Evaluation of the Effects of Electronic Waste on Topsoil and Groundwater

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Abstract— **Electronic waste is waste from obsolete electronic equipment such as computers, printers, photocopying machines, Television sets, Mobile phones etc. which are composed of sophisticated blends of plastics, metals, and other materials. These electronic devices are known to contain small amounts of toxic chemicals that when improperly disposed off, infiltrate into the soil, thereby contaminating the groundwater and this can exert, negative effects on human health and the environment. In this study soil and well water were collected from and around a dumpsite in Alaba electronics market Lagos Nigeria. The samples were analysed for the concentration of heavy metals and other physical parameters using Atomic Absorption Spectroscopy (AAS) and other equipment. The result of the analysis of the water samples revealed a slightly alkaline pH of 8.59, electrical conductivity of 3380.3µS/cm, with the heavy metal content ranging from 0.002 to 0.005mg/l for Cadmium, 0.001 to 0.008mg/l for chromium, 0.001 to 0.011mg/l for Nickel, 0.007 to 0.020mg/l for Lead, and 0.003 to 0.007mg/l for Zinc. The heavy metal concentration of the soil samples ranged from 0.5 to 12mg/kg for cadmium, 26 to 45mg/kg for chromium, 110 to 430mg/kg for Lead, 9 to 33mg/kg for nickel and 82 to 890mg/kg for Zinc. The major findings of this research work are the high levels of heavy metals in the topsoil and groundwater samples tested and the attendant health implications as some of the samples exceed the WHO/NIS Standards for water quality and FAO soil quality standards which are (Cadmium 0.005mg/l, Chromium 0.05mg/l, Nickel 0.02mg/l, Lead 0.01mg/l, Zinc 3mg/l) and (Cadmium <1mg/kg, Chromium <50mg/kg, Lead <70mg/kg, Nickel <50mg/kg, Zinc <125mg/kg) respectively. The results highlight the harmful effects of electronic waste and why it should be properly managed either through appropriate landfilling methods or recycling and it also demonstrates the urgent need for action to address the management of hazardous e-waste, and for tighter controls on the trans-boundary movement (importation) of such wastes.**

Index Terms— **Electronics, metals, soil, water, waste**

I. Introduction

Electronic waste is any broken or unwanted electrical or electronic appliance. Electronic products or appliances are substances that use electrical cables or batteries for providing its power [1]. Electronic waste (E-waste) typically consists of a broad range of electrical and electronic products including computers, mobile phones, televisions, and their components such as printed circuit boards, etc. It also encompasses a broad and growing range of electronic devices from household appliances like refrigerators, air conditioners, etc. The management of these discarded electronic devices has been an issue of concern for the solid waste community. These devices are known to contain small amounts of toxic chemicals that can exert, upon exposure, negative impacts on human health and the environment. These toxic substances include BFRs, PCBs, Lead, Cadmium, mercury, plastics, etc [2].

Even in the developed countries where Municipal Solid Waste (MSW) is properly land filled, some level of concern is still shown because some MSW landfills have been found to contain sufficient heavy metals to pollute groundwater, and can be expected to cause such pollution as the landfill liner systems deteriorate and fail to completely or reliably collect and remove the leachate. At this time it is unclear whether or not the disposal of electronic wastes in MSW landfills will significantly increase the heavy metal-pollution of groundwater once the liners systems fail to collect and remove all leachate generated in the landfill. On the other hand, In developing countries including Nigeria, waste from electronic components are managed through various inappropriate routes including disposal at open dumps, unsanitary landfills, and material recovery through back yard recycling (informal recycling) [3]. In comparison, the extent of groundwater pollution in open dump system is worse as the leachate is directly absorbed into surface and groundwater.

In the society generally, electronic waste is treated the same way as household waste as people are unaware of its relative toxicity. It is most often disposed of at open dumps, or primitively recycled which lack adequate pollution control measures [4, 5]. The hazards associated with improper management of electronic waste includes contamination of topsoil which is used for agricultural production, contamination of surface and groundwater which have attendant health implications [6, 7]. Disposal of electronic waste is an emerging global environmental issue, as these wastes have become one of the fastest growing waste types in the world [8]. The e-wastes, if not disposed of appropriately can become a source of trace metal contaminants in the environment and this is very worrying especially in Nigeria as it has been reported that it receives large volumes of e-waste from developed countries for reuse but most of these second hand electronics end up in the landfills after useful parts have been removed [9]. The intention of this study is to investigate the physical properties of groundwater and topsoil at an electronic waste disposal site and from the results obtained, highlight the toxicity of these wastes and why they should be handled appropriately.

The objectives of this study are to establish a basic

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understanding of the level and extent of trace metal contamination in soil/groundwater around an electronic waste dumpsite and thus highlight the attendant problems emanating from improper management of electronic waste and to determine the level of trace metals in topsoil and well water in the electronic waste dumpsite and neighboring residential houses.

II. METHODLOGY

A. *Study Area*

Alaba International Market in Ojo, Lagos was chosen for this study. It is one of the known electronic waste processing centres in Nigeria. Located in southern Nigeria, it is situated in a tropical region and its climate is characterized by plenty of rainfall during wet season which spans between March and September of each year while the dry season spans between October and March. Recycling of e-waste in Alaba International Market has taken place for years with several tones of computer waste handled each year [10]. Amid these activities, buying and selling go on in the market at regular frequency even though there are residential houses in the immediate surroundings. Plate 1 below shows a vivid picture of the situation; it shows a dumpsite near a residential home.

Plate 1: Electronic waste dumpsite in Alaba, Lagos State

Similarly, Figures 1 and 2 shows the map of Lagos State highlighting the study location. The central location of the market clearly indicates the potential risks or hazards that might result if proper management of wastes both solid and liquid is not done.

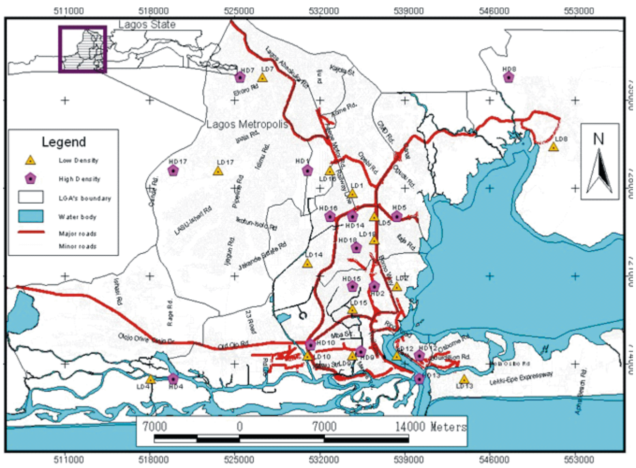

Fig. 1: Map of Lagos state showing the various local government areas.

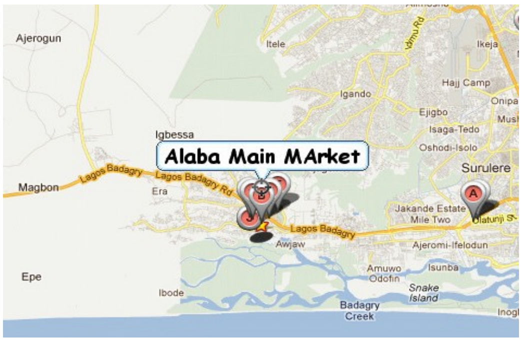

Fig. 2: Map of Lagos State showing the study location.
Sample Collection

In carrying out this study, 5 different water samples were collected from groundwater points (Hand dug wells) around the electronic waste dump in the study area. These samples were collected in September 2011 (wet season). The water samples were collected using a rubber container made from car tyre tube attached to a long rope. 4L of the water sample was collected from each study location in a sterilized plastic bottle of which 2L of the water stored in another sterilized plastic water bottle for laboratory analysis. The water samples were collected during the early hours of the morning on the same day. Also, 5 different soil samples were collected at different points around the dumpsite at the early hours of the morning of the following day so as to study the extent of heavy metal concentration in the soil. The soil samples were collected using the core soil sampler at different depths which ranged from 10 to 30cm. The samples carefully labelled and stored in an iced box to allow each of the samples retain their composition. The choice of the sample collection points considered the location, accessibility and proximity to the dumpsite.

B. *Methods of Analysis*

The water samples collected from each of the study locations were analyzed for trace metals of Cadmium, Chromium, Nickel, Lead, and Zinc while the soil samples were first grounded with a mortar and pestle before sieving. 10g from each of the samples were digested using 10mls of HNO_3 and H_2O_2 using the 3050B method suggested by [11]. The mixture was heated on a hot plate continuously until the brown fumes completely disappeared leaving white fumes. The flask was then allowed to cool and filtered into a 50ml standard volumetric flask and made up to the 50ml mark with distilled water.

Determination of the heavy metals was done in an atomic absorption spectrophotometer (AAS model 210 VGP) after calibrating the equipment with different standard concentrations of Pb: 1, 2 and 5 ppm; Cd: 0.5, 1 and 2ppm; Cr: 1, 2 and 5ppm; Ni: 1, 2 and 5 ppm, and Zn: 1, 2 and 5ppm.

III. RESULTS

The results of the heavy metals present in the well water and soil samples as well as the results for other physical parameters tested are presented in Tables 1 to 5.

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Table 1: Result of laboratory analysis for heavy metals in well water (mg/l)

Metal	Sample A	Sample B	Sample C	Sample D	Sample E
Cadmium	0.002	0.005	0.004	0.003	0.005
Chromium	0.003	0.002	0.001	0.008	0.001
Nickel	0.011	0.001	0.011	0.010	0.008
Lead	0.008	0.010	0.020	0.015	0.007
Zinc	0.003	0.004	0.004	0.007	0.003

Table 2: Results of water samples as compared with WHO Water Quality Standard (2004) and the Nigerian water quality standard

Parameters	A	B	C	D	E	WHO	NWQS
Cadmium	0.002	0.005	0.004	0.003	0.005	0.005	0.003
Chromium	0.003	0.002	0.001	0.008	0.001	0.05	0.05
Nickel	0.011	0.001	0.011	0.010	0.008	0.02	0.01
Lead	0.008	0.010	0.020	0.015	0.007	0.01	0.01
Zinc	0.003	0.004	0.004	0.007	0.003	3	3

Units are mg/l

Table 3: Laboratory result for analysis of other physical parameters

PARAMETER	AVERAGE VALUE	WHO Permissible limit	NSDWQ Standard
pH	8.59	6.5 – 8.5	6.5 – 8.5
Conductivity (µS/cm)	3380.3	1000	1000

Table 4: Results for laboratory analysis of heavy metals in the soil samples (mg/kg)

Metal	A	B	C	D	E
Cadmium	4	12	10	6	0.5
Chromium	42	45	33	34	26
Lead	430	530	745	110	168
Nickel	9	28	33	14	23
Zinc	182	492	890	130	243

Table 5: Results of soil samples as compared with FAO typical soil metal levels in (mg/kg)

Parameter	A	B	C	D	E	FAO
Cadmium	4	12	10	6	0.5	0.1-1
Chromium	42	45	33	34	26	1-50
Lead	430	530	745	110	168	10 – 70
Nickel	9	28	33	14	23	0.5 -50
Zinc	82	492	890	130	243	9 - 125

IV. DISCUSSION OF RESULTS

From the results obtained, all the metals found at high levels have known uses in electronic devices and therefore could be expected in e-waste. The results and their likely implications are discussed in detail below.

Heavy Metal Content of Groundwater Samples

The World Health Organization [12, 13, 14, 15, 16, and 17] set the maximum permissible limits of heavy metals in drinking water as follows: Cadmium (0.003 mg/l), Chromium (0.05mg/l), Zinc (3.0 mg/l), Lead (0.01 mg/l) and Nickel (0.02 mg/l). With the exception of Lead, all water samples analyzed in this project were fully within these limits and therefore posed no danger to consumers as far as these specific heavy metals are concerned (Table 1). The presence of lead in the groundwater in the study location is traceable to the dumping and open burning of electronic waste in the dumpsites within the market and environs. The high concentration of lead is an indication of contamination. Lead is immobile in the soil and once released, can remain in the soil for a long period of time [18]. From the results therefore, it is clear that the heavy metal has percolated into groundwater and this is worrisome because Lead is very toxic and can build up in the body following repeated exposures.

pH Value

The pH is a variable that regulates all biological function. It is the degree of acidity or alkalinity of a substance. Recommended values range between 6.5 – 8.5 and 7.0 – 8.5 by WHO and NSDWQ (Table 3). The pH scale ranges from 0 -14, with 7 as the neutral point while from 1 to 7 indicates increase in acidity. Similarly, from 7 to 14 shows increase in alkalinity. The average of all the values obtained in the study indicates that the groundwater resource in the area is slightly alkaline with a pH value of 8.59. This result shows that the pH value is slightly above the permissible limits which are between 6.5 and 8.5 by the WHO and NSDWQ and may need to be checked to prevent further increase.

Electrical Conductivity

Electrical conductivity is the measure of salinity which is as a result of dissolved solids in the water. These dissolved solids are mostly positively charged ions as well as negatively charged ions the water sample. The recommended values by WHO is 1000µS/cm. The average of the values shows the electrical conductivity of the water samples to be 3380.3µS/cm. This value rises above the WHO standard (1000µs/cm) and normal range probably as a result of increased volume of water and runoff as the study was carried out in the wet season. The wetter, a landfill or dumpsite is, the greater the seepage runoff and chemical enrichment of the groundwater resource [19]. High conductivity will in most cases affect the taste of water [20].

Heavy Metal Content of Top Soil Samples

Heavy metal contamination of the soil in and around the dumpsite can be observed from the results of this study. The typical soil heavy metal content limits as set by FAO (Cadmium 0.1 to 1mg/kg, Lead 10 to 70 mg/kg, Zinc 9 to 125mg/kg) were by far exceeded for Cadmium, Lead and Zinc by the samples tested. The Cadmium content obtained from the five soil samples obtained from within and around the dumpsite and tested ranged from 0.5 to 12mg/kg. This is worrisome as cadmium is a cumulative toxicant and long term exposure can result in damage to the kidney and bone toxicity. The Lead content of the samples ranged from 110 to

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745mg/kg. The high concentration of lead in the dumpsite and environs is a clear indication of lead contamination and this is of particular concern as the metal is highly toxic and can build up in the body following repeated exposures. Also, the Zinc Content ranged from 82 to 890mg/kg and this is above the acceptable limits (9 to 125 mg/kg). Chromium and Nickel were present in the samples tested although they fell within acceptable limits (Chromium 1 to 50mg/kg, Nickel 0.5 to 50mg/kg) and therefore do not pose a hazard to the environment.

V. Conclusion

The effects of electronic waste on topsoil and groundwater quality were evaluated in this study. This was done in order to highlight the toxic substances found in electronic waste and the ease with which these toxic substances can pollute the soil and groundwater in adjoining areas.

The results of this study thus provide valuable information on the leachability of heavy metals especially lead from electronic waste at waste disposal points into the soil and groundwater of the area. The heavy metal content of the soil within and around the dumpsite exceeds the set limits for Lead, Cadmium and Zinc. This indicates that the toxic substances found in electronic waste should therefore be properly managed. Although it was observed that some of the parameters fall within the specified range according to the World Health Organization (WHO) and the NSDWQ, they may exceed these limits if remedial measures are not put in place.

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