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ORIGINAL ARTICLE

ELECTRONIC WASTE: ITS HEALTH HAZARDS AND MANAGEMENT FOR SUSTAINABLE ERA

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ABSTRACT: In a world of technological advancement and countless gadgets, the quest to acquire the latest models is overwhelming: a slimmer desktop, new music system, televisions and so on. However the downside of the constant quest for better gadgetry is the rapidly piling hazardous wastes in our landfills. Discarded electronics are generated when users or owners of the products decide that they no longer want them. E-waste encompasses ever growing range of obsolete electronic devices such as computers, servers, main frames, monitors, TVs and monitor devices, telecommunication devices such as cell phones and pagers, calculators, audio and video devices, printers, scanners, copiers and fax machines besides refrigerators, air conditioners, washing machines and microwave ovens, E-waste also covers recording devices such as DVDs, CDs, floppies, tapes, printing cartridges, military electronic waste, automobile catalytic converters, electronic components such as chips, processors, mother boards, printed circuit boards, industrial electronics such as sensors, alarms, sirens, security devices, automobile electronic devices. In this manuscript impact of E-waste on health and environment, and various management strategies have been delineated.

KEYWORDS: CFCs; PCBs; Heavy metals; BFRs; Health hazards; Environmental impacts; Renewable materials; Material management

INTRODUCTION

E-waste is considered dangerous as certain components of electronic products are hazardous. E-waste is of major concern due to several significant issues, including the increasing rate and volume of materials disposed to landfills, the toxicity of some of the materials present in this type of waste product, the variability in regulatory control on disposal methods, and relatively common practice of transferring E-waste components offshore to recycling facilities that may lack adequate quality control, environmental protection and safety standards. The volume of E-waste is increasing with the growth of electronics industry and where fashion and technological obsolescence have increased the new purchases and upgrading of existing products are usually avoided. This has led to landfills over choked with discarded products. E-waste for short – or Waste Electrical and Electronic Equipment (WEEE) – is the term used to describe old, end-of-life or discarded appliances using electricity. It includes computers, consumer electronics, fridges, etc. which have been disposed of by their original users. While there is no generally accepted definition of E-waste, often it is associated with relatively expensive and essentially durable products used for data processing, telecommunications or entertainment in private households and businesses. "E-waste" is used as a generic term embracing all types of waste containing electrically powered components. E-waste contains both valuable as well as harmful materials which require special handling and recycling methods. Wastes are hazardous wastes when they exhibit one or more of the following characteristic: toxicity, ignitibility, corrosivity or reactivity. The main concerns when electronic wastes are worn-out or discarded are the hazaedous materials that they contain-CFCc (chlorofluorocarbons), PCBs (polychlorinated biphenyls), lead (Pb), mercury (Hg), tin (Sn), cadmium (Cd), hexavalent chromium (Cr)VI in circuits boards, plastics, brominated flame retardants (BFRs) and the volume or space in landfill that they will occupy (Third World Network, 1991).

Realizing the intensity of WEEE many developed countries have banned the disposal of E-waste in landfills. The use of electronic devices has increased rapidly in recent decades and the disposal of electronic devices such as PCs, cell

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phones, TVs, and other entertainment devices such as music centres and computer games have become a major problem around the world. Every year around 20 to 50 million tonnes of electronic waste are generated worldwide, bringing significant risks to human health and the environment. It is estimated that more than 500 million computers will become obsolete in the US alone between 1997 and 2007. This is growing at a rapid rate because the global computer market is far from saturation and the average lifespan of a PC is decreasing rapidly 4-6 years in 1997 to only 2 years in 2005. Composition of WEEE is very diverse and differs in products across different categories. It contains more than 1000 different substances, which fall under "hazardous" and "non-hazardous" categories. Iron and steel constitutes about 50% of the WEEE followed by plastics (21%), nonferrous metals (13%) and other constituents. Non-ferrous metals consist of like copper, aluminium, and precious metals e.g. silver (Ag), gold (Au), platinum (Pt), palladium (Pd), etc. The presence of elements like lead (Pb), mercury (Hg), arsenic (As), cadmium (Cd), selenium (Se), and hexavalent chromium (Cr)VI, halogenated substances (e.g. CFCs), polychlorinated biphenyls, plastic and circuit boards that contain brominated flame retardants (BFRs) beyond threshold quantities in WEEE/E- waste classifies them as hazardous waste. BFR can give rise to dioxins and furans during incineration (Third World Network, 1991; Balasubramaniyan and Malini, 2009).

HEALTH IMPACTS

Invariably WEEE is dumped in developing countries the technology adopted to recycle the waste is crude and done manually by the backyard recycling centres and informal sector. Heavy metals like lead, mercury can cause damage to the central and peripheral nervous system. Lead in particular has serious effects on brain development in children. It damages the circulatory system, kidneys and reproductive system. Mercury can damage the kidney and exposure to pregnant mothers could possibly affect foetal development. When in contact with water, it converts into the more lethal methylmercury, would become a part of food chain. Exposure to beryllium (Be), barium (Ba), and BFRs can cause serious health complications. Effects of E-waste constituents on health are depicted in Table 1.

Table 1: E-waste constituents and their effects on health.

Sources of E-waste	Constituents	Health Effects
Solder in printed circuit boards, glass panels ad gasket in computer monitor	Lead (Pb)	Damage to central and peripheral nervous systems, circulatory systems and kidney damage. Affects brain development of children
Chip resistors and semiconductors	Cadmium (Cd)	Accumulates in kidney and liver, causes neural damage, Teratogenic
Relays and switches, printed circuit boards	Mercury (Hg)	Chronic damage to brain, Respiraratory and skin disorders due to bioaccumulation in fishes
Corrosion protection of untreated and galvanized steel plates, decorator or hardener for steel housings	Hexavalent chromium (Cr) VI	Asthmatic bronchitis, DNA damage
Cabling and computer housing	Plastic including PVC	Burning produces dioxin, Causes reproductive problems, Damage Immune system, Interfere with regulatory hormones
Plastic housing of electronic equipments and circuit boards	BFRs	Disrupts endocrine system functions
Front panel of CRTs	Barium (Ba)	Short term exposure causes muscular weakness, Damage to heart, liver and spleen
Mother board	Beryllium (Be)	Lung cancer, Inhalation of fumes causes chronic beryllium disease (berylliocosis), Skin disease such as warts

Source: (www.basel.int)

IMPACT OF E-WASTE ON THE ENVIRONMENT

- Incineration of E-waste can emit toxic fumes and gases, thereby polluting the surrounding air mainly in developing and developed countries, where large consignments of E-waste in the form of second hand computers are being imported to reduce the digital divide. Developed countries are exporting hazardous waste to developing countries in Asia and Africa where there are no stringent environmental and safety regulations (Elizabeth, 2006; Freeman, 1989).
- Computer wastes that are land filled would leachate and eventually pollute the groundwater. Acids and sludge obtained

from melting computer chips, if disposed on the ground causes acidification of soil (Elizabeth, 2006).

- For example, Guiyu, Hong Kong a thriving area of illegal E-waste recycling is facing acute water shortages due to contamination of water resources. This is due to the disposal of recycling wastes such as acids, sludge, etc. in rivers. Now water is being transported from faraway towns to cater to the demands of the population (Elizabeth, 2006; Freeman, 1989).
- Improperly monitored landfills can cause environmental hazards. Mercury will leach when certain electronic devices, such as circuit breakers are destroyed. The same is true for polychlorinated biphenyls (PCBs) from condensers. When BFR plastic or cadmium containing plastics are land filled, both polybrominated diphenyl ethers (PBDE) and cadmium may leach into the soil and groundwater. Not only does the leaching of mercury poses specific problems, the vaporization of metallic mercury and diethylene mercury, both part of WEEE is also of concern (Balasubramaniyan and Malini, 2009).
- In addition, uncontrolled fires may arise at landfills and this could be a frequent occurrence in many countries. When exposed to fire, metal and other substances, extremely toxic dioxins and furans can be emitted (Balasubramaniyan and Malini, 2009).
- The most dangerous form of burning E-waste is the open-air burning of plastics in order to recover copper and the other metals. The toxic fall-out from the open air burning affects the local environment and broader global air currents, depositing highly toxic byproducts in many places throughout the world (Balasubramaniyan and Malini, 2009).

ENVIRONMENTAL IMPACTS

According to Basal Action Network (BAN), 'Exporting Harm' – containers of E-waste (computers) arrive from USA every month. It was found that 75% of the imports were junk. All these obsolete computers were either burned or discarded with no environmental safeguards, resulting in release of cancer causing chemicals and substances which were harmful for the hormonal and immune system. E-waste recycling and disposal operations found in India, China ad African countries are extremely polluting due to open burning, toxic solders. Ensure that the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement; Do not allow the export of hazardous wastes or other wastes to a State or group of State belonging to an economic and/or political integration organization that are Parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner, according to criteria to be decided on by the Parties at their first meeting.

The Basal Convention has established a control system for transboundary movements of hazardous and other wastes, based on the principle of prior informed consent of a State of import and state of transit before exports of wastes can take place. To this end, the Convention has established a notification procedure, functioning through the Complement Authorities designated by each. The south has emerged as dumping grounds of E-waste whilst the north has been enforcing stringent laws to tackle the problem (Balasubramaniyan and Malini, 2009).

BASEL CONVENTION

In view of the ill-effects of hazardous wastes to both environment and health, several countries exhorted the need for a global agreement to address the problems and challenges posed by hazardous wastes. Also, in the late 1980s, a tightening of environmental regulations in industrialized countries led to a dramatic rise in the cost of hazardous waste disposal. Searching for cheaper ways to get rid of the wastes, "toxic traders" began shipping hazardous waste to developing countries. International outrage following these irresponsible activities led to the drafting and adoption of strategic plans and regulations at the Basal Convention. The Convention secretariat, in Geneva, Switzerland, facilitates and implementation of the Convention and related agreements. It also provides assistance and guidelines on legal and technical issues, gathers statistical data, and conducts training on the proper management of hazardous waste.

The Basal Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is the most comprehensive global environmental agreement on hazardous and other wastes. The Convention has 170 Parties and aims to protect human health and the environment against the adverse

effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes. The Basal Convention came into force in 1992. The Draft requires action at all levels of society; training, information, communication, methodological tools, capacity building with financial support, transfer of know-how, knowledge and sound, proven cleaner technologies and processes to assist in the effective involvement and coordination by all concerned stakeholders as essential for achieving the aims of the Basal Declaration within the approach of common but differentiated responsibility (Third World Network, 1991).

The Basal Convention brought about a respite to the transboundary movement of hazardous waste. India and other countries have ratified the Convention. However, US is not a party to the ban and is responsible for disposing hazardous waste, mainly, E-waste to Asian countries even today. Developed countries such as US should enforce stricter legislations in their own country for the prevention of this horrifying act. In the European Union where the annual quantity of E-waste is likely to double in the next 10 years, the European Parliament recently passed legislation that will require manufactures to take back their electronic products when consumers discard them. This is called Extended Producer Responsibility. It also mandates a timetable for phasing out most toxic substances in electronic products. Even with rules and convention the south has emerged as dumping grounds of E-waste whilst the norths have been enforcing stringent laws to tackle the problem.

MANAGEMENT OF E-WASTE

It is estimated that 75% of the electronic items are stored due to uncertainty of how to manage it. These electronic junks lie unattended in houses, offices, warehouses, etc. and normally mixed with household wastes, which are finally disposed off at landfills. This necessitates implementable management measures. In industries management of E-waste should begin at the point of generation. This can be done by waste minimization techniques and by sustainable product design. Waste minimization in industries involves adopting, inventory management, production process modification, volume reduction, recovery and reuse.

INVENTORY MANAGEMENT

Proper control over the materials used in the manufacturing process is an important way to reduce waste generation (Freeman, 1989; Third World Network, 1991), by reducing both the quantity of hazardous materials used in the process and the amount of excess raw materials in stock, the quantity of waste generated can be reduced. This can be done in two ways i.e. establishing material-purchase review and control procedures and inventory tracking system. Developing review procedures for all material purchased is the first step in establishing an inventory management program. Procedures should require that all material be approved prior to purchase. In the approval process all production materials are evaluated to examine if they contain hazardous constituents and whether alternative non-hazardous material are available. Another inventory management procedure for waste reduction is to ensure that only the required quantity of a material is ordered. This will need the establishment of a strict inventory tracking system. Purchase procedures must be implemented which ensure that materials are ordered only on an as-needed basis and that only the amount needed for a specific period of time is ordered.

PRODUCTION-PROCESS MODIFICATION

Changes can be made in the production process, which will reduce waste generation. this reduction can be accomplished by the changing the materials used to make the product or by the more efficient use of input materials in the production process or both. Potential waste minimization techniques can be broken down into three categories:

- Improved operating and maintenance procedures,
- Material change and
- Process-equipment modification

Improvements in the operation and maintenance of process equipment can result in significant waste reduction. This can be accomplished by reviewing current operational procedures or lack of procedures and examination of the production process for ways to improve its efficiency. Instituting standard operation procedures can optimize the use of raw materials in the production process and reduce the potential for materials to be lost through leaks and spills. A strict maintenance program, which stresses corrective maintenance, can reduce waste generation caused by equipment failure. An employee-training program is a key element of any waste reduction program. Training should include correct operating and handling procedures, proper equipment use, recommended maintenance and inspection schedules, correct process control specifications and proper

management of waste materials. Hazardous materials used in either a product formulation or a production process may be replaced with a less hazardous or non-hazardous material. This is a very widely used technique and is applicable to the most manufacturing processes. Implementation of this waste reduction technique may require only some minor process adjustments or it may require extensive new process equipment.

Installing more efficient process equipment or modifying existing equipment to take advantage of better production techniques can significantly reduce waste generation. New or updated equipment can cause process materials more efficiently producing less waste. Additionally such efficiency reduces the number of rejected or off-specification products, thereby reducing the amount of materials which has to be reworked or disposed of. Modifying the existing process equipment can be a very cost-effective method of reducing waste generation. In many cases the modification can just be relatively simple changes in the way the materials are handled within the process to ensure that they are not wasted. For example, in many electronic manufacturing operation, which involve coating a product, such as electroplating or painting, chemicals are used to strip off coating from rejected products so that they can be recoated. These chemicals, which can include acids, caustic, cyanides, etc. are often hazardous waste and must be properly managed. By reducing the number of parts that have to be reworked, the quantity of the waste can be significantly reduced (Tietenberg, 2004).

8.1. Volume Reduction

Volume reduction includes those techniques that remove the hazardous portion of waste from a non-hazardous portion. These techniques are usually to reduce the volume, and thus the cost of disposing of a waste material. The techniques that can be used to reduce waste-stream volume can be divided into 2 general categories: source segregation and waste concentration. Segregation of wastes is in many cases a simple and economical technique for waste reduction. Waste containing different types of metals can be treated separately so that the metal value in the sludge can be recovered. Concentration of a waste stream may increase the likelihood that the material can be recycled or reused (Tietenberg, 2004).

8.2. Recovery And Reuse

This technique could eliminate waste disposal costs, reduce raw material costs and provide income from a salable waste. Waste can be recovered on-site, or at an off-site recovery facility, or through inter industry exchange. A number of physical and chemical techniques are available to reclaim a waste material such as reverse osmosis, electrolysis, condensation, electrolytic recovery, filtration, centrifugation, etc. for example, a printed circuit board manufacturer can use electrolytic recovery to reclaim metals from copper and tin-lead plating bath. However recycling of hazardous products has little environmental benefit if it simply moves the hazards into secondary products that eventually have to be disposed of. Unless the goal is to redesign the product to use non-hazardous materials, such recycling is a false solution.

SUSTAINABLE PRODUCT DESIGN

Minimization of hazardous wastes should be at product design stage itself keeping in mind the following factors:

9.1. Rethink The Product Design

Efforts should be made to design a product with fewer amounts of hazardous materials. For example, the efforts to reduce material use are reflected in some new computer designs that are flatter, lighter and more integrated. Other companies' purpose centralized networks similar to the telephone system.

9.2. Use Of Renewable Material And Energy

Bio-based plastics are plastics made with plant-based chemicals or plant-produced polymers rather than petro-chemicals. Bio-based toners, glues and inks are used more frequently. Solar computers also exist but they are currently very expensive.

9.3. Use Of Non-Renewable Materials That Are Safer

Because many of the materials used are non-renewable, designers could ensure the product is built for re-use, repair and/or upgradability. Some computer manufacturers such as Dell and Gateway lease out their products thereby ensuring they get them back to further upgrade and lease out again.

MANAGEMENT OPTIONS AND CONCLUSION

Considering the severity of the problem, it is imperative that certain management options be adopted to handle the bulk E-wastes. Following are some of the management options suggested for the government, industries and the public.

10.1. Responsibilities Of The Government

- Governments must encourage research into the development and standard of hazardous waste management, environmental monitoring and the regulation of hazardous waste-disposal.
- Governments should enforce strict regulations against dumping E-waste in the country by outsiders.
- Governments should enforce heavy fines levied on industries, which do not practice waste prevention and recovery in the production facilities.
- Polluter pays principle and extended producer responsibility should be adopted.
- Government should encourage and support NGOs and other organizations to involve actively in solving the nation's E-waste problems.
- Uncontrolled dumping is an unsatisfactory method for disposal of hazardous waste and should be phased out.
- Governments should explore opportunities to partner with manufactures and retailers to provide recycling services.

10.2. Responsibilities And Role Of Industries

Generators of wastes should take responsibility to determine the output characteristics of wastes and if hazardous, should provide management options. All personnel involved in handling E-waste in industries including those at the policy, management, control and operational levels, should be properly qualified and trained. Companies can adopt their own policies while handling E-wastes. Several countries have enacted legislations to regulate the volume of wastes generated. Developing cleaner technologies and safer recycling methods could be made possible by manufactures/ producers. Leading computer companies like Dell has taken responsibility for free recycling of products. Cleaner recycling plants reduce the burden of environmental pollution and there could be recovery of valuable metals. Extended producer responsibility is an important tool to reconcile environmental protection and economic growth. Responsible management of products and processes from an environmental point of view can stimulate greater awareness throughout the company, improve corporate creditability and reputation, enhance business development opportunities and facilitate dialogue and partnership with key stakeholders. Companies can be more environmentally responsible in different ways, including the analyzing of potential environmental impacts of production processes and products, restricting an activity whose impact on the environment is uncertain, promoting environmentally sound technologies , implementing cleaner production and ensuring transparency and complete communication with stakeholders. Apply precautionary approaches in different activities regarding products and processes (Tietenberg, 2004; Third World Network, 1991):

- Adopt the same operating standards regardless of location.
- Improve supply-chain management.
- Facilitates technology improvement and transfer.
- Contribute to environmental awareness in company locations.
- Communicate with different stakeholders.
- Standardize components for easy disassembly.
- Re-evaluate 'cheap products' use, make product cycle 'cheap' and so that it has no inherent value that would encourage a recycling infrastructure.
- Create computer components and peripherals of biodegradable materials.
- Utilize technology sharing particularly for manufacturing and de manufacturing.
- Encourage / promote / require green procurement for corporate buyers.
- Manufacturers, distributors and retailers should undertake the responsibility of recycling/ disposal of their own products.
- Manufactures of computer monitors, TV sets and other electronic devices containing hazardous materials must be responsible for educating consumers and the general public regarding the potential threat to public health and the environment posed by their products. At minimum, all computer monitors, TV sets and other electronic devices containing hazardous materials must be clearly labelled to identify environmental hazards and proper material management.

10.3. Responsibilities Of The Citizen

Waste prevention is perhaps more preferred to any waste management option including recycling.

- Donating electronics for reuse extends the lives of valuable products and keeps them out of the waste management system for a longer time.
- Reuse, in addition to being an environmentally preferable alternative, also benefits society.
- E-waste should never be disposed with garbage and other household wastes. This should be segregated at the site and sold donated to various organizations.

- While buying electronic products consumers should opt for those that are made with fewer toxic constituents use recycled content are energy efficient are designed for easy upgrading or disassembly utilise minimal packaging offer leasing or take back options have been certified by regulatory authorities. For upgrading their computers or other electronic items to the latest versions rather than buying new equipment.
- NGOs should adopt a participatory approach in management of E-waste.

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