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Electrical and Electronics Product Waste Management

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Abstract: ***Increase in the end of life of electrical and electronic products depends on the economic growth of the country, population growth, market penetration, technology up-gradation, and obsolescence rates. It can be assumed that the disposal of electronic products is fundamentally driven by the production of new ones. The management of electronic waste has become an environmental concern in many developing countries as urbanization continues to take place. The situation is not so grim in the developed countries, as the laws are adequate to take care of the stocking, disposal and land filling of the end-of life electronics products. Moreover, availability of skilled recyclers and adequate technologies in those countries make the e-waste recycling a profitable business. Electrical and electronic waste (e-waste) is currently the largest growing waste stream. It is hazardous, complex and expensive to treat in an environmentally sound manner, and there is a general lack of legislation or enforcement surrounding it. Today, most e-waste is being discarded in the general waste stream.***

The e-waste containing toxic material that can have adverse impact to human health and environment, if not treat properly.

Keywords: Electrical and electronic products, end-of life electronics products, Electrical and electronic waste (WEEE),e-waste recycling

1. Introduction

Electronic Waste is commonly known as “e-waste”, it refers to various types of waste electrical and electronic products. There is no standard definition of e-waste. The Organization for Economic Co-operation and development (OECD) defines e-waste as “any appliance using an electric power supply that has reached its end-of-life”. The most widely accepted definition of e-waste is as per European Commission Directive: “electrical or electronic equipment, which is waste, including all components, subassemblies and consumables, which are part of the product at the time of discarding”.

It can be divided into seven classes which are listed as computer products, communication products, audio-visual products, household & similar electrical appliances, instruments measuring & monitoring products, electric tools, and wire & cable. And all the parts, components and materials that make up these products, those waste products and imperfections generated in the production process and defective products, etc. are all included. The very quality of electronic is variety and complexity[1]. With the rapid development of electronic industry, the continuous upgrading of electronic products lead to the elimination of more and more waste electronic products and electrical equipment around the world which would result in the formation of a large amount of electronic waste. Electronic waste has become the fastest growing garbage in the world. E-waste contains a large number of heavy metals, plastic, glass and other resources that can be recycled, but it also contains a number of toxic and harmful substances. These toxic and harmful substances can transfer into water, sediment and soil through wet and dry deposition and sewage disposal, etc., thus affecting the surrounding non-contaminated or less contaminated environment and food chain, and leading to the formation of potential risky areas with heavy metals and persistent organic pollutants. These risky areas as pollution sources would become long-term contamination to environment and damage to human health if they can’t be disposed properly, and this also is a waste of resources, so we must focus on these important issues.

In the last two decades, the global growth in electricaland electronic product production andconsumption has been exponential. This is largelydue to increasing market penetration of productsin developing countries, development of a replacementmarket in developed countriesand a generally high product obsolescence rate (United Nations Environment Program [UNEP]2007), together with a decrease in prices and the growth in internet use. Today, electrical and electronic waste is the fastest growing waste stream (about 4 per cent growth a year). About 40 million tons of e-waste is created each year [1]. E-waste comprises electrical appliances such as fridges, air conditioners, washing machines, microwave ovens, and fluorescent light bulbs; and electronic products such as computers and accessories, mobile phones, television sets and stereo equipment.

In general, large household appliances representthe largest proportion (about 50 per cent) of e-waste,followed by information and communications technologyequipment (about 30 per cent) and consumerelectronics (about 10 per cent). The compositionof e-waste is very diverse and differs across productlines and categories. Overall, it contains more than toxicity of many of the chemicals in e-waste isunknown. Broadly speaking, electronic products consistof ferrous and non-ferrous metals, plastics, glass,wood and plywood, printed circuit boards, concreteand ceramics, rubber and other items. Iron and steelconstitutes about 50 per cent of e-waste followed byplastics, non ferrous metals (13 per cent)and other constituents (UNEP, DTIE, 2007). Electronicproducts often contain several persistent, bio-accumulativeand toxic substances including heavymetals such as lead, nickel, chromium and mercury,and persistent organic pollutants (POPs) such as polychlorinatedbiphenyls (PCBs) and brominated flameretardants.

2. India Scenario

The growth of electronic waste is high in India, since it hasemerged as an IT giant and due to modernization of lifestyle.However, there is no proper disposal system in our country thathas led to enormous amount of electronic waste. There is a needto find a proper recycling and disposal technique, so that reducethe environmental pollution and health hazards [4].

Consumers desire new products with the latest features. Even though an existing product performed well, electronic equipment was replaced at an alarming rate. The electronics industry thrived on planned obsolescence and estimatedthe total number of Personal Computers (PCs) emanating eachyear from business and individual households in India will bearound 1.38 million, according to a report of confederation of Indianindustries, the total waste generated by obsolete electronicand electrical equipment (EEE) in India has been estimated to be146,000 tons per year. The results of field survey conducted inChennai, metropolitan cities of India to assess the average life of PC, Television (TV) and mobile phone shows that thelow incomehouseholds use the PC for 5.94 years, TV for 8.16 years and themobile phones for 2.34 years while, the upper class income usesthe PC for 3.21 years, TV for 5.13 years and mobile phones for 1.63years. Although the per-capita waste production in India is stillrelatively small, the total absolute volume of waste generated willbe huge. The growth rate of the mobile phones 80% is very highcompared to PC 20% and TV 18%. [6].

According to TRAI, India added 113.26 million new cellular customersin 2008, with an average of 9.5 million customers addedevery month. Cellular market grew from 168.11 million in 2003-04to 261.97 million in 2007-08[7]. In Urban Areas increased from 555.28 million at the end of Mar-14 to 559.77 million at the end of Jun-14, and Urban Tele-density also increased from 145.78 to 146.24. Rural subscription increased from 377.73 million to 383.18 million, and Rural Tele-density also increased from 43.96 to 44.50.

3. Risks to Human Health and the Environment

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 bi-accumulate 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.

4. Sources of E-WASTE

Electronic Waste (e-waste) is the term used to describe old, end-of-life electronic appliances such as computers, laptops, TVs, DVD players, mobile phones, mp3 players etc. which have been disposed of by their original users. Technically, electronic waste is only a subset of WEEE (Waste Electrical and Electronic Equipment). According to the OECD any appliance using an electric power supply that has reached its end-o f-life would come under WEEE. Acknowledging the benefits of IT revolution this section presents darker reality of information technology. Very speed of innovation that lies at the heart of computer manufacturer leads to the product obsolescence. The reality of computer life cycle reveals a hazardous life cycle. The dark side of high technological development of electronic industry, especially computer and mobile technology, is revealed in the form of polluted drinking water, waste discharges that cause harm to fish, birth defects, high rate of miscarriage and cancer among cluster workers. Rapid changes in computer technology and the emergence of new electronic goods, the growing dependence on information technology, increasing rates of consumption of electronic products have led to disastrous environmental consequences. This high tech benefits and boom in the market lead to extensive use of electronic goods, especially computers and mobile. All this is turning the face of the industry and collectively form a problem of electronic waste the percentage of waste that is technology-related is growing at an alarming rate. In a recent study researchers found that the volume of e-waste is increasing by 3 - 5% per year, which is almost three times faster than the municipal waste stream is growing generally.

The lifespan of a computer has shrunk from four or five years to about two years Electronics, the largest and fastest growing manufacturing industry in the world, aggressively promotes a culture of fast obsolescence and increased consumption. Large amounts of dangerous chemicals are present in computer and other electronic goods. The toxicity is due to lead, mercury, cadmium, hexavalent chromium (ChromiumVI), brominated flame retardants, plastic, PVC etc. A typical computer monitor may contain more than 6 percent lead by weight. In general, computer and electronic equipments are complicated assembly of more than 1000 materials, few of them are highly toxic such as chlorinated and brominated substances, toxic gases, photoactive and biological active materials acids plastics and plastic additives (Clean computer campaign). Each computer display contains an average of 4-8 pound of lead. Monitor glass contains about 20 percent lead by weight. When these components are illegally disposed and crushed in landfills, the lead is released into the environment, posing a hazardous legacy for current and future generations. About 70 percent of the heavy metals including mercury and cadmium, found in landfills come from electronic equipments discarded by the users. These heavy metals and other hazardous substances found in electronics items, contaminate ground water and pose environmental and public health risks, (Poison PC and Toxic TV) A single component of computer waste, Cathode Rays Tube (CRTs), has emerged as the leading edge of hazardous waste at the local, state, national and international level. CRTs are the glass Picture Tubes in computer monitors and other video display devices that amplify and focus high energy electrons beam to create the images, which we ultimately see in our screens. In order to protect consumers from radiation damages, the glass in CRTs contain lead compasses which is approximately 20 percent of each CRT. Lead is an example of heavy metal, a metallic element that is in pure form heavy. Lead is extremely toxic, may be taken into the body, where they tend to combine with and inhibit the functioning of particular enzymes. A minute amount can have severe physiological or neurological effects. (Lead in the environment). Lead tends to accumulate in the environment and has high acute and chronic effects on plants, animals and microorganisms. It causes damage to the central and peripheral nervous system, blood system, kidney and reproductive system in human. It also affects endocrine system and brain development among the children. (E-waste India Report, 2004). Mercury used in switches, circuit boards and in flat panel displays is released into the environment when burned or smelted into the environment. Similarly Beryllium is used in every electronic assembly which is released into the environment through dust emission, during crushing, cutting and burning operations. Circuit board and plastic casing having brominated flame retardant are source of dioxins and furans.

Carbon black in printers and toner is class 2b carcinogen and beryllium, commonly used in mother boards and finger clips, is a health hazard. Beryllium has, recently, been classified as a human carcinogen as exposure to it causes lung cancer. BFRs are among a group of bad actors specifically known as persistent organic pollutants. Animal experiments have shown that a number of these chemicals affect thyroid function, have estrogenic effects, and act through the same receptor-mediated pathways as does dioxin, which is among the most potent animal carcinogens known. Further, environmentalists charge that electronics recyclers have not really come to grips with the special environmental problems that they say are inherent in the prolific use of BFRs in e-waste plastics. "There are presently no studies on the ultimate fate of BFRs when they are melted or burned in recycling or incineration applications. A closer look at some of electronic waste reveals that commonly used recycling practices can harm the environment more than the waste itself. Investigation conducted by several places found that the workers often used acid bath and other metals, washing the residue directly in to nearby rivers and other water bodies. Component that cannot be recycled are sent to landfills or burned in the open, releasing additional toxins in the environment.

Extension of life span is the key strategy in managing the gamut of environment impact. Social and financial forces for computer waste management requires efficient partnership between public and private sectors as well as networked activities between scholars, business persons and policy makers around the world. According to Xinhua News Agency, China has generated roughly 1.1 million tons of ewaste annually since 2003, including 5 million TV sets, 4 million refrigerators, 5 million washing machines, 5 million computers, and tens of millions of mobile phones and it will continue to pile up. Greenpeace estimates that by 2010, there will be 178 million new computer users in China alone. The U.S. National Safety Council predicts that in that country alone between 315 million and 680 million computers will become obsolete within the next few years. The waste will contain more than 2 billion kg of plastic, 0.5 billion kg of lead, 1 million kg of cadmium, 0.5 million kg of chromium and nearly 200,000 kg of mercury. Environmentalists also worry that with the popularity of new liquid crystal display technology, an increasing number of old monitors using cathode ray tubes are ending up in the trash. The disposal problem regarding the tens of millions of first generation mobile phones are today‟s emerging challenge. · Total estimated e-waste generated from computer , television, refrigerator and washing machines is 1,46,180 tones and is expected to go up to around 1,600,000 by 2012.

5. Recycling/Disposal of WEEE

It can be divided into two steps,
(1). Dismantling/disassembly,
(2). Treatment method/upgrading.

1) 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: combination and separation of materials using mechanical/physical and/or metallurgical processing to prepare the materials for refining processing. The followingare 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. Theshedder is often used to produce small even fine-sizedparticles. The rage of devices in usage depends strongly onthe composition of WEEE, mechanical process is ideal forupgrading recycling WEEE because it can yield full material recovery including plastics (light fraction), nonferrousmetals, and iron. The obtained fractions are enriched in certain materials,and have to be further processed using other treatmentmethods such as pyrometallurgy or hydrometallurgy, themechanical upgrading produce dust formation/gas emission(dioxins/furan), and noise [3]. Also in particle separationmany of the traditional recycling separation processes canbe used such as screening, shape separation and magneticseparation [2].

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[13] or great amount of energy consumption 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].

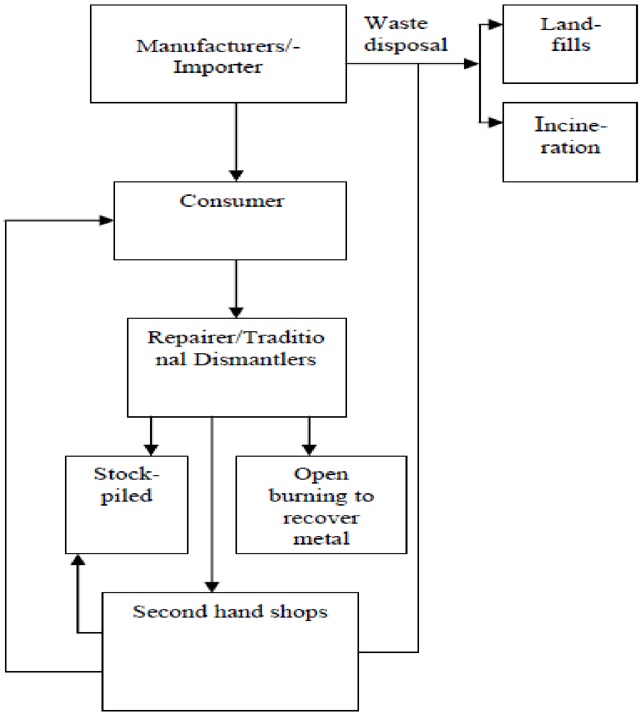

Figure 1: Recycling/Disposal method of waste home appliances

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.

6. Conclusions

The e-waste recycling is becoming non-viable business in western countries due to high cost of labour, transportation, electric power etc. The decreasing percentage of precious metal content in the modern electronics devices is the other concern for the viability of the business. The volume of e-waste is, however, enhancing alarmingly in the world. Due to presence of the toxic elements, it is all the more dangerous for the society to stock them without carrying out appropriate disposal. It is also observed that the growth of consumption of the electronics products and subsequent disposal are increasing in the developing countries, whereas, the consumption rate in the developed countries are getting saturated. The volume of the e-waste is thus increasing alarmingly in the developing countries due to their own as well as imported disposable electronics hardware products.

It is therefore appropriate to devise a holistic approach to manage and recycle the e-waste in self-sustained manner to ave the environment and the human health. The developed countries have technology and infrastructure, whereas, the cost of labour, transporting, processing etc. are cheaper in the developing countries. It is, therefore, proposed in this article to manage the ewaste involving non-formal sectors at developing countries and formal sectors in the developed countries. In the proposed approach, non-formal units will be involved in collection, disassembly and segregation of ewaste and earn appropriate incentive for their efforts.

The non-formal sector will also be responsible for preparing the homogenous powder of the PCB, assessing their precious metal content as well as obtaining certificate for attracting formal sector to buy their powder in the best market price. It will encourage e-waste collector to earn maximum without indulging in extracting gold, silver etc. through burning and chemically exposing processes. The harmful impact on environment and to human being will be reduced. This is an outsource model of e-waste recycling, where formal sector will only concentrate on the core activity of PCB recycling. The cost of the initial phase of the processes can be saved and the profitability will enhance. Enough PCBs materials will be available for the established recyclers at developed countries. It would thus address the shortage of materials for the formal units. The zero/minimum waste disposal to landfills will be achieved through this model. The proposed approach would bring mutual trust between non-formal and authorised metal extractors.

Since the non-formal recyclers are dealing majoramount of e-waste in India, the said approach will impact on the majority of the e-waste management value chain. Moreover, nearly 95% of e-waste by weight will besegregated and then managed/ recycled by the conventionalmunicipality waste management techniques. Thesaid approach is, therefore, will be impacted majorrecycling management mechanism. Since the primitivemethods are avoided, the recovery percentage of the precious metals will also be improved to a significant level. The metals (palladium, platinum, tantalum etc.) those are present in the trace level will also be recovered. At present these metals are lost due to lack skill level. The employment of the manpower involved in the non-formal sector will also remain.

References

[1] N. N. Tippayawong, and P. Khongkrapan, “Development of a laboratory scale air plasma torch and its application to electronic waste treatment.” International Journal for Environmental Science and Technology, 2009, 6(3), pp. 407-411.
[2] R. B. Balakrishnan, K. P. Anand, and A. B. Chiya. “Electrical and electronic waste: a global environmental problem.” Journal of Waste Management and Research, vol. 25, 2007, pp. 307-317.
[3] H.Antrekowitsch, M. Potesser, W. Spruzina, and F. Prior, “Metallurgical recycling of electronic scrap,” The Minerals, Metalsand Materials Society (TMS), 2006, pp. 899-904.
[4] [L.Xianbing, T. Masaru, and M. Yasuhiro. “Electrical and electronic waste management in China: progress and the barriers to overcome.” Journal of waste management and Research, vol. 24, 2006, pp. 93-100.
[5] L. P. E. Yadong, B. R. Jay, K. W. Aaron, and Y. Pao-Chiang, “TCLPHeavy metal leaching of personal computer components.” Journal of Environmental Engineering, 2006, 132 (4). pp. 497-498.
[6] EU Directive 2002/96/EC of European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipments (WEEE). 13/02/2003, 2002. Available: http://www.europe.eu.int/eurlex/en/.
[7] Industry Council for Electronic Equipment Recycling (ICER) 2000Status Report. Available: http://www.icer.org.uk.
[8] H. M. Veit, T. R. Diehl, A. P. Salami, J. S. Rodrigues, and A. M.Bernardes, “Utilization of magnetic and electrostatic separation in therecycling of printed circuit boards scrap.” Journal of wastemanagement, vol. 25, 2005, pp. 67-68.

[9] E. Forssberg, and J. Cui, "Mechanical recycling of waste electric andelectronic equipment: a review." Journal of hazardous Materials, Bvol. 99, 2003, pp. 243-262.

[10] M. Murray, "Electronics comes clean-solving the E-waste crisis inCalifornia." Journal of Waste Management, 2004 March-April, pp.59-65.

[11] C. Nnorom, and O. Osibanjo, "Overview of electronic waste (ewaste)management practices and legislations, and their poorapplications in the developing countries." Resources, Conservationand Recycling, 2008, 52 (6). pp. 843-858.

[12] J. O. Chi, O. L. Sung, S. Y. Hyung, J. H. Tae, and J. K. Myong,"Selective leaching of valuable metals from waste printed circuitboards." Journal of the Air and Waste Management Association, vol.53, 2003, pp. 897-898.

[13] L. Ching-Hwa, C. Chang-Tang, F. Kuo-Shuh, and C. Tien-Chin, "Anoverview of recycling and treatment of scrap computers." Journal ofHazardous Materials, B vol. 114, 2004, pp. 93-99.

[14] T.Matsuto, C. H. Jung, and N. Tanaka, "Material and heavy metalbalance in a recycling facility for home electrical appliances." Journalof waste Management, vol. 24, 2004, pp. 425-436.

[15] Fernanda, B. Luisa, C. Anna, and L. Isabella, "Cathode ray tubeglass recycling: an example of clean technology." Journal of WasteManagement and Research, vol. 23, 2005, pp. 1-4.

[16] L. J. P. John. (1999, November 15) Reclaiming End-of-Life cathoderay tubes (CRTs), and Electronics: A Florida Update. HazardousMaterials Management Conference Tucson, Arizona.

[17] E. M. Stephen, J. Young-Chul, G. T. Timothy, and C. IL-Hyun,"Characterization of lead leachability from cathode ray tubes usingthe toxicity characteristic leaching procedure." Journal ofEnvironmental Science and Technology, 2000, 34 (20). pp. 4376-4377.

[18] Association of Plastics Manufacturers in Europe (APME) (2003). Ananalysis of plastics consumption and Recovery in Europe. APME,Brussels, Belgium.

[19] Association of Plastics Manufacturers in Europe (APME) (2000).Plastics: Insight into Consumption and Recovery in Western Europe.APME, Brussels, Belgium. Available: http://www.sciencedirect.com/-bbib5.

[20] A.O. Oladele, "Public health and environmental benefits of adoptinglead-free solders." The Minerals, Metals and Materials Society (TMS),2007, pp. 13-15.

[21] J. R. Carl. (2002). Lead in the home garden and urban soilenvironment. University of Minnesota Extension Service [online]. pp.1-3Available:http://www.extension.uwn.edu/distribution/ horticulture/DG2543.html.

[22] I.C. Nnorom, J. C. Igwe, and C. G. Oji-Nnorom, "Trace metalscontents of facial (make-up) cosmetics commonly used in Nigeria."African Journal of Biotechnology, 2005, 4(10). pp. 1131-1133.

[23] F. Mark. (2000, December 17th) Cadmium toxicity threateningwildlife in Rocky Mountains. Oregon State University (OSU) Newsand Communication Services.

[24] Blazovics, M. Abaza, P. Sipos, K. Szentmihalyi, E. Feher, and M.Szilagyi, "Biochemical and Morphological changes in liver and gallblabber bile of broiler chicken exposed to heavy metals (cadmium,lead and mercury)." Journal of Element and Electrolytes, vol.1, 2002,pp. 4-5.

[25] E. Hsu, and C. –M. Kuo, "Recycling rates of waste home appliancesin Taiwan." Journal of Waste Management, vol. 25, 2005, pp. 53-64.

[26] M O. C. Ogwuegbu, and F. Chileshe, "Coordination chemistry inmineral processing." Journal of Mineral Processing, Extraction andMetal Recovery, vol. 21, 2000, pp.503-513.

[27] Secretariat of the Basel Convention 1999. Code of Practice for theEnvironmentally Sound management of Asbestos ContainingMaterials in the Caribbean. Secretariat of the Basel Convention,Geneva, and SBC No.99: Asbestos: 001