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Bioaccumulation of heavy metals in cane rat (*Thryonomys swinderianus*) in Ogun State, Nigeria

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Wild animals have provided complimentary protein for human populations across the world over the centuries. This study investigated on bioaccumulation of heavy metals in different organs of cane rat (*Thryonomys swinderianus*) and the health implications of its consumption. Four carcasses were collected from each of the four ecotomes (Mosinmi, Agbara, Omo forest reserve and Ibese) and concentrations of 7 heavy metals (Fe, Cu, Cd, Pb, Mn, Cr, Zn) were examined in four organs (skin, liver, lung and kidney) from each specimen used by Atomic Absorption Spectrophotometer. Analysis of variance revealed no significant difference (P>0.05) in the concentration of metals in the animal except Fe and Cu, while significant variation exists when specimens were compared across different ecotomes. Total mean concentrations were Fe (400.512±60.0107), Cu (8.569±1.0396), Cd (0.06±0.040), Pb (0.3156±0.1175), Mn (9.4200±1.0383), Cr (1.3013±0.2739) and Zn (72.771±10.5672). Average mean concentration for all the metals in the study area was found to be higher than the recommended level which suggests that consumption of animals from this ecotomes are hazardous to human health and no single organ is completely safe for human consumption.

Key words: Bioaccumulation, *Thryonomys swinderianus*, cane rat, bush meat, heavy metals, wildlife consumption, animal toxicity.

INTRODUCTION

Heavy metals are natural components of earth's crust which cannot be degraded or destroyed. Living organisms especially human, require varying amounts of heavy metals such as Fe, Co, Cu, Mn, Mo, and Zn, but exceeding

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exceeding these levels can be dangerous to the organisms. Some heavy metals (e.g. Cu, Sc Zn) are essential to maintain metabolism in human body and can also lead to poisoning at higher concentration (Thomas et al., 1997). Ingestion of metals such as Pb, Cd, Hg, As, Ba and Cr may pose great risks to human health as they accumulate in living things any time they are taken up and stored faster than they are broken down, that is, metabolized or excreted (Smith et al.,1997).

Other heavy metals like Hg and Pb are toxic metals that have no known beneficial effects on organisms whereas their accumulation over time in the body can cause serious illness. Certain elements that are normally toxic could be beneficial for some organisms under certain conditions e.g., vanadium, tungsten and cadmium (Lane et al., 2005).

Heavy metal pollution in the environment arises from many sources, but the most common are purification of metals like smelting of copper and electroplating in chromium and cadmium. Through precipitation of their compounds or by ion exchange in soils and muds, heavy metals can localize or lay dormant. Unlike organic pollutants, they do not decay and thus pose a different kind of challenge for remediation (Lane and Morel, 2000). Their uptake and accumulation can be active (energy-dependent), passive (energy-independent) or both.

For instance, heavy metals poisoning could occur from drinking-water contamination (lead pipes), high ambient air concentrations near emission sources and intake via the food chain (Bilos et al., 2001). Their presence in the atmosphere, soil and water, can cause serious problems to all organisms even in traces and bioaccumulation in the food chain can be highly dangerous to human health (Cambra et al., 1999). Heavy metals intake by human populations through food chain has been reported in many countries (Damek-Poprawa and Sawicka-Kapusta, 2003). They usually enter human body through two routes: inhalation of dust and ingestion which is the main route of exposure to these elements in human population via consumption of food plants grown in metal-contaminated soil (Cambra et al., 1999).

Vegetables take up metals by absorption from contaminated soils and deposits on parts exposed to polluted environments (Zurera-Cosano et al., 1989). Metal contamination of garden soils may be widespread in urban areas due to continuous industrial activities and the use of fossil fuels (Chronopoulos et al., 1997). Several studies have shown that the concentrations of heavy metals in vegetation and natural rodent populations are generally correlated with environmental pollution (Schleich et al., 2010; Hawley, 1985; Sánchez-Camazano et al., 1994; Sterrett et al., 1996; Van Lune, 1987). Heavy metals which usually got transferred unto man and have highly adverse effects are lead, cadmium, copper, chromium, selenium and mercury (Wong, 1996). Long term exposure to lead in human can cause acute or chronic damage to the nervous system (Dudka and Miller, 1999). Human exposure to cadmium for a long period has been associated with renal dysfunctions and obstructive lung diseases which have been linked to lung cancer and damage to respiratory systems (WHO, 1984). Copper is an essential substance to human life, but in higher doses, it can cause anemia, intestinal irritation, stomach, liver and kidney damage. Mercury causes damages to the brain, central nervous system and psychological disorder. Normally, mercury is a toxic substance which has no known beneficial functionsin human biochemistry and makes developmental changes in children (WHO, 1984; Department of Environment, Food and Rural Affairs (DEFRA), 1999).

Chromium is used in metal alloys, pigments for paint, cement, paper, rubber and other materials. Low-level exposure can cause skin irritation and ulceration, while long-term exposure can cause damages to the kidney, liver, circulatory system and nerve tissues. Chromium often accumulate in aquatic life, this increases the danger of fish consumption, while selenium causes damage to circulatory tissue and more severe damages to the nervous system (Dudka and Miller, 1999).

Bush meat or wild meat is the term commonly used for meat of wild animals, killed for subsistence or commercial purposes throughout the humid tropics of the Americas, Asia and Africa. Wild animals are efficient users of native vegetation and can also adapt to man-modified habitats. In the past, the main populations who demanded for bush meat were indigenous people, rural communities and migratory workers. These people were averagely poor and bush meat consumption is an important aspect of their livelihoods. This situation is gradually changing as consumption of bush meat is now a common practice in sub-urban and urban communities by virtually all classes of the economy (Mathew, 2008; Wilkie and Godoy, 2001; Soewu et al., 2012). Many terrestrial ecosystems, which include wild populations of small mammals, are usually contaminated with potentially toxic trace elements from the accumulation of agricultural pesticides, fertilizers, industrial effluents and wastes disposal. These wastes are usually high in heavy metals which can be absorbed by plants and later found in high concentrations in animal tissues, and finally humans (Schleich et al., 2010). Grass cutters or cane rats (*Thryonomys* species) are widely distributed and valuable animal source for protein supplements in West and Central Africa.

The plant taxonomy is as follows: Kingdom, Animalia; Phylum, Chordata; Class, Mammalia; Order, Rodentia; Suborder, Hystricomorpha; Family, Thryonomyidae; Genus, *Thryonomys*; Species, *Thryonomys swinderianus* (Temminck, 1827). Cane rats can be found in cultivated forest regions, in sugar cane plantation and field where groundnut, maize, rice and cassava are grown. With regards to diet, they are monogastric herbivores, make good use of roughages, very fond of sweet and salty foods, but are wasteful feeders. They readily adapt to a

Table 1. Result for Omo Forest Reserve ecotome.

Organ/Metal (mg/kg)	Pb	Fe	Cu	Zn	Cd	Cr	Mn
Skin	0.42	205.80	4.15	123.5	0.00	0.00	11.04
Liver	0.77	438.90	8.55	103.72	0.00	0.77	6.16
Lung	0.90	337.15	3.75	79.56	0.00	2.20	5.28
Kidney	1.45	182.80	13.50	93.20	0.00	1.44	5.76

variety of diets which includes grasses (elephant grass, guinea grass, sugar cane), leguminous fodder (Centrocema, *Pueraria phaseoloides*), roots, coconut palms, fruits (pawpaw, pineapple, mango), tubers (cassava, sweet potatoes) and food crops (groundnut, rice, maize and grain legumes) (Mathew, 2008; Wilkie and Godoy, 2001).

Grasscutter meat is regarded as delicacy in Nigerian diet. Every part of the animal except the hair is consumed and its' nutritive value is relatively about 22.7% compared to 20.7% for rabbit meat and 19.25% for chicken meat. Their hairs on the other hand are used as a lotion to treat wounds after burning and the pancreas is believed to have medicinal properties employed in local preparations for diabetes treatment (Mathew, 2008). There is no known religious discrimination against their meat consumption and no competition with man for food as they feed mostly on grasses, leguminous plants (groundnuts, millets, cassava) among others (Mathew, 2008; Wilkie and Godoy, 2001).

This study was carried out mainly to assess the differential accumulation of heavy metals in the organs of grass cutter, as the eventual consumption of this animal may lead to passage of the metals to humans, thereby causing bioaccumulation. It also attempts to determine the safety level for continuous consumption of this delicacy with due reference to globally accepted standards (WHO, 1984).

MATERIALS AND METHODS

Ogun State is entirely in the tropics. Located in the southwest zone of Nigeria with a total land area of 16,409.26 km^2, it is bounded on the west by the Benin Republic, on the south by Lagos State and the Atlantic Ocean, on the east by Ondo State and on the north by Oyo and Osun States. It is situated between Latitude 6.2°N and 7.8°N and Longitude 3.0°E and 5.0°E. The state has estimated population of 3,486,683 people for the year 2005 (Soewu et al., 2012; Martiniaková et al., 2010).

The four ecotomes used represent different levels of anthropogenic activities and consequent exposure to pollution by heavy metals. Omo Forest Reserve is a relatively undisturbed ecotome with minimal human influence on the environmental parameters and Ewekoro host a large cement producing factory which is exposed to continuous injection of effluents with heavy metals constituents into the ecotome. Mosinmiecotome is directly in the heart of a very vast conglomerate of oil and gas processing industries and Agbara is the main industrial axis of t he state where various industries and production activities are cited. Four wild grass cutters carcass were obtained from each of the identified four ecotomes. Each carcass was a daily fresh-killed grass cutter and the organs were removed immediately so as to avoid autolysis. The abdominal part of the samples was carefully macerated to remove the kidneys and liver, while lung was removed from the thoraxic cavity. Internal skin was also cut and the procedures were repeated for all the sampled ecotomes accordingly. Each set of organs was put in a separate glass container and labeled accordingly. All the samples were digested and analysed by Atomic Absorption Spectrophotometer (VGB 210 Bulk Scientific) using the standard procedure (Schleich et al., 2010). It is known that bioaccumulation of heavy metals vary according the sex, size and/or age of the animals (W HO, 1984). Therefore, adult males that weighed around 4.5 to 4.7 kg were used to avoid differences that may be caused by any of these factors. The data obtained were subjected to statistical analysis using SPSS (version 16.0) which analysed for descriptive statistics and one-way analysis of variance (ANOVA) to find out the significant difference of heavy metal in each organ. Mean values were separated using Duncan Multiple Range Test (DMRT) of variance to determine variations due to sampling errors and differences in mean values were determined and accepted as being significantly different if $P< 0.05$.

RESULTS AND DISCUSSION

Results showed that Fe and Zn were more abundant in quantity, while Pb and Cd occurred as a trace metals. Also, the mean concentration of heavy metals in the skin and liver were significantly higher than other organs studied. There is a generally low/no Pb accumulation in the carcass from ecotomes three and four (Tables 3 and 4) as no Pb load was detected in the specimens. Fe was the most accumulated metal compared to others, especially in specimens from ecotome two (Table 2). Cu was detected in relatively low quantity as against Zn concentration that was high (Tables 1 to 4). Cd had little/no accumulation with Cr and Mn occurring in small quantities. Table 5 presents the level of heavy metals in the samples between the group and within the group. Analysis of variance ($P>0.05$) showed that there was no significant variability in the concentration of the studied metals except for Fe and Cu in the samples. However, apparent and significant variation exists when the samples were compared. Fe is a major component of haemoglobin which is responsible for the transport of oxygen in the body, but it may also be toxic to animals and man when ingested in large amount. Fe had the highest mean levels among the metals examined with 400.512+60.0107 (Table 5) and the highest level was found in the lung with 578.300±141.1273, followed

Table 2. Result for Mosinmi ecotome.

Organ/Metal (mg/kg)	Pb	Fe	Cu	Zn	Cd	Cr	Mn
Skin	0.55	240.50	6.90	92.36	0.00	0.78	19.76
Liver	0.00	657.00	8.05	87.08	0.58	0.00	16.20
Lung	0.00	983.95	4.05	71.52	0.00	0.00	8.80
Kidney	0.96	661.20	13.85	95.68	0.00	1.08	11.04

Table 3. Result for Ibese ecotome.

Organ/Metal (mg/kg)	Pb	Fe	Cu	Zn	Cd	Cr	Mn
Skin	0.00	114.97	6.85	103.32	0.00	0.00	10.08
Liver	0.00	402.97	11.90	77.12	0.00	2.16	8.64
Lung	0.00	533.25	4.60	80.36	0.00	3.78	6.48
Kidney	0.00	284.70	13.90	86.40	0.00	2.04	6.72

Table 4. Result for Agbara ecotome.

Organ/Metal (mg/kg)	Pb	Fe	Cu	Zn	Cd	Cr	Mn
Skin	0.00	121.25	5.60	119.76	0.00	1.14	12.16
Liver	0.00	592.00	11.90	114.12	0.00	0.80	11.52
Lung	0.00	458.85	4.30	53.36	0.00	2.47	5.32
Kidney	0.00	192.20	15.25	97.00	0.32	2.16	5.76

by the Liver with 522.718±60.6882, while the skin had the lowest with 170.705±31.2212. 15.0 ppm of Fe was reported in fruit juice in Spain (Contreraslopez et al., 1987), while a study that analyzed the levels of Fe in fruit drink using ICP-MS and reported concentration range of iron to be 4.49 to 8.25 ppm, and considered this to be unsafe for human consumption (Adraiano, 1984). The mean level of Fe in this study is higher than the values recorded in most previous reports.

Cu is an essential element for growth, but when present in some beverages such as milk products and fruit juices tends to impair the shelf life or keeping the quality of such products, so it is expected that fruit juice and milk products should contain relatively low levels of copper. A concentration range of 0.87 to 0.97 ppm in fruit drink was reported in Italy (Paolo and Maurizio, 1978), mean levels of 5.00 ppm were reported for Spain (Contreraslopez et al., 1987) and mean levels 1.41 to 7.19 ppm was recorded for Nigeria (Chukwujindu et al., 2008). The levels of Cu found in this study are higher than that of concentrations found in selected heavy metals in bones and femoral bone structure of polluted biotopes in Slovakia (Martiniaková et al., 2010). However, the kidney and liver (with the kidney having the highest value) have the mean level exceeding reported values of trace metals in the terrestrial environment (Contreraslopez et al., 1987) (14.125±0.3854 and 10.100±1.0442), respectively. The concentration of Pb in the sampled organs follow the order: kidney (0.6025±0.3195) > skin (0.2425±0.1425) > lung (0.2250±0.2250) > liver (0.1925±0.1925). Pb levels of 0.01 ppm was reported for beverage drink in Canada (Adraiano, 1984), 0.38 ppm was recorded for food in Italy (Paolo and Maurizio, 1978), 0.15 ppm was reported for human consumption in Spain (Contreraslopez et al., 1987), while 0.6 to 1.93 ppm was reported for canned drinks in Nigeria (Chukwujindu et al., 2008). The mean levels of Pb in the various organs studied conform to the levels reported by previous researches except in kidney with 0.6025±0.3195. The Pb concentration in the lung, liver and skin conform to the standard set for human consumption (Paolo and Maurizio, 1978).

The highest concentration of Mn was found in the skin part of the specimen with 13.6200±2.2079 while the lung has the lowest concentration. The order of concentration of Mn in the examined organs follow the order: skin (13.2600±2.2079) > liver (10.6300±2.15557) > kidney (7.3200±1.26048) > lung (6.4700±0.8501). The level of Cd found in this study was generally low compared to any other metal examined and the highest mean levels was detected in the liver (0.15±0.145). Apart from the lung and skin, all other organs have mean concentrations of Cd exceeding the WHO permissible limit for human consumption (WHO, 1984) Table 6. The means concentration pattern of Zn follows the order: skin (88.385±27.5144)

Table 5. Analysis showing the concentration of the metals and the significance variance.

Heavy metal	Parameter	Sum of square	df	Mean square	f	Significance
Pb	Between groups	0.444	3	0.148	0.619	0.616
	Within group	2.868	12	0.239		
	Total	3.312	15			
Ni	Between groups	0.000	3	0.000	-	-
	Within group	0.000	12	0.000		
	Total	0.000	15			
Fe	Between groups	417120.9	3	139040.306	3.731	0.042
	Within groups	447188.6	12	37265.717		
	Total	864309.5	15			
Cu	Between groups	239.112	3	79.704	47.087	0.000
	Within groups	20.313	12	1.693		
	Total	259.424	15			
Zn	Between groups	2370.759	3	790.253	0.388	0.764
	Within groups	24429.130	12	2035.761		
	Total	26799.889	15			
Cd	Between groups	0.059	3	0.020	0.718	0.560
	Within groups	0.329	12	0.027		
	Total	0.388	15			
Cr	Between groups	6.448	3	2.149	2.231	0.137
	Within groups	11.563	12	0.964		
	Total	18.011	15			

Table 6. Accepted level of metal concentration for human consumption (WHO, 1987).

Heavy metal	Standard concentration (safe limit)
Fe	4.49 – 15.0 ppm
Cu	0.87 – 5.0 ppm
Zn	0.41 – 5.0 ppm
Mn	Yet to be affirmed
Cd	0.003 ppm
Cr	Yet to be affirmed
Pb	0.01 – 0.38 ppm

> liver (75.753±23.8742) > kidney (72.613±19.7098) > lung (54.332±17.8958). 5.0 ppm Zn was reported in foods in Spain (Contreraslopez et al., 1987), while 0.41 ppm was reported in drinks in Italy (Paolo and Maurizio, 1978). The levels of Zn found in this study were higher and greater than mean levels reported in metal content of apple juice for cider in Asturia (Contreraslopez et al., 1987) and 0.69 to 1.25 ppm recorded for drinks in Nigeria (Chukwujindu et al., 2008).

Lungs has higher mean concentration of Cr (2.1125±0.78415) followed by the kidney (1.6800±0.2545) while the liver and skin which both has value of 0.9325±0.444910 and 0.4800±0.28671, respectively. In the analysis test for variance, Fe has the highest total means of 400.512±60.0107, F=3.731 and is significant (p 0.042<0.05). The Zn sequence then follows with total means of 72.771±10.5672, F=0.388 and not significant (p 0.0764 > 0.05). Cu mean concentrations remain significant (p 0.00<0.05) and the total mean concentrations of 8.569+1.0397 and F=47.087. Other heavy metals studied were insignificant (P>0.05) with total mean concentrations of 0.3156±0.11747 (F=0.619, p 0.616), 0.06±0.0040 (F=0.718, p 0.560) and 1.3013±0.27394 (F=2.231, p 0.137) for the Pb, Cd and Cr, respectively.

This also agreed with some previous studies on some other mammals. The mean concentrations of Cu and Zn in animals captured in Malawi were higher in the liver compared to muscle while very low concentrations of Pb and Cd indicate no health risk connected with local consumption of silvery mole-rats in the study area (Figure 1) (Martiniaková et al., 2010). In the report, Cu has the highest accumulation record in both the body and stomach content of voles with very few exceptions where Ni and Pb had the highest figure (Martiniaková et al., 2010). On the overall, there is no single part (or organ) of the cane rat studied that is completely safe from all the metals, but some organs such as lung and skin are both Cu and Cd safe, while all parts except kidney is Pb safe from accumulation. Further statistical analysis shows that lung and skin are significantly less affected parts compared to other organs.

Generally, man should avoid consuming much of grass cutter from the study area as the heavy metals bio-accumulate and if it should be consumed at all, liver and the kidney should be avoided at all the time. Also, the study shows that the concentrations of heavy metals studied in the grasscutter found in the study areas were generally above safe limits for human consumption. The levels of Pb are above the guideline value for Pb in foods and drinking water except in the liver, while the level of Cd found in the various organs was higher than the value recommended (WHO, 1984; Adraiano, 1984), except for the lung and the skin which remain Cd undetected and safe for consumption. The data reported herein will be valuable in complementing available food composition and estimating dietary intakes of heavy metals in Nigeria.

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Conflicts of interest

No competing interests exist.

REFERENCES

Adraiano D (1984). Trace Metals in the Terrestrial Environment. 1st Ed., VerlagSpiegler, New York.
Bilos C, Colombo JC, Skorupka CN, Rodriguez-Presa MJ (2001). Sources, distribution and variability of airborne trace metals in La Plata City area, Argentina. Environ. Pollut. 111(1):149-158.
Cambra K, Martínez T, Urzelai A, Alonso E (1999). Risk analysis of a farm area near a lead and cadmium contaminated industrial site. J. Soil Contam. 8(5):527-540.
Chronopoulos J, Haidouti C, Chronopoulou-Sereli A, Massas I (1997). Variations in plant and soil lead and cadmium content in urban parks in Athens, Greece. Sci. Total Environ. 196(1):91-98.
Chukwujindu M A I, Nwozo SO, Ossai EK, Nwajei GE (2008). Heavy Metal Composition of Some Imported Canned Fruit Drinks in Nigeria. Am. J. Food Technol. 3:220-223.
Contreraslopez A, Llanaza CA, Santamaria DP (1987). Metal content of apple juice for cider in Asturia (Spain). Afinidad 44:501-503.
Schleich CE, Beltrame MO, Carlos DA (2010). Heavy metals accumulation in the subterranean rodent Ctenomys talarum (Rodentia: Ctenomyidae) from areas with different risk of contamination. Folia Zool. 59(2):108-114.
Damek-Poprawa M, Sawicka-Kapusta K (2003). Damage to liver, kidney and teeth with reference to burden of heavy metals in yellow-necked mice from areas around steelworks and zinc smelters in Poland. Toxicology, 186(1):1-10.
Department of Environment, Food and Rural Affairs, (DEFRA) (1999). Total Diet Study of Aluminium, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Tin and Zinc. The Stationery Office: London.
Dudka S, Miller W P (1999). Permissible concentrations of arsenic and lead in soils based on risk assessment. Water Air Soil. Pollut. 113(1/4):127-132.
Hawley JK (1985). Assessment of health risk from exposure to contaminated soil. Risk Anal. 5(4):289-302.
Köck M, Schaffler R, Sixl W, Pichler-Semmelrock FP, Kosmus W, Marth E (1989). Accumulation of heavy metals in animal parts: Heavy metal contamination in small mammals at a waste disposal site. pp. 855-1857.
Lane TW, Morel FMM (2000). A biological function for cadmium in marine diatoms. Proc. Natl. Acad. Sci. 97(9): 4627-4631.
Lane TW, Saito MA, George GN, Pickering IJ, Prince RC, Morel FM (2005). Biochemistry: A cadmium enzyme from a marine diatom. Nature 435(7038):42-42.
Martiniaková M, Omelka R, Jančová A, Stawarz R, Formicki G (2010). Concentrations of Selected Heavy Metals in Bones and Femoral Bone Structure of Bank (*Myodesglareolus*) and Common (*Microtusarvalis*) Voles from Different Polluted Biotopes in Slovakia. Arch. Environ. Contam. Toxicol. 60(3):524-532.
Mathew J (2008). The value of Grasscutter. World Ark. January-February, pp. 23-24.
Paolo B, Maurizio C (1978). Simultaneous determination of copper, lead and zinc in wine by differential pulse polarography. Analyst 107:271-280.
Rushton J, Viscarra RE (2004). Livestock Production Systems in South America-Analysis and Trends. Report for a study on livestock production systems in South America for FAO. Rome, Italy.
Sánchez-Camazano M, Sánchez-Martín MJ, Lorenzo LF (1994). Lead and cadmium in soils and vegetables from urban gardens of Salamanca (Spain). Sci. Total Environ. 146(147):163-168.
Smith TB, Robert KW, Derek JG, Michael WB (1997). A role for ecotones in generating rainforest Biodiversity. Science 276:1855-1857.
Soewu DA, Bakare OK, Ayodele IA (2012). Trade in Wild Mammalian Species for Traditional Medicine in Ogun State, Nigeria. Global J. Med. Res. 12(3):6-21.
Sterrett SB, Chaney RL, Gifford CH, Meilke HW (1996). Influence of fertilizer and sewage sludge compost on yield of heavy metal accumulation by lettuce grown in urban soils. Environ. Geochem. Health 18(4):135:142.
Van Lune P (1987). Cadmium and lead in soils and crops from allotment gardens in the Netherlands. Netherlands J. Agric. Sci. 35:207-210.
Wilkie DS, Godoy RA (2001). Income and price elasticity of bush meat demand in Lowland Amerindian Societies. Conserv. Biol. 15(3):761-

769.
Wong JWC (1996). Heavy metal contents in vegetables and market garden soils in Hong Kong. Environ. Technol. 17(4):407-414.
World Health Organization (WHO) (1984). Guidelines for Drinking Water Quality: Health Criteria and Other Supporting Information. Vol. 2, WHO, Geneva.
Zurera-Cosano G, Moreno-Rojas R, Salmeron-Egea J, Pozo LR (1989). Heavy metal uptake from greenhouse border soils for edible vegetables. J. Sci. Food Agric. 49(3)307-314.