41.

Boon, K. F., Kiefert, L. & Ctainsh, G. H. (1998). Organic matter content of rural dusts in Australia. Atmospheric Environment, *32*(16), 2817–2823.

Bulut, Y. & Tez, Z. (2007). Removal of heavy metals from aqueous solution by sawdust adsorption. Journal of Environmental Sciences (China), 19(2), 160–166.

Cabrera, F. U., Clemente, L., Dıaz, E. & Lopez, R. (1999). Heavy metal pollution of soils affected by the Guadiamar toxic flood. Science of The Total Environment. 242(1-3), 117-129

Casey, A. L., Adams, D., Karpanen, T. J., Lambert, P. A, Cookson, B. D., Nightingale, P.,Elliott, T. S. J. (2010). Role of copper in reducing hospital environment contamination. The Journal of Hospital Infection, 74(1), 72–77.

Castagnetto, J. M., Hennessy, S. W., Roberts, V. A., Getzoff, E. D., Tainer, J. A. & Pique, M. E. (2002). MDB: the Metalloprotein Database and Browser at The Scripps Research Institute. Nucleic Acids Research, 30(1), 379–382.

Cempel, M. & Nikel, G. (2006). Nickel: A review of its sources and environmental toxicology. Polish Journal of Environmental Studies, 15(3), 375–382.

Çevik, F., Ziya, M. & Göksu, L. (2009). An assessment of metal pollution in surface sediments of Seyhan dam by using enrichment factor , geoaccumulation index and statistical analyses, 309–317.

Chakraborty, S., Dutta, A. R., Sural, S., Gupta, D. & Sen, S. (2013). Ailing bones and failing kidneys: a case of chronic cadmium toxicity. Annals of Clinical Biochemistry: An International Journal of Biochemistry and Laboratory Medicine, 50(5), 492–495.

Chen, C.W., Chen, C.F. & Dong, C.D. (2012). Copper Contamination in the Sediments of Salt River Mouth, Taiwan. Energy Procedia, 16, 901–906.

Council of Scientific & Industrial Research (India), C. K., Indian National Science Academy., A. & National Institute of Science Communication and Information Resources (New Delhi, I. (2010). Indian journal of marine sciences. IJMS Vol.32(4) [December 2003]. Council of Scientific & Industrial Research. Retrieved from http://nopr.niscair.res.in/handle/123456789/4283

Dali-youcef, N., Ouddane, B. & Derriche, Z. (2006). Adsorption of zinc on natural sediment of Tafna River (Algeria). Journal of Hazardous Materials, 137(3), 1263–1270.

Dong, X., Wang, C., Li, H., Wu, M., Liao, S., Zhang, D. & Pan, B. (2014). The sorption of heavy metals on thermally treated sediments with high organic matter content. Bioresource Technology, 160, 123–128.

Dou, Y., Li, J., Zhao, J., Hu, B. & Yang, S. (2013). Distribution, enrichment and source of heavy metals in surface sediments of the eastern Beibu Bay, South China Sea. Marine Pollution Bulletin, 67(1–2), 137–145.

Eisler, R. (1993). Contaminant Hazard Reviews Zinc Hazards to Fish , Wildlife , and Invertebrates : A Synoptic Review by, (April).

El Nemr, A., El-Said, G. F., Khaled, A. & Ragab, S. (2016). Distribution and ecological risk assessment of some heavy metals in coastal surface sediments along the Red Sea, Egypt. International Journal of Sediment Research, 31(2), 164–172.

EPA (2003). Toxicological review of zinc and compounds. U.S Environmental ProtectionAgency.file:///C:/Users/User%20HP/Downloads/TOX_REVIEW_ FOR_ZINC_EXT_ REVIEW_DRAFT%20(3).PDF

FEDRIP (2004). Potential for human exposure: Federal Research in Progress Database. https://www.atsdr.cdc.gov/toxprofiles/tp60-c7.pdf

Flora, S. J. S., Mittal, M. & Mehta, A. (2016). Flora SJS , Mittal M , Mehta A . Heavy metal induced oxidative stress & its possible reversal by chelation therapy . Indian J Med Res 128 : 501- Heavy metal induced oxidative stress & its possible reversal by chelation therapy, (March), 501–523.

Fortune, J. (2006). The grainsize and heavy metal content of sediment in Darwin Harbour . Northern Territory Government. Department of Natural Resources, Environment and the arts. http://www.academia.edu/2072944/The_grainsize_and_heavy_metal_content_of_sediment_in_Darwin_Harbour

Furukawa, K. & Wolanski, E. (1996). Sedimentation in mangrove forests. Mangroves and Salt Marshes.

G.W. Suter II, & J.B. Mabrey. (1994). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota. Retrieved from https://www.osti.gov/servlets/purl/10112090

Gao, S. & Collins, M. (1994). Net sediment transport patterns inferred from grain-size trends, based upon definition of "transport vectors"—reply, *80*, 47–60.

Gao, X., Arthur Chen, C.T., Wang, G., Xue, Q., Tang, C. & Chen, S. (2010). Environmental status of Daya Bay surface sediments inferred from a sequential extraction technique. Estuarine, Coastal and Shelf Science, 86(3), 369–378.

Gao, X., Chen, C. A. & Bay, B. (2012). Heavy metal pollution status in surface sediments of the coastal Bohai Bay. Water Research, *46*(6), 1901–1911.

Ghrefat, H. & Yusuf, N. (2006). Assessing Mn, Fe, Cu, Zn, and Cd pollution in bottom sediments of Wadi Al-Arab Dam, Jordan. Chemosphere, 65(11), 2114–2121.

Ghufran, R., Abdul Halim, H., Alias, S. A. & Rahman, M. M. (2014). Assessment of heavy metal contamination at west and east coastal area of Peninsular. Malaysian Journal of Science, 33(1), 23–31.

González, A, Palma, M. G., Ziegler, K., González, E. & Álvarez, M. A. (2013). Contamination and risk assessment of heavy metals in bottom sediments from Lake Valencia , Venezuela, 16001, 10–13.

Hamzan, N. A. A., Mohamad, F. F. ., Ibrahim, M. I. & Ariffin, Z. A. (2015). Assessment of selected heavy metals in seawater and sediment at klang coastal area malaysia. Malaysian Journal of Analytical Sciences, 19(4), 730–738.

Harrison, M. R. (1999). Understanding Our Environment- An Introduction to Environmetal Chemistry and Pollution. (M. R. Harrison, Ed.) (Third). Royal Society of Chemistry.

Hernberg, S. (2000). Lead poisoning in a historical perspective. American Journal of Industrial Medicine, 38(3), 244–254.

HSE (2009). Health Safety and Executive. Cadmium and You. http://www.hse.gov.uk/pubns/indg391.pdf

Hu, B., Li, G., Li, J., Bi, J., Zhao, J. & Bu, R. (2013). Spatial distribution and ecotoxicological risk assessment of heavy metals in surface sediments of the southern Bohai Bay, China. Environmental Science and Pollution Research International, 20(6), 4099–4110.

Hund-Rinke, K., & Kördel, W. (2003). Underlying issues in bioaccessibility and bioavailability: Experimental methods. Ecotoxicology and Environmental Safety, 56(1), 52–62.

Hussein, K. O., Olalekan, S. F., Folahan, A. A., B. J. X. and R. G. S. (2012). A Review of Sequential Extraction Procedures for Heavy Metals Speciation in Soil and Sediment. Scientific Reports, 1(3).

Idriss, A. A. & Ahmad, A. K. (2013). Heavy Metals Nickel and Chromiumin Sediments in the Juru River , Penang , Malaysia. Journal of Environmental Protection, 2013(November), 1245–1250.

Ismail, A. (1993). Heavy metal concentrations in sediments off Bintulu, Malaysia. Marine Pollution Bulletin, 26(12), 706–707.

Ismail, Ahmad and Naji, Abolfazli (2011). Assessment of metals contamination in Klang River surface sediment by using different indexes. Environment Asia, 4(1). pp 30-38. ISSN 1906-1714.

IZA (1997). 2nd edition, An introduction to Zinc in the environment. Internation Zinc Association. http://www.zinc.org.in/wp-content/uploads/2013/06/Zinc-In-The-Environment.pdf

Jain, C. K., Singhal, D. C. & Sharma, M. K. (2004). Adsorption of zinc on bed sediment of River Hindon: Adsorption models and kinetics. Journal of Hazardous Materials, 114(1–3), 231–239.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B. & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology, 7(2), 60–72.

Jennerjahn, T. C. & Ittekkot, V. (2002). Relevance of mangroves for the production and deposition of organic matter along tropical continental margins. Naturwissenschaften, 89(1), 23–30.

Johnson, M. S., Roberts, R. D., Hutton, M. & Inskip, M. J. (1978). Distribution of Lead, Zinc and Cadmium in Small Mammals from Polluted Environments. Oikos, 30(1), 153.

Kabata-Pendias, A. & Pendias, H. (1992). Trace elements in soils and plants. Retrieved May 7, 2018, from http://www.sciepub.com/reference/67170

Karak, T. & Bhattacharyya, P. (2010). Heavy metal accumulation in soil amended with roadside pond sediment and uptake by winter wheat (*Triticum aestivum* L. cv. PBW 343). TheScientificWorldJournal, 10, 2314–2329.

Kehrig, H. A., Pinto, F. N., Moreira, I. & Malm, O. (2003). Heavy metals and methylmercury in a tropical coastal estuary and a mangrove in Brazil, *34*, 661–669.

Khalil, M. & El-gharabawy, S. (2016). Evaluation of mobile metals in sediments of Burullus Lagoon , Egypt. MPB, 6–11.

Khodami, S., Surif, M., W.O., W. M. & Daryanabard, R. (2017). Assessment of heavy metal pollution in surface sediments of the Bayan Lepas area, Penang, Malaysia. Marine Pollution Bulletin, 114(1), 615–622.

Klang, P., Belin, S., Sany, T., Salleh, A., Port, W., Port, N. & Port, S. (2013). Distribution and Contamination of Heavy Metal in the Coastal.

Lambert, O., Piroux, M., Puyo, S., Thorin, C., Larhantec, M., Delbac, F. & Pouliquen, H. (2012). Bees, honey and pollen as sentinels for lead environmental contamination. Environmental Pollution (Barking, Essex : 1987), 170, 254–259.

Liao, V. H. C., Chien, M. T., Tseng, Y.Y. & Ou, K.L. (2006). Assessment of heavy metal bioavailability in contaminated sediments and soils using green fluorescent protein-based bacterial biosensors. Environmental Pollution (Barking, Essex : 1987), 142(1), 17–23.

Lim, D., Choi, J. W., Shin, H. H., Jeong, D. H. & Jung, H. S. (2013). Toxicological impact assessment of heavy metal contamination on macrobenthic communities in southern coastal sediments of Korea. Marine Pollution Bulletin, 73(1), 362–368.

Lim, P. E. & Kiu, M. Y. (1995). Determination and speciation of heavy metals in. Environmental Monitoring and Assessment, 35, 85–95.

Liu, J., Zhang, X. H., Tran, H., Wang, D. Q. & Zhu, Y. N. (2011). Heavy metal contamination and risk assessment in water, paddy soil, and rice around an electroplating plant. Environmental Science and Pollution Research, 18(9), 1623–1632.

Liu, M., Zhang, A., Liao, Y., Chen, B. & Fan, D. (2015). The environment quality of heavy metals in sediments from the central Bohai Sea. MPB, 100(1), 534–543.

Long, E. R., Macdonald, D. D., Smith, S. L. & Calder, F. D. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management, 19(1), 81–97.

Looi, L. J., Aris, A. Z., Wan Johari, W. L., Md. Yusoff, F. & Hashim, Z. (2013). Baseline metals pollution profile of tropical estuaries and coastal waters of the Straits of Malacca. Marine Pollution Bulletin, 74(1), 471–476.

Maduabuchi, J.M. U., Nzegwu, C. N., Adigba, E. O., Aloke, R. U., Ezomike, C. N., Okocha, C. E.,Orisakwe, O. E. (2006). Lead and cadmium exposures from canned and non-canned beverages in Nigeria: a public health concern. The Science of the Total Environment, 366(2–3), 621–626.

Marasinghe Wadige, C. P. M., Taylor, A. M., Maher, W. A. & Krikowa, F. (2014). Bioavailability and toxicity of zinc from contaminated freshwater sediments: Linking exposure-dose–response relationships of the freshwater bivalve Hyridella australis to zinc-spiked sediments. Aquatic Toxicology, 156, 179–190.

Marchand, C., Allenbach, M. & Lallier-Vergès, E. (2011). Relationships between heavy metals distribution and organic matter cycling in mangrove sediments (Conception Bay, New Caledonia). Geoderma, 160(3–4), 444–456.

Marchand, C., Lallier-Vergès, E., Baltzer, F., Albéric, P., Cossa, D. & Baillif, P. (2006). Heavy metals distribution in mangrove sediments along the mobile coastline of French Guiana. Marine Chemistry, 98(1), 1–17.

Maslennikova, S., Larina, N., & Larin, S. (2012). the Effect of Sediment Grain Size on Heavy, *6*(1), 43–54.

Mathew, B. B., Tiwari, A. & Jatawa, S. K. (2011). Free Radicals and Antioxidants: Retrieved September 6, 2017, from https://www.researchgate.net/publication/262175269_Mathew_B_B_Tiwari_A_Jatawa_S_K_2011_Free_Radicals_and_Antioxidants_A_Review_Journal_of_Pharmacy_Research_412

Moattari, R. M., Rahimi, S., Rajabi, L., Derakhshan, A. A. & Keyhani, M. (2015). Statistical investigation of lead removal with various functionalized carboxylate ferroxane nanoparticles. Journal of Hazardous Materials, 283, 276–291.

Mohammed, A. S., Kapri, A. & Goel, R. (2011). Biomanagement of Metal-Contaminated Soils. Media, 20, 1–28.

Montagne, D., Cornu, S., Bourennane, H., Baize, D., Ratié, C. & King, D. (2007). Effect of Agricultural Practices on Trace- Element Distribution in Soil. Communications in Soil Science and Plant Analysis, 38(3–4), 473–491.

Muller G. (1969). No Title Index of geoaccumulation in sediments of Rhine River. Geojournal, 2(3), 108–118.

Munkittrick, K. R., Miller, P. A., Barton, D. R. & Dixon, D. G. (1991). Altered performance of white sucker populations in the Manitouwadge chain of lakes is associated with changes in benthic macroinvertebrate communities as a result of copper and zinc contamination. Ecotoxicology and Environmental Safety, 21(3), 318–326.

Nagajyoti, P. C., Lee, K. D. & Sreekanth, T. V. M. (2010). Heavy metals, occurrence and toxicity for plants: A review. Environmental Chemistry Letters, 8(3), 199–216.

Nagarajan, R., Jonathan, M. P., Roy, P. D., Wai-Hwa, L., Prasanna, M. V., Sarkar, S. K. & Navarrete-López, M. (2013). Metal concentrations in sediments from tourist beaches of Miri City, Sarawak, Malaysia (Borneo Island). Marine Pollution Bulletin, 73(1), 369–373.

Naji, A. & Ismail, A. (2011). Risk Assessment of Mercury Contamination in Surface Sediment of the Klang River , *5*(7), 215–221.

Naji, A., Ismail, A. & Ismail, A. R. (2010). Chemical speciation and contamination assessment of Zn and Cd by sequential extraction in surface sediment of Klang River , Malaysia. Microchemical Journal, 95(2), 285–292.

Needleman, H. (2004). Lead poisoning. Annual Review of Medicine, 55(1), 209–222.

Nehi Wadhwa, Blessy B Mathew, S. K. J. and A. T. (2012). Lipid peroxidation: Mechanism, models and significance. International Journal of Current Science, 3, 29–38. Retrieved from https://www.researchgate.net/profile/Blessy_Mathew5/publication/262176367_Lipid_peroxidation_mechanism_models_and_significance_International_Journal_of_Current_Science_2012_3_11-17/links/0deec53704e7d36b65000000.pdf

Nemati, K., Abu Bakar, N. K., Abas, M. R. & Sobhanzadeh, E. (2011). Speciation of heavy metals by modified BCR sequential extraction procedure in different depths of sediments from Sungai Buloh, Selangor, Malaysia. Journal of Hazardous Materials, 192(1), 402–410.

O'Gorman, J. & Humphreys, H. (2012). Application of copper to prevent and control infection. Where are we now? The Journal of Hospital Infection, 81(4), 217–223.

Okocha, R.O and Adedeji, O.B. (2012). Overview of copper toxicity to aquatic life. Http://www.sciencepub.net/report, 4(8).

Passos, E. D. A., Alves, J. C., dos Santos, I. S., Alves, J. D. P. H., Garcia, C. A. B. & Spinola Costa, A. C. (2010). Assessment of trace metals contamination in estuarine sediments using a sequential extraction technique and principal component analysis. Microchemical Journal, 96(1), 50–57.

Peijnenburg, W. J., Posthuma, L., Eijsackers, H. J. & Allen, H. E. (1997). A conceptual framework for implementation of bioavailability of metals for environmental management purposes. Ecotoxicology and Environmental Safety, 37(2), 163–172.

Peijnenburg, W., Posthuma, L., Zweers, P., Baerselman, R., de Groot, A. C., Van Veen, R. P. M. & Jager, T. (1999). Prediction of metal bioavailability in Dutch field soils for the oligochaete Enchytraeus crypticus. Ecotoxicology and Environmental Safety, 43(2), 170–186.

Peng, S.-H., Wang, W.-X., Li, X. & Yen, Y.-F. (2004). Metal partitioning in river sediments measured by sequential extraction and biomimetic approaches. Chemosphere, 57(8), 839–851.

Pourabadehei, M. & Mulligan, C. N. (2016). Chemosphere Effect of the resuspension technique on distribution of the heavy metals in sediment and suspended particulate matter. Chemosphere, 153, 58–67.

Praveena, S. M., Aris, A. Z. & Radojevic, M. (2010). E nvironment A sia. Environment Asia, 3, 79–83.

Praveena, S. M., Radojevic, M., Abdullah, M. H. & Aris, A. Z. (2008). S. M. Praveena, 2 M. Radojevic, 1 M. H. Abdullah, 3 A. Z. Aris, *5*(1), 35–42.

Rauret, G., Pardo, P. & Lo, J. F. (1998). Characterisation , validation and comparison of three methods for the extraction of phosphate from sediments, 376.

Real, C., Barreiro, R. & Carballeira, A. (1994). The application of microwave heating in sequential extractions of heavy metals in estuarine sediments. Science of The Total Environment, 152(2), 135–142.

Reza, M., Darvish, K., Esmaeilzadeh, M., Shemirani, F., Kazaali, A., Molamohyeddin, N., Dehghani, M. (2016). Geochemical speciation and ecological risk assessment of selected metals in the surface sediments of the northern Persian Gulf. MPB.

Riether, K. B., Dollard, M. A. & Billard, P. (2001). Assessment of heavy metal bioavailability using *Escherichia coli* zntAp::lux and copAp::lux-based biosensors. Applied Microbiology and Biotechnology, 57(5–6), 712–716.

Rosado, D. (2016). Chemosphere Assessment of heavy metals bioavailability and toxicity toward Vibrio fi scheri in sediment of the Huelva estuary, *153*, 10–17.

Rufa, T. & Ismail, A. (2016). Heavy Metals Pollution and Ecological Risk Assessment in Surface Sediments of West Coast of Peninsular, *7*(10).

Sakellari, A., Plavšić, M., Karavoltsos, S., Dassenakis, M, & Scoullos, M. (2011). Assessment of copper, cadmium and zinc remobilization in Mediterranean marine coastal sediments. Estuarine, Coastal and Shelf Science, 91(1), 1–12.

Sarmani, S. B. (1989). The determination of heavy metals in water , suspended materials and sediments from Langat River , Malaysia, (1975), 233–238.

Shrivastava, A. K. (2009). A review on copper pollution and its removal from water bodies by pollution control technologies. Indian Journal of Environmental Protection.

Sim, S. F., Ling, T. Y., Nyanti, L., Gerunsin, N., Wong, Y. E. & Kho, L. P. (2016). Assessment of Heavy Metals in Water , Sediment , and Fishes of a Large Tropical Hydroelectric Dam in Sarawak , Malaysia, *2016*.

Singh, A. K., Hasnain, S. I. & Banerjee, D. K. (1999). Grain size and geochemical partitioning of heavy metals in sediments of the Damodar River - a tributary of the lower Ganga, India. Environmental Geology, 39(1), 90–98.

Skaggs, T. H., Arya, L. M., Shouse, P. J. & Mohanty, B. P. (2001). Estimating Particle-Size Distribution from Limited Soil Texture Data. Soil Science Society of America Journal.

Smith, K. S. & Huyck, H. L. O. (1999). An Overview of the Abundance, Relative Mobility, Bioavailability, and Human Toxicity of Metals. Reviews in Economic Geology; The Environmental Geochemistry of Mineral Deposits, Volumes 6A and 6B.

Song, Y., Choi, M. S., Lee, J. Y. & Jang, D. J. (2014). Regional background concentrations of heavy metals (Cr, Co, Ni, Cu, Zn, Pb) in coastal sediments of the South Sea of Korea. The Science of the Total Environment, 482–483, 80–91.

Sörme, L. & Lagerkvist, R. (2002). Sources of heavy metals in urban wastewater in Stockholm. Science of the Total Environment, 298(1–3), 131–145.

Sreekanth, A., Mrudulrag, S. K., Cheriyan, E. & Sujatha, C. H. (2015). Trace metal enrichment and organic matter sources in the surface sediments of Arabian Sea along southwest India (Kerala coast). MPB, 101(2), 938–946.

Su, C., Jiang, L. & Zhang, W. (2014). A review on heavy metal contamination in the soil worldwide: Situation, impact and remediation techniques. Environmental Skeptics and Critics, 3(2), 24–38.

Sultan, K., Shazili, N. A. & Peiffer, S. (2011). Distribution of Pb, As, Cd, Sn and Hg in soil, sediment and surface water of the tropical river watershed, Terengganu (Malaysia). Journal of Hydro-Environment Research, 5(3), 169–176.

Suresh, G., Ramasamy, V., Sundarrajan, M. & Paramasivam, K. (2014). Spatial and vertical distributions of heavy metals and their potential toxicity levels in various beach sediments from high-background- radiation area , Kerala , India. Marine Pollution Bulletin.

Šurija, B. & Branica, M. (1995). Distribution of Cd, Pb, Cu and Zn in carbonate sediments from the Krka river estuary obtained by sequential extraction. Science of The Total Environment, 170(1–2), 101–118.

Tafesse Gebreyesus, S. (2014). Heavy Metals in Contaminated Soil: Sources & Washing through Chemical Extractants. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) ISSN (Print), 10(1), 2313–4410. Retrieved from http://asrjetsjournal.org/

Talmage, S. S. & Walton, B. T. (1991). Small mammals as monitors of environmental contaminants. Reviews of Environmental Contamination and Toxicology, 119, 47–145. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1992495

Tavakoly Sany, S. B., Salleh, A., Rezayi, M., Saadati, N., Narimany, L. & Tehrani, G. M. (2013). Distribution and contamination of heavy metal in the coastal sediments of Port Klang, Selangor, Malaysia. Water, Air, and Soil Pollution, 224(4).

Tessier, A., Campbell, P. G. C. & Bisson, M. (1979). Sequential Extraction Procedure for the Speciation of Particulate Trace Metals, 51(7), 844–851.

Tomlinson, D. L. Wilson, J. G., Harris C. R. & Jeffry D. W. (1980). Problems in the assessment of heavy metals levels in estuaries and the formation of a pollution index. Helgolander Meeresunters, 33, 566–575.

Turekian, K. K. & Wedepohl, K. H. (1961). Geological Society of America Bulletin Distribution of the Elements in Some Major Units of the Earth's Crust.

Turki, A. (2007). Metal Speciation (Cd, Cu, Pb and Zn) in Sediments from Al Shabab Lagoon, Jeddah, Saudi Arabia. Journal of King Abdulaziz University-Marine Sciences, 18(1), 191–210.

Udechukwu, B. E. & Ismail, A. (2014). Distribution , mobility , and pollution assessment of Cd , Cu , Ni , Pb , Zn , and Fe in intertidal surface sediments of Sg . Puloh mangrove estuary , Malaysia.

USDI (1998). United State Department of Interior. National Irrigation Water Quality Program Information Report No.3. Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water and Sediment-Zinc.

Veríssimo, M. I. S., Oliveira, J. a. B. P. & Gomes, M. T. S. R. (2005). The evaluation of copper contamination of food cooked in copper pans using a piezoelectric quartz crystal resonator. Sensors and Actuators B: Chemical, 111–112, 587–591.

Wang, J. P., Wang, X. J. & Zhang, J. (2013). Evaluating loss-on-ignition method for determinations of soil organic and inorganic carbon in arid soils of northwestern china. Pedosphere, 23(5), 593–599.

Wildi, W., Dominik, J., Loizeau, J. L., Thomas, R. L., Favarger, P. Y., Haller, L., Peytremann, C. (2004). River, reservoir and lake sediment contamination by heavy metals downstream from urban areas of Switzerland. Lakes and Reservoirs: Research and Management, 9(1), 75–87.

Xie, S., Dearing, J. A. & Bloemendal, J. (2000). The organic matter content of street dust in Liverpool, UK, and its association with dust magnetic properties. Atmospheric Environment, 34(2), 269–275.

Yang, J., Cao, L., Wang, J., Liu, C., Huang, C., Cai, W., Peng, X. (2014). Speciation of Metals and Assessment of Contamination in Surface Sediments from Daya Bay, South China Sea. Sustainability, 6(12), 9096–9113.

Yap, C. K., Ismail, A. & Tan, S. G. (2003). Cd and Zn concentration in the straits of Malacca and intertidal sediments of the west coast of Peninsular Malaysia. Marine Pollution Bulletin, 46(10), 1341–1348.

Yap, C. K., Ismail, A., Tan, S. G. & Omar, H. (2002a). Correlations between speciation of Cd , Cu , Pb and Zn in sediment and their concentrations in total soft tissue of green-lipped mussel Perna viridis from the west coast of Peninsular Malaysia, *28*, 117–126.

Yap, C. K., Ismail, a, Tan, S. G. & Omar, H. (2002b). Concentrations of Cu and Pb in the offshore and intertidal sediments of the west coast of Peninsular Malaysia. Environment International, 28(6), 467–479. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12503912

Yongming, H., Peixuan, D., Junji, C. & Posmentier, E. S. (2006). Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China. Science of the Total Environment, 355(1–3), 176–186.

Yoshida, F., Hata, A. & Tonegawa, H. (1999). Itai-Itai disease and the countermeasures against cadmium pollution by the Kamioka mine. Environmental Economics and Policy Studies, 2(3), 215–229.

Zahra, A., Hashmi, M. Z., Malik, R. N. & Ahmed, Z. (2013). Enrichment and geo-accumulation of heavy metals and risk assessment of sediments of the Kurang Nallah-Feeding tributary of the Rawal Lake Reservoir, Pakistan. The Science of the Total Environment, 470–471C, 925–933.

Zarcinas, B. A., Ishak, C. F., Mclaughlin, M. J., Cozens, G., Zahra, A., Zaffar, M., Navarrete-López, M. (2016). Assessment of selected heavy metals in seawater and sediment at klang coastal area malaysia. Marine Pollution Bulletin, 7(1), 730–738.

Zhang, C., Yu, Z., Zeng, G., Jiang, M., Yang, Z., Cui, F., Hu, L. (2014). Effect of sediment geochemical properties on heavy metal bioavailability. Environmental International, 73, 270–281.

Zhang, L., Liao, Q., Shao, S., Zhang, N., Shen, Q. & Liu, C. (2015). Heavy Metal Pollution, Fractionation, and Potential Ecological Risks in Sediments from Lake Chaohu (Eastern China) and the Surrounding Rivers. International Journal of Environmental Research and Public Health, 12(11), 14115–14131.

Zhang, Z., Juying, L., Mamat, Z. & Qingfu, Y. (2016). Ecotoxicology and Environmental Safety Sources identi fi cation and pollution evaluation of heavy metals in the surface sediments of Bortala River , Northwest China. Ecotoxicology and Environmental Safety, 126, 94–101.

Zhou, L., Yang, B., Xue, N., Li, F., Seip, H. M., Cong, X., Li, H. (2014). Ecological risks and potential sources of heavy metals in agricultural soils from Huanghuai Plain, China. Environmental Science and Pollution Research, 21(2), 1360–1369.

Zhu, H., Yuan, X., Zeng, G., Jiang, M., Liang, J., Zhang, C., Jiang, H. (2012). Ecological risk assessment of heavy metals in sediments of Xiawan Port based on modified potential ecological risk index. Transactions of Nonferrous Metals Society of China, 22(6), 1470–1477.

Zou, J., Dai, W., Gong, S. & Ma, Z. (2015). Analysis of spatial variations and sources of heavy metals in farmland soils of beijing suburbs. PLoS ONE, 10(2), 1–13.