HEAVY METALS MOBILIZATION AND BIOAVAILABILITY IN A TROPICAL ESTUARINE LAGOON IN SOUTH-WEST NIGERIA

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CERTIFICATION

This is to certify that the Thesis

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For the award of the degree of
DOCTOR OF PHILOSOPHY (Ph.D)
is a record of original research carried out
By
USESE Amii Isaac
in the Department of Marine Sciences

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DEDICATION

This work is dedicated to the El-Shadai God, the Incomparable Father and the Memory of my Beloved mother, Late Mrs Roseline Isaac Usese (Nee Anike) whose desire was to see her girls excel academically and be exceedingly great in life!

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'Eyes hath not seen, nor ear heard, neither have entered into the heart of man, the things which God hath prepared for them that love Him and are called according to His purpose'

Usese, A. I.

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LIST OF ABBREVIATIONS

APHA	American Public Health Association
AWWA	American Water Works Association
As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
Co	Cobalt
Fe	Iron
Mn	Manganese
Ni	Nickel
Pb	Lead
SPSS	Statistical Package for Social Sciences
Zn	Zinc
XRD	X-ray Diffractometry
SEM	Scanning Electron Microscopy
DORM-3	Dog Fish Muscle
CRM	Certified Reference Materials
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
HPLC	High Performance Liquid Spectrometry
SQG	Sediment Quality Guidelines
ASV	Average Shale Value
WHO	World Health Organization
USEPA	United State Environmental Protection Agency
FMENV	Federal Ministry of Environment
BSAF	Bio sediment Accumulation Factor
BWAF	Bio water Accumulation Factor

ABSTRACT

Environmental issues related to heavy metals and their biological effects continously heightens investigation into the risk associated with their presence and accumulation in aquatic ecosystems globally**.** This study investigated the mobilization, partitioning, bioavailability and risk associated with the heavy metal levels in the Lagos Lagoon between September 2013 and February 2015. It entailed the division of the lagoon into five zones and sampling carried out on a seasonal basis. The physicochemical and geochemical characteristics of bottom water and sediment were determined using standard methods and procedures. X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM) was used to evaluate factors responsible for metals immobilization from sediment. Heavy metal (Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd) and Lead (Pb)) levels in bottom water, pore-water, sediment, demersal fish (*Liza falcipinnis*, *Bathygobius soporator*, *Mugil cephalus*, *Chrysichthys nigrodigitatus*) and macrobenthic invertebrate (*Tympanotonus fuscatus)* were analysed by An Agilent 7500c Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Agilent Technologies, Tokyo, Japan). The quality of procedure was checked using Certified Reference Materials (DORM-3 and NIST 2711l). Potential mobility and bioavailability of heavy metals was determined after the fractionation of heavy metals into operationally defined phases using a five step sequential extraction procedure while Arsenic speciation in *C. nigrodigitatus* was achieved by 1:1 extraction with Methanol: Water. Risk indices and empirical Sediment Quality Guidelines (SQGs) were used to evaluate ecological and public health risks. The results from physicochemical analysis showed significant variations ($P < 0.05$) for a number of parameters and most parameters fluctuated with seasonal precipitation. Temperature although higher in the dry season did not significantly ($P > 0.05$) change as compared to salinity which had a seasonal bias. X-ray diffractometry (XRD) and Scanning electron microscopy implicated pH, salinity, redox potential (Eh), FeS, alumino-silicate and silty-clay minerals in enhancing metals immobilization and bioavailabilty. There were no regular or consistent seasonal variations in the levels of heavy metals in all zones sampled but heavy metals with relatively higher concentrations were also found to be the most abundant in all investigated environmental and biological media. Significantly lower concentrations of heavy metals which varied from -0.0001 mg/L for Cadmium (Cd) and 2.5550mg/L for Iron (Fe) were recorded in all zones for bottom water irrespective of season. There was also significant variation ($P <0.05$) in the levels of heavy metals in pore-water with relatively higher concentrations (0.005mg/L for Cd and 72.08mg/L for Fe) as compared to bottom water. The concentrations of observed heavy metals in sediments which rarely exceeded threshold element levels for analysed metals was in the decreasing order; Fe> Mn > Zn >Cu > Cr > Pb > Co > Ni > As >Cd. Generally, with only few exceptions, concentrations of heavy metals in zones 2 and 3 and some stations in zones 1 and 4 (adjoined by Iddo – Oworonshoki- Ikorodu) which are closest to the diverse pollution sources in the Lagos Lagoon was significantly higher than zones 4 and 5 (adjoined by Ikoyi – Ajah- Ibese). There were significant variations ($p < 0.05$) in metals concentration in tissues of biota except for Mn and Zn. The levels of metal bioaccumulated in biota were in the order: *T. fuscatus* > *L. falcipinnis* > *B. soporator* >*M. cephalus* > *C. nigrodigitatus*. Bio-sediment Accumulation Factor (BSAFs) showed that *T. fuscatus* accumulated higher levels than demersal fish species. Although, metals accumulation in fish did not exceed the international permissible standards suggesting that these species are suitable for human consumption, arsenic speciation in *C. nigrodigitatus* revealed bioaccumulation of toxic inorganic arsenic species (As III) in varying concentrations and calls for further investigation. From geochemical fractionation of metals in sediments, observed order of potential mobility and bioavailability of metals was; Cd > Zn > Mn > Co > Ni > As > Cu> Pb > Fe > Cr. Metals like Cr, Ni, Fe and Pb showed the strongest association with the residual fractions (60%–92%, 53%–67%, 24%–85% and 35%–67%) indicating significant geogenic source while Cd and Zn were found to be predominantly associated with the mobile phase (75%–99%) from anthropogenic inputs. Thus, Cd and Zn represent metal of greatest concern due to the high mobility which by implication, may enter the food chain and pose ecological risk or adverse effects to ecological receptors and humans. The evaluated pollution indices only implicated Cd and Zn around the western axis of the lagoon with very significant enrichment (Zn-19.95-32.30; Cd-14.23-134.82), high degree of contamination (C_d) for Cd (16.88-21.56) and high risk from the Risk Assessment Code (RAC) (Zn- 82.53% and Cd, 89.47%). However, based on applied sediment quality guidelines (SQG), pollution load index (PLI) and geochemical accumulation ($Igeo < 0$) and low bioavailability for almost all metals, the Lagos Lagoon can be said to be relatively unpolluted. This study therefore, establishes the significant role of anthropogenic sources of metals, geochemical fractionation, and primary crystal structure of sediments in controlling the release, distribution and bioavailability of metals in the Lagos Lagoon ecosystem.

REFERENCES

.

Abdallah, A. T. and Moustafa, M. A. (2002). Accumulation of lead and cadmium in the marine prosobranch *Nerita saxtilis*, chemical analysis, light and electron microscopy. *J. Egypt Acad. Soc. Environ. Develop. (D- Environ Stud).* **2:** 93-106

Ablabaster, J. S. and lloyd, R. (1980). *Water Quality Criteria for Freshwater Fish*. FAO and Butterworths, London.

Acevedo-Figueroa, D., Jimenez, B. D. and Rodriguez-Sierra, C. J. (2006). Trace metals in sediments of two estuarine lagoons from Puerto Rico. *Environmental pollution* **141**: 336-342.

Adámek, Z., Andreji, J. and Gallardo, J. M. (2007). Food Habits of Four Bottom-Dwelling Gobiid Species at the Confluence of the Danube and Hron Rivers (South Slovakia) I*nter. Rev. Hydrobiol*, **92**(4-5): 554–563.

Adebamowo, E. O., Agbede, O. A, Sridhar, M. K. C. and Adebamowo, C. A. (2006a). An evaluation of lead levels in residential paints sold in Nigeria markets. *Indoor Built Environ* **15**: 551–4.

Adebamowo, E. O., Agbede, O. A., Sridhar, M. K. C. and Adebamowo, C. A. (2006b). An examination of knowledge, attitudes and practices related to lead exposure in South Western Nigeria. BMC Public Health **6**: 82.

Adeniyi, A. A., Yusuf, K. A. and Okedeyi, O. O (2008). Assessment of the exposure of two fish species to metals pollution in the Ogun river catchments, Ketu, Lagos, Nigeria. *Environ. Monit. Assess*. **137**: 451-458

Aderinola, O. J., Clarke, E. O., Olarinmoye, O. M., Kusemiju, V. and Anatekhai, M. A. (2009). Heavy metals in surface water, sediments, fish and periwinkles of Lagos Lagoon. *Am.-Eurasian J. Agric. and Environmental Science*, **5**(5): 609-617.

Adite, A., Winemiller, K. O and Fiogbe, E. D (2006). Population structure and reproduction of the African bony-tongue Silver Catfish in the So River-floodplain system (West Africa): implications for management. *Ecol. Freshwat. Fishes* **15**: 30-39.

Agah, H., Leermakers, M., Elskens, M., Fatemi, S. M. R and Baeyens, W. (2009). Accumulation of trace metal in the muscle and liver tissue of five fish species from the Persian Gulf. *Environmental Monitoring Assessment*, **157**:499-514.

Aisen, P., Enns, C. and Wessling-Resnick, M. (2001). Chemistry and biology of eukaryotic iron metabolism *Int. J. Biochem. Cell Biol.* **33**: 940-959

Ajagbe, F. E.; Otitoloju, A. A. and Osibona, A.O (2012). Diversity of the edible fishes of the Lagos Lagoon, Nigeria and the public health concerns based on their Lead (Pb) content. *International Journal of Fisheries and Aquaculture.* **2(**3**):** 55-62

Ajao, E.A. and Fagade, S.O. (1990). Production and population dynamics of *Pachymelania aurita*. *Arch. Hydrobiol*. **120**(1): 97-109

Ajao, E.A., Oyewo, E.O. and Unyimadu, J. P. (1996). A review of the Pollution of Coastal Waters in Nigeria A70MR Technical paper 107,20pp.

Akhurst, D. J., Jones, G. B. and McConchie, D. M. (2004). The application of sediment capping agents on phosphorus speciation and mobility in a sub-tropical dunal lake. *Marine and Freshwater Research* **55**: 715-725.

Akhurst, D. J., Jones, G. B., Clark, M. and McConchie, D. M. (2006). Phosphate removal from aqueous solutions using neutralised bauxite refinery residues (BauxsolTM). *Environmental* Chemistry **3**: 65-74.

Akhurst, D.J., Clark, M.W., Reichelt-Brushett, A. and Jones, G.B. (2011). Grain size normalisation: a case for post extraction normalisation and inclusion of selective extraction procedures, *Limnology and Oceanography, Methods* 9: 215-231.

Akpata, T.V.I., Onyenekan, J.A and Nwankwo, D.I. (1993). Impact of organic pollution on the bacterial plankton and benthic populations of Lagos Lagoon, Nigeria. *International Journal of Ecology and environmental Science* **19:**73 – 82.

Aksoy, A., Demirezen, D. and Duman, F. (2005). Bioaccumulation, detection and analyses of heavy metal pollution in Sultan Marsh and its environment. *Water, Air and Soil Pollution,* **164**: 241-255.

Aktar, Md.W, Sengupta, D. and Chowdhury, A. (2011). Occurrence of heavy metals in fish: a study for impact assessment in industry prone aquatic environment around Kolkata in India. *Environ. Monit. Assess*. **181**: 51–61.

Alfred-Ockiya, J. F (2000). Study of food habits of goby, *Porogobius schlegelii* (Günther, 861) from Elechi Creek, off Bonny River, Niger Delta, Nigeria. *J. Aqua. Sci*., **15**: 70-72

Alfred-Ockiya, J.F. (1999). Microbial flora of partially processed periwinkles (*Tympanotonus fuscatus)* from local markets in Port Harcourt, Nigeria. Nigeria. *J. Aqua. Sci*., **14**: 51-53

Alina, M., Azrina, A., Mohd Yunus, A.S., Mohd Zakiuddin, S., Mohd Izuan Effendi, H. and Rizal, M. R. (2011). Heavy metals (Mercury, Arsenic, Cadmium, Plumbum) in selected marine fish and shellfish along the Straits of Malacca. *International Food Research Journal* **19**(1): 135-140

Allen, G. and Robertson, D (1994). Fishes of the Tropical Eastern Pacific. Honolulu, Hawaii University of Hawaii Press.

Al-majed N, Preston, M. (2000). An assessment of the total and methyl mercury content of zooplankton and fish tissue collected from Kuwait territorial waters. *Mar. Pollut. Bull.* **40**: 298–307

Alonso-Castillo, M. L., Sanchez Trujillo, I., Vereda Alonso, E., Garcia de Torres, A. and 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). *Mar Pollut Bull* **76**: 427–34.

Altundogan, H. S., Altundogan, S., Tumen, F. and Bildik, M. (2002). Arsenic adsorption from aqueous solutions by activated red mud. *Waste Management.* **22**: 357-363.

Amaeze, N. H., Egonmwan, R. I., Jolaoso, J. F. and Otitoloju, A. A. (2012). Coastal Environmental Pollution and Fish Species Diversity in Lagos Lagoon, Nigeria. International Journal of Environmental Protection. **2**(11): 8-16

Amina, L. R. S., Mandal, R., Nouri, M. H., Murimboh, J., Chakrabart, C. L., Back, M. H., Gregoire, D. C. and Schroeder, W. H. (1999). Effect of metal/fulvic acid mole ratios on the binding of Ni (II), Pb (II), Cu (II), Cd (II), and Al (III) by two well-characterized fulvic acids in aqueous model solutions, *Analytica Chimica Acta*. **402**: 211–221.

Andrewes, P., Demarini, D. M., Funasaka, K., Wallace, K., Lai Vivian, W. M., Hongsui, S. Cullen, W. R. and Kitchin K.T. (2004). Do arsenosugars pose a risk to human health? The comparative toxicities of a trivalent and pentavalent arsenosugar. *Environ. Sci. Technol.* **38**: 4140–4148.

APHA (American Public Health Association). (1998). Standard methods for the examination of water and wastewater (20th edn).Washington, DC: APHA.

APHA-AWWA-WEF (2005). *Standard Methods for the examination of water and wastewater,* 21st edition, 900pp.

Arakel, A. V. (1995). Towards developing sediment quality assessment guidelines for aquatic systems: an Australian perspective. *Australian Journal of Earth Sciences*. **42**: 335-369.

Arcega-Cabrera, F., Armienta, M. A., Daesslé, L. W., Castillo-Blum, S. E., Talavera, O., and Dótor, A. (2009). Variations of Pb in a mine-impacted tropical river, Taxco, Mexico: use of geochemical, isotopic and statistical tools. *Applied Geochemistry*. **24**: 162–171

Asuquo, F. E and Ewa-Oboho I. (2004). Fish species used as biomarker for heavy metal and hydrocarbon contamination for cross river, Nigeria. *The Environmentalist* **24**: 29–37

ATSDR (Agency for Toxic Substances and Disease Registry). (2005). Toxicological profile for nickel. US Department of Health and Human Services, Atlanta, GA, USA

Atta, M. B., Sabaie, L. A., Noaman, M. A., and Kassab, H. E. (1997). The effect of cooking on the concentration of heavy metals in fish *(Tilapia nilotica). Food Chemistry,* 58: 1–4.

Awofolu, O. R., Mbolekwa, Z., Mtshemla, V. and Fatoki, O. S. (2005). Levels of Trace Metals in Water and Sediment from Tyume River and its effects on an irrigated farmland. *Water South Africa*. **31**(1): 87-94.

Ayoola, S.O. and Kuton, M. P (2009). Seasonal Variation in Fish Abundance and Physicochemical Parameters of Lagos Lagoon, Nigeria. *African. Journal of Environmental Science and Technology* **3** (5): 149-156

Baeyens, W., Gao, Y., De Galan, S., Bilau, M., Van Larebeke, N. and Leermakers, M. (2009). Dietary exposure to total and toxic As in Belgium: Importance of As speciation in North Sea fish. *Molecular Nutrition & Food Research*. **53**(5): 558-565.

Baeyens, W., Monteny, F., Leermakers, M. and Bouillon, S. (2003). Evaluation of sequential extractions on dry and wet sediments. *Analytical and Bioanalytical Chemistry*. **376:** 890-901.

Baken, S., Degryse, F., Verheyen, L., Merckx, R. and Smolders, E. (2011). Metal complexation properties of freshwater dissolved organic matter are explained by its aromaticity and by anthropogenic ligands. *Environmental Science and Technology* **45**(7): 2584-2590.

Bard, A. J. and Faulkner, L. R. (1980). *Electrochemical methods*. Wiley, New York, 113-118pp

Barsytelovejoy, D. (1999). Heavy metal concentrations in water, sediments and Mollusks tissues. *Acta Zoologica Lituanica, Hydrobiologia,* **9** (2): 12-20.

Batley, G. E., Apte, S. C. and Stauber, J. L (2004). Speciation of trace metals in waters: progress since 1982. *Australian Journal of Chemistry* **57**: 903–919.

Becquer, T., Quantin, C., Sicot, M. and Boudot, J. P. (2003). Chromium availability in ultramafic soils from New Caledonia. *Sci Total Environ*. **301**: 251– 61

Bellucci, L.G., Frignani, M., Paolucci, D. and Ravanelli, M. (2002). Distribution of heavy metals in sediments of the Venice Lagoon: the role of the industrial area. *The Science of the Total Environment.* **295**: 35-49.

Benitez, L. N and Dubois, J. P. (1999). Evaluation of ammonium oxalate for fractionating metallic trace Elements in soils by sequential extraction. *International Journal of Environmental Analytical Chemistry* **75**: 261-273

Bernardello, M., Secco, T., Pellizzato, F., Chinellato, M., Sfrisco, A. and Pavoni, B. (2006). The changing state of contamination in the Lagoon of Venice. Part 2: Heavy metals. *Chemosphere* 337-342

Berra, T. (2001). *Freshwater Fish Distribution*. San Diego, California Academic Press.

Bhattacharya, P., Welch, A.H., Stollenwerk, K.G., McLaughlin, M. J., Bundschuh, J. and Panaullah, G. (2007). Arsenic in the environment: Biology and Chemistry. *Sci. Total Environ*. **379**: 109-120

Birch, G. F. (2003). A test of normalisation methods for marine sediments, including a new post extraction normalisation (PEN) technique. *Hydrobiologia* **492**: 5-13.

Bob-Manuel, F. G. (2012). A prelimenary study on the population estimation of the *periwinkles Tympanotonus fuscatus* (Linnaeus, 1758) and *Pachymelania aurita* (Muller) at the Rumuolumeni mangrove swamp creek, Niger Delta, Nigeria. *Agriculture and Biology Journal of North America*. **3**(6): 265-270.

Bohn, A. (1975). Arsenic in marine organisms from West Greenland. *Mar. Pollut. Bull*. **6**: 87–89.

Borggarrd, O. K. (1976). The use of EDTA in soil analysis: Acta Agriculturae Scandinavica, **26**: 114-150.

Borgman, U. (2000). Methods for assessing the toxicological significance of metals in aquatic ecosystems: bio-accumulation-toxicity relationships water concentrations and sediment spiking approaches. *Aquatic Ecosystem Health and Management* **3**: 277-289.

Bourg, A. C. M. (1988). Metal in aquatic and terrestrial systems: Sorption, speciation, and mobilization In: Salomons, W and Forstner, U., eds., Chemistry and biology of solid waste: Berlin, Springer-Verlag. 3-32.

Bradl, H (2005). *Heavy Metals in the Environment: Origin, Interaction and Remediation*. Elsevier/Academic Press, London.

Bradshaw, C., Tjensvoll, I., Sköld, M., Allan, I. J., Molvaer, J., Magnusson, J., Naes, K. and Nilsson, H. C. (2012). Bottom trawling resuspends sediment and releases bioavailable contaminants in a polluted Fjord. *Environ.Pollut*. **170**: 232–241.

Braissant, O., Decho, A.W., Dupraz, C., Glunk, C., Przekop, K.M., and Visscher, P.T. (2007). Exopolymeric substances of sulfate-reducing bacteria: Interactions with calcium at alkaline pH and implication for formation of carbonate minerals. *Geobiology* **5:** 401-411.

Brezonik, P. L. and Pollman, C. D. (1998). Phosphorus chemistry and cycling in Florida lakes: Global issues and local perspectives. In: '*Phosphorus Biogeochemistry in Subtropical Ecosystems*'. Lewis Publishers, Boca Raton, Florida. 69-110.

Brown, C. A. and Oyenekan, J. A. (1998). Temporary viability in the structure of benthic macrofaunal communities of the Lagos Lagoon, Nigeria. *Journal of Scientific Research and Development.* 7: 69-76

Brummer, G.W., Gerth J., and Herms, U. (1986). Heavy metal species, mobility and availability in soils. *Zeitschrift fur Pflanzenernahrung und Bodenkunde*. **149:** 382-398

Bryan, G. and Langston, W. J. (1992). Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: A review. *Environmental Pollution* **76**: 89–131.

BSR (Business for Social Responsibility) (2002). *Water Quality Guidelines and Pollutant Fact Sheet*. BSR. 30pp.

Buchman, M. F. (1999). NOAA *screening quick reference tables*. NOAA HAZMAT Report 99-1, Seattle, WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 pp.

Burger, J. and Gochfeld, M. (1997b). Lead and neurobehavioral development in gulls: a model for understanding effects in the laboratory and the field. *Neurotoxicology* **18**: 495–506.

Burger, J. and Gochfeld, M. (2000). Effects of lead on larids: a review of laboratory and field studies. *J. Toxicol Environ. Health B.* **3**: 59–78.

Burton, A.G. (2002). Sediment quality criteria in use around the world. *Limnology* **3**: 65-75.

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

Burton, G. A. (2010). Metal bioavailability and toxicity in sediments. *Crit Rev Environ Sci Technol.* **40***:* 852–907

Butcher, D. J. (2007). Environmental applications of arsenic speciation using atomic spectrometry detection. *App. Spec. Rev.*, **42**(1): 1-22.

Butt, D., Dowling, K. and Vinden, P. (2008). Assessment of cadmium distribution in some Australian krasnozems by sequential extraction. *Water, Air, and Soil Pollution* **190**: 157-169.

Callaway, J. C., Delaune, R. D. and Patrick, J. R. W. H. (1998). Heavy metal chronologies in selected coastal wetlands from northern Europe. *Marine Pollution Bulletin* **36**: 82-96.

Callender, E. and Rice, K. C. (2000). The urban environmental gradient: anthropogenic influences on the spatial and temporal distributions of lead and zinc in sediments. *Environmental Science and Technology* **34**: 232-238.

Calmano, W., Hong, J. and Förstner, U. (1993). Binding and mobilisation of heavy metals in contaminated sediment affected by pH and redox potential. *Water Science and Technology* **28**(8-9): 223-235.

Campbell, K. M., Root, R., O'Day, P. A. and Hering, J.G. (2008). A gel probe equilibrium sampler for measuring arsenic pore-water profiles and sorption gradients in sediments: I. Laboratory Development. *Environ. Sci. Technol*. **42**: 497-503.

Campbell, P.G.C. (1995). Interactions between trace metals and aquatic organisms: a critique of the free-ion activity model. In: Tessier A, Turner DR, editors. Metal speciation and bioavailability in aquatic systems. Chichester: Wiley. 45– 102.

Canadian Environmental Quality Guidelines (CEQG). (2003) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, *Hull*, Canada.

Canavan, R. W., Laverman, A. M. and Slomp, P. S. (2007). Modelling nitrogen cycling in coastal fresh water sediment. *Hydrobiologia*, **584**: 27-36.

Canlı, M and Atlı, G. (2003). The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. *Environmental Pollution* **121** (1): 129–136.

Cao, L., Tian, H., Yang, J., Shi, P., Lou, Q., Waxi, L., Ni, Z., and Peng, X. (2015). Multivariate Analyses and Evaluation of Heavy Metals by Chemometric BCR Sequential Extraction Method in Surface Sediments from Lingdingyang Bay, South China. *Sustainability*. **7:** 4938-4951

Carroll, S., O'Day, P. A., Esser, B. and Randall, S. (2002). Speciation and fate of trace metals in estuarine sediments under reduced and oxidised conditions, seaplane lagoon, Alameda Naval Air Station (USA). *Geochemical Transformations* **3**: 81–101.

Casas, S., Gonzalez, J. L., Andral, B., and Cossa, D. (2008). Relation between metal concentration in water and metal content in marine mussels (Mytilus galloprovincialis): impact of physiology. *Environ Toxicol Chem*, **27**: 1543-1552.

Catsiki, V. A and Strogyloudi, E. (1999). Survey of metal levels in common fish species from Greek waters. *The Science of the Total Environment*. **237**(238): 387–400.

Cempel, M. and Nikel, G. (2006). Nickel: A review of its sources and environmental toxicology. *Pol. J. Environ. Stud*. **15**: 375-382.

Cervantes C., Garcia J. C., Devars, S., Corona, F. G., Tavera, H. L. and Torres-guzman, J. (2001). Interactions of chromium with micro-organisms and plants. *FEMS Microbiol*; **25**: 335– 47.

Chakravarty, M. and Patgiri, A. (2009). Metal Pollution Assessment in Sediments of the Dikrong River, N. E. India, *Journal of Human Ecology*, **27**(1): 63-67.

Chandra Sekhar, k., Chary, N.S., Kamala, C.T., Suman Raj, D.S and Sreenivasa, A. (2003). Fractionation studies and bioaccumulation of sediment-bound heavy metals in Kolleru Lake by edible fish. *Environ. Int.* **29**:1001-1008

Chaney, R. L. (1988). Metal speciation and interaction among elements affect trace element transfer in agricultural and environmental food-chains, in Kramer, J.R. and Allen, H.E., eds., Metal Speciation: Theory, Analysis, and Application, Lewis Publications, Boca Raton, Fla. 219-259 pp.

Chapman, P. M. (1997). Is bioaccumulation useful for predicting impacts? *Mar Pollut Bull*, **34**(5): 282-283.

Chapman, P. M. (2012). "Heavy Metal" – Cacophony, Not Symphony. *Integrated Environmental Assessment and Management* **8**(2): 216.

Chapman, P. M., Wang, F.Y., Janssen, C., Persoone, G and Allen, H. E (1998). Ecotoxicology of metals in aquatic sediments: binding and release, bioavailability, risk assessment, and remediation. *Canadian Journal of Fisheries and Aquatic Sciences*, **55**(222): 1-2243.

Chapman, P.M., Wang, F., Adams, W.J. and Green, A. (1999). Appropriate applications of sediment quality values for metals and metalloids. *Environmental Science & Technology* 33: 3937-3941.

Chapman, P.M., Wang, F., Germano, J.D., Batley, G., (2002). Pore-water testing and analysis: the good the bad and the ugly. *Marine Pollution Bulletin*, **44**: 359–366.

Charlatchka, R and Cambier, P. (2000). Influence of reducing conditions on solubility of trace metals in contaminated soils. *Water Air Soil Poll*. **118**: 143–167.

Christophoridis, C., Dedepsidis., D. and 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.

Chukwu, L. O. (1991). Studies on heavy metal contamination of water, sediment and decapods crustaceans (Decapoda: Palaemonidae) from River Sasa. Ph.D Thesis University of Lagos. pp.164

Chukwu, L.O. (2006) Short-term toxicology and accumulation of heavy metals by African giant prawn, *Macrobranchium vollenhoevenii* (HERKLOTS, 1857) on exposure to treated industrial effluents. *Ecology environment and Conservation,* **12**(1): 1-7

Chukwu, L.O. (2006a). Physico-chemical characterization of pollutant load of treated industrial effluents in Lagos metropolis. *Journal of Industrial Pollution Control* Vol. **22**(1): 147 – 153.

Chukwu, L.O. and Nwankwo, D. I. (2004). The impact of land based pollution on the hydrochemistry and macrobenthic community of a tropical West African creek *Ekologia* **2**(1-2): 1-9

Clark, C.S. Rampal, K.G., Thuppil, V., Chen, C.K., Clark, R and Roda, S. (2006). "The lead content of currently available new residential paint in several Asian countries." *Environmental Research.*

Clark, C.S., Thuppil, 1 Clark, V., R., Sinha, S., Menezes, G., D'Souza, H., Nayak, N., Kuruvilla, A., Law, T., Dave, P and Shah, S. (2005). Lead in Paint and Soil in Karnataka and Gujarat, India. *Journal of Occupational and Environmental Hygiene* **2**: 38–44.

Clark, M. W. (1998). Redox stratification and heavy metal partioning in Avicennia dominated mangrove sediments: a geochemical model. *Chemical Geology* **149** (3-4), 147-171.

Clark, M. W. (2000). Geochemical Cycling of Heavy Metals in Brisbane River Estuary Dredge Sediments During Sub-aerial Disposal, and Consolidation at the Port of Brisbane Authority's Fisherman Islands Reclamation Paddocks. PhD Thesis, Southern Cross University, Lismore. 287pp

Clark, M. W., McConchie, D., Lewis, D. W. and Saenger, P. (1998). Redox stratification and heavy metal partitioning in *Avicennia*-dominated mangrove sediments: a geochemical model. *Chemical Geology* **147**(3-4): 147-171.

Cowan-Ellsberry, C. (1998). ICCA Contribution to inform the criteria Expert Group deliberations on Annexes D and E of the UNEP POPS Protocol.

Cunningham, W. P. and Cunningham, M. A. (2004). Principles of Environmental Science: Inquiry and Applications. McGraw Hill Publishers, New York, N.Y.

Cuong, D. T and Obbard, J. P. (2006). Metal speciation in coastal marine sediments from Singapore using a modified BCR-sequential extraction procedure. *Appl. Geochem* **21**: 1335–1346.

Damiens, G., His, E., Gnassia-Barelli, M., Quiniou, F. and Romeo M. (2004). Evaluation of biomarkers in oyster larvae in natural and polluted conditions. *Comparative Biochemistry and Physiology*, **138:** 121-128

Danovaro, R. and Pusceddu, A. (2007). Biodiversity and ecosystem functioning in coastal lagoons: Does microbial diversity play any role? *Estuarine, Coastal and Shelf Science* **75**: 4-12.

Darcy, G. H. (1978). Ecology of the crested goby, *Lophogobius cyprinoides* (Pisces: Gobiidae), in southern Florida. M.S. Thesis, Univ. Miami. 283pp.

Dassenakis, M., Adrianos, H., Depiazi, G., Konstantas, A., Karabela, M., Sakellari, A. and Scoullos, M. (2003). The use of various methods for the study of metal pollution in marine sediments, the case of Euvoikos Gulf, Greece. *Applied Geochemistry*. **18:** 781-794.

Davidson, W and Zhang, H. (1994). In situ speciation measurements of trace components in natural waters using thin film gels. *Nature*, **367**: 546-548.

Dawson, E. J and Macklin, M. G (1998). Speciation of heavy metals in floodplain and flood sediments: a reconnaissance survey of the Aire Valley, West Yorkshire, Great Britain *Environmental Geochemistry and Health* **20:** 67-76.

De Gieter, M., Leermakers, M., Van Ryssen, R., Noyen, J., Goeyens, L., and Baeyens, W. (2002). Total and toxic arsenic levels in North Sea Fish. *Archives of Environmental Contamination and Toxicology* **43:** 406–417.

Devesa-Rey, R., Díaz-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 of environmental management.* **91**(12): 2471–2477.

Di Toro D. M., Mahony, J. H., Hansen, D. J., Scott, K. J., Hicks, M. B., Mayr, S. M., and Redmond, M. (1990). Toxicity of cadmium in sediments: the role of acid volatile sulfides. *Environ. Toxicol. Chem.* **9**: 1487-1502.

Dietz, C., Madrid, Y., Camara, C. and Quevauviller, P. (2000). The capillary cold trap as a suitable instrument for mercury speciation by volatilization, cryogenic trapping, and gas chromatography coupled with atomic absorption spectrometry. *Anal. Chem.* **72**(17): 4178-4184.

Diouf, P. S. (1996). The Fish Population of the estuarine environment of the African coast: The example of the estuary salinity of the Sine saloum. University of Montpellier II. Thesis and Documents No. 156. ORSTOM; Paris. 267pp.

Directorate General of Drug and Food Control, Ministry of health, Republic of Indonesia (1989). Decree of the Head of NationalAgency of Drug and Food Control Republic of Indonesia No.:03725/B/SK/VII/89 regarding maximum limit of chemical contaminants in food.

Doig, L. E. and Liber, K. (2006). Nickel partitioning in formulated and natural fresh water sediments. *Chemosphere* **62**: 968-979.

Don-Pedro, K. N., Oyewo, E. O and Otitoloju, A. A. (2004). Trend of Heavy Metal Concentrations in Lagos Lagoon Ecosystem, Nigeria. *West African Journal of Applied Ecology*, **5**: 103-114.

Duffus, J. H. (on behalf of IUPAC, Chemistry and Human Health Division, Clinical Chemistry Section, Commission on Toxicology) (2002). "Heavy metals" – A meaningless term? *Pure Applied Chemistry* **74**: 793-807.

Durán, I., Sánchez-Marín, P. and Beiras, R. (2012). Dependence of Cu, Pb and Zn remobilization on physicochemical properties of marine sediments. *Mar Environ Res* 77: 43.

Duzgoren-Aydin, N.S., Wong, C. S .C., Aydin, A. Song, Z. You, M and Li, X. D. (2006). Heavy metal contamination and distribution in the urban environment of Guangzhou, SE China, *Environ. Geochem*. *Health*, **28**: 375-391

Edenborn, H.M. (2005) Rapid detection of bioavailable heavy metals in sediment porewaters using acid-volatile sulfide gel probes. *Environmental Geology*. **47**: 660-669.

Edmonds, J. S., Francesconi, K. A. (1993) Arsenic in seafoods: human health aspects and regulations *Marine Poll. Bull.*, **26**: 665-674.

Eggleton, J. and Thomas, K. V. (2004). A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. *Environ. Int.* **30**: 973–980.

Egonmwan, R.T. (1980). On the biology of *Tympanotonus fuscatus var rodula* (Gasstropoda: Prosobranchia: potamididae). Proceedings of the 8th International Malacological congress, Budapest.

Egonnwan I. R.E. (1980). The biology of *Tympanotonus fuscatus var radula* (gastropoda; prosobranchis, potamidae) M.Sc. Thesis, University of Lagos, Nigeria. 145pp

Eisler, R. (1988). Lead hazards to fish, wildlife, and invertebrates: a synoptic review. US Fish and Wildlife Service Report No. 85(114), Washington, DC.

Ekundayo, J. A. (1977). Environmental consequences of the pollution of the Lagos Lagoon. *Bull. Sci. Assoc. Nigeria* **3**: 290 –299.

Ekweozor, I. K. E., Dambo, W.B. and Daka, E. R. (2003). Zinc and Cadmium levels in *Crassostrea gasar* from the lower Bonny Estuary, Nigeria. *Journal of Nigerian Environmental Society* **1**(1): 31-40

Elder, J. F. (1989), Metal biogeochemistry in surface-water systems— A review of principles and concepts: U.S. Geological Survey Circular **10**(13): 43.

Elsokkary, L. H. and Muller, G. (1990). Assessment and speciation of chromium, nickel, lead and cadmium in the sediments of the river Nile. Egypt. *Science of the Total Environment.* **97**: 455–463

Emmanuel, B. E. (2009). The artisanal fishing gears, crafts technology and their efficiency in the Lekki lagoon, Nigeria. Ph.D Thesis, University of Lagos, Nigeria. 272pp

Emmanuel, B. E. and Onyema, I. C (2007). The Plankton and fishes of a tropical creek in South western Nigeria. *Turk. J. Fish. Aquat. Sc*. **7**: 105-113.

Erickson, R. J., Benoit., D. A., Mattson, V. R, Nelson, H. P Jr. and Leonard, E. N. (1996). The effects of water chemistry on the toxicity of copper to fathead minnows. *Environ. Toxicol. Chem.* **15**(2): 181–193

Esteves, F. A.; Caliman, A.; Santangelo, J. M.; Guariento, R. D.; Farjalla, V. F. and Bozelli, R. L. (2008). Neotropical coastal lagoons: An appraisal of their biodiversity, functioning, threats and conservation management. *Brazilian Journal of Biology,* **68**(4): 967-981.

European Commission (E.C.) (2001). Commission Regulation No. 466/2001, 08.03.2001. *Official Journal of Europian Communities* 1.77/1

Evangelou, V. P. (1995). Pyrite oxidation and its control. CRC Press. Boca-Raton.

Ewers, U. and Schlipköter, H. (1990). Lead. In: Merian Ernest, ed., Metals and Their Compounds in the Environment: Weinheim, Germany. 971-1014pp.

F.A.O. (1983). Compilation of legal limits for hazardous substances in fish and fishery products. FAO Fishery Circular. 464: 5-100

Fagade SO, Olaniyan CIO (1974). Seasonal distribution of the fish fauna of the Lagos Lagoon. *Bull.* De IFAN Ser. A, **36**(1): 244-254.

Falciani, R., Novaro, E., Marchesini, M., and Gucciardi, M. (2000). Multi-element analysis of soil and sediment by ICP-MS after a microwave assisted digestion method. *Journal of Analytical Atomic Spectrometry*, 15: 561-565.

Fan, W and Wang, W. X. (2001). Sediment geochemical controls on Cd, Cr, and Zn assimilation by the clam *Ruditapes philippinarum*. *Environ. Toxicol. Chem* **20**: 2309-2317.

Fan, W., Wang, W. X., Chen, J., Li, X. D., and Yen, Y. F. (2002). Cu, Ni and Pb speciation in surface sediments from a contaminated bay of northern China. Baseline Marine Pollution Bulletin, **44**: 816-826.

Fang, T., Li, X., and Zhang, G. (2005). Acid volatile sulfide and simultaneously extracted metals in the sediment cores of the Pearl River Estuary, South China. *Ecotoxicology and Environmental Safety.* 61: 420‑431.

FAO/FIDI, (1994). World Aquaculture production 1986 – 1997. Fisheries circular No. 815 (Review 6), FAO, Rome.

Farombi, E. O., Adelowo, O. A. and Ajimoko, Y. R. (2007). Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in African catfish (*Clarias gariepinus*) from Nigeria Ogun River. *International Journal of Environmental Research and Public Health,* **4**(2): 158-165

Fattorini, D., Notti, A., Di Mento, R., Cicero, A. M., Gabellini, M., and Russo, A. (2008). Seasonal, spatial and inter-annual variations of trace metals in musselsfrom the Adriatic Sea: A regional gradient for arsenic and implications for 1monitoring the impact of off-shore activities. *Chemosphere* **72**: 1524–1533.

Federal Ministry of Environmental Protection (FMENV) (1999). Guidelines to Standards for Environmental Pollution Control in Nigeria.

Feng, H., Han, X., Zhang, Z., and Yu, L. (2004). A preliminary study of heavy metal contamination in Yangtze River intertidal zone due to urbanization. *Marine Pollution Bulletin* **49**: 910-915.

Feyte, S., Tessier, A., Gobeil, C. and Cossa, D. (2010). In situ adsorption of mercury, methylmercury and other elements by iron oxyhydroxides and organic matter in lake sediments. *Applied Geochemistry* **25**(7): 984-995.

Fifi, U., Winiarski, T. and Emmanuel, E. (2013). Assessing the mobility of lead, copper and cadmium in a calcareous soil of Port-au-Prince, Haiti. *Int. J. Environ. Res. Public Health* **10**: 5830–5843.

Filgueiras, A. V., Lavilla, I. and Bendicho, C. (2002). Chemical sequential extraction for metal partitioning in environmental solid samples. *Journal of Environmental Monitoring* **4**: 823 -857

Fonge, B. A., Tening, A. S., Egbe, A. E., Awo, E. M., Focho, D. A., Oben, P. M., Asongwe, G. A. and Zoneziwoh, R. M. (2011). Fish *(Arius heudelotii* Valenciennes, 1840) as bioindicator of heavy metals in Douala Estuary of Cameroon. *African Journal of Biotechnology* **10**(73): 16581-16588

Food Standards Agency (2004). Total Diet Study: Total and inorganic arsenic in food. *Food Surveillance Information Sheet* 51/04.

Förstner, U. and Wittmann, G.T.W. (1983). Metal pollution in the aquatic environment. Springer-Verlag, Berlin Heidelberg New York 481pp.

Fowler, S.W., Readman, J.W., Oregioni, B., Villeneure, J. P and McKay, K. (1993). Petroleum hydrocarbons and trace metals in near shore Gulf sediments and biota before and after the 1991 War: An assessment of temporal and spatial trends. Marine Pollution Bulletin, **27**: 171-182.

Francis, T., Ramamohan, T. and Reddy, M. L. (2001). Liquid–liquid extraction of Hg (II) from acidic chloride solutions using bis-2-ethylhexyl sulfoxide. *J. Chem.Technol. Biot.* **76**(7): 737-742.

Fu, F. and Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review. *Journal of Environmental Management* **92**: 407-418.

Galhano, C., Rocha, F. and Gomes, C. (1999). Geostatistical analysis of the influence of textural, mineralogical and geochemical parameters on the geotechnical behaviour of the "Argilas de Aveiro" formation (Portugal). *Clay Minerals*. **34**: 109-116.

Gambrell, R.P., Wiesepape, J.B., Patrick, W.H., Jr., and Duff, M. C. (1991). The effects of pH, redox, and salinity on metal release from contaminated sediment: *Water, Air, and Soil Pollution* **57**(58): 359-367.

Gao, Y. (2009). Trace metal behavior in sedimentary environments. WB, Brussels, Belgium 310 pp.

Gao, Y., Leermakers, M., Gabelle, C., Divis, P., Billon, G., Ouddane, B., Fischer, J. C., Wartel, M., Baeyens, W. (2006). High-resolution profiles of trace metals in the pore waters of riverine sediment assessed by det and dgt. *Science of the Total Environment,* **362**: 266-277.

Genc, H., Tjell, J. C., McConchie, D and Schuiling, O. (2003). Adsorption of arsenate from water using neutralised red mud. *Journal of Colloid and Interface Science,* **264**: 327 334.

George S. G. and Young, P. (1986). The time course of effects of cadmium and 3-methylcholanthrene on activities of enzymes of xenobiotic metabolism and metallothionein levels in plaice, *Pleuronectes platessa, Comp Pharmacol. Toxicol. Endocrinol*. **83**: 37-44.

Gleyzes, C., Tellier, S. and Astruc, M. (2002). Fractionation studies of trace elements in contaminated soils and sediments: a review of sequential extraction procedures. *Trends in Analytical Chemistry* **21**(6-7): 451-467.

Gong, Z., Lu, X., Ma, M., Watt, C., and Le, X. C. (2002). Arsenic speciation analysis. *Talanta* **58**: 77-96.

Gonzalez, A. E., Rodriquiz, M. T., Sanchez, J., Espinosa, J. F. and Deha Rosa, F. J. B. (2000). Assessment of metal in sediments in tributary of Guadal Quiver River (Spain). Heavy metal partitioning and Relationship between the water and sediment system. *Water, Air and Soil Pollution*. **121**: 11-29.

Göttlein, A., Hell, U. and Blasek, R. (1996). A system for micro scale tensiometry and lysimetry. *Geoderma,* **69**:147-156.

Grolie, T.W. (1980). The Living World of the sea (7th edition) U.S.A. 343pp.

Guerin, T., Molenat, N., Astruc, A. and Pinel, R. (2000). Arsenic speciation in some environmental samples: a comparative study of HG-GC- QFAAS and HPLC-ICP-MS methods. *Appl Organomet Chem,* **14**: 401-410.

Gundersen, P. and Steinnes, E. (2003). Influence of pH and TOC concentration on Cu, Zn, Cd, and Al speciation in rivers. *Water Research* **37**: 307–318.

Guo, L., Hunt, B. J., Santschi, P. H. and Ray, S. M. (2001). Effect of Dissolved Organic Matter on the Uptake of Trace Metals by American Oysters. *Environ. Sci. Technol.* **35:** 885–893.

Hadson, P. V. (1988). The effect of metabolism on uptake, disposition and toxicity in fish. *Aquatic Toxicology*, **11**: 3-18.

Hahne, H. C. H. and Kroontje, W. (1973). Significance of pH and chloride concentration of behavior of heavy metal pollutants: mercury (II), cadmium (II), zinc (II) and lead (II). *J. Environ. Qual.* **2**: 444–450.

Hamelink, J. L., Landrum, P. F, Bergmann, H.L. and Benson, W. H. (Eds). (1994). *Bioavailability: Physical, chemical and biological interactions,* Lewis Publishers, Boca Raton, FL, USA.

Han F. X., Banin A., Su Y., Monts D. L., Plodinec J. M. and Kingery W. L. (2002). Industrial age anthropogenic inputs of heavy metals into the pedosphere. *Naturwissenschaften* 89: 497–504

Harmelin-Vivien, M. (2002). Energetics and Fish Diversity on Coral Reefs. In: Sale PF (ed.) Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem, San Diego, California Academic Press. 269pp.

Hedge, L., Knott, A. and Johnston, E., (2009). Dredging related metal bioaccumulation in oysters. *Mar. Pollut. Bull*. **58**: 832–840.

Hedman, J. E., Tocca, J. S. and Gunnarsson, J. S. (2009) Remobilization of polychlorinated biphenyl from Baltic Sea sediment: comparing the rolesof bioturbation and physical resuspension. *Environ. Toxicol. Chem.,* **28**; 2241–2249.

Hernández Crespo, C., Martín, M., Ferrís, M. and Oñate, M. (2012). Measurement of acid volatile sulphide and simultaneously extracted metals in sediment from Lake Albufera (Valencia, Spain). *Soil Sediment Contam Int J.* **21**: 176–191.

Heumann, K. G. (2002). Hyphenated techniques – the most commonly used method for trace elemental speciation analysis. *Anal Bioanal Chem* **373**: 323-324.

Hollert, H., Keiter, S., König, N., Rudolf, M., Ulrich, M. and Braunbeck, T. (2003). A new sediment contact assay to assess particle bound pollutantsusing zebrafish (*Danio rerio*) embryos. *J. Solid Sediments,* **3**: 197–207.

Horsfall, M. Jnr and Spiff, A. I. (1999). Speciation of Heavy Metals in inter-tidal Sediments of the Okrika River System, Rivers State, Nigeria. *Bull. of Chemical. Soc. of Ethiopia* **13**(1): 1 –9.

Horsfall, M. Jnr and Spiff, A. I. (2005). Speciation and Bioavailability of Heavy Metals in Sediments of Diobu River, Port Harcourt, Nigeria. *European Journ. of Sci. Res.* **6** (3): 20 –36

Horsfall, M. Jnr., Ogban, F. E. and Akporhonor, E. E. (2005). Sequential Fractionation of Trace Elements in Inter-Tidal Flat Sediments of the Brass River Estuary, Nigeria. *European J Scientific Research,* **7** (4): 64 -74.

Horsfall, M. Jnr; and Spiff, A. I. (2002). Distribution and Partitioning of Trace Metals in Sediments of the Lower Reaches of the New Calabar River, Port Harcourt, Nigeria. *Environ. Monitoring & Assessment, The Netherlands,* **78**: 309-326

Hosono, T., Su, C., Delinom, R., Umezawa, Y., Toyota, T., Kaneko, S. and Taniguchi, M., (2011). Decline in heavy metal contamination in marine sediments in Jakarta Bay, Indonesia due to increasing environmental regulations. *Estuar. Coast. Shelf Sci*. **92**: 297–306.

Hung Liu, H. T., Kneer, D., Asmus, H. and Ahnelt, H. (2008). The feeding habits of *Austrolethops wardi*, a gobiid fish inhabiting burrows of the thalassinidean shrimp *Neaxius acanthus. Estuarine, Coastal and Shelf Sci.,* **79**(4): 764-767

Huo, S., Xi, B., Yu, X., Su, J., Zan, F., and Zhao, G. (2013). Application of equilibrium partitioning approach to derive sediment quality criteria for heavy metals in a shallow eutrophic lake, Lake Chaohu, China. *Environ Earth Sci* **69**: 2275–85.

Ideriah, T.J.K., S.A. Braide and A.O. Briggs (2005). Distribution of Lead and total hydrocarbon in tissues of Periwinkles (*Tympauotnus* sp and *Pachymelania aurita*) in the Upper Bonny River, Nigeria. *J. Appl. Sci. Environ. Manage*. **10**(2): 135 – 143.

Ikem, A. and Adisa, S. (2011). Runoff effect on eutrophic lake water quality and heavy metal distribution in recent littoral sediment. *Chemosphere* **82**: 259‑267.

Ikem, A., Osibanjo, O., Sridhar, M.K.C. and Sobande, A. (2002), Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos, Nigeria. *Water Air Soil Pollut.* **140**: 307-333

Ip, C. C. M., Li, X. D., Zhang, G., Farmer, J. G., Wai, O. W. H. and Li, Y. S. (2004). Over one hundred years of trace metal fluxes in the sediments of the Pearl River Delta, South China. *Environmental Pollution* **132**: 157-172.

Isebor, C. E; Awosika, L. and Smith, S. V. (2006). Preliminary water, salt, and nutrient budgets for Lagos Lagoon, Nigeria. Nigerian Institute for Oceanography and Marine Research, Victoria Island, Lagos.

Ishikawa, D. N., Noale, R. Z., Ohe, T. H. K., Souza, E. B. R., Scarmínio, I. S., Barreto, W. J., and Barreto, S. R. G. (2009). Avaliation of the environmental risk by metal distribution in sediments from lakes formed by Cambé Stream at Londrina. *Quimica Nova* **32**: 1744-1449.

Iskrenova-Tchoukova, E., Kalinichev, A. G. and Kirkpatrick, R. J. (2010). Metal cation complexation with natural organic matter in aqueous solutions: molecular dynamics simulations and potential mean force. *Langmuir* **26** (20): 15909-15919.

Islam, M. S and Tanaka M. (2004). Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine Pollution Bulletin*. **48**: 624–649

ISO (2005). Soil-quality-Vocabulary. ISO, Geneva, Switzerland.11074.

Iwegbue, C.M.A.,Eghwrudje, M.O., Nwajei, G.E. and Egboh, S.H.O.(2007). Chemical speciation of heavy metals in the Ase River sediment, Niger Delta, Nigeria. *Chemical Speciation and Bioavailability*. 19(3): 117-127.

Iwegbue, C.M.A; Armioro, F. O and Onyenibe, S (2006). Study of heavy metal speciation in sediments impacted, with crude oil in the Niger Delta, Nigeria. *J of Societ Chimic Italia,* **97**(11-12): 1143 – 1155.

Jagadeesh, E. P., Azeez, P. A. and Banerjee, D. K. (2006). Modeling chemical speciation of copper in River Yamuna at Delhi, India. *Chemical Speciation and Bioavailbility*, **18**(2): 61-69.

Jain, C. K (2004). Metal fractionation study on bed sediments of River Yamuna, India. *Water Research.* **38**: 569-578.

Jain, C. K, Gupta, H and Chakrapani, G. J. (2008). Enrichment and fractionation of heavy metals in bed sediments of River Narmada, India. *Environmental Monitoring and Assessment*, **141:** 35–47.

Jain, C. K. and Ali, I. (2000). Arsenic: occurrence, toxicity and speciation techniques. *Wat. Res.* **34**: 4304-4312.

Jakimska, A., Konieczka, P., Skóra, K. and Namieśnik J. (2011). Bioaccumulation of Metals in Tissues of Marine Animals, Part I: the Role and Impact of Heavy Metals on Organisms. *Pol. J. Environ. Stud*. **20**(5): 1117-1125

Jamabo, N. A., Alfred-Ockiya, J. F. and Chinda, A. C. (2009). Growth, mortality and recruitment Studies of Periwinkle *Tympanotonus fuscatus* Var *fuscatus (*Linnaeus, 1758) in the Bonny River, Niger Delta, Nigeria. *Environment and Ecology,* **27**(4A): 1676.

Jamabo, N. and Chinda, A. (2010). Aspects of the Ecology of *Tympanotonus fuscatus* var *fuscatuis* (Linnaeus, 1758) in the Mangrove Swamps of the Upper Bonny River, Niger Delta, Nigeria. *Current Research Journal of Biological Sciences,* **2**(1): 42-47.

Janssen, C.R., K. De Schamphelaere, D. Heijerick, B. Muyssen, K. Lock, B. Bossuyt, (2000). Uncertainties in the environmental risk assessment of metals. *Hum Ecol Risk Assess*. **6:** 1003-1018.

Jones, B. And Turki, A. (1997) Distribution and speciation of heavy metals in surficial sediments from the Tees Estuary, north-east England, *Mar. Pollut. Bull* **34:** 768-779

Jones, B. G., Killian, H. E., Chenhall, B. E. and Sloss, C. R. (2003). Anthropogenic effects in a coastallagoon: geochemical characterization of Burril Lake, New South Wales, Australia. *Journal of Coastal Research*, **19**: 621-632.

Jorgensen, B. B. (1996). Material flux in the sediment. In *'Eutrophication in Coastal Marine Ecosystems - Coastal and Estuarine Studies'* **52**: 115-135. American Geophysical Union,Washington, DC.

Kalay, M., Ay, O. and Canlı, M. (1999). Heavy metal concentrations in fish tissues from the Northeast Mediterranean Sea. *Bulletin Environmental Contamination and Toxicology*, **63:** 673–681.

Kalbitz, K. and Wennrich, R. (1998). Mobilization of heavy metals and arsenic in polluted wetlands soils and its dependence on dissolved organic matter. *Sci. Total Environ.* **209**: 27–39.

Karadede, H., Oymak, S.A., and Unlu, E. (2004). Heavy metals in mullet, Liza abu, and catfish, Silurustriostegus, from the Ataturk Dam Lake (Euphrates), Turkey. *Environment International*, **30:** 183-188.

Karthikeyan, S., Palaniappan, P. L. R. M. and Sabhanayakan, S. (2007): Influence of pH and water hardness upon Nickel accumulation in edible fish *Cirrhinus mrigala. J. Environ. Biol*. **28**: 484-492.

Kaushik, A., Kansal, A., Santosh, Meena, Kumari, S. and Kaushik, C.P. (2009). Heavy metal contamination of river Yamuna, Haryana, India: Assessment by Metal Enrichment Factor of the Sediments. *Journal of Hazardous Materials*, **164**: 265-270.

Kelderman, P. and Osman, A. A. (2007). Effects of redox potential on heavy metal binding forms in polluted canal sediments in Delft (The Netherlands). *Water Research* **41**: 4251-4261.

Kersten, M and Forstner, U (1986). Chemical fractionation of heavy metalsin anoxic estuarine and coastal sediments. *Water. Sci. Technol*. **18**:121-130.

Kersten, M. and Forstner, U. (1986). Chemical Fractionation of Heavy Metals in Anoxic Estuarine and Coastal Sediments. *Water Science and Technology*. 18(4-5): 121-130.

Kersten, M., (1988). Geochemistry of priority pollutants in anoxic sludges: Cadmium, arsenic, methyl mercury, and chlorinated organics, in Salomons, W., and Forstner, U., eds., Chemistry and biology of solid waste: Berlin, Springer-Verlag, 170-213pp.

Keskin, Y., Baskaya, R., Ozyaral, O., Yurdun, T., Luleci, N. E. and Hayran, O. (2007). Cadmium, lead, mercury and copper in fish from the Marmara Sea, Turkey. *Bulletin of Environmental Contamination and Toxicology*. **78**: 258–261.

Khlifi, R. and Hamza-Chaffai, A. (2010). Head and neck cancer due to heavy metal exposure via tobacco smoking and professional exposure: A review. *Toxicology & Applied Pharmacology* **248**: 71–88.

Kim, H. J., Baek, K., Kim, B. K. and Yang, J. W. (2005). Humic substance-enhanced ultrafiltration for removal of cobalt. *Journal of Hazardous Material* **122**: 31-36.

Kim, S. D., Ma, H., Allen, H. E. and D.K. Cha (1999). Influence of dis- solved organic matter on the toxicity of copper to Ceriodaphnia dubia: effect of complexation kinetics. *Environ. Toxicol. Chem*. **18**: 2433-2437.

Knott, N. A., Aulbury, J. P., Brown, T. H. and Johnston, E. L. (2009). Contemporary ecological threats from historical pollution sources: impacts oflarge-scale resuspension of contaminated sediments on sessile invertebraterecruitment. *J. Appl. Ecol*., **46**: 770–781.

Knox, A. S, Paller, M. H, Nelson, E, Specht, W. and Gladden, J. (2006) Contaminant assessment and their distribution and stability in constructed wetland sediments, *J. Environ. Qual.* **35:** 1948-1959.

Korcharyan, A. G., Venitsianove, E. V., Safronova, N. S. and Seren Kaya, E. P. (2003). Seasonal Variation in the forms of heavy metals occurrence in the Kuibyshen Reservoirs Water and Bottom Deposits. *Water Resources* **4**: 404-412.

Kostka, J. E. and Luther, G. W. (1994). Partitioning and speciation of solid-phase iron in saltmarsh sediments. *Geochim Cosmochim Acta* **58**: 1701–10.

Koukal, B., Guéguen, C., Pardos, M. and Dominik, J. (2003). Influence of humic substances on the toxicity effects of cadmium and zinc to green alga *Pseudokirchneriella subcapitata*. *Chemosphere*. **53**: 953−961.

Kumar, B, Sajwan, K. S and Mukherjee, D. P. (2012). Distribution of heavy metals in valuable coastal fishes from North East Coast of India. *Turkish Journal of Fisheries and Aquatic Sciences* **12**: 81-88

Kuroshima, R., Kimura S., Date, K. and Yamamoto, Y. (1993). Kinetic analysis of cadmium toxicity to red sea bream Pagrus major. *Ecotoxicol Environ Saf*. **25**: 300–314.

Kuroshima, R., Kimura, S., Date, K. and Yamamoto, Y. (1993). Kinetic analysis of cadmium toxicity to Red Sea Bream, *Pagrus major*. *Ecotoxicol. Environ. Safety* **25**(3): 300-314.

Lacerda, L. D., Fernandez, M. A., Calazans, C. F. and Tanizaki, K. F. (1992) Bioavailability of heavy metals in sediments of two coastal lagoons in Rio de Janeiro, Brazil. *Hydrobiologia*, **228**: 65-70.

Lam, M. H. W. Tjia, A. Y. W., Chan, C. C., Chan, W. P. and Lee, W. S. (1997). Speciation study of chromium, copper and nickel in coastal estuarine sediments polluted by domestic and industrial effluents. *Marine Pollution Bulletin* **34**: 949 – 959.

Landis, W. G. and Yu, M (2003). Introduction to Environmental Toxicology: Impacts of Chemicals Upon Ecological Systems. CRC Press, Lewis Publishers, Boca Raton, FL Lipton, Eric and Louise Story, "Bid to Root Out Lead Trinkets Falters in U.S." New York Times.

Langmuir, D., Chrostowski, R., Vigneault, B. and Chaney, R. (2004) In: Chan,Y. C. (2013). An investigation of the bioavailability of heavy metals in tailing run-off sediment at Devon Great Consols. *The Plymouth Student Scientist*. 6(1): 211-309

Lauren D.J. and McDonald, D.G., (1987) Acclimation to copper by rainbow trout, *Salmo gairdneri* physiology, *Can. J. Fish. Aquat. Sci*, **44**: 105-111.

Lawrence, A. L, McAloon, K. M, Mason R, and Mayer M. (1999). Intestinal solubilization of particle-associated organic and inorganic mercury as a measure of bioavailability to benthic invertebrates. *Environ. Sci. Technol.* **33**: 1871-1876.

Lawson, E. O. and Jimoh, A. A. (2010). Aspects of the biology of grey mullet, *Mugil cephalus* in Lagos Lagoon, Nigeria. AACL Bioflux; **3** (3): 181-193.

Le C.X. (2000). *Environmental chemistry of arsenic* (ed WT Frankenberg), Dekker, New York, 95-106.

Le, C.X. (2002) *Environmental chemistry of arsenic* (ed WT Frankenberg), Dekker, New York, 95-106.

Lee, B. G., Lee, J. S., Luoma, S. N., Choi, H. J. and Koh, C. H. (2000). Influence of acid volatile sulphide and metal concentrations on metal bioavailability to marine invertebrates in contaminated sediments. *Environ. Sci. Technol.* **34**: 4517–4523

Lee, C., Fang, M. D. and Hsieh, M. T. (1998) Characterization and distribution of metals in surficial sediments in southwestern Taiwan. *Marine Pollution Bulletin* **36**: 464 - 471

Lee, S., An, J., Kim, Y. J. and Nam, K. (2011). Binding strength-associated toxicity reduction by birnessite and hydroxyapatite in Pb and Cd contaminated sediments. *J. Hazard Mater.* **186**: 2117–22.

Leeuwen, C. J. and Vermeire, T.G. (2007). *Risk assessment of chemicals. An introduction*. The Netherlands, Springer, 686pp

Lemus, M.J. and Chung, K. S. (1999). Effect of temperature on copper toxicity, accumulation and purification in tropical fish juveniles Petenia Kraussii (Pisces: Cichlidae). *Caribb. J. Sci.* **35**: 64−69.

Léonard, A. (1991) Arsenic In: Merian, Ernest, ed., Metals and Their Compounds in the Environment: Weinheim, Germany, VCH. 751-774pp.

Leventhal, J. and Taylor, C. (1990). Comparison of methods to determine degree of pyritization: *Geochimica et Cosmochimica Acta*. **54**: 2621-2625.

Li, S., Wang, W. and Hsieh, D. P. H. (2002). Effects of toxic dinoflagellate Alexandrium tamarense on the energy budgets and growth of two marine bivalves. *Marine Environmental Research* **53**: 145-160.

Li, X. D., Shen, Z., Wai, O. W. H., and Li, Y. S. (2000). Chemical partitioning of heavy metal contaminants in sediments of the Pearl River estuary. *Chemical Speciation and Bioavailability*. **12**(1) 17-25.

Li, X. D., Shen, Z., Wai, O. W. H., and Li, Y-S. (2000). Chemical partitioning of heavy metal contaminants in sediments of the Pearl River estuary. *Chemical Speciation and Bioavailability*. **12** (1): 17-25.

Li, X. D., Shen, Z., Wai, O. W. H., and Li, Y-S. (2001). Chemical forms of Pb, Zn and Cu in the sediment profiles of the Pearl River estuary. *Marine Pollution Bulletin* **42**(3): 215-223.

Liang, L.N., Hu, J.T., Chen, D.Y., Zhou, Q. F., He, B. and Jiang, G. B. (2004). *Bull. Environ. Contam. Toxicol.* **72**: 937.

Lim, P. E and Kiu, M. Y. (1995). Determination and speciation of heavymetals in sediments of the Juru River, Penang, Malaysia. *Environ Monit Assess* **35**: 85-95.

Lim, P. E and Kiu, M. Y. (1995). Determination and speciation of heavymetals in sediments of the Juru River, Penang, Malaysia.*Environ Monit Assess*. **35**: 85-95.

Lima, D., Freitas, J. E P., Araujo, M. E and Solé-Cava, A. M. (2005). Genetic detection of cryptic species in the frillfin goby *Bathygobius soporator. J. Exp. Mar. Biol. Ecol.* **320**: 211-223.

Lin, J.G., Chen, C.Y. and Chen, S.Y. (1999). Effects of pH on metals specification in contaminated sediment. *Journal of the Chinese Institute of Environmental Engineering*. **9**: 49–56.

Lin, Y. C., Chang-Chien, G. P., Chiang, P. C., Chen, W. H., and Lin, Y. C. (2013). Multivariate analysis of heavy metal contaminations in seawater and sediments from a heavily industrialized harbor in Southern Taiwan. *Mar. Pollut. Bull* .**76**: 266–75.

Lopez, D.L., Gierlowski-Kordesch, E. and Hollenkamp, C. (2010). Geochemical Mobility and Bioavailability of Heavy Metals in a Lake Affected by Acid Mine Drainage: Lake Hope, Vinton County, Ohio. *Water Air Soil Pollut.* 213: 27-45.

López-González., N., Borrego, J., Morales, J. A., Carro, O. and Lozano-Soria, O. (2006). Metal fractionation in oxic sediments of an estuary affected by acid mine drainage (southwestern Spain) *Estuar. Coast. Shelf. Sci.,* **68**: 297-304.

Lopez-Sanchez, J.F., Rubio, R., Samitier, C. and Rauret, G. (1996). Trace metal partitioning in marine sediments and sludges deposited off the coast of Barcelona (Spain). *Water Research* **30**(1): 153-159.

Lopez-Sanchez, J.F., Rubio, R., Samitier, C. and Rauret, G. (1996). Trace metal partitioning in marine sediments and sludges deposited off the coast of Barcelona (Spain). *Water Research,* **30**(1), 153-159.

Luoma, S.N. (1983). Bioavailability of trace metals to aquatic organisms—A review: The *Science of the Total Environment* **28**: 1-22.

Luoma, S.N. (1989) Can we determine the biological availability of sediment-bound trace elements? *Hydrobiologia* **176(**177): 379-396.

Ma, H., Kim, S. D., Cha, D. K. and Allen, H. E. (1999). Effect of kinetics of complexation by humic acid on toxicity of copper to *Ceriodaphnia dubia*. *Environ. Toxicol. Chem.* **18**(5): 828–837

Maceda-Veiga, A., Monroy, M., deSostoa, A. (2012). Metal bioaccumulation in the Mediterranean barbell (*Barbus meridionalis*) in a Mediterranean River receiving effluents from urban and industrial wastewater treatment plants. *Ecotoxicol. Environ. Saf.* **76**: 93–101.

Maheswari, N., Jayalakshmy, K. V., Balachandran, K. K., and Joseph, T. (2006). Bioaccumulation of Toxic Metals by Fish in a Semi-Enclosed Tropical Ecosystem. *Environmental Forensics* **7:** 197-206.

Malik, N., Biswas, A.K., Qureshi, T.A., Borana, K. and Virha, R. (2010). Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. *Environ. Monit. Assess*. **160**: 267–276.

Mandal, B. K., Ogra, Y., Anzai, K. and Suzuki, K. T. (2004). Speciation of arsenic in biological samples. *Toxicol Appl Pharmacol* **198**: 307-318.

Mandal, B. K., Ogra, Y., Suzuki, K. T. (2001). Identification of dimethylarsinous and monomethylarsinous acids in human urine of the arsenic affected areas in West Bengal, India. *Chem Res Toxicol* **14:** 371–378.

Mansour, S. A., and Sidky, M. M. (2002). Ecotoxicological studies. Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. *Food Chemistry*, **78:** 15-22.

Martin, J. H. and Fitzwater, E. E. (1988). Iron deficiency limits phytoplankton growth in the north-east Pacific subarctic. *Nature* **331**: 341–343.

Martin, J. M., Nirel, P and Thomas, A. J. (1987). Sequential extraction techniques: promises and problems. *Mar. Chem.* **22**: 313-342.

Martin, R., Sanchez, D. M. and Gutierrez, A. M. (1998). Sequential extraction of U, Th, Ce, La and some heavy metals in sediments from Ortigas River, Spain. *Talanta* **461**: 115-1121.

Mat, I., Maah, M. J. and Johari, A. (1994). Trace metal geochemical associationsin sediments from the culture-bed of *Anadara granosa*. *Mar. Pollut. Bull.* **28**: 319-323.

Mathee, A., Röllin, H., Levin, J and Naik, I (2007). Lead in Paint: Three Decades Later and Still a Hazard for African Children? *Environ Health Perspect* **115** (3): 321- 322.

Mathew, M., Mohanraj, R., Azeez, P. A., and Pattabhi, S. (2003). Speciation of heavy metals in bed sediments of wetlands in urban Coimbatore, India. *Bulletin of Environmental Contamination and Toxicology* **70**: 800-808.

Matsuzaki, S. S., Usio, N., Takamura, N. and Washitani, I. (2007). Effects of common carp on nutrient dynamics and littoral community composition: roles of excretion and bioturbation. *Fundamental and Applied Limnolog/Archiv für Hydrobiologie* **168** (1): 27-30

Mattusch, J. and Wennrich, R. (1998). Determination of Anionic, Neutral, and Cationic Species of Arsenic by Ion Chromatography with ICP-MS Detection in Environmental Samples. *Anal. Chem* **70**: 3649-3655.

Mayer, L.M., Chen, Z., Findlay, R.H., Fang, J., Sampson, S., Self, R.F.L., Jumars, P.A., Quetel, C. and Donard, O. F. X. (1996). Bioavailability of sedimentary contaminants subjectto deposit-feeder digestion. *Environmental Science and Technology* **30**: 2641–2645.

Medeiros, R. J., dos Santos, L. M. G., Freire, A. S., Santelli, R. E., Braga, A. M. C. B., Krauss, T. M., and Jacob, S. D. (2012). Determination of inorganic trace elements in edible marine fish from Rio de Janeiro State, Brazil. *Food Control* **23**(2): 535-541.

Medel, A. S., Bayón, M. M. and Sánchez, M. L. F. (2003). Trace element speciation by ICP-MS in large biomolecules and its potential for proteomics. *Anal. Bioanal. Chem.* **377** (2): 236-247.

Meera, R., Francis, T. and Reddy, M. L. P. (2001). Studies on the liquid-liquid extraction of mercury (II) from acidic chloride solutions using Cyanex 923. *Hydrometal*, **61**(2): 97-103.

Mellinger, R. M. (1979). Quantitative X-ray diffraction analysis of clay minerals. An evaluation. *Saskatchenwan Res. Council, Canada, SRC Report*, **79**: 1-46.

Meyers, R. A. (2000). *Encyclopedia of Analytical Chemistry*. Volume 3: Inductively Coupled Plasma Mass Spectrometry in Environmental Analysis (ed. Yamasaki, S.I.), John Wiley & Sons Ltd., 2672-2692 pp.

Mitra, A., Mitra, S., Hazra, S. and Choudhuri, A. (1999). Seasonal variation of

Mohammadi, M., Sary, A. A. and Khodadadi, M. (2011). Determination of heavy metals in two barbs, *Barbus grypus* and *Barbus xanthopterus* in Karoon and Dez Rivers, Khoozestan, Iran. *Bull. Environ.Contam. Toxicol.* **87**: 158–162.

Monteiro, P. M. S. and Roychoudhury, A.N. (2005). Spatial characteristics of sediment trace metals in an eastern boundary upwelling retention area (St. Helena Bay, South Africa). A hydrodynamic-biological pump hypothesis. *Estuarine Coastal and Shelf Sci.* **65**: 123-134

Morel, F. M. M., Kustka, A. B. and Shaked, Y. (2008). The role of unchelated Fe in the iron nutrition of phytoplankton. *Limnol. Oceanograph,* **53**(1): 400-404.

Morford, J. L and Emerson, S (1999). The geochemistry of redox sensitive trace metals in sediments. *Geochin. Cosmochim. Acta.* **63**: 1735 – 1750.

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

Mountouris, A., Voutsas, E. and Tassios, D. (2002). Bioconcentration of heavy metals in aquatic environments: the importance of bioavailability. *Marine Pollution Bulletin* **44**: 1136–1141.

Muller, G. (1969). "Index of Geoaccumulation in Sediments of the Rhine River," *Geo Journal* **2**(3): 108-118.

Muslim, I. and Jones, G. B. (2003). The seasonal variation of dissolved nutrients, chlorophyll *a*, and suspended material at Nelly Bay, Magnetic Island. *Estuarine, Coastal and ShelfScience* **57**(3): 445-455.

Naeem, M., Salam, A., Tahir, S. S and Rauf, N. (2011). The effect of fish size and condition on the contents of twelve essential and non essential elements in *Aristichthys nobilis* from Pakistan. Pakistan *Veterinary Journal* **31**: 109–112

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

Nakazato, T., Taniguchi, T., Tao, H., Tominga, M and Miyazaki, A. (2000). Ion-exclusion chromatography combined with ICP-MS and hydride generation-ICP-MS for the determination of arsenic species in biological matrices. *J. Anal. At. Spectrom* **15**: 15-46

Neff, J. M. (1997). Ecotoxicology of arsenic in the marine environment. *Environ. Toxicol. Chem.* **16**: 917–927.

Ng, J. C., Kratzmann S. Q., Crawley H., Chiswell B. and Moore, M. R. (1998). "Speciation and absolute bioavailability. Risk assessment of arsenic contaminated sites in a residential suburb in Canberra.",*Analyst*, **123:** 889-892.

Ngiam, L. S and Lim, P. E. (2001). Speciation patterns of heavy metals in tropical estuarine anoxic and oxidized sediments by different sequential extraction schemes. *Science of the Total Environment* **275**: 53-61.

Nguyen, N. T and Nguyen, V. Q (2006). *Biodiversity and living resources of the coral reef fishes in Vietnam marine waters*. Scientific and Technique Publishing House, Hanoi. 265pp

Ni, I. H., Chan. S.M. and Wang, W.X. (2005). Influences of salinity on the biokinetics of Cd, Se, and Zn in the intertidal mudskipper *Periophthalmus cantonensis. Chemosphere* **61:** 1607 – 1617.

Nicolau, R., Galera, C. A. and Lucas, Y. (2006). Transfer of nutrients and labile metals from the continent to the sea by a small Mediterranean river. *Chemosphere*. **63** (3): 469-476

NOAA (National Oceanic and Atmospheric Administration) (2009). SQUIRT, Screening Quick Reference Tables for Sediment, HYPERLINK

Nobi, E. P., Dilipan, E., Thangaradjou, T., Sivakumar, K., and Kannan, L. (2010). Geochemical and geostatistical assessment of heavy metal concentration in the sediments of different coastal ecosystems of Andaman Islands, India. *Estuar Coast Shelf Sci* **87**: 253–64.

Nouri, J., Karbassi, A. R. and Mirkia, S. (2008) Environmental management of coastal regions in the Caspian Sea. *Int. J.Environ. Sci. Tech*. **5** (1): 43-52

Nouri, J., Lorestani, B., Yousefi, N., Khorasani, N., Hasani, A. H., Seif, S. and Cheraghi, M., (2011). Phytoremediation potential of native plants grown in the vicinity of Ahangaran lead–zinc mine (Hamedan, Iran). *Environ. Earth Sci*. **62** (3): 639-644

Nwankwo, D.I. (1998). Seasonal changes in phytoplankton population and diversity in Epe Lagoon, Nigeria. *Acta Hydrobiologia* **40**(2): 82 – 92.

Nwuche C. O. and Ugoji E. O. (2010). Effect of co-existing plant specie on soil microbial activity under heavy metal stress. *Int. J. Environ. Sci. Tech*. **7** (4): 697-704

Obasohan, E. E., Oronsaye, J. A. O. and Obano, E. E. (2006). Heavy metal concentrations in *Malapterurus electricus* and *Chrysichthys nigrodigitatus* from Ogba River in Benin City, Nigeria. *African Journal of Biotechnology* **5**: 974-982

Odiete, W. O (1999). *Environmental Physiology of animals and pollution*. Diversified Resources Ltd., Lagos. 261pp.

Odum, W. E (1970). Pathways of energy flow in a South Florida estuary. Ph.D. Dissertation, Univ. Miami. 62pp.

Okoye B. C.O. (1989). A study of some heavy metals in the Lagos Lagoon (Ph.D Thesis). Obafemi Awolowo University, Ile-Ife. 142pp.

Okoye, B.C.O., 1991. Heavy metals and organisms in the Lagos Lagoon. *Int. J. Environ. Stud.* **37**: 285–92

Okoye, B.C.O., Afolabi, O.A and Ajao, E.A. (1991). Heavy metals in the Lagos Lagoon sediments. *Int. J. Environ. Stud.*, **37**:35–41

Olajire, A.A., Ayodele, E. T., Oyediran, G. O., Oluyemi, E. A. (2003). Levels and Speciation of heavymetals in soils of Industrial Southern Nigeria, *Environ Monit and Assessment*, SpringerNetherlands **85**: 135-155.

Olaniyan, C. I. O. (1978). *An Introduction to West African Animal Ecology* (2nd edition) Heinemann Educational Books Ltd. London and Ibadan. 170 pp.

Olatunji, A.S. and Abimbola, A. F. (2010). Geochemical Evaluation of the Lagos Lagoon Sediments and Water. *World Applied Sciences Journal* **9** (2): 178-193

Oliveira, A., Rocha, F., Rodrigues, A., Jouanneau, J., Dias, A., Weber, O. and Gomes C., (2002). Clay minerals from the sedimentary cover from the Northwest Iberian shelf. *Progress in Oceanography*, **52**: 233-247.

Oliver, R. L. (1993). Phosphorus dynamics and bioavailability in turbid waters. *In The Proceedings of the National workshop on Phosphorus in Australian Freshwaters* 93-103.

Omogoriola, H. O., Williams, A. B., Ukaonu, S. C., Adegbile, O. M.,Olakolu, F. C., Mbawuike, B. C., Akinnigbagbe, A. E. and Ajulo. A. A. (2012) Survey, biodiversity and impacts of economic activities on mangrovesecosystem in eastern part of Lagos Lagoon, Nigeria. *Nat. Sci*. **10**: 30–34.

Ortega, R. (2002). *Analytical Methods for Heavy Metals in the Environment*: Quantitative Determination, Speciation, and Microscopic Analysis, In: Heavy Metals in the Environment. Sarkar, B. (Ed) 35-68pp

Otitoloju, A. A, Don-Pedro K. N and Oyewo, E. O (2007). Assessment of potential ecological disruption based on heavy metal toxicity, accumulation and distribution in media of the Lagos Lagoon. *Afr. J. Ecol.* **45**: 454-463

Otitoloju, A. A, Don-Pedro, K. N. (2002). Bioaccumulation of Heavy metals (Zn, Pb, Cu and Cd) by Tympanotonus fuscatus var radula (L.) exposed to sublethal concentrations of the test metal compounds in laboratory bioassays. *W. Afr. J. Appl. Ecol.* **3**: 17-29.

Otitoloju, A. A. and Don-Pedro, K. N. (2002). Bioaccumulation of Heavy metals (Zn, Pb, Cu and Cd) by *Tympanotonus fuscatus* Var. *radula* (L.) exposed to sublethal concentrations of the test metal compounds in laboratory bioassays. *W. Afr. J. Appl. Ecol.* **3**: 17-29.

Oyenekan, J. A. (1975). A survey of the Lagos Lagoon benthos (with particular reference to the Mollusca). M.Sc. Thesis University of Lagos, Nigeria.

Oyenekan, J. A. (1979). The Ecology of the genus *Pachymelania* in Lagos Lagoon. *Arch. Hydrobiol.* **86**(4): 515 – 522.

Oyewo, E. O. (1998). Industrial sources and distribution of heavy metals in Lagos Lagoon and their biological effects on estuarine animals. (Ph.D Thesis). University of Lagos, 247pp.

Oyeyiola, A.O. (2006). Chemometric analysis, speciation and remediation of potentially toxic metals in the sediments of Lagos Lagoon ecosystem. (PhD Thesis), University of Lagos, Nigeria, 247pp.

Pailles, C. and Moody, P. W. (1995). Effect of experimental conditions on phosphorus extracted from estuarine and marine sediments. *Australian Journal of Marine and Freshwater Research* **46**: 435-440.

Paller, M. H and Knox, A. S (2013). Bioavailability of Metals in Contaminated Sediments E3S Web of Conferences 1, 02001P

Panda, D., Subramanian, V and Panigrahy, R. C (1995). Geochemical fractionation of heavy metals in Chilka Lake (east coast of India) – a tropical coastal lagoon. *Environmental Geology* **26** 199-210.

Panda, D., Subramanian, V. and Panigrahy, R.C. (1995). Geochemical fractionation of heavy metals in Chilka Lake (east coast of India) – a tropical coastal lagoon. *Environ. Geol.* **26**: 199-210.

Panigrahi, A. K. and Misra, B. N. (1978). Toxicological effects of mercury on a freshwater fish, *Anabas scandens,* and their ecological implications. *Journal of Environmental Pollution* **16**(1): 31 – 39.

Pansu, M. and Gautheyrou, J. (2006). Handbook of Soil Analysis-Mineralogical, Organic and Inorganic Methods. Springer Verlag, Heidelberg, Berlin

Pardo, R., Barrado, E., Perez, L. and Vega, M. (1990). Determination and speciation of heavy metals in sediments of the Pisuerga River. Water Research. **24**: 373–379

Parizanganeh, A., Lakhan, V.C., and Jalalian, H. (2007) A geochemical and statistical aapproach for assessing heavy metal pollution in sediments from the southern Caspian Coast. *Int. J. Environ. Sci. Tech.* **4**(3): 351-358.

Passos, E. D. A. (2010). Assessment of trace metals contamination in estuarine sediments using a sequential extraction technique and principal component analysis. *Microchem. J*. **96**: 50–57.

Pedlar, R. M., Ptashynski, M. D., Wautier, K.G., Evans, R.E., Baron, C. L and Klaverkamp, J. F. (2002). The accumulation, distribution, and toxicological effects of dietary arsenic exposure in lake whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*), *Comp. Biochem. Physiol. C, Comp.Pharmacol. Toxicol* **131**: 73-91.

Peijnenburg, W. J. G.M and Jager, T. (2003). Monitoring approaches to assess bioaccessibility and bioavailability of metals: Matrix issues *Ecotoxicology and Environmental Safety* **56**: 63–77

Peijnenburg, W., Posthuma, L., Eijsackers, H. and Allen, H. (1997). A conceptual framework for implementation of bioavailability of metals for environmental management purposes. *Ecotoxicol. Environ. Saf.* 37, 163–172.

Peijnenburg, W.J.G.M. and Vijver, M.G. (2007). Metal Specific Interactions at the Interface of Chemistry and Biology. *Pure Appl. Chem*. **79**: 2351-2366.

Peng, J. F., Song. Y. H., Yuan, P., Cui, X. Y and Qiu, G. L. (2009). The remediation of heavy metals contaminated sediment. *Journal of Hazardous Materials* **161:** 633-640.

Penn, M. R., Auer, M. T., Van Orman, E. L. and Korienek, J. J. (1995). Phosphorus diagenesis in lake sediments: Investigation using fractionation techniques. *AustralianJournal of Marine and Freshwater Research* **46**: 89-99.

Perin, G., Craboledda, L., Lucchese, M., Cirillo, R., Dotta, L., Zanetta, M. L. and Oro, A. A (1985). Heavy metal speciation in the sediments of northern Adriatic Sea. A new approach for environmental toxicity determination. In: *Heavy Metals in the Environment*. CEP Consultants, Edinburgh. 25-37pp.

Peterson, H. G., Healey, F. P and Wagemann, R. (1984). Metal toxicity to algae: a highly pH dependant phenomenon. *Can. J. Fish. Aquat. Sci.* **41**: 974−979.

Phillips, D. J. H. (1990). Arsenic in aquatic organisms: a review, emphasizing chemical speciation. *Aquat. Toxicol.* **16**: 151–186.

Pinto, L. A. and Rivera, C. (2003). Iron and manganese reduction in porewaters of the Bay of Concepcion and adjacent continental shelf during the “1997-98” El Niño” event. *Journalof the Chilean Chemical Society* **48**(3): 31-35.

Prosi, F. (1989). Factors controlling biological availability and toxic effects of lead in aquatic organisms: *The Science of the Total Environment* **79**: 157-169.

Prusty, B. A. K., Jagadeesh, E. P., Azeez, P. A., and Banerjee, D. K. (2007a). Distribution and chemical speciation of select transition metals in the waters of River Yamuna, New Delhi. *Environmental Science: An Indian Journal* **2**(3): 139-144.

Prusty, B.G., Sahu, K.C., and Godgul, G., (1994). Metal contamination due to mining and milling activities at the Zawar zinc mine, Rajasthan, India. 1. Contamination of stream sediments: *Chemical Geology* **112**: 275-292.

Ptashynski, M. D, Pedlar, R. M., Evans, R. E., Baron, C. L, Klaverkamp, J. F. (2002). Toxicology of dietary nickel in Lake Whitefish (*Coregonus clupeaformis*). *Aquatic toxicology* **58**(3-4): 229-247

Purushothaman, P and Chakrapani, G. J (2007). Heavy Metals Fractionation in Ganga River Sediments, India. *Environmental Monitoring and Assessment* **132**: 475–489.

Purushothaman, P and Chakrapani, G. J (2007). Heavy Metals Fractionation in Ganga River Sediments, India. *Environmental Monitoring and Assessment* **132:** 475–489.

Qadir, A. and Malik, R. N. (2011). Heavy metals in eight edible fish species from two polluted tributaries (Aik and Palkhu) of the River Chenab, Pakistan. *Biol. Trace Elem. Res*. **143**: 1524–1540.

Rahman, M. M., Asaduzzaman, M. and Naidu, R. (2013). Consumption of arsenic and other elements from vegetables and drinking water from an arsenic-contaminated area of Bangladesh. *Journal of Hazardous Materials* **262**: 1056–1063.

Rahman, M. S., Molla, A. H., Saha, N and Rahman, A. (2012). Study on heavy metals levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh. *Food Chemistry* **134**: 1847–1854

Rahman, M.S. and Islam, M.R. (2009). Effects of pH on isotherms modelling for Cu (II) ions adsorption using maple wood sawdust. *Chem Eng J*. **149**: 273–280

Rainbow, P.S. (1998). Phylogeny of trace metal accumulation in crustaceans. In: W.J. Langston and M. J. Bebianno (Eds.), Metal Metabolism in Aquatic Environments. Chapman and Hall, London 285-319pp.

Raja P., Veerasingam S, Suresh G, Marichamy G, and Venkatachalapathy R. (2009). Heavy metals concentration in four commercially valuable marine edible fish species from Parangipettai Coast, South East Coast of India. *International Journal of Animal and Veterinary Advances*. **1**(1): 10-14

Ramos, L., González, M. and Hernández, L. (1999) Sequential extraction of copper, lead, cadmium, and zinc in sediments from Ebro River (Spain): relationship with levels detected in earthworms. *Bulletin of Environmental Contamination and Toxicology*. **62** 301-308.

Rapin, F., Tessier, A., Campbell, P. G. C and Carignan, R. (1986). Potential artifacts in sediments by a sequential extraction procedure *Environ Sci Technol*. **20**: 836-840.

Rauret, G., Lopez Sanchez, J. F., and Sahuquillo, A. (1999). Improvement of the BCR three step sequential extraction procedure prior to the certification of new sediment and soil reference materials. *Journal of Environmental Monitoring* **1**(1): 57–61

Rauret, G., Lopez-sanchez, J. F., Sahuquillo, A., Rubio, R., Davidson, C., Ure, A. and Quevauviller, Ph. (1999). Improvement of the BCR three step sequential extraction procedure prior to the certification of new sediment and soil reference materials. *J. Environ. Monit*. **1**: 57–61.

Rauret, G., Rubio, R., Lopez-Sanchez, J. F. and Casassas, E. (1988) Determination and speciation of copper and lead in sediments of a Mediterranean river (River Tenes, Catalonia, Spain). *Wat. Res***. 22**: 449-455.

Rayment, G.E. and Barry, G. A. (2000). Indicator tissues for heavy metal monitoring-additional attributes. *Marine Poll. Bull.* **7**: 353-358.

Regine, M. B., Durrieu, G., Yannick, D. and Boudou, A. (2006). Mercury distribution in fish organs and food regimes: Significant relationships from twelve species collected in French Guiana (Amazonian basin). *Science of the Total Environment* **368**: 262-270.

Reinfelder, J. R., Fisher, N. S., Luoma, S. N., Nichols, J. W. and Wang, W. X. (1998). Trace element trophic transfer in aquatic organisms: a critique of the kinetic model approach. *Science of the Total Environment*. **219:** 117-135.

Riba I, Delvalls TÁ, Forja JM, Gómez-Parra A. (2004). The influence of pH and salinity on the toxicity of heavy metals in sediment to the estuarine clam, *Ruditapes philippinarum*. *Environ. Toxicol. Chem.* **23**: 1100–7.

Rink, L. and Gabriel, P. (2000). Zinc and the immune system. *Proc Nutr Soc* **59**:541-52

Rivaro, P., Cullaj, A., Frache., R, Lagomarsino, C., Massolo, S., De Mattia, M. C. and Ungaro, N. (2011). Heavy Metals Distribution in Suspended Particulate Matter and Sediment Collected from Vlora Bay (Albania): A Methodological Approach for Metal Pollution Evaluation. *Journal of Coastal Research* 54-66.

Rocha, M. S., da., Soldado, A. B., Blanco-González, E. and Sanz-Medel, A. (2000). Speciation of mercury compounds by capillary electrophoresis coupled online with quadrupole and double-focusing inductively coupled plasma mass spectrometry. *J. Anal. At. Spectrom.* **15**(5): 513-518.

Rodil, R., Carro, A. M., Lorenzo, R. A., Abuin, M. and Cela, R. (2002). Methylmercury determination in biological samples by derivatization, solid-phase microextraction and gas chromatography with microwave-induced plasma atomic emission spectrometry. *J. Chromatogr, A,* **963**(1-2): 313-323.

Romeo, M., Siau, Z., Sidoumou, Y. and Gnassia, M. B. (1999): "Heavy Metal Distribution in Different Fish Species from the Mauritania Coast," *Science of the Total Environment* **232**(3): 169-175.

Roozen, F. C. J. M., Lürling, M., Vlek, H., Van Der Pouw Kraan, E. A. J., Ibelings, B. W. and Scheffer, M. (2007). Resuspension of algal cells by benthivorous fish boosts phytoplankton biomass and alters community structure in shallow lakes. *FreshwaterBiology* **52**: 977-987.

Rude, J. H. and Alden, R.W. (1996). Sediment bioavailability to three estuarine animals in relation to geochemical fractions of sediments. *Arc. Environ. Contam. Toxicol*., **19**: 878-885

Ruilian, Y., Xing, Y., Yuanhui, Z., Gongren, H. and Xianglin, T. (2008). Heavy metal pollution in intertidal sediments from Quanzhou Bay, China. *J. Environ. Sci.* **20**: 664–669.

Ruttenberg, K. C. (1993). The role of bottom sediments in the aquatic phosphorus cycle. *In the Proceedings of the National Workshop on Phosphorus in Australian Freshwaters, J*. 19-24.

Saeki T, Sakai Y, Hashimoto H, Gushima K (2005). Foraging behaviour and diet composition of *Trimma caudomaculata* and *Trimma caesiura* (Gobiidae) on coral reefs in Okinawa, Japan. *Ichthyological Res.,* **52**(3): 302-305.

Saeki, K., Okazaki, M. and Matsumoto, S. (1993). The chemical phase changein heavy metals with drying and oxidation of the lake sediments. *Water Res*. **27**: 1243-1251.

Safahieh, A., Monikh, F. A., Savari, A. and Doraghi, A. (2011). Heavy metals concentration in mullet fish, *liza abu* from petrochemical waste receiving creeks, Musa Estuary (Persian Gulf). *Journal of Environmental Protection* **2**: 1218-1226

Saha, N and Zaman, M. R. (2012). Evaluation of possible health risks of heavy metals by consumption of foodstuffs available in the central market of Rajshahi City, Bangladesh. *Environ. Monit. Assess.* **185**: 3867-3878.

Sakai, T., Inoue, Y., Date, Y., Aoyama, T., Yoshida, K., and Endo, G. (2001). Simultaneous determination of neutral, anionic and cationic compounds within one chromatographic run using an inductively coupled plasma mass spectrometer as element specific detector. *Appl Organometal Chem* **15**: 285-290.

Salmons, W. and Förstner U. (1980). Trace metal analysis on polluted sediments. Part II: evaluation of Environmental impact. *Environmental science and Technology letters* 114-24.

Salomons, W. (1995). Environmental impact of metals derived from mining activities: Processes, predictions, prevention: *Journal of Geochemical Exploration* **52**: 5-23.

Salomons, W. and Stigliani, W. (1995). *Biogeodynamics of Pollutants in Soils and Sediments*. Berlin. Springer-Verlag. 352 pp

Salomons, W. and Stigliani, W. M. (1995). *Biogeodynamics of Pollutants in Soils and Sediments: Risk Assessment of Delayed and Non-linear Responses, Environmental Science*, Springer-Verlag, New York, pp. 331–343.

Sarva, M.P., Miroslav, R., MohdHarun, A. and Ahmed, Z.A. (2005). Application of sediment quality guideline in the assessment of mangrove surface sediment in Mengkabong, Lagoon Sabah. *Global Journal of Environmental Research*, **1**(3): 1-9.

Saygi, Y. and Yiğit, S. A. (2012). Heavy metal in Yenicağa Lake and its potential sources: soil, water, sediment and plankton. *Environmental Monitoring and Assessment* **184** (3): 1379-1389.

Schintu, M., Kudo, A., Sarritzu, G. and Contu, A. (1991). Heavy metal distribution and mobilization in sediments from a drinking water reservoir near a mining area: *Water, Air, and Soil Pollution* **57** (58): 329-338.

Schneider, W. (1990). FAO species identification sheets for fishery purposes. Field guide to the commercial marine resources of the Gulf of Guinea. Prepared and published with the support of the FAO Regional Office for Africa. FAO, Rome. 268 p.

Schultz, L.G. (1964). Quantitative interpretation of mineralogical composition from X-ray and chemical data for the Pierre Shale. *U.S. Geological Survey Professional Paper*, **391:** 1-31.

Seeberg-Elverfeldt, J., Schlüter, M., Feseker, T and Kölling M, (2005). Rhizon sampling of pore waters near the sediment/water interface of aquatic systems. *Limnology and oceanography: Methods*, **3**: 361-371.

Seng, C. Lim, P. and Ang, T. (1987). Heavy metal concentrations in coastal seawater and sediments off Prai Industrial Estate, Penang, Malaysia. *Marine Pollution Bulletin* **18**(11): 611 – 612.

Sezgin, N., Ozcan, H.K. Demir, G. Nemlioglu S. and Bayat, C. (2003). Determination of heavy metal concentrations in street dusts in Istanbul E-5 highway. *Environ. Int.*, **29**: 979-985.

Shanker, A. k., Djanaguiraman, M., Sudhagar, R., Chandrashekar, C. N. and Pathmanabhan G. (2004). Differential antioxidative response of ascorbate glutathione pathway enzymes and

metabolites to chromium speciation stress in green gram (*Vigna radiate* (L.) R. Wilczek. cv CO 4) roots. *Plant Science* **166**: 1035–1043.

Shanthi, K., Ramasamy, K., and Lakshmanaperumalsamy, P. (2003). Sediment quality of Singanallur wetland in Coimbatore, Tamil Nadu, India. *Bulletin of Environmental Contamination and Toxicology*. **70**: 372-378.

Shotbolt, L. (2010). Pore water sampling from lake and estuary sediments using rhizon samplers. *Journal of Paleolimnology,* **44**: 695-700.

Simpson, S. L. (2005). Exposure–effect model for calculating copper effect concentrations in sediments with varying copper binding properties: a synthesis. *Environ Sci Technol* **39**:7089–96.

Simpson, S. L., Batley, G. E., Chariton, A. A., Stauber, J. L., King, C. K., Chapman, J. C., Hyne, R. V., Gale, S. A., Roach, A. C. and Maher, W. A. (2005). *Handbook for Sediment Quality Assessment.* CSIRO: Bangor, NSW, Australia.

Simpson, S. L., Yverneau, H., Cremazy, A., Jarolimek, C. V., Price, H. L. and Jolley, D. F. (2012b). DGT-induced copper flux predicts bioaccumulation and toxicity to bivalves in sediments with varying properties. *Environ Sci Technol* **46**: 9038–46.

Singh, A. (2010). '*Modern Geotechnical Engineering'*. Third edition, CBS Publishers and Distributors PVT, Limited, New Delhi, India.11-24 pp.

Sivaperumal, P., Sankar, T. V. and Nair, P. G. V. (2007). Heavy metal concentrations in fish, shellfish and fish products from internal markets of India vis-a-vis international standards. *Food Chemistry*. **102**: 612–620

Srivastava, N. K. and Majumder, C. B. (2008). Novel biofiltration methods for the treatment of heavy metals from industrial wastewater. *Journal of Hazardous Material* **151**: 1-8.

Stauber, J. L and Davies, C. M. (2000). Use and limitations of microbial bioassays for assessing copper bioavailability in the aquatic environment. *Environ Rev*. **8**: 255–301.

Stokes, P. M. (1983). Responses of fresh water algae to metals. *Prog. Phycol. Res.* **2**: 87−112.

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

Sutherland, R. A. and Tolosa, C. A. (2000). Multielement analysis of road-deposited sediment in an urban drainage basin, Honolulu, Hawaii. *Environmental Pollution* **110**: 483-495.

Tam, N. F. Y. and Wong, W. S. (2000). Spatial variation of heavy metals in surface sediments of Hong Kong mangrove swamps. *Environmental Pollution*, **110**: 195–205

Tanji, K. K., Gao, S., Scardaci, S. C., Chow, A. T., (2003). Characterizing redox status of paddy soils with incorporated rice straw. Geoderma **114** (10): 333–353.

Tao, S., Luo, Y. M. and Cao, J. (2006). *Morphology and Bioavailability of Trace Metals in Aquatic and Terraneous Ecosystems*. Science Press, Beijing.

Taub, F. B. (2004). Fish 430 lectures (Biological Impacts of Pollutants on Aquatic Organisms), University of Washington College of Ocean and Fishery Sciences, Seattle, WA.

Taylor, D., Maddock, B. and Mance, G., (1985). The acute toxicity of nine "grey list" metals (arsenic, boron, chromium, copper, lead, nickel, tin, vanadium and zinc) to two marine fish species: dab *(Limanda limanda*) and grey mullet (*Chelon labrosus*). *Aquat. Toxicol.*, **7:** 135-144

Tekin-O¨ zan, S., (2008). Determination of heavy metal levels in water, sediment and tissues of tench (*Tinca tinca L.,* 1758) from Beysehir Lake (Turkey). *Environ. Monit. Assess.***145**: 295–302.

Templeton, D. M., Ariese, F., Cornelis, R., Danielsson, L.G., Muntau, H., Leven, H. P. and Obinzki, R. L. (2000) IUPAC Recommendations, *Pure Appl. Chem.*,**72**: 1453-1470.

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

Tessier, A.P., Campbell, G.C. and Bisson, M. (1979). Sequential extraction procedure for the speciation of particulate traces metals. *Analytical Chemistry* **51**: 844–851.

Thomas, R. P., Ure, A. M., Davidson, C. M., Littlejoh, D., Rauret, G., Rubio, R. and López-Sánchez, J. F. (1994). Three-stage sequential extraction procedure for the determination of metals in river sediments. *Analytica. Chimica. Acta.* **286:** 423-429.

Thomas, B and Arthur, M. A. (2010). Correcting pore water concentration measurements from peepers: Application of a reverse tracer. *Limnology and Oceanography Methods.* **8**:403-413.

Thorez, J., (1976). *Practical Identification of Clay Minerals.* A Handbook for Teachers and Students I. Clay Mineralogy, G. Lelotte, Dison, Belgique. 90pp.

Tipping, E; Hetherington, N. B; Hilton, J; Thompson, D. W; Bowles, E and Hamilton-Taylor J (1985). Artifacts in the use of selective chemical extraction to determine distributions of metals between oxides of manganese and iron. *Anal. Chem*. **57**: 1944-1946.

Tolla, B. (2006). Physicochemical characteristics and pollution levels of trace metals in the Little Akaki and Big Akaki River. Master Thesis Addis Ababa University, School of Graduate Studies. 75pp.

Tomlinson, D. L, Wilson, J. G., Hariis, C. R and Jeffrey, D. W (1980). Problems in the Assessment of Heavy Metal Levels in Estuaries and the Formation of a Pollution Index. *Helgolander Meeresunters* **33:** 566-575.

Trueby, P. and Aldinger, E. (1989). Eine Methode zur Bestimmung austauschbarer Kationen in Waldboeden. Zeitschrift fu¨r Pflanzenerna¨hrung und Bodenkunde, **152**: 301–306.

Trujillo-Cardenas, J. L., Saucedo-Torres, N. P., Del Valle, P. F. Z., and Donato, R. (2010). Speciation and sources of toxic metals in sediments of lake Chapala, Mexico. *Journal of the Mexican Chemical Society*. 54: 79‑87.

Tseng, C. M., Amouroux, D., Abril, G., Tessier, E., Etcheber, H and Donard, F.X. (2001). Speciation of Mercury in a fluid mud profile of ahighly turbid macrotidal estuary (Gironde, France). *Environ. Sci. Technol.* **35**: 2627 – 2633.

Tubbing, D. M. J., Admiraal, W., Cleven, R. F. M. J., Iqbal, M., van de Meent, D. and Verweij, W. (1994). The contribution of complexed copper to the metabolic inhibition of algae and bacteria in synthetic media and river water. *Water Res*. **28**: 37−44.

Turekian, K. K and Wedepohl, K. H (1961). Distribution of the elements in some major units of the earth crust. Bulletins of Geological Society of America **72**: 175-192.

Turekian, K. K. (1977). The fate of metals in the oceans. *Geochim. cosmochim. Acta* **41**: 1139-1144.

Türkmen, M., Türkmen, A., Tepe, Y., Töre, Y., and Ates, A. (2009). Determination of metals in fish species from Aegean and Mediterranean Seas. Food Chemistry,113, 233–237.

Turner, A. and Millward, G.E. (2002), Suspended Particles: Their Role in Estuarine Biogeochemical Cycles. *Estuarine, Coastal and Shelf Science*, vol. **55**: 857-883.

Turner, J.G., Ellis, C. and Devoto, A. (2002). The jasmonate signal pathway. *Plant Cell* **14**:153–164

Tyler, G. and Olsson, T. (2001a). Concentrations of 60 elements in the soil solution as related to the soil acidity. *Soil Sci.* **52**: 151-165.

Tyler, G. and Olsson, T. (2001b). Plant uptake of major and minor mineral elements as influenced by soil acidity and liming", *Plant Soil*. **230**: 307-321.

Tyler, G., Bergegren, D., Falkengren-Grerup, U., Folkeson, L. and Ruhling, A. (1985). Soil acidification and metal solubility in forest of south Sweden. In: *NATO Advanced Research Institute Workshop*. Toronto.

Uluozlu, O. D., Tuzen, M., Mendil, D., and Soylak, M. (2007). Trace metal content innine species of fish from the Black and Aegean Seas, Turkey. *Food Chemistry* **104**: 835–840.

United States Environmental Protection Agency (USEPA), (2004). *What you need to know about mercury in fish and shellfish.* EPA-823-F-04-009, 2.0pp, available at:*http://www.epa.gov/waterscience/fish/MethylmercuryBrochure.pdf*.

Ure, A., Quevaullier, P., Muntau H. and Griepink, B. (1993). Speciation of Heavy Metals in Soils and Sediments. An Account of the Improvement and Harmonization of Ex-traction Techniques Undertaken under the Auspices of the BCR of the CEC," *International Journal of Environ- mental Analytical Chemistry*. **51**(1-4): 135-151.

US Environmental Protection Agency (1986). Test Methods for Evaluating Solid Wastes, S. W 846, 3rd ed., US EPA, Washington, D. C.

US EPA. (2001). The incidence and severity of sediment contamination in surface waters of the United States. National sediment survey: second edition. EPA/823/R- 01/01. (Draft). U.S. EPA, Washington, D.C.

US NIST Certificate of Analysis (2003) Standard Reference Material® 2711 Montana Soil, Moderately Elevated Trace Element Concentrations, Gaithersburg MD 20899

USEPA (1995). Microwave Assisted Acid Digestion of Sediments, Sludges, and Soils. Test Methods for Solid Waste, Method 3052.

USEPA (1999). 'US Environmental Protection Agency; Screening Level Ecological Risk Assessment Protocol for Hazardous Waste combustion facilities', Appendix E: Toxicity Reference Values, Vol. 3

USEPA (2009). United States Environmental Protection Agency, Risk-based concentration table. Philadelphia: United States Environmental Protection Agency,Washington, DC.

Usero, J., Gamero, M., Morillo, J and Gracia, I. (1998). Comparative study of three sequential extraction procedures for metals in marine sediments. *Environment International* **24:** 478-496.

Usero, J., Izquierdo, C., Morillo, J., and Gracia, I. (2003). Heavy metals in fish (Soleavulgaris, Anguilla anguilla and Liza aurata) from salt marshes on the southern Atlantic coast of Spain. *Environment International*, **29**: 949–956.

Uwumarongie-Ilori, E.G., Okieimen, F.E. and Uwumarongie, O.H. (2011). Speciation of trace metals in chromated-copper-arsenate contaminated sediment of Ogba River. *Chemical Speciation and Bioavailability*. **23**(2): 118-124.

Van Leeuwen, H. P., Town, R. M., Buffle, J., Cleven, R. F. M. J., Davison, W., Puy, J., Van Riemsdijk, W. H. and Sigg, L. (2005). Dynamic speciation analysis and bioavailability of metals in aquatic systems. *Environmental Science and Technology* **39**(22): 8545-8556.

Van-Den-heever, D. J. and Frey, B. J. (1994). Human health aspects of the metals zinc and copper in tissues of the African sharp tooth Catfish, *Clarias gariepinus*, kept in treated sewage effluent and in Krugers drift dam. *Water S. A. (Pretoria)* **20** (3): 205-212.

Vasile, D.G.; Nicolau, M. and Vladescu, L. (2010). Zinc speciation in sediments from a polluted river, as an estimate of its bioaccessibility. *Environ. Monit. Assess* **160:** 71–81.

Vinodhini, R. and Narayanan, M. (2008)**.** Bioaccumulation of heavy metals in organs of freshwater fish *Cyprinus carpio* (Common carp). *International Journal of Environmental Science* and *Technology* **5**: 179-182.

Violante, A., Cozzolino, V., Perelomov, L., Caporale, A. G. and Pigna, M. (2010). Mobility and Bioavailability of Heavy Metals and Metalloids in Soil Environments. *Journal of Soil Science and Plant Nutrition*. **10** (3): 268-292.

Wang, S., Jia Y., Wang, S., Wang, X., Wang, H., Zhao, Z and Liu, B (2010). Fractionation of heavy metals in shallow marine sediments from Jinzhou Bay, China. *J. Environ. Sci*., **22**(1): 23-31.

Webb, J. E. (1958). The ecology of Lagos Lagoon. 1. The lagoons of the Guinea coast. *Phil. Trans.Roy. Soc. Lond.*, **683**(241): 307 – 318.

Webb, J. E. and Hill M. B. (1958). The ecology of Lagos Lagoon. 4. On the reactions of *Branchiostoma nigeriense*. *Phil. Trans. Roy. Soc. Lond*., **683**(241): 355 – 391.

Weber, G., Neumann, G. and Romheld, V. (2002). Speciation of iron coordinated by phytosiderophores by use of HPLC with pulsed amperometric detection and AAS. *Anal. Bioanal. Chem.* **373**(8): 767-771.

WHO, "Guidelines for Drinking Water Quality," 3rd Edition, World Health Organization, 2004, 515pp.

Wong, C. S. C., Xiangdong, L. and Thornton, I. (2006). Urban environmental geochemistry of trace metals. *Environmental Pollution* **142**: 1-16.

World Health Organization (WHO) (1995). Inorganic Lead, Environmental Health Criteria 165. United Nations Environment Programme, International Labour Organization and the World Health Organization, Geneva, Switzerland.

Wright, David A. and Welbourn, P (2002). Environmental Toxicology. Cambridge University Press, Cambridge, U.K.

Yang, J.; Cao, L.L.; Wang, J .H. and Liu, C.L. (2014). Speciation of metals and assessment of contamination in surface sediments from Daya Bay, South China Sea. *Sustainability* **6**: 9096–9113.

Yi, Y., Wang Z., Zhang, K., Yu, G. and Duan, X. (2008). Sediment pollution and its effect on fish through food chain in the Yangtze River. *Int. J. Sediment Res.* **23**: 338-347.

Yi, Y., Wang, Z., Zhang, K, Y.U.G. and Duan, X. (2008). Sediment pollution and its effect on fish through food chain in the Yangtze River. *Int. J. Sediment Res.* **23**: 338-347.

Yin, X. B., Yan, X. P., Jiang, Y. and He, X. W. (2002). On-line coupling of capillary electrophoresis to hydride generation atomic fluorescence spectrometry for arsenic speciation analysis. *Anal. Chem.*, **74**(15): 3720-3725.

Yobouet, Y. A., Aduby, K., Trokourey, A. and Yao, B. (2010). Cadmium, Copper, Lead and Zinc speciation in contaminated soils. *Int. J. Eng. Sci. and Tech.* **2**(5): 802-812.

Yu, X. J., Yan, Y. and Wang, W. X. (2010). The distribution and speciation of trace metals in surface sediments from the Pearl River Estuary and the Daya Bay, Southern China. *Mar. Pollut. Bull.*, **60**: 1364–1371.

Yuan, C., Jiang, G., Liang, L., Jin, X. and Shi, J. (2004). Sequential extraction of some heavy metals in Haihe river sediments, People's' Republic of China. *Bulletin of Environmental Contamination and Toxicology.* **73**: 59-66.

Yusuf, K. A., and Osibanjo, O. (2006). Trace metals in water and sediments from Ologe Lagoon, South-western Nigeria. *Pak. J. Sci. Ind. Res*. **49**(2): 88-96

Zedler, J. B. and Kercher, S. (2005). Wetland resources: Status, trends, ecosystem services, and restorability. *Annual Review of Environment and Resources.* **30**: 39-74.

Zerbe, J., Sobczynski, T., Elbanowska, H. and Siepak, J. (1999). Speciation of heavy metals in bottom sediments of lakes. *Polish Journal of Environmental Studies* **8**(5): 331-339.

Zhang, I. and Wong, M. H. (2007). Environmental mercury contamination in China: Sources and impacts. *Environmental International* **33**: 108–121.