Journal of Toxicology and Environmental Health Sciences Vol. 5(1) pp. 1-11, January 2013
Available online at http://www.academicjournals.org/JTEHS
DOI: 10.5897/JTEHS11.081
ISSN 2006-9820 ©2013 Academic Journals

Full Length Research Paper

Environmental metals pollutants load of a densely populated and heavily industrialized commercial city of Aba, Nigeria

Tobias I. Ndubuisi Ezejiofor[1]*, A. N. Ezejiofor[2], A. C. Udebuani[1], E. U. Ezeji[1], E. A. Ayalogbu[1], C. O. Azuwuike[1], L. A. Adjero[2], C. E. Ihejirika[3], C. O. Ujowundu[4], L. A. Nwaogu[4] and K. O. Ngwogu[5]

[1]Department of Biotechnology, Federal University of Technology, Owerri, Imo State Nigeria.
[2]Toxicology Unit, Department of Clinical Pharmacy University of Port Harcourt, Rivers State, Nigeria.
[3]Department of Environmental Technology, Federal University of Technology, Owerri, Imo State, Nigeria.
[4]Department of Industrial Biochemistry, Federal University of Technology, Owerri, Imo State, Nigeria.
[5]Department of Chemical Pathology, College of Medicine and Health Sciences, Abia State University Teaching Hospital, Aba, Nigeria.

Accepted 22 November, 2012

Diseases and their associated health defects are most often related to the quality of the total environment which in itself is also related to the quality and quantity of wastes generated in those areas, as partly defined by the nature of activities carried out by the populace. This environment-health relationship dynamics are particularly evident in most tropical environments like Nigeria where various environmental media are laden with sundry pollutants including metals, most of which are often furnished by wastes. This study aims at investigating the environmental metal load of Aba, a major commercial city in South-east Nigeria which is home to many artisanal, small- and medium-scale industrial activities, but presently experiencing waste-related menace. Randomly collected soil samples from different areas of Aba metropolis and a sub-urban community considered less polluted (to serve as control) were analyzed for heavy and non-heavy metals. Results show that while the mean of the estimated heavy metals in the six sites ranged from 0.31 ± 0 to 1293.75 ± 0 µg/g, for non-heavy metals it ranged between 55.01 ± 24.88 and 903.74 ± 1081.25. In the control site, the range is between 0 and 1293.75 ± 0 for heavy metals while for the non-heavy metals, it is between 72.73 ± 0 and 410.50 ± 0. The results indicate that the mean concentrations for most of the metals were high with respect to the Nigerian Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO) standards. Findings in this study have serious implications for public health.

Key words: Environmental, heavy metals pollutants load, Aba, Nigeria.

INTRODUCTION

Heavy metals have been variously defined as those metals with higher atomic number and weight (Norman, 1981); large group of elements with an atomic density of greater than 6 g cm^{-3}, which are both biologically and industrially important (Alloway, 1995); any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentration (Holdings, 2004). They are trace metals that are at least five times denser than water, and as such, they are stable elements (meaning they cannot be metabolized by the body) and bio-accumulative (passed up the food chain to humans). Over 20 different heavy metals are known and include aluminium, antimony, arsenic, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium, tin, vanadium, zinc, platinum, and copper (metallic form versus ionic form) etc. (WHO, 1996b). Heavy metals are natural components of the environment, being present in rocks, soil, plants and animals. They occur in different

---

*Corresponding author. E-mail: tinezejiofor@gmail.com; favourtine@yahoo.com. Tel: +2348036774598.

forms: as minerals in rock, sand and soil; bound in organic or inorganic molecules or attached to particles in the air. In today's industrial society, there is no escaping exposure to toxic chemicals and metals. This is so because somehow, our society is dependent upon metallurgy for proper functioning. It is therefore not surprising that human exposure to heavy metals has risen dramatically in the last 50 years as a result of an exponential increase in the use of heavy metals and/or their compounds in industrial and agricultural processes. In the United States for instance, tons of toxic industrial waste are reportedly mixed with liquid agricultural fertilizers and dispersed across America's farmlands (United States Department of Agriculture (USDA), 2000). Mining, manufacturing and the use of synthetic products (for example, pesticides, paints, batteries, industrial waste, and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils. Potentially contaminated soils may occur at old landfill sites (particularly those that accepted industrial wastes), old orchards that used insecticides containing arsenic as an active ingredient, fields that had past applications of waste water or municipal sludge, areas in or around mining waste piles and tailings, industrial areas where chemicals may have been dumped on the ground, or in areas downwind from industrial sites (USDA, 2000). Environmental contamination and exposure to heavy metals is a serious growing problem throughout the world, as both natural sources and anthropogenic processes emit heavy metals into various environmental media.

The rapid industrialization and urbanization of the world have dramatically heightened these emissions, thus increasing the overall environmental load of heavy metals and consequent human exposures to them. Human exposure to aluminium, for instance, is caused by environmental factors such as soil contamination whereby aluminium can be mobilized as a consequence of soil acidification due to the use of certain fertilizers or acid rain; or as a result of aluminium use in some Industrial processes such as metallurgy, food preservation (yokel et al., 2008), water purification (Krewski et al., 2007), and the use of pharmacological and cosmetic products ((Ernst, 2002; Ernst and Coon, 2001; Garvey et al., 2001; Ganrot, 1986).

Arsenic and its compounds is also possessing great human exposure scenario as they are used in pesticides, insecticides, herbicides, and some kinds of alloys. Contaminated food, water, air and cigarette smoking are part of the sources of exposure to arsenic (American Conference of Government Industrial Hygienists (ACGIH), 2003; Namgung and Xia, 2001). As for lead, human exposure also occurs through food, water, air and soil. Food and water lead sources include the use of lead-containing ceramics dishware, metal plumbing, and food cans that contain lead solder (White et al., 2007). People can also be exposed to lead contamination from industrial sources such as lead smelting and manufacturing industries (Goyer, 1996; White et al., 2007). Though the risk of lead contamination from motor vehicle exhaust of leaded gasoline has decreased in the last couple of decades as a consequence of reduction of lead addition to petrol (Stromberg et al., 2008), because lead is a cumulative metal, it still remains a major hazard for human health. Same is the case for many metals because of the problem of non-degradability and accumulation. Occupational activities are part of the environmental factors responsible for environmental distributions and human exposures to metals. Workers that produce or use various metals (for example, arsenic) and their compounds are also at the risk of their exposure. Indeed, many occupations involve daily heavy metal exposures such that over 50 professions entail exposure to mercury alone. It is therefore not quite surprising that despite the efforts of the regulatory agencies, many studies have demonstrated variable concentrations of various heavy metals in various environmental media, thus indicating that the problem of environmental metal pollution is very much around us.

Iwegbue et al. (2006) studied the characteristic levels of heavy metals (Cd, Cr, Cu, Pb, Ni and Zn) of soil profiles of automobile mechanic waste dumps and reported that the concentration of heavy metals decreased with the depth of the profile and lateral distance from the dumpsites; the levels found in this study exceeded background concentrations and limits for agricultural and residential purposes; the distribution pattern of heavy metals in the soil profiles were in the order Pb > Zn > Cu > Cd > Ni > Cr, with the mechanic waste dumps representing a potential sources of heavy metal pollution to environment. Similarly, soils at different dumpsites located within Ikot Ekpene, South Eastern Nigeria and control soil samples taken 10 km away from the dumpsites were all analysed for the concentration of Na, Ca, Pb, Ni, Mn, Mg, Fe, P, N, Cu and Zn (Eddy et al., 2006). The result of the analysis shows that the dumpsites contain significant amount of toxic and essential elements, as significant difference existed between the concentration of these elements in the dumpsites and 10 km away from the dumpsite ($p > 0.05$).

Another study by Inuwa et al. (2007) investigated the concentration of trace metals in soil found around the major industrial areas of the North-western state of Nigeria using absorption spectrophotometry. The results obtained indicated that these metals on dry weight basis in the soil ranged between (0.1 to 0.7 µg/g) Cd, (14.2 to 92.7 µg/g) Cr, (151.5 to 540 µg/g) Pb and (3.5 to 24.7 µg/g) Ni, the results indicating relatively high concentrations of tested metals in industrial areas than those of the control sites. Similarly, the study of Igwilo et al. (2006) showed that the mean metal contents of soil samples from Otuocha agricultural river basin exceeded the WHO guidelines for the parameter in soil. Their result is as follows: Cd (0.07 to 3.345 ppm), Cu (4.38 to 13.54

ppm), Pb (0.59 to 7.34 ppm) and Ni (0.36 to 5.64 ppm), revealing that the obtained values were higher for Pb, Cd, Cu, Ni and other measured parameters in soils from agriculturally active Otuocha river basin relative to the controls just as the study of Adewuyi and Opasina (2011) also showed high concentrations of Fe, Mn, Cu, Zn, Ni, Cd and Pb, and all the parameters were above control, and also exceeded FEPA and WHO guidelines.

However, Aderinola et al. (2009) reported varying concentration of heavy metals in surface water, sediments, fish and periwinkles of Lagos Lagoon. Their report showed that the mean levels of heavy metals in the sediments of Lagos lagoon were generally low and fell within the acceptable limits described by WHO and FEPA. The average concentrations for the heavy metals were (0.083 ± 0.035 mg/kg) As; (1.150 ± 0.090 mg/kg) Cd; (0.867 ± 0.075 mg/kg) Ni; (0.618 ± 0.193 mg/kg) Cr; (0.600 ± 0.272 mg/kg) Cu; (19.393 ± 6.649 mg/kg) Fe; (0.450 ± 0.598 mg/kg) Pb; (2.040 ± 1.049 mg/kg) Mn; (0.730 ± 0.337 mg/kg) Zn, while Iron, Manganese and Nickel were not defined. Equally, a study on Ibeche (Ikorodu) Lagos lagoon area (Ladigbolu et al., 2011) reported higher concentrations of Fe, Cu, Pb, Cd and Zn when compared with the values in unpolluted sediment as well as the standards of the regulatory authorities (WHO, 1982 and FEPA, 1988).

However, apart from the contributions from anthropogenic sources, soils naturally contain trace levels (ppb to ppm) of heavy metals. For example, median concentrations of metals in U.S. soils are 0.2 mg/kg cadmium, 11 mg/kg lead, and 18.2 mg/kg nickel (FEPA, 1999). There are however, considerable variations in these metals concentrations by geographic region and soil type. Thus, threshold limit values (TLV) for metals in soils are determined by some factors including the following: the spatial and temporal changes of geochemical background, the possible effects of deep geological structures and other geochemical factors, natural anomalies exceeding baseline values by order of magnitudes (natural processes may lead to anomalies exceeding baseline values by order of magnitudes) without anthropogenic contamination, and the results of monitoring examinations of metal groups (Sipos and Pokas, 2008).

There are 35 metals that concern us because of occupational or residential exposure; 23 of these are the heavy elements or ‘heavy metals’: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium and zinc (Glanze, 1996). Indeed, the body actually has need for approximately 70 friendly trace element heavy metals. Interestingly, small amounts of these elements are common in our environment and diet and are actually necessary for good health but large amounts of any of them may cause acute or chronic toxicity (poisoning). Some of these are trace elements (micronutrients) and perform essential functions for both plants and animals in which they constitute essential part of the metabolizing and/or detoxifying proteins or enzymes.

Selenium, copper, zinc and iron are examples of this class of metals. Iron for example, prevents anaemia, and zinc is a cofactor in over 100 enzyme reactions. Magnesium and copper are other familiar metals that in minute amounts, are necessary for proper metabolism to occur. They normally occur at low concentrations and are known as trace metals. At high concentrations however, they can be toxic and therefore pose a risk to the health of animals and man. There are 12 others that are very toxic even at levels that are only moderately above background levels (that is, very low concentrations).

These are the toxic heavy metals and include arsenic cadmium, lead, mercury, Nickel, etc. (WHO, 1996a; Carpenter, 2001). They act as poisonous interference to the enzyme systems and metabolism of the body. No matter how many good health supplements or procedures one takes, heavy metal overload will be a detriment to the natural healing functions of the body.

The most common problem-causing cationic metals (metallic elements whose forms in soil are positively charged cations for example, Pb^{2+}) are mercury, cadmium, lead, nickel, copper, zinc, chromium and manganese, while the most common anionic compounds (elements whose forms in soil are combined with oxygen and are negatively charged for example, MoO_4^{2-}) are arsenic, molybdenum, selenium, and boron (USDA, 2000).

Toxic heavy metals have no function in the body and can be highly toxic. The metals are taken into the body through inhalation, ingestion and skin absorption. If heavy metals enter and accumulate in body tissue faster than the body’s detoxification pathways can dispose of them, a gradual build-up of these toxins will occur. High-concentration exposure is not necessary to produce a state of toxicity in the body tissues and over time, toxic concentration levels may be reached. Heavy metals are dangerous not only because of their inherent nature but also because of their bioaccumulative tendency and problem of biomagnifications with increasing trophic levels, and therefore can cause permanent damage to health. While the inorganic form of the metal may not be easily taken up, the organic (alkylated) forms are readily taken up by body tissues and can be retained for a considerable length of time (Berlin and Ulberg, 1963; Garrett et al., 1992).

Consequently, organometals regardless of which base it is, are in general more toxic to humans than the inorganic form, primarily because they are lipid soluble and therefore penetrate the body more easily, especially the brain (Carpenter, 2001). Methyl mercurials for instance, can easily pass the placental barrier and the blood brain barrier, while inorganic mercury passes these barriers less easily. When the rate of introduction of toxic metals into the body system is greater than that of removal, the metals accumulate and this could play a major role in heavy metal toxicity. Accumulated heavy metals at different levels of body burdens exhibit corresponding levels of toxicity that may be more acute on juvenile stages of organisms than on adults (WHO, 1996a, b; Carpenter, 2001). The negative impacts of heavy metals result from their toxicity to biological processes including those catalyzed by micro organisms (Kelly and Tate, 1998). The degree to which a system, tissue, organ or cell is affected by a heavy metal toxin depends on the toxin itself and the individual's degree of exposure to the toxin (Extreme Health, 2004). For any metal, the toxicity is a function of its molecular configuration and physico-chemical properties such as solubility, particle size, and other determinants of the extent to which a material can intrude into biochemical processes (Norman, 1981).

Excess heavy metal accumulation in soils is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time) due to food chain transfer. Acute (immediate) poisoning from heavy metals is through ingestion or dermal contact. Chronic problems associated with long-term heavy metal exposures are: lead, mental lapse; cadmium, affects kidney, liver, and gastrointestinal tract; arsenic, skin poisoning, affects kidneys and central nervous system. Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Long-term exposure may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer (International Occupational Safety and Health Information Centre, 1999).

Most human load of toxic metals is acquired from the ambient concentrations of these metals through inhalation of dust and fumes, ingestion of food and drink and/or absorption through skin in extreme cases (Occupational Safety and Health Administration (OSHA), 1991; Agency for Toxic Substance and Disease Registry (ATSDR), 2003). However the most classical toxicities associated with these metals have come through massive pollution of the environment through industrial activities. Apart from the raw materials or process chemicals, production of wastes is an integral part of industrial activities that can increase the metal load of the ambient environment through pollution of the environment with metal-bearing wastes in the form of solids, liquids, gases and air-borne particulate matter; and quite often, facilities needed for their proper disposal are not adequate. This underscores the need for investigation into the toxic metal load of our immediate environment, given the massive degradation suffered by most of our cities from various forms of wastes.

Aba, a commercial city east of the Niger is one of those cities of Nigeria currently under very heavy load of waste related degradation, with very high possibilities of heavy metal pollution. Again, this city plays host to large army of artisans (technicians of various sorts) engaged in all forms of industrial ventures, particularly numerous small-scale artisanal activities involving use, conversion and reuse of metal-containing compounds with consequent release of metal-bearing wastes. They include masons, electricians, paint makers and painters, petroleum pump attendants and the street-side freelance retailers of petroleum products, automobile repairers of various categories (including mechanics, panel beaters, etc.), welders, tinkers and other metal smelting artisans, etc. To mention this few. Consequently, all forms of metal-containing wastes and metal junks form part of the massive heaps of wastes that litter every nook and crannies of the town. Indeed the city plays host to uncountable small- and medium-scale industrial ventures that generate equally uncountable varieties of wastes which are eventually released to human surroundings.

Thus, there is indeed very high possibility of soil, water and air pollution from several environmental pollutants that most probably include some metal forms with equally very high possibilities of human contaminations through the environmental media. The extent of metals pollutant load of this city is presently unknown, thus making this study a very highly warranted one.

MATERIALS AND METHODS

Samples and preparation

Specifically, the study examined the heavy metal load of soils from randomly selected areas of Aba metropolis. Soil samples from a particular area of Aba (a housing estate) considered less polluted because of its low industrial activities as at the time of this study, and a sub-urban area within the outskirt of Aba were also included to serve as controls. In all, soil samples were collected from six different locations in Aba metropolis and its environs as follows:

Site 1: Ndiegoro Area (beyond the popular Ngwa road);
Site 2: Aba Main River (popularly called Aba Waterside);
Site 3: Ogbor Hill Area (area beyond the Aba river);
Site 4: Aba Main Area (Aba Central Township area);
Site 5: World Bank Housing Estate, Aba;
Site 6: Umuamacham village, a sub-urban area within the outskirt of Aba.

Accordingly, soil samples from these sites constitute samples 1 to 6 analyzed in the study. At each sampling site, about 9 × 9 cm^2 hole was dug on the ground to the depth of about 15 to 20 cm from the soil surface, and a generous amount of soil sample was collected. The samples were collected in sterile plastic containers previously rinsed in a solution of 95% ethyl alcohol, and then distilled water. At the base laboratory, one gram of each of the samples was carefully weighed out, with caution not to contaminate the samples with extraneous metal sources.

Metal analysis

Pre-metals analyses treatments of soil samples involve acid digestion of the soil samples. The weighed out gram of each of the samples was dried, sieved and transferred into a 100 mL beaker.

Table 1. Concentrations of the heavy metals at the various soil samples (µg/g) compared with FEPA and WHO standards.

Metal	Soil sample					Mean ± S.D	Control soil sample	WHO (1984)/FEPA (1991) standards in sediments (mg/l)	WHO (1984)/FEPA (1991) standards in water (mg/l)
	1	2	3	4	5				
Cd	4.17	N.d	6.25	N.d	N.d	5.21±1.47 (n=2)	N.d	0.003	0.005 (WHO) 0.01 (FEPA)
Co	2.78	2.78	2.78	6.94	2.78	3.61±1.66 (n=5)	N.d	NA	NA
Cr	25.0	N.d	N.d	25.0	N.d	25.0±0 (n=2)	N.d	2.000	0.05
Zn	13.4	4.6	26.6	1.4	8.6	10.92±8.77 (n=5)	0.12	3.000	1.5
Cu	80.0	19.5	18.0	66.5	11.0	39.0±28.43 (n=5)	17.5±0	1.000	0.05
Pb	131.25	35.0	32.5	150.0	6.25	71.00±64.89 (n=5)	N.d	0.010	0.05
Ni	25.0	10.0	40.0	7.50	17.50	20.00±13.11 (n=5)	N.d	0.02	0.1-0.2
V	0.31	0.31	0.31	0.31	N.d	0.31±0 (n=4)	N.d	NA	NA
Mn	391.94	33.07	106.45	133.06	66.13	146.13±127.55 (n=5)	28.42±0	0.050	NA
Fe	778.03	741.67	731.82	815.90	853.03	784.09±45.47 (n=5)	1293.75±0	0.300	0.3-1.00

N.d - Not detected :NA=Not Available

Table 2. Concentrations of the non-heavy metals in the various soil samples compared with those of the control (µg/g).

Metal	Soil sample					Mean ± S.D	Control soil sample
	1	2	3	4	5		
Mg	108.63	52.63	104.25	96.63	81.50	88.73±20.27 (n=5)	186.00±0
Ca	1337.5	12.50	2843.75	125.00	200.00	821.54±1081.25 (n=6)	410.50±0
K	81.82	34.09	88.66	38.64	31.82	58.00±24.88 (n=6)	72.73±0
Na	287.50	125.00	381.25	75.00	100.00	194.78±119.64 (n=5)	200.00±0

Concentrated nitric acid (HNO_3) (10 mL) and concentrated perchloric acid ($HClO_4$) (5 mL) (that is, acid volume ratio of 2:1) were added and the mixture was placed on a hot plate under fume cupboard and heated to near dryness, until its colour changed to white.

This residue was allowed to cool and then dissolved with 20% nitric acid (5 mL). After filtering the mixture with filter paper, the filtrate was made up to 20 cm^3 volumes with distilled water. The various concentration standards for the various elements as well as the blank were equally prepared. Each of these preparations was then analyzed for heavy metals using elemental atomic absorption spectrophotometric method (Dawson, 1978) (AAS-UNICAM 919 model was used) while analyses of monovalent metals like sodium (Na) and potassium (K) was performed using low temperature flame photometric method (Ramsay et al., 1953) (Jenway Flame photometer, PFP.7 model was used).

RESULTS

Results of the metals analyzed in the study are shown in Table 1 (heavy metals) and Table 2 (non-heavy metals). Results show that the means of the estimated heavy metals in the six sites ranged from 0.31 ± 0 µg/g for vanadium to 1293.75 ± 0 µg/g for iron. The non-heavy metals ranged between 55.01 ± 24.88 µg/g (potassium) and 903.74 ± 1081 µg/g (calcium). While between 0.31 ± 0 µg/g (vanadium) and 784.09 ± 45.47 µg/g (iron) remained the mean concentration range for heavy metals in the test site, that of the non-heavy metals was between 55.01 ± 24.88 µg/g (potassium) and 903.74 ± 1081.25 µg/g (calcium). In the control site, the range was between zero (for the non-detected heavy metals- cadmium, cobalt, chromium, lead, nickel and vanadium) and 1293.75 ± 0 µg/g for iron; while for the non-heavy metals, the range was between 72.73 ± 0 µg/g (potassium) and 410.50 ± 0 µg/g

Table 3. Concentration ranges and means of Heavy Metals in the various Soil Samples compared with the Mean Concentrations in the Control (µg/g), and with FEPA and WHO standards.

Metal	Concentration range for soil samples 1 to 6 (µg/kg)	Mean ±S.D	Average concentration in Hungarian soil^{a,b,c}	Hungarian baseline value (Threshold limit)^{d}	Average concentration in Nigerian soil and FEPA threshold limit value
Cd	0-6.5	5.21±1.47 (n=2)	0.01-2	1	NA
Co	2.78-6.94	3.61±1.66 (n=5)	50-200	30	NA
Cr	0-25.0	25.0±0 (n=2)	10-15	75	NA
Zn	0.12-26.6	10.92±8.77 (n=5)	50-100	200	NA
Cu	11.0-80.0	39.0±28.43 (n=5)	10-15	30	NA
Pb	0-150.0	71.00±64.89 (n=5)	15-30	100	NA
Ni	0-40.0	20.00±13.11 (n=5)	15-30	40	NA
V	0-0.31	0.31±0 (n=4)	NA	NA	NA
Mn	28.42-391.94	146.13±127.55 (n=5)	NA	NA	NA
`Fe	`731.82-1293.75	784.09±45.47(N=5)	NA	NA	NA

a: Aubert and Pinta (1978), b: Kabata-Pendias (1984), c: Andriano (1986), d: Hungarian Government Regulation number10/2000 (NA = not available).

Table 4. Mean concentrations of heavy metals of the various soil samples (µg/kg) compared with both Hungarian and Nigerian threshold limit.

Metal	Concentration range for soil samples 1-6 (µg/kg)	Mean ±SD	Average concentration in Hungarian soil$^{a, b, c}$	Hungarian baseline value (Threshold limit)^{d}	Average concentration in Nigerian soil and FEPA threshold limit value
Cd	0-6.5	5.21±1.47 (n=2)	0.01-2	1	NA
Co	2.78-6.94	3.61±1.66 (n=5)	50-200	30	NA
Cr	0-25.0	25.0±0 (n=2)	10-15	75	NA
Zn	0.12-26.6	10.92±8.77 (n=5)	50-100	200	NA
Cu	11.0-80.0	39.0±28.43 (n=5)	10-15	30	NA
Pb	0-150.0	71.00±64.89 (n=5)	15-30	100	NA
Ni	0-40.0	20.00±13.11 (n=5)	15-30	40	NA
V	0-0.31	0.31±0 (n=4)	NA	NA	NA
Mn	28.42-391.94	146.13±127.55 (n=5)	NA	NA	NA
Fe	731.82-1293.75	784.09±45.47 (n=5)	NA	NA	NA

[a]Aubert and Pinta (1978), [b]Kabata-Pendias(1984), [c]Andriano(1986), [d]Hungarian Government Regulation number 10/2000 (2000), NA= not available.

(calcium).

In Table 3, the concentration ranges and means of the evaluated heavy metals for both the test and control soil samples are presented with the standards (permissible limits) prescribed by the regulatory agencies, FEPA and WHO. In Table 4, the mean concentrations recorded in our study for Aba, a typical tropical environment, are presented for comparison with the average concentrations documented for Hungary, a typical European country.

DISCUSSION

A study of the results generally revealed that the mean concentrations for most of the metals including such toxic ones as lead, nickel, chromium, cadmium, etc. were all found to be quite high relative to those of the control sites where (except iron, manganese and copper) most of them were either not detected at all or the concentration of the detected ones were relatively low (Table 1). However, the same could not be said for the non-heavy metals since the control site recorded higher mean concentrations for most of them (except calcium) than was the case for the mean concentrations of equivalent metals in other sample sites (Table 2). The mean metal contents of all the soil samples that is, sites 1 to 6, were quite high with respect to Fe, Ca, Na and Mg in that order (Tables 1 and 2).

Among the toxic metals, Pb (71.00 ± 64.89 µg/g), Cu (35.42 ± 29.76 µg/g), Cr (25.0 ± 0 µg/g) and Ni (20.00 ± 13.11 µg/g) recorded worrisome mean concentrations. Even Zn, Cd and Co at mean concentrations of 9.12 ± 9.5, 5.21 ± 1.47 and 3.61 ± 1.86 µg/g, respectively cannot simply be glossed over, since the least of these concentrations has surpassed the limits allowable in soil by regulatory agencies including the Nigerian Federal Environmental Protection Agency (FEPA, 1991) and World Health Organization (WHO, 1984) (Table 3). However, it was observed that regulatory data were not wholesomely available for all the metals for the different environmental media, particularly soil, thus making data comparisons for safe limits a fairly difficult task.

An alternative approach was to compare our data with average concentrations of these metals in Nigerian soil (that is, baseline value for Nigerian soil) and this too was not available. Consequently, in addition to comparing our data with the availables from the regulatory bodies, we also compared them with those of a typical European country (Hungary) with fairly complete soil metal data (Table 4). As can be easily gleaned from the table, the mean concentrations for Cd, Pb, Cr and Cu for Aba metropolis also surpassed the average concentration range for Hungarian soils, while the concentration range for Zn (50 to 100) and Co (50 to 200) in Hungarian soil surpassed by far the level of these metals in Aba soils. For other metals however, the values in our study are nearly close to the available concentration ranges, as not all of these were available also for the Hungarian soil.

A close look at the results of the individual sites (Tables 1 and 2) revealed that apart from Fe, Ca, Na, Mg and K that were generally high, soil samples from the control community (site 6) had relatively lower values for most of the heavy metals, although as high as 17.5 µg/g of copper was obtained therein, just as 17.5 µg/g of nickel was also recorded for its immediate neighbour, site 5- the World bank housing estate. In the former, most of these metals were not detected at all, whereas at site 5, Cu (11.0 µg/g), Zn (8.6 µg/g), Pb (6.25 µg/g) and Co (2.78 µg/g) were also detected. As at the time of this study, Site 5 remained a newly mapped out residential estate, planned and being developed as a world bank assisted housing project, and housing construction and related activities including block moulding businesses were the most dominant activities here; while site 6 was a sub-urban community few kilometres away from the heart of Aba metropolis, but rapidly being annexed by the expanding metropolis since residents of the metropolis are now resorting to this and other nearby communities in quest for solution to their housing/accommodation problems now becoming tighter in the main areas of the metropolis. But for the encroaching urbanization, this was just a quiet community, farming being the major activity of note in this area.

In areas of sites 5 and 6, anthropogenic activities such as high human density, high industrial and vehicular activities/associated emissions, high turnover of wastes, etc., were still occurring at a very low level, though at a relatively faster rate in the former than the later. This might explain the metal distribution patterns found in these areas whereby comparatively lower values of toxic heavy metals like Cd, Co, Cr, Pb, Ni and V were found relative to what is obtained in other areas in the heart of the metropolis.

However, the world bank housing estate (site 5) recorded higher values for these toxic metals relative to the situation in the sub-urban community (site 6) where except for Cu detected in fairly reasonable amount (17.5 µg/g), and Zn detected in quite insignificant quantity (0.12 µg/g), most of the toxic heavy metals were not detected at all (Table 1). When this is taken along with the unfavourable situation in the other areas of the city with regard to metal pollution, it is clearly evident that indeed anthropogenic variables may actually be responsible for the high metal load of Aba metropolis generally, as noted in other studies (National Institute of Occupational Safety and Health (NIOSH), 1991; Egbuna, 1992; WHO, 1996b; Gazso, 2002; Agency for Toxic Substance and Disease Registry (ATSDR), 2003; Iwegbue et al., 2006; Eddy et al., 2006; Igwilo et al., 2006; Inuwa, 2007; Ladigbolu et al., 2011; Adewuyi and Opasina, 2011).

Despite the seemingly lower values recorded for these other metals, the higher values recorded for iron in the control site, and the reckonable presence of such heavy metals as Cu, Zn, Pb and Co at site 5 (Table 1) showed that neither the so-called control site nor the world bank housing estate (considered to have very close characteristic to the control site in terms of human activities) was totally free of the hazards of metal pollution. The reason for the high iron contents in these two sites is not presently known. However, for most of the soil samples, the levels of Fe, Ca, Na, Mg, and Mn (Tables 1 and 2) were also quite high and could be attributable to the fact that this group of metals constitute over 99% of the total element content of the earth's crust (Mitchell, 1964). Again, this could be as a result of climatic factors as observed by Aubert and Pinta (1977) that soils in the tropical climate zones (which Nigeria is among) are mostly ferrallitic, and the levels of Mn in such soils ranges from 20 to 5000 ppm.

Though the central area of the metropolis (site 4) recorded formidable presence of most metals, this was in no way comparable to the situation observed within Ndiegoro area of the city (site 1), for although various metals' presence were observed for most sites in the heart of this commercial city, Ndiegoro area in particular showed remarkable presence of most metals at varying concentrations, including those of Pb, Cu, Zn, Ni, Cr, etc. (Tables 1 and 2). The findings in this area expectedly rivalled what was obtained in a Romanian study (Lacatusu et al., 2001) in which most of the heavy metals were found to be many times in excess of their maximum allowable limits (MAL), and in some instances also surpassed the Hungarian data (Table 4).

As can be easily gleaned from the table, the mean concentrations for Cd, Pb, Cr and Cu for Aba metropolis surpassed the average concentration range for Hungarian soils. For other metals however, the values in our study are nearly close to the available concentration ranges. However, the findings in Ndiegoro area are not surprising at all, since this is a very squalid urban slum beyond the popular Ngwa road. In this area of Aba noted for its in-glorious status as the "Aba erosion disaster area" of the 1980s, there are multiple erosion sites with stagnant pools following erosion menace in most of the area. In spite of this, this area is very thickly populated, bringing about a very high population density. In terms of activity, there are legions and varieties of it, for apart from trade on many commercial items including textiles products of various descriptions, all forms of artisanal works such as tinkering and other metal works are found in this area. The popular "New market" noted for the sale of mainly food items occupies almost the length of the equally popular Ngwa road through which many gateways in terms of streets opened into this urban slum. In the central part of the city (site 4), though trading activities also thrive in most of the roads, electronics and other household items are the major items of trade here; in this area is located the Aba shopping centre where apart from the sale of textiles and electronics, repairs and engineering conversions of various electrical and electronic wares take place, and accordingly, various categories of artisans are found in this centre. Auto-repair related activities and their workshops are also predominant just as the resultant metal junks/wastes from mechanic and panel beating workshops.

This area of Aba is also predominantly characterized by public and private office works. It is therefore not quite surprising that the findings here mirrored the situation in one of the home studies (Iwegbue et al., 2006) in which the characteristic levels of heavy metals of soil profiles of automobile mechanic wastes were found to exceed background concentrations and limits for agricultural and residential purposes.

Apparently, the electronic and mechanic waste junks represented potential sources of heavy metal pollution in this area's environment. This is in spite of the fact that what could be considered as organized municipal waste collection and evacuation program is found in this area where also there are city network of roads. As in the World Bank housing estate, sanitation is fair here relative to the situation in other parts of the metropolis. A striking observation made in this study was the fact that most of the metals (apart from iron and cadmium) were relatively low in soil sample 3 (from Aba Main River). The findings here though similar to that of Aderinola et al. (2009) in which the mean levels of heavy metals in the sediments of Lagos lagoon were generally low and fell within the acceptable limits described by WHO and FEPA, they were however quite contrary to expectations, given the fact that the river receives discharges/washouts from sundry activities being carried out along its banks including those of a soap/detergent industry, a major brewery producing assorted drinks, and the city animal slaughterhouse/meat processing centre. However, the reason for these lowered metals concentrations may be due to dilution effect, since this is a free-flowing stream. Though the area immediately bordering this river, the Ogbor Hill area (site 3) showed reduced metal loads relative to Ndiegoro area (site 1), toxic metals such as Nickel, lead, Zinc, Copper and Cadmium, in addition to other metals like iron, sodium, Magnesium and Manganese showed noticeable presence in this area (Tables 1 and 2). Also in this same area, there was a profuse presence of calcium, thus indicating the need for geological studies of Ogbor hill area for mineral deposits, particularly, those of calcium compounds. Apart from trading and artisanal activities common to almost every street in Aba, this area houses the slaughter and the nearby meat market; meat processing and other related ventures including tanning, burning/conversion of cow bones and horns are carried out just at the basement of the bridge across the river into this area of the town. Glass and bottle-producing industries are housed in this area also. Who knows, these might be contributory to the high calcium content of this area.

The peculiar terrain that characterized both Ndiegoro and Ogbor hill areas, their very thick population density with the associated high waste turnover, coupled with the near total absence of any form of waste management program make these area the most dirty areas of the metropolis. These factors might explain the pattern of results obtained for these areas. Following these findings, it is most likely that the bore holes sunk in most parts of Aba, particularly Ndiegoro and Ogbor Hill areas would be yielding hard water. This might explain the observation by this lead/corresponding author that water from bore holes from Ndiegoro area of Aba (site 1) usually has nauseating taste, and presents with somewhat milky/turbid sediments on standing, some moments after collection. The need for qualitative studies of water supply sources of Aba and its environs is thus highly warranted, particularly as it concerns Ndiegoro and Ogbor hill areas (sites 1 and 3) not only as a quality control measure, but also to establish a good basis for policy options that will properly address the public health implications of these findings, thus stemming the tide of the potential health problems associated with these.

Soil metal contents as high as revealed in this study for some areas have serious public health implication for the residents of this metropolis, given the catalogue of health effects associated with exposure to metals generally, and toxic heavy metals in particular. Several substances including metals, enter the body through gastrointestinal tract, and after absorption are transported by the hepatic portal vein to the liver; thus, the liver is the first organ perfused by chemicals that are absorbed in the gut (Adedara et al., 2011). Metals act by attacking nervous tissues as protoplasmic poisons, or as histotoxins by destroying liver, kidneys and/or other body tissues. In general, heavy metals are systemic toxins with specific neurotoxic, nephrotoxic, fetotoxic and teratogenic effects. Heavy metals can directly influence behavior by impairing mental and neurological functions, influencing neurotransmitter production and utilization, and altering numerous metabolic body processes. Systems in which toxic metal elements can induce impairment and dysfunction include the blood, cardiovascular, eliminative pathways (colon, liver, kidneys, skin), endocrine (hormonal), energy production pathways, enzymatic, gastrointestinal, immune, nervous (central and peripheral), reproductive, and urinary systems. These toxic impacts of Metals are affected through the formation of free radicals (highly reactive oxygen species), a disturbance of the pro- and antio-xidant balance of the body, both of which can cause cell damage by destruction of proteins, degradation of nucleic acids, or lipid peroxidation (Gutteridge, 1995; Adedara et al., 2011). Toxic heavy metals have been implicated in many health defects arising due to their toxic effects involving several body tissues, organs and systems (WHO, 1996b). The health effects range from contact dermatitis to other damages involving these body parts and functions. Such include neurological and behavioral disorders, haematological defects, liver and kidney damage, cardiovascular defects including increased blood pressure/hypertension, skeletal tissue damage, reproductive defects, genetic defects and induction of many types of cancers often effected through membrane lipid peroxidation, induction of oxidative stress and damage to cellular components of the affected organs, and possibly, the activation of oxidant-sensitive trans-cription factor, among others (WHO, 1983, 1996a, b; Schwartz, 1995; Ankra et al., 1996; Reeves and Vanderpoo, 1997; Ezeonu and Ezejiofor, 1999, 2002; Hu, 2001; Noonan et al., 2002; Zeitz et al., 2002; ATSDR, 2003; Dioka et al., 2004; Aimo and Oteiza, 2006; Alimba et a.l, 2006; Adedara, 2011). The deleterious effect of lead for instance, can involve both reactive oxygen species (ROS) and reactive nitrogen species. Oxidative stress has been associated with Pb exposure in humans and in experimental animal models.

In humans occupationally exposed to lead, biomarkers of oxidative stress such as malondialdehyde, reduced glutathione (GSH) status, glutathione peroxidase (GSPx) and catalase are known to have exceeded the mean value concentration of the control population (Costa et al., 1997; Garcon et al., 2004; Devi et al., 2007). Against the backdrop of these possible health effects, a subsequent study is highly indicated to investigate the Aba residents for these and other markers of metal-facilitated toxicity and indeed insipient health defects that may for now be silent but ravaging away lives secretly among the populace. Equally indicated is a study of both flora and fauna (indeed, the biodiversity) within this study area, since effects of metal toxicity stops not only at the door steps of humankinds, but also usually cut across all life forms. As observed by Nriagu (1988), environmental metal poisoning is a silent epidemic, and based on the findings of this study, the residents of Aba may already be at great risk of this epidemic.

Conclusion

This is the first study that documented the metal load of Aba metropolis (also known as, Enyimba city), a comercial nerve centre South-east of Nigeria. The study revealed that the mean concentrations for most of the metals including such toxic ones as Pb, Ni, Cr, Cd, etc. were quite high with respect both to those of the control sites and the standards prescribed by Nigerian Federal Environmental Protection Agency (FEPA, 1991) and World Health Organization (WHO, 1984), and these findings have serious implications for public health. The high metal load revealed in this study showed that this city presently under siege by wastes, particularly refuse, is under very heavy load of metal pollution and therefore under serious threat of metal epidemic. A direct relationship existing between anthropogenic activities, waste load, and metal pollutant load of a place as shown by this study meant that a greater number of Nigerian urban cities may already be under this threat of metal pollution, given the mountainous heaps of refuse and other wastes that are common sights in most of these cities. Since environmental metal poisoning is a silent epidemic, the findings of this study suggest that every resident of Aba and perhaps most other Nigerian urban cities may already be at great risk of this epidemic, which possibly is already ravaging away lives silently.

ACKNOWLEDGEMENTS

Miss Uloma Eke (R.I.P) of the Department of Industrial

Microbiology, Federal University of Technology, Owerri and a former student of this lead/corresponding author, is hereby remembered for her field assistance, while the staff of Central laboratories, University of Uyo, Nigeria is also appreciated for their laboratory support.

REFERENCES

Adedara IA, Teberen R, Ebokaiwe AP, Ehwerhemuepha T, Farombi EO (2011). Induction of oxidative stress in liver and kidney of rats exposed to Nigerian bonny light crude oil. Environmental Toxicol. DOI 10, 1002/tox.20660 (In press).

Aderinola OJ, Clarke E.O, Olarinmoye O.M, Kusemiju V, Anatekhai M.A (2009). Heavy Metals in Surface Water, Sediments, Fish and Periwinkles of Lagos Lagoon. American-Eurasian J. Agric. Environ. Sci. 5 (5): 609-617.

Adewuyi GO, Opasina MA (2011). Physicochemical and Heavy Metals Assessments of Leachates from Aperin Abandoned Dumpsite in Ibadan City, Nigeria. E-Journal of Chemistry. http://www.e-journals.net, 7(4), 1278-1283.

Agency for Toxic Substance and Disease Registry (ATSDR) (2003).Case studies in Environmental Medicine, Lead toxicity (http//www.atsdr.cdc.gov/hec/csem/Lead exposure pathways.html).

Aimo L, Oteiza PI (2006). Zinc deficiency increases the susceptibility of human neuroblastoma cells to lead-induced activator protein-1 activation. Toxicol. Sci. 91:184-191.

Alimba CG, Bakare AA, Latunji CA (2006). Municipal landfill leachate induces chromosome aberrations in rat bone marrow cells. Afr. J. Biotechnol. 52053-2057.

Alloway BJ (1995). Heavy Metals in Soils 2nd edition, Blackie academic and Professional, Glasgow, p. 500.

American Conference of Government Industrial Hygienists(ACGIH) (2003). Documentation of the arsenic, elemental and inorganic compounds except arsine TLV, in threshold limit values for chemical substances and Physical Agents and Biological Exposure Indices. Cincinnati, Ohio, ACGIH Worldwide.

Ankrah N-A, Kamiya Y, Appiah-Opong R, Akyeampong YA, Addae MM (1996). Lead levels and related biochemical findings occurring in Ghanaian subjects occupationally exposed to lead. East Afr. Med. J. 375 – 379.

Aubert H, Pinta M (1977). Trace Elements in soils, Elsevier Scientific Publishing Company, Amsterdam, p.395.

Berlin M, Uberg S (1963). Accumulation and retention of mercury in mouse 111: An auto radiographic compensation of methyl mercury dicyanidiamide with organic mercury Arch. Environ Health 6: 610-616.

Carpenter DO (2001). Effects of Metals on the Nervous System of Humans and Metals. Int. J. Occup. Med. Environ. Health 14(3): 209-218.

Costa CA, Trivelato GC, Pinto AM, Bechara EJ (1997). Correlation between plasma 5-aminolevulinic acid concentrations and indicators of oxidative stress in lead exposed workers. Clin Chem 43:1196-1202.

Dawson JB (1978). Analytical Atomic Spectroscopy. In: Williams DL, Nunn RF and Marks V (Eds), Scientific Foundations of Clinical Biochemistry Vol.1. William Heinemann Medical books Ltd; Pp95-120

Devi SS, Biswas AR, Biswas RA, Vinayagamoorthy N, Krishnamurthi K, Shinde VM, Hengstler JG, Hermes M, Chakrabati T (2007). Heavy metal status and oxidative stress in diesel engine tuning workers of central Indian population. J Occup Med 49: 1228-1234.

Dioka CE, Orisakwe OE, Adeniyi FAA, Meludu SC (2004). Liver and Renal Function Tests in Artisans occupationally exposed to lead in mechanic Village in Nnewi, Nigeria. Int. J. Environ. Res. Pub, Hlth. 1: 21 – 25.

Eddy NO, Odoemelem SA, Mbaba A (2006). Elemental Composition of Soil in Some Dumpsites. Electron. J. Environ. Agr. Food Chem. 5 (3): 1349-1365.

Egbuna DO (1992). Understanding Refining and Petrochemicals Operations. Obingoz African Holdings Publishers Ltd Lagos. vol.1, pp. 25–26.

Ernst E (2002). Heavy Metals in traditional Indian remedies. Eur. J. Clin. Pharmacol. 57:891-896.

Ernst E, Coon JT (2001). Heavy metals in traditional Chinese medicines: A systematic review. Clin. Pharmacol. Therapeut. 70 (6): 497-504.

Extreme Health (2004). Toxic Metal- Sources and specific effects HYPERLINK "mailto:Info@%20extreem"Info@ extreme healthusa.com.

Ezejiofor TIN, Ezeonu FC (2002). Biochemical indicators of occupational health hazards in Enugu coal miners, Nigeria. Inter. J. Environ. Hlth Hum. Dev. 3 (2): 31 – 35.

Ezeonu FC, Ezejiofor TIN (1999). Biochemical indicators of occupational health hazards in Nkalagu cement industry workers, Nigeria. Sci. Total Environ. 228: 275 – 278.

Federal Environmental Protection Agency (FEPA) Act (1991). Guidelines and standards for Industrial effluent, gaseous emissions and hazardous waste management in Nigeria. National Environmental Protection Regulations, Federal Republic of Nigeria. Supplement to Official Gazette Extraordinary - Part B. 78 (42): B15 – 31.

Federal Environmental Protection Agency (FEPA) Guidelines and Standards for environmental pollution control in Nigeria. Decree 58 of 1988; p. 238.

Ganrot PO (1986). Metabolism and possible health effect of aluminium. Environ. Health, Perspect, 65: 363-441.

Garcon G, Leleu B, Zerimech F, Marez T, Haguenoer JM, Furon D, Shiral P (2004). Biologic markers of oxidative stress and nephrotoxicity as studied in biomonitoring of adverse effect of occupational exposure to lead and cadmium. J. Occup. Environ. Med. 46:1180-1186.

Garrett NE, Garrett RJB, Archdeacon JW (1992). Placental transmission of mercury to foetal rat. Toxicol. Appl. Pharmacol. 22: 649-654.

Garvey GJ, Hahn G, Lee RV, Harbison RD (2001). Heavy Metal of Hazards Asians traditional remedies Inter. J. Environ. Hlth Res. 11:63-71.

Gazso LG (2002). The key microbial process in the removal of toxic metals and radionuclides from Environment. Minireview. National Center for Public Health, Hungary 7:3-4.

Goyer RA (1996). Results of lead research: Prenatal exposure and neurological consequences. Environ. Health Perspec,t 104:1050-1054.

Gutteridge JMC (1995). Lipid peroxidation and antioxidants as biomarkers of tissue damage. Clin. Chem. 41:1819-1828.

Holding BV (2004). Heavy Metals (http: www. Lenntech. Com/heavy metals.htm).

Hu H (2001). Heavy Metal Poisoning. In: Fauci AS, Braunwald E, Isselbacher KJ, Kasper DL, HU Howard. Poorly controlled Hypertension in a painter with chronic Lead Toxicity. Environ.l Health Perspective, 109(1): 95- 99.

Igwilo IU, Afonne OJ, Maduabuchi UJ, Orisakwe OE (2006). Toxicological study of the Anam River in Otuocha, Anambra State, Nigeria. Arch Environ. Occup. Health, 61(5):205-208.

International Occupational Safety and Health Information Centre(1999). Metals. In Basics of Chemical Safety, Chapter 7. Geneva: International Labour Organization.

Inuwa M, Abdulrahman FW, Birnin-Yauri UA, Ibrahim SA (2007). Analytical Assessment of Some Trace Metals in Soils around the Major Industrial Areas of North-western Nigeria. Trends, Appl. Sci. Res. 2:515-521.

Iwegbue CMA, Isirima NO, Igwe C, Williams ES (2006). Characteristic levels of heavy metals in soil profiles of automobile mechanic waste dumps in Nigeria. Environmentalist, 123-128, DOI: 10.1007/s10669-006-7482-0.

Kelly JJ, Tate RL (1998). Effect of Heavy Metal Contamination and Remediation on Soil Microbial Communities in the Vicinity of a Zinc Smelter. J.Environ. Qual. 27:609-617.

Krewski D, Yokel RA, Nieboer E, Borchelt D, Cohen J, Harry J, Kacew S, Lindsay J, Mahfouz AM, Rondeau V (2007). Human health risk assessment for aluminium, aluminium oxide and aluminium hydroxide. J. Toxicol. Environ. Health B Crit. Rev. 10(Suppl1) 1-269

Ladigbolu IA, Balogun KJ, Shelle RO (2011). Hydrochemistry and levels of some heavy metals in samples of Ibeshe, Lagos Lagoon Complex, Nigeria. J. Am. Sci. 7(1):625-632.

Mitchell RL (1964). Chemistry of the soil 2nd edition. John Willey and sons, New York: USA. Pp.268-320.

Namgung U, Xia Z (2001). Arsenic induces apoptosis in rat cerebellar neurons via activation of JNK3 and P38 MAP kinases. Toxicol. Appl. Pharmacol. 174:130.

National Institute of Occupational Safety and Health (NIOSH) (1991) Criteria for a recommended standard- occupational exposure to ethylene glycol Monoethyl ether and their acetates. Washington, DC: NIOSH (Publication number 91–119).

Noonan CW, Sarosua SM, Campagna D, Kathman SJ, Lybarger JA, Mueller PW (2002). Effects of exposure to low levels of environmental cadmium on renal biomarkers. Environ. Health Perspectives, 110(2): 151 -155.

Norman MT (1981) Environment and Health. Ann Arbor Inc. Michigan Pp.367-406.

Nriagu JO (1988). A Silent epidemic of environmental metal Poisoning. Environ. Pollut. 50: 139-161.

Occupational Safety and Health Administration (OSHA) (1991). Substance data sheet for Occupational exposure to Lead (W.W.W. OSHA. Gov).

Ramsay JA, Brown RHJ, Falloons SWHW (1953). Simultaneous determination of sodium and potassium in small volumes of fluid by flame photometry. J. Exptl. Biol. 30:1.

Reeves PG, Vanderpoo RA (1997). Cadmium burden of men and woman who report regular consumption of confectionery sunflower kernels containing a natural abundance of cadmium. Environ. Health Perspect. 105(10): 1098 -1104.

Schwartz J (1995). Lead, blood pressure and cardiovascular disease in men. Arch Environ. Health. 50(1): 31-37.

Sopos P, Poka K (2008) Threshold Limit Values for Heavy metals in Soils is the function of spatial and temporal variation of geochemicalScience, H-1112, Budapest, Hungary, p. 1-8.

Stromberg U, Lundh T, Skerfving S (2008). Yearly measurements of blood lead in Swedish children since 1978: the declining trend continues in the petro-lead-free period 1995-2007. Environ. Res. 107:332-335.

United States Department of Agriculture (USDA) (2000). Heavy Metal Soil Contamination. Soil Quality Institute, Natural Resources Conservation Service, Urban Technical Note No.3; pp1-7.

White LD, Cory-Slechta DA, Gilbert ME, Tiffany-Castiglioni E, Zawia Nh, Virgolini M, Rossi-George A, Lasley SM, Qian YC, Basha MR (2007). New and evolving concepts in the neurotoxicology of lead. Toxicol. Appl. Pharmacol. 225:1-27.

WHO (1982). Rapid Assessment of sources of Air, Water and Land pollution. Offset Publication; 62: 7.

WHO (IPCS) (1983) Environmental Health Criteria 27: Guidelines on Studies in Environmental Epidemiology. WHO, Geneva. Pp. 351

World Health Organization (WHO) (1996a). Trace elements in human nutrition and health. WHO, Geneva. pp. 343.

World Health Organization (WHO) (IPCS) (1996b). Environmental Health Criteria 171: Diesel Fuel and Exhaust Emissions. WHO, Geneva. 389pp.

Yokel RA, Hicks CL, Florence RL (2008). Aluminium bioavailability from basic sodium aluminium phosphate, an approved food additive emulsifying agent, incorporated in cheese. Food Chem. Toxicol. 46:2261-2266.

Zeitz PA, Orr MF, Kaye WE (2002). Public Health consequences of Mercury Spills: Hazardous Substances Emergency Events Surveillance System, 1993-1998. Environ. Health Perspect. 110(2): 129 -13.