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OVERVIEW OF ELECTRONIC WASTES AND THEIR IMPLICATIONS ON HEALTH AND ENVIRONMENT

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ABSTRACT: Electronics technology has gained much relevance in our world due to its role and effectiveness in solving complex problems. However, such equipment after a period of active service age out, begin to malfunction and may breakdown. As a result, they are abandoned in offices, homes, institutions and sometimes treated as waste. Obsolete electronic equipment and computers are known as electronic wastes (e waste). These e-wastes constitute unnoticed hazards to people and their environment. This paper provides an overview of e-waste, identifies its compositions and the negative effects of such composite elements on the environment, their health implications, and appropriate methods of disposal. It was discovered that lead, mercury, arsenic, cadmium, selenium, hexavalent chromium and brominated flame retardants constitute the most dangerous constituents of electronic products. If not disposed properly pose serious threats to life and environment. Among the treatment and disposal methods are incineration, acid bath, landfilling and recycling. Recommendations are provided which if implemented will rescue our environment from degradation and also preserve human health.

INTRODUCTION

Electronic waste refers to electronic products which have become obsolete and are ready for disposal. E-waste is harmful if untreated and discarded improperly as it contains many toxic components such as lead, cadmium, mercury, polychlorinated biphenyls etc, but at the same time could be a valuable source of secondary raw material if properly treated (Bandyopadhyay, 2010).

A greater percentage of e-waste is generated by developed countries as they have advanced so much in Information Technology and electronics Industries. These industries are the fastest growing manufacturing industries in the world and consequent upon the accelerated growth, coupled with rapid electronic product obsolescence, discarded electronic products is now the fastest growing solid wastes in the world (Kaya and Sözeri (2007); Benebo (2009)). There is a persistent problem of e-waste accumulation in Nigeria because derisory national legislation about importation of used electronic and electrical equipments, relaxed and insufficient enforcement of existing related laws, lack of awareness on the dangers of e-wastes, poor social responsibility by the industries, and lack of adequate infrastructure for dealing with e-wastes, among other factors (Fagbohun, 2011).

E-wastes contain different toxic substances such as Pb, Be, Hg, Cd, Cr and Brominated Flame Retardants (BFRs), which subsequently leads to occupational/environmental health hazards. These substances also create serious pollution problems during land filling and burning. For example, Cathode Ray Tubes (CRTs) in computer monitors, video display devices, and TV sets contain significant concentrations of Pb and heavy metals. According to Kaya and Sözeri (2007), each computer set display contains 2-4 kg of Pb, which protects consumers from X-ray radiation. Consumer electronics already constitute 40% of Pb and about 70% of the heavy

metals (Hg and Cd) found in landfills. These heavy metals found in electronic equipment can contaminate underground water, pollute the air and cause other serious environmental problems as the obsolete equipment are traditionally dumped in landfills or burnt openly.

Some substances used in manufacturing computers are listed in Table 1 (Puckett, *et. al.* 2002).

Table 1: Composition of a Personal Desktop Computer weighing ~70lbs

Name	Content (% of total weight)	Recycling Efficiency	Weight of Material (lbs.)	Use/Location
Plastics	22.9907	20%	13.8	Includes organics, oxides other than silica
Lead	6.2988	5%	3.8	Metal joining, radiation shield/CRT,PWB
Aluminum	14.1723	80%	8.5	Structural, conductivity/housing, CRT, PWB, connectors
Germanium	0.0016	0%	<0.1	Semiconductor/PWB
Gallium	0.0013	0%	<0.1	Semiconductor/PWB
Iron	20.4712	80%	12.3	Structural, magnetivity/(steel) housing, CRT, PWB
Tin	1.0078	70%	0.6	Metal joining/PWB, CRT
Copper	6.9287	90%	4.2	Conductivity/CRT, PWB, connectors
Barium	0.0315	0%	<0.1	Vacuum tube/CRT
Nickel	0.8503	80%	0.51	Structural, magnetivity/(steel) housing, CRT, PWB
Zinc	2.2046	60%	1.32	Battery, phosphor emitter/PWB, CRT
Tantalum	0.0157	0%	<0.1	Capacitors/PWB, power supply
Indium	0.0016	60%	<0.1	Transistor, rectifiers/PWB
Vanadium	0.0002	0%	<0.1	Red phosphor emitter/CRT
Terbium	< 0	0%	<0	Green phosphor activator, dopant/CRT, PWB
Beryllium	0.0157	0%	<0.1	Thermal conductivity/PWB, connectors
Gold	0.0016	99%	<0.1	Connectivity, conductivity/PWB, connectors
Europium	0.0002	0%	<0.1	Phosphor activator/PWB
Titanium	0.0157	0%	<0.1	Pigment, alloying agent/(aluminum) housing
Ruthenium	0.0016	80%	<0.1	Resistive circuit/PWB
Cobalt	0.0157	85%	<0.1	Structural, magnetivity/(steel) housing, CRT, PWB
Palladium	0.0003	95%	<0.1	Connectivity, conductivity/PWB, connectors
Manganese	0.0315	0%	<0.1	Structural, magnetivity/(steel) housing, CRT, PWB
Silver	0.0189	98%	<0.1	Conductivity/PWB, connectors
Antinomy	0.0094	0%	<0.1	Diodes/housing, PWB, CRT
Bismuth	0.0063	0%	<0.1	Wetting agent in thick film/PWB
Chromium	0.0063	0%	<0.1	Decorative, hardener/(steel) housing
Cadmium	0.0094	0%	<0.1	Battery, blue-green phosphor emitter/housing, PWB, CRT
Selenium	0.0016	70%	.00096	Rectifiers/PWB
Niobium	0.0002	0%	<0.1	Welding alloy/housing
Yttrium	0.0002	0%	<0.1	Red phosphor emitter/CRT
Rhodium	< 0	50%	<0.	Thick film conductor/PWB
Platinum	< 0	95%	<0.1	Thick film conductor/PWB
Mercury	0.0022	0%	<0.1	Batteries, switches/housing, PWB
Arsenic	0.0013	0%	<0.1	Doping agents in transistors/PWB
Silica	24.8803	0%	15	Glass, solid state devices/CRT, PWB

Sources of E-Wastes

The major sources of e-wastes include the following:

a. Original equipment manufacturers.
b. Individuals.
c. Small businesses.
d. Government.
e. Institutions.
f. Large organizations.
g. Cell phones.
h. Illegal importation.
i. Second-hand electronics.

The constituents of e waste are given in Table 3.

Table 3: Hazardous Constituents in E-wastes

Constituents	Possible hazardous contents
Cooling	Ozone Depleting Substances (ODS)
Plastic	Phthalate plasticizer, brominated flame retardants (BFR)
Insulation	Insulation ODS in foam, asbestos, refractory ceramic fiber
Cathode Ray Tube	Lead, Antimony, Mercury, Phosphor
Liquid Crystal Display	Mercury
Rubber	Phthalate plasticizer, BFR
Wiring / electrical	Phthalate plasticizer, BFR, Lead
Circuit Board	Lead, Beryllium, Antimony, BFR
Fluorescent lamp	Mercury, Phosphorous, Flame retardants
Thermostat	Mercury
BFR-containing plastic	BFRs
Batteries	Lead, Lithium, Cadmium, Mercury
CFC,HCFC,HFC,HC	ODS
External electric cables	BFRs, plasticizers
Electrolyte capacitors	Glycol, other unknown substances

Nigeria's Involvement in E-Waste Reduction

Nigeria has been theoretically involved in the concerted efforts to control the menace of e-waste in the country in particular and in the world at large. The country is a recipient of the obsolete electronic equipment in the form of gifts, donations, bridging the digital divide, technology-enhancement support, educational/scientific assistance and so on from the technological advanced countries. For instance, Nigeria had been receiving about 500 container-loads of e-waste into the country through the Lagos ports every month and about 2% of these materials are fully functional and can be directly re-used, about 5% can be put to use with minimum repairs, another 15-20% can have their components used for local repairs, while the rest are unusable and end up as junks (Benebo, 2009).

The major exporters to Nigeria, according to Benebo (2009), are given in Table 4.

Table 4: A List of E-Waste Exporting Countries to Nigeria

Country	Volume of Export
European Union	45%
United States of America	45%
Japan, Korea, Malaysia, Singapore, etc	10%

E-WASTE SCENES

The following snapshots depict the state of electronic wastes in the country. Note again that the craving for second-hand electrical/electronic equipments as shown in this section helps to reduce the volume of the waste in the originating country and increase it in the receiving country like Nigeria.

Fig. 1: Used computers delivered in Nigeria from developed countries

Fig. 2: Warehouse for used electrical/ the electronic equipment

Fig. 3: A typical e-waste dumpsite

Fig. 4: Open burning at a dumpsite

Efforts toward E-Waste Control in Nigeria

Concerted efforts had been made by Nigeria to exercise control over e-wastes through the following initiatives:

- A party to the Basel Convention on the trans-boundary movement of hazardous wastes;
- Establishment of the National Environmental Standards and Regulations Enforcement Agency (NESREA) by an Act in July 2007 to enforce all environmental laws, regulations and guidelines including monitoring and control of e-waste;
- Establishment of a multi-stakeholder Consultative Committee on e-waste to prepare national policy on e-waste, national guidelines on e-waste management, and national action plan for the management of e-waste
- Hosting of the regional coordinating and training centre for Basel Convention in Africa
- Development of specific Regulations on e-waste control
- Collaboration with other African countries and some international organizations in bringing to international focus the problems of e-waste

Health and Environmental Impacts of Substances In e-waste

E-waste contains substances such as lead and cadmium in circuit boards; lead oxide and cadmium in monitor cathode ray tubes (CRTs); mercury in switches and flat screen monitors; cadmium in computer batteries; polychlorinated biphenyls (PCBs) in older capacitors and transformers; and brominated flame retardants on printed circuit boards, plastic casings, cables and polyvinyl chloride (PVC) cable insulation that release highly toxic dioxins and furans when burned to retrieve copper from the wires as it is widely practiced. The effects of various elements of e-waste have been established and are listed as follows (Puckett *et. al.*, 2002; Kaya, 2007).

E-Waste Treatment/Disposal Methods

Several methods for disposal of electronic wastes have been in operation although none of them is without its accompanying weakness. They are incineration, landfilling, acid bath (neutralisation), and recycling.

a. **Incineration**: This is the process of burning waste in a confined and controlled environment usually referred to as incinerators. Such waste materials are subjected to high temperatures ranging between 800-1000 degrees Celsius. As such, the emission of hazardous toxins are minimized but not eliminated. Incineration is one of the approaches used in waste volume reduction and energy is created during the process of incinerating combustible materials (ENVIS Newsletter, 2008).

b. **Land-filling**: Although not an effective means of disposal, it is one of the widely used methods of e-waste disposal. Landfills are trenches created through soil excavation for the purpose of e-waste disposal. Landfills are usually covered with thick layer of soil once its holding capacity is exhausted. Modern state-of-the-art- landfills use impermeable base liner such as clay and plastic. These base liners possess gutters that channels leachate to adequate treatment plants (E-waste, 2012; ENVIS Newsletter, 2008).

c. **Acid bath (Neutralisation)**: In acid bath technique, hazardous materials are neutralised using corresponding acid or base solutions. This is usually achieved by adjusting the pH of the hazardous material thereby limiting its leaching capability before being disposed of in a landfill.

d. Recycling: Recycling is the process of converting waste into reusable materials.

The United Nations Environmental Programme (UNEP, 2009) recognizes three main steps in recycling (Figure 5) namely:

i. **Collection**: E-waste collection is of great essence as it is the medium in which e-waste are retrieved from households. Collection programmes are designed to suit the device to be collected and societal/social factors of the benefiting community.

ii. **Dismantling and Pre-processing** (*sorting, dismantling, mechanical treatment*): This step aims at releasing the materials from a system into their functional parts and subjecting them to an end-process suitable for each material type.

iii. **End-processing** (*refining and disposal*): This step is concerned with metal recovery and the isolation cum disposal of hazardous waste.

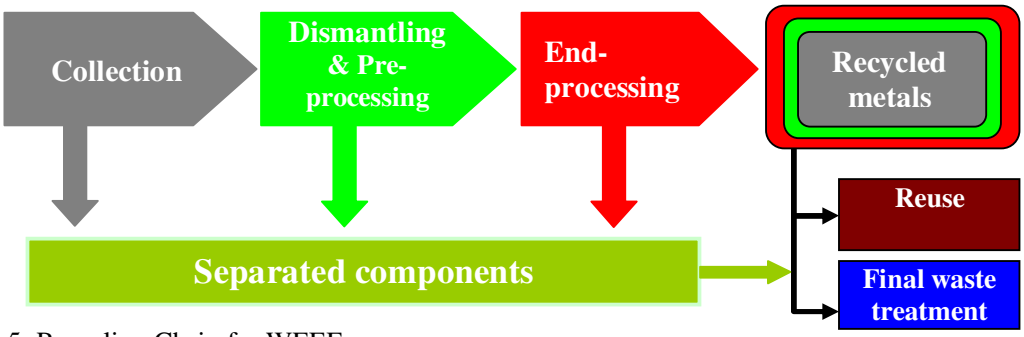

Fig. 5: Recycling Chain for WEEE

Proposed Waste Management Framework

A waste management proposal is presented in Figure 6.

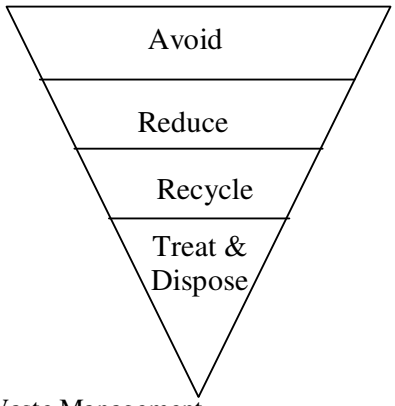

Fig. 6: Simple Approach To E-Waste Management

a. **AVOID:** Here, we are to avoid practices that may generate more e-waste or significantly increase the total volume of e-waste in a particular location. This will compliment the efforts that are made in reducing existing volumes of e-waste.

(i). **Redesign**: Manufacturers should focus on designing products that contains fewer to zero hazardous materials. For example, use of bio-based chemicals rather than petrochemicals (Ramachandra and Saira, 2004). In terms of automobile air conditioners, HFC-134a, which is more ozone friendly with an Ozone Depletion Potential (ODP) of zero, should be used in place of CFC-12. Also, the replacement of Lead solder with SAC (Tin, Silver, Copper) alloy solder or BSA (Bismuth, Tin, Silver) alloy solder is preferred, even though they are not entirely environmentally safe but are safer than Lead alloy solder (The Ames Laboratory, 2012; EPA, 2005).

(ii). **Rethink**: Consumers should think again on how products will impact the environment before purchase.

(iii). **Stop**: The importation of fairly used electronics into the country in the guise of gifts and assistances from developed countries should be stopped.

b. **REDUCE:** Reduction of e-waste could be achieved through reuse, adoption of cloud computing and wireless dumb terminals.

(i). **Reuse**. This usually constitutes the use of functional second-hand electronics/parts or the refurbishment of faulty ones to serve similar purpose. Example of reusable parts includes inkjet cartridges.

(ii). **Cloud Computing**. Cloud computing can greatly reduce the demand of server computer systems, and hence its resulting waste, if universally embraced. Here, Cloud Providers own and maintain server systems which are used to float Information Communication and Technology (ICT) services that individual users and organizations may subscribe to as the need arises

(iii). **Wireless Dumb Terminals**. Dumb terminals cannot perform active computations on their own, but rather depend on the computing capability of the server machines. Each unit has a wireless chip attached to establish communication with the server. It is proposed here that dumb terminals that consist of only a visual display unit with its input devices such as keyboard and mouse be used in large organizations rather than desktop computers.

c. **RECYCLE:** The segregated components are to be cycled back to generate useful constituents that can go into the manufacture of new products.

Repurchase: Manufacturers should provide an avenue where consumers can see off in their old electronics as part payment for new ones. If passed into law, the long-desired involvement of manufacturers in solving e-waste problems will be addressed.

d. **TREAT AND DISPOSE**: Recycling has by-products, which includes hazardous wastes that require appropriate handling. Effective handling process would usually include treatment of the by-product to neutralize its toxicity, and finally, disposal. The disposal method used in this case would be land-filling.

RECOMMENDATIONS

In order to ameliorate the influx and effects of e-wastes in Nigeria, several recommendations are hereby provided.

a. Government should encourage private initiatives on product reuse and recycling by providing needed infrastructure and perhaps reduction of tax payables for organisations in the recycling business.
b. There is a dire need for regulatory agencies to be adequately empowered and thoroughly supervised if this menace is to be curbed.
c. Nigerians should be sensitized to know the adverse effects of e waste.
d. Stricter measures should be applied on borders with regards to “second-hand electronics”. Ratification of Bamako Convention might well be a stepping stone/statement of intent.
e. Since e-waste is as injurious to health (or more) as biomedical, industrial and municipal waste, provisions should also be made for e-waste management and disposal by the government by providing treatment and recycling plants.

f. Training of resource persons for proper e-waste management.

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