Managing E-Waste in India: [A Review]

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Abstract: The developing countries are facing a huge challenge in the management of electronic waste (e-waste) which are either internally generated or imported illegally as 'used' goods. E-waste contains hazardous constituents that negatively impact the environment and human health. Electronic waste (e-waste) is one of the fastest growing waste streams in the country. Growth of Information and Communication Technology sector has enhanced the usage of the electronic equipment exponentially. Faster obsolescence and subsequent up-gradation of electronics product, are forcing consumers to discard old products, which in turn accumulate huge e-waste to the solid waste stream. E-waste is growing in India at the rate of 10%, because of lack of adequate infrastructure to manage wastes safely; major recycling of e-waste is carried out in the non-formal sector using primitive and hazardous methods. These wastes are buried, burnt in the open air or dumped into the surface water bodies. We should have in place legislation mandating electronic manufacturers and importers to take-back used electronic products at their end-of-life (EoL) based on the principle of extended producer responsibility (EPR). Adequate legislative measures and cost-effective, environmental friendly, technological solution would be needed to address the issue.This paper gives an in- sight into various forms and the quantumof e-waste in the Indian scenario, the source and the circulation routes, the nature and the amount of toxic and valuable constituents of e-waste, potential pollution threat to environment, re- cycling methods, efficient management techniques for e-waste, awareness of people and legal requirements.

Keywords: e-waste, Recycle, Reuse,WEEE, EPR, Production Process, Hazardous components.

1. INTRODUCTION

Electronic waste, e-scrap, or Waste Electrical and Electronic Equipment (WEEE) may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets and refrigerators. This definition includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal. Others define the re-usable (working and repairable electronics) and secondary scrap (copper, steel, plastic, etc.) to be "commodities", and reserve the term "waste" for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations. Because loads of surplus electronics are frequently commingled (good, recyclable, and non-recyclable), several public policy advocates apply the term "e-waste" broadly to all surplus electronics[2].

Extended Producers Responsibilities (EPR): The most important component of any legislative exercise for establishing a WEEE management system should be a focus on EPR. The original motivation for EPR was: first, to relieve municipalities of some of the financial burden of waste management, especially when it comes to complex wastes such as e-waste, and, second, to provide incentives to producers to reduce resources, use more secondary materials, and undertake product design changes to reduce waste. The main E-waste sources are imports, government, public and private sector discards (over 70%), PC retailers and manufacturers, secondary market of old PCs; and individual Households.[1]

E-waste is not hazardous if it is stocked in safe storage or recycled by scientific methods or transported from one place to the other in parts or in totality in the formal sector. The e-waste can, however, be considered hazardous if recycled by primitive methods. E-waste contains several substances such as heavy metals, plastics, glass etc., which can be potentially toxic and hazardous to the environment and human health, if not handled in an environmentally sound manner. E-waste recycling in the non-formal sector by primitive methods can damage the environment [1, 2].

According to an Indian Scenario E-waste of developed countries, such as the US, disposes their wastes to India and other Asian countries. A recent investigation revealed that much of the electronics turned over for recycling in the United States ends up in Asia, where they are either disposed of or recycled with little or no regard for environmental or worker health and safety. Major reasons for exports are cheap labor and lack of environmental and occupational standards in Asia and in this way the toxic effluent of the developed nations would flood towards the world's poorest nations. The magnitude of these problems is yet to be documented. However, groups like Toxic Links India are already working on collating data that could be a step towards controlling this hazardous trade.[5]

2. HAZARDOUS SUBSTANCES IN E-WASTE

Electrical and electronic equipment contain different hazardous materials which are harmful to human health and the environment if not disposed of carefully. While some naturally occurring substances are harmless in nature, their use in the manufacture of electronic equipment often results in compounds which are hazardous (e.g. chromium becomes chromium VI). The following list gives a selection of the mostly found toxic substances in e-waste [4].

Substance	Occurrence in e-waste
Halogenated compounds:	
-PCB(polychlorinated biphenyls)	Condensers, Transformers
-TBBA(tetrabromo-bisphenol-A) **-PBB(polybrominated biphenyls)** **-PBDE (polybrominateddiphenyl ethers)**	Fire retardants for plastics (thermoplastic components, cable insulation) TBBA is presently the most widely used flame retardant in printed wiring boards and casings.
-Chlorofluorocarbon (CFC)	Cooling unit, Insulation foam
-PVC (polyvinyl chloride)	Cable insulation
Heavy metals and other metals:	
-Arsenic	Small quantities in the form of gallium arsenide within light emitting diodes
-Barium	Getters in CRT
-Beryllium	Power supply boxes which contain silicon controlled rectifiers and x-ray lenses
-Cadmium	Rechargeable NiCd-batteries, fluorescent layer (CRT screens), printer inks and toners, photocopying-machines (printer drums)
-Chromium IV	Data tapes, floppy-disks
-Lead	CRT screens, batteries, printed wiring boards
-Lithium	Li-batteries
-Mercury	Fluorescent lamps that provide backlighting in LCDs, in some alkaline batteries and mercury wetted switches
-Nickel	Rechargeable NiCd-batteries or NiMH-batteries, electron gun in CRT
- Rare Earth elements (Yttrium, Europium)	Fluorescent layer (CRT-screen)
-Selenium	Older photocopying-machines (photo drums)
-Zinc sulphide	Interior of CRT screens, mixed with rare earth metals
Others:	
-Toner Dust	Toner cartridges for laser printers / copiers
Radioactive Substances:	
-Americium	Medical equipment, fire detectors, active sensing element in smoke detectors

3. EFFECTS OF HAZARDEOUS COMPONENTS ON HUMANS & ENVIRONMENT

Following are the hazardeous components in e-waste with there effects on humans[4]:

3.1 Arsenic

Arsenic is a poisonous metallic element which is present in dust and soluble substances. Chronic exposure to arsenic can lead to various diseases of the skin and decrease nerve conduction velocity. Chronic exposure to arsenic can also cause lung cancer and can often be fatal.

3.2 Barium

Barium is a metallic element that is used in sparkplugs, fluorescent lamps and "getters" in vacuum tubes. Being highly unstable in the pure form, it forms poisonous oxides when in contact with air. Short-term exposure to barium could lead to brain swelling, muscle weakness, damage to the heart, liver and spleen. Animal studies reveal increased blood pressure and changes in the heart from ingesting barium over a long period of time. The long- term effects of chronic barium exposure to human beings are still not known due to lack of data on the effects.

3.3 Beryllium

Beryllium has recently been classified as a human carcinogen because exposure to it can cause lung cancer. The primary health concern is inhalation of beryllium dust, fume or mist. Workers who are constantly exposed to beryllium, even in small amounts, and who become sensitized to it can develop what is known as Chronic Beryllium Disease (beryllicosis), a disease which primarily affects the lungs. Exposure to beryllium also causes a form of skin disease that is characterized by poor wound healing and wart-like bumps. Studies have shown that people can still develop beryllium diseases even many years following the last exposure.

3.4 Brominated flame retardants (BFRs)

The 3 main types of BFRS used in electronic and electrical appliances are Polybrominated biphenyl (PBB), Polybrominateddiphenyl ether (PBDE) and Tetrabromobisphenol - A (TBBPA). Flame retardants make materials, especially plastics and textiles, more flame resistant. They have been found in indoor dust and air through migration and evaporation from plastics. Combustion of halogenated case material and printed wiring boards at lower temperatures releases toxic emissions including dioxins which can lead to severe hormonal disorders. Major electronics manufacturers have begun to phase out brominated flame retardants because of their toxicity.

3.5 Cadmium

Cadmium components may have serious impacts on the kidneys. Cadmium is adsorbed through respiration but is also taken up with food. Due to the long half-life in the body, cadmium can easily be accumulated in amounts that cause symptoms of poisoning. Cadmium shows a danger of cumulative effects in the environment due to its acute and chronic toxicity. Acute exposure to cadmium fumes causes flu-like symptoms of weakness, fever, headache, chills, sweating and muscular pain. The primary health risks of long term exposure are lung cancer and kidney damage. Cadmium also is believed to cause pulmonary emphysema and bone disease (osteomalacia and osteoporosis).

3.7 CFCs (Chlorofluorocarbons)

Chlorofluorocarbons are compounds composed of carbon, fluorine, chlorine, and sometimes hydrogen. Used mainly in cooling units and insulation foam, they have been phased out because when released into the atmosphere, they accumulate in the stratosphere and have a deleterious effect on the ozone layer. This results in increased incidence of skin cancer in humans and in genetic damage in many organisms.

3.8 Chromium

Chromium and its oxides are widely used because of their high conductivity and anti-corrosive properties. While some forms of chromium are non toxic, Chromium (VI) is easily absorbed in the human body and can produce various toxic effects within cells. Most chromium (VI) compounds are irritating to eyes, skin and mucous membranes. Chronic exposure to chromium (VI) compounds can cause permanent eye injury, unless properly treated. Chromium VI may also cause DNA damage.

3.9 Dioxins

Dioxins and furans are a family of chemicals comprising 75 different types of dioxin compounds and 135 related compounds known as furans. Dioxins® is taken to mean the family of compounds comprising polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Dioxins have never been intentionally manufactured, but form as unwanted by-products in the manufacture of substances like some pesticides as well as during combustion. Dioxins are known to be highly toxic to animals and humans because they bio-accumulate in the body and can lead to malformations of the foetus, decreased reproduction and growth rates and cause impairment of the immune system among other things. The best-known and most toxic dioxin is 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin (TCDD).

3.10 Lead

Lead is the fifth most widely used metal after iron, aluminium, copper and zinc. It is commonly used in the electrical and electronics industry in solder, lead-acid batteries, electronic components, cable sheathing, in the glass of CRTs etc. Short-term exposure to high levels of lead can cause vomiting, diarrhea, convulsions, coma or even death. Other symptoms are appetite loss, abdominal pain, constipation, fatigue, sleeplessness, irritability and headache. Continued excessive exposure, as in an industrial setting, can affect the kidneys. It is particularly dangerous for young children because it can damage nervous connections and cause blood and brain disorders.

3.11 Mercury

Mercury is one of the most toxic yet widely used metals in the production of electrical and electronic applications. It is a toxic heavy metal that bioaccumulates causing brain and liver damage if ingested or inhaled. In electronics and electrical appliances, mercury is highly concentrated in batteries, some switches and thermostats, and fluorescent lamps.

3.12 Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a class of organic compounds use in a variety of applications, including dielectric fluids for capacitors and transformers, heat transfer fluids and as additives in adhesives and plastics. PCBs have been shown to cause cancer in animals. PCBs have also been shown to cause a number of serious non-cancer health effects in animals, including effects on the immune system,

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reproductive system, nervous system, endocrine system and other health effects. PCBs are persistent contaminants in the environment. Due to the high lipid solubility and slow metabolism rate of these chemicals, PCBs accumulate in the fat-rich tissues of almost all organisms (bioaccumulation). The use of PCBs is prohibited in OECD countries, however, due to its wide use in the past, it still can be found in waste electrical and electronic equipment as well as in some other wastes.

3.13 Polyvinyl chloride (PVC)

Polyvinyl chloride (PVC) is the most widely-used plastic, used in everyday electronics and appliances, household items, pipes, upholstrery etc. PVC is hazardous because contains up to 56 percent chlorine which when burned produces large quantities of hydrogen chloride gas, which combines with water to form hydrochloric acid and is dangerous because when inhaled, leads to respiratory problems.

3.14 Selenium

Exposure to high concentrations of selenium compounds cause selenosis. The major signs of selenosis are hair loss, nail brittleness, and neurological abnormalities (such as numbness and other odd sensations in the extremities).

4. INVENTORY OF E-WASTE IN INDIA

The growth rate of discarded electronic waste is high in India since it has emerged as an **Information Technology** giant and due to modernization of lifestyle. We are using electronic products for last **60 years** however, there is **no proper disposal system** followed in our country that has **lead to enormous amount of e-waste**. **A study carried out by MAIT/GTZ in 2007** estimates the total quantities of generated, recyclable and recycled e- **w**aste are **3,32,979, 000 Kg, 1,44,43 000 Kg and 19,000 000 Kg respectively.** The e-waste processed in**2007**consisted of **12000 000 Kg of computers and 7000 000Kg of televisions**. The **2.2 million computers** had becomeobsolete in 2007. India had about 20 million computers in2007, which would grow to **75 million by 2010**. Around **14 million mobile handsets** had **been replaced in 2007** asper another study (MAIT-GTZ Study, 2007).Reports on inventory of e-waste are based on models **of obsolescence and not based on actual** physical **inventories in** India. The statistics of production, exportsand sales of each product and their average life havebeen considered in these studies. The average life of apersonal computer (PC) was assumed to be 5 and 7years and television **(TV) to be 15 and 17 years.** It **was also assumed** that **100% of electronic units sold** inone particular year would become obsolete at the end ofthe average life. These perceptions of life of e-waste are **based on urban conditions; the conditions are far from** itconsidering the rural scenario.Moreover, apart from the domestic generation of e-waste, the imported electronics waste has alsocontributed a significant impact in the total inventory ofthe material. India is becoming a big market for importede-waste. A study indicates that PCs imported to Delhi in 2003 was nearly 3,600, 000Kg/year (The HindustanTimes, 2007). Another study predicts that the nearly50,000 to 70,000 tons of e-waste is being importedannually to India . Most developed countries, find it **financially** pro-**fit able to send e-waste for** re-use/**recycling** in dev**eloping countries. The cost of** recycling **of a single computer in the United States is $ 20** while **the same could be recycled in India for only US** $ 2, a **gross saving of US $ 18** if **the computer is exported to** India (ELCINA, 2009)[5].

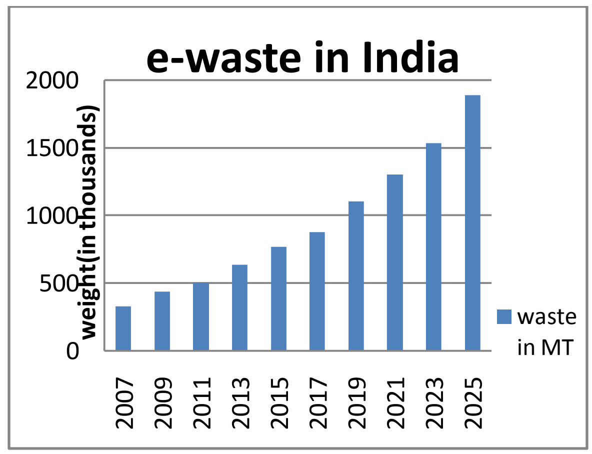

Fig 1. Shows e-waste in India

5. E-WASTE TREATMENT & DISPOSAL METHODS

It is estimated that 75% of 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 [5, 6].

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 [5]:

- Inventory management,
- Production-process modification,
- Volume reduction,
- Recovery and reuse.

5.1 Inventory Management

Proper control over the materials used in the manufacturing process is an important way to reduce waste generation (Freeman, 1989). 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 materials 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 materials are available.

Another inventory management procedure for waste reduction is to ensure that only the needed quantity of a material is ordered. This will require 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.

5.2 Production-Process Modification

Changes can be made in the production process, which will reduce waste generation. This reduction can be accomplished by 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:

i. Improved operating and maintenance procedures,
ii. Material change and
iii. 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 most manufacturing processes. Implementation of this waste - reduction technique may require only some minor process adjustments or it may require extensive new process equipment. For example, a circuit board manufacturer can replace solvent-based product with water-based flux and simultaneously replace solvent vapor degreaser with detergent parts washer.

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 use process materials more efficiently producing less waste. Additionally such efficiency reduces the number of rejected or off-specification products, thereby reducing the amount of material which has to be reworked or disposed of. Modifying 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 operations, 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, caustics, cyanides etc are often a hazardous waste and must be properly managed. By reducing the number of parts that have to be reworked, the quantity of waste can be significantly reduced.

5.3 Volume Reduction

Volume reduction includes those techniques that remove the hazardous portion of a 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. Wastes 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.

Methods include gravity and vacuum filtration, ultra filtration, reverse osmosis, freeze vaporization etc.

For example, an electronic component manufacturer can use compaction equipments to reduce volume of waste cathode ray-tube.

5.4 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.

6. RESPONSIBILITIES OF THE GOVERNMENT

1) Governments should set up regulatory agencies in each district, which are vested with the responsibility of coordinating and consolidating the regulatory functions of the various government authorities regarding hazardous substances [5].

2) Governments should be responsible for providing an adequate system of laws, controls and administrative procedures for hazardous waste management (Third World Network. 1991). Existing laws concerning e-waste disposal be reviewed and revamped. A comprehensive law that provides e-waste regulation and management and proper disposal of hazardous wastes is required. Such a law should empower the agency to control, supervise and regulate the relevant activities of government departments.

Under this law, the agency concerned should

- Collect basic information on the materials from manufacturers, processors and importers and to maintain an inventory of these materials. The information should include toxicity and potential harmful effects.
- Identify potentially harmful substances and require the industry to test them for adverse health and environmental effects.
- Control risks from manufacture, processing, distribution, use and disposal of electronic wastes.
- Encourage beneficial reuse of "e-waste" and encouraging business activities that use waste". Set up programs so as to promote recycling among citizens and businesses.
- Educate e-waste generators on reuse/recycling options.

3) Governments must encourage research into the development and standard of hazardous waste management, environmental monitoring and the regulation of hazardous waste-disposal.

4) Governments should enforce strict regulations against dumping e-waste in the country by outsiders. Where the laws are flouted, stringent penalties must be imposed. In particular, custodial sentences should be preferred to paltry fines, which these outsiders / foreign nationals can pay. [5, 7]

5) Governments should enforce strict regulations and heavy fines levied on industries, which do not practice waste prevention and recovery in the production facilities.

6) Polluter pays principle and extended producer responsibility should be adopted.

7) Governments should encourage and support NGOs and other organizations to involve actively in solving the nation's e-waste problems.

8) Uncontrolled dumping is an unsatisfactory method for disposal of hazardous waste and should be phased out.

9) Governments should explore opportunities to partner with manufacturers and retailers to provide recycling services.

7. RESPONSIBILITY AND ROLE OF INDUSTRIES

1) Generators of wastes should take responsibility to determine the output characteristics of wastes and if hazardous, should provide management options [5, 7].

2) 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. Some are given below:

- Use label materials to assist in recycling (particularly plastics).
- Standardize components for easy disassembly.
- Re-evaluate 'cheap products' use, make product cycle 'cheap' and so that ithas 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.
- Look at green packaging options.

3) Companies can and should adopt waste minimization techniques, which will make a significant reduction in the quantity of e-waste generated and thereby lessening the impact on the environment. It is a "reverse production" system that designs infrastructure to recover and reuse every material contained within e-wastes metals such as lead, copper, aluminum and gold, and various plastics, glass and wire. Such a "closed loop" manufacturing and recovery system offers a win-win situation for everyone, less of the Earth will be mined for raw materials, and groundwater will be protected, researchers explain.

4) Manufacturers, distributors, and retailers should undertake the responsibility of recycling/disposal of their own products.

5) Manufacturers of computer monitors, television 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, television sets and other electronic devices containing hazardous materials must be clearly labeled to identify environmental hazards and proper materials management.

8. RESPONSIBILITIES OF THE CITIZEN

Waste prevention is perhaps more preferred to any other 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. But care should be taken while donating such items i.e. the items should be in working condition.

Reuse, in addition to being an environmentally preferable alternative, also benefits society. By donating used electronics, schools, non-profit organizations, and lower-income families can afford to use equipment that they otherwise could not afford[5, 6].

E-wastes should never be disposed with garbage and other household wastes. This should be segregated at the site and sold or donated to various organizations.
While buying electronic products opt for those that:

- Are made with fewer toxic constituents
- Use recycled content
- Are energy efficient
- Are designed for easy upgrading or disassembly
- Utilize minimal packaging
- Offer leasing or take back options
- Havebeen certified by regulatory authorities. Customers should opt for upgrading their computers or other electronic items to the latest versions rather than buying new equipments.

NGOs should adopt a participatory approach in management of e-wastes.

9. CONCLUSION

The present study reveals that the e-waste are going to become a great challenge for environmentalists and technologists as the rate of growth is much higher than the rate it is disposed, reused or recycled. There is an urgent need for improvement in e-waste management covering technological improvement, operation plan, implementing a protective protocol for the workers working in e-waste disposal and educating public about this emerging issue posing a threat to the environment as well as public health.

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The e-wastes problem is a major threat to our health and environment. The effectiveness of an environmental planning and management greatly depends on the accuracy of the waste statistics which will serve as the barometer on the amount of e-waste that is going to flood our landfill.

One significant factor is the lack of timely, accurate data needed to help fully understand the scope of the potential problem. It is almost impossible to know exactly how much e-waste is generated, to what extent it is processed domestically (e.g., to what degree it is sorted or disassembled by domestic recyclers), how much is exported, and, of the waste that is exported, how much is actually reusable or sent to a facility that will manage it properly. That is not to say that all or even the majority of e-waste that is exported is managed improperly. It is simply impossible to know using existing data.

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