



UNIVERSITI PUTRA MALAYSIA

***HUMAN HEALTH, ECOLOGICAL RISK AND HEAVY METAL
POLLUTION ASSESSMENT IN LANGAT RIVER BY
TRANSPLANTATION OF *Corbicula javanica****

WONG KOE WEI

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By
WONG KOE WEI

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

July 2016

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

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Chairman: Associate Professor Yap Chee Kong, PhD

Faculty: Science

Heavy metal pollution has become a major concern nowadays because these pollutants are not biodegradable and may be biomagnified and bioaccumulated and could potentially be harmful to biota over certain level. Therefore, assessment of the potential risks of heavy metal pollutions to ecosystem and human health are necessary. The freshwater bivalve clam *Corbicula javanica* (Family: Cyrenidae) is abundant, easily identifiable, sedentary life style and tolerant to the increased bioavailable heavy metals in the environment, besides having large enough for analysis and the potential to reflect bioavailability. Therefore, it is suitable to be a good biomonitor. The first objective of this study was to assess the heavy metal pollution in the Langat River by transplantation of *C. javanica* from upstream pristine site to downstream polluted sites of the river. The freshwater clams *C. javanica* was transplanted from upstream Pangsun (PS) to Semenyih (SM), Dusun Tua (DT) and Kajang (KJ). Heavy metal in *C. javanica* and surface sediments was analysed by using FAAS for Cu, Fe, Ni, Pb and Zn, and ICP-MS for As, Co, Cd, Cr and Mn. Besides, the geochemical speciation of the heavy metals in surface sediments were analysed by using sequential extraction technique (SET). The second objective was to determine the ecological risk assessment of heavy metals in the surface sediments of the Langat River by comparison with sediment quality guidelines (SQGs), and calculations of geoaccumulation index (I_{geo}), enrichment factor (EF), potential risk for individual metal (Er), potential ecological risk index (PERI) and combined pollution index (CPI). Lastly, the third determine the human health risk assessment via the consumption the clam collected from the transplantation study in the Langat River by comparison with food safety guidelines and calculation of estimated daily intake (EDI) and target hazard quotients (THQ).

From the results, the higher concentration of Co, Cr, Fe, Mn, Ni and Zn in the sediment of PS, are associated with the periodic discharge of dam impoundment of Pangsun Dam. Higher As and Cd in SM, are related to the use of phosphate fertilizers and pesticides in the oil palm plantation nearby the particular site. Higher Pb, and Cu were KJ, are associated to the domestic waste emission in urban area. The clams' Total Soft Tissue (TST) has the ability to accumulate Fe, Zn, Cu, Mn, Co, Cr, As and Cd and the shell has the ability to accumulate higher level of Pb and Ni. The correlation analysis revealed that 8 metals (As, Co, Cr, Fe, Mn, Ni, Pb and Zn) in TST while 5 metals (As, Cd, Cr, Fe and Mn) in shell have positively and significantly correlation

with respective metal concentration in sediment, indicating the clams is a good biomonitor of the metal levels. Geo-chemical fractions extraction revealed that As, Cr, Fe, Mn, Ni and Pb in the sediment were dominated by the resistant (R) fraction suggested that it may be less potentially bioavailable and be poorly mobilized. However, care should be taken for As since its concentrations are higher than previous studies. Zn and Cd were found to be abundant in Acid Reducible fraction (AR) in all sites, this indicated that these two metals were highly mobilized with potential environmental consequences. However, the impact might be limited since the concentration of Zn and Cd are not higher than previous studies. The difference in geochemical fraction distribution in Co indicates four sites may have different source. Cu in KJ are abundant in oxidizable-organic (OO) fraction. This indicates that the Cu in KJ were organic in nature and it is easily absorbed. Various geochemical indexes for a single metal pollutant (I_{geo} , EF, C_f , and Er) all agreed that Cd, Co, Cr, Cu, Fe, Mn, Ni and Zn are not likely to cause adverse effect to the river ecosystem, but As and Pb could pose a potential ecological risk to the river ecosystem. When all metals were accounted, all indexes (C_d , CPI and PERI) showed that overall metal concentrations in Langat River are still within safe limit. The values of EDI of *C. javanica* were found to be all lower than oral reference dose (RfD) guidelines for all metals. Furthermore, the calculated THQ and total THQ were found to be less than 1. Therefore, there will be no non-carcinogenic human health risk on both average and high level consumption of total soft tissue of *C. javanica*.

The finding of present study indicated that TST and shell of *C. javanica* are good biomonitors of heavy metal bioavailability. We deduced that the elevated heavy metals of PS, SM and KJ are associated with dam discharge, use of fertilizers or pesticides and domestic waste discharge respectively. Ecological risk assessment indicated that most of the metals are unlikely to cause adverse effects except As and Pb. Human health risk assessment indicated that prolonged consumption of *C. javanica* in this river are safe.

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

**PENILAIAN RISIKO KESIHATAN MANUSIA, EKOLOGI DAN
PENCEMARAN LOGAM SURIH DI SUNGAI LANGAT DENGAN
TRANSPLANTASI *Corbicula javanica***

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Pencemaran logam surih menjadi kebimbangan utama sekarang sebab pencemar ini tidak terbiodegradasi, dapat biomagnifikasi dan bioakumulasi serta berpotensi membahayakan unsur biota dalam ekosistem lepas tahap tertentu. Oleh itu, penilaian potensi risiko kepada ekosistem dan juga kesihatan manusia disebabkan pencemaran logam surih adalah diperlukan. Kerang air tawar *Corbicula javanica* (Famili: Cyrenidae) berpotensi digunakan sebagai bio-pemantau kerana populasinya yang banyak, mudah untuk dikenal pasti, cukup besar untuk dianalisis, gaya hidup tidak aktif dan berupaya untuk bertoleransi dengan peningkatan logam berat yang bio-tersedia di alam sekitar, selain mempunyai cukup besar untuk analisis logam dan juga berpotensi untuk mencerminkan bio-kesediaan logam surih. Objektif pertama kajian ini adalah untuk menilai pencemaran logam berat di Sungai Langat melalui pemindahan *C. javanica* dari tapak bersih di hulu (Pangsun, PS) ke hilir sungai yang tercemar [Semenyih (SM), Dusun Tua (DT) dan Kajang (KJ)]. Kaedah FAAS (untuk Cu, Fe, Ni, Pb dan Zn) dan ICP-MS (As, Co, Cd, Cr dan Mn) untuk telah digunakan untuk menganalisis kandungan logam surih di dalam *C. javanica* dan juga sedimen permukaan sungai. Fraksi geokimia logam surih dalam sedimen juga dianalisis dengan *Sequential Extraction Technique* (SET). Objektif kedua kajian ini adalah untuk menjalankan penilaian risiko ekologi logam surih dalam sedimen permukaan Sungai Langat dengan perbandingan dengan panduan kualiti sedimen (SQGs) dan pengiraan *geoaccumulation index* (I_{geo}), *enrichment factor* (EF), *potential risk for individual metal* (Er), *potential ecological risk index* (PERI) dan *combined pollution index* (CPI). Akhirnya, objektif ketiga kajian ini adalah untuk menjalankan penilaian risiko kesihatan manusia melalui pemakanan kerang yang dikumpulkan dari Sungai Langat dalam kajian transplantasi ini. Penilaian risiko kesihatan manusia ini dilakukan dengan perbandingan dengan garis panduan kesihatan makanan dan pengiraan indeks estimated daily intake (EDI) dan target hazard quotients (THQ).

Dari keputusan, sedimen dari PS yang mengandungi Co, Cr, Fe, Mn, Ni dan Zn yang paling tinggi adalah berkaitan dengan pelepasan berkala air takungan empangan Pangsun. As dan Cd didapati tinggi di SM. Ia adalah berkaitan dengan penggunaan baja fosfat dan racun perosak di tapak penanaman kelapa sawit. Manakala, pelepasan sisa domestik menyebabkan peningkatan Pb dan Cu di KJ. Analisis kolerasi menunjukkan kolerasi signifikan ($p < 0.05$) dan positif di antara 8 elemen logam di jumlah tisu lembut (TST) (As, Co, Cr, Fe, Mn, Ni, Pb dan Zn) dan 5 elemen logam (As,

Cd, Cr, Fe dan Mn) di cangkerang dengan kandungan logam di sedimen. Ini menunjukkan bahawa kerang ini adalah agen biomonitor untuk pencemaran logam surih yang baik. Pengekstrakan fraksi geokimia menunjukkan dominasi fraksi *Resistant* (R) untuk As, Cr, Fe, Mn, Ni and Pb. Ini menunjukkan logam-logam tersebut adalah sukar dimobilisasi dan kurang bioavailabiliti. Namun, perhatian masih perlu dibagi kepada As memandangkan kandungan As di sedimen lebih tinggi berbanding dengan kajian dahulu. Kandungan Zn dan Cd di semua tapak tertumpu di fraksi *Acid Reducible* (AR). Ini menunjukkan kedua-dua logam ini mempunyai mobiliti yang tinggi dan berpotensi mengakibatkan kesan negatif alam sekitar. Tetapi, kesan mobiliti tinggi logam tersebut mungkin terhad kerana kandungan Zn dan Cd bukanlah lebih tinggi daripada kajian dahulu. Perbezaan agihan kandungan Co antara fraksi geokimia menunjukkan Co di empat tapak mungkin berasal dari sumber yang berlainan. Cu di KJ tertumpu di fraksi *oxidizable organic* (OO), menunjukkan kebanyakan logam ini adalah bersifat organik dan senang diserap. Semua indeks-indeks geokimia untuk satu pencemar (I_{geo} , EF, C_f , dan Er) bersetuju bahawa Co, Cr, Cu, Fe, Mn, Ni and Zn tidak akan membawa kesan buruk kepada ekosistem sungai. Indeks-indeks pencemar tergabung (C_d , CPI and PERI) menunjukkan bahawa kandungan logam surih secara keseluruhan adalah dalam had selamat. Nilai EDI untuk *C. javanica* dijumpai lebih rendah daripada garis panduan *oral reference dose* (RfD) untuk semua logam yang dikaji. Tambahan pula, pengiraan THQ dan jumlah THQ menunjukkan nilai kurang daripada 1. Oleh itu, tiada risiko kesihatan manusia bukan karsinogenik akan dialami oleh pengguna tahap sederhana dan tinggi TST *C. javanica*.

Penemuan kajian ini menunjukkan TST dan cangkerang *C. javanica* adalah bio-pemantau yang baik untuk menunjukkan bioavailabiliti logam surih. Kita menyimpulkan bahawa kandungan logam yang tinggi di PS, SM, DT dan KJ adalah berkaitan dengan pelepasan empangan, penggunaan baja dan racun perosak dan pelepasan sisa domestik. Penilaian risiko ekologi menunjukkan selain daripada As dan Pb, semua logam lain tidak akan menyebabkan kesan buruk kepada ekosistem. Penilaian risiko kesihatan manusia menunjukkan penggunaan kepanjangan *C. javanica* adalah selamat.

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LIST OF ABBREVIATIONS

Zn	Zinc
Cu	Copper
Pb	Lead
Ni	Nickel
Fe	Iron
Mn	Manganese
Co	Cobalt
Cr	Chromium
As	Arsenic
Cd	Cadmium
PS	Pangsun
SM	Semenyih
DT	Dusun Tua
KJ	Kajang
FAAS	Flame Atomic Absorption Spectrometry
ICP-MS	Induced Coupled Plasma-Mass Spectrometry
SET	Sequential Extraction Technique
EFLE	Easily, freely or leachable and exchangeable
PERI	Potential Ecological Risk Index
EDI	Estimated Daily Intakes
CPI	Combined Pollution Index
THQ	Target Hazard Quotient
RfD	Oral reference dose
CI	Condition index
DO	Dissolved oxygen
Cond	Electrical conductivity
ALM	Average level mollusc consumer
HLM	High level mollusc consumer
EF	Enrichment factor
CV	Coefficient of variation

CHAPTER 1

INTRODUCTION

Heavy metals exist naturally in large variations in concentration. Nowadays however, due to rapid development and industrialization, anthropogenic heavy metals introduced to the ecosystem causing heavy metal pollution. There are several sources including the periodic discharge of river dam impoundment, agricultural activities and discharge of domestic wastes are identified as a possible source of anthropogenic heavy metals (Wang *et al.*, 2015; Fuge, 2013). Much of the heavy metals with industrial significance have known to toxic not only to human beings but to other organisms. The bioconcentration of certain pollutants including heavy metals may increase significantly through the food chains by the effect of bioaccumulation and biomagnification. The heavy metals as a pollutant are non-degradable in nature, in contrast of organic pollutants that can be degenerated, producing carbon dioxide and water as by-product (Lim *et al.*, 2013; Khan *et al.*, 2004; Gupta *et al.*, 2001). Therefore, it will be wise that heavy metal pollution be constantly monitored. Rapid development has increases the introduction of heavy metal pollutants into the environment. Along with the increasing of the industrial activity across the globe, development of a way of monitoring the pollution level of the environment with the hope of controlling, reducing and ultimately solving the pollution has been crucial to any nations in the world.

Malaysia underwent mass industrialization since independence. the rapid modernization in Malaysia has caused the degradation of river quality, depletion of river resources, public health risks and loss of river biodiversity due to artificial alteration of river environment. The river ecosystem are blessed with immense biodiversity, biological productivity and high assesibility. It is one of the crucial natural asset to human society. The high economic value of a clean river is relied on their suitability for aquaculture activities, food source, recreation, ecotourism and as a genetic resource (Lim *et al.*, 2013). Therefore, in order to maintain the health of such valueable asset, constant monitoring of the river ecosystem health and level of potential pollutions are a crucial part of a broader effort of ecosystem preservation and conservation.

The utilization of aquatic organism to monitor trace metal abundance and bioavailability has been well established (Phillips *et al.*, 1988). Various aquatic organisms existing in aquatic environment can be potentially useful as biomonitor of heavy metal pollution, including fishes, molluscs, aquatic plants and algae (Torres *et al.*, 2008). The idea of using the molluscs as biomonitor to monitor heavy metal pollution was proposed by Goldberg (1975) as Mussel Watch Program. Its method has since become a common practice in biological monitoring or biomonitoring of the heavy metal pollution (Yap *et al.* 2007). The Goldberg's (1975) study has also established *Perna viridis* as a biomonitor species in various place in the Asia-Pacific coastal region (Yap, 2012). But the use of *Perna viridis* are limited to coastal area. Therefore, there is a necessity to established a freshwater based biomonitor in order to implement Goldberg (1975) concept of biomonitoring in inland freshwater context.

The concept of large scale biomonitoring was proposed by Goldberg *et al.* (1978) as 'Mussel Watch' program in order to examine the spatial and temporal trends in

chemical pollution in estuarine and coastal environment. This program was used bivalves as sentinel organism that is capable of sensing trends in the concentration of numerous marine pollutants (Goldberg *et al.*, 1978; Zhou *et al.*, 2008). Due to their ability of mussels or other bivalves to accumulate pollutants from their living habitat in quantities that are many times higher than the background levels, they are a popular choice for biomonitoring of aquatic heavy metal pollution (Cheng and Yap, 2015). Molluscs also exhibit greater spatial sensitivity to heavy metal concentration in the environment, therefore it can be considered as a more reliable method to point out the sources of heavy metal in the environment that are bioavailable (Goldberg *et al.*, 1978; Koide *et al.*, 1982; Thomson *et al.*, 1984; Hamed and Emara, 2006). The heavy metal uptake and accumulation into the tissue of the molluscs are in proportional to the degree of environmental pollution signifies their ability as biomonitor of heavy metal pollution (Goldberg *et al.*, 1983; Elder and Matraw, 1984; Bu-Olayan and Subrahmanyam, 1997; Yap, 2012).

In Malaysia, biomonitoring works and studies of the background levels of heavy metals were mainly focused on marine mussels and intertidal snail that can be widely found in the on the coastal and intertidal area in Peninsular Malaysia (Cheng and Yap, 2015; Yap *et al.*, 2012, 2002). For better monitoring of the biomonitor candidate for freshwater region located within continent should be established. Freshwater clam *Corbicula javanica* were chosen due to its availability at the site of study. Although *C. javanica*'s genus sibling, *Corbicula fluminea* were well studies as a biomonitor in various countries due to its invasive nature, there are lack of information about *C. javanica* in Malaysia, and there is no literature from this region ventured the possibility to use *C. javanica* as a potential biomonitor of heavy metal pollution in Malaysia, nor in other countries within South East Asia. Being a genus sibling of a well-established biomonitor, it has potential to be a potential biomonitor for heavy metal pollution in this region. Since *C. javanica* is not an invasive species like *C. fluminea*, there were some places around study area which *C. javanica* cannot be found, therefore transplantation of the *C. javanica* from sites where this species can be found to other sites, were done to cope with the uneven distribution of this species.

Comparing the heavy metal concentration between river surface sediment and the hard and soft tissue of *C. javanica* are crucial. The potential risk of the heavy metal poses to both ecosystem and human beings in both sediments and edible tissue of *C. javanica* are equally important. Therefore, ecological risk and human health risk assessment were done by calculation of several established indices. Since the main objective of ecotoxicological study are to evaluate the impact of the alteration of environmental chemical and physical properties to ecosystem and human health. The assessment of the risk caused by a pollutant to both ecosystem and human health would be a crucial aspect of ecotoxicology. Ecological risk assessment (ERA) were done in order to assess the ecological impact of heavy metal. Enrichment factors (EF), geo-accumulation index (I_{geo}), potential ecological risk index (PERI) were calculated based on the findings. By these indices, the degree of heavy metal pollution can be determined. Human health risk assessment was done to determine the potential health risks related with trace metal contamination via the consumption of edible parts of the sentinel organism. Human health risk assessment was usually achieved by screening level risk assessment that are usually conducted through consideration of established international dietary guidelines and determination of

estimated daily intake (EDI) and target hazard quotient (THQ) (Cheng and Yap, 2015). The estimated daily intake (EDI) and target hazard quotient (THQ) were calculated to assess the potential impact of the heavy metal concentration to human health based on the amount of consumption.

1.1 Objectives of Study

The main objectives of this study were to:

1. To assess the heavy metal pollution in the Langat River Basin by transplantation of *Corbicula javanica* from upstream pristine site to downstream polluted sites of the river.
2. To determine the ecological risk assessment of heavy metals in the surface sediments of the Langat River.
3. To determine the human health risk assessment via the consumption the clam *C. javanica* collected from the transplantation study in the Langat River.



REFERENCES

- Abdallah M.A.M. (2013). Bioaccumulation of Heavy Metals in Mollusca Species and Assessment of Potential Risks to Human Health. *Bulletin of Environmental Contamination and Toxicology* 90: 552–557.
- Abraham, G.M.S. (2005). *Holocene sediments of Tamaki Estuary: Characterisation and impact of recent human activity on an urban estuary in Auckland, New Zealand*. Ph.D. thesis, University of Auckland, Auckland, New Zealand.
- Abraham, G.M.S. and Parker, R.J. (2008). Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. *Environmental Monitoring and Assessment* 136: 227–238.
- Achard, M., Baudrimont, M., Boudou, A. and Bourdineaud, J.P. (2004). Induction of a multixenobiotic resistance protein (MXR) in the Asiatic clam *Corbicula fluminea* after heavy metals exposure. *Aquatic Toxicology* 67: 347–357.
- Adepoju, M.O. and Adekoya, J.A. (2014). Heavy metal distribution and assessment in stream sediments of River Orle, Southwestern Nigeria. *Arabian Journal of Geosciences* 7: 743–756.
- Akberali, H.B. and Trueman, E.R. (1985). Effects of environmental stress on marine bivalve molluscs. *Advances in Marine Biology* 22: 102-198.
- Akbulut, A. and Akbulut, N.E. (2010). The study of heavy metal pollution and accumulation in water, sediment, and fish tissue in Kızılırmak River Basin in Turkey. *Environmental Monitoring and Assessment* 167: 521-526.
- Al-haidarey, M.J.S., Hassan, F.M., Al-kubaisey, A.R.A. and Douabul, A.A.Z. (2010). The geoaccumulation index of some heavy metals in Al-Hawizeh Marsh, Iraq. *E-Journal of Chemistry* 7: 157–162.
- Ali J.H.; Maschinchian, A., Yoong, Y.K. and Jambari, L. (2002). Use of mollusks as sentinel species for monitoring pollution and indicators for quality of river waters. International Congress on Medicinal and Applied Malacology, Los Banos, Laguna (Philippines), *Food and Agriculture Organization, United Nations*. 21-24 Oct 2002.
- Alloway B.J. (1995). *Heavy metals in soils*, 2nd edn. Blackie Academic & Professional, London.
- Amin, B., Ismail, A., Arshad, A., Yap, C.K. and Kamarudin, M.S. (2009). Gastropod Assemblages as Indicators of Sediment Metal Contamination in Mangroves of Dumai, Sumatra, Indonesia. *Water Air Soil Pollution* 201:9–18.
- Anderson, M.P., Sakuma, H. and Stipp, S.L.S. (2014). Strontium, Nickel, Cadmium, and Lead Substitution into Calcite, Studied by Density Functional Theory. *Langmuir* 30(21): 6129–6133.
- Apichitchat, S. and Jung, K. (2015). Hydrological Simulation for Impact Assessment of Kaeng Sue Ten Dam in Thailand. *KSCE Journal of Civil Engineering* 19(7): 2325-2332

- Arain, S.S., Kazi, T.G., Arain, J.B., Afridi, H.I., Kazi, A.G., Nasreen, S. and Brahman, K.D. (2014). Determination of nickel in blood and serum samples of oropharyngeal cancer patients consumed smokeless tobacco products by cloud point extraction coupled with flame atomic absorption spectrometry. *Environmental Science and Pollution Research* 21: 12017–12027.
- Arini, A., Daffe, G., Gonzalez, P., Feurtet-Mazel, A. and Baudrimont, M. (2014). Detoxification and recovery capacities of *Corbicula fluminea* after an industrial metal contamination (Cd and Zn): A one-year depuration experiment. *Environmental Pollution* 192: 74-82.
- Aris A.Z., Lim W.Y. and Looi L.J. (2015). Natural and Anthropogenic Determinants of Freshwater Ecosystem Deterioration: An Environmental Forensic Study of the Langat River Basin, Malaysia. In *Environmental Management of River Basin Ecosystems*, ed. Ramkumar M.U., Kumaraswamy K., Mohanraj, R., pp. 455-476. Springer International Publishing.
- Aydin, S. and Kucuksezgin, F. (2012). Distribution and chemical speciation of heavy metals in the surficial sediments of the Bakırçay and Gediz Rivers, Eastern Aegean. *Environmental Earth Sciences* 65: 789–803.
- Azrina M.Z., Yap C.K., Rahim Ismail A., Ismail A. and Tan S.G. (2006). Anthropogenic impacts on the distribution and biodiversity of benthic macroinvertebrates and water quality of the Langat River, Peninsular Malaysia. *Ecotoxicology and Environmental Safety* 64: 337–347.
- Badri M.A. and Aston S.R. (1983). Observation on heavy metal geochemical associations in polluted and non-polluted estuarine sediments. *Environment Pollution Series B* 6: 181–93.
- Barlas, N., Akbulut, N. and Aydoğan, M. (2005). Assessment of Heavy Metal Residues in the Sediment and Water Samples of Uluabat Lake, Turkey. *Bulletin of Environmental Contamination and Toxicology* 74: 286-293.
- Beg, M.U., Al-Jandal, N., Al-Subiai, S., Karam, Q., Husain, S., Butt, S.A., Ali, A., Al-Hasan, E., Al-Dufaileej, S. and Al-Husaini, M. (2015). Metallothionein, oxidative stress and trace metals in gills and liver of demersal and pelagic fish species from Kuwait's marine area. *Marine Pollution Bulletin* 100: 662–672.
- Belanger, S. E., Cherry, D. S., and Cairns, J., Jr. (1986). Uptake of Chrysotile Asbestos Fibers Alters Growth and Reproduction of Asiatic Clams, *Canadian Journal of Fisheries and Aquaculture Science* 43: 43-52.
- Berry, A.J. (1974). Freshwater bivalves of peninsular Malaysia with special reference to sex and breeding. *Malayan Nature Journal* 27: 99-110.
- Binelli A. and Provini A. (2003). The PCB pollution of Lake Iseo (N. Italy) and the role of biomagnification in the pelagic food web. *Chemosphere* 53: 143–151.
- Binta Hasan, A., Kabir, S., Selim Reza, A.H.M. and Nazim Zaman, M. (2013). Enrichment factor and geo-accumulation index of trace metals in sediments of the ship breaking area of Sitakund Upazilla (Bhatiairy–Kumira), Chittagong, Bangladesh. *Journal of Geochemical Exploration* 125: 130–137.

- Birth, G. (2003). *A scheme for assessing human impacts on coastal aquatic environments using sediments*, eds., Woodcoffe, C. D., Furness, R. A. Sydney, Australia: Coastal GIS.
- Blake, L. and Goulding, K.W.T. (2002). Effects of atmospheric deposition, soil pH and acidification on heavy metal contents in soils and vegetation of semi-natural ecosystems at Rothamsted Experimental Station, UK. *Plant and Soil* 240: 235–251.
- Britton, J. C. and B. Morton. (1986). Polymorphism in *Corbicula fluminea* (Bivalvia: Corbiculidea) from North America. *Malacological Review* 19: 1-43.
- Buat-Menerd, P. and Chesselt, R. (1979). Variable influence of the atmospheric flux on the trace metal chemistry of oceanic suspended matter. *Earth Planet Science Letter* 42: 398–411.
- Cataldo, D. H., Boltovskoy, D., Stripkeikis, J., and Pose, M. (2001). Condition index and growth rates of field caged *Corbicula fluminea* (Bivalvia) as biomarkers of pollution gradients in the Parana River Delta (Argentina). *Aquatic Ecosystem Health Management* 4: 187–201.
- CCME (Canadian Council of Ministers of the Environment). (1999). *Sediment Quality Guidelines for the Protection of Aquatic life*. (<http://st-ts.ccme.ca/en/index.html>) retrieved 28 June (2015).
- Chen, C.W., Kao, C.M., Chen, C.F., and Dong, C.D. (2007). Distribution and accumulation of metals in sediments of Kaoshiung Harbor, Taiwan. *Chemosphere* 66: 1431–1440.
- Cheng, S. (2003). Heavy metal pollution in China: Origin, pattern and control. *Environmental Science and Pollution Research* 10(3): 192-198.
- Cheng, W.H. and Yap, C.K. (2015). Potential human health risks from toxic metals via mangrove snail consumption and their ecological risk assessments in the habitat sediment from Peninsular Malaysia. *Chemosphere* 135: 156–165.
- Cheng, W.H., (2008). Distribution and concentrations of several heavy metals in snails (*Nerita lineata*) from the intertidal areas of Peninsular Malaysia. Master thesis submitted to the Faculty of Science, Universiti Putra Malaysia.
- Chuan, M.C., Shu, G.Y. and Liu, J.C. (1996). Solubility of heavy metals in a contaminated soil: effects of redox potential and pH. *Water, Air, and Soil Pollution* 90: 543-556.
- Ciobanu G. and Samide, A. (2013). Thermogravimetric analysis of plant water content in relation with heavy metal stress. *Journal of Thermal Analysis and Calorimetry* 111: 1139–1147.
- Copat, C., Arena, G., Fiore, M., Ledda, C., Fallico, R., Sciacca, S. and Ferrante, M. (2013). Heavy metals concentrations in fish and shellfish from eastern Mediterranean Sea: Consumption advisories. *Food and Chemical Toxicology* 53: 33–37.
- Cordell, D., Rosemarin, A., Schröder, J.J., Smit, A.L., (2011). Towards global phosphorus security: a systems framework for phosphorus recovery and reuse options. *Chemosphere* 84: 747-758.

- Costa, P.M., Santos, H.M., Peres, I., Costa, M.H., Alves, S., Capeli-Martinez, J.L. and Diniz, M.S. (2009). Toxicokinetics of Waterborne Trivalent Arsenic in the Freshwater Bivalve *Corbicula fluminea*. *Archives of Environmental Contamination and Toxicology* 57: 338–347.
- Cui, C., Zang, S., Zhai, D. and Wu, B. (2014). Potential ecological risk of heavy metals and metalloid in the sediments of Wuyuer River basin, Heilongjiang Province, China. *Ecotoxicology* 23: 589–600.
- Daniel M.H.B., Montebelo, A.A., Bernades, M.C., Ometto, J.P.H.B., De Camargo, P.B., Krusche, A.V., Ballester M.V., Victoria, R.L. and Martinelli, L.A. (2002). Effects of Urban Sewage on Dissolved Oxygen, Dissolved Inorganic and Organic Carbon, and Electrical Conductivity of Small Streams along a Gradient of Urbanization in the Piracicaba River Basin. *Water, Air, and Soil Pollution* 136(1): 189-206.
- Darmawanti. (2004). Penentuan kadar asam lemak omega-3 dalam *Corbicula javanica*. *Jurnal Farmasi Airlangga*. 4: 82-83.
- Demirel, Z. (2007). Monitoring of Heavy Metal Pollution of Groundwater in a Phreatic Aquifer in Mersin-Turkey. *Environmental Monitoring and Assessment* 132(1): 15-23.
- Department of Justice, Hong Kong. (1997). Food adulteration (metallic contamination) regulation. Cap 132, section 55(1), Schedule 2. Retrieved from:
[http://www.legislation.gov.hk/blis_pdf.nsf/4f0db701c6c25d4a4825755c00352e35/05FECBCB00468409482575EE0042BB5B/\\$FILE/CAP_132V_e_b5.pdf](http://www.legislation.gov.hk/blis_pdf.nsf/4f0db701c6c25d4a4825755c00352e35/05FECBCB00468409482575EE0042BB5B/$FILE/CAP_132V_e_b5.pdf). 12th October 2015.
- Díaz-de Alba, M., Galindo-Riano, M.D., Casanueva-Marengo, M.J., García-Vargas, M., Kosore, C.M., 2011. Assessment of the metal pollution, potential toxicity and speciation of sediment from Algeciras Bay (South of Spain) using chemometric tools. *Journal of Hazardous Materials* 190: 177–187.
- Doherty, F.G. (1990). The Asiatic Clam, *Corbicula* spp., as a biological monitor in freshwater environments. *Environmental Monitoring and Assessment* 15: 143-181.
- Du Laing, G., Rinklebe, J., Vandecasteele, B., Meers, E. and Tack, F.M.G. (2009). Trace metal behaviour in estuarine and riverine floodplain soils and sediments: A review. *Science of the Total Environment* 407(13): 3972-3985.
- Duc, T.A., Loi, V.D. and Thao, T.T. (2013). Partition of heavy metals in a tropical river system impacted by municipal waste. *Environmental Monitoring and Assessment* 185: 1907-1925.
- EC and MENVIQ (Environment Canada and Ministère de l'Environnement du Québec). (1992). Interim criteria for quality assessment of St. Lawrence River sediment. *Environment Canada*. Ottawa, Ontario.
- Elder J.F. and Collins J.J., (1991). Freshwater molluscs as indicators of bioavailability and toxicity of metals in surface-water systems. *Reviews of Environmental Contamination and Toxicology* 122, 36-79.
- Emsley, J. (2001). "Manganese". *Nature's Building Blocks: An A-Z Guide to the Elements*. pp. 249–253. Oxford, UK: Oxford University Press.

- Enquix González, A., Ternero Rodríguez, M., Jiménez Sánchez, J.C., Fernández Espinosa, J. and Barragán de la Rosa, F.J. (2000). Assessment of metals in sediments in a tributary of Guadalquivir River (Spain). Heavy metal partitioning and relation between the water and sediment system. *Water, Air and Soil Pollution* 121: 11-29.
- Eugene Ng, Y.J., Yap, C.K., Zakaria, M.P. and Tan S.G. (2013). Assessment of Heavy Metal Pollution in the Straits of Johore by Using Transplanted Caged Mussel, *Perna viridis*. *Pertanika Journal of Science and Technology* 21 (1): 75 – 96.
- European Commission. (2006). Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs (Text with EEA relevance). Retrieved from: <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:02006R1881-20100701>. 12th October 2015.
- Fan, H., He, D. and Wang, H. (2015). Environmental consequences of damming the mainstream Lancang-Mekong River: A review. *Earth-Science Reviews* 146:77–91.
- Finley, B.L., Monnot, A.D., Paustenbach, D.J. and Gaffney, S.H. (2012). Derivation of a chronic oral reference dose for cobalt. *Regulatory Toxicology and Pharmacology* 64(3): 491-503.
- Food Standards Australia New Zealand. Australia New Zealand Food Standards Code. Food Standards Australia New Zealand Act 1991. Volume 2, Schedules 19.03. Retrieved from: https://www.foodstandards.gov.au/code/proposals/Documents/P1025_CFS_Attach_A2_Schedules.pdf. 12th October 2015.
- Förstner, U. and Wittmann, G. T.W. (1979). Metal Transfer between Solid and Aqueous Phases. In *Metal Pollution in the Aquatic Environment*, pp 197-270. Springer Berlin Heidelberg.
- Foster, P. and Cravo, A. (2003). Minor elements and trace metals in the shells of marine gastropods from a shore in tropical East Africa. *Water, Air and Soil Pollution* 145: 53–65.
- Francesco, R., and Enzo, O. (1994). Accumulation and subcellular distribution of metals (Cu, Fe, Mn, Pb and Zn) in the Mediterranean mussel *Mytilus galloprovincialis* during a field transplant experiment. *Marine Pollution Bulletin* 28(10): 592-600.
- Franchitto, N., Gandia-Mailly, P., Georges, B., Galinier, A., Telmon, N., Ducassé, J.L. and Rougé, D. (2008). Acute copper sulphate poisoning: a case report and literature review. *Resuscitation* 78(1): 92-96.
- Fu, C., Guo, J., Pan, J., Qi, J., Zhou, W. (2009). Potential Ecological Risk Assessment of Heavy Metal Pollution in Sediments of the Yangtze River Within the Wanzhou Section, China. *Biological Trace Element Research* 129: 270–277.

- Fu, J., Zhao, C.P., Luo, Y.P., Liu, C.S., Kyzas, G.Z., Luo, Y., Zhao, D.Y., An, S.Q., Zhu, H.L. (2014). Heavy metals in surface sediments of the Jialu River, China: their relations to environmental factors. *Journal of Hazardous Materials* 270:102-109.
- Fuge, R. (2013). Anthropogenic Sources. In *Essentials of Medical Geology*, ed. Selinus, O., pp 59-74. Springer Netherlands.
- Gama, M., Crespo, D., Dolbeth, M. and Anastácio, P. (2015). Predicting global habitat suitability for *Corbicula fluminea* using species distribution models: The importance of different environmental datasets. *Ecological Modelling* 319: 163-169.
- Glaubrecht, M., Rintelen, T.V. and Korniushev, A.V. (2003). Toward a systematic revision of brooding freshwater Corbiculidae in Southeast Asia (Bivalvia, Veneroida): on shell morphology, anatomy and molecular phylogenetics of endemic taxa from islands in Indonesia. *Malacologia* 45: 1–40.
- Godinho, R.M., Freitas, M.C. and Wolterbeek, H.T.H. (2004). Assessment of Lichen Vitality During a Transplantation Experiment to a Polluted Site. *Journal of Atmospheric Chemistry* 49: 355–361.
- Goldberg E. D. (1975). The Mussel Watch - A first step in global marine monitoring. *Marine Pollution Bulletin* 6: 111.
- Graney, R. L. and Geisy, J. P., Jr. (1988), Alterations in the Oxygen Consumption, Condition Index and Concentration of Free Amino Acids in *Corbicula fluminea* (Mollusca: Pelecypoda) Exposed to Sodium Dodecyl Sulfate, *Environmental Toxicology and Chemistry* 7: 301-315.
- Gundacker, C. (2000). Comparison of heavy metal bioaccumulation in freshwater molluscs of urban river habitats in Vienna. *Environmental Pollution* 110: 61-71.
- Haag I., Kern U. and Westrich B. (2001). Erosion investigation and sediment quality measurements for a comprehensive risk assessment of contaminated aquatic sediments. *Science of the Total Environment* 266: 249–257.
- Hakanson, L., (1980). An ecological risk index for aquatic pollution control. A sedimentary approach. *Water Research* 14: 975–1001.
- Hall, B.D., St. Louis, V.L., Rolffus, K.R., Bodaly, R.A., Beaty, K.G., Paterson, M.J. and Peech Cherewyk, K.A. (2005). Impacts of Reservoir Creation on the Biogeochemical Cycling of Methyl Mercury and Total Mercury in Boreal Upland Forests. *Ecosystems* 8: 248–266.
- Han, F.X., Su, Y., Monts, D.L., Plodinec, M.J., Banin, A. and Triplett G.E. (2003). Assessment of global industrial-age anthropogenic arsenic contamination. *Naturwissenschaften* 90: 395–401. 0
- Han, J., Shi, J., Zeng, L., Xu, J. and Wu, L. (2015). Effects of nitrogen fertilization on the acidity and salinity of greenhouse soils. *Environmental Science and Pollution Research* 22: 2976–2986.

- Harguinteguy, C.A., Noelia Cofré, M., Fernández-Cirelli, A. and Luisa Pignata, M. (2016). The macrophytes *Potamogeton pusillus* L. and *Myriophyllum aquaticum* (Vell.) Verdc. as potential bioindicators of a river contaminated by heavy metals. *Microchemical Journal* 124: 228–234.
- Haris, H. and Aris, A.Z. (2013). The geoaccumulation index and enrichment factor of mercury in mangrove sediment of Port Klang, Selangor, Malaysia. *Arabian Journal of Geoscience* 6: 4119–4128.
- Harrison, F.L., Knezovich, J.P., and Rice, D.W., Jr. (1984), The Toxicity of Copper to the Adult and Early Life Stages of the Freshwater Clam, *Corbicula manilensis*'. *Archives of Environmental Contamination and Toxicology* 13: 85-92.
- Heiri O., Lotter A.F. and Lemcke G. (2001). Loss-on-ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. *Journal of Paleolimnology* 25: 101–110.
- Helal, H.M. and Sauerbeck, D. (1984). Influence of plant roots on carbon and phosphorus metabolism in soil. *Plant Soil* 76: 175–182.
- Hendershot, W.H., H. Lalande, and M. Duquette. (2008). Ion exchange and exchangeable cations. In *Soil Sampling and Methods of Analysis. 2nd edition*, ed. Carter, M.R., and Gregorich, E.G. Canadian Society of Soil Science, CRC Press and Taylor & Francis Group. Oxford, UK.
- Hooda, P.S. (ed.) (2010). *Trace Elements in Soils*. Chichester, UK: John. Wiley & Sons, Ltd.
- Hosoi, M., Yoshinaga, Y., Toyohara, M., Shiota, F. and Toyohara H. (2008). Freshwater bivalve *Corbicula sandai* uses free amino acids as osmolytes under hyperosmotic condition. *Fisheries Science* 74: 1339–1341.
- Howard, P.J.A. and Howard, D.M. (1990). Use of organic carbon and loss-on-ignition to estimate soil organic matter in different soil types and horizons. *Biology and Fertility of Soils* 9: 306-310.
- Iguchi J., Isshiki M., Takashima Y., Yamashita Y. and Yamashita M. (2014). Identifying the origin of *Corbicula* clams using trace element analysis. *Fisheries Science* 80: 1089–1096.
- International Agency for Research on Cancer (IARC). (1993). Beryllium, cadmium, mercury, and exposures in the glass manufacturing Industry. *IARC monographs on the evaluation of carcinogenic risks to humans*, vol 58. Lyon, pp 119–237.
- International Agency for Research on Cancer (IARC). (2006). Cobalt in hard metals and cobalt sulfate, gallium arsenide, indium phosphide and vanadium pentoxide. *IARC monographs on the evaluation of carcinogenic risks to humans*, vol 86. Lyon, pp 119–237
- International Agency for Research on Cancer. (1990). Chromium, Nickel and Welding. *IARC monographs on the Evaluation of Carcinogenic Risks to Human*, Vol 49, , IARC Scientific Publications, Lyon, pp 1–648, 677–691.
- Irish EPA (Environmental Protection Agency). (2001). *Parameters of Water Quality: Interpretation and Standards*. Environmental Protection Agency, Ireland.

- Irish Minister for the Environment. (1989). *European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations*, 1989. Statutory Instrument No 294 of 1989.
- Iwegbue, C.M.A. (2015). Metal concentrations in selected brands of canned fish in Nigeria: estimation of dietary intakes and target hazard quotients. *Environmental Monitoring and Assessment* 187: 85
- Iwegbue, C.M.A., Nwajei G.E., Ogala, J.E. and Overah, C.L. (2010). Determination of trace metal concentrations in soil profiles of municipal waste dumps in Nigeria. *Environmental Geochemistry and Health* 32: 415–430.
- Izumi, T., Itoh, Y., Endo T. and Ohyama, T. (2004). Brackish water benthic shellfish (*Corbicula japonica*) as a biological indicator for *Cryptosporium parvum* oocysts in river water. *Bulletin of Environmental Contamination and Toxicology* 72:29-37.
- Jovic, M., Stankovic, S., (2014). Human exposure to trace metals and possible public health risks via consumption of mussels *Mytilus galloprovincialis* from the Adriatic coastal area. *Food and Chemical Toxicology* 70: 241–251.
- Joy, J.E., Pritchard, A.J. and Danford, D. (1983). *Corbicula fluminea* (Mollusca: Pelecypoda) as a Biological Indicator of Heavy Metals in the Kanawha River, WV', *West Virginia Academy of Science* 55: 113-117.
- Junaidi, E., Sagala E. P., dan Joko. (2010). Kelimpahan Populasi dan Pola Distribusi Remis (*Corbicula* sp.) di Sungai Borang Kabupaten Banyuasin. *Jurnal Penelitian Sains* 13(3D): 13310.
- Kefford, B.J. (1998). Is salinity the only water quality parameter affected when saline water is disposed in rivers? *International Journal of Salt Lake Research* 7: 285-300.
- Kefford, B.J. (2000). The effect of saline water disposal: Implications for monitoring programs and management. *Environmental Monitoring and Assessment* 63: 313–327.
- Khelifi, R., Olmedo, P., Gil, F., Feki-Tounsi, M., Chakroun, A., Rebai, A. and Hamza-Chaffai, A. (2013). Blood nickel and chromium levels in association with smoking and occupational exposure among head and neck cancer patients in Tunisia. *Environmental Science and Pollution Research* 20: 8282-8294.
- Kijviriya, V., E.S. Upatham, V. Viyanant and D.S. Woodruff. (1991). Genetic studies of Asian clams, *Corbicula*, in Thailand: allozymes of 21 nominal species are identical. *American Malacological Bulletin* 8(2): 97-106.
- Kijviriya, V. (1990). Studies of the Asiatic clam (*Corbicula* Muhlfeld. 1811) in Thailand: Electrophoretic estimates of enzyme variation and the use of anatomy a species indicator. Doctoral Thesis. Mahidol University. Bangkok. Thailand.
- Krailas, D., Chotesaengsri, S., Dechruksa, W., Namchote, S., Chuanprasit, C., Veeravechskij, N., Boonmekam, D. and Koonchornboon, T. (2012). Species Diversity of Aquatic Mollusks and Their Cercarial Infections; Khao Yai National Park, Thailand. *The Journal of Tropical Medicine and Parasitology* 35: 37-47.

- Kramer A., Willier B. H., Edge R., Smith H. R., Tubman A. W., Lee C. F. and Toompas C. A. (1962). The government industry cooperative oyster research program. Part II. Native oyster studies. *Journal of the Association of Official Agricultural Chemists* 45(2): 565-577.
- Krauskopf, K.B. and Bird, D.K., (1995). Introduction to Geochemistry, 3rd edition. McGrawHill, Inc., New York. (647 pp.).
- Kunitake, M.E., Mangani, L.M., Peloquin, J.M., Baker, S.P. and Estroff, L.A. (2013). Evaluation of strengthening mechanisms in calcite single crystals from mollusk shells. *Acta Biomaterialia* 9: 5353–5359.
- Kurnia, R. (2011). *Pengaruh metode pengolahan terhadap kandungan mineral remis (Corbicula javanica)*. Departmen Teknologi Hasil Perairan Fakultas Perikanan dan Ilmu Kelautan, Institut Pertanian Bogor, Bogor.
- Landis W. G. and Yu M. H. (2003). *Introduction to Environmental Toxicology: Impacts of Chemicals Upon Ecological Systems*, Third Edition. CRC Press LLC.
- Lawrence, D.R. and Scott, G.I. (1982). The determination and use of condition index of oysters. *Estuaries* 5(1): 23-27.
- Lécuyer, C., Hutzler, A., Amiot, R., Daux, V., Grosheny, D., Otero, O., Martineau, F., Fourel, F., Balter, V. and Reynard, B. (2012). Carbon and oxygen isotope fractionations between aragonite and calcite of shells from modern molluscs. *Chemical Geology* 332–333(2012): 92–101.
- Lee, C.S., Lim, Y.W., Kim, H.H., Yang, J.Y. and Shin D.C. (2012). Exposure to heavy metals in blood and risk perception of the population living in the vicinity of municipal waste incinerators in Korea. *Environmental Science and Pollution Research* 165: 349–363.
- Li, J., Huang, Z.Y. and Yang, H. (2013). Potential risk assessment of heavy metals by consuming shellfish collected from Xiamen, China. *Environmental Science and Pollution Research* 20: 2937–2947.
- Li, P. and Gao, X. (2014). Trace elements in major marketed marine bivalves from six northern coastal cities of China: Concentrations and risk assessment for human health. *Ecotoxicology and Environmental Safety* 109: 1–9.
- Li, X., Jia, L., Zhao, Y., Wang, Q. and Cheng, Y. (2009). Seasonal bioconcentration of heavy metals in *Onchidium struma* (Gastropoda: Pulmonata) from Chongming Island, the Yangtze Estuary, China. *Journal of Environmental Sciences* 21:255–262.
- Lim, W. Y., Aris, A. Z. and Tengku Ismail, T.H. (2013). Spatial Geochemical Distribution and Sources of Heavy Metals in the Sediment of Langat River, Western Peninsular Malaysia. *Environmental Forensics*, 14: 133–145.
- Lim, W.Y., Aris A.Z. and Zakaria M.P. (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* 2012, Article ID 652150.
- Linder M.C. and Hazegh-Azam M. (1996) Copper biochemistry and molecular biology. *The American Journal of Clinical Nutrition* 63: 797–811.

- Li-qun, C., Yeboah, S., Cheng-sheng, S., Xiao-dong, C. and Ren-zhi, Z. (2015). GIS-based assessment of arable layer pollution of copper (Cu), zinc (Zn) and lead (Pb) in Baiyin District of Gansu Province. *Environmental Earth Science* 74: 803-811.
- Long, E.R. and Morgan, L.G. (1991). The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. *NOAA Technical Memorandum NOS OMA*. National Oceanic and Atmospheric Administration. Seattle, Washington.
- Loska, K., Cebula, J., Pelczar, J., Wiechula, D. and Kwapulinski, J. (1997). Use of enrichment factors together with geoaccumulation indexes to evaluate the content of Cd, Cu and Ni in the Rybnik Water Reservoir in Poland. *Water, Air and Soil Pollution* 93: 347-365.
- Lu, H., Shi, H., Costa, M. and Huang, C. (2005). Carcinogenic effect of nickel compounds. *Molecular and Cellular Biochemistry* 279: 45-67.
- Lundebye, A.K., Langston, W.J. and Depledge, M.H. (1997). Stress proteins and condition index as biomarkers of tributyltin exposure and effect in mussels. *Ecotoxicology* 6: 127-136.
- Ma, L.Q. and Rao, G.N. (1997). Chemical fractionation of cadmium, copper, nickel, and zinc in contaminated soils. *Journal of Environmental Quality* 26: 259-264.
- Ma, X., Zuo, H., Tian, M., Zhang, L., Meng, J., Zhou, X., Min, N., Chang, X. and 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: 264-272.
- Ma, Y., Qin, Y., Zheng, B., Zhang, L. and Zhao, Y. (2015). Seasonal variation of enrichment, accumulation and sources of heavy metals in suspended particulate matter and surface sediments in the Daliao river and Daliao river estuary, Northeast China. *Environmental Earth Sciences* 73: 5107-5117.
- MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. (2000b). Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. *Archives of Environmental Contamination and Toxicology* 39: 20-31.
- MacDonald, D.D., L.M. DiPinto, J. Field, C.G. Ingersoll, E.R. Long, and R.C. Swartz. (2000a). Development and evaluation of consensus-based sediment effect concentrations for polychlorinated biphenyls (PCBs). *Environmental Toxicology and Chemistry* 19: 1403-1413.
- Marcé, R., Moreno-Otos, E., García-Barcina, J.M. and Armengol, J. (2010). Tailoring dam structures to water quality predictions in new reservoir projects: Assisting decision-making using numerical modelling. *Journal of Environmental Management* 91: 1255-1267.
- Markert B. (1996). *Instrumental element and multi-element analysis of plant samples methods and applications*, John Wiley and Sons, Chichester.

- Markert B., Wappelhorst O., Weckert V., Herpin U., Siewers U., Friese K. and Breulmann G. (1997). The use of bioindicators for monitoring the heavy-metal status of the environment, *Journal of Radioanalytical and Nuclear Chemistry* 240(2): 425-429.
- Marmolejo-Rodriguez, A.J., Prego, R., Meyer-Willerer, A., Shumilin, E., Cobelo-Garci, A. (2007). Total and labile metals in surface sediments of the tropical river-estuary system of Marabasco (Pacific coast of Mexico): influence of an iron mine. *Marine Pollution Bulletin* 55: 459-468.
- Martínez-Martínez, S., Acosta, J.A., Faz Cano A., Carmona, D.M., Zornoza R. and Cerda C. (2013). Assessment of the lead and zinc contents in natural soils and tailing ponds from the Cartagena-La Unión mining district, SE Spain. *Journal of Geochemical Exploration* 124: 166-175.
- Matchallat, J. (2000). Arsenic in the geosphere - a review. *The Science of the Total Environment* 249: 297-312.
- McCully, P. (2001). Rivers No More: The Environmental Effects of Dams. *Silenced Rivers: The ecology and politics of large dams*. UK: ZedBooks.
- Mei, H., Ke, C.H., Tian, L. and Li, H.B. (2016). Bioaccessibility and Health Risk Assessment of Cu, Cd, and Zn in “Colored” Oysters. *Archives of Environmental Contamination and Toxicology* 70(3): 595-606
- Mielke H.W. (1994). Lead in New Orleans soils: New images of an urban environment. *Environmental Geochemistry and Health* 16: 123-128.
- Mo, C. and Neilson, B. (1994). Standardization of oyster soft dry weight measurements. *Water Research* 28: 243-246.
- Mohapatra, P.K. (2006a). Issues and scope of environmental biotechnology. *Textbook of Environmental Biotechnology*. India: I K International Publishing House Pvt. Ltd.
- Mohapatra, P.K. (2006b). Treatment of wastewater of the food processing industries. *Textbook of Environmental Biotechnology*. India: I K International Publishing House Pvt. Ltd.
- Mohidin, H., Hanafi, M.M., Rafii, Y.S., Abdullah, S.N.A., Idris, A.S., Man, S., Idris, J. and Sahebi, M. (2015). Determination of optimum levels of nitrogen, phosphorus and potassium of oil palm seedlings in solution culture. *Bragantia, Campinas* 74 (3): 247-254.
- Moiseenko, T.I., Gashkina, N.A., Dinu, M.I., Kremleva, T.A. and Khoroshavin, V.Y. (2013). Aquatic geochemistry of small lakes: Effects of environment changes. *Geochemistry International* 51(13): 1031-1148.
- Morton. B. (1986). *Corbicula* in Asia - updated synthesis. *American Malacological Bulletin Special* 2: 113-124.
- Muhammad Ali, B.N., Lin, C.Y., Cleophas, F., Abdullah, M.H. and Musta B. (2015). Assessment of heavy metals contamination in Mamut river sediments using sediment quality guidelines and geochemical indices. *Environmental Monitoring and Assessment* 187: 4190.
- Muller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. *GeoJournal* 2: 108-118.

- Nan, Z., Zhao, C., Li, J., Chen, F. and Sun, Wu. (2002). Relations between Soil Properties and Selected Heavy Metal Concentrations in Spring Wheat (*Triticum aestivum* L.) Grown in Contaminated Soils. *Water, Air, and Soil Pollution* 133: 205–213.
- Nemati, K., Abu Bakar, N.K., Abas, M.R. and Sobhanzadeh, E., (2011). Speciation of heavy metals by modified BCR sequential extraction procedure in different depths of sediments from Sungai Buloh, Selangor, Malaysia. *Journal of Hazardous Material* 192: 402–410.
- Normando, F.T., Santiago K.B., Vinicius, M., Gomes, T., Rizzo, E. and Bazzoli, N. (2014). Impact of the Três Marias dam on the reproduction of the forage fish *Astyanax bimaculatus* and *A. fasciatus* from the São Francisco River, downstream from the dam, southeastern Brazil. *Environmental Biology of Fishes* 97: 309–319.
- Nott, J. A. and Nicolaidou, A. (1996). Kinetics of metals in molluscan faecal pellets and mineralized granules, incubated in marine sediments. *Journal of Experimental Marine Biology and Ecology* 197: 203-218.
- Olajire, A.A. and Ayodele, E.T. (1998). Heavy metal analysis of solid municipal wastes in the western part of Nigeria. *Water, Air, and Soil Pollution* 103: 219–228.
- Oliveira, P., Lopes-Lima, M., Machado, J. and Guilhermino, L. (2015). Comparative sensitivity of European native (*Anodonta anatina*) and exotic (*Corbicula fluminea*) bivalves to mercury. *Estuarine, Coastal and Shelf Science* 167: 191-198.
- Ong, G.H., Yap, C.K., Maziah, M., Suhaimi, H. and Tan S.G. (2013). An investigation of arsenic contamination in Peninsular Malaysia based on *Centella asiatica* and soil samples. *Environmental Monitoring and Assessment* 185(4): 3243-54.
- Osman, K.T. (2014). Soil Pollution. *Soil Degradation, Conservation and Remediation*. Netherland: Springer.
- Otachi, E.O., Körner, W., Avenant-Oldewage, A., Fellner-Frank, C. and Jirsa, F. (2014). Trace elements in sediments, blue spotted tilapia *Oreochromis leucostictus* (Trewavas, 1933) and its parasite *Contracaecum multipapillatum* from Lake Naivasha, Kenya, including a comprehensive health risk analysis. *Environmental Science and Pollution Research* 21: 7339–7349.
- Otachi, E.O., Plessl, C., Körner, W., Avenant-Oldewage, A. and Jirsa, F. (2015). Trace Elements in Water, Sediments and the Elongate Tigerfish *Hydrocynus forskahlii* (Cuvier 1819) from Lake Turkana, Kenya Including a Comprehensive Health Risk Analysis. *Bulletin of Environmental Contamination and Toxicology* 95(3): 286-291.
- Pal, S. (2016). Impact of Massanjore Dam on hydro-geomorphological modification of Mayurakshi River, Eastern India. *Environment, Development and Sustainability* DOI 10.1007/s10668-015-9679-1.
- Pan, K. and Wang, W.X., (2011). Trace metal contamination in estuarine and coastal environments in China. *Science of the Total Environment* 421/422: 3–16.

- Pandey, M., Tripathi, S., Pandey, A.K. and Tripathi, B.D., (2014). Risk assessment of metal species in sediments of the river Ganga. *Catena* 122:140-149.
- Persaud, D., R. Jaagumagi, and A. Hayton. (1993). *Guidelines for the protection and management of aquatic sediment quality in Ontario*. Standards Development Branch. Ontario Ministry of Environment and Energy. Toronto, Ontario. pp. 27.
- Phillips D. J. H. and Rainbow P. S. (1988). Barnacles and mussels as biomonitors of trace elements: a comparative study. *Marine Ecology - Progress Series* 49: 83-93.
- Phillips, D.J.H. and Rainbow, P.S. (1993). *Biomonitoring of trace aquatic contaminants*, pp. 371. Springer Science and Business Media Dordrecht.
- Pizzol, M., Smart, J.C.R. and Thomsen, M. (2014). External costs of cadmium emissions to soil: a drawback of phosphorus fertilizers. *Journal of Cleaner Production* 84: 475-483.
- Purushothaman, P. and Chakrapani, G.J. (2007). Heavy Metals Fractionation in Ganga River Sediments, India. *Environmental Monitoring and Assessment* 132(1): 475-489.
- Rai L. C., Gaur J. P. and Kumar H. D. (1981). Phycology and Heavy Metal Pollution. *Biological Reviews* 56(2): 99–151.
- Ravera, O. (1984). Cadmium in freshwater ecosystems. *Experientia* 40: 2-14.
- Roberts, T.L. (2014). Cadmium and Phosphorous Fertilizers: The Issues and the Science. *Procedia Engineering* 83: 52-59.
- Rosales-Hoz, L., Carranza-Edwards, A. and Lopez-Hernandez, M. (2000). Heavy metals in sediments of a large, turbid tropical lake affected by anthropogenic discharges. *Environmental Geology* 39: 3–4.
- Ross, S. (1994) *Toxic metals in soil-plant systems*. Wiley, Chichester.
- Rudnick, R.L. and Gao, S. (2003). Composition of the continental crust. In *The Crust*, vol. 3 ed. Rudnick, R.L, pp. 1–64. Elsevier.
- Ruhling A. (ed.) (1994). *Atmospheric heavy metal deposition in Europe—estimations based on moss analysis*. Nordic Council of Ministers, Copenhagen.
- Ruiz J.M., Barreiro R. and González J.J. (2005). Biomonitoring organotin pollution with gastropods and mussels. *Marine Ecology Progress Series* 287: 169–176.
- Sakan, S., Grzetic, I. and Dordevic, D. (2007). Distribution and Fractionation of Heavy Metals in the Tisa (Tisza) River Sediments. *Environmental Science and Pollution Research* 14 (4): 229 – 236.
- Salamah, E., Sri Purwaningsih dan Kurnia, R. (2012). Kandungan mineral Remis (*Corbicula javanica*) akibat proses pengolahan. *Jurnal Akuatika* 3(1): 74-83.
- Saleem, M., Iqbal, J. and Shah, M.H. (2015). Geochemical speciation, anthropogenic contamination, risk assessment and source identification of selected metals in freshwater sediments—A case study from Mangla Lake, Pakistan. *Environmental Nanotechnology, Monitoring & Management* 4: 27–36.

- Saleem, M., Iqbal, J. and Shah, M.H. (2015). Geochemical speciation, anthropogenic contamination, risk assessment and source identification of selected metals in freshwater sediments—A case study from Mangla Lake, Pakistan. *Environmental Nanotechnology, Monitoring & Management* 4: 27-36.
- Sando, S.K. and Lambing, J.H., (2011). Estimated loads of suspended sediment and selected trace elements transported through the Clark Fork Basin, Montana, in selected periods before and after the breach of Milltown Dam (water years 1985–2009). *U.S. Geological Survey Scientific Investigations Report* 2011-5030 (64 pp.)
- Sarmani, S.B. (1989). The determination of heavy metals in water, suspended materials and sediments from Langat River, Malaysia. *Hydrobiologia* 176–177(1):233–238.
- Scheiber, I., Dringen, R. and Mercer, J.F.B. (2013). Copper: Effects of Deficiency and Overload. In *Interrelations between Essential Metal Ions and Human Diseases*, ed. Sigel, A., Sigel, H., and Sigel, R.K.O., pp. 359-387. Springer Science+Business Media Dordrecht.
- Schi, K.C. and Weisberg, S.B. (1999). Iron as a reference element for determining trace metal enrichment in Southern California coast shelf sediments. *Marine Environmental Research* 48: 161–176.
- Schoen A., Beck B., Sharma R. and Dube E. (2004). Arsenic toxicity at low doses: epidemiological and mode of action considerations. *Toxicology and Applied Pharmacology* 198: 253–267.
- Sedláček, J., Bábek, O. and Grygar, T.M. (2013). Trends and evolution of contamination in a well-dated water reservoir sedimentary archive: the Brno Dam, Moravia, Czech Republic. *Environmental Earth Sciences* 69: 2581–2593.
- Setiawan, D. (2010). Studi komunitas makrozoobenthos di perairan Sungai Musi sekitar kawasan industri bagian hilir Kota Palembang. *Prosiding Seminar Nasional Limnologi V*, Indonesia.
- Shafie, N., Aris, A.Z. and Hazzeman, H. (2014). Geoaccumulation and distribution of heavy metals in the urban river sediment. *International Journal of Sediment Research* 29: 368–377.
- Shafie, N.A., Aris, A.Z. and Haris, H. (2014). Geoaccumulation and distribution of heavy metals in the urban river sediment. *International Journal of Sediment Research* 29: 368-377.
- Shi, X., Chen, L. and Wang, J. (2013). Multivariate analysis of heavy metal pollution in street dusts of Xianyang city, NW China. *Environmental Earth Science* 69: 1973–1979.
- Shi, Z., Wang, X. and Ni, S. (2015). Metal Contamination in Sediment of One of the Upper Reaches of the Yangtze River: Mianyuan River in Longmenshan Region, Southwest of China. *Soil and Sediment Contamination* 24: 368–385.
- Shuman, B. (2003). Controls on loss-on-ignition variation in cores from two shallow lakes in the northeastern United States. *Journal of Paleolimnology* 30: 371-385.

- Sinex, S.A. and Helz, G.R. (1981). Regional geochemistry of trace elements in Chesapeake Bay. *Environmental Geology* 3: 315–323.
- Slobodskova, V.V., Solodova, E.E., Slinko, E.N., Chelomin, V.P. (2010). Evaluation of the Genotoxicity of Cadmium in Gill Cells of the Clam *Corbicula japonica* Using the Comet Assay. *Russian Journal of Marine Biology* 36(4):311–315.
- Smith, S.L., D.D., MacDonald, K.A. Keenleyside, C.G. Ingersoll, and J. Field. (1996). A preliminary evaluation of sediment quality assessment values for freshwater ecosystems. *Journal of Great Lakes Research* 22: 624–638.
- Song, Y., Ji, J., Yang, Z., Yuan, X., Mao, C. and Frost, R. L. (2011). Geochemical behavior assessment and apportionment of heavy metal contaminants in the bottom sediments of lower reach of Changjiang River. *Catena* 85(1): 73–81.
- Storelli, M.M., (2008). Potential human health risks from metals (Hg, Cd, and Pb) and polychlorinated biphenyls (PCBs) via seafood consumption: estimation of target hazard quotients (THQs) and toxic equivalents (TEQs). *Food and Chemical Toxicology* 46: 2782–2788.
- Sundaray, S.K., Nayak, B.B., Lee, B.G. and Bhatta, D. (2014). Spatio-temporal dynamics of heavy metals in sediments of the river estuarine system: Mahanadi basin (India). *Environmental Earth Sciences* 71: 1893–1909.
- Suwignyo S., Widigdo B., Krisanti M. and Wardianto Y. (2005). *Avertebrata Air Jilid 2*. Bogor: IPB Press.
- Tahri, M., Benyaïch, F., Bounakhla, M., Bilal, E., Gruffat, J.J., Moutte, J. and Garcia, D. (2005). Multivariate analysis of heavy metal contents in soils, sediments and water in the region of Meknes (Central Morocco). *Environmental Monitoring and Assessment* 102: 405–417.
- Tao, H.H., Slade, E.M., Willis, K.J., Caliman, J.P. and Snaddon, J.L. (2016). Effects of soil management practices on soil fauna feeding activity in an Indonesian oil palm plantation. *Agriculture, Ecosystems and Environment* 218: 133–140.
- Taylor, S.R., (1964). Abundance of chemical elements in the continental crust: a new table. *Geochimica et Cosmochimica Acta* 28: 1273–1285.
- Teisserenc, R., Lucotte, M., Canuel, R., Moingt, M. and Obrist, D. (2014). Combined dynamics of mercury and terrigenous organic matter following impoundment of Churchill Falls Hydroelectric Reservoir, Labrador. *Biogeochemistry* 118: 21–34.
- Tong, S. L. and Gian H. F. (1977). Analysis of arsenic in environmental samples by an arsine generation radiometric methods, proc Symp. *Improving the Quality of live in Malaysia*, Kuala Lumpur, 125–133.
- Torres, M. A., Barros, M. P., Campos, S. C. G., Pinto, E., Rajamani S., Sayre, R. T. and Colepicolo, P. (2008), Biochemical biomarkers in algae and marine pollution: A review, *Ecotoxicology and Environmental Safety* 71: 1– 15
- Tran, D., Boudou, A., Massabau, J.C., (2001). How water oxygenation level influences cadmium accumulation pattern in the asiatic clam *Corbicula fluminea*: A laboratory and field study. *Environmental Toxicology and Chemistry* 20(9): 2073–2080.

- Tseng, C.H., Chong, C.K., Chen, C.J. and Tai, T.Y. (1996). Dose-response relationship between peripheral vascular disease and ingested inorganic arsenic among residents in blackfoot disease endemic villages in Taiwan. *Atherosclerosis* 120(1-2): 125-33.
- Turner, A. and Millward, G.E. (2000). Particle dynamics and trace metal reactivity in estuarine plumes. *Estuarine, Coastal and Shelf Science* 50: 761–774.
- USEPA (United States Environmental Protection Agency). (1996).. Calculation and evaluation of sediment effect concentrations for the amphipod *Hyaella azteca* and the midge *Chironomus riparius*. *Assessment and remediation of contaminated sediments (ARCS) program*. EPA 905/R-96/008. Great Lakes National Program Office. Chicago, Illinois.
- USEPA (United States Environmental Protection Agency). (2002). *A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems*. US EPA-905-B02-001-C.
- USEPA (US Environmental Protection Agency) (1989). *Guidance manual for assessing human health risks from chemically contaminated, fish and shellfish*. EPA-503/8-89-002. USEPA, Washington DC.
- USEPA (US Environmental Protection Agency), (2000). Risk-Based Concentration Table. Philadelphia PA: USEPA, Washington, DC.
- USFDA (US Food and Drug Administration). (1993). *Guidance Documents for Trace Elements in Seafood*. Center for Food Safety and Applied Nutrition, Washington, DC, USA.
- USFDA/CFSAN and ISSC. (2007). Guide for the control of molluscan shellfish 2007 – Guidance documents chapter II. Growing areas: 04. Action levels, tolerances and guidance levels for poisonous or deleterious substances in seafood, pp 1–4.
- Venkatesha Raju, K., Somashekar R.K. and Prakash K.L. (2012). Heavy metal status of sediment in river Cauvery, Karnataka. *Environmental Monitoring and Assessment* 184: 361–373.
- Villar, C., Stripeikis, J., D’Huicque, L., Tudino, M., Troccoli, O. and Bonetto, C. (1999). Cd, Cu and Zn concentrations in sediments and the invasive bivalves *Limnoperna fortunei* and *Corbicula fluminea* at the Rio de la Plata basin, Argentina. *Hydrobiologia* 416: 41–49.
- Vincent, J.B. (2013). Chromium: Is It Essential, Pharmacologically Relevant, or Toxic? In *Interrelations between Essential Metal Ions and Human Diseases*, ed. Sigel, A., Sigel, H., and Sigel, R.K.O., pp. 171-198. Springer Science+Business Media Dordrecht.
- Vodopirez, C., Curtosi, A., Villaamil, E., Smichowski, P., Pelletier, E. and Mac Cormack, W.P. (2015). Heavy metals in sediments and soft tissues of the Antarctic clam *Laternula elliptica*: More evidence as a possible biomonitor of coastal marine pollution at high latitudes? *Science of the Total Environment* 502:375–384.

- von Rintelen, T. and Glaubrecht, M. (2006). Rapid evolution of sessility in an endemic species flock of the freshwater bivalve *Corbicula* from ancient lakes on Sulawesi, Indonesia. *Biology Letters* 2: 73–77.
- Wallner-Kersanach, M., Theede, H., Eversberg, U. and Lobo, S. (2000). Accumulation and Elimination of Trace Metals in a Transplantation Experiment with *Crassostrea rhizophorae*. *Archives of Environmental Contamination and Toxicology* 38: 40–45.
- Walsh, K., Dunstan, R. H., Murdoch, R. N., Conroy B. A., Roberts T. K. and Lake P. (1994). Bioaccumulation of Pollutants and Changes in Population Parameters in the Gastropod Mollusc *Austrocochlea constricta*. *Archives of Environmental Contamination and Toxicology* 26: 367–373.
- Wan, Y.L., Aris, A.Z. and Mohamad, P.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, B., Xia, D.S., Yu, Y., Jia, J. and Xu, S.J. (2013). Magnetic records of heavy metal pollution in urban topsoil in Lanzhou, China. *Chinese Science Bulletin* 58(3): 384–395.
- Wang, P., Dong, S. and Lassoie, J.P. (2014). Environmental Impacts of Dams in China: Focusing on Biological Diversity and Ecological Integrity. *The Large Dam Dilemma*. Springer Netherlands.
- Wang, Y., Chen, P., Cui, R., Si, W., Zhang Y. and Ji, W. (2010). Heavy metal concentrations in water, sediment, and tissues of two fish species (*Triplophysa pappenheimi*, *Gobio hwanghensis*) from the Lanzhou section of the Yellow River, China. *Environment Monitoring and Assessment* 165: 97–102.
- Wang, Z.Y., Lee, J.H.W. and Cheng, D. (2005). Impacts of the TGP project on the Yangtze River ecology and management strategies. *International Journal of River Basin Management* 3(4): 237–246.
- Wang, Z.Y., Lee, J.H.W. and Melching, C.S. (2015). Dams and Impounded Rivers. In *River Dynamics and Integrated River Management* ed. Wang, Z.Y., Lee, J.H.W., Melching, C.S. pp. 397–465. Tsinghua University Press, Beijing and Springer-Verlag Berlin Heidelberg.
- Wannaz, E.D. and Pignata, M.L. (2006). Calibration of Four Species of Tillandsia as Air Pollution Biomonitors. *Journal of Atmospheric Chemistry* 53: 185–209.
- Wardani, I., Affandi, M. and Irawan, B. (2012) Keanekaragaman dan pola distribusi longitudinal spesies kerang air tawar Corbiculidae di Sungai Brantas periode Januari – Februari 2012. *Water Research* 28: 243–246.
- WHO (1996) Chromium in drinking water, guidelines for drinking water quality, vol 2, 2nd edn. World Health Organization, Geneva.
- WHO. (2011). Chemical fact sheets. *Guidelines for Drinking-water Quality*. World Health Organization.
- Wilcox, A.C., O'Connor, J.E. and Major, J.J., (2014). Rapid reservoir erosion, hyperconcentrated flow, and downstream deposition triggered by breaching of 38-m-tall Condit Dam, White Salmon River, Washington. *Journal of Geophysical Research: Earth Surface* 119: 1376–1394.

- Wilcox, D.E. (2013). Arsenic. Can This Toxic Metalloid Sustain Life? In *Interrelations between Essential Metal Ions and Human Diseases*, ed. Sigel, A., Sigel, H., and Sigel, R.K.O., pp. 475-498. Springer Science+Business Media Dordrecht.
- Williams, W.A.I.D. and Hudson, M.D. (2014). Limitations of metallothioneins in common cockles (*Cerastoderma edule*) and sponges (*Haliclona oculata*) as biomarkers of metal contamination in a semi-enclosed coastal area. *Science of the Total Environment* 473–474: 391–397.
- Wu, G., Pan, L. and Guo, L. (2015). Decreased mobility of heavy metals in Haihe River sediments: The possible role of tide gate. *Journal of Geochemical Exploration* 157: 92–99.
- Wu, Q., Zhou, H., Tam, M.F.Y., Tian, Y., Tan, Y., Zhou, S., Li, Q., Chen, Y. and Leung, J.Y.S. (2016). Contamination, toxicity and speciation of heavy metals in an industrialized urban river: Implications for the dispersal of heavy metals. *Marine Pollution Bulletin* (In press, doi:10.1016/j.marpolbul.2016.01.043).
- Xiao, B., Li, E., Du, Z., Jiang, R., Chen, L., Yu. N. (2014). Effects of temperature and salinity on metabolic rate of the Asiatic clam *Corbicula fluminea* (Müller, 1774). *SpringerPlus* 3: 455.
- Yamada, K. (2013). Cobalt: Its Role in Health and Disease. In *Interrelations between Essential Metal Ions and Human Diseases*, ed. Sigel, A., Sigel, H., and Sigel, R.K.O., pp. 295-320. Springer Science+Business Media Dordrecht.
- Yan, X. and Luo, X. (2015). Heavy metals in sediment from Bei Shan River: distribution, relationship with soil characteristics and multivariate assessment of contamination sources. *Bulletin of Environmental Contamination and Toxicology* 95: 56–60.
- Yang, Z., Lu, W., Long, Y., Bao, X. and Yang, Q. (2011). Assessment of heavy metals contamination in urban topsoil from Changchun City, China. *Journal of Geochemical Exploration* 108(1): 27-38
- Yap, C. K., Ismail, A. and Tan, S.G. (2009). Effect of Body Size on Heavy Metal Contents and Concentrations in Green-Lipped Mussel *Perna viridis* (Linnaeus) from Malaysian Coastal Waters. *Pertanika Journal of Science and Technology* 17(1): 61 – 68.
- Yap, C.K, Ismail A. and Tan, S. G. (2004). Biomonitoring of Heavy Metals in the West Coastal Waters of Peninsular Malaysia Using the Green-lipped Mussel *Perna viridis*: Present Status and What Next? *Pertanika Journal of Tropical Agricultural Science* 27(2): 151- 161.
- Yap, C.K, Rahim Ismail, A., Ismail, A. and Tan, S.G. (2003). Species Diversity of Macrobenthic Invertebrates in the Semenyih River, Selangor, Peninsular Malaysia. *Pertanika Journal of Tropical Agricultural Science* 26(2): 139 - 146.
- Yap, C.K. (2012). *Perna viridis* as biomonitor. *Mussel Watch in Malaysia: past, present and future*. Universiti Putra Malaysia Press.

- Yap, C.K. and Cheng, W.H. (2010b). Depuration of Gut Contents in the Intertidal Snail *Nerita lineata* is Not Necessary for the Study of Heavy Metal Contamination and Bioavailability: A Laboratory Study. *Pertanika Journal of Tropical Agricultural Science* 33(2): 167 – 170.
- Yap, C.K. and Mohd Khairul, I.M.H. (2010c). A comparative study of heavy metal concentrations in the clam *Corbicula javanica* and surface sediments collected from clean and polluted sites of Langat River, Selangor. *Malaysian Applied Biology* 39(2): 61-66.
- Yap, C.K. and Rahim Ismail, A. (2011). Relationships of Distribution of Macrobenthic Invertebrates and the Physico-chemical Parameters from Semenyih River by Using Correlation and Multiple Linear Stepwise Regression Analyses. *Pertanika Journal of Tropical Agricultural Science* 34 (2): 229 – 245.
- Yap, C.K., Cheng, W.H., Ismail, A., Ismail, A.R. and Tan, S.G. (2009a). Biomonitoring of heavy metal (Cd, Cu, Pb, and Zn) concentrations in the west intertidal area of Peninsular Malaysia by using *Nerita lineata*. *Toxicological & Environmental Chemistry* 91(1): 29-41.
- Yap, C.K., Cheng, W.H., Ismail, A., Tan, S.G. and Rahim Ismail, A. (2005). Tissue Distribution of Heavy Metals (Cd, Cu, Pb and Zn) in the Green-lipped Mussel *Perna viridis* from Nesasi and Kuala Pontian, East coast of Peninsular Malaysia. *Pertanika Journal of Tropical Agricultural Science* 28(1): 13-22.
- Yap, C.K., Hisyam, M.N.D., Edward, F.B., Cheng, W.H. and Tan, S.G. (2010a). Concentrations of Heavy Metal in different Parts of the Gastropod, *Faunus ater* (Linnaeus), collected from Intertidal Areas of Peninsular Malaysia. *Pertanika Journal of Tropical Agricultural Science* 33 (1): 45 – 60.
- Yap, C.K., Ismail, A. and Tan, S.G. (2002). Condition index of green-lipped mussel *Perna viridis* (Linnaeus) as a potential physiological indicator of ecotoxicological effects of heavy metals (Cd and Pb). *Malaysian Applied Biology* 31(2): 37-45.
- Yap, C.K., Ismail, A. and Tan, S.G. (2003). Water Content, Shell Thickness, Conversion Factor and Condition Index of the Green-Lipped Mussel *Perna viridis* (Linnaeus) from Malaysian Coastal Waters. *Malayan Nature Journal* 56:4, 387-396.
- Yap, C.K., Ismail, A., and Tan, S.G. (2004b). The shell of the green-lipped mussel *Perna viridis* (Linnaeus) as a biomonitoring material for Zn: Correlations of shells and geochemical fractions of surface sediments. *Malaysian Applied Biology* 33(1): 83-92.
- Yap, C.K., Ismail, A., Omar, H., and Tan, S.G. (2003). Accumulation, depuration and distribution of cadmium and zinc in the green-lipped mussel *Perna viridis* (Linnaeus) under laboratory condition. *Hydrobiologia* 498: 151-160.
- Yap, C.K., Ismail, A., Tan, S.G. and Omar H. (2002). Correlations between speciation of Cd, Cu, Pb and Zn in sediment and their concentrations in total soft tissue of green-lipped mussel *Perna viridis* from the west coast of Peninsular Malaysia. *Environment International* 28, 117–126

- Yap, C.K., Ismail, A., Tan, S.G. and Rahim Ismail A. (2007). The distribution of the heavy metals (Cu, Pb and Zn) in the soft and hard tissues of the green lipped mussel *Perna viridis* (Linnaeus) collected from Pasir Panjang, Peninsular Malaysia. *Pertanika Journal of Tropical Agricultural Science* 30(1): 1-10.
- Yap, C.K., Ismail, A., Tan, S.G. and Rahim Ismail, A. (2007). The distribution of the heavy metals (Cu, Pb and Zn) in the soft and hard tissues of the green lipped mussel *Perna viridis* (Linnaeus) collected from Pasir Panjang, Peninsular Malaysia. *Pertanika Journal of Tropical Agricultural Science* 30(1): 1-10.
- Yap, C.K., Noorhaidah, A., Azlan, A., Nor Azwady, A.A., Ismail, A., Ismail, A.R., Siraj, S.S. and Tan, S.G. (2009). *Telescopium telescopium* as potential biomonitors of Cu, Zn, and Pb for the tropical intertidal area. *Ecotoxicology and Environmental Safety* 72: 496–506.
- Yoshida T., Yamauchi H. and Fan Sun G. (2004). Chronic health effects in people exposed to arsenic via the drinking water: dose-response relationships in review. *Toxicology and Applied Pharmacology* 198: 243–52.
- Young, S.M. and Ishiga, H. (2014). Assessment of dam removal from geochemical examination of Kuma River sediment, Kyushu, Japan. *Environmental Monitoring and Assessment* 186: 8267–8289.
- Yuksel, O. (2015). Influence of municipal solid waste compost application on heavy metal content in soil. *Environmental Monitoring and Assessment* 187: 313.
- Zaharah, A.R., Zulkifli, H. and Sharifuddin, H.A.H. (1997). Evaluating the efficacy of various phosphate fertilizer sources for oil palm seedlings. *Nutrient Cycling in Agroecosystems* 47: 93-98.
- Zambelli, B. and Ciurli, S. (2013). Nickel and Human Health. In *Interrelations between Essential Metal Ions and Human Diseases*, ed. Sigel, A., Sigel, H., and Sigel, R.K.O., pp. 321-357. Springer Science+Business Media Dordrecht.
- Zar, J.H. (1996). *Biostatistical analysis*, 3rd edition. New Jersey: Prentice Hall.
- Zhang, Y., Xia, J., Liang, T. and Shao, Q. (2010). Impact of Water Projects on River Flow Regimes and Water Quality in Huai River Basin. *Water Resource Management* 24: 889–908.
- Zhao, H., Li, X., Wang, X. and 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: 203–210.
- Zhao, Q., Liu, S., Deng, L., Dong, S. and Wang C. (2013). Longitudinal distribution of heavy metals in sediments of a canyon reservoir in Southwest China due to dam construction. *Environmental Monitoring and Assessment* 185: 6101–6110.
- Zheng, N., Wang, Q., Zhang, X., Zheng, D., Zhang, Z. and Zhang, S., (2007). Population health risk due to dietary intake of heavy metals in the industrial area of Huludao city, China. *Science of the Total Environment* 387: 96–104.
- Zhou, J., Dang, Z., Cai M. and Liu C. (2007). Soil heavy metal pollution around the Dabaoshan mine, Guangdong province, China [J]. *Pedosphere* 17(5): 588-594

- Zhou, Q., Zhang, J., Fu, J., Shi, J. and Jiang, G. (2008). Biomonitoring: An appealing tool for assessment of metal pollution in the aquatic ecosystem. *Analytica Chimica Acta* 606: 135–150.
- Zhu, H., Yuan, X., Zeng, G., Jiang, M., Liang J., Zhang C., Yin, J., Huang, H., Liu, Z. and Jiang, H. (2012). Ecological risk assessment of heavy metals in sediments of Xiawan Port based on modified potential ecological risk index. *Transactions of Nonferrous Metals Society of China* 22: 1470-1477.
- Zhu, X., Ji, H., Chen, Y., Qiao, M. and Tang, L. (2013). Assessment and sources of heavy metals in surface sediments of Miyun Reservoir, Beijing. *Environmental Monitoring and Assessment* 185: 6049–6062.
- Zimmer A.L., Asmund, G., Johansen P., Mortensen, J. and Hansen B.W. (2011). Pollution from mining in South Greenland: uptake and release of Pb by blue mussels (*Mytilus edulis* L.) documented by transplantation experiments. *Polar Biology* 34: 431–439.