Journal of Advances in Environmental Health Research

Potential human health risk assessment of heavy metals in the flesh of mallard and pochard in the South Eastern Caspian Sea region of Iran

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Brief Communication

Abstract

Every year, migratory waterfowl are hunted and consumed by people in Golestan Province of Iran. Due to the heavy metal contamination of wintering habitats, an estimation of the human health risks associated with the consumption of these ducks is necessary. Therefore, this study was conducted to estimate the health risks of exposure to cadmium (Cd), total chromium (Cr), iron (Fe), lead (Pb), and zinc (Zn) due to the consumption of pectoral muscle of mallard (Anas platyrhynchos) and pochard (Aythya ferina) harvested and hunted in the South-Eastern Caspian Sea region of Iran. The mean values of these metals in the pectoral muscle of mallards and pochards were used to calculate estimated daily intake (EDI), estimated weekly intake (EWI), and target hazard quotients (THQ). The EDI (µg/day/70 kg body weight) for Cd, Cr, Fe, Pb, and Zn in mallard were 0.2, 0.04, 58, 1.1, and 12.8, respectively. The EDI (µg/day/70 kg body weight) for Cd, Cr, Fe, Pb, and Zn in pochard were 0.8, 0.1, 69, 0.8, and 13.4, respectively. The estimated total THQ (higher than 1) indicated that heavy metal levels in pochard flesh were unsafe for consumption. The EDI and EWI of the metals examined were below those recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and oral doses suggested by the United States Environmental Protection Agency (USEPA). There appears to be little risk of exposure to metals associated with the consumption of mallard and pochard in this region.

KEYWORDS: Heavy Metals, Risk, Ducks, Food Additives, Humans

Date of submission: 19 Oct 2014, ***Date of acceptance:*** 22 Jan 2015

Citation: Sinkakarimi MH, Pourkhabbaz AR, Hassanpour M, Levengood JM, Ghasempouri SM. **Potential human health risk assessment of heavy metals in the flesh of mallard and pochard in the South Eastern Caspian Sea region of Iran.** J Adv Environ Health Res 2015; 3(2): 139-45.

Introduction

Contamination of the environment with metals is increasing, and may pose a threat to some species and populations. They may exert beneficial or harmful effects on plant, animal, and human life depending upon the concentration.[1] These elements are introduced into the environment through various routes, such as smelting processes, fuel combustion, and industrialization.[1] They make their way into aquatic systems through atmospheric fallout, dumping of wastes, accidental leaks, runoff from terrestrial systems (industrial and domestic effluents), and geological weathering.[2] Birds obtain heavy metals from their food and the surrounding environment, and their body burdens represent a balance between rates of intake and elimination.[3]

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Heavy metals discharged into the aquatic environment can damage both aquatic species diversity and ecosystems, due to their toxicity and accumulative behaviour.[4] Inorganic contaminants such as Cd, Cr, and Pb are among the most studied metal contaminants. These metals react with diffusing ligands, macromolecules, and ligands present in membranes, which mostly cause bioaccumulation and biomagnification in the food chain, persistence in the environment, and disorders in the metabolic processes of living organisms.[5]

High concentrations of metals in the Gomishan and Miankaleh Wetlands of North-Eastern Iran are of great concern due to their potential effects on wildlife and human health.[6] These two wetlands are under the protection of the Ramsar Convention. With the rapid industrialization and economic development in the watershed, pollution has become widespread in these areas.[6]

The objectives of this study were to determine the concentrations of cadmium (Cd), chromium (Cr), iron (Fe), lead (Pb) and zinc (Zn) in the pectoral muscle of mallard and pochard from Miankaleh and Gomishan International wetlands and to assess the potential human health risk for hunters' family members via consumption of the ducks. To our knowledge, this is the first study of the metal exposure risk from consumption of flesh of ducks wintering in the South Eastern Caspian Sea region, Iran.

Materials and Methods

During the winter of 2012, 30 mallard (15 males and 15 females) and 30 pochard (15 males and 15 females) ducks were shot in the Miankaleh (36° 20' N, 53° 43' E) and Gomishan (54° 53' N, 37° 9' E) International Wetlands under license of the Environmental Protection Agency of Golestan, Iran. These sites are among the important wetlands and wintering areas for birds in the Middle East (Figure 1).

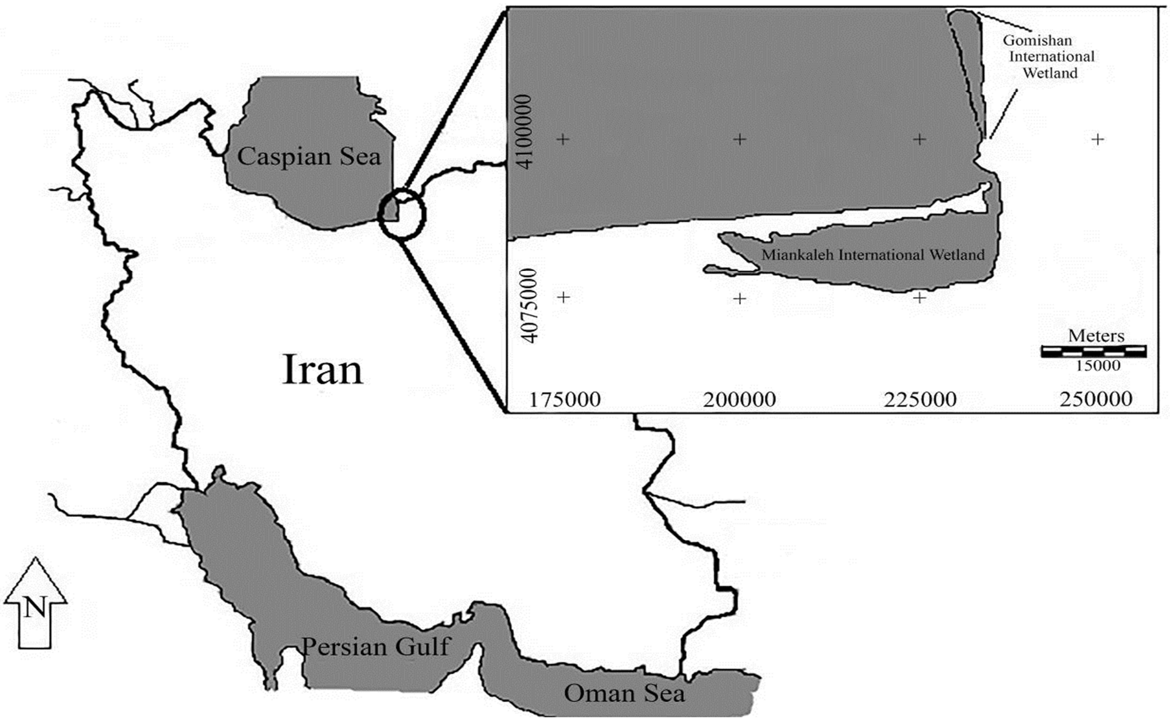

Figure 1. Sampling sites in the South East of the Caspian Sea

Upon collection, specimens were immediately transported to a laboratory where pectoral muscles were excised and samples frozen for later analysis. Median body mass and total length of mallard were 1.178 kg and 55.95 cm and of pochard were 0.924 kg and 44.1 cm, respectively. Approximately 5 g of wet tissue of pectoral muscle was placed in a porcelain crucible and dried at 135 °C for 2 hours. Samples were then transferred to a cool muffle furnace and the temperature was slowly raised to 450-500 °C overnight. After cooling, 2 ml of HNO_3 were added and the sample was then heated on a hot plate until dry. The sample was returned to the cooled furnace and the temperature was raised to 450-500 °C for an hour. After cooling, 10 ml of 1N HCL were added and heated on the hot plate to dissolve the ash. Digested samples were filtered and diluted to 25 ml in 1N HCL.[7] Metal concentrations were determined using an atomic absorption spectrophotometer (GFS97, Thermo Electron, Cambridge, UK). The accuracy of the analysis was confirmed by measuring certified reference material tissue (DORM-2; National Research Council, Canada). Recoveries ranged from 95 to 105%. Detection limits (μg/g) were 0.004 for Cd, 0.03 for total Cr, 0.05 for Fe, 0.001 for Pb, and 0.005 for Zn. The concentrations of metals in samples were expressed as microgram per gram wet weight (μg/g ww).

THQ was calculated according to the guidelines of the United States Environmental Protection Agency (USEPA).[8] Based on the USEPA guidance, we assumed that the adsorbed contaminant dose was equal to the ingestion dose and that cooking had no effect on the contaminants.[8] Furthermore, because of the unavailable oral reference dose (R_fD_o) of Pb, the value is specified as the permissible tolerable daily intake (PTDI) suggested by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) 2013.[9]

THQ was calculated using the following equation:

$$THQ = (EF \times ED \times MS \times C)/(R_fD_o \times BW \times AT) \times 10^{-3} \qquad (1)$$

where THQ is the Target Hazard Quotient, which indicates the ratio between exposure and reference dose. A THQ of higher than 1 means that the THQ is higher than the daily reference dose and systemic effects may occur.[10] In general, the R_fD_o is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. EF is the exposure frequency or number of exposure events per year of exposure (about 182.5 days) and ED is the exposure duration (72 years).[11] MS is the meal size of 95 g; Sinkakarimi et al. indicated that a Golestan province hunter's family members consume about 95 g/day of waterfowl.[6] C is the metal concentration (μg/g w.wt). R_fD_o is the oral reference dose (μg/g/day); the R_fD_o values used in this study were 1×10^{-3} for Cd, 7×10^{-1} for Fe, 4×10^{-3} for Pb, and 3×10^{-1} for Zn.[9,12] BW is the body weight of 70 kg,[8] and AT is the averaging time (it is equal to EF × ED).

In this study, total THQ is treated as the arithmetic sum of the individual metal THQ values, obtained using the method of Chien et al.[13]

$$\text{Total THQ (TTHQ)} = \text{THQ (toxicant 1)} + \text{THQ (toxicant 2)} + \dots \dots + \text{THQ (toxicant n)} \qquad (4)$$

The estimated daily intake (EDI) and estimated weekly intake (EWI) depend on both the metal concentration in food and the daily and weekly food consumption. In addition, body weight influences the tolerance to contaminant exposure. The EDI and EWI account for these factors and are calculated as follows:

$$\text{EDI } (\mu g/g/\text{daily}) = (MS \times C)/BW \qquad (2)$$

$$\text{EWI } (\mu g/g/\text{week}) = (MS \times C)/BW \qquad (3)$$

Results and Discussion

Concentrations of metals

The concentration of metals in the pectoral muscle tissue of mallard and pochard follows the sequence Fe > Zn > Pb > Cd > Cr (Table 1). Lead is a non-essential element and it is well documented that Pb can cause neurotoxicity, nephrotoxicity, and many other adverse health effects.[14] The maximum permitted concentration of Pb in food proposed by both the Australian National Health and Medical Research Council (ANHMRC) and Spanish legislation are 2.0 µg/g as wet weight basis.[15,16] Moreover, the United Kingdom has a legislated permissible level for Pb in food of 1.0 µg/g.[17] In our study, the concentrations of Pb in mallard and pochard flesh were lower than these thresholds (Table 1). In contrast, the European Commission (EC) and Institute of Turkish Standards for Food (ITSF) considered 0.1 and 0.5 µg/g w.w, respectively, as the permissible threshold for Pb in food.[18,19] The flesh of mallard and pochard we examined clearly exceeded this lower threshold and, according to these guidelines, pose health risks to humans consuming them. In a similar study in Poland, Binkowski examined Pb levels in the flesh of mallard and coot (Fulica atra), and concluded that their flesh was unfit for human consumption.[20] The mean concentration of Pb (µg/g w.w) in our study was higher than that in common teal (Anas crecca) (0.32) from Northern Iran (Sinkakarimi et al.,[6] Unpublished data), and mallard (0.23), garganey (Anas querquedula) (0.48), and tufted duck (Aythya fuligula) (0.15) from Warmia and Mazury, Poland.[21] It was also higher than that in mallard (0.04) and coot (0.06) from Zator, in Southern Poland,[20] scaup (Aythya marila) (0.55) from Szczecin Lagoon, Poland,[22] and gadwall (Anas strepera) (0.92) from Northern Iran (Sinkakarimi et al.,[6] Unpublished data).

The mean Cd concentrations we observed in mallard and pochard did not exceed the maximum permitted concentration of the ANHMRC (2 µg/g), Western Australian authorities (5.5 µg/g), and Spanish legislation (1 µg/g).[15,16] On the other hand, observed concentrations of Cd in the pectoral muscle of mallards and pochards were greater than the EC threshold (0.05 µg/g ww) for Cd in food.[15,17,18] Similarly, Binkowski reported that the flesh of mallard and coot from Poland was unfit for human consumption due to its Cd content.[20]

The mean concentration of Cd in our study was greater than that of common teal (0.13) from Northern Iran (Sinkakarimi et al.,[6] Unpublished data), mallard (0.01) and coot (0.02) from Zator, in Southern Poland,[20] and scaup (0.06) from Szczecin Lagoon, Poland.[22]

Although naturally occurring, most Cr to which biota are exposed originate from anthropogenic activities involved in pigments, municipal sewage, mining, and refining.[23] The Cr concentrations we observed were lower than the Western Australian Food and Drug Regulations' stated concentration of 5.5 µg/g for Cr in seafood for consumption.[15]

Iron and Zn are essential elements that are regulated through normal homeostatic mechanisms.[24] The concentrations of Zn we observed in pochard and mallard flesh were below the acceptable limit (1000 µg/g) in food set by the ANHMRC and WHO.[15,25] The mean concentrations of Fe and Zn in this study were within the ranges normally found in other ducks in other regions.[21,26,27]

THQ

The health risk of heavy metals in seafood is usually estimated by the THQ.[28] The THQ does not provide a quantitative estimate of the probability of an exposed population experiencing an adverse health effect, but it does offer an indication of the risk level due to pollutant exposure. The THQ of each metal we examined was lower than 1, suggesting that people would not experience health risks from consumption of mallards and pochards from the wetlands of the South East of the Caspian Sea (Table 2). On the other hand, values of the THQ index for total exposure were higher than 1 for pochard, indicating that the estimated exposure is a major health concern.

Dietary intake

An important aspect in assessing risk to human health from potentially harmful chemicals in food is the knowledge of the dietary intake of such substances that must remain within the determined safety limits. In the present study, we have shown that the estimated daily intakes of Cd, Fe, Pb, and Zn through the consumption of mallard and pochard by adults are lower than the acceptable daily intake recommended by the JECFA (Table 3).[9] With respect to Cr, the JECFA does not set a provisional tolerable intake limit. However, comparing the estimated intake with the oral reference dose suggested by the USEPA (equal to 3 and 1500 µg/g/day for Cr VI and Cr III, respectively), our results indicate that daily intake was lower than this reference dose (Table 1). Furthermore, our results for Cd, Zn, and Fe were lower than the oral reference dose (µg/g/day) suggested by the USEPA (Cd: 1, Zn: 300, and Fe: 700). No oral reference dose has been suggested by the USEPA for Pb or total Cr.[8]

Conclusion

Prior to this study, no published information existed on the risks of consuming the flesh of these popular waterfowl from the Caspian Sea region. The results of this study indicated that the estimated provisional permissible tolerable weekly intake (PTWI) and PTDI values for Cd, total Cr, Fe, Pb, and Zn in the pectoral muscle of mallard and pochard were lower than the values established by various authorities.[29-32] In addition, THQ indices for total exposure in pochard were higher than 1.0; thus, consumption of the pectoral muscle of this species wintering in the South Eastern Caspian Sea region was a human health concern.

Table 1. Metal concentrations (mean ± Standard deviation) in the pectoral muscle of mallard and pochard collected from wetlands in the South Eastern region of the Caspian Sea

Species	N	Pb	Cd	Cr	Zn	Fe
Mallard	30	0.83 ± 0.32	0.21 ± 0.09	0.03 ± 0.01	9.46 ± 2.51	43.05 ± 12.46
Pochard	30	0.62 ± 0.40	0.59 ± 0.37	0.09 ± 0.06	9.92 ± 3.14	50.88 ± 17.18

Table 2. Estimated target hazard quotients (THQ) for individual metals and total THQ from consumption of the pectoral muscle of mallard and pochard from the South Eastern region of the Caspian Sea

Species	Pb	Cd	Cr	Zn	Fe	TTHQ
Mallard	0.281	0.285	-	0.043	0.083	0.692
Pochard	0.210	0.801	-	0.045	0.045	1.101

TTHQ: Total target hazard quotients

Table 3. The estimated daily and weekly intakes for mallard and pochard flesh by adult humans in the South East of the Caspian Sea

Metal	PTWI	PTWI*	PTDI	Mallard EWI (EDI)	Pochard EWI (EDI)
Pb	25	1750	250	7.9 (1.10)	5.9 (0.8)
Cd	6	420	60	2.0 (0.20)	5.6 (0.8)
Cr	-	-	-	0.3 (0.04)	0.9 (0.1)
Zn	7000	490000	70000	89.9 (12.80)	94.3 (13.4)
Fe	5600	392000	56000	409 (58.40)	483.4 (69.0)

Mean daily waterfowl consumption in Iran is 95 g per person
PTWI: Provisional permissible tolerable weekly intake in µg/week/kg body weight; * PTWI per 70 kg body weight of adults (µg/week/70 kg body weight); PTDI: Permissible tolerable daily intake (µg/day/70 kg body weight); EWI: Estimated weekly intake (µg/week/70 kg body weight); EDI: Estimated daily intake (µg/day/70 kg body weight)

Conflict of Interests

Authors have no conflict of interests.

Acknowledgements

The authors wish to express their gratitude to the Iran Department of Environment, Golestan Provincial Directorate of Environment Protection and the many people, who have devoted their time and expertise to this project.

References

1. Frstner U, Wittmann GT. Metal Pollution in the Aquatic Environment. Berlin, Germany: Springer-Verlag; 1981. p. 486.
2. Eisler R. Trace metal concentrations in marine organisms. London, UK: Pergamon Press; 1981.
3. Evans PR, Moon SJ. Heavy metals in shorebirds and their prey in Northeast England. In: Say PJ, Whitton BA, Editors. Heavy Metals in Northern England: Environmental and Biological Aspects. Durham, UK: Department of Botany, University of Durham; 1981.
4. Matta J, Milad M, Manger R, Tosteson T. Heavy metals, lipid peroxidation, and ciguatera toxicity in the liver of the Caribbean barracuda (Sphyraena barracuda). Biol Trace Elem Res 1999; 70(1): 69-79.
5. Morgano MA, Rabonato LC, Milani RF, Miyagusku L, Balian SC. Assessment of trace elements in fishes of Japanese foods marketed in Sao Paulo (Brazil). Food Control 2011; 22(5): 778-85.
6. Sinkakarimi MH, Pourkhabbaz RR, Hassanpour M. The study of waterfowl organs as bioindicators of metals pollution in southeastern Caspian Sea [MSc Thesis]. Birjand, Iran: Department of Environment, University of Birjand; 2013.
7. Horwitz W. Official Methods of Analysis of the Association of Official Analytical Chemists. Gaithersburg, MD: The Association p. 2200; 2000.
8. Environmental Protection Agency. Assessing human health risks from chemically contaminated fish and shellfish: a guidance manual. Washington, DC: U.S. Environmental Protection Agency; 1989.
9. World Health Organization. Evaluations of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) [Online]. [cited 2013]; Available from: URL: http://apps.who.int/food-additives-contaminants-jecfa-database/search.aspx?fc=47
10. Copat C, Vinceti M, D'Agati MG, Arena G, Mauceri V, Grasso A, et al. Mercury and selenium intake by seafood from the Ionian Sea: A risk evaluation. Ecotoxicol Environ Saf 2014; 100: 87-92.
11. Ministry of Health and Medical Education of Iran. Heavy Metals, Risk, Ducks, Food Additives, Humans [Online]. [cited 2015]; Available from: URL: http://behdasht.gov.ir/?siteid=1&pageid=1508&newsview=129600
12. United States Environmental Protection Agency. Risk based concentration table. Washington, DC: USEPA; 2009.
13. Chien LC, Hung TC, Choang KY, Yeh CY, Meng PJ, Shieh MJ, et al. Daily intake of TBT, Cu, Zn, Cd and As for fishermen in Taiwan. Sci Total Environ 2002; 285(1-3): 177-85.
14. Garcia-Leston J, Mendez J, Pasaro E, Laffon B. Genotoxic effects of lead: an updated review. Environ Int 2010; 36(6): 623-36.
15. Plaskett D, Potter IC. Heavy Metal Concentrations in the Muscle Tissue of 12 Species of Teleost from Cockburn Sound, Western Australia. Australian Journal of Marine and Freshwater Research 1979; 30(5): 607-16.
16. El-Sikaliy A, Khaled A, Nemr A. Heavy metals monitoring using bivaleves from Mediterranean Sea and Red Sea. Environ Monit Assess 2004: 98(1-3): 41-58.
17. United Kingdom Lead in Food Regulations. Food and Drugs Act. London, UK: Her Majesty's Stationery Office; 1955.
18. The commission of the European communities. Commission regulation (EC) no 466: setting maximum levels for certain contaminants in foodstuffs [Online]. [cited 2001]; Available from: URL: http://ec.europa.eu/food/fs/sfp/fcr/fcr02_en.pdf
19. Dirican S, Cilek S, Ciftci H, Biyikoglu M, Karacinar S, Yokus A. Preliminary study on heavy metal concentrations of Anatolian Khramulya, Capoeta tinca (Heckel, 1843) from Çamlıgöze Dam Lake, Sivas, Turkey. J Environ Health Sci Eng 2013; 11(1): 1-7.
20. Binkowski LJ. Is the meat of wild waterfowl fit for human consumption? Preliminary results of cadmium and lead concentration in pectoral muscles of Mallards and Coots shot in 2006 in southern Poland. J Microbiol Biotechnol Food Sci 2012; 1: 1120-8.
21. Szymczyk K, Zalewski K. Copper, Zinc, Lead and Cadmium Content in Liver and Muscles of Mallards (Anas Platyrhychnos) and Other Hunting Fowl Species in Warmia and Mazury in 1999-2000. Pol J Environ Stud 2003; 12(3): 381-6.
22. Kalisinska E, Salicki W. Lead and Cadmium Levels in Muscle, Liver, and Kidney of Scaup Aythya marila from Szczecin Lagoon, Poland. Pol J Environ Stud 2010; 19(6): 1213-22.
23. Barbieri E, Passos EA, Filippini A, dos Santos IS, Garcia CA. Assessment of trace metal concentration

in feathers of seabird (Larus dominicanus) sampled in the Florianopolis, SC, Brazilian coast. Environ Monit Assess 2010; 169(1-4): 631-8.
24. Kim J, Oh JM. Metal levels in livers of waterfowl from Korea. Ecotoxicol Environ Saf 2012; 78: 162-9.
25. Gabriel UU, Ugwemorubong UG, Horsfall M. Trace Metals in the Tissues and Shells of Tympanotonus Fuscatus var. Radula from the Mangrove Swamps of the Bukuma Oil Field, Niger Delta). Eur J Sci Res 2008; 24(4): 468-76.
26. Bojar H, Bojar I. Monitoring of contamination of the Lublin region wetlands using Mallards [Anas platyrhynchos] as a vector of the contamination by various conditionally toxic elements. Annals of Animal Science 2009; 9(2): 195-204.
27. Kalisinska E, Salicki W, Myslek P, Kavetska KM, Jackowski A. Using the Mallard to biomonitor heavy metal contamination of wetlands in north-western Poland. Sci Total Environ 2004; 320(2-3): 145-61.
28. Wang SL, Xu XR, Sun YX, Liu JL, Li HB. Heavy metal pollution in coastal areas of South China: a review. Mar Pollut Bull 2013; 76(1-2): 7-15.
29. Qin CY, Fang ZQ, Tang YJ, An D, Yang XB. Contents and evaluation of heavy metals in common aquatic from Lingding Yang in Pearl River estuary, South China Sea. Journal of South China Normal University 2010; 1(3): 104-9.
30. Huang CJ, Zhao Z. Assessment on contents of heavy metals in seafoods from Zhanjiang Harbor. Journal of Shantou University 2007; 22(1): 30-6.
31. Qiu YW, Yu KF, Zhang G, Wang WX. Accumulation and partitioning of seven trace metals in mangroves and sediment cores from three estuarine wetlands of Hainan Island, China. J Hazard Mater 2011; 190(1-3): 631-8.
32. Ihedioha JN, Okoye CO. Dietary intake and health risk assessment of lead and cadmium via consumption of cow meat for an urban population in Enugu State, Nigeria. Ecotoxicol Environ Saf 2013; 93: 101-6.