EVALUATION OF THE EFFECTS OF ELECTRONIC WASTE ON TOPSOIL AND GROUNDWATER QUALITY

BY

OJI, DORIS MADUKA

2006/24068EA

A PROJECT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA,

NIGER STATE.

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) IN AGRICULTURAL AND BIORESOURCES ENGINEERING.

FEBRUARY, 2012.

DECLARATION

I, Oji Doris Maduka, hereby declare that the project was done solely by me under the supervision of Dr M. Y. Otache of the department of Agricultural and Bioresources Engineering, Federal University of Technology Minna. I also declare that this work has never been submitted elsewhere for any degree award.

Oji Doris Maduka

2/3/2012

Date

CERTIFICATION

This is to certify that the project entitled "Evaluation of the effects of electronic waste on topsoil and groundwater quality" by Oji Doris Maduka meets the regulations governing the award of the degree of Bachelor of Engineering (B.Eng) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

.... 02/03/2012

Dr M. Y. Otache (MNIAE, MNAHS) Date

(Supervisor)

.... 02/03/2012

Engr. Dr P. A. Idah Date

(Head of Department)

.... 22-02-2012

External Examiner Date

DEDICATION

This project is dedicated to the Almighty God, and to the memory of my Great Dad, Late Mazi Josiah Maduka Oji who has left his imprints in my life forever.

ACKNOWLEDGEMENTS

Firstly, I want to acknowledge God Almighty for his mercy, kindness and provision throughout the course of this work and my stay in school.

My gratitude goes to Dr Martins Y. Otache who supervised and furnished me with information at every stage of this project work, and to the Head of Department, Engr. Dr. P. A. Idah for his immeasurable contribution and fatherly advice. I highly appreciate the contribution of my lecturers; Engr. Dr. I. E. Ahaneku, Engr. Dr. O. Chukwu, Engr. M. A. Sadeeq, Mal Isiaku, Mr John Jiya Musa, my loving level adviser Engr. (Mrs) Bosede Orhevba and the entire staff of Agricultural and Bioresources Engineering Department for their support and guidance. It has been great interacting with you all.

I cannot fail to acknowledge the contribution and support of my Mum, Mrs Joan I. Oji for being the best mother in the world, and Mr Chidi Nnorom for his immense support and guidance. My sisters Mrs. Chioma Oji-Nnorom, Mrs. Julie Oji-Osuji, Dr Mrs. Christy Oji-Mmuo, Engr Mrs. Lynda Oji-Ukomadu, Arc. Jane Oji, Barr. Joanne Oji, and Miss Betsy Oji, are all enjoined in my appreciation.

My sincere appreciation goes to my friends especially Obinna Molokwu, Tinuola Fasina, and to my classmates Opeyemi Kolade, Abduljelil and other people that contributed to the success of this project. Not forgetting my fellow project colleagues Emeka, Stephen, Gbenga, Adaora, and Kunle. Thanks for being a great team. God bless you all.

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.

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

2.0 REVIEW OF RELATED LITERATURE

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
BCL	Blood Cadmium Level
BFR	Brominated Flame Retardant
BLL	Blood Lead Level
CRT	Cathode Ray Tube
DNA	Deoxyribonucleic Acid
E-o-L	End-of-Life
E-waste	Electronic Waste
FAO	Food and Agricultural Organization
FEPA	Federal Environmental Protection Agency
MSW	Municipal Solid Waste
NWQS	Nigerian Drinking Water Quality Standard
PVC	Polyvinyl Chloride
TC	Toxicity Characterization
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization
WQS	Water Quality Standard

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

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 (Marion and Hornyak, 1984). 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 (Agimam, 2008).

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) (Osibanjo and Nnorom, 2008). 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. 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. 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. 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 (BAN, 2002). 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.

1.2 Statement of Problem

There has been a growing concern over the management practices for waste electrical and electronic equipment (WEEE) in the developing countries, where these potentially toxic materials are disposed of with municipal solid waste at open dumps and even into surface waters. The problem with inappropriate disposal of obsolete electronics is that they contain a significant amount of heavy metals which may leach upon disposal and therefore pose significant environmental hazards. Uncontrolled burning, disassembly and disposal of electronic waste causes a variety of environmental problems among which are surface and groundwater contamination, atmosphere pollution or even water pollution either by immediate discharge or due to surface runoff (especially near coastal areas). Also, among the problems of improper waste management is the fact that there is a seeming lack of measurable control efforts/strategy in place.

1.3 Objectives of the Study

The objectives of this study are:

1. To establish a basic 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.
2. To determine the level of trace metals in topsoil and well water in the electronic waste dumpsite and neighbouring residential houses.

1.4 Justification of the Study

E-waste has been termed the “silent killer” because very little is known about how hazardous it is. It is very common to hear people ask “What is electronic waste?” and this has led people to treat it the same way other waste is treated forgetting how hazardous it is. A lot of research has been done in the past to evaluate and characterize electronic waste as harmful but little has been done to evaluate its effect on groundwater quality. One of the principal sources of this contamination is lead, obsolete equipment dumped recklessly contain a lot of this metal. In Nigeria, the system of Municipal waste management is mostly the open dump system and the extent of groundwater pollution in open dump system is very bad as the leachate is directly absorbed into surface and groundwater. Thus, against the backdrop of the fact that groundwater contamination results from the leaching of toxic materials from these equipments, the study is designed to evaluate the processes adopted in the disposal of electronic waste vis -a-vis health and environmental degradation impacts.

1.5 Scope of the Study

The scope of this study is limited to the determination of probable toxic substances found in electronic waste, and the corresponding effect(s) of its leachate on soil and groundwater in the study location.

CHAPTER TWO

2.0. REVIEW OF RELATED LITERATURE

2.1 General Overview of Electronic Waste

The manufacture of electrical and electronic equipment is a major and fast growing industry. As a consequence, the waste stream of obsolete electrical and electronic products, commonly called "e-waste", is also vast and growing, with estimates of 20-50 million tonnes per year being generated world-wide (UNEP, 2005). Large quantities of waste computer monitors are presently being disposed in Nigeria. As much as 2.4 million units of 'used' computer monitors are imported annually into the country. Significant proportions of these imported devices are non-functioning and are never reused, but rather disposed of at open dumps (Nnorom, et al., 2009).

The recycling and disposal of e-waste poses significant problems, largely because many of the products contain numerous hazardous chemicals and materials (including heavy metals such as lead and cadmium, and organic compounds of chlorine and bromine) which can pose a threat to the environment and to human health. Impacts resulting from the recycling and disposal of e-waste have been reported in many countries, particularly in Asia (e.g., Brigden et al., 2005). Consumer electronic products are made of such valuable components like metals, glass, plastics and other materials which can be profitably refurbished and sometimes reused with little effort. However, if these materials are not properly managed when they are disposed, it will be throwing away resources, which will have environmental pollution implications as well as waste of resources. For example, cathode ray tubes, which are found in television receivers and in monitors, contain some hazardous materials such as lead, chromium and other toxic materials that if not properly disposed can end up being washed away by rains into rivers and dams thereby polluting drinking water (Nnorom et al., 2009).

Pollution of groundwater sources by leachate from landfills have been recognized for a long time (Alloway and Ayres, 1997). Clark (2006) described landfill practices as the disposal of solid wastes by infilling depressions on land. The depressions into which solid wastes are often dumped include valleys, abandoned sites of quarries, excavations, or sometimes a selected portion within the residential and commercial areas in many urban settlement where the capacity to collect, process, dispose of, or re-use solid waste in a cost-efficient, safe manner is often limited (Townsend, 2004) by available technological and managerial capacities. In most developing countries such as Nigeria, several tons of garbage are left uncollected on the streets each day, acting as a feeding ground for pests that spread disease, clogging drains and creating a myriad of related health and infrastructural problems.

2.2 Substances found in Electronic waste

Electronic waste usually contains harmful substances; some of these are as follows:

2.2.1 **Lead** - this is used in the construction of computers mainly for metal joining and radiation shielding. This element is highly hazardous if not properly disposed of or if its disposal in the landfill is not reduced because it is capable of causing damage to the central nervous system, blood system and kidneys in human beings. Its effects have also been found to have a serious negative impact on the children's brain development. If it is left to accumulate on the environment it will have highly toxic effects on plants, animals and microorganisms. (Huo et al., 2006).

2.2.2 **Cadmium** – this is used in small amounts in batteries and cathode ray tubes and also as a stabilizer but poses as a risk on human health that may be irreversible. Humans can take it from polluted drinking water and its substances will accumulate in the kidneys. It can be inhaled too and be taken in with food. This, in the end causes poisoning and its effects are direct.

2.2.3 **Mercury** – it is mostly used in batteries and printed circuit boards. If inorganic mercury is allowed to leak into drinking water, it changes into methylated mercury, which easily accumulates in living organisms and concentrates through the food chain; this causes chronic damage to the brain.

2.2.4 **Chromium** – this can penetrate through the cell membranes of a human being producing highly toxic effects in those cell membranes. The effects of this lead to allergic reactions such as asthmatic bronchitis and are also capable of causing DNA damages.

2.2.5 **Plastics** - it has been observed that of all the plastics that are largely used in computers, the largest volume causing more health hazards and environmental negative effects is polyvinyl chloride (PVC). Production and burning of PVC generates dioxins and furans. This plastic which is commonly used in household products is a major cause of dioxin formation in open burning and garbage incinerators.

2.2.6 **Brominated flame retardants** – These are products that are used in consumer electrical and electronic products in order to reduce flammability in these products. Substances of these retardants can cause neurotoxic effects in humans just like the toxic substances in printed circuit boards. It has also been found that these substances reduce the levels of thyroxin if exposed to animals and even enters the blood brain barrier in the developing foetus. Thyroid is a mostly important hormone to both humans and animals of all species since it regulates normal development of all these species. The substances can also increase the risks of cancer of digestive and lymph systems, stomach, pancreas and liver cancers.

2.2.7 **Arsenic** – Some of the electronic components such as relays, switches and circuit boards contain arsenic substances. Arsenic is also used as a doping agent in transistors. If these materials are not properly disposed of, they lead to arsenic effects resulting in minor skin damage as well as lung and lymphatic cancer.

Electronic waste substances are present in varying amounts. Table 2.1 gives an illustration of the classification in terms of the degree of presence.

Table2. 1: Degree of presence of electronic waste substances.

S/NO	SIGNIFICANT AMOUNTS	SMALL AMOUNTS	TRACE AMOUNTS
1.	Epoxy resins	Thallium	Americium
2.	Fibre glass	Cadmium	Antimony
3.	PCBs	Mercury	Barium
4.	PVC		Boron
5.	Tin		Cobalt
6.	Copper		Europium
7.	Silicon		Gallium
8.	Beryllium		Gold
9.	Carbon		Manganese
10.	Iron		

(UNEP, 2005)

2.3 Criteria for Classification of Electronic Waste as Hazardous Waste

According to Keith et al., (2008), a hazardous waste is waste that poses substantial threats to public health or the environment. Some of the characteristics that lead to electronic waste being classified as hazardous are:

Ignitability: This can be defined as the relative ease with which a material will ignite or burn. Since electronic waste is comprised of plastics and other materials that burn easily, it can be classified as ignitable and is therefore hazardous.

Reactivity: This is defined as the capability of an electronic waste to explode when exposed to heat or extreme pressure. It may also include reacting violently when exposed to incompatible substances. When e-waste is burned in open fires, the glass components may explode upon high pressures and cause harm to people in the vicinity.

Corrosivity: This can be defined as the ability to burn or destroy living tissues and materials by chemical reactions. A corrosive substance is one that will destroy or irreversibly damage another substance when it comes in contact. The main hazards to people include damage to the eyes, the skin, etc. Inhalation of corrosive substances may damage the respiratory and gastrointestinal tracts.

Toxicity: This can be defined as the ability to cause severe injury or death when inhaled, ingested or absorbed through the skin.

Table 2.2 shows some of these heavy metals along with their appropriate Toxicity Characterization (TC) concentrations. If the leachate concentration exceeds the TC concentration, the solid waste is classified as a Toxicity Characterization hazardous waste.

Table 2.2 Toxicity Characterization Acceptable Limits

S/No	Metal	Symbol	Tc Regulated Concentration
1.	Arsenic	As	5mg/l
2.	Barium	Ba	100mg/l
3.	Cadmium	Cd	1mg/l
4.	Chromium	Cr	5mg/l
5.	Lead	Pb	5mg/l
6.	Mercury	Hg	0.2mg/l
7.	Selenium	Se	1mg/l
8.	Silver	Ag	5mg/l

(Townsend, 2004.)

2.4 Water Quality Concept

Water quality refers to the suitability of water for human and ecological uses based on selected physical, chemical and biological characteristics. Some physical parameters such as temperature, pH, dissolved oxygen, electrical conductance, turbidity, etc., can be measured directly in a river or well. Analyses of specific chemicals that can be found in the water are done in a laboratory. The measured values of a water quality parameter change over time and depend on the characteristics of the water body such as its flow, nutrients, pollutant sources, etc.

Pure water means different things to different people. Home owners are primarily concerned with domestic water problems related to colour, odour, taste and safety to family health, as well as the cost of soap, detergents, “softening” or other treatments required for improving the water quality. Engineers working in industries are concerned with the purity of water as it relates to scale deposition and pipe corrosion. Also, Engineers concerned with rural water supply are concerned with the characteristics of the water and the relative safety of using the water for daily activities. On the other hand, Farmers are interested in the effects of irrigation waters on the chemical, physical and osmotic properties of soils, particularly as they influence crop production. Hence they are concerned with the water's total mineral content, proportion of sodium, etc. One means of establishing and assuming purity and safety of waters is to set a standard for various contaminants. A standard is a definite rule/principle or measurement which is established by governmental authority. The fact that it has been established by authority makes a standard official and legal. One of such standards is the Nigerian Standard for Drinking Water Quality. Table 2.3 shows the Nigerian drinking water quality standard acceptable limits for selected physical parameters.

Table 2.3 Nigerian Drinking Water Quality Standard acceptable Limits

S/NO	Physical Parameter	Nigeria Drinking Water Quality Standard
1.	pH	6.5 – 8.5
2.	Conductivity	1000 μS/cm
3.	Cadmium	0.003mg/l
4.	Chromium	0.05mg/l
5.	Nickel	0.01mg/l
6.	Lead	0.02mg/l
7.	Zinc	3mg/l

(Nigerian Industrial Standard, SON, 2007)

2.5 Soil Quality Concept

High levels of heavy metals in soil can be a health concern. They pose a potential human health concern when concentrations are at high levels in soils. Metals may be harmful to humans through ingestion of edible plants containing metals through normal uptake, ingestion of plants splashed with contaminated soil or by accidental direct ingestion of soil usually by children. Breathing dust coming from soil may also pose a health risk. Metals of concern are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), selenium (Se), and zinc (Zn). High levels of soil Pb can be present due to paint from older homes and gasoline emissions. Arsenic can be high in soil due to leaching from pressure treated lumber or use of arsenic-bearing pesticides. Soils can have elevated levels of metals due to industrial activity or land-application of bio-solids from wastewater treatment, and various by-products (animal/poultry wastes, fly-ash, etc.) that are land-applied due to their fertilizer value (nitrogen, phosphorus, and potassium).

2.6 Groundwater System

2.6.1 Groundwater Occurrence

Water is important to life, without it life cannot go on. Domenico (1972) said it all when he stated that human life as with animals and plant life on the planet is dependent on water. Because of the intimate relationship between water and life, water can be said to be woven into the fabric of all cultures, religious societies in myriad ways. Water on the earth can be said to be enormous in quantity when it is considered that more than two-thirds of the earth surface is covered by water (Abdulaziz, 2003). But UNEP and WHO (1996) argued that it is not sufficient merely to have access to water in adequate quantities, the water also needs to be of adequate quality to maintain health and it must be free from harmful biological and chemical contamination.

Groundwater occurs in many different geological formations. Nearly all rocks in the upper part of the Earth's crust, whatever their type, origin or age, possess opening called pores or voids. In unconsolidated granular materials, the voids are the spaces between the grains which may become reduced by compaction and cementation. In consolidated rocks, the only voids may be the fractures or fissures which are generally restricted by or be enlarged by solution. (Champam,1980).

2.7 Groundwater Contamination – Electronic Waste Interactions

Groundwater quality comprises the physical, chemical, and biological qualities of groundwater. Temperature, turbidity, colour, taste, and odour make up the list of physical water quality parameters. Since most ground water is colourless, odourless, and without specific taste, one is typically most concerned with its chemical and biological qualities. Although spring water or groundwater products are often sold as "pure," their quality is different from that of pure water. In a similar context, Dauda (1993) observed that as surface water becomes increasingly polluted, people turn to groundwater for alternative supplies. Naturally, groundwater contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer.

Groundwater pollution works differently from surface water pollution, although they have many sources in common, such as fertilizers, pesticides, and animal wastes. Several important concepts should be kept in mind:

(i.) Electronic waste when dumped on the soil, is exposed to rainfall and precipitation and when a storm occurs, the runoff from these wastes seeps into the soil and flows down towards the water table thereby contaminating the groundwater.

(ii.) A Leachate is any liquid that in passing through matter extracts solutes, suspended solids or any other component of the material through which it has passed thereby making it hazardous. In this regard, electronic waste leachate can be defined as leachate from waste disposal sites that extracts the toxic components of electronic waste and infiltrates into the soil, thereby contaminating it and the groundwater.

Physical, chemical and biological processes occurring simultaneously at the municipal solid waste dumpsites result in waste decomposition as well as generation of leachate and landfill gas. Chemically contaminated leachates are one of the by products in landfill degradation reactions (O'Learly and Walsh, 1995). One of the severe problems associated with the open dumps is infiltration of leachate into the surrounding environment, subsequent contamination of the land and water (Kumar et al., 2002). It is essential to protect ground and surface waters and soil from contamination due to leachate percolation in and around the dumpsites. Knowledge of leachate quality will be useful in planning and providing remedial measures such as proper liner systems and leachate treatment.

2.8. HAZARDS OF ELECTRONIC WASTE LEACHATE

2.8.1 Leachability of heavy metals from Electronic waste.

Heavy metals present in electronic components may leach upon disposal and therefore pose significant environmental hazards. The potential leaching of Lead, Cadmium, Chromium and Silver from Computer cathode ray tubes, printed circuit boards (PCBs), PC mice, TV remote controls, and mobile phones were assessed by Keith et al., (2008). Electrical components were obtained from a local electronics waste collection centre for analysis. Brands of e-waste included MDNHA, NCR, Samsung and Toshiba and the following components were studied: cathode ray tube (CRT) glass–front of monitor (face plate), CRT glass–back of monitor (funnel), computer printed circuit boards (PCBs), PC mice, TV remote controls; and mobile telephones. The Samples were prepared by manually deconstructing the electronics devices and subsequently cutting with heavy-duty hand shears and/or crushing with a mortar and pestle. All particles were passed through a 9.5mm-mesh sieve. Four replicates of each component were analyzed.

After controlled crushing, each component was extracted using the Toxicity Characteristic Leaching Procedure (TCLP), EPA Method 1312 (SPLP), NEN 7371 (Dutch Environmental Agency), and DIN S4 (Germany). The TCLP consistently leached the greatest amounts of Lead from all components. The SPLP, NEN 7371 and DIN S4 extracted relatively small amounts of metals compared with the TCLP and were not considered effective as leaching tests for e-waste. The smallest size fraction (<2 mm) of CRT glass and PCBs leached significantly ($p < 0.05$) highest Lead via the TCLP. A modified TCLP removed 50.9% more

extractable Lead compared with the conventional procedure.

At the end of the study, it was concluded that among the heavy metals tested, Lead was the predominant metal associated with toxicity of e-waste components. CRT funnels leached Lead at 70 times over the U.S. EPA limit, circuit boards leached Lead at approx. 35 times over regulatory levels, mobile phones leached 16 times above the limit, TV remotes were 9 times higher, and PC mice were approximately 3 times higher than the regulatory limit for Lead; therefore, all the e-waste components tested in this study were determined to be characteristic hazardous wastes based on TCLP data for Lead. Although Cadmium, Chromium and Silver occur in measurable amounts in many of the components tested, they were minimally leachable under the TCLP and do not pose toxicity hazards. (Keith et al., 2008)

2.8.2 Open Dumps

Open dump sites used to be the norm for disposal in the developed countries. These were often nothing more than valleys or quarries or mines whose owners decided to allow people to dump trash. Along with solid wastes, into these open dumps went all kinds of household and commercial hazardous wastes and industrial materials. The open dump is a hazard because of its potential for producing leachate, becoming a rodent and insect breeding ground, and its general health dangers. Nnorom et al., (2010), in their study, evaluated heavy metal release from the disposal of waste computer monitors at an open dump. The study simulated the breaking of cathode ray tubes at open dumps and assessed the total available metals in the cathode ray tube glass; the printed wiring board and plastic components as well as the ability of rainwater to leach and mobilize the metals through batch extraction using weak electrolytes ($CaCl_2$, $Ca(NO_3)_2$, and H_2O). The extractable Lead from the cathode ray tubes and printed wiring board failed to pass the established limit for leaching tests such as the toxicity characteristic leaching procedure limits used in toxicity characterization of solid waste (5mg/l). The results of the study revealed the dangers of inappropriate management of computer monitors, especially the disposal at open dumps or with municipal solid waste and provided valuable information on the leachability/mobilization of heavy metals especially Lead from broken computer monitors at waste disposal points. Of much concern was the observation that de-ionized water extracted as much as 10% of the lead content of the CRT glass indicating the extent storm runoff could mobilize toxins from inappropriately disposed CRTs. (Nnorom et al, 2010)

2.8.3 Biological and Health Related Implications

The blood lead and cadmium levels and relevant factors among children from an e-waste recycling town in china was studied by Zheng et al., in 2007. Primitive electronic waste (e-waste) recycling is ongoing in Guiyu, china. The soaring levels of lead had been found in samples of dust, soil, river sediment, surface water, and groundwater because of primitive e-waste recycling during the last 10 years (Brigden et al., 2005). Some related factors may contribute to the elevation of blood lead levels (BLLs) or blood cadmium levels (BCLs).

Two hundred and seventy-eight children less than 8 years who lived in Guiyu and Chendian were observed, and their Blood Lead Levels and BCLs were determined by graphite atomizer absorption spectrophotometer. Questionnaire survey for risk factors was also performed and data were analyzed using spearman correlation analyses and logistic regression analyses.

From the results obtained after the study, it was observed that Children living in Guiyu had significantly higher BLLs and BCLs as compared with those living in Chendian (po0.01). In Guiyu, 70.8% of children (109/154) had BLLs410 mg/dL, and 20.1% of children (31/154) had BCLs42 mg/L, compared with 38.7% of children (48/124) had BLLs410 mg/dL and 7.3% of children (9/124) had BCLs42 mg/L in Chendian (po0.01, respectively). It was also observed that a significant increasing trend in BLLs with increasing age in Guiyu (po0.01). Mean height of children in Guiyu was significantly lower than that in Chendian (po0.01). The risk factors related to children's BLLs and BCLs mainly included father's engagement in the work related to e-waste, children's residence in Guiyu and the amount of time that children played outside near the road daily. It was thus concluded that, there are close relationships between the BLLs, BCLs in children and the primitive e-waste recycling activities in Guiyu. Environmental pollution, especially lead pollution, has threatened the health of children living around e-waste recycling site. Parents' behaviours, educational levels, incomes, and habits also could influence the BLLs of children. Soaring levels of lead also were found in water courses of Guiyu (Wong et al., 2007). Under this situation, children could intake lead contaminants from air, water, and food with more outdoor activities, especially the older children. Therefore, the higher BLLs and BCLs, especially the elevated BLLs in Guiyu children are found in this study. The higher lead and cadmium levels may be due to environmental contamination, which is related to the primitive e-waste recycling activities in the local region. It is necessary to pay more attention to the health effects of primitive e-waste recycling. Policies that help reduce environmental lead and cadmium exposure should be made, and health education and reasonable nutrition should be provided to local families. (Liangkai Zheng et al., 2007)

2.9 Global Management Strategy in Perspective

Globally, various programmes are being developed for the sound management of electronic waste. These programmes vary from country to country and may include leasing programs, warranty programs, and explicit take back agreements (Nnorom et al., 2010). Options adopted in the return WEEE in general in some countries for effective management include, one-day drop-off opportunities, point of purchase collection and curb side collection, among others. In Australia for example, WEEE still ends up in landfills even though some sort of recovery for some electronic components like cathode ray tubes is present in the country. Due to the limitations of active WEEE recycling and take-back programs activities in Australia, most of the WEEE ends up being disposed of into the landfills.

In some Asian countries, however, the existing management strategy is grossly inadequate. Literature indicates that majority of e-waste in China is processed in backyards or small workshops using manual disassembly, crude recycling techniques and open burning (Nnorom, et al., 2009). The waste electronic devices are stripped of their most valuable and easily extractable components. These are then processed to directly reusable components and secondary raw materials in a variety of refining and conditioning processes (Liu et al., 2006). In India, Electronic waste is managed through various low-end management alternatives such as reuse, open burning, backyard recycling and disposal in open dumps. The re-gunned CRTs are used in the production of unbranded (or locally branded) PC monitors and TVs. The other recovered components resulting from the dismantling process such as integrated circuits (ICs), and capacitors are re-used in the production of unbranded monitors and televisions. The study of Greenpeace International at the sites used in the storage of e-waste in India revealed high levels of contamination of soils and dust (Greenpeace, 2005b). In countries like Japan and Korea, about 53% of the collected WEEE is being recycled in Korea (Liu et al., 2006). The rest are either exported or land filled.

In Europe, it varies from country to country. In Germany, prior to the implementation of the WEEE Directive, electrical equipment was chiefly dismantled and recycled by workshops providing employment for handicapped or challenged persons. These workshops were granted subsidies by society. However, the strict stipulations of the WEEE Directive have forced manufacturers to build up efficient and cost-optimized reverse logistics and recycling systems (Schmidt, 2005). In Spain, WEEE is collected with municipal waste in approximately 600 collection points, which are neither adequate nor evenly spread over the country. In some cases, only the metal components are recycled and the other components discarded in dumpsites. This indicates that available recycling infrastructure is grossly inadequate (Queiruga et al., 2008). Consequently, some discarded products may still be going to landfills and dumpsites in Spain (Queiruga et al., 2008).

There is presently formal recycling of waste electronic waste in the US. However, available infrastructure appears to be grossly inadequate considering the e-waste generation rate in the country. The recycling rates for TVs in the US vary from 0.7% to 0.11%. Only about 1000 units of the estimated 1.3 million TVs that became obsolete in Florida in 1999 were recycled. Similarly, the recycling rate for computer monitors varies from 9.4% to 15.7%; and only about 88,000 units of the 941,000 monitors that became obsolete were recycled (Price, 1999). Consequently, large quantities of waste TVs and monitors are stored, land filled, incinerated or exported. With increasing bans on landfilling, the viable options narrow down to storage and export.

In most developing countries, electronic waste is disposed at open dumps and into surface water bodies, often used for domestic purposes. When disposed of through these routes, there is a potential for toxic substances to leach into soil and eventually contaminate surface/groundwater. An estimated 400,000 units of second hand desktop computers (PCs or CRTs) are imported into Nigeria every month (Nnorom and Osibanjo, 2008; BAN, 2005). Plate 2.1 is a picture of workers at the Alaba electronics market in Lagos unloading a container filled with used television sets and computer monitors. Imported used electronic goods also include cast off cell phones.

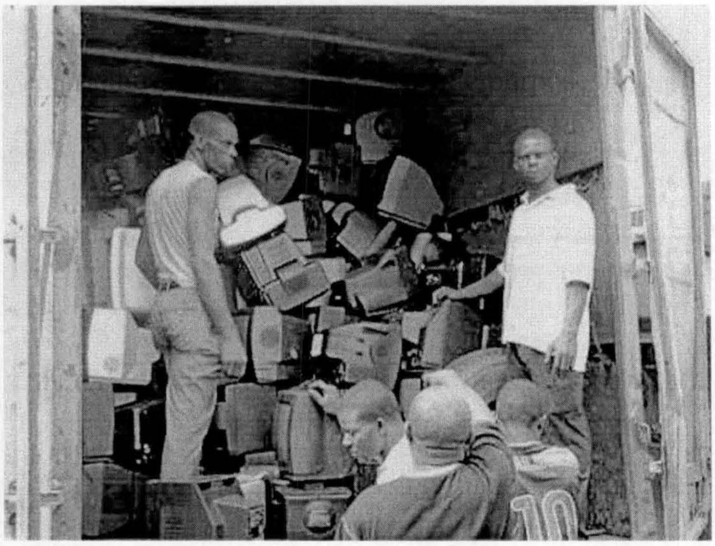

Plate 2.1 Workers unloading a container of second hand electronics at Alaba Market, Lagos.

Without basic waste management infrastructure, these imported second hand devices end up in the open dumps which are almost the available option for solid waste disposal, even in the capital cities. Sanitary landfill, however, is rare and unpopular, except perhaps among few institutions and few affluent people. Financial and institutional constraints are the immediate identifiable reasons for this in Nigeria and some other developing countries, especially where local governments are weak or underfinanced and rapid population growth continues (Elaigwu et al., 2007). Other reasons include the issue of inappropriate guidelines for siting, design and operation of new landfills as well as missing recommendations for possible upgrading options of existing open dumps (Zurbrugg et al., 2003). Often, the available guidelines for landfills available are those from high-income countries, and they are based on technological standards and practices suited to the conditions and regulations of the source countries, they often do not take into account the different technical, economical, social and institutional aspects of developing countries. In another case, many of the municipal officials think that uncontrolled waste disposal is the best that is possible (Zurbrugg et al., 2003).

2.10 Issues and Probable Future Impact Mitigation Framework.

Some of the material effects and substantial risks from WEEE when released into the environment have been pointed out in the preceding sections. It must be noted however that these materials can weigh differently from one product to the other and the effects on health and the environment will also vary depending on the quantities used. The high rate of accumulation on the environment can also lead to highly significant negative impacts, posing a serious health risk on the community and the environment.

It is possible however to convert these materials from the disposals into the landfills by either reuse or recycling. The recycling of WEEE is not yet fully economical but the few recycling activities that already exist have generated capital investments and created employment for the community.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 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 in the wet season (March-September) and dry in the dry season (October-March). Recycling of e-waste in Alaba International Market has taken place for years with several tones of computer waste handled each year (LASEPA, 2007). Amid these activities, buying and selling go on in the market at regular frequency even though there are residential houses in the immediate surroundings. The plate 3.1 below paints a vivid picture of the situation; it shows a dumpsite in the area under discourse.

Plate 3.1 Electronic waste dumpsite in Alaba, Lagos State

Similarly, figure 3.1 and 3.2 show 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.

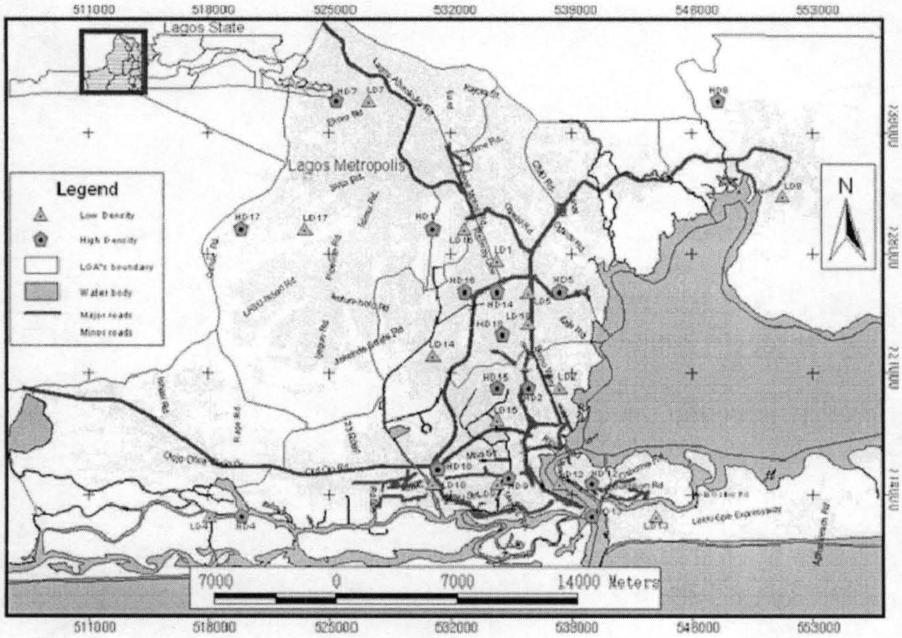

Fig 3.1 Map of Lagos state showing the various local government areas.

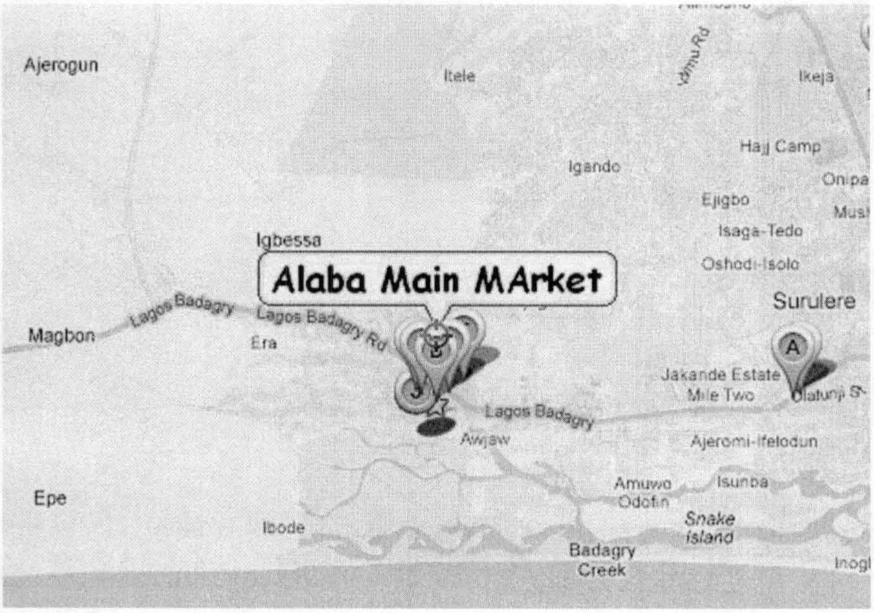

Fig 3.2 Map of Lagos State showing the study location.

3.1.2 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. Using this about 4L of the water was collected in a large plastic bowl. 2L of the water was then taken from the bulk 4L sample and stored in plastic water bottles for laboratory analysis. Also, 5 different soil samples were collected at different points around the dumpsite so as to study the extent of heavy metal concentration in the soil. The soil samples were collected using a plastic parker at different depths which ranged from 10 to 30cm. They were appropriately labelled and stored in plastic bags. The choice of the sample collection points considered the location, accessibility and proximity to the dumpsite.

3.2 Methods of Analysis

3.2.1 Analysis of the Water Samples For Heavy Metals

The trace metals analyzed for were Cadmium, Chromium, Nickel, Lead, and Zinc.

Apparatus: Atomic absorption spectrophotometer (AAS), 100ml volumetric flask, 1ml and 10ml pipettes, wash bottle, beakers were used.

Reagents: 100ppm lead salt standard solution, 100ppm cadmium salt solution, 100ppm chromium salt solution, 100ppm nickel salt solution, 100ppm zinc salt solution, distilled de-ionized water were similarly applied for the tests.

Procedure: Serial dilution of 1ppm, 2ppm, 3ppm and 5ppm of the various salt solutions were prepared in the 100ml volumetric flasks. The flasks were tagged according to the different concentrations to be prepared. Depending on the concentration of the specific metal salt required, the corresponding millimetre (ml) was measured and poured into the corresponding tagged volumetric flask. The serial dilutions were used to standardize the AAS for the corresponding metal analysis. The AAS was set at a particular wavelength for the specific metal to be analyzed before standardizing. These wavelengths are Chromium (Cr): 540nm, Cadmium (Cd): 532nm, Nickel (Ni): 560nm, Lead (Pb): 515nm and Zinc (Zn): 620nm. The values displayed on the screen was taken and used to plot a graph. The slope of the graph was taken and inverted and this inverse was taken as a constant value. The constant was used to multiply the value of the sample metal absorbency obtained. The result thus obtained was taken as the metal concentration for the particular sample.

3.2.1.1 pH Determination

Apparatus: pH meter

Procedure: pH meter and associated electrode were standardized against reference buffer solution of pH 6 to 8.5 (buffer 7) and the temperature of the water was compensated for. The electrodes were then rinsed with distilled water and carefully dried using a magnetic stirrer. The electrodes were placed in the sample. The galvanometer reading was then recorded.

3.2.1.2 Determination of Electrical Conductivity

Apparatus: Conductivity meter

Procedure: The conductivity meter was washed with distilled water and then rinsed several times with the sample. The sample was taken into a small beaker and stirred using the magnetic stirrer. The conductivity cell electrode was then inserted into the sample. The meter deflection was taken and recorded. The value of the meter reading was multiplied by the number indicated on the bottom pressed and the cell constant.

Calculation: Conductivity (µs/cm) = (meter deflection) × (bottom constant) × (cell constant)

3.2.2 Analysis of the soil samples

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 USEPA (1996). 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, its contents, 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 as follows:

Pb: 1, 2 and 5 ppm.

Cd: 0.5, 1 and 2ppm.

Cr: 1, 2 and 5ppm.

Ni: 1, 2 and 5 ppm.

Zn: 1,2 and 5ppm

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

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 4.1 to 4.5. The implications of these results are equally discussed.

4.1 Presentation of Results

TABLE 4.1: 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 4.2: Results of water samples as compared with WHO Water Quality Standard (2004) and the Nigerian water quality standard

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

Table 4.3: Laboratory result for analysis of other physical parameters

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

TABLE 4.4: Results for laboratory analysis of heavy metals in the soil samples (mg/kg)

Metal	Sample A	Sample B	Sample C	Sample D	Sample 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 4.5: Results of soil samples as compared with FAO typical soil metal levels in (mg/kg)

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

4.2 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.

4.2.1 Heavy Metal Content of Groundwater Samples

The World Health Organization (1993, 1996, 2004) 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 analysed 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 4.1). 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 (Popoola et al., 2009). 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.

4.2.2 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 NIS (Table 4.3). 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 NIS and may need to be checked to prevent further increase.

4.2.3 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. According to Jackson (1989), the wetter, a landfill or dumpsite is, the greater the seepage runoff and chemical enrichment of the groundwater resource. High conductivity will in most cases affect the taste of water. (Langenegger, 1990).

4.2.4 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 745mg/kg and this exceeded the FAO limit of 10 to 70mg/kg for typical soils. 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.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 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. Thus, the objectives of this study were achieved as the results of the study were able to 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 and it was determined that the heavy metal content of the soil within and around the dumpsite exceeded 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 Organisation (WHO) and the Food and Agricultural Organisation (FAO), they may exceed these limits if remedial measures are not put in place.

5.2 Recommendations

From the results of the study it is evident that electronic waste is hazardous and as such should not be treated as other household waste. Options in the sound management of electronic waste include reuse, remanufacturing, feedstock recycling and landfilling. To curb excess dumping, the Government can look into the importation of second-hand electronic equipment as it has been noticed that exportation of obsolete electronics is a means of disposal of electronic waste for the developed countries. Nigeria should cease to be a dumping ground for electronic waste. To this end, research should be carried out to determine the effects of the electronic waste on surface water such as streams and ponds in the area as communities use these sources of water for domestic and recreational purposes. Beside research, the populace should be enlightened on the implications of these electronic wastes.

REFERENCES

Abdulaziz, M. (2003). Spatial variation in water quality in Nguru Urban. Unpublished MSc Project. University of Maiduguri, Nigeria.

Agimam, E. (2008) E-waste remains a challenge to the regulatory agencies Vanguard Newspaper Tuesday 8th April 2008.

Alloway, B. J., Ayres, D. C. (1997). Chemical principles of environmental pollution, In: Wastes and their disposal, 2nd ed., Blackie Acad. Professional, Lond., UK pp. 353-357.

BAN. (2002).The digital dump: exporting re-use and abuse to Africa. Basel Action Network. Jim Puckett (Editor). *www.ban.org.*

Brigden, K., Labunska, I., Santillo, D., Allsopp, M., (2005). Recycling of electronic wastes in China and India: workplace and environmental contamination. Available from: */http://www.greenpeace.org/india/press/reports/recycling- of-electronic-wastes.*

Champam, D. (1980). Water Quality Assessment, published by Champam and Hall Ltd, London p. 371

Clark, J. (2006). Rivers and their catchments: impact of landfill on water quality, Earth Sci. Branch, Scottish Natural Heritage p. 2.

Dauda, A. M. (1993): A Comprehensive approach in water resources management for the 21st century, *Environmental Bullets vol.12. Nigeria.*

Domenico, P. A. (1972): Concept and models in groundwater hydrology. New York. McGraw hill p. 186

Elaigwu, S. E., Ajibola, V. O., Folaranmi, F. M. (2007). Studies on the impact of municipal waste dumps on surrounding soil and air quality of two cities in Northern Nigeria, J. Appl. Sci. 7(3): 421-425.

Federal Environmental Protection Agency (FEPA) (1991). Water Quality, Federal Water Standards, Guidelines and Standard for Environmental Pollution Control in Nigeria, National Environmental Standards – Part 2 and 3, Government Press, Lagos p. 238.

Greenpeace Report. Greenpeace International; August (2005).

Huo, X., Peng, L., Xu, X., Zheng, L., Qiu, B., Qi, Z., Zhang, B., Han, D. & Piao, Z. (2007) Elevated Blood Lead Levels of Children in Guiyu, an Electronic Waste Recycling Town in China. Environmental Health Perspectives 115 (7):113-117.

Keith, Ashley, Keesling, Kara , Fitzwater, Kendra K. , Pichtel, John and Houy, Denise (2008) 'Assessment of Pb, Cd, Cr and Ag leaching from electronics waste using four extraction methods', *Journal of Environmental Science and Health, Part A,* 43: 14, 1717 — 172

Kumar, D., Khare, M. and Alappat, B. J.,(2002). 'Threat to ground water from the municipal landfills in Delhi', India. Proceedings 28th WEDC conference on sustainable environmental sanitation and water services, Kolkata, India. pp.377-380

Langeneggar, O., (1990). Groundwater quality in rural areas of western African UNDP project 81(26): 10.

LASEPA (2007). E-waste seminar organized by the Lagos state environmental protection agency titled "electronic waste and its effects on the environment" 7th and 8th Nov.

Liangkai , Z., Kusheng, Wu, Yan, Li (2007). Blood lead and cadmium levels and relevant factors among children from an e-waste recycling town Environmental Research 108.15–20

Liu, X., Tanaka, M., Matsui, Y. (2006). Electrical and electronic waste management in China: progress and the barriers to overcome. Waste Manage Res; 24:92–101.

Marion, B. and W. F. Hornyak (1984) principles of physics, CBS, College Publishing Japan, 772pp

Nigerian Industrial Standard (2007). *Nigerian standard for drinking water quality. NIS 554pp* 13 - 15

Nnorom, I., and Osibanjo, O. (2008). "Overview of electronic waste e-waste management practices and legislations, and their poor applications in the developing countries". Resources Conservation and Recycling pp. 843-858.

Nnorom, I., Osibanjo, O., Kanno Okechukwu, Onwughara Nkwachukwu and Chukwuma, R. (2010) Evaluation of Heavy Metal Release from the Disposal of Waste Computer Monitors at an Open Dump *International Journal of Environmental Science and Development,* Vol. 1, No. 3,

Osibanjo O. Nnorom I. C, (2008)Electronic waste e-waste: material flows and management practices in Nigeria. Waste Management; 28:1472–9.

O'Leary, P. and Walsh, P., (1995). 'Decision maker's guide to solid waste management', Vol. II. Solid and Hazardous waste Education Center, University of Wisconsin.

Oyeku, O. T. (2007). Dispersion of some chemical constituents of seepage from a refuse dumpsite into the surrounding groundwater in Ojota, Lagos State: A GIS perspective, Unpublished Project Report, ARCSSTE-E, Nigeria p. 121.

Price J. L. (1999). "Reclaiming end-of-life cathode ray tubes (CRTs), and electronics: A Florida update". Hazardous materials Management Conference, Tucson, Arizona.

Queiruga, D., Walther, G., Gonzalez-Benito. J., Spengler, T. (2008). Evaluation of sites for the location of WEEE recycling plants in Spain. Waste Management; 28: 181–90.

Schmidt, C.W., (2002). *e-Junk Explosion, Environ Health Perspect, Vol. 110(4), pp. A188-94.*

Townsend, T.G., Musson, S., Y-C. Jang, and I.H. Chung. (2004). "Characterization of lead leachability from cathode ray tubes using the toxicity characteristic leaching procedure". Report No. 99-5. Florida, Gainesville, Fla. *http://www.floridacenter.org/Publications/lead_leachability_99-.pdf*

UNEP and WHO (1996): Water quality Monitoring. An imprint of Chapman and Hall, London.

UNEP (2005) "E-waste: the hidden side of IT equipment's manufacturing and use". Early Warnings on Emerging Environmental Threats No. 5, United Nations Environment Programme.

United States Environmental Protection Agency (USEPA) (1998) Approach for addressing dioxin in soil at CERCLA and RCRA Sites. Washington, DC. OSWER Directive 9200.4-26

Wong, C. S., Wu, S. C., Duzgoren-Aydin, N. S., Aydin, A., Wong, M. H., (2007). Trace metal contamination of sediments in an e-waste processing village in China. Environ. Pollut. 145, 434–442.

World Health Organisation (1998). World Health Organisation's Guidelines for Drinking water, Vol. 1, Geneva.

waste management, (2009). In: City Management and Services, USAID. *w.makingcitieswork.org*

, SANDEC, EAWAG (2003) Solid Waste Management in Developing Countries, roductory text on www.sanicon.net p. 5.