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Contributions of municipal refuse dumps to heavy metals concentrations in soil profile and groundwater in Ibadan Nigeria

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ABSTRACT

Objective: To determine the concentrations of heavy metals in soil and groundwater at municipal refuse dumps in Ibadan, Nigeria, and make recommendations to improve refuse management.

Methodology and results: Soil and groundwater samples from 7 municipal refuse dumps and a green uncontaminated control site at the Institute of Agricultural Research and Training in Ibadan, Nigeria were analysed for Cadmium (Cd), Cobalt (Co), Lead (Pb), Chromium (Cr) and Nickel (Ni). Soil samples were obtained in triplicates and at depths of 0-15, 15-30, 30-45 and 45-60cm. Water samples were obtained from dug wells at the dump sites. The values of Cd, Co, Pb, Ni and Cr in the dumpsites soil samples ranged from 0.75-16.30; 3.45-21.00; 45.00-624.50; 4.35-49.80 and 13.15-75.55mg/kg, respectively. Evidence of contamination of these soils by Cd, Pb, Ni and Cr was obvious when compared to the control site. Ni was below detection limit in all control samples while Pb and Cd were less than 0.05 and 0.002mg/kg, respectively. Cr ranged from 6.25-19.75mg/kg. The range obtained for Co at the dumpsites was comparable to that of the control soil which was 7.22-28.15mg/kg. Compared to established limits set for soils in some countries, the values measured in this study were higher, particularly for Pb. Co conformed to the only established limit cited in Austria. Values measured in the groundwater samples were lower than the limits set by WHO for drinking water, except Cd which was detected in 3 of the samples at a concentration close to the WHO limit.

Conclusion and application of findings: This study found that there is an ongoing build up of heavy metals in soil at the waste dumps studied and concentrations were already higher than established limits for some metals. The recommendations of the study include formulation and enforcement of a directive to prevent any form of farming on the dumpsites, relocation of the dumpsites out of the city and the enforcement of other environmental protection regulations to stop the ongoing buildup of these metals on those locations. Findings from this study will be of immense help to researchers and environmental regulators in developing countries.
Key words: Soil, groundwater, heavy metals, Nigeria

INTRODUCTION

Ibadan (7°23'47"N 3°55'0"E) is one of the three largest metropolises in Nigeria. It occupies an area of 828 km^2 and has a population of approximately 2.6 million according to the 2006 census (NPC, 2009). Ibadan has several manufacturing businesses dealing with plastics, glass, batteries, matches, cigarettes, canned and bottled drinks, electrical wire and cable, and hundreds of petrol stations, most of which use materials which contain heavy metals. Its estimated motor vehicle population of 700,000 uses tires, motor oil, body paints, greases, battery electrodes and electrolytes as well as myriads of other parts which contain heavy metals. In addition, a huge artisan population exists in the city to render welding, soldering, brazing, sheet metal working, electrical and other services to the public. Furthermore, used consumer products such as electronics, light bulbs, house dust and paints, aerosols, lead foils, ink bottle caps and other materials are continually generated on a large scale by residents of the city. All these contribute significant quantities of heavy metals to the waste of the city. Because Ibadan does not have a centralized refuse collection system or treatment facility that should be expected for a city of this size, much of these heavy metal laden wastes are deposited in refuse dumps. There are environmental threats associated with this practice

Municipal refuse dumps are important feeding sites for pestiferous species especially birds, rats, and stray animals; thereby contributing greatly to their sustenance and multiplication (Bellebaum, 2005). Another problem of these waste dumps is air pollution which sometimes results in temporary restrictions on movement of people and consequent slowing of economic activities in urban areas (Elaigwu et al., 2007). Perhaps of greater and longer term impact are the substances deposited on the soil that adversely impact the flora and fauna. Heavy metals such as arsenic, cadmium, lead, chromium, nickel, cobalt and mercury are of concern primarily because of their potential to harm soil organisms, plants, animals and human beings. In addition to affecting plant and animal health, heavy metals contained in municipal solid wastes may be leached from the soil and enter either surface water or groundwater (Woodbury, 2005). The direct use of dumpsites for cultivating vegetables and the on-farm use of compost sourced from the dumpsites is a common practice in urban and suburban centers in Nigeria (Ogunyemi et al, 2003; Amusan et al., 2005). This practice is potentially harmful to the health and well being of the populace. When agricultural soils are polluted, these heavy metals are taken up by plants and consequently accumulate in their tissues (Trueby, 2003). Heavy metals enter the body system when these plants are directly or indirectly consumed, and also through air and water and may bioaccumulate over a period of time (Lenntech, 2004; UNEP/GPA, 2004). Soil is one of the repositories for anthropogenic wastes. Biochemical processes can mobilize the chemical substances contained in it to pollute water supplies and impact food chains. Heavy metal contamination in the soils is a major concern because of their toxicity and threat to human life and the environment.

A study conducted by Kimani (2010) in Kenya on the Dandora waste dump site in Nairobi showed high levels of heavy metals, in particular Pb, Hg, Cd, Cu and Cr in the soil samples obtained on the site. A medical examination of the children and adolescents living and schooling near the dump site indicated a high incidence of diseases that are associated with high exposure levels to these metal pollutants. For example, about 50% of children examined who lived and schooled near the dump site had respiratory ailments and blood lead levels equal to or exceeding internationally accepted toxic levels (10ug/dl of blood), while 30% had size and staining abnormalities of their red blood cells, confirming high exposure to heavy metal poisoning. These findings demonstrate the severe risks associated with municipal waste dumps. As observed by Begun et al. (2009), assessing pollutants in different components of the ecosystem has become an important task in preventing risk to wildlife and public health.

This research work studied the contributions of selected municipal refuse dumps to heavy metals concentrations in the soil and groundwater in Ibadan. The objective was to compare the measured values with established standards from various countries, make conclusions and propose recommendations to guide all stakeholders towards ensuring a safer environment through better management of refuse generated in this large metropolis.

MATERIALS AND METHODS

Soil sampling: Seven municipal refuse dump sites spread over the city of Ibadan were randomly selected for investigation. A green, uncontaminated site at the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria was used as control. Soil samples were obtained in triplicates at each site at depths of 0-15; 15-30; 30-45; and 45-60cm using a depth calibrated soil auger. Each sample was immediately placed in a fresh plastic bag and tightly sealed. All the samples were transported to the laboratory where on arrival, analytical procedure commenced. These investigations were conducted in the month of July, 2010.

Heavy metal analysis: The fresh soil was spread on a clean plastic sheet placed on a flat surface and air-dried in open air in the laboratory under room conditions for 24 hours. Afterwards, the soil was sieved using a 0.5mm sieve. After sieving, 0.5g was weighed from the sieved soil of each sample and put into a pyrex beaker. Ten ml of perchloric/nitric acid mixture ratio 1:2 was added to the sample. The beaker was then covered with a lid and placed on a hot plate at 105 ^{0}C for 30 minutes in a fume cupboard for digestion. After the 30 minutes period, the beaker containing the digested solution was brought out of the fume cupboard and allowed to cool. After cooling, the mixture was transferred into a 25ml volumetric flask and made to 25ml mark with distilled water. Next, the 25ml solution was used for the determination of Co, Cr, Cd, Pb and Ni. Determination of the concentration of heavy metals was done using an Atomic Absorption Spectrophotometer, AAS (model 210/211VGP); 220GF Graphite furnace 220 AS Autosampler. pH was determined with an electronic JENWAY glass electrode pH meter (model 3510).

Water sampling and analysis: Water samples were obtained from existing wells on each of the sites following standard water sampling procedure. The wells ranged from 8 to 10m in depth. Each sample was directly collected into a factory-fresh 1.5litre plastic bottle, with cap securely tightened. After collection the bottles were placed inside ice coolers for transportation to the laboratory where they were then transferred to the refrigerator. Laboratory analysis commenced the same day. The methods used are described in APHA et al. (1998).

RESULTS AND DISCUSSION

Many studies have shown that urban soils receive loads of contaminants that are usually greater than in the surrounding sub-urban or rural areas due to the concentration of anthropogenic activities of urban settlements (Charlesworth et al., 2003; Kormanicki, 2005; Othman and Ghandour, 2005; Lee et al., 2006; Yang et al., 2006; Srivastava and Jain, 2007). This finding is confirmed by the present study. Lead and Cd are anthropogenic metals, and without external interference, are normally not abundant in upper layer soils (Al-Turki and Helal, 2004; Ren et al., 2005). However, in the present study, Pb ranged between 215.50 to 624.50mg/kg in the top layer (0-15cm depth) of the soil (table 1). These values are several times the allowable limits of Pb in several countries (table 9). Regardless, several of the values obtained in this study were still higher than the relatively relaxed criteria of 400mg/kg and 300mg/kg set by USEPA (2008) and NEPCA (2010), respectively. In virtually all the cases the value of Pb gradually reduced through the soil layers, and at the depth of 45-60cm, the values recorded for Pb were still higher than the allowable limits in most of the countries shown.

The results showed elevated levels of Pb at the dumpsites, compared to the value of Pb in the control samples which was <0.05mg/kg at all depths. This finding of elevated Pb concentrations at these refuse dumps is consistent with that of Adelekan and Abegunde (2011) which investigated the occurrence of heavy metals at automobile mechanic villages in Ibadan and reported concentrations ranging between 18.25-15100mg/kg in the soil.

Table 1: Lead content (mg/kg) of soils at four depths at municipal dump sites in Ibadan, Nigeria.

Dump site	**Depth (cm)**			
	0-15	**15-30**	30-45	45-60
Agodi	206.50	120.00	98.50	95.50
Ijokodo	624.50	575.50	369.00	90.50
Dugbe	364.50	334.50	231.50	363.00
Challenge	215.50	352.00	198.50	210.50
Olorunsogo	358.00	266.50	184.50	156.50
Oja Oba	222.50	108.50	84.00	194.0
Mokola	306.0	132.5	80.50	45.00
Control	<0.05	<0.05	<0.05	<0.05

Means are values of three measurements.

Human exposure to heavy metals occurs through three primary routes, i.e. Inhalation, ingestion and skin absorption. Pb is a particularly dangerous metal which has no biological role (Sobolev and Begonia, 2008) and negatively affects children in significant ways. It is documented that in the normal course of daily life, infants and children have a greater intake per unit of body weight of soil, air, certain types of food and water (USEPA, 1997). Consequently, for a given concentration of a contaminant in soil, air, food, or water, a child will receive a different exposure (in terms of mg/kg/bw) than will an adult exposed to the same medium (Plunkett et al., 1992). Usually a child's intake per unit of body weight (bw) is higher than an adult's.

It is also known that there are differences in the body's manner of handling heavy metals across gender and age groups. In the case of women, pregnancy and lactation increase demand for some essential metals, particularly copper, zinc, and iron (Picciano, 1996; NAS/IOM, 2003). Although the high susceptibility of women to metal toxicity usually refers to the effects on the fetus during pregnancy (e.g. of lead and mercury), there may also be basic gender differences independent of pregnancy that would account for differences in toxicokinetics between women and men. Women have only about two-thirds the fat-free body mass of men—so that their protein and energy requirements are lower—while having a larger percentage of body fat. The male/female ratio for urinary creatinine excretion (an index of body muscle mass) is 1.5. Men are generally larger than women, and because both the skeletal size as well as the body content of calcium is a function of height, these differences have an impact on body content of minerals (IPCS, 2002). Women also have significant loss of iron during menstruation, and it has been shown that absorption and toxicity of cadmium are greater in women, related to decrease in iron stores (Berglund et al., 1994). The efficiency of intestinal uptake of some trace metals, particularly zinc, declines in the elderly. However, differences between mature adults for other metals of interest have not been demonstrated (WHO, 1996a). These facts underscore the great risks which any ongoing build-up of heavy metals in the environment portends for human health and well being. The elevated levels of Pb found on these waste dumps should be properly addressed. This can be done if the dumps are relocated outside the city as a first step thus preventing further deposition of more contaminants on these sites. Next, some form of phytoremediation of the sites should be done particularly in respect of Pb.

Considering all samples obtained at the dump sites, Co ranged from 3.45 to 21.00mg/kg (table 2). This range was lower than that of the control which was 7.22 to 28.15mg/kg. The health risks associated with Co have not been fully established and only Austria has an established permissible limit of 50mg/kg of Co in soil (table 9). Unlike certain other trace metals, Co is beneficial to humans because it is part of vitamin B_{12} which is essential to human health. However, uptake of high concentrations of Co causes vomiting, nausea, vision problems, heart ailments and thyroid damage (Lenntech, 2009). The International Agency for Research on Cancer has listed Co and related compounds within group 2B of pollutants and this group comprises agents which are possibly carcinogenic to human beings (Lenntech, 2009).

Values of Co in soil obtained in this study were lower than 105 – 810 mg/kg reported by Awokunmi et al. (2010) in soil from dumpsites located within Ikere and Ado-Ekiti, South West Nigeria. The higher levels found were attributed to indiscriminate disposal of cobalt containing wastes on the dumpsites. Looking closely at the results (Table 2), no general pattern of change in cobalt concentration through the soil layers could be established. Agodi, Dugbe, Olorunsogo and Oja-Oba showed decreases in concentration of Co with depth while the others including the control showed an increase in concentration with depth. The explanation for this observation is that soil pH, other factors such as the presence of competing ligands, the ionic strength of the soil solution and the simultaneous presence of competing metals can significantly affect sorption processes and leaching potential through a soil profile (Harter and Naidu, 2001). The absorption of heavy metals also differs in the different soil horizons due to texture composition in different soil horizons.

Table 2: Cobalt content (mg/kg) of soils at four depths at municipal dump sites in Ibadan, Nigeria.

Dump site	**Depth (cm)**			
	0-15	**15-30**	30-45	45-60
Agodi	5.80	5.70	4.90	6.10
Ijokodo	9.65	9.90	8.80	7.80
Dugbe	8.80	8.25	21.00	6.25
Challenge	10.80	9.45	12.50	12.40
Olorunsogo	19.45	15.60	11.10	9.35
Oja Oba	5.55	3.95	4.70	3.45
Mokola	10.05	14.25	12.25	12.40
Control	7.22	11.50	25.75	28.15

The concentrations of Cr in soil ranged from 13.15 to 75.55mg/kg, which was higher than that of the control (6.25 to 19.75mg/kg). Allowable limits of Cr concentrations vary widely with country, being 150mg/kg in France; 100mg/kg in Austria and Spain; 60mg/kg in Germany and Sweden; and 30mg/kg in Denmark and the Netherlands (table 9). Therefore most of the values obtained in this study conform to the acceptable limits. The values of Cr obtained in this study were lower than the 900–2000mg/kg reported by Adefemi and Awokunmi (2009) in dumpsites within Ado-Ekiti town in South West Nigeria. The elevated concentrations were ascribed to deposited wastes which contained high concentrations of Cr. As observed by Adelekan and Abegunde (2011), Chromium is one of the heavy metals whose concentration in the environment is steadily increasing due to industrial growth, especially the development of metal, chemical and tanning industries. Other sources of chromium pollution are water erosion of rocks, liquid fuels, and industrial and municipal waste. Although Cr toxicity in the environment is relatively rare, it still presents some risks to human health since chromium can be accumulated on skin, lungs, muscles, fat, in liver, dorsal spine, hair, nails and placenta where it is traceable to various heath conditions (Reyes-Gutiérrez et al., 2007).

Table 3: Chromium content (mg/kg) of soils at four depths at municipal dump sites in Ibadan Nigeria.

Dump site	**Depth (cm)**			
	0 - 15	15 - 30	30 - 45	45 - 60
Agodi	23.50	44.70	23.95	13.35
Ijokodo	35.90	75.55	24.65	19.95
Dugbe	62.75	57.30	44.10	57.15
Challenge	61.85	34.15	32.60	13.15
Olorunsogo	41.30	26.90	24.85	22.40
Oja Oba	17.55	24.40	19.75	16.15
Mokola	15.30	45.05	14.05	18.20
Control	19.75	6.25	8.50	8.25

The concentration of Ni in the soil samples at the dumpsites ranged from 4.35 to 49.80mg/kg (table 4). For the control samples, Ni was below the detection level. Ni levels were higher than the limit of 15mg/kg set in Denmark and The Netherlands (table 9). The study by Awokunmi et al., (2010) found Ni to range between 18–335 mg/kg at the surface layer of soil for all the dumpsites. Ni was not detected at a distance of 200 m away from the dumpsites. The highest concentration (335 mg/kg) was obtained at the centre of Atikankan dumpsite. The concentrations of Ni found in this study are in the same range with those reported in literature.

Nickel content in soil can be as low as 0.2mg/kg or as high as 450mg/kg although the average is about 20mg/kg (Lenntech, 2009). The UK Soil and Herbage Survey found total nickel concentrations in the range of 1.16 to 216 mg/kg for rural UK soils, with a mean value of 21.1 mg/kg. Urban UK soils were found to contain nickel concentrations in the range 7.07 to 102 mg/kg, with a mean value of 28.5 mg/kg (Environment Agency, 2007). Global input of nickel to the human environment is approximately 150,000 and 180,000 metric tonnes per year from natural and anthropogenic sources, respectively, including emissions from fossil fuel consumption, and the industrial production, use, and disposal of nickel compounds and alloys (Kasprzak et al., 2003). A study by Nwuche and Ugoji (2008) showed that the rate of respiration of soil microbial populations is inhibited by the heavy metals Cu, Zn and Ni. Nickel is known to accumulate in plants and with intake of too large quantities of Ni from plants grown on nickel-rich soils (such as tea, beans, vegetables), there are higher chances of developing cancers of the lung, nose, larynx and prostrate as well as respiratory failures, birth defects and heart disorders (Duda-Chodak and Blaszczyk 2008; Lenntech, 2009).

Table 4: Nickel Content (mg/kg) of Soils at Four Depths at Municipal Dump sites in Ibadan, Nigeria.

Dump site	**Depth (cm)**			
	0 - 15	15 - 30	30 - 45	45 - 60
Agodi	5.65	5.15	10.80	8.65
Ijokodo	13.75	12.35	6.10	BDL
Dugbe	18.35	11.90	49.80	16.75
Challenge	19.40	14.55	10.45	11.20
Olorunsogo	17.10	29.30	16.10	11.20
Oja Oba	7.00	4.35	10.00	6.05
Mokola	5.00	11.10	11.25	9.55
Control	BDL	BDL	BDL	BDL

BDL: the heavy metal was below detectable limit in the soil sample analysed

Cd values at the dumpsites ranged from below detection limit to a high of 16.30mg/kg (tables 5 and 7), while the control samples had <0.002mg/kg. Notably in Oja-Oba, Cd was below detection level at all soil layers of the profile. A similar situation was noticed for Agodi where Cd was measured to be 0.85mg/kg at the depth of 45-60cm while it was below detection limit at all the upper depths. The reason for this similarity in readings could not be presently ascertained. The study by Awokunmi et al. (2010) reported cadmium levels of 219 – 330 mg/kg at the surface layer of dumpsites and none at 200m away. The results were similar to those of Amusan et al. (2005) for soils of Obafemi Awolowo University central refuse dumpsite. However, their results were far higher than for dumpsites in Ibadan (this study).

As with plant uptake, soil pH, organic matter content, and other soil characteristics affect the amount of leaching. Cadmium, lead and mercury can be harmful to animals and humans at relatively low concentrations and thus should receive close scrutiny in relation to application of municipal solid waste composts to agricultural soil. The deposition of industrial waste, mining activities, incidental accumulations, atmospheric deposition, and agricultural chemicals are some sources for the pollution of soils with heavy metals (Ferguson and Kasamas, 1999). The mobile forms of those heavy metals constitute a risk as they may leach into groundwater that is used for human or animal consumption (Alloway, 1995). Human diseases have resulted from consumption of cadmium contaminated foods (Kobayashi, 1978; Nogawa, et al., 1987). The threat that heavy metals pose to human and animal health is aggravated by their low environmental mobility, even under high precipitations, and their long term persistence in the environment (Mench et al., 1994; Chirenje et al., 2004). The soil-plant barrier limits transmission of many heavy metals through the soil-crop-animal food chain, with the exception of Cd, Zn, Mo, and Se. Cadmium, which has lower affinity for metal-sorbing phases (e.g., oxides) has the greatest potential for transmission through the food chain in levels that present risk to consumers (Chaney and Ryan, 1994; Chaney et al., 1999). This fact assumes greater importance in view of the people's practice to cultivate vegetables on these dumpsites. This practice should as a matter of urgency be discouraged henceforth.

Table 5: Cadmium Content (mg/kg) of Soils at Four Depths at Municipal Dump sites in Ibadan, Nigeria.

Dump site	**Depth (cm)**			
	0 - 15	15 - 30	30 - 45	45 - 60
Agodi	BDL	BDL	BDL	0.85
Ijokodo	1.05	1.20	0.75	BDL
Dugbe	2.40	1.55	1.85	1.65
Challenge	3.50	1.40	4.80	4.70
Olorunsogo	16.30	7.70	8.85	7.15
Oja Oba	BDL	BDL	BDL	BDL
Mokola	0.75	0.65	0.15	BDL
Control	<0.002	<0.002	<0.002	<0.002

BDL: the heavy metal was below detectable limit in the soil sample analysed.

Table 6: pH of Soils at Four Depths at Municipal Dump sites in Ibadan Nigeria.

Dump site	**Depth (cm)**			
	0 - 15	15 - 30	30 - 45	45 - 60
Agodi	5.4	5.4	5.4	5.3
Ijokodo	5.8	5.8	5.8	5.8
Dugbe	6.2	6.1	6.1	6.1
Challenge	5.6	5.7	5.7	5.7
Olorunsogo	5.5	5.5	5.4	5.4
Oja Oba	5.6	5.5	5.4	5.4
Mokola	6.0	5.9	5.9	5.8
Control	5.8	5.7	5.8	5.8

The pH of all the samples measured at the four depths indicated that the soils were slightly acidic (table 8). Soil pH has a major influence on the availability of heavy metals that present predominantly as cations (Cu^{2+}, Co^{2+}, and Pb^{2+}). Under acid conditions, sorption of heavy metal cations by soil colloids is at a minimum, and the solution concentrations are relatively high. Additionally, soil pH, cation exchange capacity (CEC) and redox potential can also regulate the mobility of metals in soils (Lombi and Gerzabek, 1998). Soil pH, for instance is very important for most heavy metals, since metal availability is relatively low when pH is around 6.5 to 7. Lower pH would favor availability, mobility and redistribution of the metals Pb and Cd in the various fractions (Oviasogie and Ndiokwere, 2008). In the present study soil pH ranged from 5.3 to 6.2 indicating only moderate soil acidity. Therefore the dispersal of these cations from the surface to the underlying soil layers appears to be at a slow rate.

Table 7: Maximum and Minimum Measured Values of Heavy Metals Contents (mg/kg) of Soils at Municipal Dump sites in Ibadan Nigeria.

Dump site	**Measured limits**	**Co**	**Pb**	**Cr**	**Ni**	**Cd**
Agodi	Max.	6.10	206.50	44.70	10.80	0.85
	Min.	4.90	95.50	13.35	5.15	BDL
Ijokodo	Max.	9.90	624.50	75.55	13.75	1.20
	Min.	7.80	90.50	19.95	BDL	BDL
Dugbe	Max.	21.00	364.50	62.75	49.80	2.40
	Min.	6.25	231.50	44.10	11.90	1.55
Challenge	Max.	12.50	352.00	32.60	19.40	4.80
	Min.	9.45	198.50	13.15	10.45	1.40
Olorunsogo	Max.	19.45	358.00	41.30	29.30	16.30

	Min.	9.35	156.50	22.40	11.20	7.15
Oja Oba	Max.	5.55	222.50	24.40	10.00	BDL
	Min.	3.45	84.00	16.15	4.35	BDL
Mokola	Max.	14.25	306.00	45.05	11.25	0.75
	Min.	10.05	45.00	14.05	5.00	BDL
Control	Max.	28.15	<0.05	19.75	BDL	<0.002
	Min.	7.22	<0.05	6.25	BDL	<0.002

BDL: the heavy metal was below detectable limit in the soil sample analysed

Table 8: Heavy Metal Content (mg/l) of Water from Dug Wells at Municipal Dump sites in Ibadan Nigeria.

Dump site	Cd	Co	Pb	Cr	Ni
Agodi	BDL	BDL	BDL	BDL	BDL
Ijokodo	0.001	BDL	BDL	BDL	BDL
Dugbe	BDL	BDL	BDL	BDL	BDL
Challenge	BDL	BDL	BDL	BDL	BDL
Olorunsogo	0.001	BDL	BDL	BDL	BDL
Oja Oba	BDL	BDL	BDL	BDL	BDL
Mokola	0.001	BDL	BDL	BDL	BDL
Control	BDL	BDL	BDL	BDL	BDL

BDL: Below detectable limit

Table 9: Allowable Limits of Heavy Metal Concentrations in Soil (mg/kg).

Heavy metal	Austria	Germany	France	Denmark	Nether-lands	Sweden	Spain (pH<7)
Cd	1-2	1	2	0.5	0.5	0.4	1
Cr	100	60	150	30	30	60	100
Co	50	-	-	-	-	-	-
Ni	50-70	50	50	15	15	30	30
Pb	100	70	100	40	40	40	50

Source: ECDGE (2004)

This study found that heavy metals concentrations were below detectable limits in the water sourced from most of the wells at the dumpsites (table 8) and therefore posed none of the known dangers (table 10). Only Cd which was detected at 0.001mg/l at Ijokodo, Olorunsogo and Mokola dumpsites should raise immediate concern since the WHO (2004) guideline value is just 0.003mg/l.

Table 10: Harmful Health Effects of Excessive Levels of Heavy metals in drinking water.

Heavy metal	Harmful health effects	WHO guideline value (mg/l)
Cadmium	Neurotoxin, hypertension, carcinogenic, teratogenic, mutagenic, liver and kidney dysfunction	0.003
Chromium	Chronic toxicity (above 5mg/l), bleeding of the gastrointestinal tract, cancer of the respiratory tract, ulcers of the skin and mucus membrane	0.05
Cobalt	Possibly carcinogenic. High concentrations cause vomiting, nausea, vision problems, heart problems, thyroid damage	None yet
Lead	High blood levels can inhibit haem synthesis, cause irritation, mental retardation, brain damage; produce tumour	0.01
Nickel	Carcinogenic. Negatively affects reproductive health	0.02

CONCLUSION AND RECOMMENDATIONS

Elevated values of Pb, Cd, and Cr were found in soils at the refuse dumps when compared to control samples and established guidelines of several countries. No evidence of elevated values of Co in soils was found; but Ni was slightly elevated in some samples. It was found that Pb generally has the highest concentrations in the soil layers while Cd generally is least detected. The order observed for this study is Pb > Cr > Ni > Co > Cd. The values of Pb obtained from this study were above the allowable limits for soils, in several countries. This raises significant concern for safety of the environment and health impacts on the populace and calls for urgent attention and appropriate response. Soil samples from some dump sites also exceeded the allowable limits in the cases of Cr and Cd. These refuse dumps should be relocated outside the city and some phyto-remediation measures of soil especially in respect of Pb should be initiated as a matter of urgency at these locations. The groundwater samples met the WHO (1993, 1996b, 2004) guideline values set for Pb, Cd, Cr and Ni. There is no guideline as yet for concentration of Co in water although it was below detectable limit in the samples analyzed. The recommendations of the study include formulation and enforcement of a directive to prevent any form of farming on the dumpsites, relocation of the dumpsites out of the city and the enforcement of other environmental protection regulations to arrest the ongoing buildup of the heavy metals in those locations. Findings from this study will be of immense help to researchers and environmental regulators working in developing countries.

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