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Extraction of Valuable Substances from E-Waste

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***Abstract:* -** Globally, e-waste is the fastest growing waste stream due to rapid growth in technology, planned obsolesces in electronics industry and increased desire for new electronic products. E- waste has the ugly and good sides because it contains substances that can be classified as hazardous and non-hazardous. This paper focuses on the good side-extraction of valuable substances by means of recycling. Millions of dollars of gold, silver and other precious metals are hidden away e-waste landfills because electronic machines use so much precious metals and their waste can be recovered in the process called urban mining. E-waste now contains precious metal deposits that are 40 to 50 times richer than ores mined from the ground. The processes involved in e-waste recycling are: collection, dismantling, pre-processing, end processing and final metal recovery. To achieve environmental sustainability, the trend in e-waste management is green computing.

***Keywords:* -** *e-waste, green computing, precious metals, recycling, urban mining*

I. INTRODUCTION

The Information and Communication Technology (ICT) has gradually but steadily permeated virtually every facet of our lives through the emergence of new technologies that have made it possible to produce a wide range of electronic products at relatively affordable prices. Consequently, there are ever increasing demands for electronic items leading to alarming rate in waste generation.

E-waste is the shortened form of the term electronic waste and is the waste material generated from electronic products. It is also called e-garbage, e-scrap and Waste Electrical and Electronic Equipment. [1] E-waste therefore refers to electrical or electronic materials that are unwanted, discarded, and obsolete and are broken. Some of the sources of this category of waste include: radio and television sets, computers, monitors, all types of phones, fax machines and copiers, personal digital assistants and electronics from industrial sources.

1.1 E-waste Generation

The rapid e-waste generation witnessed globally today is attributed to some factors. People have discovered the ability of electronic products to make life more convenient and therefore have developed almost insatiable craving for them, resulting in the growth of electronic waste. Furthermore, technologies are rapidly changing positively and prices of electronic products are now lower and thus users can conveniently do away with their old electronics. Again, manufacturers have tactically planned obsolesce of their electronic and electrical products by rapidly introducing new ones with better features. Equally, users of electronic products have observed that it is often cheaper and more convenient to buy new electronics than to upgrade the old ones. That is not all; liquid crystal display (LCD) screens have now replaced cathode-ray tube (CRT) monitors because they are smaller and have energy economy resulting in massive dumping of CRT monitors. Very importantly, manufacturers have embarked on aggressive marketing resulting in consumers' cravings for electronic products.

1.2 E-waste Statistics

Statistics on e-waste is frightening. According to Causes International, 20- 50 million tons of e-waste are generated worldwide annually. [3] Also, the USA is seen as the world leader in e-waste generation, producing about 3 million tons annually. [4] In addition, according to Greenpeace International in the developing countries, the lifecycle of mobile phones is less than two years. [5].

1.3 Electronic Waste Substances

The composition of e-waste differs from one product to another. Some of them are found in large quantities. There are some elements that are found in small amounts, while others are in trace amounts. [4]

1.3.1 Elements found in trace amounts

Americium, antimony, arsenic, barium, bismuth, boron, cobalt, europium, gallium, germanium, gold, indium, lithium, manganese, nickel, niobium, palladium, rhodium, ruthenium, selenium, silver, tantalum, terbium, thorium, titanium, vanadium and yttrium. [4]

1.3.2 Elements found in small amounts

Cadmium, mercury and thallium.[4]

1.3.3 Substances found in large quantities

Epoxy resins, fibre glass, PCBs, PVC, thermosetting plastics, lead, tin, copper, silicon, beryllium, carbon, iron and aluminium., [4]

1.4 The Dark and Bright Sides of E-waste

Like two side of a coin, electronic waste has the ugly and the good sides. Being a highly complex waste stream e-waste contains both very scarce and valuable as well as highly toxic components.

1.4.1 Ugly Side

Electronic materials contain substantial amounts of lead and other substances which are harmful to the body.. Unfortunately, they are either dumped at landfills or burnt. Worst still, some of the developed countries have been sending large amounts of e-waste to developing countries such as China, India, and Nigeria where there are poor environmental standards. By so doing, they are indirectly converting them to waste dump sites for the developed countries.

1.4.2 Economic Perspective

As e-waste also contains valuable substances, it also serves as source of secondary raw materials or wealth when properly treated. This achieved through recycling to extract precious materials from he e-waste stream.

The objectives of this study are to gain an understanding of e-waste, its substances and associated hazards; to review the various e-waste management options and to stress that e-waste contains several precious materials that can be extracted through recycling. This paper is divided into five chapters. Of course, chapter one is the introduction. In chapter two, there is a review of e-waste management efforts. Chapter three deals extensively on processes employed in extracting gems from e-waste. The emerging trends in e-waste threats and opportunities are handled in chapter four while chapter five is the conclusion.

II. REVIEW OF E-WASTE MANAGEMENT OPTIONS

Generally, in waste management, waste materials are collected, transported, disposed or possibly processed and recycled with the view to reducing their negative impacts on health, the environment or aesthetics. It is also carried out in order to recover resources from it. Some of the methods used in managing e-waste include the following.

2.1 Disposal to Landfill

In this method, which is one of the most widely used methods of waste disposal, e-waste is buried. Mining voids or borrow pits can be used in land filling. [4] However, this has the disadvantages of uncontrolled fires which can release toxic fumes and also that toxic components of e-waste may contaminate ground water and pollute the environment.

2.2 Incineration

Here, the waste materials are burnt in incinerators at high temperatures. When e-waste is incinerated, there is a reduction in the waste volume and the energy content of combustible materials can be utilised. However, this method results in pollution, more so because most e-wastes contain some quantities of lead-tin solders and therefore should not be encouraged..

2.3 Re-use Method

In this method the original equipment is put into second hand use or use after modifications. This method equally has an advantage of reducing the volume of e-waste generation.

2.4 Avoidance and Reduction Methods

Waste reduction or prevention involves the prevention of e-waste from being created. This method is good in waste management because it is only when waste is generated that it has associated waste management costs. In addition, it helps in resources conservation.

2.5 Extended Producer Responsibility (EPC)

Usually producers push the responsibility for the end-of-life product management to the general public. However, this method places it appropriately on the shoulders of the producers and all entities involved in the product chain. With this in mind, product designers are challenged to ensure that at every stage of products lifecycle, there is minimisation of impact on human health and the environment.

2.6 Legislation

The issue of e-waste has sparked off a number of initiatives around the world with the aim of promoting the reuse of electronic devices and mandating manufacturers to use safer substances in their products. For instance, in some states in the USA developed policies banning cathode ray tubes from landfills due to the fear that the heavy metals contained in them would contaminate ground water. Also in Europe, legislation has been drafted to deal with the problem. [4]

2.7 Export to Developing Countries

Some developed countries have adopted a method of exporting e-waste to developing countries like China, India and Nigeria under the guise of sale or donation of second hand electronics. [6] These countries have gradually become their e-waste dump sites extensions. The exporting countries carry out their illegal business because they see it as less expensive than normal disposal.

2.8 Recycling

The best method of e-waste management is to recycle the equipment. Recycling is the process of extracting resources of value from e-waste. Here the equipment is disassembled and the valuable components are recovered and are used for manufacturing new products. This method is extensively treated in the next chapter.

III. GEMS EXTRACTION FROM E-WASTE

It has been explained earlier that, when properly managed, e-waste can be a source of wealth and employment because it contains several precious materials. Thus, e-waste recycling is a rapidly thriving business in the developed world today. In fact, during the first e-Waste Academy held in Accra Ghana, the organisers revealed that electronic goods contain 40 t0 50 times the amount of gold and other precious metals mined from the ground. [7][11] It was an eye-opener to what is now called urban mining.

3.1 Urban Mining

Usually, mining involves digging out ores from the ground in remote areas. These ores are refined and used to make, among other things, electronic products. With the astronomical rise in the consumption of electronic products, the demand for precious substances used in their manufacture is simultaneously on the increase. An initiative, known as "Solving the E-waste Problem" (StEP) found out that 320 tons of gold and 7,500 tons of silver are required annually for global electronic goods production. Also, a financial estimate on urban mining of e-waste provided by experts from United Nation University is challenging. According to them, e-waste could generate $21 annually. [7][11] This makes urban mining imperative.

Generally, urban mining refers to resources in the cities that can be recycled and reused and in particular, recycling electrical and electronic equipment. [8] The term, urban mining, derives from the fact that, these days, cities have become mines that are rich in valuable substances but located above the ground. [9] Actually, most of these substances end up in cities where actual mining does not usually take place but are locked up in e-waste waiting to be mined. Electronic wastes are now other electronic gold mines. Thus, the process of reclaiming gems from e-waste in urban areas is known as urban mining. This new terminology was coined by John S. Shegerian of Electronics Recycling, Inc. [10] There are now urban mining recycling plants whose function is turn trash into treasure.

3.2 Gems E-waste

E-waste usually contains various precious metals which are of high economic value thereby turning recycling of these wastes into an economic opportunity. [12] The gems include gold and silver which are good conductors of electricity and commonly found in printed circuit boards. Germanium, indium and gallium are needed in semiconductor devices. There are tin and lead that are useful for soldering and coating of component leads. Mercury serves a useful purpose in fluorescent tubes. Aluminium, being a good conductor is a good heat sink while zinc is used in paintings for steel parts. [4][13]

3.3 Informal and Formal Recycling

Recycling of e-waste is done in both formal and informal ways. Informal recycling is found more in developing countries and usually involves large workforce requiring manual operation and intensive labour. Though it is a profitable e-waste management method, it lacks skills and technologies to manage e-waste in an environmentally friendly manner and substantial resource recovery. [14][15]

Informal recyclers can be found in scrap metal yards, dumpsites or in recycling sites around second hand markets. Here, e-wastes are disassembled, assorted and sold. In most cases, these recyclers are only interested in copper, aluminium, lead and steel. To liberate copper, cables and other plastics are incinerated while high grade printed circuit boards are separated and sold. At times, fire is used to reduce waste volume. [15] On the other hand, formal recyclers have the capacity to manage e-waste in a more environmentally friendly way and enhanced resource recovery. [15]

3.4 E-waste Recycling Processes

The factors that affect the selection of the recycling process are type and complexity of material, metal content and volume. There are several methods and technologies that are involved. However, to extract valuables from e-waste, it has to go through a basic process: collection, dismantling, pre-processing, and end processing and final metal recovery. This is illustrated in Fig.1.

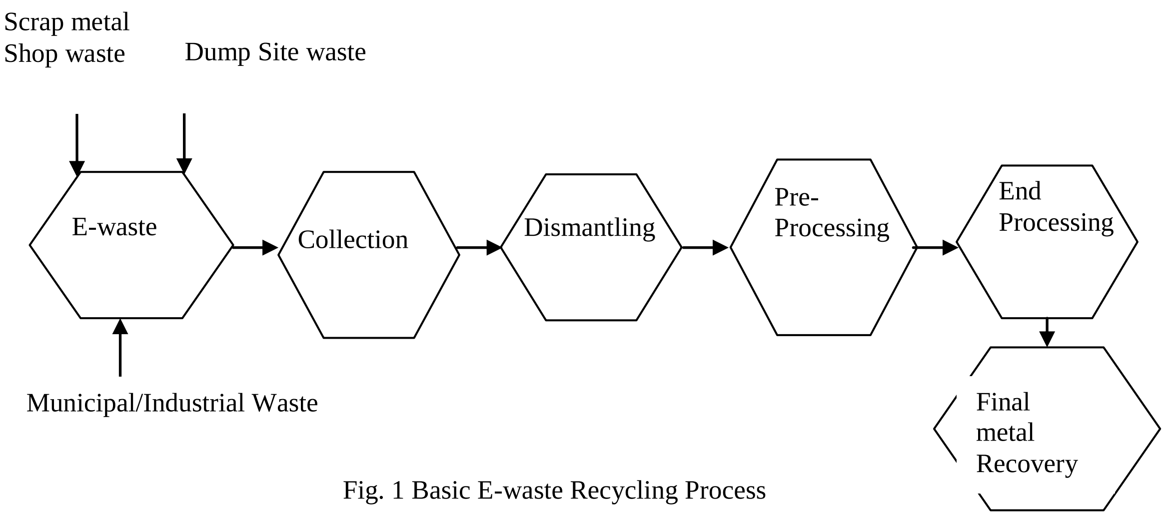

Fig. 1 Basic E-waste Recycling Process

The figure shows that e-waste for recycling can come from various sources such as dump sites, scrap metal shops and municipal and industrial wastes.

3.4.1 Collection

This is the first and crucial step in the recycling process because if no wastes are collected, it will be impossible to establish a recycling chain. Furthermore, collection mechanism of e-waste is very important because it is the determinant of the quantity of waste that is available for recovery through recycling and the amount that is lost in the process of storage. Several collection programmes exist; however their efficiencies are functions of place and recycling technologies in use.

In the developed countries, for instance, there are municipal collection points where consumers are obliged to hand in electronic wastes. On the other hand, in the developing countries there is an informal method where collectors go house-to-house and pay money to consumers in order to be allowed to pick e-waste.[15][16] Furthermore, the materials are classified, evaluated and separated according to metal content and recoverability. [12]

3.4.2Dismantling

The next step is the removal of some functioning or valuable components such as copper cables, memories, drives, batteries, capacitors and so on for re-use. The non-functioning components are dismantled and sorted according to their main functions while the hazardous substances are removed and are either stored or treated safely [15][16]. This step is sometimes called enrichment because critical materials are removed to avoid dilution or contamination with toxic substances. [12] Two methods are employed here; one is mechanical shredding and sorting, while the other is manual dismantling and sorting.[15] Simple tools are used in the second method and thus they can be carried out by unskilled workers. This method is preferable in the developing countries with lower wages. Mechanical shredding method is economically preferred in the developing countries. [12][18]

3.4.3 Pre-processing

Dismantling and pre-processing are interwoven; the slight difference is that pre-processing activities are last activities before end processing. For instance, in air conditioners and refrigerators, a very important pre-processing step is de-gassing stage because the refrigerants like CFC have to be removed with care in order to avoid emission. Also before end processing of appliances that contain CRT such as monitors and TVs, coatings in the panel glass are removed. Usually circuit boards and motherboards are manually removed before shredding to prevent losses of precious and special metals. [16] [18]

3.4.4 End Processing:

Some of the outputs of pre-processing are: steel scraps, aluminium scraps, structural components of drives, high grade precious metals fractions like contacts, copper cables and plastics. [15] These outputs are sent to end-processing operations that are capable of achieving efficient material recovery in an eco-friendly way. For instance, steel are sent to steel plants to produce secondary steel items while aluminium are sent to smelters. As for high- grade metal fractions, they are sent to pyrometallurgical and hydrometallurgical refineries for precious metal recovery. [15]

A very important component of end-processing is mechanical processing. Usually, this is an industrial operation that gives rise to greater percentage of concentrates of recyclable material. Typical mechanical processing plants have the following components: shredders, magnetic separators, eddy- current separators and air separators. [12]

Precious metals are extracted by means of chemical stripping using acids usually cyanides. This method strips the metal content from the material surface into solution. To reach metals embedded in components, the material is first finely milled. For instance, to mine gold from hard drives and motherboards, they are left in acid bath and left until they are fully dissolved. Other chemicals are then added to precipitate gold. [12][17]

Similar to chemical stripping is leaching. In this operation, useful materials are extracted by dissolving the solid waste in liquids. [12][18]

3.5. E-waste Recycling Plants

Several e-waste recycling plants are available. Characteristically, they combine best component dismantling and increased capacity to process large amount of e-waste in a cost effective way. It usually starts with feeding e-waste materials into a hopper from where it travels up a conveyor and dropped into a mechanical separator. Following this a series of screening and granulating machines. Expectedly, the whole system is enclosed and usually employs a dust collection system to ensure eco-friendliness.[1]

IV. EMERGING TRENDS IN E-WASTE THREATS AND OPPORTUNITIES

Nowadays households and businesses are generating electronic wastes like never before resulting in ever-increasing mountains of e-waste in urban areas and mounds of the same waste in rural areas. Up till now several developing countries are stilling undergoing their technological revolutions leading to rise in living standard and demand for electronic products.[19]

E-waste is a global threat. The trend is to ban the importation of e-waste and also preventing the use of toxic materials in computers and other electronics. The challenge is having a global standard on e-waste. What exists are regulations or laws in some states like California (USA) and other countries [20] The implication therefore is that any region that that lacks regulation turns itself into a global collection centre for e-waste. [21] Interestingly, some voluntary organizations are rising up to the occasion. For instance, Green Electronics Council has launched a program, Electronic Product Environment Assessment Tool (EPEAT). EPEAT was designed to provide standards for greener computers and also to keep e-waste out of landfills. [20] It encourages the manufacture of environmentally friendly electronics. This has resulted in the reduction of mercury but adopting a technology that eliminates mercury and uses light emitting diodes (LEDs) in computer screens. [20]
Another interesting trend focuses on packaging of products making them lighter than before and leading to decrease in the amount waste that goes to the landfills. [22]

Furthermore, there is an increasing awareness of the potential value of resources in e-waste thereby making it a business opportunity. E-waste recycling market has therefore received a boost, however with some challenges. For instance, to recover precious metals from e-waste, heavy investments are required and this tends to discourage investors [21]

V. CONCLUSION

E-waste cannot be eliminated as long as there is global population growth and increased dependence on electrical and electronic equipment that generate mountains of wastes. Recycling has remained the best option in e-waste management. Researches should be focused on developing technologies that enhance efficient e-waste recycling /valuable materials extraction and greener electronics and green computing. This e-waste management option is both eco-friendly and wealth generating. Many people seem to be uneducated concerning e-waste; there should therefore be increased awareness on the dangers in this waste material and the business opportunities in urban mining. Finally, International standards are urgently needed in order to control this global menace and encourage recyclers.

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