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E-Waste: Reduce, Recycle & Reuse

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Abstract:

The production of electrical and electronic equipment (EEE) is one of the fastest growing global manufacturing activities. Rapid economic growth, coupled with urbanization and a growing demand for consumer goods, has increased both the consumption and the production of new electronic gadgets providing our society with more comfort with easy information, acquisition and exchange. However the knowledge society is creating its own toxic footprints by generating E-waste which is emerging as a new environmental challenge for the whole world. The increasing 'market penetration' in the developing countries, 'replacement market' in the developed countries and 'high obsolescence rate' make e-waste one of the fastest waste streams.E- Waste contains very harmful and hazardouschemicals that come into environmentdue to its improper recycling. This new kind of waste is posing a serious challenge in disposal and recycling to both developed and developing countries. This review present an overview of the problem and analyze the current progress on E-waste management.

Key Words: *E-waste, environmental challenges, developing countries, India, recycle, reuse*

Introduction

Electronic and information technology industry is being widely recognized as main driver of the human civilization in the 21st century. This industry has been the power house of the global economy. Software and hardware part of it has touched most of the parts of social,technical, economic and natural environment. Exponentially increasing production of electronic equipment has posed major challenges of proper disposal of the E-waste produced by this industry. Electronic waste [1][2] may be defined as anything that runs on electricity/battery or has wire and completed its life. The electronic and electrical goods are largely classified under three major heads, as: 'white goods,' comprising of household appliances like air conditioners, dishwashers, refrigerators and washing machines; 'brown goods,' comprising of TVs,

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camcorders, cameras, etc.; ‘grey goods,’ like computers, printers, fax machines, scanners, etc. The grey goods are comparatively more complex to recycle due to their toxic composition.[3]

These e-waste items has been classified with respect to 26 common components found in them. These components form the ‘building blocks’ of each item and therefore they are readily ‘identifiable’ and ‘removable.’ These components are metal, motor/ compressor, cooling, plastic, insulation, glass, LCD, rubber, wiring/electrical, concrete, transformer, magnetron, textile, circuit board, fluorescent lamp, incandescent lamp, heating element, thermostat, brominated flamed retardant (BFR)-containing plastic, batteries, CFC/HCFC/HFC/HC, external electric cables, refractory ceramic fibers, radioactive substances and electrolyte capacitors (over L/D 25 mm).

Industrial revolution followed by the advances in information technology during the last century has radically changed people's lifestyle. Although this development has helped the human race, mismanagement has led to new problems of contamination and pollution. The technical process acquired during the last century has posed a new challenge in the management of wastes. For example, personal computers (PCs) contain certain components, which are highly toxic, such as chlorinated and brominated substances, toxic gases, toxic metals, biologically active materials, acids, plastics and plastic additives. The hazardous contents [4] [5] of these materials pose an environmental and health threat. Thus proper management is necessary while disposing or recycling e-wastes. The aim of this article is to spread awareness among our readers about the various issues involved in generation and management of E-waste and pose some concrete suggestions.

Recent Studies

Debate continues over the distinction between"commodity" and "waste" electronics definitions. Some exporters are accused of deliberately leaving difficult-to-recycle, obsolete, or non-repairable equipment mixed in loads of working equipment. Protectionists may broaden the definition of "waste" electronics in order to protect domestic markets from working secondary equipment. The high value of the computer recycling subset of electronic waste can help pay the cost of transportation for a larger number of worthless pieces than can be achieved with display devices, which have less scrap value.

By 2017,the global volume of discarded refrigerators, TVs, cell phones,computers, monitors and other electronic waste will weigh almost as much as 200 Empire State Building [6].The data gathered by UNO. and science organisations in a partnership known as the StEP “Solving the E-Waste Problem Initiative” predicts E- waste generation swell by a third in the next five years ,led by the U.S. and China The StEP Initiative forecasts that by 2017, the world will produce about 33 percent more e-waste, or 72 million tons (65 million metric tons). China currently leads the world in production of electrical and electronic equipment. In 2012, China produced about 12.2 million tons (11.1 million metric tons), followed by the U.S. with about 11 million tons (10 million metric tons).[6]

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However, the United States eclipses China in e-waste generation, because more products previously put on the market in the U.S. are likely to be retired. In 2012, the U.S. produced about 10.4 million tons (9.4 million metric tons), versus China's 8 million tons (7.3 million metric tons).

The U.S. generated the seventh highest amount of e-waste per person — about 66 lbs. (30 kg) per capita.

About 258.2 million units of used computers, monitors, TVs and cell phones in 2010, 171.4 million of which were collected for recycling, and 14.4 million were exported, according to the report. [Green Guide to Holiday Electronic Gifts (Op-Ed)]

The U.S. is a major exporter of used electronics. The U.S. exports more CRT (cathode ray tube) monitors by weight than any other product, and more cell phones than any other electronics product in terms of numbers.

Tracking the world's E- Waste generation(2017 total, in millions of tons)

Dynamics of E- Waste generation in India

The Indian electronic waste industry is booming at a very rapid pace. It is expected to be increasing at a rate of 20% annually. With increasing per capita income, changing life styles and revolutions in information and communication technologies, India is the second largest electronic waste generator in Asia. India is generating around 4,00,000tons of electronic waste per year according to Ministry of Environment and Forest MoEF. Not only this, it gets around 50,000 tons of e waste through illegal means of imports. TATA Strategic Management Group says that India is expected to have 11% share in global electronic market.[7]. MoEF'2012 report says that Indian electronic waste output has jumped 8 times in the last seven years .e. 8, 00,000 tones now. India has majorly two types of electronic waste market called organized and unorganized market. 90% of the electronic waste generation in the country lands up in the unorganized market. And out of this only 5.7 % of e waste is recycled. Electronic waste accounts for 70% of the overall toxic wastes which are currently found in landfills which is posing toxic chemical contamination in soil and other natural resources. Another report from

Central Pollution Control Board CPCB says that around 36,165 hazardous waste generating industries in India accounts for 6.2 million tons of toxic wastes every year. Indian PC industry is growing at a rate of 25% annually as per MAIT study [7].
Out of the total electronic waste generation in India, only 40 % of these are taken into the recycling processes and rest 60% remains in warehouses due to inefficient and poor collection systems. Generally, people hand over electronic waste to unauthorized recycling centres/ scrap dealers etc. for quick money. The e-waste scrap is managed through various management alternatives such as reuse of equipment from second hand dealers, back yard recycling and finally into the municipal dumping yard.
MAIT (Manufacturers Association for Information Technology)[7] study says that waste from discarded electronics will rise dramatically in the developing world within a decade, with computer waste in India alone to grow by 500 per cent from 2007 levels by 2020. Over 100,000 tons from refrigerators, 275,000 tons from TVs, 56,300 tons from personal computers, 4,700 tons from printers and 1,700 tons from mobile phone.

Health And Environment Impact

The practice of developed countries exporting e-waste to developing countries has become commonplace for a variety of reasons. High labour costs and stringent environmental regulations for hazardous waste disposal in developed countries encourage the exportation of e-waste to less developed and less regulated countries. Importing e-waste for recycling may provide some short-term economic benefits. However, many developing countries lack the technology, facilities, and resources needed to properly recycle and dispose of e-waste [8]. Recyclers in developing countries that receive e-waste from other countries frequently rely on rudimentary techniques to extract valuable materials from e-waste [8]. E-waste is physically dismantled by using tools such as hammers, chisels, and screw drivers [9]. Printed circuit boards are heated and components are removed. Gold and other metals are recovered from the stripping of metals in open-pit acid baths [9]. Plastics are chipped and melted without necessary and protective ventilation. Burning electrical cables, often in open pits and at relatively low temperatures, to retrieve copper is one of the most common crude recycling practices. Such primitive techniques may appear efficient to the untrained and less equipped recyclers, but they do not ensure environmental protection or occupational safety. When developed countries export e-waste for recycling, the opportunity to establish more safe, clean, and efficient techniques is lost.

Sources of Exposure

E-waste recycling can lead to direct or indirect exposure to a variety of hazardous substances that are contained in EEE or formed and released by unsafe recycling practices (Fig. 1). Direct exposure entails skin contact with harmful substances, the inhalation of fine and coarse particles, and the ingestion of contaminated dust. Individuals who directly engage in e-waste recycling with poor protection incur high levels of direct, occupational exposure [10] [11]. Unsafe recycling techniques used to regain valuable materials often increase the risk for hazardous exposures. There often is a lack of suitable off-gas treatment during such recycling processes, particularly smelting.

[Fig. 1]***Adapted from reference [12]***

Persistant organic pollutants	Component of electrical and electornic	Ecological source of exposure	Route of exposure
Brominated flame retardants Polybrominated diphenyl ethers (PBDEs) Polybrominated biphenyls (PBBs)	Flame retardants for electronic equipment	Air, dust, food, water, and soil	Ingestion, inhalation, and transplacental
Polychlorinated biphenyls (PCBs)	Dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, ceiling fans, dishwashers, and electric motors	Air, dust, soil, and food (bio-accumulative in fish and seafood)	Ingestion, inhalation or dermal contact, and transplacental
Dioxins			
Polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs)	Released as combustion byproduct	Air, dust, soil, food, water, and vapour	Ingestion, inhalation, dermal contact, and transplacental
Dioxin-like polychlorinated biphenyls	Released as a combustion byproduct but also found in dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, ceiling fans, dishwashers, and electric motors	Released as combustion byproduct, air, dust, soil, and food (bioaccumulative in fish and seafood)	ngestion, inhalation, and dermal absorption
Polyaromatic hydrocarbons (PAHs)	Released as combustion byproduct	Released as combustion byproduct, air, dust, soil, and food	Ingestion, inhalation, and dermal contact
Elements			
Lead (Pb)	Printed circuit boards, cathode ray tubes (CRTs), light bulbs, televisions, solder, and batteries	Air, dust, water, and soil	Inhalation, ingestion, and dermal contact
Chromium (Cr) or hexavalent chromium	Anticorrosion coatings, data tapes, and floppy disks	Air, dust, water, and soil	Inhalation and ingestion
Cadmium (Cd)	Switches, springs, connectors, printed circuit boards, batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, cathode ray tubes, and mobile phones	Air, dust, soil, water, and food (especially rice and vegetables)	Inhalation and ingestion
Mercury (Hg)	Thermostats, sensors, monitors, cells, printed circuit boards, cold cathode fluorescent lamps, and liquid crystal display (LCD) backlights	Air, vapour, water, soil, and food (bioaccumulative in fish)	Inhalation, ingestion, and dermal contact
Zinc (Zn)	Cathode ray tubes and metal coatings	Air, water, and soil	Ingestion and inhalation
Nickel (Ni)	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, dermal contact, and transplacental
Lithium (Li)	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, and dermal contact
Barium (Ba)	Cathode ray tubesmand fluorescent lamps	Air, soil, water, and food	Ingestion, inhalation and dermal contact
Berylium (Be)	Power supply boxes, computers, x-ray machines, ceramic components of electronics	Air, food, and water	Inhalation, ingestion, and transplacental

Plastics are burned, often at low temperatures, to either dispose of computer casings or to retrieve metals from electronic chips and other components. Incineration releases heavy metals such as lead, cadmium, and mercury [10] [12]. The toxic fumes released by these techniques often contain polyhalogenated dioxins and furans generated by incomplete combustion at low temperatures [12]. Polystyrene form, rubber, tires, crop residue, or biomass may be used as fuel for these fires and can cause harmful exposures, independent of the burning e-waste. Additionally, the working materials used in rudimentary recycling can be injurious. Working materials include cleaning solvents and reagents such as cyanide and other strong leaching acids. Acid leaching can lead to direct contact with liquid acid and the inhalation of acid fumes. "De-soldering" of circuit boards to recover rare and precious metals can release lead-saturated fumes.

The combination of toxic by-products, working materials, and the actual e-waste may lead to adverse health outcomes. Environmental contamination that is the result of improper e-waste recycling can lead to indirect exposures through contamination of soil, air, and water around e-waste recycling sites. The release of hazardous chemicals into the environment can lead to bioaccumulation, food contamination, and widespread ecological exposure [10] [11]. Children may be exposed in schools, playgrounds, or homes that are near an e-waste recycling site. Environmental contamination and resulting ecological exposure requires intensive research not only because hazardous e-waste recycling materials have the ability to spread far distances but they also possess high environmental persistence capabilities. With longer half-lives, these substances have the ability to remain in the environment for extended periods. Ecological exposure may have long-term and widespread health risks [12].

Recommendations for Action

1.Technical Interventions[14, 15, 16]

- Product design and engineering interventions

The solution for the e-waste crisis lies in ‘prevention at the manufacturing source’ or the ‘precautionary principle.’ This can be done by employing waste minimization techniques and by a sustainable product design. Waste minimization in industries involves adopting:--

- Inventory management
- Production process modification
- Volume reduction
- Recovery and reuse
- Sustainable product design involves:
- Rethinking on procedures of designing the product (flat computers)
- Use of renewable material and energy
- Creating electronic components and peripherals of biodegradable material
- Looking at a green packaging option
- Utilizing a minimum packaging material

  Extended Producer Responsibility is considered one of the most appropriate frameworks that amalgamates all the enlisted principles on environmental justice. This shifts the responsibility of safe disposal onto the producers. It promotes sound environmental technology and also aims at better raw material, cleaner production technology and designing for longevity.

2. Policy-level Interventions

- Clear definition of e-waste for regulation.
- Import and export regulatory regime.
- An integrated IT waste management policy
- Extended producer responsibility

Lack of clarity on the issue of e-waste and the inability of current hazardous waste rules to govern and effectively monitor the e-waste recycling are some of the prime reasons for experts and members of civil society demanding a separate set of rules to guide and control these processes.

3. Implementation and Capacity Building

- Legislation for collection, recycling and disposal.
- Institutional capacity building.
- Formalizing the informal recycling sector.

Workers are given formally recognized jobs where they can use skills and where occupational health safety (information about their occupation-related health hazards involved and self protection, protective gear and equipment and periodic medical checkups) is assured.

4. Awareness Building

The current awareness regarding the existence and dangers of e-waste are extremely low, partly because the e-waste being generated is not as large as in developed countries. Urgent measures are required to address this issue.The role of citizens in e-waste management include:

- Donating electronics for reuse, which extends the lives of valuable products and keeps them out of the waste management system for a long time.
- While buying electronic products, opting for those that are made with fewer toxic constituents, use recycled content, are energy efficient, are designed for easy upgrading or disassembly, use minimal packaging and offer leasing or take back options.
- Building of consumer awareness through public awareness campaigns is a crucial point that can attribute to a new responsible kind of consumerism.

Conclusion

Most waste is inherently dangerous. It can degrade to produce leachate, which may contaminate ground water, and create landfill gas, which is explosive. In addition, because of the dangers associated with landfill sites, there are now very strict requirements on the construction, operation and aftercare of such sites. Most planning authorities want a worked out quarry to be used for landscaping rather than a landfill site which no one wants in their back yard. Product design must be employed to help to minimize not only the nature and amount of waste, but also to maximize end-of-life recycling. Manufacturers, retailers, users, and disposers should share responsibility for reducing the environmental impacts of products. Adopt product stewardship approach i.e. a product-centred approach should be adopted to preserve and protect environment.India is placed in a very interesting position.It is ready to deal with future problems and can set global credible standards concerning environmental and occupational health.

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