Review of Sustainable Management of e-waste in India

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Abstract

Electronic waste is the end of life remnant of electronic devices and is increasing at a much higher rate than all other waste streams. Due to the fast-growing electronics industries arising from the demands of information and communication technologies around the world coupled with the rapid product obsolescence and lack of end-of-life management options, have all led to the unsustainable management of the waste stream. Electronic devices such as computers are manufactured from over 1,000 materials, many of which are toxic, and they contribute significantly to the e-waste stream, which is estimated to be approximately 20 to 50 million tonnes annually. Government of India has taken substantial measures to curb e-waste by the adoption of e-waste Management and Handling rules 2011. Amongst the various initiatives worldwide, design for environment cleaner production, extended producer responsibility, standards and labelling, product stewardship, recycling and remanufacturing are some of the practices adopted by various countries around the world to deal with the e-waste stream. The paper attempts to review these practices as well look into the manner in which they contribute to the sustainable management of e-waste.

1 Introduction: Waster Electrical and Electronic Equipment or WEEE or e-waste is one of the fastest growing waste streams in the world. In developed countries, on an average It constitutes 1% of the total solid waste. In developing countries it accounts for 0.01% to 3% of total municipal solid waste generation, with annual generation per capita being less than 1 kg. The increasing 'market penetration' in developing countries, 'replacement market' in developed countries„ and 'high obsolescence rate' make WEEE/e-waste as one of the fastest growing waste stream.

Various regulations and practices have been adopted by governments around the world to deal the above problem. The aim of this paper is to provide an overview of these practices in India and the world, and to investigate how they contribute to the sustainable management of e-waste. In particular, the paper concentrates on the most challenging issue of managing obsolete computers in the e-waste stream.

2.Growth of Electrical and Electronic Industry in India vis-s-vis the World. The Indian economy has rapidly undergone a major shift since 1990 from being controlled and regulated to open, seamless and being globalised. The telecom industry was the first sector to be impacted by such a shift followed by the IT industry. The computer industry has also seen a rampant growth and the driver for growth of computer industry is mainly rapid pace of industrialisation coupled with application of technology in systems application. The PC market in India comprising of desktops, notebooks and workstations recorded a year-over-year (YOY) growth of over 15.8% at the end of third quarter of 2019 according to the data from International Data Corporation (IDC) Worldwide Quarterly Personal Computing Device Tracker.

The IT industry has also diversified with the advent of BPO (Business Process Outsourcing), a new concept borne out of economic necessity and availability of human resource in India. This sector has recorded huge growth in recent past and is singly responsible for the high consumption of hardware materials apart from fuelling growth in other associated sectors.

Lead is widely used as a major component of solders and as lead oxide in the glass of the cathode ray tubes (CRTs) used in computer monitors, as well as in acid batteries. Lead is highly toxic to humans and can cause damage to the central and peripheral nervous systems, blood system, and kidneys. 40% of the lead found in landfills is supposed to come from obsolete electronic items. Cadmium is classified as toxic with a possible risk of irreversible effects on human health. Similar to lead, cadmium can accumulate in the body over time causing long term damage to human body organs.

In terms of e-waste, cadmium occurs in certain components such as chip resisters, infrared detectors and semi-conductors. e-Waste also contains flame retardants such as polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDEs). In computers these are used in printed circuit boards, connectors, covers, and cables. Electronics are often seen as one answer to achieving a reduced level of resource use. The growth of e-commerce may have reduced the resource consumption and waste disposal but this has more than been compensated for by increased consumer spending, mostly geared towards high energy and material consumption. However, this is not the case in many instances. The increasing use of electronics for commerce and tendency towards miniaturization has actually seen an increase in resource consumption. This miniaturization of electronic devices has actually been counteracted by the ever growing number of devices produced.

Whilst miniaturization has taken place, the price per functional unit has decreased by a factor more than compensating for the reduction in mass flow. This all assumes that the resources will be available indefinitely for the production of these devices. A study by the United Nations has found that, on average, the manufacture of a computer and its screen could use at least 240 kg of fossil fuels, 22 kg of chemicals, and 1.5 tonnes of water. This does not take into account the pollution impact of chemicals utilized or the waste side of this process.

The WEEE and RoHS legislation in Europe is just the beginning for the electronics and electrics industries. Legislation will now require electronic and electrical companies to significantly reduce the use of energy in the components or materials used in their manufacturing processes, the number of product intended uses, and even their "end-of-life" recovery. The new Energy Using Products (EUP) Directive leaves the US EPA Energy Star requirements looking minimal. Also, the recently debated EU REACH (Registration, Evaluation and Authorization of Chemicals) directive's impact upon the electronics industry has yet to be comprehensively evaluated. More and more regions, including individual US States such as California, whose market is larger than many separate countries, have increased environmental performance requirements and there will be an even greater number doing so in the future. Individual companies are moving ahead with their own supply chain initiatives in preparation for the EU Directives. Sony has issued its own list of restricted hazardous substances and the result is the disqualification of hundreds of suppliers who did not meet their requirements. Hitachi, NEC, Toshiba, HP, and Nokia are closely following Sony in this initiative. The suppliers of these organizations face a situation where change must be accepted, or they will no longer be involved in the business of supplying.

It has been established that e-waste is one of the fastest growing areas of the international waste stream. E-waste is growing at a compound annual growth rate (CAGR) of about 30 per cent in the country. ASSOCHAM, one of the apex trade associations of India, estimated that e-waste generation was 1.8 MT per annum in 2016 and would reach 5.2 MT per annum by 2020.

India generates more than two million tonnes of e-waste annually, and also imports undisclosed amounts of e-waste from other countries from around the world – including Australia. Squatting outside shop units they were busy dismantling these products and sorting circuit boards, capacitors, metals and other components (without proper tools, gloves, face masks or suitable footwear) to be sold on to other traders for further recycling. Seelampur is the largest e-waste dismantling market in India. Each day e-waste is dumped by the truckload for thousands of workers using crude methods to extract reusable components and precious metals such as copper, tin, silver, gold, titanium and palladium. The process involves acid burning and open incineration, creating toxic gases with severe health and environmental consequences.

Workers come to Seelampur desperate for work. We learned that workers can earn between 200 and 800 rupees per day. Women and children are paid the least; men who are involved with the extraction of metals and acid-leeching are paid more. This is all due to informal recyclers, the kabadiwalas or raddiwalas. They are resourceful enough to extract value at every stage of the recycling process, but this comes with a heavy toll to their health and the environment.

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3. Design for the Environment: Currently, a major problem that exists in the manufacturing process of computer equipment is that of its design. The manufacturing process in the electronics industry is linear in nature and adheres to the standard "profit" focused approach, which is labeled as one of "take-make and waste". A computer manufacturer or other industry player may have an environmentally certified manufacturing plant and be extremely mindful of its eco-responsibility.

However, if the end product is not "clean" in terms of process, then the impact of any improvement through accreditation is weakened. It must be recognized that accreditation is only the first step towards sustainability. It is not an end in itself. Once a product is on the market, the ability to improve its environmental performance is essentially eliminated. Resources may be expended on attempting to do so, but it will be relatively ineffective and environmental impact and degradation will not be reduced at this stage.

A product is like a messenger between the acts of production and consumption. They have been described as "the carriers of a material's flow, energy usage, functional performance and environmental impact". Products are one possible key by which progress can be made towards sustainability.

The challenge is to ensure that an integrated circular "whole systems design" or as Doppelt argues, for a borrow-use-return approach to be taken and the linear method to be abandoned. This process incorporates Design for the Environment (DfE). DfE or eco-design also referred to as cleaner production, is becoming an increasingly important priority for manufacturers of electronic equipment, as a result of major regulatory changes that have and are currently taking place internationally and pressure from end-users. DfE is not a compliance activity, but an integrated, cross functional strategy. DfE is an integrated strategy that has the goal of reducing the environmental impact of a product at the design stage. It begins with research and development using environmental impact as the basis for the product, whilst procurement and quality assurance work closely with suppliers by ensuring that they meet or exceed the criteria for environmental performance. DfE will not only see the total elimination of toxic products from the system, better disassembly, lower weight and smaller footprints, it will enable manufacturers to achieve a level of competitive advantage over more conventional manufacturers that do not follow this path. It will also eventually eliminate these conventional manufacturers from the largest markets.

The introduction of legislation resulting in two major regulations in the EU, i. e., the WEEE and RoHS (Restriction of the use of certain hazardous substances in electrical and electronic equipment) Directives and in India (e-Waste M&H rules), is now combining with market forces and lean manufacturing to force manufacturers to undertake a totally new and integrated approach to design. The directive on the RoHS has changed the whole process of interaction along the supply chain and is causing original equipment manufacturers (OEMs) to implement closer interaction between customers and suppliers, as well as a reduction in the number of component suppliers. Further directives including the Energy-using-Products (EuP) Directive, restrictions on chemicals (REACH) and an updated battery directive will further reinforce this DfE push. These directives, particularly the EuP, encompass the full product life cycle from component manufacture to disposal and establish legal parameters for the eco-design of products. This will be beneficial to both the OEM and the consumer as shown in a study by the UK Environmental Consulting organization Environ-wise, which argues that the UK electronics sector could collectively save US$ 400 million per annum by adopting eco-design practices. The People's Republic of China, US states including California and Massachusetts, Korea and Taiwan have all formulated their own RoHS and WEEE legislation as a direct result of the EU Directives. Directives from the EU have effectively become international directives as OEMs cannot afford to run both compliant and noncompliant manufacturing lines, and therefore, these DfE changes are in effect, being implemented globally.

4 Extended Producer Responsibility In order to assist in improving environmental performance within the electronics industry, there has been a growing perception of the need to introduce measures that will improve the ability of governments and corporations to progress environmental performance. This includes a variety of initiatives and legislation that has been introduced internationally. These include global guidance standards published by the International Standards Organization (ISO), work by the Organization for Economic Cooperation and Development (OECD), the United Nations Environment Programme towards providing information on product stewardship and extended producer responsibility (EPR) and guidance on public procurement with a view to improving environmental performance.

A definition of EPR is as follows: "… a policy principle to promote total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer of the product to various parts of the product's life cycle and especially to the take-back, recovery and final disposal of the product."

The goal of EPR is to prioritize three major areas. These are prevention, life-cycle thinking and incentive mechanisms for industry to conduct ongoing improvement in processes and product design. This is not just about simply setting up a recycling system that does not encourage manufacturers to examine their own processes. The most comprehensive use of EPR lies in the fact that it states that producers should bear responsibility for all the environmental impact of their products at all stages of the life cycle. This includes upstream impacts arising from the choice of materials, the manufacturing process and downstream impacts from the use and disposal of the products.

Producers will only accept their duties when they assume legal, physical, and/or financial responsibility for the environmental impacts of their products. By linking both the upstream phase of the product's life cycle with the downstream phase, EPR internalizes costs and provides both the incentive and emphasis on the need for manufacturers to design products that enable a transformation from the liner production model to a sustainable "borrow-useretum" cycle as highlighted by Tojo.

A number of key features of EPR are outlined by Tojo. These include the following items: It is a product policy – not a waste policy; It gives priority to prevention over end-of-pipe pollution control; It aims to reduce the environmental impact of products and product systems throughout their life cycle instead of focusing on point sources, such as production sites; It seeks to prevent environmental problems at source by providing incentives for changes at the product design phase, without prescribing what should be done; It enacts the, polluter pays principle' and attempts to internalize waste management costs into the product price.

5 Standards and Labeling: Initiatives at a national level to implement eco-labeling have also been implemented in a number of countries. These schemes began in 1977 with Germany's Blue Angel system being established. There are currently 28 established ISO Type I eco-labeling programmes operating in 33 countries and districts. In 1994, this led to the formation of the Global Eco-Labeling Network (GEN), an organization which encourages the facilitation of, access to and the exchange of information and the promotion of eco-

labeling and ultimately, the demand for and supply of more environmentally responsible goods and services.

The Electronic Product Environmental Assessment Tool (EPEAT) developed by the US EPA is another label that was introduced recently. EPEAT provides the means for the evaluation of electronic products according to three tiers of environmental performance – Bronze, Silver, and Gold. EPEAT incorporates IS 1680 which includes 51 environmental criteria in IEEE 1680, of which 23 are required and 28 are optional criteria.

6. Recycling of e-Waste The UNEP as quoted in currently estimates that between 20 to 50 million tonnes of e-waste is generated internationally each year and this will increase at three to five percent per annum, a rate nearly three times faster than the municipal waste stream's general growth. In total, 500 million PCs became obsolete around the world between 1994 and 2003 and these PCs contain ca. 2,872,000 tonnes of plastic, 718,000 tonnes of lead, 1363 tonnes of cadmium, and 287 tonnes of mercury. It is also estimated that approximately 315 million computers may now require disposal in the US alone and that of those being discarded for “recycling”, up to 80% are being exported to less developed countries (LDCs) for disassembly and recycling' using methods that would be unacceptable within the US. The US Government Accountability Office (GAO) agrees that the export of significant quantities of e-waste from the US to LDCs is currently taking place. It provides official figures for the disposal of only 4 million computer monitors and 8 million television sets in landfills each year. This quantity is only a fraction of the amount becoming obsolete and it is suggested by the GAO that whilst many of these may be in storage, it is probable that most have been exported to LDCs for ‚dirty' recycling. Computers comprise only a small segment of the e-waste stream. In 2005 alone, it was estimated that 130 million mobile phones became obsolete and similar figures are applicable to PDAs, MP3 players, computer games and peripherals, not to mention batteries and CDs.

There are a number of international programmes designed to dramatically increase collection and reuse/recycling of e-waste. In pariticular, the implementation of the WEEE Directive in the EU has a huge potential for increasing the rate of recycling in the EU, which should lead to a large reduction in pollution. In the short-term, there is a need to prioritize recycling, since waste prevention though various EPR related DfE measures is a long-term process and will be unable to resolve issues associated with the current level of existing and potential e-waste generation.

A report by the Basel Action Network (BAN) and the Silicon Valley Toxics Coalition ‚Exporting Harm: Trashing of Asia’ asserts that 50 to 80% of e-waste collected for recycling in the US is exported to developing nations. BAN produced a film on the report which depicts Guiyu village in the Guangdong province in China as an ‚electronics junkyard’ where 100,000 men, women and children make US$ 1.50 a day dismantling e-waste by their bare hands to retrieve the valuable metals and materials. The circuit boards are melted over coal grills to release valuable metals giving highly toxic dioxin fumes and riverbank acid baths are used to extract the gold. The soil and drinking water in Guiyu are contaminated by lead to much higher levels than allowed by WHO limits, e. g., soil by 200 times and water by 2,400 times the allowed levels [20]. These findings have triggered a vast number of scientific studies especially in the Guiyu area. Yu et al. [21] studied the concentration, distribution, profile and possible sources of polycyclic aromatic hydrocarbons (PAHs) in soils in this area. They found very high concentrations (2065 lg per kg) of PAH in soils near burning sites, suggesting that soil in Guiyu may be affected by the primitive e-waste recycling activities in the area. A similar study was conducted by Deng et al. to monitor the PAH levels and heavy metals in total suspended particles with aerodynamic diameters smaller than 2.5 lm (PM2.5). They found PAH concentrations which were 2 to 6 times higher and chromium, copper and zinc concentrations which were 4 to 33 times higher than in other Asian countries, further confirming that high concentrations of PAHs and heavy metals in the air in Guiyu could pose serious environmental and health concerns. A study conducted by Wong et al. of the sediment samples taken from the Lianjiang and Nanyang rivers, both flowing past Guiyu, found contamination levels of cadmium (up to 10.3 mg/kg), copper (17.0 – 4540 mg/kg), nickel (12.4 – 543 mg/kg), lead (28.6 –590 mg/kg) and zinc (51.3 –324 mg/kg), indicating significantly higher levels compared to uncontaminated sediments. As a result of these studies, there is strong evidence that atmospheric air, soil and water in the Guiyu area are all contaminated with chemicals and metals due to e-waste recycling operations. A more general study by Wang and Guo on surface water, ground water and sediment samples in the Guiyu area has confirmed these findings.

7. Remanufacturing: While it is necessary to examine closed systems as a whole and account for the energy expended and any external factors that create an environmental impact, they should also be more eco-efficient than linear systems. In a study of Fuji-Xerox in Australia and taking into account all aspects of the supply chain process, it was found that remanufacturing is able to make a significant contribution to the eco-efficiency of a product system. Reductions up to a factor of 3 times the energy consumption were achieved.

However, the current model for remanufacturing exemplified by Fuji-Xerox is not necessarily a suitable model for future remanufacturing systems where factors of four to ten are seen as requisite target outcomes. To achieve this level of factor 3 efficiency, substantial investment was made by Fuji-Xerox over the ten year period up to the study and most importantly, a design for disassembly was incorporated into the product in order to achieve the desired savings.

The high rate of technological change in the electronics industry presents a critical challenge for the process of remanufacturing and particularly DfE and is of major importance to levels of e-waste. With only a three year average life span for computers, there is a "technological pull away from the environmental principles of longevity, reuse and resource productivity" and remanufacturing runs the risk of prolonging the life of already obsolete products. However, the GAO argues that whilst remanufacturing may run the risk of extending the life of a technologically obsolete product, the energy saved by reuse or refurbishment is huge. Up to 80% of the energy utilized in the life cycle of a computer can be saved in this way instead of manufacturing a new unit from raw materials. Recycling and reuse also provide substantial cost savings over the manufacture of a new product.

8.Concluding Remarks: e-Waste is being generated around the world at a higher rate than most other waste streams. The high uptake of information and communication technologies and the rapid development of newer designs by producers on a regular basis result in current electronic equipment becoming obsolete much sooner than before, and contributes more and more towards e-waste generation. In order to address the issue, regulations and policies are being evaluated, developed or implemented urgently in many countries around the world. These incorporate practices such as DfE, EPR, labeling, product stewardship, recycling, and remanufacturing. As a result, several developed countries have now addressed the issue of e-waste transport to LDCs, to a certain extent. However, this requires commitments from all parties. For example, while countries such as the US are now developing policies and practices to promote domestic end-of-life management of electronic equipment, countries such as China and India must develop stricter regulations to ban the import of such items. However, the longer term solution to the e-waste problem can only be achieved through practices such as DfE, cleaner production and sustainable consumption. Therefore, consumers should look for electronics products which are:: Capable of providing ‚leasing' or ‚take-back' options after becoming obsolete; Made with fewer toxic constituents; Made from more recycled contents and components; Designed for the environment with attributes such as ‚easy to upgrade' and ‚easy to dismantle (disassemble)' for recycling; Energy efficient with higher ‚Energy Star' ratings; Presented with minimal packaging materials or use biodegradable packaging materials; and In possession of a certification of recognition from an independent certification group confirming that they are an environmentally preferable product..

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