UNIVERSITI PUTRA MALAYSIA

EVALUATION OF SOURCES, DISTRIBUTION AND HUMAN BIO-ACCESSIBILITY BURDEN OF HEAVY METALS POLLUTION IN SURFACE SEDIMENT AND CATFISH Arius maculatus Thunberg (1792) FROM LANGAT AND BERNAM RIVERS, MALAYSIA

SAFAA ABD ALZAHRA KADHUM

FPAS 2017 15

EVALUATION OF SOURCES, DISTRIBUTION AND HUMAN BIO-ACCESSIBILITY BURDEN OF HEAVY METALS POLLUTION IN SURFACE SEDIMENT AND CATFISH *Arius maculatus* Thunberg (1792) FROM LANGAT AND BERNAM RIVERS, MALAYSIA

By

SAFAA ABD ALZAHRA KADHUM

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

June 2017

COPYRIGHT

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

EVALUATION OF SOURCES, DISTRIBUTION AND HUMAN BIO-ACCESSIBILITY BURDEN OF HEAVY METALS POLLUTION IN SURFACE SEDIMENT AND CATFISH *Arius maculatus* Thunberg (1792) FROM LANGAT AND BERNAM RIVERS, MALAYSIA

By

SAFAA ABDALZAHRA KADHUM

June 2017

Chairman : Mohd Yusoff Ishak, PhD
Faculty : Environmental Studies

The present study was conducted to identify the spatial distribution and sources concentrations of heavy metal from eighteen surface sediment samples of Langat and Bernam rivers using multivariate techniques and pollution indices with their geochemical partitioning in different solid phases and to investigate factors influencing these partitioning on bioaccessibility of metals contamination from geochemical perspectives. The *in vitro* digestion model in fish tissue are dependent on pH and solid-liquid factors.

Results indicated that the concentrations of metals in surface sediment of Langat River decreased in the order of Sn> Cr >Ni > Fe> Cd> Hg and for heavy metals in surface sediment of Bernam River decreased in the order of Sn> Cr >Ni >Fe> Cd> Hg.

Pearson's correlation indicated that effectiveness of total organic matter and cation exchange capacity were effecting heavy metals distribution more than grain size and pH. In addition, cluster analysis results had divided Bernam River into three clusters namely; stations of Selisek, Tanjong Malim and Bagan Tepi sungai which were grouped into cluster one representing considerable degree of contamination; cluster two represents moderately high degree of contamination at Ulu Bernam, Kampung Bagan, Bandar Behrang and Kampung Tanjung while cluster three represents moderately medium degrees of contamination at Slim River and Sabak Bernam.

Meanwhile for the Langat river, cluster one represents considerably high degree of contamination at UKM, Jalan Hulu Langat and Pangsun; cluster two represents considerably medium degree of contamination at Kajang, Batu Hulu Langat and Cheras; cluster three represents considerably low degree of contamination at Jugra, Banting and Jenjarom.

The PCA showed that the main factors influencing the bioaccessibility of Hg in surface sediments of Langat River were the sediment TOM, F1 (EFLE) while mercury bioaccessibility in Bernam River were more affected by F1 (EFLE), CEC and TOM. The factor influencing bioaccessibility of cadmium from Langat River sediment were T-Cd and F3 (oxidation-organic), whereas, cadmium bioaccessibility in Bernam River sediment were influenced by F1 (EFLE). Tin bioaccessibility were influenced by CEC and pH in surface sediment of Langat River while F4 (resistance) was the most influencing factor for bioaccessibility of tin in surface sediment of Bernam River.

The rank of biota-sediment accumulation factor (BSAF) for catfish (*Arius maculatus*) were in the descending order of Hg> Cr> Cd> Ni> Fe> Sn in Langat River while biota-sediment accumulation factor for catfish in Bernam River were in the decreasing order of Cd> Ni> Cr> Fe> Sn. Mercury was greater than one in terms of BSAF indicating an intensive accumulation of this metal from sediment of Langat River in tissues of catfish (*Arius maculatus*). Results showed that the bioaccessibility and chemicals forms of heavy metal in surface sediment were significantly correlated with catfish organs in Bernam and Langat Rivers.

The results of bioaccessibility of heavy metals varied significantly with different *in vitro* assays in different stations along Langat and Bernam Rivers. The highest relative bioaccessibility of Ni (93.1%), Cr (46.9%), and Sn (23.2%) were observed in the IVG (gastric phase) compared with other in vitro assays of Bernam River. Meanwhile, the highest relative bioaccessibility of Ni (13.2%), Cr (42.3%), Sn (5.8%) and Hg (23.8%) were also noted in the IVG (gastric phase) of Langat River.

The results of heavy metals accumulation within the different organs are as follows (in descending order): muscle Cr > Ni > Hg > Cd > Fe > Sn; liver Cr > Ni > Hg > Fe > Sn > Cd, and kidney Cr > Ni >Hg > Sn > Cd > Fe for Langat River. While, in Bernam River the highest metal concentrations was mostly in muscle and the pattern of metal concentration in the muscle was in the decreasing order of Ni > Cr > Fe > Cd > Sn> Hg Meanwhile for liver, heavy metals were found in the order of Cr> Sn> Ni > Fe> Cd> Hg and for kidney, was found in the descending order of Sn > Cr > Fe > Ni > Cd> Hg.

A human health risk assessment of these metals was performed based on total and bioaccessibility concentrations of tissue. The hazard quotient (HQ) of total and bioaccessibility of heavy metals in catfish (*Arius maculatus*) from Langat and Bernam Rivers were calculated based on risk levels and results indicated that consumption could posed a serious threat to human health.

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

PENILAIAN TERHADAP SUMBER TABURAN, DAN BEBAN BIO-AKSESIBILITI LOGAM BERAT DALAM SEDIMEN DAN IKAN DURI DARI SUNGAI LANGAT DAN SUNGAI BERNAM, MALAYSIA

Oleh

SAFAA ABD ALZAHRA KADHUM

Jun 2017

Pengerusi : Mohd Yusoff Ishak, PhD
Fakulti : Pengajian Alam Sekitar

Kajian ini dijalankan untuk mengenal pasti taburan ruang dan sumber logam-logam berat daripada lapan belas sampel lapisan permukaan sedimen yang diambil dari Sungai Langat dan Sungai Bernam menggunakan teknik *multivariate* dan indeks pencemaran berdasarkan pengagihan geokimia dalam fasa pepejal yang berbeza-beza dan untuk mengkaji faktor-faktor yang mempengaruhi taburan tersebut pada bioaksesibiliti pencemaran logam mengikut perspektif geokimia. Model pencernaan in vitro bagi tisu ikan didapati bergantung kepada faktor pH dan fasa pepejal-cecair.

Keputusan menunjukkan bahawa kepekatan logam pada lapisan permukaan sedimen di Sungai Langat berkurangan mengikut susunan Sn> Cr> Ni> Fe> Cd> Hg dan untuk logam berat di lapisan permukaan sedimen di Sungai Bernam menurun dalam urutan Sn> Cr> Ni> Fe> Cd> Hg.

Korelasi Pearson menunjukkan bahawa jumlah jisim organik dan kapasiti pertukaran kation lebih mempengaruhi taburan logam berat berbanding dengan saiz bijirin dan pH. Selain itu, keputusan analisis kluster membahagikan Sungai Bernam kepada tiga kelompok iaitu; Stesen Selisek, Tanjong Malim dan Bagan Tepi Sungai yang dikelompokkan ke dalam kumpulan yang mewakili tahap pencemaran yang besar; Kluster Dua mewakili pencemaran tahap sederhana tinggi di Ulu Bernam, Kampung Bagan, Bandar Behrang dan Kampung Tanjung manakala Kluster Tiga mewakili tahap sederhana pertengahan berdasarkan pencemaran di Slim River dan Sabak Bernam.

Sementara untuk Sungai Langat, Kluster Satu mewakili pencemaran darjah yang tinggi di stesen UKM, Jalan Hulu Langat dan Pangsun; Kluster Dua mewakili tahap pencemaran yang sederhana di Kajang, Batu Hulu Langat dan Cheras; Kluster Tiga mewakili tahap pencemaran yang rendah di Jugra, Banting dan Jenjarom.

PCA memperlihatkan bahawa faktor utama yang mempengaruhi bioaksessibiliti Hg di lapisan permukaan sedimen Sungai Langat ialah TOM sedimen, F1 (EFLE) manakala bioaksessibiliti Hg di Sungai Bernam lebih dipengaruhi oleh F1 (EFLE), CEC dan TOM. Faktor yang mempengaruhi bioaksessibiliti Cd dari sedimen Sungai Langat ialah T-Cd dan F3 (pengoksidaan-organik), manakala bioaksessibiliti Cd untuk sedimen Sungai Bernam dipengaruhi oleh F1 (EFLE). Bioaksessibiliti Sn di lapisan permukaan sedimen Sungai Langat dipengaruhi oleh CEC dan pH manakala F4 (rintangan) adalah faktor yang paling mempengaruhi untuk bioaksessibiliti Sn dalam lapisan permukaan sedimen Sungai Bernam.

Faktor pengumpulan sedimen (BSAF) untuk Ikan Duri (*Arius maculatus*) menunjukkan susunan menurun Hg> Cr> Cd> Ni> Fe> Sn di Sungai Langat manakala faktor pengumpulan sedimen-biota bagi Ikan Duri di Sungai Bernam berada dalam aturan menurun Cd> Ni> Cr> Fe> Sn. Merkuri adalah lebih besar daripada satu berdasarkan BSAF yang menunjukkan pengumpulan intensif logam ini dari sedimen Sungai Langat ke dalam tisu Ikan Duri. Keputusan menunjukkan bahawa bioaksessibiliti dan bentuk kimia logam-logam berat di lapisan permukaan sedimen berkorelasi secara signifikan dengan organ-organ Ikan Duri di Sungai Bernam dan Sungai Langat.

Kajian mendapati bioaksessibiliti logam berat menunjukkan variasi berbeza dengan *in vitro assay* yang berbeza di stesen-stesen yang berlainan sepanjang Sungai Langat dan Sungai Bernam. Nilai tertinggi bioaksessibiliti relatif Ni (93.1%), Cr (46.9%) dan Sn (23.2%) ditunjukkan oleh IVG (fasa gastrik) berbanding dengan ujian *in vitro* lain untuk Sungai Bernam. Sementara itu, nilai tertinggi bioaksessibiliti relatif tertinggi adalah pada Ni (13.2%), Cr (42.3%), Sn (5.8%) dan Hg (23.8%) yang juga dicatatkan dalam IVG (fasa gastrik) untuk Sungai Langat.

Keputusan menunjukkan pengumpulan logam berat dalam organ-organ yang berlainan adalah seperti berikut (dalam urutan menurun): organ otot Cr> Ni> Hg> Cd> Fe> Sn; organ hati Cr> Ni> Hg> Fe> Sn> Cd, dan organ buah pinggang Cr> Ni> Hg> Sn> Cd> Fe. Namun, di Sungai Bernam, kepekatan logam tertinggi kebanyakannya adalah di dalam organ otot dan corak kepekatan logam dalam otot adalah dalam susunan menurun Ni> Cr> Fe> Cd> Sn> Hg bagi organ hati, logam berat didapati dalam susunan menurun Cr> Sn> Ni> Fe> Cd> Hg dan untuk organ buah pinggang, didapati dalam urutan menurun Sn> Cr> Fe> Ni> Cd> Hg.

Penilaian tentang risiko terhadap kesihatan manusia oleh logam-logam ini dilakukan berdasarkan kepekatan keseluruhan dan bioaksessibiliti tisu. Pengiraan *Hazard Quotient* (HQ) bagi menilai tahap risiko berdasarkan jumlah kepekatan logam berat dan bioaksesibiliti logam berat dalam Ikan Duri (Arius maculatus) dari Sungai Langat dan Sungai Bernam menunjukkan bahawa penggunaan ikan dalam diet tersebut boleh menimbulkan ancaman serius kepada kesihatan manusia.

ACKNOWLEDGEMENTS

All praises be to almighty Allah, the lord of whole creations, for inspiring and guiding me towards the utmost goodness

I also would like to express my sincere gratitude and appreciation to supervisor committee Dr.Mohd Yusoff Ishak, Dr. Syaizwan Zahmir Zulkifli and Dr.Rohasliney binti Hashim for their priceless guidance, continued supervision, advice, comment, encouragement and support throughout the research journey.

Also, I would like to express my utmost appreciation and gratitude to Universiti Putra Malaysia (Vot: 9458700) for the financial support. Special thanks to Mr. Zairi bin Ismail, Mr. Tengku Shahrul Tengku Md. Yusoff and Mr. Abdullah Talib for their technical supports.

Finally, I would like to thank the University of Qadissyah, Ministry of Higher Education and Scientific Research, Iraq for the financial supporting of the scholarship.

Safaa Abd Alzahra Kadhum

June 2017

I certify that a Thesis Examination Committee has met on 9 June 2017 to conduct the final examination of Safaa Abd Alzahra Kadhum on her thesis entitled "Evaluation of Sources, Distribution and Human Bio-Accessibility Burden of Heavy Metals Pollution in Surface Sediment and Catfish *Arius maculatus* Thunberg (1792) from Langat and Bernam Rivers, 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 Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Mohammad Firuz bin Ramli, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Chairman)

Zailina binti Hashim, PhD
Professor
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Internal Examiner)

Aziz bin Arshad, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Bintal Amin, PhD
Professor Ir.
Kampus Binawidya Universitas Riau
Indonesia
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 4 September 2017

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

Mohd Yusoff Ishak, PhD
Senior Lecturer
Faculty of Environmental Studies
Universiti Putra Malaysia
(Chairman)

Rohasliney binti Hashim, PhD
Senior Lecturer
Faculty of Environmental Studies
Universiti Putra Malaysia
(Member)

Syaizwan Zahmir Zulkifli, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Member)

____
ROBIAH BINITI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: __________________

Name and Matric No.: Safaa Abdalzahra Kadhum (GS38965)

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ______________________
Name of Chairman of Supervisory Committee: Dr. Mohd Yusoff Ishak

Signature: ______________________
Name of Member of Supervisory Committee: Dr. Rohasliney binti Hashim

Signature: ______________________
Name of Member of Supervisory Committee: Dr. Syaizwan Zahmir Zulkifli

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
ANOVA	Analysis of Variance
ADD	Average daily dose
BDL	Below Detection Limits
Bio-Cd	Bioaccessibility of Cadmium
Bio-Hg	Bioaccessibility of Mercury
Bio-Sn	Bioaccessibility of Tin
Bio-Fe	Bioaccessibility of Iron
Bio-Cr	Bioaccessibility of Chromium
Bio-Ni	Bioaccessibility of Nickel
Ca	Calcium
CCME	Canadian Council of Ministers of the Environment
Cd	Cadmium
CEC	Cation Exchange Capacity
DO	Dissolved Oxygen
EF	Enrichment Factor
EPA	Environmental Protection Agency
ERL	Effects Range Low
FIMS-100	Flow Injection Mercury Systems
Fe	Iron
HCA	Hierarchical Cluster Analysis
HQ	Hazard Quotient
ICP-MS	Inductively Coupled Plasma Spectrometry
I_{geo}	Geo-accumulation Index
ISQG	Interim Sediment Quality Guideline
ISQV	Interim Sediment Quality Value
IVG IP	In Vitro digestion Intestinal Phase
IVG GP	In Vitro digestion Gastric Phase
IVG GI	In Vitro digestion Gastricintestinal
IRIS	Integrated Risk Information System
K	Potassium
Mg	Magnesium
Na	Sodium
Ni	Nickel
NOAA	National Oceanic and Atmospheric Administration
PCA	Principal Component Analysis

PEL	Probable Effect Level
R-Bio.	Relative bioaccessibility
RfD	References Dose
SD	Standard Deviation
SPSS	Statistical Package for Social Science
Sn	Tin
SBET GP	Simple bioaccessibility Extraction test Gastric Phase
TOM	Total Organic Matter
USEPA	United State Environmental Protection Agency
WHO	World Health Organization

LIST OF UNITS

<	Not more than
>	More than
µm	Micrometer
cm	Centimeter
g	Gram
%	Percent
km	Kilometer
km^2	Square kilometer
m	Meter
m^2	Square meter
m^3	Cubic meter
ppt	Parts per trillion
%	Percent
meq/g	Miliequivalent per gram
mL	Millimeter
º C	Degrees Celsius
ppb	Parts per billion

CHAPTER 1

INTRODUCTION

1.1 General

Rapid economic development and urbanization over the past few decades have brought progress and prosperity to various countries worldwide, including Malaysia. However, such development and progress have also shown a downside that is of concern and needs to be investigated and addressed. For example, in recent years anthropogenic and natural activities have resulted in adverse environmental and ecological effects like the extinction of various species, loss of biodiversity, acid rains, global warming, climate change, hazardous waste disposal problems causing acute pollution of land, air and water, while numerous and significant eco accidents are also on the rise. Despite the fact that all these are a threat to the well-being of mankind, at present and in the future, many people seem not to have realized the extent of these threats, particularly, metals pollution, which affects humans directly through the food chain, like fish for instance (Alloway & Ayres, 1993; Hanninen *et al*., 2014).

In light of such a situation, using geochemical partitioning such as sequential extraction technique (SET) and in vitro digestion model are practical and effective ways to assess health risk of human consumption in order to improve ecological risk assessment and pollution control. These techniques provide substantial information to evaluate the relative bioavailability, which can be acquired by studying the solubility of sediment and heavy metals in the digestive juice of fish and to find out the bioavailability status, which involves the level of heavy metals mobilization from sediment and fish to the digestive juice, absorbed by the body and how this affects the circulation system (Ruby *et al*., 1999).

Although direct aqua regia digestion methods have been widely used in different studies involving potential risk assessments, it is still a poor indicator of the actual hazard due to toxicity and bioaccumulation of metals, which have a relationship with their mobility and chemical speciation (Gu *et al*., 2015; Madrid *et al*., 2008; Camusso & Gasparella, 2006). Bioaccessibility of heavy metals depends mainly on heavy metal binding to sediment reactive surfaces and are regulated by sorption, complexation, and redox processes. Furthermore, individually these approaches are mainly regulated as a result of the wide ranging differences of soil properties, such as pH, organic matter, and soil texture (Pelfrene *et al*., 2011; Rodrigues *et al*., 2013). This connection allows the possibility of predicting the bioaccessibility of heavy metals from sediment into biota (Buchter *et al*., 1989; Ruby *et al*., 1999). The in vitro digestion approach has been commonly employed by many researchers to study physiological variations, digestibility, and the releasing of food components through simulation of gastrointestinal experimnts (Hur *et al*., 2011). The in vitro digestion approach is suitable for the determination of the bioavailability of heavy metal in food as it closely mirrors the physiological state of the human body. Earlier researches carried out used the digestion model which can be a reference for more investigation of the bioavailability of heavy metal in fish. However, relatively few researches have assessed the risk to health using the in vitro digestion approach output (bioavailability of heavy metal). This approach is essential and its inclusion in *in vitro* digestion studies provides an efficient and effective indicator of the presence of heavy metal and possible risk to human health. To reproduce the digestion process in the human gastrointestinal tract simulation is carried out in a simplified manner by the application of some physiologically- based parameters that are affected by physiological conditions such as gastric pH, intestinal pH, food constituents, residence time, and particle size.

In recent years, the contamination of the surface sediments particularly of water ways like rivers with toxic metals has attracted much public interest. Furthermore, this ecosystem receives anthropogenic sources of metals owing to human activities such as industry, agriculture, mining, domestic sewage, boat activities, and construction works in the building of cities and towns. These can pose a significant threat to the food chain in the aquatic environment (Martin *et al*., 2015). Thus, these wastes are known to contain heavy metals which are toxic, can bio-accumulate and are persistent in the environment. Sediments are essential sinks and receive various contaminants including pesticides and heavy metals and also have a considerable influence on the the way contaminants in rivers and lakes are remobilized when conditions are suitable. (Ikem *et al*., 2003; Sow *et al*., 2013). Sediments are perceived as an important recipient of heavy metals in the process of their eventual transportation to aquatic environments and also serve as a marker of pollution history (Rodríguez-Barroso *et al*., 2010). To successfully obtain the accumulation of heavy metals from natural and anthropogenic sources there is a need to apply normalizing methods to distinguish the two varying sources (Idris, 2008). Geochemical normalization techniques like the enrichment factor (EF) and geo-accumulation index (Igeo) approaches have been typically employed for this purpose. Fish can accumulate large amounts of heavy metals from the surrounding waters and sediment and uptake by fish species to humans would be through fish consumption. The how mobile or available heavy metals are in contaminated materials is dependent on the numerous chemical and mineralogical forms that occur. Sediments make suitable homes for a wide range of organisms in rivers and are a primary recipient of heavy metals introduced into surface waters. Therefore, it is necessary to look into the relationship between heavy metals levels in sediment and in fish tissue which can be an advantage for identifying the effects of anthropogenic activities on the food chain in the Langat and Bernam Rivers.

To address this gap, the present work has investigated the geochemistry of sediment and to determine the spatial distribution of the elements in sediments, along the Langat and Bernam Rivers, taking into consideration their geochemical partitioning in various solid phases, which is a measure of their mobility and investigated the factors influencing these partitioning on bioaccessibility of metals contamination depending on physicochemical properties. The work also involved to improve the determination of different in vitro digestion models in fish tissue depending on pH factor and solid factors. In order to the development of more robust (validated) models and more confidence in the used of these predictive models for estimating metals bioaccessbility for the purpose of minimizing the risk to human health.

1.2 Problem statement

The Langat and Bernam River basin is located in an economically strategic place in Peninsular Malaysia that is important as an agriculture area and as the largest source of water supply for the states of Selangor and Perak in Peninsular Malaysia, especially for irrigation. However, due to rapid urbanization within these regions and changes in economic policies which involved changes in land use activities, the rivers have been more exposed to different pollution problems such as industrial (palm oil mills, rubber processing, and steel works foundries) and domestic sewage, agrochemicals (fertilizers and herbicides) applied in agricultural activities, and sand mining (Santhi & Mustafa, 2013; Idrus *et al.*, 2004; Yap & Ong, 1990), All these activities are significant contributors to heavy metal pollution in these rivers.

These rivers were chosen for the current study due to their location in the heavily urbanized and the most developed areas in the states of Selangor and Perak, serving a population of approximately 1.2 million living around the Langat Basin and 2.3 million a population of populations living around Bernam Basin (Department of Statistics Malaysia, 2010). In addition, it provides water for industries and agriculture located along its banks. The lack of pollution control compounded by the discharge of pollution from both industries and other economic activities directly and indirectly into the river definitely affects the ecosystem and human health (Mokhtar *et al.,* 2009). In fact, using only the total metal content in determining potential risk assessments is a poor indicator of metals effect and does not give enough information about the release and toxicity of metals (Gu *et al*., 2015; Madrid *et al.,* 2008; Camusso & Gasparella, 2006). Thus, evaluating metal bioaccessibility by using *in vitro* digestion model would not only provide a rapid estimation of ecosystem quality but also allow for a realistic assessment of the potential exposure risk to humans and biota (Ahmed *et al*., 2015). Moreover, analysis of catfish (*Arius maculates*) would give a better answer to the question of bioaccessibility and bioavailability of hazardous metals which is a concern due to this fish being a common local menu item as freshwater fish consumption provides an important source of protein requirements, besides being abundant and easy to sample.

Therefore, to solve this problem requires an understanding of some of the important characteristics, speciation, and effects of bioaccessibility metals released to the environment in human health.

1.3 Research Objectives

This research was carried out to invistgate the level, distribution and bioaccessbility related to trace metals linked to industrial discharge and agricultural activities and to make an assessment of the general catregorization of some metals and besides their risk status in catfish (*Arius maculates*) and surface sediments of Langat and Bernam Rivers. The specific research objectives are as follows (Figure 1.1):

1- To identify the spatial distribution and sources of heavy metals namely Hg, Cd, Cr, Ni, Sn and Fe concentrations in surface sediment from Langat and Bernam rivers by using multivariate techniques and pollution indices .
2- To determine the bioaccessibility of heavy metals in surface sediment from Langat and Bernam Rivers using sequential extraction technique (SET) and simple bioavailability extraction test (SBET).
3- To assess the influence of physicochemical properties and the chemical fractions factors of surface sediment on the bioaccessibility of heavy metals contaminant in Langat and Bernam Rivers
4- To evaluate the bioaccumulation of heavy metal in different organs of catfish namely muscles, kidney and livers and their relationship with chemical fractions and bioaccessibility in surface sediment from Langat and Bernam Rivers.
5- To quantify the concentrations of heavy metals in muscles of catfish in bioaccessible fraction obtained after an in vitro assay based on pH and solid-liqiud factors with estimated potential risk of heavy metals consumption.

1.4 Significance of Study

Bioaccessibility and bioavailability data are of great significance in assessing the health risk of trace elements in sediment and fish. There was a gap in the literature on the bioaccessibility of trace elements in sediment and fish tissue in Langat and Bernam Rivers. Using sequential extraction techniques (SET) would give results in selective metals that are associated with non-resistance form (anthropogenic) and resistance form (natural). Therefore, this technique can help to determine the origins of pollution from the location. Bioaccessibility data are definitely an extra tool to help us to better understand human health risk at polluted locations which can potentially act as a practical decision-support tool. Thus, it is important to investigate the dominant factors which may influence bioaccessibility of heavy metals from one region to another and then improve health risk assessment and control pollution through developed predicting models based on the Langat and Bernam Rivers locations. Using comparisons between different types of an in vitro digestion model (IVG and SBET) is also important by incorporating these methods for the prediction of the heavy metals bioaccessibility in the fish samples based on chemical fractions.

Multivariate technique and pollution indices analyses were conducted to better assess the sources of metals in surface sediment of rivers as well as to know the status of metals contamination. Multivariate can provide offer valuable information on the interaction of metals and physicochemical properties in surface sediment by investigating the physicochemical factors influencing the distribution and bioaccessibility of heavy metals.

Thus, this information will assist current exposure assessments regarding the health risks of metal contamination in the fish. Therefore, the results can be beneficial as a baseline data for government bodies to adopt corrective measures to address the issue of heavy metals pollution in the Langat and Bernam Rivers in the future.

1.5 Research Hypothesis

This study tested the following hypothesis:

1. There are significant influencing factors of the sediment characteristics (pH, TOM, cation exchange capacity, sand, silt and clay) and chemical fractions on the bioaccessibility of heavy metal contamination in Langat and Bernam Rivers.
2. There are significant correlations between the heavy metals fractions and bioaccessibility in sediment and metals bioaccumaltion in catfish tissue of Langat and Bernam Rivers.
3. There are significant differences in heavy metals concentrations of IVG and SBET models in catfish (*Arius maculates*) tissue between locations in the Langat and Bernam Rivers.

REFERENCES

Ahmad, J. Z., Mohsen, S. L. (2015). A risk assessment index for bioavailability of metals in sediments: Anzali International Wetland case study. *Environmental Earth Science*. 73: 2115–2126.

Ahmed, K., Baki, M., Islam, S., Kundu, G., Al-Mamun, H., Sarkar, S., Hossain, M. (2015). Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. *Environmental Science and Pollution Research*. 22:15880–15890.

Ahmed, F., Chamhuri, S. (2001). *Industrial development degradation: case study of Langat Basin, Malaysia. Sustainability at the millenium: globalization, competitiveness and the public trust*. January 21-25, 2001 Ninth International Conference of Greening of Industry Network Bangkok.

Ahmad, A. S., (1996). Distribution of some heavy metals in the Kemaman coast, Terengganu. *MS. Thesis*, Universiti Pertanian Malaysia.

Abdallah, A. M., Abdallah, Aly, M. A. (2008). Biomonitoring study of heavy metals in biota and sediments in the South Eastern coast of Mediterranean sea, Egypt. *Environmental Monitoring and Assessment*. 146: 139-145.

Abrahim, G, Parker, R. (2008). Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. *Environmental Monitoring and Assessmen*. 136(1): 227–238.

Agresti, A. (1996). *An introduction to categorical data analysis*. (Vol. 135). Wiley New York.

Akoto, O., Bruce, T., Darko, G. (2008). Heavy metals pollution profiles in streams serving the Owabi reservoir. *African Journal of Environmental Science and Technology*. 2(11):354–359

Ali, M.F., Heng, L.Y., Ratnam, W., Nais, J. Ripin, R. (2004). Metal distribution and contamination of the Mamut River, Malaysia, caused by copper mine discharge. *Bulletin of Environmental Contamination and Toxicology*. 73 (3): 535-542.

Ali, S., Mustafa, S., Selehattin, Y., Hasan, Ö. (2014). Determination of heavy metals in sediments of the Ergene River by BCR sequential extraction method. *Environmental Earth Sciences*.72 (9): 3293-3305

Alireza S, Ahmed I, Aziz A, Che R (2007) Kepekatan Logam Berat Di Dalam Sedemen Dan Organisma Terpilih Di Sungai Lukut, Malaysia Dan Kesan Toksikologi Mereka Ke Atas JuvenalPENAEUS MONODON (FABRICIUS). Science Faculty. UPM. Thesis.

Alloway, B. J., Ayres, D.C. (1993). *Chemical principles of Environmental Pollution*. Blackie academic U.K. 140-149

Alonso Castillo, M.L., Sanchez Trujillo, I., Vereda Alonso, E., Garcia de, Torres, A., Cano Pavon, J.M. (2013). Bioavailability of heavy metals in water and sediments from a typical Mediterranean Bay (Malaga Bay, Region of

Andalucia, Southern Spain). *Marine Pollution Bulletin*. 76: 427–34.

Ashraf, M. A., Maah , M. J. Yusoff, I. (2012). Speciation of heavy metals in the sediments of former tin mining catchment. *Iranian Journal of Science and Technology*. A2: 163-180

Apello, C.A.J., Postma, D. (2005). *Geochemistry, Groundwater and Pollution*. 2nd edition. Roterdam, Balkema, CRC Press

Amiard, J.C., Amiard-Triquet, C., Berthet, B., Metayer, C. (1987) Comparative study of the patterns of bioaccumulation of essential (Cu, Zn) and non-essential (Cd, Pb) trace metals in various estuarine and coastal organisms. *Journal of Experimental Marine Biology and Ecology*. 106: 73–79.

Angulo, E. (1996). The Tomlinson Pollution Load Index applied to heavy metal,Mussel-Watch data: a useful index to assess coastal pollution. *Science of the Total Environment*. 187: 19- 56

Armitage, P.D., Bowes, M.J., Vincent, H.M. (2007). Long-term changes in macroinvertebrate communities of a heavy metal polluted stream: the River Nent (Cumbria, UK) after 28 years. *Applied Research and Technology*. 23: 997–1015.

Arain, B., Kazi, G., Jamali, K., Afridi, I., Jalbani, N., Sarfiraz, A., Baig, A., Kandhro, A., Memon, A. (2008). Time saving modified BCR sequential extraction procedure for the fraction of Cd, Cr, Cu, Ni, Pb and Zn in sediment samples of polluted lake. *Journal of Hazardous Materail*. 160: 235–239.

Aris, Z., Abdullah, H., Praveena, M., Yusoff, K., Juahir, H. (2010). Extenuation of Saline Solutes in Shallow Aquifer of a Small Tropical Island: A Case Study of Manukan Island, North Borneo. *Environment Asia*. 3: 84-92.

Aris, A.Z., Lim, W.Y., Looi, L.J. (2015). Natural and Anthropogenic Determinants of Freshwater Ecosystem Deterioration: An Environmental Forensic Study of the Langat River Basin, Malaysia. *Environmental Management of River Basin Ecosystems*. Springer.

Arain, M.B., Kazi, T.G., Jamali, M.K., Jalbani, N., Afridi, H.I., Baig, J.A. (2008). Speciation of heavy metals in sediment by conventional, ultrasound and microwave assisted single extraction methods: a comparison with modified sequential extraction procedure. *Journal of Hazard Materterial*. 154:998–1006

Athalye, R.P., Gokhale, K.S. (1991). Heavy metals in the polychaete Lycastisouanar- yensis from Thane Creek. India. *Marine Pollution Bulletin*. 22: 233–236.

Audry, S., Schäfer, J., Blanc,G., Jouanneau, J. (2004). Fifty-year sediment aryrecord of heavy metal pollution (Cd,Zn,Cu,Pb) in the Lot River reservoirs (France). *Environment Pollution*. 132: 413–426.

Azlan, A., Nasir, N.N.M., Shamsudin, N., Rahman, H.A., Khoo, H.E., Razman, M.R., (2015). PCDD and PCDF exposures among fishing community through intake of fish and shellfish from the Straits of Malacca. *BMC Public Health*. 15: 683.

Baolin, L., Liu, Ku. Hu., Zhenglong, J., Juan, Y., Ximing, Y., Aihua, L. (2011). Distribution and enrichment of heavy metals in a sediment core from the Pearl River Estuary. *Environment Earth Science*. 62: 265–275

Baumann, Z., Fisher, N.S. (2011). Relating the sediment phase speciation of arsenic, cadmium, and chromium with their bioavailability for the deposit-feeding polychaete Nereis succinea. *Environmental Toxicology and Chemistry*. 30:747−756

Badri, M., A. Aston, S., R. (1983). Observation on heavy metal geochemical associations in polluted and nonpolluted estuarine sediments. *Environmental Pollution (Series B).* 6: 181– 193.

Baker, A. J. M., McGrath, S. P., Reeves, R. D., Smith, J. A. C. (2000). *Metal hyperaccumulator plants: A review of the ecology and physiology of a biological resource for phytoremediation of metal-polluted soils*. In N. Terry & Q. Banuelos (Eds.), Phytoremediation of contaminated soil and water (85–197). Boca Raton, FL: Lewis

Besser, J.M., Brumbaugh, W.G., May, T.W. (2003). Ingersoll CG. Effects of organic amendments on the toxicity and bioavailability of cadmium and copper in spiked formulated sediments. *Environmental and Toxicology Chemistry*. 22:805–15

Bernard, A. (2008). Cadmium & its adverse effects on human health. *Indian Journal of Medical Research*. 128 (4): 557–64.

Bian, H. SPSS Discriminant Function Analysis: Office for Faculty Excellence: (http://core.ecu.edu/ofe/StatisticsResearch/SPSS%20Discriminant%20Function%20Analysis.pdf date accessed:15/8/15).

Bintal, A., Ismail, A., Arshad, A., Yap, C. K., Kamarudin, M. S. (2008). Anthropogenic impacts on heavy metal concentrations in the coastal sediments of Dumai, Indonesia. *Environmental Monitoring and Assessment.* 148: 291-305.

Birch, G. (2003). *Ascheme for assessing human impacts on coastal aquatic environments using sediments*. In C.D.Woodcoffe & R. A. Furness (Eds.). Coastal GIS, Wollongong University Papers in Center for Marinetime Pollicy,14, Austrailia. Retrieved from http://www. ozestuaries.org/indicators/DEF_sedement_scheme.html.

Bouchra, K., Mohamed, E., Abderrahmane, R., Youssef, A. (2015). Assessment of heavy metal availability (Pb, Cu, Cr, Cd, Zn) and speciation in contaminated soils and sediment of discharge by sequential extraction. *Environmental Earth Science*. 74:5849–5858

Bochenek, I., Protasowicki, M., & Brucka-Jastrzębska, E. (2008). Concentrations of Cd, Pb, Zn, and Cu in roach Rutilus rutilus (L.) from the lower reaches of the Oder River, and their correlation with concentrations of heavy metals in bottom sediments collected in the same area. *Archives of Polish Fisheries*. 16: 21–36

Bolondi, L., Bortolotti, M., Santi, V., Calletti, T., Gaiani, S., Labo, G. (1985). Measurement of gastric emptying time by real-time ultrasonography. *Gastroenterology*. 89(4): 752–759

Bowles, K.C, Apte S.C, Maher, W.A., Kawei, W., Smith, R. (2001). Bioaccumulation and biomagnification of mercury in Lake Murray, Papua New Guinea. *Journal Fisheries and Aquatic Science*. 2001. 58: 888-897.

Bourgoin, B.P., Risk, M.J., Evans, R.D., Cornett, R.J. (1991). *Relationships between the Partitioning of Lead in Sediments and its Accumulation in the Marine Mussel, Mytilus-edulis Near a Lead Smelter*. Kluwer Academic Publishers, Dordrecht (Hingham, MA). 377–386

Brandon, E. F. A., Oomen, A. G., Rompelberg, C. J. M., Versantvoort, C. H. M., Engelen, J. G. M. V. and Sips, A. J. A. M. (2006). Cosumer product in vitro digestion model: bioaccessibility of contaminants and its application in risk assessment. *Regulatory Toxicology and Pharmacology*. 44: 161-171.

Bradl, H.B. (2004): Adsorption of heavy metal ions on soils and soils constituents. *Journal of Colloid and Interface Science*. 277: 1–18.

Bradham, K., Laird, B., Rasmussen, P., Schoof, R., Serda, S., Siciliano, S., Hughes, M. (2014). Assessing the bioavailability and risk from metal contaminated soils and dusts. *Human and Ecological Risk Assessment.* 20: 272-286

Buchter, B., Davidoff, B., Amacher, M., Hinz, C., Iskandar, I., Selim, H. (1989). Correlation of Freundlich Kd and n retention parameters with soils and elements. *Soil Science*. 148: 370–379.

Burton, E.D., Phillips, I.R., Hawker, D.W. (2006b). Factors controlling the geochemical partitioning of trace metals in estuarine sediments. *Soil and Sediment Contamination*. 15:253–76.

Burger, J., Gaines, K. F., Boring, S., Syephans, L., Snodgrass, J., Dixon, C. (2002). Metals levels in fish from the Savannah River: potential hazards to fish and other receptors. *Environmental Research*. 89: 95–97.

Budavari, S. (2001). The Merck Index: *An Encyckopida of Chemicals, Drugs, and Biologicals*. 13th ed. Merck and Co., Inc. Whitehouse Station. NJ.

Calvert, S. E., Pedersen, T. F., Thunell, R. C. (1993). Geochemistry of the surface sediments of the Sulu and South China Seas. *Marine Geology*. 114: 207–231.

Chapman, P.M., Allard, P.J. and 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.

Camusso, M., Gasparella, A. (2006). Measuring bioavailable trace metals from freshwater sediments by diffusive gradients in thin films (DGT) in monitoring procedures for quality assessment, *Ann Chim*. 96: 205–213

Cabanero, A.I., Madrid, Y., Camara, C. (2004). Selenium and mercury bioaccessibility in fish samples: an in vitro digestion method. *Analytica Chimica Acta*. 526, 51–61.

Cabanero, A. I., Madrid, Y., Camara, C. (2007). Mercury-selenium species ratio in representative fish samples and their bioaccessibility by an in vitro digestion method. *Biological Trace Element Research*. 119:195–211.

Camberato, J. (2001). Cation exchange capacity—everything you want to know and much more. South Carolina Turfgrass Foundation News. Retrieved on 8 May

2011 from http://ebookbrowse.com/cation-exchange-capacity-pdf-d19788599

CCME (2002). Canadian sediment quality guidelines for the protection of aquatic life: Summary tables. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Chan, H.M. (1988). Accumulation and tolerance to cadmium, copper, lead and zinc to the green-lipped mussel Perna viridis. *Marine Ecology Progress Series*. 48: 295-303.

Chen, W., Kao, M., Chen, F., Dong, D. (2007). Distribution and accumulation of heavy metals in the sediments of Kaohsiung Harbor, Taiwan. *Chemosphere*. 66(8): 1431-440.

Chen, J., Gaikwad, V., Holmes, M., Murray, B., Povey, M., Wang, Y. (2011). Development of a simple model device for in vitro gastric digestion investigation. *Food and Function journal*. 2 (3-4): 174-182.

Christophoridis, C., Dedepsidis, D., Fytianos, K. (2009). Occurrence and distribution of selected heavy metals in the surface sediments of Thermaikos Gulf, N. Greece. Assessment using pollution indicators. *Journal of Hazardous Materials*. 168, 1082-1091.

Coles, L. T., Moughan, P. J., Darragh, A. J. (2005). In vitro digestion and fermentation methods, including gas production techniques, as applied to nutritive evaluation of foods in the hindgut of humans and other simple-stomached animals. *Animal Feed Science and Technology.* 123-125 (1): 421-444.

Collasiol, A., Pazebon, D., Maia, M. (2004). Ultrasound assisted mercury extraction from soil and sediment. *Analytica Chimica Acta*. 518: 157–164

Connell, D.W., Miller, G.J. (1984). *Chemistry and Ecotoxicology of Pollution*. New York: John Wiley & Sons.

Das, K.K., Buchner, V. (2007). Effect of nickel exposure on peripheral tissues: role of oxidative stress in toxicity and possible protection by ascorbic acid. *Review on Environmental Health*. 22(2):157–173

Daskalakis, K.D., O'Connor, T.P. (1995). Normalization and elemental sediment contamination in the coastal United States. *Environmental Science Technology*. 29(2):470–477

Department of Environment, Malaysia. (1991). *Environmental quality report.* Malaysia. Ministry of Science, Technology and Environment , Putraja. 127.

Department of Environment (DOE). (2005). *Malaysia Environmental Quality Report 2005.* Department of Environment, Ministry of Natural Resources and Environment, Malaysia

Department of Environment. (2002). *Environmental quality report 2002-2005*. Malaysia. Ministry of Science, Technology and Environment , Putraja.

Department of Statistics Malaysia. (2010). *The population development in Perak*. http://www.citypopulation.de/php/malaysia-admin.php?adm1id=07

Devesa-Rey, R., Paradelo, R., Díaz-Fierros, F., Barral, M.T. (2008). Fractionation and bioavailability of arsenic in the bed sediments of the Anllóns River (NW Spain). *Water, Air, and Soil Pollution*. 195: 189–199

Devesa-Rey, R., Diaz-Fierros, F., Barral, M.T. (2010). Trace metals in river bed sediments: an assessment of their partitioning and bioavailability by using multivariate exploratory analysis. *Journal Environment Management*. 91: 2471–2477

De Almeida, P.D.V., Gregio, A.M.T., Machado, M.A.N., De Lima, A.A.S., Azevedo, L.R. (2008). Saliva composition and functions: a comprehensive review. *Journal Contemporary Dental Practice*. 9(3):72–80

Di Toro, D.M., McGrath, J.A., Hansen, D.J., Berry, W.J., Paquin PR, Mathew, R. (2005). Predicting sediment metal toxicity using a sediment biotic ligand model: methodology and initial application. *Environmenal and Toxicology Chemistry*. 24:2410–27

Dig-Acids. (2001). *Guidelines for Microwave Acid Digestion*. In: E.D , (Ed.). DigAcid. (⟨http://www.scribd.com/doc/6789831/DigAcids⟩).

Dohrmann, R. (2006). Cation exchange capacity methodology II: A modified silver–thiourea method. *Apply Clay Science*. 34-38.

DOA. (1995). *Landuse of Selangor and Negeri Sembilan*. Department of Agriculture. Kuala Lumpur, Malaysia.

Dou, Y., 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: 137–145

Drexler, J.W., Brattin, W.J. (2007). An in vitro procedure for estimation of lead relative bioavailability: with validation. *Human Ecology Risk Assessment*. 13:383–401

Duruibe, J. O., Ogwuegbu, M. O. C., Egwurugwu, J. N. (2007) Heavy Metal Pollution and Human Biotoxic Effects. *International Journal of Physical Sciences*. 2 (5): 112-118

Dundar, M.S., Altundag, H., Eyupoglu, V., Keskin, S.C., Tutunoglu, C. (2012) Determination of heavy metals in lower Sakarya river sediments using a BCR-sequential extraction procedure. *Environmental Monitoring Assessment*. 184 (1):33–41

Durán, I., Sánchez-Marín, P., Beiras, R. (2012). Dependence of Cu, Pb and Zn remobilization on physicochemical properties of marine sediments. *Marine Environmental Research*. 77:43–9.

Durali, M., Ömer, F.Ü., Mustafa, T., Mustafa, S. (2010). Determination of trace metals in different fish species and sediments from the River Yesilırmak in Tokat, Turkey. *Food Chemistry Toxicology*. 48: 1383–1392.

Du Laing, G., Rinklebe, J., Vandecasteele, B., Meers, E., Tack, F. (2009). Trace metal behaviour in estuarine and riverine floodplain soils and sediments: A review. *Science of Total Environment*. 407:3972-3985.

EPA. (2006). Region III BTAG Freshwater Sediment Screening Benchmarks.

Environmental Protection Agency. http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm

Edwards, G. C., P. E., Rasmussen, W. H., Schroeder, R. J., Kemp, G. M., Dias, C. R., Fitzgerald-Hubble, E. K., Wong, L. (2001) Halfpenny-Mitchell, and M. S. Gustin (2001), Sources of variability in Hg flux measurements, *Journal Geophsica. Research*. 106(D6): 5421–5435.

(Eds.), Ekspedisi Matahari. (1989). Faculty of Fisheries and Marine Science. *Occasional Publication*. 9: 75–80.

El-Radaideh, N., Al-Taani, A. A., Al-Momani, T., Tarawneh, K., Batayneh, A., Taani, A. (2014). Evaluating the potential of sediments in Ziqlab Reservoir (northwest Jordan) for soil replacement and amendment. *Lake and Reservoir Management*. 30: 32–45.

Ettler, V., Kribek, B., Majer, V., Knesl, I., Mihaljevic, M. (2012). Differences in the bioaccessibility of metals/metalloids in soils from mining and smelting areas (Copperbelt, Zambia). *Journal of Geochemical Exploration*. 113: 68-75

Farkas, A., Salanki, J., Specziar, A. (2003). Age-and size-specific patterns of heavy metals in the organs of freshwater fish Abramis brama L populating a low-contaminated site. *Water Resource*. 37: 959–964

Fan, W.H., Wang, W.X. Chen J.S. (2002). Geochemistry of Cd, Cr and Zn in highly contaminated sediments and its influences on assimilation by marine bivalves. *Environmental Science and Technology*. 36: 5164- 5171.

FAO/WHO. (2004). Risk assessment of Listeria monocytogenes in ready to eat foods: interpretative summary. *Microbiological Risk Assessment Series*. 4.78. Rome, FAO.

Fernandes, C., Fontainhas-Fernandes, A., Cabral, D., Salgado, M.A. (2008). Heavy metals in water, sediment and tissues of Liza saliens from Esmoriz-Paramos lagoon, Portugal. *Environmetal Monitoring Assessessment*. 136:267–75.

Fernandes, L., Nayak, G.N., Ilangovan, D., Borole, D.V. (2011). Accumulation of sediment, organic matter and trace metals with space and time, in a creek along Mumbai coast, India. *Estuary Coastal Shelf Science*. 91:388–99

Fernandes, C., Fontainhas-Fernandes, A. (2008). Cabral D, Salgado MA. Heavy metals in water, sediment and tissues of Liza saliens from Esmoriz-Paramos lagoon, Portugal. *Environment Monitoring Assessment*.136:267–75.

Fendorf, S., La Force, M.J., Li Guangchao. (2004). Temporal changes in soil partitioning and bioaccessibility of arsenic, chromium, and lead. *Journal of Environmental Qualality*. 33:2049–2055

Fisher, N.S. Reinfelder, J.R. (1995). *The trophic transfer of metals in marine systems*. In: Tessier A, Turner DR, editors. Metal speciation and bioavailability in aquatic systems. Chichester: John Wiley. 1995:363-406.

Filgueiras, V., Lavilla, I., Bendicho, C. (2004). Evaluation of Distribution, Mobility and Binding Behaviour of Heavy Metals in Surficial Sediments of Louro River using Chemometric Analysis: A Case Study. *Science of Total Environment*. 330: 115-129

Forstner, U., Wittmann, W. (1981). *Metal Pollution in the Aquatic Environment*. 2ed. Berlim. Springer- Verlag. 486.

Forghani, G., Moore, F., Lee, S., Qishlaqi, A. (2009). Geochemistry and speciation of metals in sediments of the Maharlu Saline Lake, Shiraz, SW Iran. *Environmental Earth Science*. 59:173-184.

Foureman, P. Mason, J.M., Valencia, R., Zimmering, S. (1994). Chemical mutagenesis testing in Drosophila. X. Results of 70 coded chemicals tested for the National Toxicology Program. *Environmental and Molecular Mutagenesis*. 23:208–227.

Foth, H. D. (1990). *Fundamentals of Soil Sciens*. John Wiley & Sons. Inc., Canada Geochemical Atlas of Europe, Part 1 and Part 2. Geological Survey of Finland, Espoo, 2006

Fu, J., Hu, X., Tao, X., Yu,H., Zhang, X. (2013). Risk and toxicity assessments of heavy metals in sediments and fishes from the Yangtze River and Taihu Lake, China. *Chemosphere*. 93:1887–1895

Fujita, M, Ide, Y., Sato, D., Kench, P.S., Kuwahara, Y., Yokoki, H., Kayanne, H. (2014). Heavy metal contamination of coastal lagoon sediments: Fongafale Islet, Funafuti Atoll, Tuvalu. *Chemosphere*. 95:628–634

Fussenegger, D., Suppin, D., Raheem, A., Widhalm, K. (2007). What kind of fish on the table? Omega-3 fatty acids versus mercury contamination. *Journal für Ernahrungsmedizin*. 9: 6-13.

Fuentes, A., Lorens, M., Saez, J., Aguilar, I., Ortuno, F., Meseguer, F. (2008). Comparative study of six different sludges by sequential speciation of heavy metals. *Bioresource Technology*. 99: 517-525.

Gee, G.W., Bauder, J.W. (1986). *Particle-size analysis*. Madison, Wisconsin.

Gerald, J. Z., Christophe, B., Bruno, W. (2009). Influence of Mercury Speciation and Fractionation on Bioaccessibility in Soils. *Archive of Environmental Contamination and Toxicology*. 56:371–379.

Golia, E. E.; Tsiropoulos, N. G., Dimirkou, A., Mitsios, I. (2007). Distribution of heavy metals of agricultural soils of central Greece using the modified BCR sequential extraction method. *International Journal of Environmental Analytical Chemistry*. 87 (13- 14): 1053-1063

Gu, Y., Yan, G., Qin, L. (2015). Contamination, bioaccessibility and human health risk of heavy metals in exposed-lawn soils from 28 urban parks in southern China's largest city, Guangzhou. *Applied Geochemistry*. 67: 52-58

Goyer, R.A., T.W., Clarkson. (2001). Chapter 23: *Toxic Effects of Metals. In Casarett and Doulls Toxicology*: The Basic Science of Poisons. Ed. by C.D. Klaasen. Pages 811- 867

Gumgum, B., Unlu, E., Tez, Z. Gulsun, N. (1994). Heavy metal pollution in water, sediment and fish from the Tigris River in Turkey. *Chemosphere*. 290 (1): 111- 116.

Gu¨ven, D.E., Akıncı, G. (2008). Heavy metals partitioning in the sediments of Izmir Inner Bay. *Journal of Environmental Science*. 20:413–418

Gu¨ven, D.E., Akinci, G. (2013). Effect of sediment size on bioleaching of heavy metals from contaminated sediments of Izmir Inner Bay. Journal of Environmental Science. 25:1784–94.

Hänninen, O., Knol, A., Jantunen, M., Lim, T., Conrad, A., Rappolder, M., Carrer, P., Fanetti, A., Kim, R., Buekers, J., Torfs, R., Iavarone, I., Classen, T., Hornberg, C., Mekel, O. (2014). Environmental burden of disease in Europe: assessing nine risk factors in six countries. *Environmental Health Perspectives*. 122: 439-446.

Hall, J.A, Frid, C.J., Gill, M.E. (1997). The response of estuarine fish and benthos to an increasing discharge of sewage effluent. *Marine Pollution Bulletin*. 34:537–535

Hall, S. J. (1994). Physical disturbance and marine benthic communities: Life in unconsolidated sediments. Oceanography and Marine Biology: *an Annual Review*. 32: 179–239.

Hart, B.T. (1982). Up take of trace metals by sediments and suspended particulates: a review. *Hydrobiologia*. 91–92: 299–313.

Hadi Bazli bin Hassan (2011). *Kajian Terhadap Bukti PerubahanIklim Di Projek Pengairan Barat Laut Selangor.* Universiti Teknologi Malaysia

Hare, L., Tessier, A. (1996). Predicting animal cadmium concentrations in lakes. *Nature*. 380:430–2

HauserDavis,A.R., deCampos,C.R., Ziolli, L.R. (2012).Fish metalloroteins as biomarkers of environmental contamination. In: Whitacre DM (ed) Reviews of environmental contamination and toxicology, *Springer*, Berlin. 218

Hauser-Davis R.A., Gonçalves, R.A., Ziolli, R.L., de Campos, R.C. (2012). A novel report of metallothioneins in ish bile: SDS–PAGE analysis, spectrophotometry quantiication and metal speciation characterization by liquid chromatography coupled to ICP-MS. *Aquatic Toxicology*. 116:54–60
Hadi Bazli bin Hassan (2011). *Kajian Terhadap Bukti PerubahanIklim Di Projek Pengairan Barat Laut Selangor.* Universiti Teknologi Malaysia
Hajeb, P.S., Jinap, A.B., Fatimah, Jamilah, B. (2010). Methylmercury in marine fish from Malaysian waters and its relationship to total mercury content. *International Journal of Environmental Analytical Chemistry*. 90: 812-820.

Hajeb, P.S., Ismail, A., Mahyudin, A. (2012). Mercury Pollution in Malaysia. *Reviews of Environmental Contamination and Toxicology*. 220: 45-66

Hamilton, J.W., Wetterham, K.E. (1988). Chromium. In H.G. Seiler, H. Sigel, and A. Sigel, Eds., *Handbook on Toxicity of Inorganic Compounds*. New York: Marcel Dekker, Inc., p. 239.

Hakanson, L. (1980). An Ecological Risk Index for Aquatic Pollution Control: *A Sedimentological Approach, Water Resources*. 14: 975–1001.

Håkanson, L., Jansson, M. (1983). *Principles of Lake Sedimentology*. Springer-Verlag, Berlin, 315.

Hamid, M. Y. A., Sidhu, H. S. (1993). *Metal finishing wastewater:characteristics and minimization.* In: B. G. Yeoh, K. S. Chee,S. M. Phang, Z. Isa, A. Idris,

M. Mohamed (Eds.), Waste man-agement in Malaysia: Current status and prospects for biore-mediation , pp. 41–49. Ministry of Science, Technology and the Environment, Malaysia

Hamel, S.C., Buckley, B., Lioy, P.J. (1998). Bioaccessibility of metals in soils for different liquid to solid ratios in synthetic gastric fluid. *Environmental Science and Technology*. 32:358–362

Haque, M.A, Subramanian, V. (1982). Cu, Pb and Zn pollution of soil environment. CRC *Critical Reviews in Environmental Control*. 12: 13 – 90

Hazzeman, H., Ahmed, Z. (2013). The geoaccumulation index and enrichment factor of mercury in mangrove sediment of Port Klang, Selangor, Malaysia. *Arab Journal of Geoscience*. 6:4119–4128

He, M., Wang, W. X. (2011). Factors affecting the bioaccessibility of methylmercury in several marine fish species. *Journal Agriculture and Food Chemistry*. 59, 7155–7162.

He, M., Ke, C. H., Wang, W. X. (2010). Effects of cooking and subcellular distribution on the bioaccessibility of trace elements in two marine fish species. *Journal Agriculture and Food Chemistry*. 58, 3517–3523.

He, M., Wang, W.X. (2013). Bioaccessibility of twelve trace elements in marine molluscs: dependent on subcellular distribution. *Food Chemistry and Toxicology*. 55: 627–636

He, M., Cai-Huan, K., Lei, T., Hai-Bei, L. (2015). Bioaccessibility and Health Risk Assessment of Cu, Cd, and Zn in ''Colored'' Oysters. *Archives of Environmental Contamination and Toxicology*. 70: 595–606

Holt, E. A., Miller, S. W. (2011). *Bioindicators: using organisms to measure environmental impacts.* Nature Education Knowledge. 3- 8.

Heikkila, R. (1991). The influence of land-use on the sedimentation of the river delta on the Kyronjoki drainage-basin. *Hydrobiologia*. 214:143–147

Horowitz, J., Stephens, C. (2008). The effects of land use on fluvial sediment chemistry for the conterminous U.S.Results from the first cycle of the NAWQA Program: Trace and major elements, phosphorus, carbon, and sulfur. *Science of Total Environment*. 400: 290–314.

Horowitz, A. J. (1991). *A primer on trace metal—Sediment chemistry* (2nd ed., p. 136). Chelsea: Lewis Publisher.

Houlbreque, F., Herve-Fernandez, P., Teyssie, J.L., Oberhaensli, F., Boisson, F., Jeffree, R. (2011). Cooking makes cadmium contained in Chilean mussels less bioaccessible to humans. *Food Chemistry*. 126:917–921

Hong, S.W., Kim, H.S., Chung, T.H. (2010). Alteration of sediment organic matter in sediment microbial fuel cells. *Environment Pollution*. 158:185–91.

Hoanninen, O., Knol, A., Jantunen, M., Lim, T., Conrad, A., Rappolder, M., Carrer, P., Fanetti, A., Kim, R., Buekers, J., Torfs, R., Iavarone, I., Classen, T., Hornberg, C., Mekel, O. (2014). Environmental burden of disease in Europe: assessing nine risk factors in six countries. *Environmental Health Perspective*. 122: 439-446.

Holt, E. and Miller, S. (2011). Bioindicators: Using Organisms to Measure Environmental Impacts. *Nature Education Knowledge.* 3(10):8

Huberty, Carl J. (1994). *Applied Discriminant Analysis*. NY: WileyInterscience.

Hussein, K., Okoro, S., Fatoki, A., Adekola, J., Ximba, Reinette, G. (2014). Fractionation, mobility and multivariate statistical evaluation of metals in marine sediments of Cape Town Harbour, South Africa. *Chemical Speciation and Bioavailability*. 26 (3)

Huse, A. (1999). *Environmentally hazardous substances in products*. Data for 1997. SFT-Report 99/03. TA-1613/1999. 73.

Hu, B., Li, J., Zhao, J., Yang, J., Bai, F., Dou, Y. (2012). Heavy metal in surface sediments of the Liaodong Bay, Bohai Sea: distribution, contamination, and sources. *Environmental Monitoring and Assessment*. 1–13.

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*. 20 (6):4099–4110
Hussein, K., Okoro, S., Fatoki, A., Adekola, J., Ximba, Reinette, G. (2014). Fractionation, mobility and multivariate statistical evaluation of metals in marine sediments of Cape Town Harbour, South Africa. *Chemical Speciation and Bioavailability*. 26 (3)
Hur, S. J., Lim, B. O., Decker, E. A., & McClements, D. J. (2011). In vitro human digestion models for food applications. *Food Chemistry*. 125: 1-12

Huang, J.Z., Ge, X., Wang, D. (2012). Distribution of heavy metals in the water column, suspended particulate matters and the sediment under hydrodynamic conditions using an annular flume. *Journal of Environmental Science*. 24:2051–9.

Ikem, A., Egiebor, O., Nyavor, K. (2003). Trace Elements in Water, Fish and Sediment from Tuskegee Lake, South- Eastern USA. *Water, Air and Soil Pollution*.149:51-75

Idris, M. (2008). Combining multivariate analysis and geochemical approaches for assessing heavy metal level in sediments from Sudanese harbors along the Red Sea coast. *Microchemical Journal*. 90 (2):159–163

Idrus, S., Shah, A. Z. A., Mohamed, A. Z. (2004). *Analyses of land use and land cover changes 1974-2001 in Langat Basin, Malaysia using geographical information system (GIS).* In Proceedings of the 2003 Langat Basin ecosystem research symposium, ed. M. Mokhtar, S. Idrus and S. A. Abdul Ghani. Penerbit LESTARI, UKM. Selangor.

Idris, A., M., Eltayeb, M. A. H., Potgieter-Vermaak, S. S., Grieken, R. V., Potgieter, J. H. (2007). Assessment of heavy metals pollution in Sudanese harbours along the Red Sea Coast. *Microchemical Journal.* 87: 104-112.

Idriss, A., Ahmad, A. (2013). Heavy Metals Nickel and Chromiumin Sediments in the Juru River, Penang, Malaysia. *Journal of Environmental Protection*. 4: 1245-1250.

Intawongse, M., Dean, J.R. (2008). Use of the physiologically-based extraction test to assess the oral bioaccessibility of metals in vegetable plants grown in contaminated soil. *Environment. Pollution*. 152: 60–72

International Agency for Research on Cancer. (1990). *Chromium, Nickel and Welding. Lyon*, (IARC Monographs on the Carcinogenic Risk of Chemicals to Humans, Vol. 49).

Ismail, A., Ramli, R. (1997). Trace Metals in Sediments and Molluscs from an Estuary Receiving Pig Farms Effluent. *Environmental Technology*. 18 (5): 509- 515.

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

Islam, M.S., Han, S., Masunaga, S. (2014). Assessment of trace metal contamination in water and sediment of some rivers in Bangladesh. *Journal of Water and Environment Technology*. 12: 109–121.

Irfan, M., Hayat, S., Ahmad, A., Alyemeni, M.N. (2013). Soil cadmium enrichment: Allocation and plant physiological manifestations. *Saudi Journal of Biological Science*. 20 (1): 1–10.

Irwandi, J., Farida, O. (2009). Mineral and heavy metal contents of marine fin fish in Langkawi island, Malaysia. *International Food Research Journal*. 16: 105-112.

Jamaluddin, I. B. (2014). *Analysis of trend in hydrologic system for Sungai Bernam Basin*. Faculty of Engineering. Universiti Putra Malaysia. Master thesis

Javed, M. (2005). Heavy metal contamination of freshwater fish and bed sediments in the river Ravi stretch and related tributaries. *Pakistan Journal of Biology Science*. 8 (10): 1337-1341.

Jinghua, R., Paul, N., Williams, Jun, L., Hongrui, M., Xiaorong, W. (2015). Sediment metal bioavailability in Lake Taihu, China: evaluation of sequential extraction, DGT, and PBET techniques. *Environmental Science and Pollution Research*. 22: 12919–12928

Jeyaseelan, M.J.P. (1998). *Manual of fish eggs and larvae from Asian mangrove waters*. United Nations Educational. Scientific and Cultural Organization. Paris. 193.

Joseph, F., Rolph, E., Ronald, L. and William, C. (1995). *Multivariate Data Analysis With Readings*. Prentice-Hall International. Inc.

Juhasz, A. L., Smith, A., Weber, J., Gancarz, D., Rees, M., Rofe, A., Kuchel, T., Sansom, L., Naidu, R. (2011). *Predicting the relative bioavailability of arsenic, cadmium, and lead via the incident soil ingestion pathway using in vitro techniques*. 19th World Congres of soil Science, Soil Solution for a Changing World.

Kalantzi, I., Shimmield, T.M., Pergantis, S.A., Papageorgiou, N., Black, K.D., Karakassis, I., (2013). Heavy metals, trace elements and sediment geochemistry at four Mediterranean fish farms. *Science Total of Environmental*. 444:128–137.

Kannel, P. R., Lee, S., Kanel, S. R. and Khan, S. P. (2007). Chemometric application in classification and assessment of monitoring locations of an urban river system. *Analytica Chimica Acta*. 582(2): 390-399.

Kamaruzzaman, B. Y., Husain, M. L., Shazili, N. A. M., Sulong, I. (2002). Geochemistry of some heavy metals as recorded in the sediment of the Kuala Kemaman mangrove forests, Terengganu, Malaysia. Oriental Journal of Chemistry. 18: 7–14.

Kakuschke, A., Valentine-Thon, E., Griesel, S., Fonfara, S., Siebert, U., Prange, A. (2005). The immunological impact of metals in Harbor Seals (Phoca vitulina) of the North Sea. *Environmental Science and Technology*. 39 (19):7568-7575.

Kenneth, P., Simon, J., Blott. (2004). Particle size analysis of sediments, soils and related particulate materials for forensic purposes using laser granulometry. *Forensic Science International*. 19-27.

Keller, B.E.M., Lajtha, L. Cristofor, S. (1998), Trace metal concentration in the sediment and plants of Danube Delta, Romania. *Wetlands*. 18 (1): 42-50.

Klecka, W. R. (1980). *Discriminant analysis*. Sage.

Kim, J.Y., Kim, K.W., Lee, J.U., Lee, J.S., Cook, J. (2002). Assessment of As and heavy metal contamination in the vicinity of Dunckum Au-Ag mine, Korea. *Environmental Geochemistry and Health*. 24: 215–227

Krauskopf, K.B., Bird, D.K. (1995). *Introduction to geochemistry*. McGraw-Hill Inc, New York.

Krishnan, G. (2009, July 15). Salak Tinggi water treatment plant may be closed for good. The Star Online. Retrieved from http:// www. thestar. com. my/ story/ ?file= %2F 2009% 2F7%2 F15%2Fcentral%2F4317744&sec=central

Kucuksezgin, F., Uluturhan, E., Batki, H. (2008). Distribution of heavy metals in water, particulate matter and sediments of Gediz River (Eastern Aegean). *Environmental Monitoring Assessment*. 141:213–25

Kulkarni, D., Acharya, R., Rajurkar, S., Reddy, R. (2007). Evaluation of bioaccessibility of some essential elements from wheatgrass (Triticum aestivum L.) by in vitro digestion method. *Food Chemistry*. 103: 681–688

Kwok, C. K., Liang, Y., Wang, H., Dong,Y. H., Leung, S. Y., Wong, M. H. (2014). Bioaccumulation of heavy metals in fish and Ardeid at Pearl River Estuary, China. *Ecotoxicology and Environmental Safety*. 106:62–67.

Lachenbruch, P. A. (1975). *Discriminant analysis*. Wiley Online Library.

Laird, B.D., Shade, C., Gantner, N., Chan, H.M., Siciliano, S.D., (2009). Bioaccessibility of mercury from traditional northern country foods measured using an in vitro gastrointestinal model is independent of mercury concentration. *Science of Total Environment*. 407: 6003–6008.

Lalor, G.C. (2008). Review of cadmium transfers from soil to humans and its health effects and Jamaican environment. *Science of Total Environment*. 400(1–3):162–172.

Landrum, P.F., Robbins, J.A. (1990). Bioavailability of sediment associated contaminants to benthic invertebrates. In: Baudo R, Giesy JP, Muntau H (eds) Sediments: chemistry and toxicity of in-place pollutants. Lewis Publishers. *Ann Arbor*. MI. 237–263

Lamberson, J.O., DeWitt, T.H., Swartz, R.C. (1992). *Assessment of sediment toxicity to marine benthos.* In: Burton GA Jr (ed) Sediment toxicity assessment. Lewis Publishers. Boca Raton. FL. 183–211

Laparra, J.M., Velez, D., Montoro, R., Barbera, R., Farre, R. (2003). Estimation of arsenic bioaccessibility in edible seaweed by an in vitro digestion method. *Journal Agriculture and Food Chemistry.* 51: 6080–6085.

Leung, H.M., Leung, A.O.W., Wang, H.S., Ma, K.K., Liang, Y., Ho, K.C., Cheung, K.C., Tohidi, F.,Yung, K. K.L. (2014). Assessment of heavy metals/metalloid (As,Pb,Cd, Ni, Zn, Cr, Cu, Mn) concentrations in edible fish species tissue in the Pearl River Delta (PRD), China. *Marine Pollution Bulletin*. 78:235–245.

Li, B., Wang, Q., Huang, B., Li,S. (2001). Evaluation of the results from aquasi Tessier's sequential extraction procedure for heavy metal speciation in soil sand sediments by ICP-MS. *Analytical Science*. 17: 11561–11564.

Li, G., Zhang, S., Liu, Y., Wan, Y., Zhang, H., Chen, F. (2002). Soil nutrient assessment for urban ecosystems in Hubei, China. *Soil Nutrient of Urban Ecosystems*. Plos (8) 9

Li, Y., Demisie, W., Zhang, M. (2013). The function of digestive enzymes on Cu, Zn, and Pb release from soil in in vitro digestion tests. *Environmental Science and Pollution Research*. 20(7): 4993–5002

Li, Y., Demisie, W., Zhang, Z. (2015). Digestion Tests to Measure Heavy Metal Bioavailability in Soils. CO2 *Sequestration, Biofuels and Depollution*. Chapter. 5: 275-305

Liu, C.-W., Lin, K.-H. and Kuo, Y.-M. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *Science of the Total Environment*. 313 (1): 77-89.

Liu, J., Qian, M., Cai, G., Yang, J., and Zhu, Q. (2007). Uptake and translocation of Cd in different rice cultivars and the relation with Cd accumulation in rice grain. *Journal of Hazardous Materails*. 143, 443–447.

Liu, R.Q., Zhao, D.Y. (2007). The leachability, bioaccessibility, and speciation of Cu in the sediment of channel catfish ponds. *Environmental Pollution.* 147: 593–603

Liu, X., Lou, C., Xu, L., Sun, L. (2012). Distribution and bioavailability of cadmium in ornithogenic coral-sand sediments of the Xisha archipelago, South China Sea, *Environmental Pollution*. 168: 151–160

Looi, L. J., Aris, A. Z., Haris, H., Yusoff, F. M., Hashim, Z. (2016). The levels of mercury, methylmercury and selenium and the selenium health benefit value in grey-eel catfish Plotosus canius) and giant mudskipper (Periophthalmodon schlosseri) from the Strait of Malacca. *Chemosphere. 152*, 265–273.

Looi, L., Zaharin, A., Yusoff, F., Hashim, H. (2015). Mercury contamination in the estuaries and coastal sediments of the Strait of Malacca. *Environment Monitoring Assessment*. 187: 4099

Long, E.R., MacDonald, D.D. (1998). Recommended uses of empirically-derived sediment quality guidelines for marine and estuarine ecosystems. *Human Ecology Risk Assessment*. 4:1019- 1039.

Lu, X.Q., Werner, I., Young, T.M. (2005). Geochemistry and bioavailability of metals in sediments from northern San Francisco Bay. *Environment International*. 31:593–602

Lu, Y., Gong, Z., Zhang, G., Burghardt, W. (2003). Concentrations and chemical speciations of Cu, Zn, Pb and Cr of urban soils in Nanjing, China. *Geoderma.* 115:101–111.

Lund-Research (2013). *Testing for normality in SPSS*: https:// statistics. laerd. com/ premium/ tfn/testing-for-normality-in-spss-2.php: (accessed on 14th/08/15).

Luoma, S.N., Rainbow, P.S. (2008). *Metal contamination in aquatic environments: science and lateral management*. Cambridge University Press, Cambridge

Luo, S., Ding, J., Xu, B., Wang, J., Li, B., Yu, S. (2012a). Incorporating bioaccessibility into human health risk assessments of heavy metals in urban park soils, *Science of Total Environment*. 424, 88–96

Luo, Z., Yu, S., Li, X.d. (2012b). The mobility, bioavailability, and human bioaccessibility of trace metals in urban soils of Hong Kong. *Applied Geochemistry*. 27: 995-1004

Ma X., Zuo H., Tian M., Zhang L., Meng J., Zhou X., Min N., Chang X., Liu Y. (2016). Assessment of heavy metals contamination in sediments from three adjacent regions of the Yellow River using metal chemical fractions and multivariate analysis techniques. *Chemosphere*. 144, 264.

Ma, L.Q., Rao, G.N. (1997). Chemical fractionation of cadmium, copper, nickel, and zinc in contaminated soils. *Journal Environmental Quality*. 26: 259–264.

MacDonald, D.D., Ingersoll, C.G., Berger, T. (2000). Development and evaluation of consensusbased sediment quality guidelines for freshwater ecosystems. *Archive Environmental Contamination and Toxicology*. 39:20-31.

Malaysian Adult Nutrition Survey. (2009). In: Amin, I., Rusidah, S., Norhayati, M.K., Fairulniza,l M.N., Norliza, A.H. (2012). Current status of food composition data in Malaysia. First *Australian Food Metrology Symposium*. 23 October 2012. Melbourne, Australia

Malaysian Food Act. (1983). *Food Act 1983 (Act 281) & Regulations (1985)*. International Law Book Services. Kuala Lumpur. 307.

Malaysian Meteorological Department (2011).General Climate of Malaysia. http://www.met.gov.my/index.php?option=com_content&task=view&id=75 &Itemid=1089&lang=english. Assessed on 26/02/2011

Manga, N. (1983). Heavy metal concentrations in the sediments of the tidal section of the river Lagan. *Irish Journal of Environmental Sciences*. l. 2: 6064.

Mahmood, A., Malik, R. (2014). Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, Pakistan. *Arabian Journal of Chemistry*. 7: 91–99

Madrid, F., Biasioli, M., Ajmone-Marsan, F. (2008). Availability and bioaccessibility of metals in fine particles of some urban soils. *Archives of Environmental Contamination and Toxicology*. 55: 21–32

Martin, R., Arana, D., Ramos-Miras, J., Gil, C., Boluda, R. (2015). Impact of 70 years urban growth associated with heavy metal pollution. *Environment Pollution*.196; 156–163.

Manikandarajan, T., Ramamoorthy, K., Srilatha, G., Sankar, G., Kathirvel, K. (2014). Stomach content analysis of catfish - Arius maculatus (Thunberg, 1792) from Parangipettai Coast, South East Coast of India. *Asian Journal of Biomedical and Pharmaceutical Sciences*. 4(38), 50–56.

Matsumoto, S.T., Mantovani, M.S., Rigonato, J., Marin-Morales, M.A. (2005). Evaluation of the genotoxic potential due to the action of an effluent contaminated with chromium, by the comet assay in cho-k1 cultures. *Caryologia*. 58:40-46.

Mazlan, A.G., Abdullah, S., Shariman, M.G., Arshad, A. (2008). On the biology and bioacoustic characteristic of spotted catfish Arius maculatus (Thunberg 1792) from the Malaysian Estuary. *Research Journal of Fisheries Hydrobiology*. 3: 63-70.

McBride, M. B. (1994). *Environmental chemistry of soils*. Oxford university press.

McLean, O. (1982). *Method of Soil analysis*, In: Page, A.L., et al. (Eds.), Soil pH analysis, Madison, Wisconsin. 199-224.

McLachlan, A. (1990). Dissipative beaches and macrofauna communities on exposed intertidal sands. *Journal of Coastal Research.* 61(1): 57-71

McClements, D. J., Li, Y. (2009). Review of in vitro digestion models for rapid screening of emulsionbased systems. *Food and Function journal*. (1): 32-59.

Mercier, G., Duchesne, J., Carles-Gibergues, A. (2002). A simple and fast screening test to detect soils polluted by lead. *Environmental Pollution*. 118:285–296

Metian, M., Charbonnier, L., Oberhaensli, F., Bustamante, P., Jeffree, R., Amiard, J.C. (2009). Assessment of metal, metalloid, and radionuclide bioaccessibility from mussels to human consumers using centrifugation and simulated digestion methods coupled with radiotracer techniques. *Ecotoxicology and Environmental Safety*. 72:1499–1502

Meybeck, M., Lestel, L., Bonte, P., Moilleron, R., Colin, J. L., ´ Rousselot, O., Herve, D., de Pontev ´ es, C., Grosbois, C., Thevenot, D. R. (2007). Historical perspective of heavy metals (Cd, Cr, ´ Cu, Hg, Pb, Zn) in the Seine river basin (France) following a DPSIR approach (1950–2005), *Science of Total Environment.* 375: 204–231.

Miller, R.M. (1995). Biosurfactant-facilitated remediation of metal-contaminated soils. *Environmental Health Perspective*. 103(Suppl 1):59–62

Mohamed, C. A. R., Shazili, N. A. M. (1998). Recent concentrations of trace elements in coastal sediment of Terengganu, Malaysia. *Sains Malaysiana*. 27: 73–82.

Mohmadisa H., Suhaily M. Y., Nasir N. (2012). *Trend Hujan JangkamasaPanjang Dan Pengaruhnya Terhadap Hakisan Permukaan* : ImplikasinyaKepada Tapak Kampus Baru Sultan Azlan Shah, Tanjung Malim. Jabatan Geografi dan Alam Sekitar, Fakulti Sains Kemanusiaan, Universiti PendidikanSultan Idris

Mokhtar, M. B., Toriman, M.E.H., Hossain, M.A.A. and Tan, K.W. (2011). Institutionalchallenges for integrated river basin management in Langat River Basin, Malaysia. *Water and Environment Journal*. 25(4): 495-503.

Mokhtar, M., Aris, A. Z., Munusamy, V., Praveena, S. M. (2009). Assessment level of heavy metals in Penaeus Monodon and Oreochromis Spp in Selected Aquaculture Ponds of High Densities Development Area. *European Journal of Scientific Research*. 30 (3):348-360.

Morillo, J., Usero, J., Gracia, I. (2004). Heavy metal distribution in marine sediments from the southwest coast of Spain. *Chemosphere*. 55: 431-442.

Moreda-Piñeiro, J., Alonso-Rodríguez, E., Romarís-Hortas, V., Moreda-Piñeiro, A. López-Mahía, P., Muniategui-Lorenzo, S. (2012). Assessment of the bioavailability of toxic and non-toxic arsenic species in seafood samples. *Food Chemistry*. 130 (3): 552–560.

Moreda-Piñeiro, J., Moreda-Piñeiro, A., Romarís-Hortas, V., Moscoso-Pérez, C., López-Mahía, P., Muniategui-Lorenzo, S. (2011). In-vivo and in-vitro testing to assess the bioaccessibility and the bioavailability of arsenic, selenium and mercury species in food samples. TrAC, *Trends in Analytical Chemistry*. 30(2): 324–345.

Muller, G. (1981). The heavy metal pollution of the sediments of Neckars and its tributary: a stocktaking. *Chemiker- Zeitung*. 105:157–164.

Mucha, A.P., Vasconcelos, M.T.S.D. Bordalo, A.A. (2003). Macrobenthic community in the Douro estuary: relations with trace metals and natural sediment. characteristics. *Environmental Pollution*. 121(2): 169-180.

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

Naji, A., Ismail, A. (2011). Risk Assessment of Mercury Contamination in Surface Sediment of the Klang River, Malaysia. *Australian Journal of Basic and Applied Sciences*. 5(7): 215-221.

Naji, A., Ismail, A. (2011). Assessment of metals contamination in Klang River surface sediments by using different indexes. *EnvironmentAsia*..4 (1): 30-38.

Nance, P., Pattersona, J., Willisa, A., Forondab, N., Doursona M. (2012). Human health risks from mercury exposure from broken compact fluorescent lamps (CFLs). *Regulatory Toxicology and Pharmacology*. 62: 542-552.

Newarman, M. C. (1998). *Fundamentals of Ecotoxicology*. Ann Arbor Press. Chelsea. USA. 25–39.

Nguyen, T., Minoru, Y., Maiko, I., Masato, T. (2013). Source discrimination of heavy metals in sediment and water of To Lich River in Hanoi City using multivariate statistical approaches. *Environmental Monitoring Assessment*. 185:8065–8075.

Nobi, E.P., Dilipan, E., Thangaradjou, T., Sivakumar, K., Kannan, L. (2010). Geochemical and geo–statistical assessment of heavy metal concentration in the sediments of different coastal ecosystems of Andaman Islands, India. *Estuarine, Coastal and Shelf Science*. 87(2): 253- 264.

NOAA (1999). *Screening quick reference tables (SquiRTs).* National Oceanic and Atmospheric. Administration.<http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html>

NYSDEC. (2006). *New York State Brownfield Cleanup Program Development of Soil Cleanup Objectives Technical Support Document*. New York State Department of Environmental Conservation and New York State Department of Health, Albany, NY. Available at: http://www.dec.ny.gov/chemical/34189.html

Oguzie, F.A., Okhagbuzo, G.A. (2010). Concentrations of heavy metals in effluent discharges downstream of Ikpoba river in Benin City, Nigeria. *African Journal of Biotechnology*. 9: 319-325.

Olivares-Rieumont, S., de la Rosa, D., Lima, L., Graham, W., D' Alessandro, K., Borroto, J., Martinez, F., Sanchez, J. (2005). Assessment of heavy metal levelsin Almendares River sediments – Havana City, Cuba. *Water Research*. 39:3945-3953.

Omar, N. A., Praveena, S. M., Aris, A. Z., Hashim, Z. (2013). Bioavailability of heavy metal in rice using in vitro digestion model. *International Food Research Journal.* 20(6): 2979-2985

Oomen, A.G., Hack, A., Minekus, M., Zeijdner, E., Cornelis, G., Verstraete, W., De Wiele, T.V., Wragg, J., Rompelberg, C.J.M., Sips, A.J.A.M., Van Wijnen, J.H. (2002). Comparison of five in vitro digestion models to study the bioaccessibility of soil contaminants. *Environmental Science and Technology*. 36:3326–3334

Oomen, A.G., Rompelberg, C.J.M., Kamp, E.V., Pereboom, D.P.K.H., Zwart, L.L.D., Sips, A.J.A.M. (2004). Effect of bile type on the bioaccessibility of soil contaminants in an in vitro digestion model. *Archives of Environmental Contamination and Toxicology*. 46:183–188

Oomen, A.G., Tolls, J., Sips, A.J.A.M., Groten, J.P. (2003a). In vitro intestinal lead uptake and transport in relation to speciation. *Archive of Environmental Contamination and Toxicology* 44:116–124

Oomen, A.G., Rompelberg, C.J.M., Bruil, M.A., Dobbe, C.J.G., Pereboom, D.P.K.H., Sips, A.J.A.M. (2003b). Development of an in vitro digestion model for estimating the bioaccessibility of soil contaminants. *Archive of Environmental Contamination and Toxicology*. 44:281–287

Osman, R., Saim, N., Juahir, H., Abdullah, M. P. (2012). Chemometric application in identifying sources of organic contaminants in Langat river basin. *Environmental monitoring and assessment*. 184(2), 1001-1014.

Pansu, M., Gautheyrou, J. (2006). Handbook of Soil Analysis. Springer, New York

Parthasarathi, C., Raghunadh, V. (2015). Environmental controls on the speciation and distribution of mercury insurface sediments of a tropical estuary, India. *Marine Pollution Bulletin*. 95: 350–357

Pelfrene, A., Waterlot, C., Mazzuca, M., Nisse, C., Cuny, D., Richard, A., et al. (2012). Bioaccessibility of trace elements as affected by soil parameters in smelter-contaminated agricultural soils: A statistical modeling approach. *Environmental Pollution*. 160: 130–138.

Pelfrene, A., Waterlot, C., Mazzuca, M., Nisse, C., Bidar, G., Douay, F. (2011). Assessing Cd, Pb, Zn human bioaccessibility in smelter-contaminated agricultural topsoils (northern France). *Environmental Geochemistry and Health*. 33: 477-493

Pempkowiak, J., Sikora, A., Biernacka, E. (1999). Speciation of heavy metals in marine sediments vs their bioaccumulation by mussels. *Chemosphere*. 39 (2): 313–321

Phillips, J. D. (1991). `Fluvial sediment budgets in the North Carolina Piedmont', *Geomorphology*. 4: 231-241.

Pittman, H.T., W.W., Bowerman, L.H., Grim, T.G., Grub, W.C., Bridges. (2011). Using nestling to assess spatial and temporal concentrations of mercury in bald eagles at Voyageurs National Park, Minnesota, USA. *Ecotoxicology*. 20: 1626-1635.

Pourahmad, J., Rabiei, M., Jokar, F., O'brien, P. (2005). A comparison of hepatocyte cytotoxic mechanisms for chromate and arsenite. *Toxicology*. 206: 449–460.

Polprasert, C. (1982). Heavy metal pollution in the Chao Phraya River estuary, Thailand. *Water Research*. 16: 775-784.

Qian, J., Skyllberg, U., Tu, Q. Bleam, W. (2000). Efficiency of Solvent Extraction Methods for the Determination of Methyl Mercury in Forest Soils. *Fresenius' Journal of Analytical Chemistry*. 367:467–73.

Radojević, M., Bashkin, V.N. (2007). *Practical environmental analysis*. Royal Society of Chemistry, United Kingdom.

Rahman, R.A., Surif, S. (1993). *Metal finishing wastewater: characteristics and minimization. In Waste management in Malaysia: Current status and prospects for bioremediation*,eds. B.G. Yeoh, K.S. Chee, S.M. Phang, Z. Isa, A. Idris, and M. Mohamed, Ministry of Science, Technology and the Environment, Malaysia

Rahman, M.,, Ling, H., Kasim, Z., Nik, W. (2009). Determination of mercury in environmental samples in muar river estuary. *Malaysian Journal of Civil Engineering*. 21 (2) : 168-178

Rauf, A., Javed, M., Ubaidullah, M. (2009). Heavy metal levels in three major carps (Catla catla, Labeo rohita and Cirrhina mrigala) from the River Ravi. *Pakistan Veterinary Journal*. 29:24–26.

Rao, R.M., Sahuquillo, A., Lopez Sanchez, J.F. (2008). A review of the different methods applied in environmental geochemistry for single and sequential extraction of trace elements in soils and related materials. *Water, Air and Soil Pollution*. 189:291–333.

Rauret, G. (1998). Extraction procedures for the determination of heavy metals in contaminated soil and sediment. *Talanta*. 46: 449–455.

Reimann, C., de Caritat, P. (1998). *Chemical elements in the environment—factsheets for the geochemist and environmental scientist*. Berlin, Germany7 Springer-Verlag; ISBN 3-540-63670-6.

Reza, R., Singh, G. (2010). Heavy metal contamination and its indexing approach for river water. *International Journal of Environmental Science and Technology*. 7(4): 785-792.

Rodrigues, J.L., Pellizari, V.H., Mueller, R., Baek, K., Jesus, E.D.C., Paula, F.S., Mirza, B., Hamaoui Jr., G.S., Tsai, S.M., Feigl, B., Tiedje, J.M. (2013). Conversion of the Amazon rainforest to agriculture results in biotic homogenization of soil bacterial communities. *Proceedings of the National Academy of Sciences*. 110 (3): 988-993.

Rodríguez-Barroso, M., García-Morales, J., Coello-Oviedo, M., Quiroga-Alonso, J. (2010). An assessment of heavy metal contamination in surface sediment using statistical analysis. *Environmental Monitoring and Assessment*. 163 (1): 489–501.

Rodríguez-Barroso, M., García-Morales, J., Coello-Oviedo, M., Quiroga-Alonso, J. (2010). An assessment of heavy metal contamination in surface sediment using statistical analysis. *Environmental Monitoring and Assessment*. 163(1): 489–501.

Rodriguez, R.R., Basta, N. (1999). An in vitro gastrointestinal method to estimate bioavailable arsenic in contaminated soils and solid media. *Environmental Science and Technology*. 33:642–649

Rohasliney, H., Tan, H.S., Noor Zuhartini, Md., M., Tan, P.Y. (2014). Determination of Heavy Metal Levels in Fishes from the Lower Reach of the Kelantan River, Kelantan, Malaysia. Tropical Life Science Research. 25(2): 21–39

Rossi, A., Poverini, R., Di Lullo, G., Modesti, A., Modica, A. Scarino, M.L. (1996). Heavy metal toxicity following apical and basolateral exposure in the human intestinal cell line Caco- 2. *Toxicology in vitro*. 10(1): 27-36.

Ruby, M.V., Schoof, R., Brattin, W., Goldade, M., Post, G., Harnois, M., Mosby, D.E., Casteel, S.W., Berti, W., Carpenter, M., Edwards, D., Cragin, D., Chappell, W. (1999). Advances in evaluating the oral bioavailability of inorganics in soil for use in human health risk assessment. *Environmental Science and Technology*. 33: 3697–3705

Ruby, M.V., Davis, A., Kempton, J.H., Drexler, J.W., Bergstrom, P.D. (1992). Lead bioavailability: dissolution kinetics under simulated gastric conditions. *Environmental Science and Technology*. 26:1242–1248

Ruby, M.V., Davis, A., Schoof, R., Eberle, S., Sellstone, C.M. (1996). Estimation of lead and arsenic bioavailability using a physiologically based extraction test. *Environmental Science and Technology*. 30:422–430

Sadeghi, S.H.R., Harchegani, M., Younesi, H.A. (2012). Suspended sediment concentration and particle size distribution, and their relationship with heavy metal content. *Journal Earth System Science*. 121:63–71

Saim, N., Osman, R., Spian, D. R. S. A., Jaafar, M. Z., Juahir, H., Abdullah, M. P. A. B., Ghani, F. (2009). Chemometric approach to validating faecal sterols as source tracer for faecal contamination in water. *Water research*. 43(20): 5023-5030.

Samir, M., Nasr, N., Soliman, F., Mohammed, A., Khairy, Mohamed, A., Okbah. (2015). Metals bioavailability in surface sediments off Nile delta, Egypt: Application of acid leachable metals and sequential extraction techniques. *Environmental Monitoring and Assessment*. 187: 312

Santhi, V. A., Mustafa, A. M. (2013). Assessment of Organochlorine Pesticides and Plasticisers in the Selangor River Basin and Possible Pollution Sources. *Environment Monitoring Assessment*. 185 (2), 1541–1554.

Santos Bermejo, C., Beltrán, R., Gómez Ariza, L. (2003). Spatial variations of heavy metals contamination in sediments from Odiel River (Southwest Spain). *Environmental International*. 29: 69–77

Saeedi, M., Li, L.Y., Karbassi, A.R., Zanjani, A.J. (2013). Sorbed metals fractionation and risk assessment of release in river sediment and particulate matter. *Environmental Monitoring Assessment*. 185: 1737–54

Sarmani, S. (1989). The determination of heavy metals in water, suspended materials and sediments from Langat River, Malaysia. *Hydrobiologia*. 176/177: 233-238.

Samloff, I.M., O'Dell, C. (1985). Inhibition of peptic activity by sucralfate. *American Journal of Medicine.* 79(2):15–18

Sankar, T.V., Zynudheen, A.A., Anandan, P.G., Viswanathan, N.P.G. (2006). Distribution of organochlorine pesticides and heavy metal residues in fish and shellfish from Calicutregion, Kerala, India. *Chemosphere*. 65:583–590.

Schenkels, L.C.P.M., Veerman, E.C.I., Amerongen, A.V.N. (1995). Biochemical composition of human saliva in relation to other mucosal fluids. *Critical Reviews in Oral Biology and Medicine.* 6(2):161–175

Selvaraj, K, Ram Mohan, V., Szefer, P. (2004). Evaluation of metal contamination in coastal sediments of the Bay of Bengal, India: geochemical and statistical approaches. *Marine Pollution Bulletin*. 49(3):174–185.

Senesi, G.S., Baldassarre, G., Senesi, N., Radina, B. (1999). Trace element inputs into soils by anthropogenic activities and implications for human health. *Chemosphere*. 39(2):343–377.

Sevcikova, M., Modra, H., Slaninova, A., Svobodova, Z. (2011). Metals as a cause of oxidative stress in fish: a review. *Veterinarni Medicina*. 11: 537-546

Sekhar, K.C., Chary, N.S., Kamala, C.T., Raj, D.S.S., Rao, A.S. (2004). Fractionation studies and bioaccumulation of sediment-bound heavy metals in Kolleru lake by edible fish. *Environmental International*. 29: 1001-1008.

Shafie, A., Ahmad, A., Nadzhratul P. (2013). Influential factors on the levels of cation exchange capacity in sediment at Bernam river. Arabian Journal of Geosciences. 6 (8): 3049–3058

Shaari, H., Siti, N., Khawar, S., Joseph, B., Yuzwan, M. (2015). Spatial Distribution of Selected Heavy Metals in Surface Sediments of the EEZ of the East Coast of Peninsular Malaysia. International Journal of Oceanography. 10

Shazili,N. A. M., Rashid, M. K. A., Husain, M. L., Nordin, A., Ali, S.(1999a). Trace metals in the surface sediments of the South China Sea, Area I: Gulf of Thailand and the East Coast of Peninsular Malaysia. pp. 73–85. In: *Proceedings of the First Technical Seminar on Marine Fishery Resources Survey in the South China Sea Area I*: Gulf of Thailand and East Coast of Peninsular Malaysia. (1997). November. 24–26 Southeast Asian Fisheries Development Center. Samutprakan. Thailand.

Shazili, N. A. M., Rashid, M. K. A., Husain, M. L.,Yaakob, R. (1999b). Trace metals in surface sediment of the South China Sea AreaII: Sarawak, Sabah and Brunei. 46–155. In: *Proceedings of the Second Technical Seminar on Marine Fishery Resources Survey in the South China Sea Area II: Sarawak, Sabah and Brunei Darussalam 1998 December 14–15*. Southeast Asian Fisheries Development Center. Samutprakan. Thailand.

Sin, S.N., Chua, H., Lo, W., Ng, L.M. (2001). Assessment of heavy metal cations in sediments of Shing Mun River, Hong Kong. *Environmental International*. 26: 297–301.

Singh. M. D., Singh, K., Malik, A. (2005). Studies on distribution and fractionation of heavy metals in Gomti river sediments a tributary of the Ganges, India. *Journal of Hydrology*. 312:14-27.

Sow, Y., Ismail, A., Zulkifli, Z. (2013). An assessment of heavy metal bioaccumulation in Asian swamp eel, Monopterus albus, during plowing stages of a paddy cycle. *Bulletin of Environmental Contamination and Toxicology*. 1-7

Spisto, G. (1989). *The chemistry of soils*. (p. 277). New York (NY): Oxford University Press.

Srebotnjak, T., Carr, G., de Sherbinin, A., Rickwood, C. (2012). A global water quality index and hot-deck imputation of missing data. *Ecology Indicator*. 17: 108-119.

Stacey, S., G. Merrington, McLaughlin, M.J. (2001). The effect of aging biosolids on the availability of cadmium and zinc in soil. *European Journal of Soil Science*. 52:313–321.

Stanković, S., Jović, M. (2012). Health risks of heavy metals in the Mediterranean mussels as seafood. Environ. Chemistry Letters. 10: 119-130.

Strom, D., Simpson, S.L., Batley, G.E., Jolley, D.F. (2011). The influence of sediment particle size and organic carbon on toxicity of copper to benthic invertebrates in oxic/suboxic surface sediments. *Environmental Toxicology and Chemistry*. 30:1599–610

Su, S., Xiao, R., Mi, X., Xu, X., Zhang, Z., Wu, J. (2013). Spatial determinants of hazardous chemicals in surface water of Qiantang River. *China Ecology Indicator*. 24: 375–381.

Sun, Y.B., Zhou, Q.X., Xie, X.K., Liu, R. (2010). Spatial sources and risk assessment of heavy metal contamination of urban soils in typical regions of Shenyang, China. *Journal of Hazardous Materials*. 174:455–462

Sundaray, S.K., Nayak, B.B.,Lin, S., Bhatta, D. (2011). Geochemical speciation and risk assessment of heavy metals in the river estuarine sediments a case study: Mahanadi basin, India. *Journal Hazardous Materail*. 186: 1837–1846.

Sungur, A., Soylak, M., Özcan, H. (2016). Chemical fractionation, mobility and environmental impacts of heavy metals in greenhouse soils from C¸ anakkale, Turkey. *Environmental Earth Sciences*. 75:334

Superville, P. J., Prygiel, E., Magnier, A., Lesven, L., Gao, Y., Baeyens, W. (2014). Daily variations of Zn and Pb concentrations in the Deûle River in relation to the resuspension of heavily polluted sediments. *Science of Total Environment*. 470–471: 600–7.

Sutherland, R. A. (2000). Bed Sediment-Associated Trace Metals in An Urban Stream, Oahu, Hawaii. Environmental Geology 39 (6):611-627.

Swyngedouw, C., Crepin, J.M. (2008). *Sampling Methods for Site Characterization*. In B. de Vivo, H.E. Belkin, A. Lima Eds Environmental Geochemistry: Site Characterization, Data Analysis and Case Histories. Elsevier, Oxford, 13-26.

Tan, Q., Wang, W. (2008). The influences of ambient and body calcium on cadmium and zinc accumulation in Daphnia magna. *Environmental Toxicology and Chemistry*. 27 (7):1605-13.

Taylor, S. (1964). Abundance of chemical elements in the continental crust: a new table. *Geochimica et Cosmochimica Acta*. 28: 1273-1285.

Taweel, A., Shuhaimi-Othman, M., Ahmad, A.K. (2013). Assessment of heavy metals in tilapia fish (*Oreochromis niloticus*) from the Langat River and Engineering Lake in Bangi, Malaysia, and evaluation of the health risk from tilapia consumption. *Ecotoxicology and Environment safety* .45–51.

Tessier, A., Campbell, P.G.C. (1987). Partitioning of trace metals in sediments: relationships with bioavailability. *Hydrobiologia*.149: 43–52.

Tessier, A., Campbell, P.G.C., Auclair, J.C., Bisson, M. (1984). Relationships between the partitioning of trace metals in sediments and their accumulation in the tissues of the freshwater mollusc Elliptio complanata in a mining area. *Canadian Journal of Fisheries and Aquatic Science*. 41:1463–72.

Thompson, B. Lowe, S. (2004). Assessment of macrobenthos response to sediment contamination in the San Francisco estuary, California, USA. *Environmental Toxicology and Chemistry*. 23: 2178–2187

Topcuoglu, S., Kirbasoglu, C., Gungor, N. (2002). Heavy metals in organisms and sediments from Turkish coast of the Black Sea, 1997–1998. *Environment International*. 27 (7): 521– 526.

Torres-Escribano, S., Ruiz, A., Barrios, L., Vélez, D., Montoro, R. (2011a). Influence of mercury bioaccessibility on exposure assessment associated with consumption of cooked predatory fish in Spain. *Journal Agriculture and Food Chemistry*. 91: 981–986.

Torres-Escribano, S., Denis, S., Blanquet-Diot, S., Calatayud, M., Barrios, L., Vélez, D., Alric, M., Montoro, R. (2011b). Comparison of a static and a dynamic in vitro model to estimate the bioaccessibility of As, Cd, Pb and Hg from food reference materials Fucus sp. (IAEA-140/TM) and Lobster hepatopancreas (TORT-2). *Science of Total Environment*. 409: 604–611.

Tomlinson, D.C., Wilson, J.G., Harris, C.R., Jeffrey, D.W. (1980). Problems in the assessment of heavy metals in estuaries and the formation pollution index. *Helgoland Marine Research*. 33: 566-575.

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.

Tuzen, M. (2003). Determination of trace metals in the River Yesilirmak sediments in Tokat, turkey using sequential extraction procedure. *Microchemical Journal*. 74: 105–110.

USEPA (2000). *Risk-based concentration table*. Philadelphia PA: United States Environmental Protection Agency, Washington D.C.

USEPA. (2006). *USEPA region III risk-based concentration table*: Technical background information. Unites States Environmental Protection Agency

USEPA. (2013). *Reference dose (RfD)*: Description and use in health risk assessments, Background Document 1A, Integrated risk information system (IRIS); United States Environmental Protection Agency: Washington, DC, 15 March 2013; http://www epa.gov/iris/rfd.htm

USEPA. (2001). *Water quality criterion for the protection of human health: methylmercury*. Office of Science and Technology and Office of Water, Washington, DC

USEPA (United States Environmental Protection Agency). (2012). *EPA Region III Risk-Based Concentration (RBC) Table 2008 Region III*. 1650 Arch Street, Philadelphia, Pennsylvania 19103

Van Den Berg, G.A., Loch, J.P.G., Van Der Heijdt, L.M., Zwolsman, J .J. G. (1999). Mobilisation of heavy metals in contaminated sediments in the river Meuse, The Netherlands. *Water Air Soil Pollution*. 166:567–586.

Van Veen, M.P. (2001). *CONSEXPO 3.0 – Consumer exposure and uptake models*. RIVM report no. 612810011, Bilthoven, The Netherlands: National Institute for Public Health and the Environment. Available at http://www.rivm.nl/bibliotheek/ rapporten/612810011.pdf.

Varol, M. (2011). Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques. *Journal of Hazardous Materials*. 195:355–364

Vega, M., Pardo, R., Barrado, E., Debán, L. (1998). Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis. *Water research*. 32(12), 3581-3592.

Vicente-Martorell, J.J., Galindo-Riano, M.D., Garcia-Vargas, M. (2009). Bioavailability of heavy metals monitoring water, sediment and fish species from a polluted estuary. *Journal of Hazardous Materials*. 162:823–836

Wallace, W.G., Lopez, G.R., Levinton, J.S. (1998) Cadmium resistance in an oligochaete and its effect on cadmium trophic transfer to an omnivorous shrimp. *Marine Ecology Progress Series*. 172: 225–237.

Wallace, W.G., Luoma, S.N. (2003). Subcellular compartmentalization of Cd and Zn in two bivalves. II. Significance of trophically available metal (TAM). *Marine Ecology Progress Series* (in press)

Wan, Y, Ahmad, Z., Mohamad, Z. (2012). Spatial Variability of Metals in Surface Water and Sediment in the Langat River and Geochemical Factors That Influence Their Water-sediment Interactions, *The Scientific World Journal*.14

Wang, Q., Li, Y., Klassen, W. (2005). Determination of Cation Exchange Capacity on Low to Highly Calcareous Soils. *Communications in Soil Science and Plant Analysis*. 36: 1479–1498

Wang, S., Qin, Y. (2005). Correlation between magnetic susceptibility and heavy metals in urban top soil: a case study from the city of Xuzhou, China. *Environmental Geology*. 49: 10-18.

Wang, W., Qin, Y., Song, D.,Wang, K. (2008). Column leaching of coal and its combustion residues, Shizuishan, China. *International Joiurnal of Coal Geology*. 75(2):81–87

Wang, W.X. Rainbow, P.S. (2008). Comparative approaches to understand metal bioaccumulation in aquatic animals. *Comparative Biochemistry and Physiology – Part C*. 148:315–323

Wang, H.Y., Lu, S.G. (2011). Spatial distribution, source identification and affecting factors of heavy metals contamination in urban–suburban soils of Lishui city, China. *Environmental Earth Sciences*. 64:1921–1929.

Wang, W.X., Fisher, N.S. (1999). Delineating metal accumulation pathways for marine invertebrates. *Science of Total Environment*. 237/238: 459−472

Wedepohl, K.H. (1995). The composition of the continental crust. *Geochimica et Cosmochimica* Acta.59(7): 1217-1232

Wenning, R.J., Ingersoll. C.G. (2002). *Summary of the SETAC Pellston workshop on use of sediment quality guidelines and related tools for the assessment of contaminated sediments*; 17-22 August 2002, Fairmont, MT. Society of Environmental Toxicology and Chemistry: Pensacola. FL. 44 pp.

Whitcomb, D. C., Lowe, M. E. (2007). Human pancreatic digestive enzymes. *Digestive Diseases and Sciences*. 52(1):1–17.

Williams, C.R., J.J., Leaner, V.S., Somerset, J.M., Nel. (2011). Mercury concentrations at a historically mercury-contaminated site in KwaZulu-Natal (South Africa). *Environmental Science and Pollution Research.* 18(7): 1079–89.

Woitke, P., Wellmitz, J., Helm, D., Kube, P., Lepom, P., Litheraty, P. (2003). Analysis and assessment of heavy metal pollution in suspended solids and sediments of the river Danube. *Chemosphere*. 51: 633–642.

Wood, P.J., Armitage, P.D. (1997). Biological effects of fine sediment in the lotic environment. *Environmental Management*. 21:203–17.

Wood, J.M. (1974). Biological cycles for toxic elements in the environment. *Science*. 183(4129): 1049-1052.

Won-Wook, C., Chen, K.Y. (1976). Associations of chlorinated hydrocarbons with fine particles and humic substances in nearshore surficial sediments. *Environmental Science and Technology*. 10: 782–6

WHO (World Health Organization). (1990). *International programme on chemical safety Geneva*: environmental health criteria.

World Health Organization (WHO). (1985). *Guidelines for drinking water quality (ii)*: Health criteria and supporting information. Geneva: WHO, 130.

Wragg, J., Cave, M., Basta, N., Brandon, E., Casteel, S., Denys, S., Gron, C., Oomen, A., Reimer, K., Tack, K., Wiele, T.V. (2011). An inter-laboratory trial of the unified BARGE bioaccessibility method for arsenic, cadmium and lead in soil. *Science of Total Environment.* 409:4016–4030.

Wu, M.-L., Wang, Y.-S., Sun, C.-C., Wang, H., Dong, J.-D., Yin, J.-P. Han, S.-H. (2010). Identification of coastal water quality by statistical analysis methods in Daya Bay, South China Sea. *Marine Pollution Bulletin*. 60(6): 852-860.

Xiaodong, Z., Fen, Y., Chaoyang, W. (2015). Factors influencing the heavy metal bioaccessibility in soils were site dependent from different geographical locations. *Environment Science and Pollution Research*. 22: 13939–13949

Xiaodong, Z., Fen, Y., Chaoyang, W. (2016). Bioaccessibility of heavy metals in soils cannot be predicted by a single model in two adjacent areas. *Environmental Geochemical and Health*. 38: 233–241

Yap, C.K. Ismail, A. Tan, S.G. Omar, H. (2002a). Concentrations of Cu and Pb in the offshore and intertidal sediments of the west coast of Peninsular Malaysia. *Environment International*. (28): 467–479.

Yap, C. K., Ismail, A., Tan, S. G., Omar, H. (2002b). 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.

Yap, S. Y., Ong, H. T. (1990). The effects of agrochemicals on an aquatic ecosystem: A case study from the Krian River Basin, Malaysia. *The Environmentalist* 10 (3): 189–202.

Yap, C.K., Ismail, A., Tan, S.G. (2003). Background concentrations of Cd, Cu, Pb and Zn in the green-lipped mussel Perna viridis (Linnaeus) from Peninsular Malaysia. *Marine Pollution Bulletin*. 46, 1043- 1048.

Yap,. C K., Choh, M. S., Edward, F. B., Ismail, A., Tan, S. G. (2006). Comparison of heavy metal concentrations in surface sediment of Tajung Piai wetland with other sites receiving anthropogenic inputs along the southwestern coast of Peninsular Malaysia, *Wetland Science*. 4 (1): 48–57

Yang, L. S., Zhang, X. W., Li, Y. H., Li, H. R., Wang, Y. Wang, W. Y. (2012). Bioaccessibility and Risk Assessment of Cadmium from Uncooked rice using an in vitro digestion model. *Biological Trace Element Research*. 145 (1): 81-86.

Yi, Y., Yang, Z., Zhang, S. (2011). Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River basin. *Environment Pollution*. 159: 2575–2585.

Yobouet, Y.A., Adouby, K., Trokourey, A., Yao, B. (2010). Cadmium, copper, lead and zinc speciation in contaminated soils. *International Journal of Engineering Science and Technology*. 2(5):802–812

Yuan, G.L., Liu, C., Chen, L., Yang, Z. (2011). Inputting history of heavy metals into the inland lake recorded in sediment profiles: Poyang Lake in China. *Journal Hazardous Materail*. 185: 336–345.

Yu, R., Yuan, X., Zhao, Y., Hu, G., Tu, X. (2008). Heavy metal pollution in intertidal sediments from Quanzhou Bay, China. *Journal of Environment Science.* 20: 664-669.

Yusof, A.M., Mahat, M.N., Omar, N., Wood, A.K.H. (2001). Water quality studies in an aquatic environment of disused tin-mining pools and in drinking water. *Ecological Engineering*. 16(3): 405-414.

Zhang, L., Ye, X., Feng, H., Jing, Y., Ouyang, T., Yu, X., Liang, R., Gao, C., Chen, W. (2007). Heavy metal contamination in western Xiamen Bay sediments and its vicinity, China. *Marine Pollution Bulletin*. 54: 974–982.

Zhao, H., Li, X., Wang, X., Tian, D. (2010). Grain size distribution of road-deposited sediment and its contribution to heavy metal pollution in urban runoff in Beijing, China. *Journal of Hazardous Materials*. 183:203–10

Zhao, S., Feng, C., Wang, D., Liu, Y., Shen, Z. (2013). Salinity increases the mobility of Cd, Cu, Mn, and Pb in the sediments of Yangtze Estuary: relative role of sediments' properties and metal speciation. *Chemosphere*. 91: 977-984.

Zhang, X.B., Ohta, Y. (1991). In vitro binding of mutagenic pyrolyzates to lactic acid bacterial cells human gastric juice. *Journal of Dairy Science*. 74(3):752–757

Zhang, L., Blanchard, P., Johnson, D. (2012). Assessment of modeled mercury dry deposition over the Great Lakes Region. *Environment Pollution.* 161: 272-283

Zhang, C., Yu, Z.G., Zeng, G.M., Jiang, M., Yang, Z.Z., Cui, F., Zhu, M.Y., Shen, L.Q., Hu, L. (2014). Effects of sediment geochemical properties on heavy metal bioavailability. Environment International. 73: 270-281.

Zulkifli, S.Z., Mohamat-Yusuff, F., Arai, T., Ismail, A., N. Miyazaki. (2010). An assessment of selected trace elements in intertidal surface sediments collected from the Peninsular Malaysia. *Environmental Monitoring and Assessment*, 169(1-4): 457-472.