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Disposal Methods and Heavy Metals Released from Certain Electrical and Electronic Equipment Wastes in Nigeria: Adoption of Environmental Sound Recycling System

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***Abstract*—The rapid improvements in the electronics industry, electronic waste (E.waste), including all obsolete electronic products, has becoming the fastest growing component in the solid waste stream. This phenomenon has been a source of hazardous wastes such as personal computers (PCs) and Televisions (TVs), which contain heavy metals and organic compounds that pose risk to the environment and to sustainable economic growth.**

Informal E.waste recycling practices in Nigeria such as open burning to recover metals, dumped or stockpiled resulted due to lack of national management strategies. In this work, various toxic chemicals that are released during these disposal habits were outlined, with their environmental effects, using the major components cathode ray tubes (CRTs), printed wiring boards (PWB), and plastics of personal computers or television as an example. Various upgrading methods of environmental sound recycling system were emphasized after each component undergoes dismantling or disassemble which reduced the emissions of toxic substances in the environment and promote recovery of valuable materials. The adopting of extended producer responsibility (EPR) was suggested as the best policy to enhance sustainable E.waste management growth in developing country Nigeria.

***Index Terms*—CRTs, Hazardous materials, Plastics, Policy, PWB, Recycling, Scrap.**

I. Introduction

Once electronic devices reach the end of their useful life, they become electronic waste (E.waste) or WEEE, waste from electrical and electronic equipment [1]. WEEE has been defined as any equipment that is dependent on electric currents or electromagnetic fields in order to work properly, including equipment for the generation, transfer and measurement of current [2]. Besides, there is no standard or generally accepted definition of e.waste in the world [3], [4]. E.waste has become the fastest growing component in the solid waste stream [5]. In response to the increasing volumes of WEEE and their potential environmental impacts through various disposal routes, the European Commission has published a proposal or definition given in Directive 2002/96/EC of the European parliament [6]. The Directive of the parliament and European Union Council on waste electrical and electronic equipment subdivides WEEE into ten categories that are listed in Table I, [6].

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TABLE I: WEEE Categories According to the EU Directive.

No	Category	Label	Example
1.	Large Household appliances	Large HH	Refrigerators/freezers, washing machines dishwashers.
2.	Small Household appliances	Small HH	Vacuum cleaners, kitchen machines.
3.	Information technology and telecommunication equipment	ICT	Computers, telephone, mobile phones, copying equipment, printers.
4.	Consumer Equipment	CE	Televisions, stereo equipment, electric toothbrushes, transistor radios.
5.	Lighting Equipment	Lighting	Fluorescent lamps.
6.	Electrical and Electronic tools (with the exception of large scale stationary industrial tools)	E&E tools	Handheld drills, saws, screwdrivers.
7.	Toys, Leisure and sports equipment	Toys	Video games, sports computers, car racing, etc.
8.	Medical Devices (with the exception of	Medical Equipment	Therapeutic, diagnostic and analytical equipment,

	all implanted and infected product)		massage devices, X-ray equipment, sterilizers.
9.	Monitoring and Control Instruments	M&C	Control boxes.
10.	Automatic Dispensers	AD	Automatic dispensers

Worldwide, WEEE constitutes one of the fastest growing waste fractions generated, accounting for 8% of all municipal waste [2]. The major categories of electrical and electronic equipments in circulation (worldwide percentage (%) of total) in Table II.

TABLE II: MAJOR CATEGORIES OF ELECTRICAL AND ELECTRONIC EQUIPMENTS

Category of WEEE	**Worldwide % of total**
Large HH	43
Small HH	3
Lamps	1
IT equipment	39
Telecommunication	1
Radio, TV, audio	8
Monitoring and control	1
E & E tools	3
Toys	1

(Source: UK status report of WEEE) [7].

In Western Europe, 6 million tons of electric and electronic waste generated in 1998. The amount of this waste is expected to increase by at least 3-5% per annum [8]. In the USA 2004, 315 million computers were predicted to be at the end of their life [9], in Austria the total e.scrap amounts 85,000 tons per year with a tendency to rise, whereas 5000 tons are declared as hazardous waste [3]. In California, it is estimated that some 6 million obsolete PCs and TVs are stored in people's home another 10,000 are joining them every day [5], [10].

In Nigeria, all the electric and electronic equipment (EEE) are imported from foreign countries, most EEE have under gone End of their Life (EOL) before imported. Nigeria has become the destination for a large proportion of e.waste importation from developed countries [11]. The development of the electronics industry has led to an increase not only in the production of new goods but also in the scrap generation and the volume of waste material left after lifetime of these goods. This e.waste has toxic heavy metals that pose a serious environmental threat unless proper treatment of these wastes is carried out [11], [12].

The municipal solid waste in Nigeria contain all source of wastes, such as commercial refuse, construction and demolition debris, electronic wastes, garbage etc. which are dumped indiscriminately on roadside and any available open pits or open burning irrespective of the health implication on people. The objectives of this study are (1). To elaborate on hazardous toxic substance that releases from e.wastes, (2). To outline the environmental impact of WEEE, (3). Recommendation of sound recycling practice than open burning of e.waste to recover metal as waste reduction (volume) in the developing countries. The hazardous components were emphasized using cathode ray tubes (CRTs) and printed wiring boards (PWB) from PCs and TV to examine the discharge of heavy metal contents and also the plastics.

A. E.Waste Generation In Nigeria

E.waste is becoming an important waste stream in terms of both quantity and toxicity in Nigeria. The importation of end of life (EOL) EEE and updated ones are sources of e.waste in the country. The actual quality of e.wastes imported is unavailable, due to the rate of illegal importation is far greater than due process, of which end of life (EOL) e.wastes were declared as secondhand goods or mixed metals. The disposal rate of these wastes stream is accelerating because the global market for electronic is far from saturated and the lifespan of electronic goods is becoming shorter, so that obsolete equipment is increasing. For example, for computer central processing units (CPUs), their lifespan has dropped from 4-6 years in 1997 to 2 years in 2005 [2], [11]. More than 180 million personal computers (PCs) were sold worldwide in 2004 and estimated 100 million obsolete PCs were discarded with some recycled for the recovery of materials [2]. WEEE contains various materials such as ferrous metals, non-ferrous metals, plastics etc. Table III, below [2].

TABLE III: MATERIALS FOUND IN ELECTRONIC EQUIPMENT.

Materials found in WEEE	**Percentage (%) of Material**
Ferrous metals	38
Plastics	19
Non-ferrous metals	28
Glass	4
Wood	1
Other	10

II. HAZARDOUS COMPONENTS

E.waste contains a complex array of hazardous substances that can threaten human and the environment if not handled or disposed properly. PCs constitute the second largest component next to CRTs in the E.waste stream and growing most rapidly. PCs also contain the largest amount of printed wiring board (PWB) among electric products [5].

PWBs have been known to contain many types of heavy metals and brominated flame-retardants (BFRs), which are toxic to human being and the environment [5], [8], [13]. Also phosphor coatings of cathode ray tubes (CRTs), high-lead content in the CRT funnel glass, batteries, PWB capacitors and mercury-containing parts, contained in computer may seriously pollute the environment if they are not properly disposed of. In addition to the hazardous materials, some valuable materials (i.e., copper-containing motors, plastic or iron parts, gold-, silver- and copper-bearing printed wiring boards etc.) contained in scrap computers make them worth being recycled [13]-[15].

A. Cathode Ray Tubes (CRTs) Components

Cathode ray tubes (CRTs) are the technology used in most televisions and computer display screens, which represents about two-thirds of the weight of a television or a computer monitor and is composed of 85% glass [15]. A CRT in a TV or computer can contain from ~1.5 to nearly 6 pounds of lead depending on the size and year of manufacture (4 pounds per CRT is sometimes used as a rough average) [16]. TV and computer CRTs present a disposal problem because of their growing magnitude in the waste stream and their role as a major source of lead in municipal solid waste (MSW). The CRT glass can be divided into 4 parts that have differing amounts of lead in different chemical and physical forms.

1) Panel or face plate (the front part): a very homogeneous barium strontium glass, of a green-blue colour, whose weight is about two-thirds of the whole CRT. A minimal amount of lead (~2-3%) bound up in the glass matrix and barium content (up to 13%).

2) Cone or funnel (the hidden part inside the TV set): a lead glass whose weight is about one-third of the whole CRT of (22-25%lead), for shielding us from the radiation produced by the gun.

3) Neck: a glass with a very high lead content enveloping the electron gun, (source of the signal leading to the display we see when we look at the screen).

4) Frit (the connection between the panel and the cone: a low-melting temperature lead glaze as a type of glass solder used to join the panel and cone sections. It contains from ~15 to nearly 100 grams of lead per CRT, depending on the size. The lead from the frit is in a soluble form, primarily lead oxide as compared to the insoluble lead in the glass matrix of the funnel and faceplate [13], [15]-[17].

The lead content in various CRT glass components by mass (i.e. colour CRT and monochrome CRT %) is shown in Table IV [17].

TABLE IV: LEAD CONTENT IN VARIOUS CRT GLASS COMPONENTS BY MASS

Glass	**Colour CRT (%)**	**Monochrome CRT (%)**
Panel	0.3	0.3
Funnel	24	4
Neck	30	30
Frit	70	N/A

(N/A= Not Available).

CRT glass may be considered as hazardous waste due to its high-lead content. The hazardous characteristics of such glass can be determined using a toxicity characteristic leaching procedure (TCLP), which has been adopted by the USEPA to determine the leaching toxicity of wastes [13]. Other toxic substances including barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu) and zinc (Zn) [5].

B. Printed Wiring Boards (PWB)

The printed wiring boards (PWB) or printed circuit boards (PCB) are part of this WEEE and their composition is quite varied, the amount of printed wiring boards in electronic scrap is approximately 3wt% [3]. About 28% metals are highly cross linked the glass fibers and resins; fixed on top of the boards are assemblies such as capacitors, semiconductors, switches batteries etc.

"Reference [8] reported that the metal content is around 28% (copper: 10-20%, lead: 1-5%, nickel: 1-3%)". The content of the most important materials remaining is plastics 19%, bromine (especially as flame-retardant) 4%, glass and ceramics 49%. The typical composition of a scrap PWB is shown in Table V [13].

TABLE V: TYPICAL COMPOSITION OF THE SCRAP PWB.

Material	**Weight %**
Gold	0.035
Copper	22.0
Solder (tin)	1.5
Solder(lead)	2.6
Fiber glass	30.0
Epoxy resin	15.0
Other (Fe, Ni, Si…etc.)	29.0

The copper and precious metals contained therein make it a potentially recyclable material. "Reference [5] said that PWBs have been known to contain many types of heavy metals and brominated flame-retardants (BFRs) which are toxic to human being and the environment," according to reference [3], that the flame-retardants and organic compounds make the treatment of PWB difficult. These flame-retardants, according to reference [8], contained antimony trioxide, which is suspected to be carcinogenic, as well as precious metals (in decreasing order: silver, platinum metals like palladium, gold to a total of approximately 0.3-0.4%).

The important organic compounds found in circuit boards: isocyanates and phosgene from polyurethanes, acrylic and phenolic resins, exposides and phenols such as chip glues [8]. Therefore, the circuit boards cannot be considered inert materials and are not suited for direct disposal in landfills or open burning done in Nigeria, (computer village in Lagos State, Nigeria).

C. Plastics

This have unique electrical insulating properties, such as their strength, stress resistance, flexibility and durability make them important materials for use in electronics. It can found both internally or on the exterior facade of electronic devices, such as personal computers and television. Plastics were the second largest component in WEEE and approximately 30% of the mass electronic scrap consists of plastics [2], [3].

"Reference [18] shows that in Western Europe, plastic consumption by the electrical and electronic industry was 2.78 million tonnes in 2002 and the quantity of plastic waste from industries increased to approximately 1.13 million tonnes in the year 2005." The materials used in electronics have several important characteristics, in PCs monitors and TVs, acrylonitrile butadiene styrene (ABS) and high-impact polystyrene (HIPS) are used for CRT protection, also polyphenylene oxide PPO) has good properties such as high temperature resistance, rigidity, impact strength and creep resistance Table VI, below shows summary of typical resins used in different electrical and electronics equipment (EEE) [2], [19].

TABLE VI: RESINS USED IN ELECTRONIC PRODUCTS.

EEE	Resins
Computers	ABS, HIPS, PPO, PPE, PVC, PC/ABS
TVs	HIPS, PC, ABS, PPE, PVC
Miscellaneous	HIPS, PVC, ABS, PC/ABS, PPE, PC

Table VII, shows the weight percentage (wt. %) of manufacture of plastic from organic compounds, HIPS and ABS are the major resins in computers and TV sets, and they are widely used plastic in the electronic industry, of HIPS (59 wt. %), ABS (20 wt. %) and PPE (11wt. %) [2].

TABLE VII: MANUFACTURE OF PLASTIC FROM ORGANIC COMPOUNDS.

Manufacture of plastic	Weight percentage (wt. %)
HIPS	59
ABS	20
PPO	16
PP or PE	2
Other	3

HIPS: high-impact polystyrene; ABS: acrylonitrile butadiene styrene; PPE: polypenylene ether; PVC: polyvinyl chloride; PC: polycarbonate; PPO: polypenylene oxide; miscellaneous: fax, telephone, refrigerator, etc.

There is an added danger that some of this plastic with flame-retardant and can be damaging to the environment of not disposed of properly.

D. Toxic Chemical Discharge/ Environmental Effects

One of the problems in the municipal waste is the content of substance such as heavy metals, organic compounds and others. In combination with halogens in the plastic fraction they can form volatile metal halides but they also have a catalytic effect on the formation of dioxins and furans [3]. WEEE should not be combined with unsorted municipal waste destined for landfills or open burning of garbage because electronic waste can contain more than 100 different substances (toxic chemicals), many of which are toxic such as lead, mercury, hexavalent chromium, selenium, cadmium and arsenic [1]. Some of the specific components that contain toxic chemical wastes include:

Printed wiring boards, Cathode ray tubes, Mercury switches, Batteries, Sensors and connectors, Light generators (e.g. lamps), Wires and cables Capacitor and resistors.

The toxic chemicals can be grouped into 4 categories as they can be found in electrical and electronic waste, (Table VIII) [3], [14].

TABLE VIII: TOXIC CHEMICALS IN WEEE.

Substances	Application
(1). Heavy metals	**In**
Cd, Ni, Zn, Pb, Hg	Accumulators and batteries
Sn, Pb, Cd	Solders
Ba, Sr, Pb	Cathode ray tubes
Cd, Y, Eu, Se, Zn	Screen coating, getter
Hg	Mercury switches, thermostats, sensors and discharge lamps
Cr (vi)	Metal coatings for corrosion protection and wear resistance.
(2). Semiconductors	**In**
Si-technology: B, G, In; As	Switch
GaAs	LED light emitting Diode
GaAs	Solar cells
Ge	Photodiodes
(3). Organic compounds	**In**
Polychlorinated Biphenyls (PCB)	Capacitors
Polybrominated biphenyls (PBBB) and Polybrominated diphenyl ether (PEDE)	Flame-retardants in PWB, connectors and plastic covers.
Mineral oil	Bearing
(4). Plastic	**In**
Cl, Br	Halogenated plastic
Cd, Pb, Ni, Ti, Sb	Pigments
Pb, Ba, Cd, Sn	Stabilizers.

Most Toxic Chemicals Restricted by EU Law

- Chemicals controlled by the European Union restriction of the use of certain hazardous substances in electrical and electronic equipment regulations are as follows:
- Mercury in compact fluorescent lamps not exceeding 5mg per lamp.
- Mercury in straight fluorescent lamps for general purpose not exceeding halophosphate-10mg; triphosphate with normal lifetime-5mg and triphosphate with long life time-8mg.
- Mercury in straight fluorescent lamps for special purposes.

- Mercury in other lamps.
- Lead in glass of cathode ray tubes, electronic components and fluorescent tubes.
- Lead as an alloying element in steel containing up to 0.35% lead by weight and as a copper alloy containing up to 4% lead by weight.
- Lead in high-melting-temperature-type solders (i.e. tin-lead solder alloys containing more than 85% lead), specially, lead in solders for servers storage and storage array systems (exemption grated until 2010); lead in solders for networking infrastructure equipment for switching, signaling, transmission as well as networking management for telecommunication, and lead in electronic ceramic parts (e.g. Piezoelectronic devices).
- Cadmium plating except for applications banned under Directive 91/338EEC amending Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations.
- Hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators.

Environmental Effects

According to reference [20], human exposure to lead from electronic products is more problematic because of illegitimate recycling in cottage industries in developing countries that have little or no regulatory oversight. Without a well developed recycling and refurbishing program in developed countries, we can expect that health risks associated with outmoded electronic products will continue to be shifted from one part of the world to another [20]. Currently the majority of e.waste in Nigeria is processed in backyards or small workshop such as manual disassembly or open burning to recover metals and reduce the volume of waste. The remaining parts are dumped or stockpiled directly. The existing informal recycling and disposal of e.waste in Nigeria have caused serious consequence to the surrounding environment and human health. Some of the toxic effects of the heavy metals from e.waste are:

1) Lead: which cause damage to the central and peripheral nervous systems, blood system, kidney and reproductive system in human. This lead is known neurotoxin (kills brain cells), and excessive blood lead levels in children have been linked to learning disabilities, attention deficit disorder (ADD), hyperactivity syndromes, and reduced intelligence and school achievement scores [21], [22].

2) Cadmium: cadmium and its compounds are toxic, they can biaccumulate and they pose a risk of irreversible affects on human health. It causes kidney and liver dysfunction, brittle bones and adversely affects reproduction and survival [23].

3) Mercury: according to reference [24], mercury can cause damage to various organs in the body such as brain and kidney; that the greatest risk for harm, even with only minute or short-term exposure, is to infants, young children and pregnant women.

4) Hexavalent chromium: breathing high levels of chromium (VI) can cause irritation to the nose, such as runny nose, nosebleeds and ulcers and holes in the nasal septum. Skin contact with chromium (VI) compounds can cause skin ulcers [24].

5) Silver and silver compounds: can cause biological effects such as digestive tract irritation and agryria, which is characterized by a permanent blue-gray pigmentation of the skin, eyes, and mucous membranes.

6) Antimony and its compounds can cause severe digestive tract irritation with abdominal pain, nausea, vomiting and diarrhea.

7) Copper and copper compounds: can cause severe digestive tract irritation with abdominal pain, nausea, vomiting and diarrhea.

8) Additional harmful substances in WEEE can include arsenic, polychlorinated biphenyls (PCBs), chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) and nickel. These toxic chemicals, even when present in small amounts, some of these chemicals can be potent pollutants and contribute to toxic landfill leachate and vapours, such as vaporization of metallic and dimethylene mercury [2]. During burning of WEEE, toxic chemicals such as dioxins and furans may be release to the environment; furthermore run off water carries leachate (ash acidic + water = toxic water) into the sea affect the aquatic life, also the ash leached into the soil which cause ground water contamination.

III. E.Waste Sound Recycling System

In the informal e.waste recycling practices in Nigeria, currently the majority of E.waste is processed in backyards or small workshops using primary methods such as manual disassembly and open burning, (Fig. 1). The appliances are stripped of their most valuable materials such as ICs, cables, plastics, condensers, PWB, CRTs and metals (by open burning). Some of these materials are processed directly to reusable components. The remaining parts are dumped or stockpiled as shown in Fig. 2, below.

This system poses serious consequences to the surrounding environment and human health and can replace by environmentally sound manners. "Reference [25] said that recycling of waste electric and electronic equipment is important not only to reduce the amount of waste requiring treatment, but also to promote the recovery of valuable materials."

Meanwhile the valuable recycled materials such as iron, copper, aluminum and plastic can be recovered and further reused. Traditional dismantlers without proper facilities cannot suitably recover the hazardous substances, the valuable parts of waste home appliances such as compressors in air conditioners and refrigerators are separated and sold to second handshops; whereas, improper treatment will leave problems of secondary pollution behind.

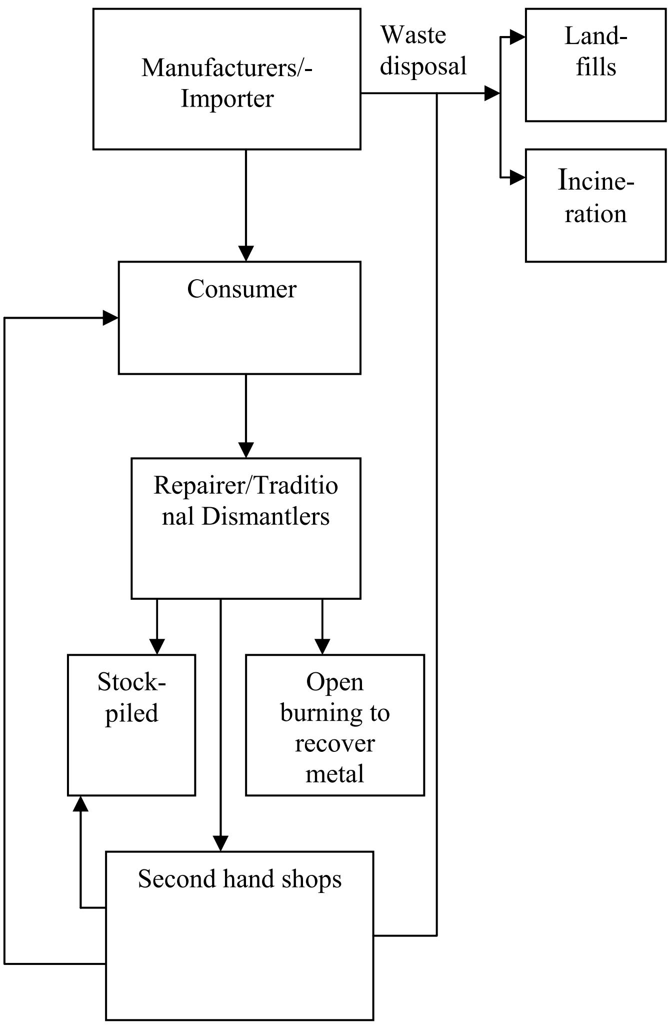

Fig. 1: Recycling/Disposal method of waste home appliances in Nigeria.

A. Environmental Sound Recycling System

Recycling of e.waste was primarily intended to reduce the volume of waste and to increase material recycling rates. Because of the high content of heavy metals in some components of products, it is also expected that recycling will lessen adverse impacts of the environment.

Fig. 2: Dumped or stockpiled e.wastes in an uncompleted building in Abeokuta, Ogun State, Nigeria.

Sound or quality recycling practice of recovery components will lead to a significant reduction of heavy metal emissions to the environment. Efforts to divert WEEE from landfills and incinerators have resulted in hazardous dismantling, shredding, burning, exporting and other unsafe or irresponsible disposal methods. However, manual disassembly and recovery of components, which are the main processes in new recycling facilities, contribute to only a minor improvement in recycling rates.

To achieve cost-effective and environmentally sound recycling system, the characterization of these wastes, which is paramount importance, should be developed, since EEE is diverse and complex with respect to the materials and components used. Recycling of WEEE can be divided into two steps, (1). Dismantling/disassembly, (2). Treatment method/upgrading.

5) Dismantling/Disassembly: The dismantling or disassemble technology is used to retrieve various components from the electronic scrap like computers. Simple components such as plastic, iron and metal parts, usually to isolate hazardous or valuable materials.

2) Treatment method/upgrading: This step includes two stages: comminution and separation of materials using mechanical/physical and/or metallurgical processing to prepare the materials for refining processing. The following are various treatment methods that can apply to WEEE based on the nature of the WEEE:

a) *Mechanical separation*
b) *Thermal/Pyrometallurgical treatment*
c) *Hydrometallurgical treatment*
d) *Electrochemical treatment.*

Mechanical Separation:

The different components and devices can be separated in a first mechanical step into various fractions such as metals (iron, aluminum, copper etc.), plastics, paper, wood and devices such as capacitors, batteries, PWB etc. After hand sorting and the removal of the contaminants (mercury switches, PCP containing capacitors etc.), the materials undergoes a first size reduction step with different devices are used such as hammer mills, shredders or crushers. The shedder is often used to produce small even fine-sized particles. The rage of devices in usage depends strongly on the composition of WEEE, mechanical process is ideal for upgrading recycling WEEE because it can yield full material recovery including plastics (light fraction), nonferrous metals, and iron.

The obtained fractions are enriched in certain materials, and have to be further processed using other treatment methods such as pyrometallurgy or hydrometallurgy, the mechanical upgrading produce dust formation/gas emission (dioxins/furan), and noise [3]. Also in particle separation many of the traditional recycling separation processes can be used such as screening, shape separation and magnetic separation [2], [8].

Thermal/Pyrometallurgical Treatment:

This method involves incineration, smelting in a plasma arc furnace or blast furnace, drossing, sintering, melting and reactions in a gas phase at high temperature [3]. To remove organics and plastic material, incineration process can be used to further concentrate the materials. The crushed scrap can be burned in a furnace or in a molten bath to remove plastics, leaving a molten metallic residue. The plastic burns and the refractory oxides form a slag phase. Silver and gold containing scrap materials can be treated in a copper smelter, when material is heated up in an inert gas atmosphere (pyrolysis), at certain temperatures, the organic fractions (plastic, rubber, paper, wood etc.) decompose and form volatile substances which can be used in the chemical industry or for the generation of energy by the combustion of the gases or oils.

In this thermal method, high purity of metal can be obtained often more than one metal, e.g. in a copper plant nickel is also a product as well as the noble metals. There is no composite material problem, since they are destroyed by heat. Thermal treatment produce waste gases and flue dusts, the halogen content can lead to dioxin problems [3], [13] or great amount of energy consumption [8] and large quantity of slag produced resulting in a lower recovery of valuable materials. In particular, the recovery of Zn, Al, Pb and Sn is not possible [12].

Hydrometallurgical Treatment:

This treatment involves acid or caustic leaching of solid material. To increase the metal yield, a small grain size of the material is required. The metal of interest are isolated from the solution and concentrated through process as solvent extraction, precipitation, cementation, ion exchange, filtration and distillation [3], [26]. Usually, in solvent extraction, it involves interaction between a metal ion in the aqueous solution, and a complexing agent, commonly a chelating agent, dissolved in an immiscible organic phase. According to reference [26], that silver, lead and cuprous chlorides are insoluble in water. But of particular interest is the fact that these compounds have moderately high solubilities in hot concentrated chloride solutions. As a result, aqueous chlorides are commonly employed for extraction of anionic chloro-complexes. Iron powder was employed to simultaneously recover Pb and Ag by cementation.

This method cannot treat more complicated scrap materials [12] and thus pretreatment is necessary. Furthermore, the problems are resulting from the corrosiveness and toxicity of the leaching solution as well as the relatively large volume required, present major environmental drawbacks with this method. With the selective leaching of the metals in various steps using different solvents, high purity of the metals will be achieved. But metal loss due to composite materials, there is great amount of effluents generation [3], [8].

Electrochemical Treatment:

In order to separate the metals among themselves, this upgrading method is applied. Usually in molten salts or aqueous electrolytes, example recovery of gold and silver in iodide electrolysis containing aqueous KI/KOH solution.

Above all treatments or upgrading, it is expected that a mechanical recycling process will be developed for upgrading low metal content scraps. From reference [2] shows that mechanical upgrading is more easier to operate and more environmentally sound, are becoming more prevalent.

Policy Implications

In order for recycling to be successful, the cost of labour, the structure of the economy (including the important informal sector), the existing regulatory framework, and the possibilities and limits of law enforcement must be taken into account in order to find solutions that can improve the situation, with regard to environmental impacts, occupational hazards and economic revenue. The system must also have the ability to adapt to future changes in the quantity and quality of the waste flows to ensure sustainability.

The backlogged demand for EEE in developing countries as well as lack of national regulation and/or lax enforcement of existing laws can promote the growth of informal WEEE recycling economies that are poorly controlled and involve extremely risky techniques. Legislative polices, timely regulatory and producers are needed in order to accelerate the rate at which proper processing and management methods are employed. Also there will be collaborative efforts of not only researchers concerned with recycling but also of government agencies and manufacturers.

The best WEEE management scheme policy to adopt in developing countries is introduction of extended producer responsibility (EPR), the informal e.waste recycling process must be prohibited by legislation and replace by large-scale facilities. “Reference [25] said that EPR system is a better way to increase the recycling efficiency.”

The EPR system requires producers to have full obligation for recycling the products they produce, from the

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United Nations Basel Convention (1989), on the tranboundary movement of hazardous waste materials and their disposal is an international agreement to control the movement and management of hazardous waste across national borders. The convention puts the onus on exporting countries to ensure that hazardous wastes are managed in an environmentally sound manner in the country of import [27].

On this regulation, on 1st June 1998, a producer responsibility recycling program for scrap computers was officially implemented in Taiwan, under this programme, five recycling plants have been established locally to treat the collected scrap computers [13]. It is essential that the EPR is applied and defined well enough to establish effective management framework in Nigeria.

Finally, it is also necessary to arouse and enhance public awareness regarding effects of WEEE on the environment and health, and also kwon the significance of informal recycling practices.

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