European Journal of Biotechnology and Bioscience
ISSN: 2321-9122
Impact Factor: RJIF 5.44
www.biosciencejournals.com
Volume 5; Issue 5; September 2017; Page No. 73-78

Environmental pollution and heavy metals

[1] Eke Ugorji Iheanacho, [2] Ndulaka JC, [3] Onuh CF
[1] Department of Medical Biochemistry, Abia State University, Uturu, Nigeria
[2, 3] Department of Biochemistry, Abia State Polytechnic, Aba, Nigeria

Abstract
Heavy metals contribute to the part of earth crust, heavy metals such as Cu, Pb, Cr, and Hg, are non nutritive toxic metals and are environmental pollutants. Agricultural activities through the application of phosphate fertilizers make this toxic metal readily available in the soil, which can leach in the spring aquifer. Even in traces, these elements can pose a sever risk in the environment, and their bio-accumulation in the food chain can cause drastic problem to humans, this is as a result of accumulation of metals in plant parts having secondary metabolites, which is responsible for a particular pharmacological activity.

Keywords: heavy metals, vegetables, food chain, biotoxicity

Introduction
Heavy metal contamination of vegetables cannot be underestimated as these foodstuffs are important components of human diet. Vegetables are rich sources of vitamins, minerals, and fibres and also have beneficial antioxidative effects (Marshall, 2009) [55].
However, intake of heavy metal-contaminated vegetables may pose a risk to human health. Heavy metal contamination of food is one of the most aspects of food quality assurance and is non-biodegradable and persistent environmental contaminants, which may be deposited on the surfaces and then absorbed into the tissues of vegetables.
Fertilizers have been shown to contain not only nutrients necessary for plant growth but heavy metal impurities (Schroeder *et al.*, 1963) [54].
Monitoring and assessment of heavy metal concentrations in the fertilizers from the market sites have been carried out in some developed and developing countries (Sharma *et al.*, 2009) [55].
Heavy metals, such as copper, lead, chromium, and mercury are important environmental pollutants, their presence in the atmosphere, soil and water even in traces, can cause serious problem to humans.
Heavy metal accumulation in soils is of concern in agricultural production due to adverse effect in food quality and safety and crop growth (due to phytotoxicity) (Fergusson, 1990) [16] and environmental health.
The mobilization of heavy metals into the biosphere by human activity has become an important process in the geochemical cycling of these metals. This is acutely evident in urban areas where various stationary and mobile sources release large quantities of heavy metals into the atmosphere and soil exceeding the natural emission rates (Bilos *et al.*, 2001) [6].
Heavy metal bioaccumulation in the food chain can be especially highly dangerous to human health. These metals enter the human body mainly through two routes namely: inhalation and ingestion, and with ingestion being the main route of exposure to these elements in human population.
In Nigeria, according to recent studies, it has been shown that vegetables are widely cultivated and consumed all through the year (Opabode and Adeboye, 2005). Rapid technological advance in agriculture have caused the continuous injection and release of manmade inorganic and organic chemicals into the natural ecosystem. Some of these chemicals are toxic and resistant to physical, chemical or biological degeneration, thus presenting an environmental burden of considerable magnitude (Ebong *et al.*, 2008) [12].
Man in his effort to increase agricultural yields has resorted to the application of both organic and inorganic fertilizers to soil (Nwaugo *et al.*, 2008) [46].
Recent study shows that inorganic fertilizers contain heavy metals and all these heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues.
Some people cannot excrete them efficiently enough and a build up occurs (Godfrey *et al.*, 2003) [20].
Fertilizers were implicated in raising some heavy metals concentrations in food crops and since then, researchers have been urged to investigate the impact of impurities in fertilizer on crop uptake of potentially toxic element (Schroeder *et al.*, 1963) [54].
Several studies have shown that the main source of fertilizer derived heavy metals in soil is phosphatic fertilizers manufactured from phosphate rocks that contain various metals as minor constituents in their ores (Kpomblekon *et al.*, 1994) [32].
These heavy metals accumulate in the soil and become readily available to plant. The use of these fertilizers has increased significantly over last few decades and is projected to increase even more (Bumb and Baanaunte, 1996) [8].
In Nigeria, NPK fertilizers are main inorganic fertilizers used

in the agricultural sector. It is believed that most farmers use excess rates of inorganic fertilizer due to lack of proper measurement (Uwah *et al.*, 2009) [62].

For many years, commercial fertilizer applications have been regulated to ensure that the product label provides accurate information on essential plant nutrient contents.

Quality in some fertilizer products have extended beyond nutrient content to the potential presence of non-nutrient toxic element in fertilizer such as heavy metals.

Plants are dependent on the local soil. Ultimately, fertilized soil is the primary natural source of trace elements and toxic elements in animals and man. It has been established that plant food has been clearly shown to be an avenue of heavy metal entry into the human food chain with harmful effects on health (Oliver, 1997) [49].

Heavy metals and living organisms

Heavy metals are reported to encourage mutations at greater amount in animals, they have capacity to produce genetic harm in germ cells of both male and female animals. Chronic low- level intakes of heavy metals have damaging effects on humans and other animals, since there is no good mechanism for their elimination. Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptional toxic (Ejaz *et al.*, 2006). Vegetables take up metals by absorbing them from contaminated soils, which may arise from improper fertilizer application or improper disposal of mining materials (Eke *et al.*, 2015). Potentially toxic metals are also present in commercially produced foodstuffs and however, predicting the exposure to these metals from consumption of food is more complicated because uptake of metals by plants depends on soil properties and plant physiologic factors.

Lead is toxic and very harmful to plants, although plants usually show ability to accumulate large amount of lead without visible changes in their appearance or yield. Lead is a naturally occurring toxic metal found in the Earth's crust. Its widespread use has resulted in extensive environmental contamination, human exposure and significant public health problems in many parts of the world.

Important sources of environmental contamination include mining, smelting, manufacturing and recycling activities, and, in some countries, the continued use of leaded paint, leaded gasoline, and leaded aviation fuel. More than three quarters of global lead consumption is for the manufacture of lead-acid batteries for motor vehicles. Lead is, however, also used in many other products, for example pigments, paints, solder, stained glass, lead crystal glassware, ammunition, ceramic glazes, jewellery, toys and in some cosmetics and traditional medicines. Drinking water delivered through lead pipes or pipes joined with lead solder may contain lead. Much of the lead in global commerce is now obtained from recycling (UNEP, 2016).

Young children are particularly vulnerable to the toxic effects of lead and can suffer profound and permanent adverse health effects, particularly affecting the development of the brain and nervous system. Lead also causes long-term harm in adults, including increased risk of high blood pressure and kidney damage. Exposure of pregnant women to high levels of lead can cause miscarriage, stillbirth, premature birth and low birth weight, as well as minor malformations (IHME, 2015).

Health effects of lead poisoning on children

Lead can have serious consequences for the health of children. At high levels of exposure, lead attacks the brain and central nervous system to cause coma, convulsions and even death. Children who survive severe lead poisoning may be left with mental retardation and behavioural disorders. At lower levels of exposure that cause no obvious symptoms, and that previously were considered safe, lead is now known to produce a spectrum of injury across multiple body systems. In particular lead affects children's brain development resulting in reduced intelligence quotient (IQ), behavioural changes such as reduced attention span and increased antisocial behaviour, and reduced educational attainment. Lead exposure also causes anaemia, hypertension, renal impairment, immunotoxicity and toxicity to the reproductive organs. The neurological and behavioural effects of lead are believed to be irreversible. There is no known safe blood lead concentration. But it is known that, as lead exposure increases, the range and severity of symptoms and effects also increases. Even blood lead concentrations as low as 5 µg/dl, once thought to be a "safe level", may result in decreased intelligence in children, behavioural difficulties and learning problems.

Iron toxicity can be classified as corrosive or cellular. Ingested iron can have an extremely corrosive effect on the gastrointestinal (GI) mucosa, which can manifest as nausea, vomiting, abdominal pain, hematemesis, and diarrhea; patients may become hypovolemic because of significant fluid and blood loss.

Cellular toxicity occurs with the absorption of excessive quantities of ingested iron. Severe overdose causes impaired oxidative phosphorylation and mitochondrial dysfunction, which can result in cellular death. The liver is one of the organs most affected by cellular iron toxicity, but other organs such as the heart, kidneys, lungs, and the hematologic systems also may be impaired. With chronic iron overload, the deposit of iron into the heart may cause death due to myocardial siderosis.

With both corrosive and cellular toxicity, the end result is significant metabolic acidosis, due to several factors. Hypo perfusion due to significant volume loss, vasodilatation, and negative inotropic effect of iron will result in lactic acidosis. Inhibition of oxidative phosphorylation will promote anaerobic metabolism.

Individuals demonstrate signs of GI toxicity after ingestion of more than 20 mg/kg. Moderate intoxication occurs when ingestion of elemental iron exceeds 40 mg/kg. Ingestions exceeding 60 mg/kg can cause severe toxicity and may be lethal.

Biotoxicity of heavy metals

Heavy metals apply to the group of metals and metalloids with atomic density greater than 4g/cm^3 and are toxic even at lower concentration (Garbarino *et al.*, 1995; Hawkes, 1997) [19]. Heavy metals can be broadly classified with respect to their effects on bio-processes (Duruibe *et al.*, 2007) [11]. The classes are listed as follows; the essential nutritive elements which include copper, Iron, Zinc, Magnesium etc.- non essential non nutritive elements which include chromium, nickel, cobalt etc., and non nutritive toxic elements which are known to have detrimental effects, example cadmium, arsenic, lead etc.

The biotoxic effect of heavy metal refers to the harmful effects of heavy metals on the body when consumed above the biological recommended limits. The individual metal exhibit specific signs of toxicity, the following have been reported as general signs associated with Cd, Pb, Zn, Hg, and As.

Cadmium is toxic at extremely low levels. In humans, long term exposure results in renal dysfunction, characterized by tubular proteinuria. Cadmium is also associated with bone defects viz; osteomalacia, osteoporosis and spontaneous fractures, increased blood pressure and myocardiac dysfunction (Sharma, 2005). Depending on the severity of exposure, the symptoms of effect include nausea, vomiting, abdominal cranps, dyspnea and muscular weakness. Severe exposure may result in pulmonary odema and death (Young, 2005) [65].

Lead is the most significant toxin of the heavy metals, and the inorganic forms are absorbed through ingestion by food, water and inhalation (Ferner, 2001) [17]. A notable serious effect of lead toxicity is its tetratogenic effect. Lead poisoning also causes inhibition of the synthesis of haemoglobin; dysfunctions of kidneys, joints and reproductive systems, cardiovascular system and acute, chronic damage to the central nervous (CNS) and peripheral nervous (PNS) (Ogwuegbu and Mahanga, 2005). Other effects include damage to the Gastrointestinal tract (GIT) and urinary tract resulting in bloody urine, neurological disorder and can cause severe and permanent brain damage. While inorganic form of lead typically affects the CNS, PNS, GIT and other biosystems, organic forms predominantly affect the CNS (Sharma, 2005). Lead affects children by leading to the poor development of the grey matter of the brain, thereby resulting in poor intelligence quotient (IQ) (Udedi, 2003) [60]. Its absorption in the body is enhanced by Ca and Zn deficiencies.

Zn has been reported to cause the same sign of illness as does lead, and can easily be mistakenly diagnosed as lead poisoning (Sharma, 2005). Zinc is considered to be relatively non toxic, especially if taken orally. However, excess amount can cause system dysfunctions that result in impairment of growth and reproduction (Nolan, 2003) [44]. The clinical signs of Zinc toxicosis have been reported as vomiting, diarrhea, bloody urine, liver failure, kidney failure and anemia (Fosmire, 1990) [18].

Mercury is toxic and has no known function in human biochemistry and physiology (Sharma, 2005). Inorganic forms of mercury cause spontaneous abortion, congenial malfunction and gastrointestinal disorders. Poisoning by its organic forms, which include monomethyl and dimethyl mercury present with erethism (an abnormal irritation or sensitivity of an organ or body part to stimulation), acrodynia (pink disease which is characterized by rash and desquamation of the hands and feet). Neurological disorders, total damage to the brain and CNS are also associated with congenial malformation (Ferner, 2001) [17].

As lead and mercury, arsenic toxicity symptoms depends on the chemical form ingested (Holum, 1983; Ferner, 2001) [26, 17]. Arsenic acts to coagulate protein, forms complexes with co-enzymes and inhibits the production of adenosine triphosphate (ATP) during respiration (INECAR, 2000) [28]. It is possibly carcinogenic in level exposure and can cause death (Ogwuegbu and Ijioma, 2003) [27].

Contamination of heavy metals with vegetables

Heavy metal pollution is of significant ecological / environmental concern. This is due to the fact that they are not easily biodegradable or metabolized, thus precipitating far reaching effects on the biological system such as humans, animals, plants and other soil biota (Yoon, 2003). Uptake of metals is dependent on chemical form of the metals in the contaminated soil (Gundermann *et al.*, 1995). Elevated levels of heavy metals in soil may lead to uptake by native and agronomic plants. Several studies have indicated that vegetables, particularly leafy crops, grown in heavy metals contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soil (Vousta *et al.*, 1996).

Some metals such as Fe, Zn, and Cu are known to be essential in plant nutrition, however many other heavy metals do not play any significant role in a plant physiology. Plants growing in a polluted environment can accumulate toxic metals at high concentration causing serious risk to human health when consumed (Vahter *et al.*, 2007).

Many metals are extremely toxic because of their Solubility in water and even in low concentrations, some trace metals have damaging effect to humans and animals because there is no mechanism for their elimination from the body (Reilly, 1980; Davies and white, 1981).

Plants growing in a polluted environment can accumulate the toxic metals at high concentration causing serious risk to human health when consumed. Vegetables absorb and adsorb these metals from the ground as well as from the parts of vegetable exposed to air from polluted environment (Vousta *et al.*, 1996).

Conclusion

Heavy metals are important in many respects to man, especially in the manufacturing of certain important products of human use, such as accumulators (Pb), mercury-arch lamps and thermometers (Hg), utensils (Al) and a wide range of other products (Yaw, 1990; McCluggage, 1991). But the biotoxic effects, when unduly exposed to them could be

potentially life threatening hence, cannot be neglected. While these metals are in many ways indispensable, good precaution and adequate occupational hygiene should be taken in handling them. Although heavy metal poisoning could be clinically diagnosed and medically treated, the best option is to prevent heavy metal pollution and the subsequent human poisoning.

References

1. Ademoroti CMA. Environmental Chemistry and toxicology, foludex press Ltd, Ibadan, 1996.
2. Allen LH. Supplement: Forging Effective Strategies to combat Iron Deficiency, Journal of Nutrition, the American Society for Nutritional Sciences, 2002; 132:8135-8195.
3. Alloway BJ. Heavy metals in soils. Chapman and Hall, London, 1997.
4. ASTM. American Society for Testing and materials. Official documents on methods of testing all types of materials Washington DC, 2010.
5. APHA. Standard methods for the examination of water and waste water American public health association, 18th edition, Washington DC, 1999.
6. Bilos C, Colombo JC, Skoruoka CN, Rodriguez Pres AMJ. Distribution and variability of airborne trace metals, plata city area, Argentina, 2001.
7. Brooks RR. Plants that hyperaccumulate heavy metals. Waving ford: CAB International; Phytochemistry of hyperaccumulators, 2004, 15.
8. Bumb B, Baanaunte C. World trends in fertilizer use and projections to 2020. International food policy research institute, 2020 brief No.38 Washington DC, 1996.
9. Cardenas A, Lauwerys R. Cadmium and health: The Belgian experience. IARC Scientific publications, 1997; 118:15-17.
10. De Zwart D. IMP-Data used for modelling environmental vegetation effects on a European scale. Annual report UN-ECE, ICP-IM http://www.eoiss.net/EOISS-sampleall chapter.aspx, 1999.
11. Duruibe JO, Ogwuegbu MOC, Egwurucywu YN. Heavy metal pollution and human biotoxic effects. International Journal of Physical Sciences, 2007; 2:112-118.
12. Ebong GA, Akpan MM, Mkpenie VN. Heavy metals contents of municipal and rural dumposite soils and rate of accumulation by carica papaya and Talinum triangulare in Uyo, Nigeria E-Journal of chemistry. 2008; 5(2)281-290.
13. EFMA European Fertilizer Manufactures Association. Safety data sheet. NPK fertilizers, http://www.efma.org, 2005.
14. Erisman, Jan Willem, MA Sutton, J. Galloway, Z. Klimont, Winiwarter W. 2008; 1(10):636.
15. European Union. Heavy metals in wastes, European Commission on Environment http://ec.europa.eu/ environment/waste/studies/pdf/heavy_metalsreport.pdf, 2002.
16. Fergusson JE. The heavy elements: Chemistry, environmental impact and health effects. Oxford: Pergamin press, 1990, 382-399.
17. Ferner DJ. Toxicity, heavy metals. EMED J. 2001; 2(5):1.
18. Fosmire GJ. Zinc toxicity. Am. J. Clin. Nutr. 1990; 51(2):225-227.
19. Garbarino JR, Hayes H, Roth D, Antweider R, Brinton TI, Taylor H *et al*. Contaminants in the Mississippi River, US Geological Survey circular 1133, Virginia, USA www.pubs.uusggs.gov/circ/circ1133, 1995.
20. Godfrey M, Wojuk DP, Krone CA. A polipoprotein E. Genotypiny as a potential biomarker for mercury neurotoxicity J. Alzheimer Dis. 2003; 5(3):189-195.
21. Harrison RM. Pollution: Causes Effects and control. Royal society of chemistry, London, 1990, 297-307.
22. Halliwel B, Gutteridge JMC. Detection of free radicals and other reactive species: Free radical in biology and medicine Oxford University Press, 1999, 351.
23. Hawk JS. Heavy metals, J. Chem. Educ. 1997; 74(11):1374.
24. Heckmah JK. Public concerns with hazardous materials in fertilizers. The soil profile; A Newsletter providing information on issues relating to soils and plant nutrition, in New Jersey, USA, 2006; 16:1-6.
25. Hensley I, Adams JB, Barsal M, Geis E, Mitchell J, Gehn E *et al.* The severity of Austism is associated with toxic metal body burden and red blood cell glutathione levels, 2009.
26. Holum JR. Elements of general and biological chemistry, 6th Edition, John Wiley and Sons, N.Y., 1983, 424-426.
27. Ijioma MA, Ogwuegbu MO. Effects of certain heavy metals on the population due to mineral exploitation. In: International Conference on Scientific issues in the population, Environment and sustainable development in Nigeria, University of Ado-Ekiti, Ekiti State, Nigeria, 2003, 8-10.
28. INECAR. Institute of Environmental Conservation and Research. Position paper against mining in Rapu-Rapu, published by INECAR, Ateneo de Naga University, Philippines. www.adnu.edu.ph/institutes/inecar/pospaper 1.asp, 2000.
29. Jarup L, Berglund M, Elinder CG, Nordberg G, Vahter M. Health effects of cadmium exposure a review of the literature and a risk estimate. Scand J work Environ. Health. 1998; 24(1):1-51.
30. Johnson CA, Ndimele PE. Some aspects of Limnology and heavy metals content of water, sediments and Oreochromis. Lagoon, Lagos Nigeria, 2011.
31. Kolonel LN. Association of cadmium with renal cancer. Cancer; 1976; 37:1782-1787.
32. Kpomblekon AK, Tabatabai MA. Metal contents of phosphate rocks. Communication in soil science and plant Analysis, 1994; 25:2871-2882.
33. Lidsky TI, Schneider JS. Lead neurotoxicity in children: basic mechanisms and clinical correlates brain, 2003; 126:5-19.
34. Marshall FM, Sharma RK, Agrawal M. Heavy metal contamination of vegetables in urban Indian: a case study

in Varanasi. Environ. Pollut., 2008; 154:254-263.
35. McBride MB. Toxic Metal Accumulation from Agricultural Use of Sludge: Are USEPA Regulations protective? J Environ Qual, 1995; 24:5-18.
36. McCluggage D. Heavy metal poisoning, NCS Magazine published by Bird Hospital, Co, USA www.cockatiles. org/articles/disease/metal.html, 1996.
37. McDowell LR. Minerals in animal and human nutrient. Elsevier Science BV. Amsterdam. The Netherlands, 2003, 644.
38. McGrath SP. The Range of Metal Concentrations in Topsoils of England and Wales in Relations to Soil Protection Guidelines; Trace Subst. Environ. Health, 1986; **20**:242-252.
39. McKeague JA, Wolynetz MS. Background Levels of Minor Elements in Some Canadian soils; Geoderma, 1980; 24(1980):299-307.
40. McLaughlin MJ, Tiller KG, Naedu R, Stevens DP. Review: the behavior and environmental impact of contaminants in fertilizers. Australian Journal of Soil Research, 1996; 34:01-54.
41. Miller RW, Donahue RL. Soils: An introduction to soils and plants growth. 6th EEdition. Prentice – hall of Indian private limited Delhi, 1992, 281-307.
42. Modaihsh AS, Al-Swailem MS, Mahjoub MO. Heavy Metals contents of commercial inorganic fertilizers used in the kingdom of Saudi Arabia. Agricultural and Marine Sciences. 2004; 9(1):21-25.
43. Muhammed F, Farooq A, Umer R. Appraisal of heavy metal contents in different vegetables grown in the vicinity of an industrial area. Pak.J. Bot. Food Agric. Nutr. Dev. 2008; 7(1):1-8.
44. Nolan K. Copper toxicity syndrome, J. Orthomol. Psychiatry. 2003; 12(14):270-282.
45. Nriagu JO. A Global Assessment of Natural Sources of Atmospheric Trace Metals, Nature, 1989; 338:47-49.
46. Nwaugo VO, Onyeagbe RA, Akubugwo EI, Ugbogu O. Soil Bacterial flora and enzymatic activities in zinc and lead contaminated soil. Biokemistri. 2008; 20(2):77-84.
47. Ogwuegbu MOC, Muhanga W. Investigation of lead concentration in the blood of people in the copper belt province of Zambia, J. Environ. 2003; (1):66-75.
48. Olawoyin R, Oyewole SA, Grayson RL. Potential risk effect from elevated levels of soil heavy metals on human health in Niger Delta. Ecotoxicol. Environ Saf., 2012; 85:120-130.
49. Oliver MA. Soil and human health: a review. European Journal of soil science, 1997; 48:573-592.
50. Onyedele DJ. Asonugho C, Awotoye. Heavy metal in soil and accumulation by edible vegetable after phosphate fertilizer application. E. Journal of Environ Agriculture and food chemistry. 2006; 5(4):35-42.
51. Opabode JT, Amujoyegbe BJ. Effect of organic and inorganic fertilizer on yield and chlorophyll content of maize and sorghum bicolour Afr. J. Biotechnol, 2007; 6:1869-1873.
52. Panagos P, Van Liedekerke M, Yigini Y, Montanarella L. Contaminated sites in Europe: Review of the current situation based on data collected through an European Network. Journal of Environment and public Health press, 2013.
53. Pezzarossa BF, Malorgio F, Lubrano L, Tognoni F, Petruzzeli G. Phosphatic fertilizers as sources of heavy metals in protected cultivation. Communication in Soil Science and Plant Analysis, 1990, 21:7.
54. Schroeder HA, Balassa JJ. Cadmium: Uptake by vegetable from superphosphate and soil. Science, 1963; 140:819.
55. Sharma RK, Agrawal M, Marshall FM. Heavy metals in vegetables collected from production and market sites of a tropical urban area of Indi. Food Chem. Toxicol, 2009; 47:58-91.
56. Stessen JA, Roels HA, Emelianow D, Kuznetsovat, Thijs L, Vangronsueld J *et al*. Environmental exposure to cadmium, forearm bone density and risk of fractures: prospective population study. Public health and Environmental exposure to cadmium Pheecad study group. Lancent, 1999; 353:1140-4.
57. Snyder CS, Bruulsema TW. Nutrient use Efficiency and Effectiveness in North America; Indices of Agronomic and Environment Benefit. International plant Nutrition Institute. Norcross, Georgia, USA, 2007.
58. Stewart WM, Dibb DW, Johnston AE, Smyth TJ. The contribution of commercial fertilizer nutrient to food production. Agronomy Journal, 2005; 97:1-6.
59. Thannickal VJ, Fanburg BL. Reactive oxygen species in cell signalling. Am. J. Physiol. Lung cell. Mol. Physiol. 2000; 279(6):L1005-L10028.
60. Udedi SS. From Guinea worn scourage to metal toxicity in Ebonyi State. Chemistry in Nigeria as the new Millennium unfolds. 2003; 2(2):13-14.
61. Ukpabi Chibueze F, AAkubugwo EI, Agbafor Kingsley N, Lebe Nnanna A, Nwaulari Nwokocha J. Appraisal of heavy metal contents in commercial inorganic fertilizer blended and marketed in Nigeria, 2013.
62. Uwah EI, Ndah NP, Ogugbuaja VO. Study of the levels of some agricultural pollutants in soils and waterleaf Talinum triangulare obtained in Maiduguri, Nigerian Journal of Applied Science in Environmental Sanitation. 2009; 4(2):71-78.
63. Valko M, Mories H, Cronin MTD. Metals, toxicity, and oxidative stress. Curr. Med. Chem., 2007; 12:1161-1208.
64. Yu Z, Terry DL. Food control officials, Division of regulatory services University of Kentucky, 1994.
65. Young RA. Toxicity profiles: Toxicity summary for cadmium risk assessment information system. RALS, University of Tennessee rais.oml.gov/tox/profiles/ cadmium.shtml, 2005.
66. Wakefield ZT. Distribution of cadmium and selected heavy metals in phosphate fertilizer processing. Bulletin Y-159. National Fertilizer Development Centre. Tennessee Valley Authority, Muscle Shoals, AL, 1980.
67. WHO. Lead Environmental Health Criteria, Cyeneva: World Health Organization, 1995, 165.

68. WHO. Arsenic and Arsenic compounds. Environmental Health Criteria, Geneva: World Health Organization, 2001; 224.
69. Williams GH, David DJ. The effect of superphosphate on the cadium contents of soils and plants. Australian Journal of Soil Research, 1973; 11:43-56.