VERTICAL DISTRIBUTIONS OF ZINC, CADMIUM, LEAD AND COPPER IN SEDIMENTS OF SELECTED COASTAL AREAS IN THE WEST COAST OF PENINSULAR MALAYSIA

By

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

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DEDICATION

My beloved parents and family, supervisor and fellow friends who endlessly provide their mental, spiritual, and financial support until the completion of this thesis.

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 : Khairul Nizam Mohamed @ Mohd Ramli, PhD
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A comprehensive study on sediment profile is important in comprehending the historical condition of sediment degradation by heavy metal content elevation caused by anthropogenic activities such as agricultural practices, urbanization, and industries such as tourism. The extraction of heavy metals in sediment particularly in getting measurement with good accuracy and precision is challenging, hence, this study includes the optimization of heavy metals extraction in sediment through acid digestion, assessing sediment quality from Sungai Buloh, Bagan Pasir estuary, and Kampung Baharu coastline through the determination of heavy metal profiles, and analyzing data using pollution indices. The optimization of metals namely zinc (Zn), cadmium (Cd), lead (Pb), and copper (Cu) extractions from Certified Reference Material, BCR®-667 of Estuarine Sediment was carried out to get good metals recoveries with Differential Pulse Stripping Voltammetry (DPSV) and Inductive Coupled Plasma-Mass Spectrometry (ICP-MS) determination. The recovery values determined by DPSV and ICP-MS ranged from 18.85-154.38% and 75.28-90.13%, respectively, where Zn, Cd, Pb, and Cu were simultaneously measured in BCR®-667. The mixture of hydrochloric acid, nitric acid, and hydrofluoric acid coupled with ICP-MS determination was selected as the best method and employed to assess the status of Zn, Cd, Pb, Cu distribution in core sediments of Bagan Pasir estuary, Sungai Buloh, and the coastline of Kampung Baharu, Port Dickson. Based on the vertical profiles of heavy metals concentrations, the order of metals in decreasing manner was Zn>Pb>Cu>Cd in Bagan Pasir estuary and Sungai Buloh stations, while Zn>Cu>Pb>Cd in Kampung Baharu, Port Dickson. Most of the means of the analyzed metals were below Interim Sediment Quality Guidelines and the effect range-low (ERL) in all sampling locations except for Cu in Kampung Baharu coastline and Zn in Sungai Buloh where their concentrations ranges were between the ERL and effect range-median (ERM). The results of geo-accumulation index,

contamination factor and pollution load index classified the sediment quality as not polluted with studied metals with the exception of the element Pb at certain depths of the sediment cores as well as historical pollution at bottom sediment of SB2 sediment core. Therefore, heavy metal concentration in the sediments of these three areas were not at an alarming stage, however, requires regular monitoring from the authorities to maintain sustainable management of these areas.

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

TABURAN MENEGAK ZINK, KADMIUM, PLUMBUM, DAN KUPRUM DI DALAM SEDIMEN TERPILIH PANTAI BARAT SEMENANJUNG MALAYSIA

Oleh

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Penyelidikan menyeluruh terhadap profil sedimen adalah penting untuk mengetahui sejarah degradasi sedimen disebabkan oleh penambahan kepekatan logam yang terutamanya disebabkan oleh aktiviti-aktiviti antropogenik sepertiaktiviti pertanian, perbandaran, dan industri seperti pelancongan. Pengekstrakan logam berat terutamanya dalam mendapatkan ukuran yang tepat adalah mencabar, oleh itu, penyelidikan ini merangkumi pengoptimuman pengekstrakan logam berat daripada sedimen melalui pencernaan asid, menilai kualiti sedimen dari Sungai Buloh, kuala Bagan Pasir, and persisiran pantai Kampung Baharu melalui profil logam berat, dan menganalisis data menggunakan indeks-indeks pencemaran. Pengoptimuman pengekstrakan logam berat zink (Zn) , cadmium (Cd), plumbum (Pb), kuprum (Cu) daripada Bahan Rujukan Bersijil, BCR®-667 *Estuarine Sediment* telah dijalankan untuk mendapatkan perolehan logam berat yang baik dengan menggunakan penentuan *Differential Pulse Stripping Voltammetry (DPSV)* dan *Inductive Coupled Plasma-Mass Spectrometry (ICP-MS).* Nilai perolehan yang ditentukan oleh DPSV dan ICP-MS masing-masing adalah dalam julat dari 18.85-154.38% dan75.28-90.13% di mana Zn, Cd, Pb, dan Cu telah diukur secara serentak di dalam BCR®-667. Campuran asid hidroklorik, asid nitrik, dan asid hidrofluorik bersama penggunaan ICP-MS telah dipilih sebagai kaedah yang terbaik serta digunakan untuk menilai status taburan Zn, Cd, Pb, Cu di dalam *sediment core* kuala Bagan Pasir, Sungai Buloh dan pantai Kampung Baharu, Port Dickson. Berdasarkan profil menegak kepekatan logam berat, susunan kepekatan logam berat secara menurun adalah Zn>Pb>Cu>Cd di kuala Bagan Pasir dan Sungai Buloh, manakala Zn>Cu>Pb>Cd di Kampung Baharu, Port Dickson. Kebanyakan purata kepekatan logam yang dianalisis adalah di bawah nilai *Interim Sediment Quality Guidelines* dan *effect range-low (ERL)*di semua lokasi persampelan kecuali Cu di pantai Kampung Baharu dan Zn di Sungai Buloh yang mana nilai kepekatannya terletak di antara *(ERL)* dan *effect range-median (ERM)*Keputusan dari indeks geoakumulasi, faktor

pencemaran dan indeks beban pencemaran mengkelaskan kualiti sedimen sebagai tidak tercemar dengan logam berat yang dikaji kecuali elemen Pb pada beberapa kedalaman di dalam *sediment core* serta pencemaran terdahulu pada bahagian dasar *sediment core* SB2. Oleh itu, kepekatan logam berat di dalam sedimen di kawasan-kawasan ini adalah tidak membimbangkan tetapi perlu pemantauan teratur daripada pihak-pihak berkuasa untuk tujuan pengekalan pengurusan lestari kawasan-kawasan tersebut.

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This thesis was submitted to the Senate of 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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I hereby confirm that:

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LIST OF ABBREVIATIONS

Zn	Zinc
Al	Aluminium
Cd	Cadmium
Pb	Lead
Cu	Copper
Ni	Nickel
Cr	Chromium
Hg	Mercury
Fe	Iron
V	Vanadium
Co	Cobalt
Ag	Silver
Bi	Bismuth
Sn	Tin
Tl	Thallium
$g.cm^{-3}$	Gram per Cubic Centimetre
$mg.kg^{-1}$	Milligram per Kilogram
$ug.g^{-1}$	Microgram per Gram
mg/L	Milligram per Litre
PTFE-Bombs	Polytetrafluoroethylene
SRM	Standard Reference Material
CRM	Certified Reference Material
BCR	Community Bureau of Reference
GIS	Geographical Information System

USEPA	United State Environmental Protection Agency
FAO	Food and Agriculture Organization
HCl	Hydrochloric acid
HNO_3	Nitric acid
HF	Hydrofluoric acid
$HClO_4$	Perchloric acid
H_2SO_4	Sulphuric acid
H_2O_2	Hydrogen peroxide
KCl	Potassium Chloride
I(A)	Current
U(V)	Voltage
SET	Sequential Extraction Technique
FIZ	Free Industrial Zone
EEZ	Exclusive Economic Zone
EF	Enrichment Factor
Igeo	Geoaccumulation Index
CF	Contamination Factor
Cd	Degree of Contamination
Er	Potential Risk for Individual Metal
PERI	Potential Ecological Risk Index
PLI	Pollution Load Index
CPI	Combined Pollution Index
SQGs	Sediment Quality Guidelines
CCME	Le Conseil Canadien des Ministres de L'environnement
ICP-MS	Coupled Plasma Mass Spectrometry

AAS	Atomic Absorption Spectroscopy
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
PM_{10}	Particulate Matter
DPSV	Differential Pulse Stripping Voltammetry
IRMM	Institute for Reference Materials and Measurements
HMDE	Hanging Mercury Drop Electrode
WE	Working Electrode
AE	Auxiliary Electrode
SD	Standard Deviation
ERL	Effective Range Low
ERM	Effective range Median
ISQG	Interim Sediment Quality Guidelines
ANOVA	Analysis of Variance

CHAPTER 1

INTRODUCTION

1.1 Background

For the past centuries, elevation of heavy metals concentration has been threatening us due to its tenacity in the environment and their potential toxicity and bioavailability (Idriss & Ahmad, 2013; Xu et al., 2017). In response to population growth and anthropogenic activities, heavy metal pollution has become a great worldwide concern as their input to the coastal areas particularly in developing countries are exponentially increasing (Hamzan et al., 2015). Urbanizations, industrialization, shipping activities, and domestic wastes are the major sources for the contamination to occur (Elias et al., 2018). Metals are usually bound to particulate matter when discharged into the aquatic system eventually settled and incorporated into the sediment (Khodami et al., 2017) through the processes of precipitation, diffusion, chemical reactions or biological activity and adsorption (Idriss & Ahmad, 2013; Tavakoly Sany et al., 2013).

The settling of heavy metals in sediment could become secondary or point source of metals from the remobilization of heavy metals resulted from the sediment mixing at the sediment-seawater interface level (Turki, 2007). Eventually, the re-suspended heavy metals will be taken up by aquatic organisms that have direct contact with contaminated sediment (Pejman et al., 2015) and subsequently, human health is to be affected (Yap et al., 2002). As in many developing countries, the Malaysian coastal zone has experienced severe deterioration as a result of pollution (Buhari & Ismail, 2016). As the final destination of considerable pollutant input from the land, coastal areas became an active targets for the study of heavy metals changes in the marine environment (Al-Mur et al., 2017; Nawrot et al., 2019). Furthermore, studying the metals distribution in sediments next to industrial and residential zones could provide researchers with indications of the anthropogenic effects on ecosystems, while assisting in assessing the potential risks with the disposal of human waste (Tiwari et al., 2013).

Therefore, continuous researches of metals content in the marine environment are crucial for the following reasons; to assess the risks of environmental health, to understand the heavy metals distribution, to identify the problem, causes and solution relating to the contamination of heavy metals, to monitor and mitigate industrial development, to manage river developments, to control the sustainable future usage of the river water, to provide scientific references for protecting the relative local aquatic environment, and ultimately to protect human from the deleterious effect of heavy metals (Khodami et al., 2017; Wang et al., 2017; Wong et al., 2017; Xu et al., 2017). The inclusive study of the ecotoxicology of the deadly heavy metals and metalloids and the environmental chemistry confirms that we should act to minimize the implication of heavy metals to the environment and humans (Ali et al., 2019).

1.2 Problem statements

The surrounding anthropogenic activities of Bagan Pasir, Sungai Buloh, and Port Dickson varied from agriculture, urban, and tourism industry as well as port activities (Abdullah et al., 2012; Kadhum at el., 2016; Ramli et al., 2013). Sediment in these areas are expected to have the risk of degradation if the nearby lands are not regularly monitored and sustainably managed (Redzwan et al., 2014). The degradation of sediment quality poses an unfavourable effect to the aquatic organisms such as blood cockles. The production rate of blood cockles declined from 40,000 tons in 2010 to 25,000 in 2011 (Yurimoto et al., 2014). High amount of ammonia in water, low food availability as well as freshwater flooding associated in changing environments (Yurimoto et al., 2014) were reported to be the potential factors that had affected the production of blood cockles (Ramli et al., 2013). Nonetheless, information on heavy metals pollution level of these sites are scarce and still requires studies to be executed because the main factor has yet to be confirmed due to the constantly changing environment in cockles breeding grounds (Harith et al., 2016). In addition, it is crucial to have good condition of cockles breeding ground because heavy metals tend to be accumulated in blood cockles whole body tissue and this poses a threat to human beings (Yurimoto et al., 2014) and this makes it is unarguably important to study heavy metal levels in the sediment. Despite some heavy metals are essential to humans such as zinc and copper, excess of these metals pose threat to human health (Nriagu, 2011). Whereas, non-essential heavy metals such as cadmium and lead provide harmful effects even in trace amount (Wani et al., 2015). Which is why study on these four metals is important to emphasize.

Coastal degradation is inevitable as the activities in its surrounding continue to increase. For example, the ruined of the beaches of Port Dickson's natural surrounding from the effects of the tourism industry (Nair et al., 2016). The building of beach resorts, and related services to meet the needs of the tourism industry in Port Dickson had given the authorities hard times to restore the beaches to its natural beauty and still is (Abdullah et al., 2012; Nair et al, 2016). Coastal area contamination in Malaysia is yet to be controlled nor completely reported, despite the constant monitoring by the authority (Redzwan et al., 2014). Hence, there should be ongoing studies on the status of pollution in these areas so the data could be utilized as scientific references in the future for a sustainable management to be maintained.

Sediment cores was chosen instead of surface sediment in the present study because studies on sediments at depths greater than 5cm are still very limited in Malaysia despite the valuable information that can be extracted from core sediment. The recent and historic contamination can be extracted from sediment core (Nartey et al., 2019) and when coupled with dating analysis, it provided us to historical evidence of anthropogenic effect in the aquatic environment (Al-Mur et al., 2017; Natesan & Ranga, 2011; Yusoff et al., 2015).

1.3 Objectives

The general objective of this study is to identify the status of heavy metals distribution at a few selected sites along the west coast of Peninsular Malaysia. To achieve the main goal, the scope of study includes specific objectives as follow;

i) Determination of Zinc, Cadmium, Lead, and Copper distributions in sediment profiles from Bagan Pasir Estuary, Sungai Buloh, Selangor, and Kampung Baharu coastline, Port Dickson.
ii) Assessment of Zinc, Cadmium, Lead, and Copper pollution status with pollution indices in selected study sites.

1.4 Research Questions

Based on the objectives of study, the research questions were as follows;

a) What is the level of Zn, Cd, Pb, and Cu in sediment cores of Bagan Pasir estuary, Sungai Buloh, and Kampung Baharu coastline?
b) What is the status of studied heavy metals pollution in these areas?

1.5 Significance of study

The study managed to determine all metals of interest throughout the sediment cores and assessed their pollution status. The established vertical profiles of Zn, Cd, Pb, and Cu in sediment of Bagan Pasir estuary, Sungai Buloh, Selangor, and coastline of Kampung Baharu, Port Dickson could serve as scientific references for further sustainable management of the studied areas. The heavy metals vertical profiles successfully determined, however due to financial constraint, the study did not manage to perform sediment dating.

REFERENCES

Abdullah, M. A., Ali, N., Aznie, R., Rose, C., Fuad, M., & Jali, M. (2012). Industri pelancongan dan alam sekitar di Port Dickson: menyorot titik keseimbangan antara permintaan dan penawaran. *Geografia: Malaysian Journal of Society & Space*, *8*(7), 135–146.

Abrahim, G. M. S., & Parker, R. J. (2008). Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. *Environmental Monitoring and Assessment*, *136*(1–3), 227–238. https://doi.org/10.1007/s10661-007-9678-2

Abbruzzini, T. F., Silva, C. A., Andrade, D. A., & Carneiro, W. J. O. (2014). Influence Of Digestion Methods On The Recovery Of Iron , Zinc , Nickel , Chromium , Cadmium And Lead Contents In 11 Organic Residues *(1)*. (4), 166–176.

Al-Mur, B. A., Quicksall, A. N., & Al-Ansari, A. M. A. (2017). Spatial and temporal distribution of heavy metals in coastal core sediments from the Red Sea, Saudi Arabia. *Oceanologia*, *59*(3), 262–270. https://doi.org/10.1016/j.oceano.2017.03.003

Ali, H., Khan, E., & Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. *Journal of Chemistry*, *2019*(Cd). https://doi.org/10.1155/2019/6730305

Aoshima, K. (2016). Itai-itai disease: Renal tubular osteomalacia induced by environmental exposure to cadmium—historical review and perspectives. *Soil Science and Plant Nutrition*, *62*(4), 319–326. https://doi.org/10.1080/00380768.2016.1159116

Ariño, C., Serrano, N., Díaz-Cruz, J. M., & Esteban, M. (2017). Voltammetric determination of metal ions beyond mercury electrodes. A review. *Analytica Chimica Acta*, *990*, 11–53. https://doi.org/10.1016/j.aca.2017.07.069

Asghari, A., Saadatjou, N., & Rajabi, M. (2008). Simultaneous determination of trace amounts of lead and zinc by adsorptive cathodic stripping voltammetry. *Chemia Analityczna*, *53*(3), 410–418.

Ashraf, A., Saion, E., Gharibshahi, E., Yap, C. K., Kamari, H. M., Elias, M. S., & Rahman, S. A. (2018). Distribution of Heavy Metals in Core Marine Sediments of Coastal East Malaysia by Instrumental Neutron Activation Analysis and Inductively Coupled Plasma Spectroscopy. *Applied Radiation and Isotopes*, *132*, 222–231. https://doi.org/10.1016/j.apradiso.2017.11.012

Babich, H., & Stotzky H. G., (1976). Effects of Cadmium on the Biota: *Influence* *o f Environmental Factors*.

Baby, J., Raj, J., Biby, E., Sankarganesh, P., Jeevitha, M., Ajisha, S., & Rajan, S. (2011). Toxic effect of heavy metals on aquatic environment. *International Journal of Biological and Chemical Sciences*, *4*(4). https://doi.org/10.4314/ijbcs.v4i4.62976

Barbieri, M. (2016). The Importance of Enrichment Factor (EF) and Geoaccumulation Index (Igeo) to Evaluate the Soil Contamination. *Geology & Geophysics* *5*(1), 1–4. https://doi.org/10.4172/2381-8719.1000237

Besser, J. M., & Leib, K. J. (2007). Toxicity of Metals in Water and Sediment to Aquatic Biota. In Stanley E. Church, Paul von Guerard, and Susan E. Finger (Eds.), *Integrated Investigations of Environmental Effects of Historical Mining in the Animas River Watershed, San Juan County, Colorado* (pp. 840-846).

Blossom, N. (2015). Copper in the Ocean Environment. *American Chemet Corporation*, (406), 1–8. Retrieved from http://www.chemet.com/assets/1/6/Copper_and_the_Ocean_Environment.pdf

Bradl, H. B. (2005). Sources and Origins of Heavy Metals. In H. B. Bradl (Ed.).*Heavy Metals in the Environment; origin, interaction and remediation* (pp.1–27).

Brady, J. P., Ayoko, G. A., Martens, W. N., & Goonetilleke, A. (2015). Development of a hybrid pollution index for heavy metals in marine and estuarine sediments. *Environment Monitoring and Assessment,* 187, 306. https://doi.org/10.1007/s10661-015-4563-x

Buffle, J., & Tercier-Waeber, M. L. (2005). Voltammetric environmental trace-metal analysis and speciation: From laboratory to in situ measurements. *TrAC - Trends in Analytical Chemistry*, *24*(3 SPEC. ISS.), 172–191. https://doi.org/10.1016/j.trac.2004.11.013

Buhari, T. R., & Ismail, A. (2016). Heavy Metals Pollution and Ecological Risk Assessment in Surface Sediments of West Coast of Peninsular Malaysia. *International Journal of Environmental Science and Development*, *7*(10), 750–756. https://doi.org/10.18178/ijesd.2016.7.10.874

Buzica, D., Gerboles, M., Borowiak, A., Trincherini, P., Passarella, R., & Pedroni, V. (2006). Comparison of voltammetry and inductively coupled plasma-mass spectrometry for the determination of heavy metals in PM10 airborne particulate matter. *Atmospheric Environment*, *40*(25), 4703–4710. https://doi.org/10.1016/j.atmosenv.2006.04.015

Chand, V., & Prasad, S. (2013). ICP-OES assessment of heavy metal contamination in tropical marine sediments : A comparative study of two digestion techniques. *Microchemical Journal*, *111*, 53–61.

https://doi.org/10.1016/j.microc.2012.11.007

Chapman, P. M., Allard, P. J., & Vigers, G. A. (1999). Development of Sediment Quality Values for Hong Kong Special Administrative Region: A Possible Model for Other Jurisdictions. *Marine Pollution Bulletin*, *38*(3), 161–169. https://doi.org/http://dx.doi.org/10.1016/S0025-326X(98)00162-3

Chen, C. F., Ju, Y. R., Chen, C. W., & Dong, C. Di. (2016). Vertical profile, contamination assessment, and source apportionment of heavy metals in sediment cores of Kaohsiung Harbor, Taiwan. *Chemosphere*, *165*, 67–79. https://doi.org/10.1016/j.chemosphere.2016.09.019

Companys, E., Galceran, J., Pinheiro, J. P., Puy, J., & Salaün, P. (2017). A review on electrochemical methods for trace metal speciation in environmental media. *Current Opinion in Electrochemistry*, *3*(1), 144–162. https://doi.org/10.1016/j.coelec.2017.09.007

Corrill, L. S., & Huff, J. E. (1976). Occurrence, physiologic effects, and toxicity of heavy metals - arsenic, cadmium, lead, mercury, and zinc in marine biota: an annotated literature collection. *Environmental Health Perspectives*, *Vol.18*(December), 181–183. https://doi.org/10.2307/3428700

Covaci, E., Darvasi, E., & Ponta, M. (2017). Simultaneous determination of Zn, Cd, Pb and Cu in mushrooms by differential pulse anodic stripping voltammetry. *Studia Universitatis Babes-Bolyai Chemia*, *62*(3), 133–144. https://doi.org/10.24193/subbchem.2017.3.10

Cuculić, V., Cukrov, N., Kwokal, Ž., & Mlakar, M. (2009). Natural and anthropogenic sources of Hg, Cd, Pb, Cu and Zn in seawater and sediment of Mljet National Park, Croatia. *Estuarine, Coastal and Shelf Science*, *81*(3), 311–320. https://doi.org/10.1016/j.ecss.2008.11.006

Dahms, S., Baker, N. J., & Greenfield, R. (2017). Ecological risk assessment of trace elements in sediment: A case study from Limpopo, South Africa. *Ecotoxicology and Environmental Safety*, *135*, 106–114. https://doi.org/10.1016/j.ecoenv.2016.09.036

Dong, C.-D., Chen, C.-F., & Chen, C.-W. (2013). Contamination of Zinc in Sediments at River Mouths and Channel in Northern Kaohsiung Harbor, Taiwan. *International Journal of Environmental Science and Development*, *3*(6), 517–521. https://doi.org/10.7763/ijesd.2012.v3.278

Dyer, K. R. (1995). Sediment transport processes in estuaries. *Developments in Sedimentology*, *53*(C), 423–449. https://doi.org/10.1016/S0070-4571(05)80034-2

Elias, M. S., Ibrahim, S., Samuding, K., Rahman, S. A., & Hashim, A. (2018). The sources and ecological risk assessment of elemental pollution in sediment of Linggi estuary, Malaysia. *Marine Pollution Bulletin*, *137*(June), 646–655. https://doi.org/10.1016/j.marpolbul.2018.11.006

Ergin, M., Saydam, C., Baştürk, Ö., Erdem, E., & Yörük, R. (1991). Heavy metal concentrations in surface sediments from the two coastal inlets (Golden Horn Estuary and İzmit Bay) of the northeastern Sea of Marmara. *Chemical Geology*, *91*(3), 269–285. https://doi.org/10.1016/0009-2541(91)90004-B

Facchinelli, A., Sacchi, E., & Mallen, L. (2001). Multivariate statistical and GIS-based approach to identify heavy metal sources in soils. *Environmental Pollution, 114,* 313-324*.*

Gaines, P. R. (2011). ICP Operations Guide A Guide for using ICP-OES and ICP-MS. *Inorganic Ventures*, 44.

Geana, E. I., Iordache, A. M., Voica, C., Culea, M., & Ionete, R. E. (2011). Comparison of three digestion methods for heavy metals determination in soils and sediments materials by ICP-MS technique. *Asian Journal of Chemistry*, *23*(12), 5213–5216.

Gidlow, D. A. (2004). Lead toxicity. *Occupational Medicine*, *54*(2), 76–81. https://doi.org/10.1093/occmed/kqh019

Goemann, K., Panietz, E., Noble, T., Chase, Z., Townsend, A. T., & Durand, A. (2016). Improved methodology for the microwave digestion of carbonate-rich environmental samples. *International Journal of Environmental Analytical Chemistry*, *96*(2), 119–136. https://doi.org/10.1080/03067319.2015.1137904

Gorman, R. (2000). What regulates sedimentation in estuaries ? *Water and Atmosphere*, *8*(4), 13–16.

Güven, D. E., & Akinci, G. (2011). Comparison of acid digestion techniques to determine heavy metals in sediment and soil samples. *Gazi University Journal of Science*, *24*(1), 29–34.

Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. *Water Research*, *14*(8), 975–1001. https://doi.org/10.1016/0043-1354(80)90143-8

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.

Harikumar, P. S., & Nasir, U. P. (2010). Ecotoxicological impact assessment of heavy metals in core sediments of a tropical estuary. *Ecotoxicology and Environmental Safety*, *73*(7), 1742–1747. https://doi.org/10.1016/j.ecoenv.2010.08.022

Harith, H., Husain, M. L., & Mohd Akhir, M. F. (2016). Coastal oceanographic processes associated with blood cockle (*Anadara granosa*) induce spawning season in Kapar, Selangor, Malaysia. *Journal of Ocean Engineering and Science*, *1*(4), 289–299. https://doi.org/10.1016/j.joes.2016.09.003

Helaluddin, A. B. M., Khalid, R. S., Alaama, M., & Abbas, S. A. (2016). Main analytical techniques used for elemental analysis in various matrices. *Tropical Journal of Pharmaceutical Research*, *15*(2), 427–434. https://doi.org/10.4314/tjpr.v15i2.29

Hogstrand, C. (2011). Zinc. *Fish Physiology*, *31*(PART A), 135–200. https://doi.org/10.1016/S1546-5098(11)31003-5

Hossen, M. F., Hamdan, S., & Rahman, M. R. (2014). Cadmium and Lead in Blood Cockle (*Anadara granosa*) from Asajaya, Sarawak, Malaysia. *Scientific World Journal*, *2014*. https://doi.org/10.1155/2014/924360

Hossen, M. F., Hamdan, S., & Rahman, M. R. (2015). Review on the risk assessment of heavy metals in Malaysian clams. *Scientific World Journal*, *2015*. https://doi.org/10.1155/2015/905497

Hübner, R., & Haslam, R. (2011). Investigation of the effect of mesh size on the effectiveness of hotplate Aqua regia extractions. *Communications in Soil Science and Plant Analysis*, *42*(2), 159–166. https://doi.org/10.1080/00103624.2011.535066

Hurst, D. T. (1995). Chapter 6.3 Six-Membered Ring Systems: Triazines, Tetrazines, and Fused Ring Polyaza Systems. *Progress in Heterocyclic Chemistry*, *7*(C), 244–267. https://doi.org/10.1016/S0959-6380(06)80016-4

Idera, F., Omotola, O., Paul, U. J., & Adedayo, A. (2014). Evaluation of the Effectiveness of Different Acid Digestion on Sediments. *Journal of Applied Chemistry, 7*(12), 39–47.

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. https://doi.org/10.4236/jep.2013.411144

Idrus, S., Lim, C.-S., & Hadi, A.-S. (2005). Kemudahterancaman (Vulnerability) Penduduk Terhadap Perubahan Guna Tanah di Selangor yang didorong oleh pelbagai faktor dalaman dan luaran tersebut daripada nilai tanah dan ekonominya atau sekadar menjadi suatu kawasan yang tinggi dengan kesudahan yang. *Malaysian Journal of Environmental Management*, *5*(2004), 79–98.

Ishak, I., Rosli, F. D., Mohamed, J., & Mohd Ismail, M. F. (2015). Comparison of digestion methods for the determination of trace elements and heavy metals in human hair and nails. *Malaysian Journal of Medical Sciences*, *22*(6), 11–20.

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. https://doi.org/10.2478/intox-2014-0009

Järup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin*, *68*, 167–182. https://doi.org/10.1093/bmb/ldg032

Kadhum, S. A., Ishak, M. Y., & Zulkifli, S. Z. (2016). Evaluation and assessment of baseline metal contamination in surface sediments from the Bernam River, Malaysia. *Environmental Science and Pollution Research*, *23*(7), 6312–6321. https://doi.org/10.1007/s11356-015-5853-0

Kadhum, S. A., Ishak, M. Y., Zulkifli, S. Z., & Hashim, R. B. (2017). Investigating geochemical factors affecting heavy metal bioaccessibility in surface sediment from Bernam River, Malaysia. *Environmental Science and Pollution Research*, *24*(14), 12991–13003. https://doi.org/10.1007/s11356-017-8833-8

Kadhum, S. A., Ishak, M. Y., Zulkifli, S. Z., & Hashim, R. binti. (2015). Evaluation of the status and distributions of heavy metal pollution in surface sediments of the Langat River Basin in Selangor Malaysia. *Marine Pollution Bulletin*, *101*(1), 391–396. https://doi.org/10.1016/j.marpolbul.2015.10.012

Kemp, A. J., & Brown, C. J. (1990). Microwave digestion of carbonate rock samples for chemical analysis. *The Analyst*, *115*(9), 1197–1199. https://doi.org/10.1039/AN9901501197

Khodami, S., Surif, M., Wan, 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. https://doi.org/10.1016/j.marpolbul.2016.09.038

Koki, I. B. (2015). Efficiencies of Acid Digestion / Leaching Techniques in the Determination of Iron Concentrations in Soils from Challawa Industrial Estate Kano, Nigeria. *Merit Research Journal of Environmental Science and Toxicology*, *3*(5), 65–71.

Kowalska, J. B., Mazurek, R., Gąsiorek, M., & Zaleski, T. (2018). Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination–A review. *Environmental Geochemistry and Health*, *40*(6), 2395–2420. https://doi.org/10.1007/s10653-018-0106-z

Kwok, K. W. H., Batley, G. E., Wenning, R. J., Zhu, L., Vangheluwe, M., & Lee, S. (2014). Sediment quality guidelines: Challenges and opportunities for improving sediment management. *Environmental Science and Pollution Research*, *21*(1), 17–27. https://doi.org/10.1007/s11356-013-1778-7

Lee, J. W., Choi, H., Hwang, U. K., Kang, J. C., Kang, Y. J., Kim, K. Il, & Kim,

J. H. (2019). Toxic effects of lead exposure on bioaccumulation, oxidative stress, neurotoxicity, and immune responses in fish: A review. *Environmental Toxicology and Pharmacology*, *68*(March), 101–108. https://doi.org/10.1016/j.etap.2019.03.010

Li, X. F., Wang, P. F., Feng, C. L., Liu, D. Q., Chen, J. K., & Wu, F. C. (2019). Acute Toxicity and Hazardous Concentrations of Zinc to Native Freshwater Organisms Under Different pH Values in China. *Bulletin of Environmental Contamination and Toxicology*, (0123456789), 120–126. https://doi.org/10.1007/s00128-018-2441-2

Liu, B., Hu, K., Jiang, Z., Yang, J., Luo, X., & Liu, A. (2011). Distribution and enrichment of heavy metals in a sediment core from the Pearl River Estuary. *Environmental Earth Sciences*, *62*(2), 265–275. https://doi.org/10.1007/s12665-010-0520-8

Liu, J., Yin, P., Chen, B., Gao, F., Song, H., & Li, M. (2016). Distribution and contamination assessment of heavy metals in surface sediments of the Luanhe River Estuary, northwest of the Bohai Sea. *Marine Pollution Bulletin*, *109*(1), 633–639. https://doi.org/10.1016/j.marpolbul.2016.05.020

Locatelli, C, & Torsi, G. (1998). Simultaneous voltammetric determination of toxic metals in sediments. *Talanta*, *46*(4), 623–629.

Locatelli, Clinio, & Melucci, D. (2013). Voltammetric method for ultra-trace determination of total mercury and toxic metals in vegetables. Comparison with spectroscopy. *Central European Journal of Chemistry*, *11*(5), 790–800. https://doi.org/10.2478/s11532-013-0221-8

Locatelli, Clinio, & Torsi, G. (2002). A new voltammetric method for the simultaneous monitoring of heavy metals in sea water, sediments, algae and clams: Application to the Goro Bay ecosystem. *Environmental Monitoring and Assessment*, *75*(3), 281–292. https://doi.org/10.1023/A:1014856302333

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. https://doi.org/10.1007/BF02472006

Maciel, J., Souza, M., Silva, L., & Dias, D. (2019). Direct Determination of Zn, Cd, Pb and Cu in Wine by Differential Pulse Anodic Stripping Voltammetry. *Beverages*, *5*(1), 6. https://doi.org/10.3390/beverages5010006

Matloob, M. H., Al-joufi, A. M., Al-badani, A. A. S., & Aqlan, E. M. K. (2004). Application of Stripping Voltammetry for the Determination of Cadmium , Lead , Copper and Zinc in Yemeni soils and Vegetables. *Qatar Univ. Sci. J. 24*, 91- 100.

Melaku, S., Dams, R., & Moens, L. (2005). Determination of trace elements in agricultural soil samples by inductively coupled plasma-mass spectrometry: Microwave acid digestion versus aqua regia extraction. *Analytica Chimica Acta*, *543*(1–2), 117–123. https://doi.org/10.1016/j.aca.2005.04.055

Mohan, M., Augustine, T., Jayasooryan, K. K., Shylesh Chandran, M. S., & Ramasamy, E. V. (2012). Fractionation of selected metals in the sediments of Cochin estuary and Periyar River, southwest coast of India. *Environmentalist*, *32*(4), 383–393. https://doi.org/10.1007/s10669-012-9399-0

Morrison, G. M. P., Batley, G. E., & Florence, T. M. (1989). Metal speciation and toxicity. *Chem. Br.*, *25*(8), 791–796.

Mueller, G. (1979). Schwermetalle in Den Sedimenten Des Rheins - Veranderungen Seit 1971. *Umsch. Wissensch. Techn.*, *79*(24), 778–783.

Müller, E. I., Mesko, M. F., Moraes, D. P., Korn, M. das G. A., & Flores, É. M. M. (2014). Wet Digestion Using Microwave Heating. In *Microwave-Assisted Sample Preparation for Trace Element Determination*. https://doi.org/10.1016/B978-0-444-59420-4.00004-0

Muratli, J. M., McManus, J., Mix, A., & Chase, Z. (2012). Dissolution of fluoride complexes following microwave-assisted hydrofluoric acid digestion of marine sediments. *Talanta*, *89*, 195–200. https://doi.org/10.1016/j.talanta.2011.11.081

Nair, V., Hussain, K., Ali, F., & Singh, S. (2016). Re-vitalising Port Dickson as a leading beach resort tourism destination in Malaysia: A benchmarking approach. *Heritage, Culture and Society: Research Agenda and Best Practices in the Hospitality and Tourism Industry - Proceedings of the 3rd International Hospitality and Tourism Conference, IHTC 2016 and 2nd International Seminar on Tourism, ISOT 2016*, (May), 427–432. https://doi.org/10.1201/9781315386980-76

Naji, A., & Ismail, A. (2012). Sediment quality assessment of Klang Estuary, Malaysia. *Aquatic Ecosystem Health and Management*, *15*(3), 287–293. https://doi.org/10.1080/14634988.2012.706108

Nartey, N. N., Hogarh, J. N., Antwi-Agyei, P., Nukpezah, D., Abaidoo, R. C., & Obiri-Danso, K. (2019). Sedimentation and sediment core profile of heavy metals in the Owabi reservoir in Ghana. *Lakes and Reservoirs: Research and Management*, *24*(2), 173–180. https://doi.org/10.1111/lre.12270

Natesan, U., & Ranga Rama Seshan, B. (2011). Vertical profile of heavy metal concentration in core sediments of Buckingham canal, Ennore. *Indian Journal of Marine Sciences*, *40*(1), 83–97.

Nawrot, N., Wojciechowska, E., Matej-Łukowicz, K., Walkusz-Miotk, J., & Pazdro, K. (2019). Spatial and vertical distribution analysis of heavy metals in urban retention tanks sediments: a case study of Strzyza

Stream. *Environmental Geochemistry and Health*, *8*. https://doi.org/10.1007/s10653-019-00439-8

Nemati, K., Bakar, N. K. A., 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. https://doi.org/10.1016/j.jhazmat.2011.05.039

Niu, Y., Sun, F., Xu, Y., Cong, Z., & Wang, E. (2014). Applications of electrochemical techniques in mineral analysis. *Talanta*, *127*, 211–218. https://doi.org/10.1016/j.talanta.2014.03.072

Nriagu, J. (2011). Zinc Toxicity in Humans. *Encyclopedia of Environmental Health*, (c), 801–807. https://doi.org/10.1016/B978-0-444-52272-6.00675-9

Ong, M. C., Fok, F. M., Sultan, K., & Joseph, B. (2016). Distribution of Heavy Metals and Rare Earth Elements in the Surface Sediments of Penang River Estuary , Malaysia. *Journal of Marine Science*, *6*(January), 79–92. https://doi.org/10.4236/ojms.2016.61008

Pahri, S. D. R., Mohamed, A. F., & Samat, A. (2016). Preliminary water quality study in cockle farming area in Malaysia: A case study in Jeram, Selangor. *AACL Bioflux*, *9*(2), 316–325.

Yap, C. K., & Pang, B. H. (2011). Assessment of Cu, Pb, and Zn contamination in sediment of north western Peninsular Malaysia by using sediment quality values and different geochemical indices. *Environmental Monitoring and Assessment*, *183*, 23–39. https://doi.org/10.1007/s10661-011-1903-3

Patil, C. J., & Patil, M. C. (2018). Study on Quality of Soil: Part-I. Simultaneous Determination of Trace Metals Cd, Cu, Pb and Zn in Soil Samples of Bhavnagar by Electrochemical Tecnhnique. *International Journal of Green and Herbal Chemistry*, *7*(1). https://doi.org/10.24214/ijghc/gc/7/1/02634

Pejman, A., Nabi Bidhendi, G., Ardestani, M., Saeedi, M., & Baghvand, A. (2015). A new index for assessing heavy metals contamination in sediments: A case study. *Ecological Indicators*, *58*, 365–373. https://doi.org/10.1016/j.ecolind.2015.06.012

Peng, J. feng, Song, Y. hui, Yuan, P., Cui, X. yu, & Qiu, G. lei. (2009). The remediation of heavy metals contaminated sediment. *Journal of Hazardous Materials*, *161*(2–3), 633–640. https://doi.org/10.1016/j.jhazmat.2008.04.061

Qiu, Z., Li, F., Liu, C., Wu, Z., & Zhang, J. (2016). Comparison Of Different Microwave Digestion Methods For Heavy Metals From Stream Sediment. Presented in International Conference on Advances in Energy, Environment and Chemical Science (Aeecs), 149–152. https://doi.org/10.2991/aeecs-16.2016.32

Raj, J., Raina, A., Mohineesh, & Dogra, T. D. (2013). Direct Determination of Zinc, Cadmium, Lead, Copper Metal in Tap Water of Delhi (India) by Anodic Stripping Voltammetry Technique. *E3S Web of Conferences*, *1*, 09009. https://doi.org/10.1051/e3sconf/20130109009

Rajmohan, N., Prathapar, S. A., Jayaprakash, M., & Nagarajan, R. (2014). Vertical distribution of heavy metals in soil profile in a seasonally waterlogging agriculture field in Eastern Ganges Basin. *Environmental Monitoring and Assessment*, *186*(9), 5411–5427. https://doi.org/10.1007/s10661-014-3790-x

Ramli, M. F. S., Hasan, F. R. A., & Saadon, M. N. (2013). Declining Production of Cockles in Relation to Ammonia Concentrations in Sungai Buloh River , Selangor. *Journal of Environment and Earth Science, 3*(10), 1–6.

Ravanbakhsh, M., Mahernia, S., Bagherzadeh, K., & Dadrass, O. G. (2017). Determination of heavy metals (Cd, Pb, Cu) in some herbal drops by Polarography. *Iranian Journal Of Pharmacology & Therapeutics 15*, 1–4.

Redzwan, G., Abdul Halim, H., Alias, S. A., & Rahman, M. M. (2014). Assessment of Heavy Metal Contamination At West and East Coastal Area of Peninsular Malaysia. *Malaysian Journal of Science*, *33*(1), 23–31. https://doi.org/10.22452/mjs.vol33no1.4

Santoro, A., Held, A., Linsinger, T. P. J., Perez, A., & Ricci, M. (2017). Comparison of total and aqua regia extractability of heavy metals in sewage sludge: The case study of a certified reference material. *TrAC - Trends in Analytical Chemistry*, *89*, 34–40. https://doi.org/10.1016/j.trac.2017.01.010

Sany, S. B. T., Salleh, A., Sulaiman, A. H., Sasekumar, A., Rezayi, M., & Tehrani, G. M. (2013). Heavy metal contamination in water and sediment of the Port Klang coastal area, Selangor, Malaysia. *Environmental Earth Sciences*, *69*(6), 2013–2025. https://doi.org/10.1007/s12665-012-2038-8

Scholz, F. (2015). Voltammetric techniques of analysis: the essentials. *ChemTexts*, *1*(4), 1–24. https://doi.org/10.1007/s40828-015-0016-y

Seshan, B. R. R., Natesan, U., & Deepthi, K. (2010). *Statistical Approach for Evaluation of Heavy Metal*. International Journal of Environmental Science and Technology, *7*(2), 291–306.

Shaari, H., Nurul, S., Mohamad, H., Sultan, K., Bidai, J., & Mohamad, Y. (2015). Spatial Distribution of Selected Heavy Metals in Surface Sediments of the EEZ of the East Coast of Peninsular Malaysia Spatial Distribution of Selected Heavy Metals in Surface Sediments of the EEZ of the East Coast of Peninsular Malaysia. *International Journal of Oceanography, 2015*, ID 618074. https://doi.org/10.1155/2015/618074

Sharma, H., Rawal, N., & Mathew, B. B. (2015). The characteristics , toxicity and effects of cadmium. *International Journal of Nanotechnology and Nanoscience*, *3*, 1–9.

Shazili, N. A. M., Yunus, K., Ahmad, A. S., Abdullah, N., & Rashid, M. K. A. (2006). Heavy metal pollution status in the Malaysian aquatic environment. *Aquatic Ecosystem Health and Management*, *9*(2), 137–145. https://doi.org/10.1080/14634980600724023

Stengel, D., O'Reilly, S., & O'Halloran, J. (2006). Contaminants and pollutants. In John Davenport and Julia L. Davenport, (Eds.), *The Ecology of Transportation: Managing Mobility for the Environment*, 361–389, © 2006 Springer. (pp. 361–389). Netherlands:Springer.

Sudsandee, S., Tantrakarnapa, K., Tharnpoophasiam, P., Limpanont, Y., Mingkhwan, R., & Worakhunpiset, S. (2017). Evaluating health risks posed by heavy metals to humans consuming blood cockles (*Anadara granosa*) from the Upper Gulf of Thailand. *Environmental Science and Pollution Research*, *24*(17), 14605–14615. https://doi.org/10.1007/s11356-017-9014-5

Sun, Y., Chi, P., & Shiue, M. (2005). Comparison of Different Digestion Methods for Total Decomposition of Siliceous and Organic Environmental Samples. *Analytical Sciences*, *17*(12), 1395–1399. https://doi.org/10.2116/analsci.17.1395

Suresh, G., Ramasamy, V., Sundarrajan, M., & Paramasivam, K. (2015). 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*, *91*(1), 389–400. https://doi.org/10.1016/j.marpolbul.2014.11.007

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). https://doi.org/10.1007/s11270-013-1476-6

Tiwari, M., Sahu, S. K., Bhangare, R. C., Ajmal, P. Y., & Pandit, G. G. (2013). Depth profile of major and trace elements in estuarine core sediment using the EDXRF technique. *Applied Radiation and Isotopes*, *80*, 78–83. https://doi.org/10.1016/j.apradiso.2013.06.002

Turekian, K. K., & Wedepohl, K. H. (1961). Distribution of the Elements in Some Major Units of the Earth's Crust. Geological Society of *America Bulletin*, *72*, 175–192.

Turki, A. J. (2007). Metal Speciation (Cd, Cu, Pb and Zn) in Sediments from Al Shabab Lagoon, Jeddah, Saudi Arabia. *JKAU: Mar. Sci*, *18*, 191–210. https://doi.org/10.4197/mar.18-1.11

Udechukwu, B. E., & Ismail, A. (2015). Distribution, mobility, and pollution assessment of Cd, Cu, Ni, Pb, Zn, and Fe in intertidal surface sediments of Sg. Puloh mangrove estuary, Malaysia. *Environmental Science and Pollution Research, 22*, 4242–4255. https://doi.org/10.1007/s11356-014-3663-4

Unit Perancang Ekonomi Negeri Sembilan. (2015). *Data Sosioekonomi Negeri Sembilan (Socioeconomic Data of Negeri Sembilan) 2015*. Retrieved from http://www.ns.gov.my/images/contents/data-sosio-ekonomi-n9-2015.pdf

Unit Perancang Ekonomi Negeri Sembilan. (2016). *Data Sosioekonomi Negeri Sembilan (Socioeconomic Data of Negeri Sembilan) 2016*. Retrieved from http://www.ns.gov.my/images/contents/data-sosio-ekonomi-n9-2016.pdf

Vukosav, P., Mlakar, M., Cukrov, N., Kwokal, Ž., Pižeta, I., Pavlus, N., … Omanović, D. (2014). Heavy metal contents in water, sediment and fish in a karst aquatic ecosystem of the Plitvice Lakes National Park (Croatia). *Environmental Science and Pollution Research*, *21*(5), 3826–3839. https://doi.org/10.1007/s11356-013-2377-3

Wang, A. jun, Bong, C. W., Xu, Y. hang, Hassan, M. H. A., Ye, X., Bakar, A. F. A., … Loh, K. H. (2017). Assessment of heavy metal pollution in surficial sediments from a tropical river-estuary-shelf system: A case study of Kelantan River, Malaysia. *Marine Pollution Bulletin*, *125*(1–2), 492–500. https://doi.org/10.1016/j.marpolbul.2017.08.010

Wang, Y., Hu, J., Xiong, K., Huang, X., & Duan, S. (2012). Distribution of Heavy Metals in Core Sediments from Baihua Lake. *Procedia Environmental Sciences*, *16*, 51–58. https://doi.org/10.1016/j.proenv.2012.10.008

Wong, K. W., Yap, C. K., Nulit, R., & Hamzah, M. S. (2017). Effects of anthropogenic activities on the heavy metal levels in the clams and sediments in a tropical river. *Environmental Science and Pollution Research*, 116–134. https://doi.org/10.1007/s11356-016-7951-z

Xie, M., Simpson, S. L., & Wang, W. X. (2019). Bioturbation effects on metal release from contaminated sediments are metal-dependent. *Environmental Pollution*, *250*, 87–96. https://doi.org/10.1016/j.envpol.2019.04.003

Xu, Y., Wu, Y., Han, J., & Li, P. (2017). The current status of heavy metal in lake sediments from China: Pollution and ecological risk assessment. *Ecology and Evolution*, *7*(14), 5454–5466. https://doi.org/10.1002/ece3.3124

Yap, C. K., Hatta, Y., Edward, F. B., & Tan, S. G. (2008). Comparison of heavy metal concentrations (Cd, Cu, Fe, Ni and Zn) in the shells and different soft tissues of Anadara granosa collected from Jeram, Kuala Juru and Kuala Kurau, Peninsular Malaysia. *Pertanika Journal of Tropical Agricultural Science*, *31*(2), 205–215.

Yap, C. K., Ismail, A., Tan, S. G., & Omar, H. (2002). 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. *Environment International, 28*, 117–126.

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. https://doi.org/10.1007/BF03353912

Yunus, S. M., Hamzah, Z., Ariffin, N. A. N., & Muslim, M. B. (2014). Cadmium, chromium, copper, lead, ferum and zinc levels in the cockles (*Anadara granosa*) from Kuala Selangor, Malaysia. *The Malaysian Journal of Analytical Sciences*, *18*(3), 514–521.

Yurimoto, T, Nurlemsha, B. I., Roziawati, M. R., & Saadon, K. (2016). Food Safety Aspects In Blood Cockles (*Tegillarca Granosa*) Cultured Off Selangor, Peninsular Malaysia. M*alaysian Journal of Science 35*(2), 226–240.

Yurimoto, Tatsuya, Mohd Kassim, F., Fuseya, R., & Man, A. (2014). Mass mortality event of the blood cockle, Anadara granosa, in aquaculture ground along Selangor coast, Peninsular Malaysia. *International Aquatic Research*, *6*(4), 177–186. https://doi.org/10.1007/s40071-014-0077-3

Yusoff, A. H., Zulkifli, S. Z., Ismail, A., & Mohamed, C. A. R. (2015). Vertical Trend of Trace Metals Deposition in Sediment Core off Tanjung Pelepas Harbour, Malaysia. *Procedia Environmental Sciences*, *30*(November), 211–216. https://doi.org/10.1016/j.proenv.2015.10.038

Zafarzadeh, A., Bay, A., Fakhri, Y., Keramati, H., & Hosseini Pouya, R. (2018). Heavy metal (Pb, Cu, Zn, and Cd) concentrations in the water and muscle of common carp (Cyprinus carpio) fish and associated non-carcinogenic risk assessment: Alagol wetland in the Golestan, Iran. *Toxin Reviews*, *37*(2), 154–160. https://doi.org/10.1080/15569543.2017.1386684

Zalewska, T., Woro, J., Danowska, B., & Supli, M. (2015). Temporal changes in Hg, Pb, Cd and Zn environmental concentrations in the southern Baltic Sea sediments dated with ^{210}Pb method. *Oceanologia, 57,* 32–43. https://doi.org/10.1016/j.oceano.2014.06.003

Zhang, G., Zhang, Y., & Bao, S. (2018). The effects of sodium ions, phosphorus, and silicon on the eco-friendly process of vanadium precipitation by hydrothermal hydrogen reduction. *Minerals*, *8*(7), 566–575. https://doi.org/10.3390/min8070294

Zhang, Y., Lu, X., Shao, X., Liu, H., & Xing, M. (2015). Influence of Sedimentation Rate on the Metal Contamination in Sediments of Bohai Bay , China. *Bulletin of Environmental Contamination and Toxicology*, *95*(4), 507–512. https://doi.org/10.1007/s00128-015-1599-0

Zimmerman, A. J., & Weindorf, D. C. (2010). Heavy Metal and Trace Metal Analysis in Soil by Sequential Extraction: A Review of Procedures. *International Journal of Analytical Chemistry*, *2010*, 1–7. https://doi.org/10.1155/2010/387803

Zulkifli, S. Z., Mohammat-Yusuff, F., Ismail, A., Aziz, A., Sabuti, Asnor, A., & Mohamed, C. A. R. (2015). Status of Heavy Metals in Surface Sediments of the Western Part of the Johor Straits Using a Sediment Quality Guideline. *World Journal of Fish and Marine Sciences*, *7*(3), 214–220. https://doi.org/10.5829/idosi.wjfms.2015.7.3.94265