

Assessment of Heavy Metals Leached from Electronic Waste Dumpsites in Ibadan City

Renshaw Benjamin¹, Ogungbile Peter^{2*} and Sridhar Mynepalli¹

¹Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria

²Environmental management and Crop Production Unit, College of Agriculture, Engineering and Science, Bowen University, Osun State, Nigeria

***Corresponding author:** Ogungbile Peter, Environmental management and Crop Production Unit, College of Agriculture, Engineering and Science, Bowen University, Osun State, Nigeria, Tel: 234-8037708479, E-mail: ogungbilepeter@yahoo.com

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Abstract

Electronic wastes (e-waste) are hazardous and are being generated rapidly due to the preponderance of electrical and electronic equipment, and is adversely impacting the environment and human health. In this study, pH values and heavy metals levels from soils and leachates collected from three waste dump sites in Ibadan were assessed. Atomic absorption spectrometry (AAS) was used for determining Co, Pb, As, Se, Ni, Cd, Hg and Cr. Results of heavy metal concentrations of leachates at the three locations A were (mg/l): Co 0.06 ± 0.02 , Pb 0.14 ± 0.8 , Ni 0.10 ± 0.04 , Cd 0.02 ± 0.01 , Hg 0.03 ± 0.02 , Cr 0.20 ± 0.05 location B Pb 0.13 ± 0.06 , Cd 0.01 ± 0.00 and location C Pb 0.11 ± 0.06 , Cd 0.02 ± 0.01 . Heavy metal concentrations in leachates at location A was in the order Cr > Pb > Ni > Co > Hg > Cd while As and Se were below detectable limits in the three locations. Heavy metal concentrations in the top soil of the three sampling locations were as follows: Location A: Co > Pb > Se > Ni > Hg > Cd, Location B: Co > Pb > Se > Cd > Hg and Location C: Pb > Ni > Cd. Heavy metal concentrations in the subsoil of the three locations showed this sequence: Location A: Co > Hg > Pb > Se > Ni > As > Cr > Cd. Location B: Co > Hg > Pb > Se > Cr > Ni > Cd > As. Location C: Co > Pb > Cd > Ni > Cr. Conclusively, the concentration of cobalt (Co) was the highest among all metals analyzed followed by lead (Pb). This suggested that the dumpsites have capacity to impact the environment negatively and a concern for public health. pH values of leachates at locations A, B and C were 7.61 ± 2.5 , 6.00 ± 2.00 and 8.13 ± 2.8 respectively. As for the pH values of leachates, the top soils and sub-soils of dumpsites A and C were alkaline while those of dumpsite B was acidic and traceable to mixed solid wastes typical of e-waste and biodegradables. It is therefore recommended that proper e-wastes management should be strengthened through legislations, capacity building and enhanced budget allocation.

Keywords: Dumpsites, Heavy Metals; pH Value; E-Wastes; Environmental Pollution

Introduction

Electrical and Electronic Equipment's (EEC) are electric equipments that are dependent on electric currents or electromagnetic field in order to work and these include equipments for generation, transfer and measurements of such currents and fields. It applies to products that are designed for use with a voltage rating not exceeding 1000V for alternating current and 1500V for direct current [1,2].

Electrical and Electronic Equipment (EEE) market in recent years is expanding and experiencing remarkable growth around the world. This is due to increment in the utilization of products such as mobile phones, televisions, and computers including laptops and notebooks. Electronic equipments have become indispensable part of human day-to-day life activities. The technology is ubiquitous and has expanded the quantum of cheap EEE used worldwide. Incidentally the cheap articles became rapidly obsolete and has resulted in large volumes of e-waste disposal globally [3]. E-waste is a fastest-growing waste stream in the world (World Economic Forum, 2019). Electrical Waste or e-waste often refers to all items of EEE that have been discarded as a waste without the intent of re-use (StEP Initiative, 2014) [4]. It can be further defined as disposed computers, electronic equipment, entertainment devise electronics, mobile phones television sets and refrigerators [5].

According to Waste Electrical and Electronic Equipment (WEEE, 2006b) [6], chemical elements found in e-wastes can be grouped into elements in bulk including, lead, tin, copper, silicon, carbon, iron, and aluminum. They could also be elements in small amounts like cadmium and mercury, and those in trace amounts include germanium, gallium barium, nickel, tantalum, indium, vanadium

terbium, beryllium, gold, europium, titanium, ruthenium, cobalt, palladium, manganese, silver, antimony, selenium, niobium, yttrium, rhodium, platinum, arsenic, lithium, boron and americium. Some of the heavy metals in e-wastes are pollutants with harmful influences on natural ecosystem and human health and Hg, Pb and Cd were already implicated in this category. Also, mercury and cadmium are known to cause injury to the kidney or cause kidney dysfunction. Even micronutrient elements considered as essential food ingredients like Zn, Fe, Cu, Co, Mo can become hazardous at higher concentrations.

Heavy metals pollution of terrestrial ecosystem is of concern for a number of reasons. Pollutants in the soil may be absorbed, through the roots and they may cause injury to the plant or pass through the food chain when these plants are eaten. Also, metals present in atmospheric aerosols, rain water or fog may be deposited on to plant surfaces.

Electronic waste (e-waste) contains a variety of hazardous materials including toxic metals such as antimony, lead, nickel and others and organic compounds such as phthalates and brominated flame retardants (BFRs) that could potentially leach into the environment after disposal and threaten human health [7-10].

Unlike organic pollutants, which are broken down to a greater or lesser extent depending on their reactivity, heavy metals cannot be degraded and will remain in the soil permanently unless they are leached out. However, when they are leached out, heavy metals move into surface and ground waters and may eventually end up in drinking water. The pH of the soil is a controlling factor in the leaching of many heavy metals from soil; the greater the acidity, the more of the heavy metals will leach out. Metal pollutants can easily be mobilized from poorly maintained dumpsites and leached into soils [11].

Eventually a significant proportion of dumped e-wastes eventually end up in landfills and municipal waste incinerators, while clean technology advances promote recycling facilities in order to recover reusable and recyclable materials also trace amounts of precious metals. The methods largely used in the recycling EEE include smelting of electronic boards on open fire to extract metals and valuable chips, burning of cable wires to recover copper and open burning of residual waste materials (Feldt et al., 2014). These methods result in emission of high concentrations of toxins into the atmosphere thereby polluting the environment, endangering the health of recycling workers and residents in adjoining communities.

In general, there are three main exposure pathways including inhalation, ingestion and dermal contact [12]. Studies showed that people living around e-waste recycling sites have a higher daily intake of heavy metals and a more serious health burden. Potential risks include mental health, impaired cognitive function, and general physical damage [13]. DNA damage was also found more prevalent in e-waste exposed populations (i.e. adults, children and neonates than populations in the control area. Apart from a number of heavy metals and a variety of organic toxins like polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs), research has shown that PAHs constitute an important emission from informal e-waste recycling.

In developing countries e-wastes are usually discarded in a diverse unsuitable way including open burning, dumping into water bodies and at obscure places. Leaching of dangerous chemicals and toxic metals from such sites could cause contamination of groundwater [14]. In Nigeria, e-wastes are often discarded off at open dumps, burnt in open while valuable materials are recovered using crude methods all of which pollute the environment and expose humans to toxins. For many years, leachates have been known as a source of pollution, especially in soil and water bodies (Ogban, 2000). Several researches have used leaching procedures to characterize e-waste with a revelation that Pb is the metal that most persistently exceeds regulatory limits for hazardous waste at all permissible levels [15-18].

Ibadan, being a major populous city in Africa has e-waste disposal problems. A large volume of e-wastes are indiscriminately disposed. Few of the waste dumpsites in Ibadan receive significantly larger quantities of disposed e-waste than others. For instance, the University of Ibadan dumpsite located at Ajibode in Ibadan North LGA receives large quantity of e-wastes due to large population in the University which generate increased volumes of obsolete computers and other e-wastes. Another main e-wastes dumpsite which receives most other e-wastes across the city is located at Ekotedo in Ibadan Southwest LGA. It is a popular e-waste destination in Ibadan and has nearly six (6) years of unregulated e-wastes disposal history. This work reports data obtained on contamination of heavy metals leached out on soils from e-wastes disposal on the dump sites in Ibadan.

Materials and Methods

Study site

The study sites are located in Ibadan, the capital of Oyo State Nigeria. The city is geographically positioned on longitude 3°5 E of Greenwich meridian and latitude 70°23N of the equator. The city is divided into eleven local government areas of which five are inner core namely; Ibadan north, Northeast, Northwest, Southwest, Southeast. The other six which includes Lagelu, Oluyole, Onara, Egbeda and Akinyele are at the outskirts and they surround the inner core of the city. The city is reputed to have the largest indigenous population in Africa and it is expanding unchecked.

Soils Contaminated with E-wastes

Ibadan is a recipient of used electrical and electronic equipments (UEEE) shipped from developed countries. Incidentally, UEEE have reduced life-span and many constitute mere garbage. E-waste may contain valuable metals such as Cu, and gold as well as hazardous

substances such as Pb, Hg and persistent organic pollutants. Unfortunately, Ibadan lacks the necessary recycling infrastructure to manage E-waste, thus, recycling at informal sectors that used crude dismantling and backyard recycling techniques; uncontrolled open burning of cables to recover copper wire and E-waste disposal at dumpsites are popular. These activities result in environmental contamination and human exposure to harmful heavy metals.

Sampling Dumpsites

Experimental samples were collected from three dumpsites purposively selected for differential evidence of E-wastes clearly visible at the sites and classified as (A) Exclusive E-waste Dumpsite, (B) Mixed Dumpsite and (C) Zero E-waste dumpsite.

(A) This is located in Ekotedo, in Southwest Local Government Area (LGA) of Ibadan. The dumpsite is about 20sqm in size. It is very close to the popular Ogunpa market. There are residential areas surrounding the dumpsite. The dumpsite has been used for dumping of only e-waste for the past 6 years.

(B) The Mixed dumpsite has an area of about 25sqm located at Ajibode behind the University of Ibadan, along Ojo road in Ibadan North Local Government Area (LGA). Farming activities go on around the dumpsite. The nearest residential area is about 500m from the site. The dumpsite attracts all categories of wastes, including e-wastes, biodegradable wastes, plastics, cans, nylon etc. scavengers can be seen sorting and selecting useful components in the wastes. Periodic burning is carried out at the dumpsite.

(C) The Zero E-waste dumpsite is located about 200m from the Exclusive E-waste Dumpsite (A). The site is close to the popular Ogunpa market. It is basically a commercial area that also consists of artisans, traders, mechanics and electricians. The three dumpsite locations A, B and C are shown in Figure 1.

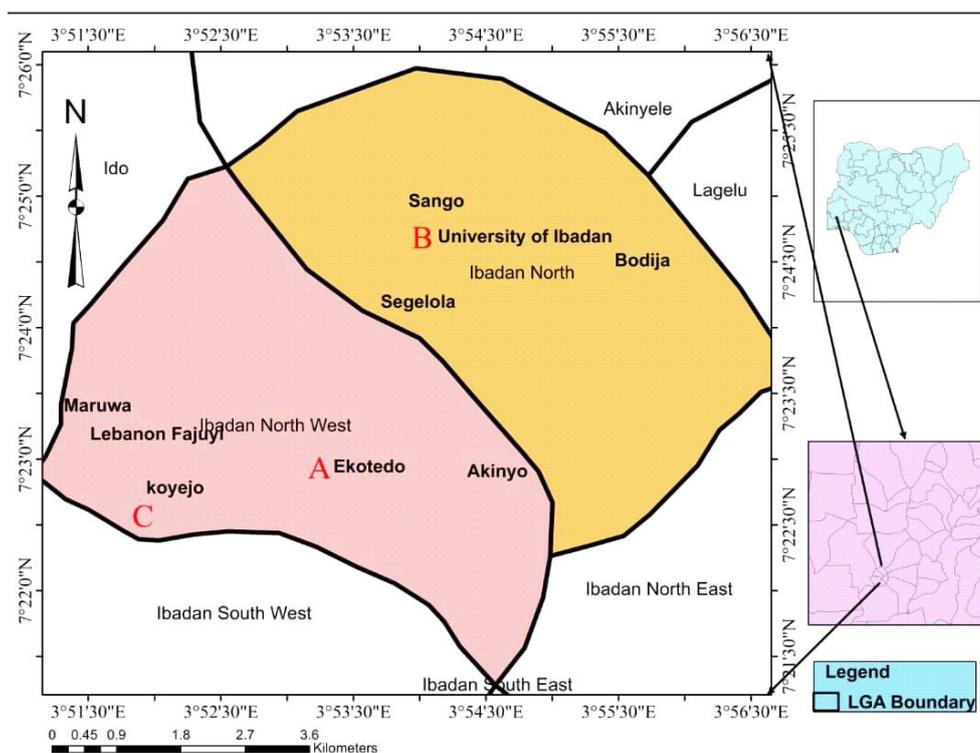


Figure 1: The dumpsites sampled

Collection of Leachates

From each dumpsite, leachate samples were collected from the three selected sample spots. Leachate holes (5 meters apart) were dug to a depth of 30cm at each dumpsite. The test leachates were taken in triplicates per location, labeled and taken to the laboratory for analyses using 3 plastic containers per location.

Collection of Soil Samples

Top soil was collected at a depth of 0--15cm and subsoil was collected at the depth of 15-30cm from the three locations A, B, and C. The soil samples were kept in polythene bags that were labeled and taken to laboratory for analyses. Samples were air-dried and grinded into fine powder before passing through a 160µm sieve. Grinded samples were packed in polythene bags and stored below -20 °C prior for elemental analyses.

Digestion Procedures

For the digestion of leachate, 50ml of each of the samples from locations A, B and C were transferred into pyrex beakers and 10ml of conc. HNO_3 was added. The samples were boiled slowly and then evaporated on a hot plate to about 20ml; the beakers were allowed to cool down and another 5ml of conc. HNO_3 added. Heating continued with the addition of conc. HNO_3 as necessary until the digestion was completed.

To digest the soil samples (Top and subsoils), Nitric acid – perchloric acid method was adopted. One gram each of the soil samples from A, B and C were placed in 250ml digestion tubes and 10ml of conc. HNO_3 added. The mixtures were boiled gently for 30-45 minutes after cooling 5ml of 70% HClO_4 was added and the samples boiled gently until dense white fumes appeared. After cooling, 20ml of distilled water was added and the mixtures boiled to further release the fumes. The solutions were cooled and filtered and the filtrates were transferred to 25ml volumetric flasks by adding distilled water. Triplicate digestion was done for each sample and finally transferred to 25ml volumetric flasks and diluted to the final volume.

Heavy Metal Analysis

All the digested samples were kept and later subjected to elemental analysis using Atomic Absorption Spectrophotometer (AAS). The digested samples were analysed for heavy metal such as Co, Pb, As, Se, Ni, Cd, Hg and Cr.

Determination of pH

pH value in Leachates: The pH value was determined in the leachate samples by glass electrode probe method with standard calibrated pH meter made by Techmel and Techmel, USA Model Number, pH 525. The pH meter was standardized using buffer solutions of pH 4.0 and 7.0 standard tablets.

pH of soil samples: Twenty grams of air dried soil samples were weighed into 50ml beakers after which 20ml of distilled water was dispensed into each beaker, stirred and allowed to stand for 30 minutes. Stirring was done occasionally with a glass rod. The pH determination was carried out by probe method using standard pH meter pH. 525 manufactured by Techmel and Techmel. after standardization of the pH meter with buffer solutions pH 4.0 and 7.0. The electrode of the pH meter was rinsed with distilled water after each measurement. The pH of the soil suspension was then measured using the Electronic pH determination method and recorded accordingly for Top-soil subsoil from locations A, B and C.

Statistical analysis

All data collected were analyzed using SPSS package looking at significant differences of data at 5% level of confidence.

Results

The results of heavy metal analysis of leachate, top soil and sub soil at locations A, B and C are presented in Table 1, 2 and 3. The heavy metal results were compared with applicable standards as published by Guideline Limits by the World Health Organization (WHO).

Heavy Metals in Leachate

The leachate samples from the three locations A, B and C were analysed for heavy metals such as Co, Pb, As, Se, Ni, Cd, Hg and Cr. The overall order of heavy metals concentrations at the location A are as follows: $\text{Cr} > \text{Pb} > \text{Ni} > \text{Co} > \text{Hg} > \text{Cd}$. In all the three locations As and Se were below detectable limits. Similarly, at locations B and C Co, Ni, Hg and Cr are below detectable limits. (Table 1).

PARAMETER	A	B	C
Co (mg/l)	0.06+0.02	0.00+0.00	0.00+0.00
Pb (mg/l)	0.14+0.8	0.13+0.06	0.11+0.06
As (mg/l)	0.00+0.00	0.00+0.00	0.00+0.00
Se (mg/l)	0.00+0.00	0.00+0.00	0.00+0.00
Ni (mg/l)	0.10+0.04	0.00+0.00	0.00+0.00
Cd (mg/l)	0.02+0.01	0.01+0.00	0.02+0.01
Hg (mg/l)	0.03+0.02	0.00+0.00	0.00+0.00
Cr (mg/l)	0.20+0.05	0.00+0.00	0.00+0.00
pH value	7.61 + 2.5	6.00 + 2.00	8.13 + 2.8

Table 1: Heavy metal levels of Leachates

Cobalt concentrations in the leachate samples in location A was 0.06 + 0.02 mg/kg. Lead is used in batteries, it is used widely in solders as an alloying element for machining metals, printed circuit boards, components, incandescent light bulbs. Lead-based solder (typically a 60:40 of tin to lead), which is used to attach electrical components, represents the major solder type used in most EEE applications and typical motherboards have been reported to contain approximately 50g/m² lead (Five Winds International, 2001).

The mean concentration of Pb in the leachate from locations A, B and C are $0.14 + 0.8$, $0.13 + 0.06$ and $0.11 + 0.06$ mg/L respectively (Table 1). The Pb concentration from A, the e-waste dump has the highest value $0.14 + 0.8$ mg/L while the lowest value was recorded at location C, the control with $0.11 + 0.6$ mg/L (Table 1).

Nickel is used for alloying elements batteries and some mobile phones. Nickel based alloys include Ni-base super alloy, Ni-base corrosion resistant alloy. The mean value of Ni in the leachate from location A was $0.10 + 0.04$ mg/L Table 1. Nickel was below detectable limits in location B and C (Table 1).

Cadmium concentrations in the leachate samples from the three locations (A, B, C) averaged $0.02 + 0.01$, $0.01 + 0.00$, $0.02 + 0.01$ mg/L respectively Table 1. The concentration of Cd at locations A and C were the same $0.02 + 0.1$ mg/L (Table 1). Cadmium occurs in Printed Circuit Boards (PCBs) in certain components such as chip resistors, infrared detectors and semiconductors (European Commission, 2000) [19]. Furthermore, cadmium has been used as a stabilizer in PVC. Cadmium metal or powder is used as part of the negative electrode material in nickel-cadmium (NiCad) batteries, as an electrodeposited, vacuum deposited or mechanically deposited coating on iron, steel, aluminum-base materials titanium base alloys or other ferrous alloys and as an alloying element in lozo-melting brazing, soldering and other specialty alloys. Cadmium oxide forms part of the negative cadmium electrode in nickel-cadmium batteries, and cadmium sulphide found widely in CRT and electronic devices (AEA 2004) [20].

The mean concentration of mercury in the leachate sample in location A was $0.03 + 0.02$ mg/L (Table 1). Concentrations of mercury of location B and C were below detectable limits. Mercury is basically used in thermostats sensors, relays and switches (on printed circuit boards and in measuring equipment and discharge lamps). Furthermore, it is used in medical equipment data transmission, telecommunications and mobile phones.

Mean concentration of Cr in leachate at location A was $0.20 + 0.05$ mg/L (Table 1). Cr were below detectable levels at locations B and C (Table 1). Hexavalent chromium is used in the plastics of personal computers, cabling and packaging. Chromium VI is typically used as a hardner or stabilizer for plastic housings and a colorant in pigments [21].

Heavy Metals in Top Soil

The mean values of heavy metal concentration in the top soil of the three sampling locations are presented in Table 2. The overall mean concentrations of the heavy metals in location A, B and C are summarized as follows:

Location A: $Co > Pb > Se > Ni = Hg > Cd$

Location B: $Co > Pb > Se > Cd > Hg$ and

Location C: $Pb > Ni > Cd$ in all the three locations As and Cr are below detectable limits.

The concentration of Co from the three locations in top soil ranged from (mg/kg) $0.00 + 0.00$ © to $0.38 + 0.20$ (B) (Table 2). The Co level in location A was $0.12 + 0.11$ cobalt was below detectable limit in the top soil at location C.

PARAMETER	A	B	C	WHO/FAO (2001)
CO (mg/kg)	0.12+0.11	0.38+0.20	0.00+0.00	50
Pb (mg/kg)	0.09+0.07	0.21+0.14	0.07+0.02	50
As (mg/kg)	0.00+0.00	0.00+0.00	0.00+0.00	20
Se (mg/kg)	0.07+0.05	0.08+0.02	0.00+0.00	10
Ni (mg/kg)	0.05+0.02	0.00+0.00	0.03+0.01	50
Cd (mg/kg)	0.03+0.01	0.05+0.02	0.02+0.02	3.0
Hg (mg/kg)	0.05+0.02	0.03+0.02	0.00+0.00	2.0
Cr(mg/kg)	0.00+0.00	0.00+0.00	0.00+0.00	100
pH	8.12 + 2.03	6.67 + 3.11	8.08 + 4.32	

Table 2: Heavy metal characteristics of top soil in the three locations (A, B, C)

The mean concentration of Co recorded at the locations A and B of top soil were below the WHO/FAO (2001) permissible limits of 50mg/kg for soils.

The Pb content (mg/kg) in the top soil range from $0.07 + 0.02$ (C) to $0.21 + 0.14$ (B) and Pb level in location A was $0.09 + 0.07$ (Table 2). The mean concentration of Pb at the three sampling locations were below the WHO/FAO (2001) permissible limit of 50mg/kg for soils.

For the present analysis, the Se content in the top soil (mg/kg) in location A was $0.07 + 0.05$ and $0.08 + 0.02$ in location B (Table 2). Se was below detectable limit in location C. The mean concentration of Se recorded at the three sampling locations were below the WHO/FAO (2001) [22] limit of 10mg/kg for soils.

The Ni content in the top soil from the three locations ranged from $0.03 + 0.1$ (C) to $0.07 + 0.05$ (A), while Ni was below detectable limit in location C (Table 2). The mean concentration of Ni recorded at locations A and C of top soil were below the WHO/FAO (2001) permissible limit of 50mg/kg for soils.

Cd in the top soil (mg/kg) in location A, B and C were $0.03 + 0.01$, $0.05 + 0.02$ and $0.2 + 0.02$ respectively (Table 2). The mean concentration of Cd recorded at all the sampling locations were below WHO/FAO (2001) [22] permissible limit of 3.0mg/kg for soils.

In top soil Hg (mg/kg) ranged between $0.03 + 0.02$ (B) and $0.05 + 0.02$ (A), while Hg was below detectable limit in location C (Table 2). The mean concentration of mercury recorded at three different sites was below the WHO/FAO (2001) limit of 2.00mg/kg for soils.

Heavy Metal Concentrations in Sub-Soil at Different Locations in the Study Area

The results of the analysis of heavy metals analysed for sub-soil samples drawn from the three locations are presented in Table 3.

PARAMETER	A	B	C	WHO/FAO (2001)
Co(mg/kg)	0.52+0.3	0.45+0.2	0.26+0.02	50
Pb (mg/kg)	0.26+0.02	0.17+0.1	0.06+0.03	50
As (mg/kg)	0.04+0.00	0.01+0.01	0.00+0.01	20
Se (mg/kg)	0.14+0.12	0.05+0.02	0.00+0.00	10
Ni (mg/kg)	0.09+0.04	0.03+0.01	0.01+0.05	50
Cd (mg/kg)	0.02+0.01	0.02+0.01	0.02+0.01	3.0
Hg (mg/kg)	0.30+0.00	0.30+0.15	0.00+0.00	2.0
Cr (mg/kg)	0.02+0.02	0.04+0.02	0.01+0.01	100
pH	7.06 + 3.3	6.47 + 4.2	8.83 + 3.1	

Table 3: Heavy metal characteristics of Sub soil in the three locations

The overall mean concentrations of the heavy metal from the sub-soils in locations A, B and C can be summarized as follows:

Location A: Co > Hg > Pb > Se > Ni > As > Cr > Cd

Location B: Co > Hg > Pb > Se > Cr > Ni > Cd > As

Location C: Co > Pb > Cd > Ni > Cr

In location C As, Se and Hg were below detectable limit from the sub-soil samples. The Co content in mg/kg from sub-soil locations A, B and C were $0.52 + 0.03$, $0.45 + 0.2$ and $0.26 + 0.02$ respectively (Table 3). The mean concentration of Co obtained in the sub-soil at all the sampling sites were below WHO/FAO (2001) permissible limit of 50mg/kg for agricultural soils.

For the present analysis Pb content (mg/kg) in sub-soil ranged from $0.06 + 0.03$ (C) to $0.26 + 0.02$ (A) (Table 3). The mean concentration of Pb as recorded at the three sampling locations was below WHO/FAO (2001) permissible limit of 50.00mg/kg for soils.

Mean concentration of As in mg/kg from the sub-soil for the present analysis ranged from $0.01 + 0.01$ (B) to $0.04 + 0.00$ (A) (Table 3). The presence of As in the sub-soil of location C was below detectable limit. The mean concentrations of As at all sampling sites A and B in the sub-soil were below WHO/FAO (2001) permissible limit of 20.00mg/kg.

The Se content (mg/kg) in sub-soil from location A was $0.14 + 0.12$, while in location B was $0.05 + 0.02$ (Table 3). Se was below detectable limit on location C. The mean concentration of Se obtained in locations A and B were below the WHO/FAO (2001) permissible limits of 10.00mg/kg for soils.

The concentration of Ni (mg/kg) in sub-soil samples from locations A, B and C are $0.09 + 0.14$, $0.03 + 0.01$ and $0.01 + 0.05$ respectively. The mean concentration of Ni recorded at the three locations of the sub-soil were below the WHO/FAO (2001) permissible limit of 50mg/kg for soils.

The concentration of Cd (mg/kg) in the sub-soil in location A, B and C were the same $0.02 + 0.01$. Cd mean concentration from the sampling locations recorded values were below WHO/FAO permissible limits of 3mg/kg for soils.

Hg in mg/kg in sub-soil from location A was $0.30 + 0.00$ and in location B was $0.30 + 0.15$ while Hg was below detectable limit in location C (Table 3). The mean concentration of mercury recorded at A and B locations of sub-soils were below the WHO/FAO (2001) limit of 2.0mg/kg for soils.

The mean concentrations of Cr in mg/kg in sub-soil samples ranged from $0.01 + 0.01$ (C) to $0.04 + 0.02$ (Table 3). The mean values of Cr at the various sites were below the WHO/FAO (2001) permissible limit of 100mg/kg for soils.

pH Values

The pH values in leachate samples at the three sampling locations varied from 6.00 + 2.00 (B) to 8.13 + 2.8 C (Table 1). The pH values in A and C and were generally alkaline, while the pH at B was acidic. The pH values at the sampling locations are within the WHO permissible limits of 6.5 – 8.5 for water.

The pH value in the three sampling locations from the top soil ranged between 6.67 + 3.11 (B) and 8.08 + 4.32 (C) (Table 2). The pH values were alkaline except for sampling location B that was acidic.

The pH values at locations A and C were generally alkaline. The pH values ranged from 6.47 + 4.2 (B) to 8.83 + 3.1 (C) (Table 3). The pH of the leachate in the sub soils was 7.06 + 3.3 A (Table 3)

Discussion

Generally, the heavy metal concentrations in all the three locations of the top soils were lower than the WHO/FAO permissible limits for soils for all the heavy metals analysed. Based on the heavy metal concentrations of the top soil, the soil samples collected from B (Mixed dumpsite) contained higher concentrations of heavy metals than for locations A (Exclusive E-waste dumpsite) and C (Zero dumpsite) metals for such as Co, Pb, Se and Cd. The heavy metal concentrations in location B (Mixed dumpsite) was higher than that location A (Pure E-wastes dump) can be attributed to differential geochemical conditions of the soil types of e-wastes processing activities and their resultant discharge. One of the likely contributory factors was the low pH measured (pH 6.67) in location B as against pH 8.12 recorded at location A. The microbial activities from organic waste present at B (Mixed dumpsite) have contributed to the reduction in pH which was capable of lowering the pH of soil and increased metal solubility, hence reducing absorption of heavy metals to the e-wastes components [23].

However the heavy metal concentrations in location A were higher than the concentrations in location C for metals such as Co, Pb, Se, Ni, Cd and Hg. The low values of Hg in the Top Soil from the sampling locations can be attributed to the fact that Hg easily evaporates into organo-mercury forms (Environmental Health and Safety Manual 2000) [24].

The heavy metal characteristics in the sub soil at location A revealed highest concentrations for Co, Pb, As, Se and Ni when compared with the mean concentrations of heavy metals found in location B and C. The range of values of heavy metal components recorded in majority of the soil samples were comparable to values reported by Thomas (2003) [25].

The heavy metal distributions of the soil showed distinctive differences in the concentrations and leaching potentials of heavy metals between A, B and C dumpsites for soil collected from top and sub-soils. In general, heavy metals in the e-wastes may remain relatively stable and inert, and are not easily released into the soil [26]. Distribution of heavy metals, such as Co, Pb, Se and Cd in contaminated top soils showed larger concentration of these heavy metals are in the dumpsite B than dumpsite A, while the reverse is the case for sub-soils for such metals as Co, Pb, As, Se and Ni. Generally heavy metals in top soil samples were predominantly found in dumpsite B which had mostly organic fraction indicating that it has strong affinity for organic complexes [23]. A particular concern was Pb level in the B dumpsite in the Top soil. Pb in this fraction of the B dumpsite soil samples accounted for 56.8% of the total Pb in the three dumpsites, effectively representing as much as 0.21mg/kg of Pb. Physical and geochemical changes at dumpsite B top soil, such as decomposition of organic matter and oxidation of anaerobic sediments, could potentially trigger the release of heavy metals from the e-wastes, leading to an increase in dissolved heavy metal concentration in the B dumpsite [27].

The distribution of Cd in the three dumpsites appeared relatively similar in sub soil. The soil samples in B dumpsite had pH value, ranging from 6.47 to 6.67 and the pH in dumpsite A increased in the order from the top soil to sub soil. This might be due to the organic decomposition taking place at the top soil enhanced by microorganisms.

This implies that the low pH of soil could lead to an increase in solubility hence leaching of heavy metals in location B and that lowered pH could alter the geochemistry of the soil at dumpsite located at B. In general, Co in dumpsite B topsoil samples represented 18.75% of the total Co, while that in dumpsite A Co accounted for 81.25%. In the dumpsite A top and sub-soil the Co was noticeably higher in the soil samples with pH 7.06 than in those with pH 8.12.

Furthermore, a decreasing trend was observed for Co in the top soil and sub soil with increasing pH at location A soil samples. This might also be the effect of pH a sign of heavy metal in the soil. The fact that active human activities are taking place around the contaminated dumpsite A warrant a genuine health concern, as there are still substantial agricultural activities within and immediate surroundings of the dumpsite B.

It is also noteworthy to mention that the dumpsites are part of the many others from which possible leaching of heavy metals into underground water used for drinking other domestic use occur. Long-term use of dumpsites especially at location B in turn will elevate heavy metal loadings of the soils and crops, potentially resulting in high levels of uptake of toxic metals in edible food crops [28].

The concentration of all heavy metals in leachate were below the guideline limits. However, the concentration of Cr was the highest in the leachate samples followed by Pb. The characteristics of the leachates indicated that the leachates in location A are more contaminated with heavy metals such as Co, Pb, Ni, Cd, Hg and Cr. The long-term consequences of this contamination can have a high toll on the environment and pose increasing hazard to health and environment.

Changes in physico-chemical parameters of water quality around the dumpsites A and B could predispose residents to some diseases as a result of consistent exposure to pollutants. Also, the communities around dumpsite A are mainly restaurants, markets and local residents, the leaching potential especially in rainy seasons are likely to be high. People around dump sites A and B use water from wells and boreholes for drinking and other domestic activities. Therefore, heavy metals which are been discharged from e-wastes may accumulate in the underground water, and may result in the buildup of specific pollutants in exposed population. This may predispose developmental anomalies concerns and leukemia after some time [29]. However, dilution may have lessened the severity of the contamination by reducing peak concentration through dispersive mechanism [30,31].

Conclusion

This study assessed the physicochemical properties in terms of heavy metal concentration and pH value in leachates and soils from three locations in Ibadan where e-waste are involved were assessed. Values obtained for heavy metals in leachates and soils were generally found below the recommended values of World Health Organization (WHO). The concentration of cobalt was discovered to be the highest among all the heavy metals studied followed by lead. This trend showed that the dumpsites have potential capacity to impact adversely the environment and human health. The results showed that the soils at the location B, which comprises of mixed solid waste characterized with e-waste and other biodegradable wastes have more heavy metal concentration than the dumpsite at location A for the topsoil category. The concentrations of the heavy metals at location B dumpsite topsoil may also pose some health and environmental challenges in the future due to exposure. From this study the sub soil at location A dumpsite have more heavy metal concentrations than the location B and C. On the other hand, the control C location contained low concentrations of heavy metals when compared with the heavy metal concentrations at location A and B. With the persistent dumping metal concentration may reach toxic levels through the food chain.

It is recommended that treatment of leachate be implemented in order to prevent soils been contaminated by the accumulation of heavy metals been leached from the disposal e-wastes at the dumpsites. Such measure will reduce the health and environmental impacts associated with its disposal into the environment at the e-wastes dumpsite.

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