Volume-4, Issue-9, Sept-2015 • ISSN No 2277 - 8160

Research Paper Engineering

E-Waste Management in India - an Overview

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ABSTRACT

Rapid changes in technology, changes in media (tapes, software, MP3), falling prices, with the advancement in Science and Technology every second new electronic gadgets like mobile phones, tablets, i-pods, note-book, LED TV, plasma TV are launched. Due to the invention of these modern gadgets we have become slaves of gadgets and planned obsolescence have resulted in a fast-growing surplus of electronic waste around the globe. The growth of E-waste has significant economic and social impacts. The increasing obsolescence rate of electronic products also adds to the huge import of used electronics products. E-wastes contain over 1000 different substances many of which are toxic and potentially hazardous to environment and human health, if these are not handled in an environmentally sound manner. This paper presents an overview of toxic substances present in E-waste, their potential environmental and health impacts together with management strategies being used in India.

KEYWORDS : E-Waste, Health Impacts, Management Practices

Introduction

E-waste is a popular informal name for electronic products nearing the end of their useful life. Anything that runs on electricity/battery or has wires and completed its life is E-waste**.** Electronic waste may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets and refrigerators. E-wastes are considered dangerous, as certain components of some electronic products contain materials that are hazardous, depending on their condition and density. The hazardous content of these materials pose a threat to human health and environment. Electronic waste, E-waste, e-scrap, or Waste Electrical and Electronic Equipment (W.E.E.E) describes discarded electrical or electronic devices. The lifespan of many electronic goods has been substantially shortened due to advancements in electronics, attractive consumer designs and marketing and compatibility issues. For example, the average lifespan of a new computer has decreased from 4.5 years in 1992 to an estimated 2 years in 2005 and is further decreasing resulting in much greater volumes of computers for either disposal or export to developing countries [1]. 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. E-waste comprises of wastes generated from used electronic devices and household appliances which are not fit for their original intended use and are destined for recovery, recycling or disposal.

METHODOLOGY

Secondary sources of data like recent newspaper and journal articles, authentic internet resources, etc were evaluated for the purpose of this study. Through such resources, attempt has been made to formulate an inventory of E-waste in global and Indian context, which in turn helped in identifying the wide range of diverse stakeholders in the E-waste generation. Secondary sources of data were preferred in order to accommodate the current scenario and research related to E-waste in India which are highly dispersed and diversified.

GLOBAL SCENARIO

Electronic waste (E-waste) is one of the fastest-growing pollution problems worldwide given the presence if a variety of toxic substances which can contaminate the environment and threaten human health, if disposal protocols are not meticulously managed. Managing electronic waste (or E-waste) is one of the most rapidly growing pollution problems worldwide. New technologies are rapidly superseding millions of analogue appliances leading to their disposal in prescribed landfills despite potentially their adverse impacts on the environment. The consistent advent of new designs, "smart" functions and technology during the last 20 years is causing the rapid obsolescence of many electronic items.

An overview of the volume of E-waste generated in a range of categories estimates that over 130 million computers, monitors and televisions become obsolete annually and that the annual number is growing in the United States [2]. In China 5 million new computers and 10 million new televisions have been purchased every year since 2003 [3], and around 1.11 million tons of E-waste is generated every year, mainly from electrical and electronic manufacturing and production processes, end-of-life of household appliances and information technology products, along with imports from other countries.

Switzerland is the first country to implement the organized E-waste management system in the world. Extended Producer Responsibility (EPR) and Advance Recycling Fee (ARF) are the backbone of E-waste management system in Switzerland and other developed countries. Advanced countries like USA, UK, France, and Germany generate 1.5 to 3 million tons of E-waste annually and are among the largest generators of E-waste. But these countries also have standardized E-waste management processes in place.

Proper E-waste management, from efficient sourcing and collection right up to extraction and disposal of material, has ensured that this huge pile of junk turns into a lucrative business opportunity [4]. Due to very stringent environmental standards, the cost of collection, preprocessing, recycling and disposal are pretty high. So for every organized recycler in the first world countries, there are quite a few who pose as recyclers and are mere brokers who ship these obsolete items to developing countries like India and China in the pretext of donation or second hand goods. There are many countries that have already started the "take back" system for electronic products and they also have dedicated laws on E-waste management.

INDIAN SCENARIO

Due to the rapid developmental activities, countries like India, today, face a fast increasing load of WEEE originating from both inland and through illegal imports. Moreover, as one of the fastest growing economies of the world, demand for consumer durables in the country has been on a rapid rising trend [5].

E-waste is one of the fastest growing waste streams in the world due to increasing "market penetration" in developing countries, "replacement market" in developed countries and "high obsolescence rate". In India, it has been argued that due to low market penetration rate in the past, the stock of WEEE already put on the market has not been as large as that in Organisation for Economic Co-operation and Development countries and the market of most products is far from saturated.

In India, domestic E-waste is significant in addition to illegal imports. Over the last few decades, India has become a major destination for E-waste exports from the developed nations.

Moreover, Indians have been generating rapidly increasing amounts of E-waste domestically. IT and telecom are two fastest growing industries in the country. India, by 2011, has achieved a PC penetration of 95 per 1000 from the 14 per 1000 in 2008. At present, India has 95 million PCs. One of the most threatening substances is lead, of which only 5 percent is recycled in India.

E-Waste Production in India

The Indian electronic waste industry is booming at a very rapid pace. It is expected to increase 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. A MOEF 2010 report [6] says that Indian electronic waste output has jumped 8 times in the last seven years i.e. 8,00,000 tons .The future projection of E-waste in India as per the Dept. of Information Technology is shown in Fig. 1. India has majorly two types of electronic waste market called organized and unorganized markets. 90% of the electronic waste generated in the country ends up in the unorganized market.

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. Indian PC industry is growing at a rate of 25% annually.

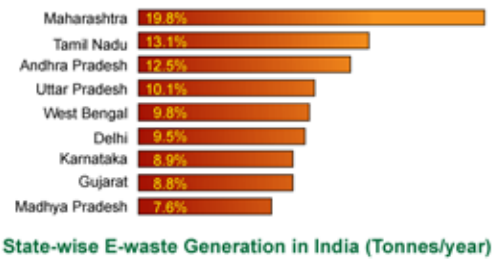
Projection of E-waste generation in India.

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. MAIT (Manufacturers Association for Information Technology) 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.

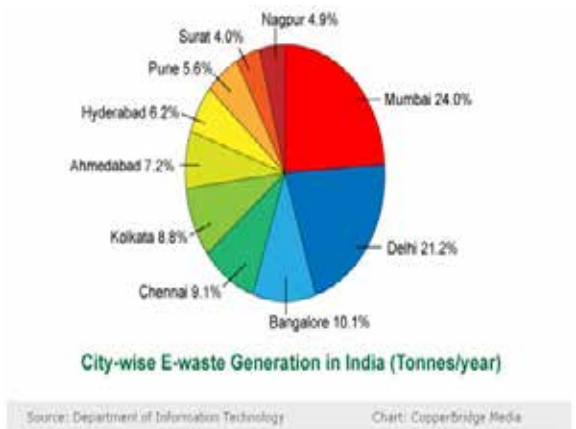
E-waste Generation in Major Indian Cities

A study was conducted in Hyderabad and Bangalore to access the generation of E-waste in the two cities by Environment Protection Training and Research Institute (EPTRI) and sponsored by World Health Organization, (WHO), India Country Office, New Delhi. The study has been carried out through field work in two cities: Hyderabad and Bangalore. The total E-waste generated in Hyderabad, due to computers, printers, television and mobile phones usage by 246 surveyed samples is 36,027.90 kg and in Bangalore by 148 surveyed samples is 48,254.55 kg. The annual E-waste generation has been estimated for Hyderabad and Bangalore as 3,263.994 and 6,743.87 MT, respectively from computers, printers, television and mobile phones. The projected E-waste generation restricting to above items from house hold sector alone was 95,120 MT in 2009 and expected to reach 1,07,886 MT in 2013 in Hyderabad and 1,21,410 MT in 2009 and expected to reach 1,30,383 MT in 2013 in Bangalore.

Sixty five cities in India generate more than 60% of the total E-waste generated in India. MoEF (2008) [7] stated that ten states generate 70% of the total E-waste generated in India. Maharashtra ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab in the list of E-waste generating states in India (Fig. 2). Among top ten cities generating E-waste, Mumbai ranks first followed by Delhi, Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pune, Surat and Nagpur. Complementing this, a study conducted by MPCB (2007) [8] states that Mumbai and Pune fall under the top ten cities that are generating maximum quantities and Mumbai alone generates maximum among all the cities of India.(Fig. 3).



Statewise contribution to E-waste in India.



Major E-waste generating cities in India.

Impacts of E-waste on Human Health

The major E-waste problem in developing countries arises from the importation of E-waste and electronic goods from developed countries because it is the older, less ecologically friendly equipment that is discarded from these Western countries 80% of all E-waste in developed countries is being exported [3]. Limited safeguards, legislation, policies and enforcement of the safe disposal of imported E-waste and electronic goods have led to serious human and environmental problems in these countries. For instance, E-waste disposal impacts on human health has become a serious issue that has already been noted in case studies from China [9-15].

Informal processing of electronic waste in developing countries may cause serious health and pollution problems, though these countries are also most likely to reuse and repair electronics. E-waste disposals impact human health in two ways which include: (a) food chain issues: contamination by toxic substances from disposal and primitive recycling processes that result in byproducts entering the food chain and thus transferring to humans; and (b) direct impact on workers who labor in primitive recycling areas from their occupational exposure to toxic substances.

EFFECT OF E-WASTE CONSTITUENT ON HUMAN HEALTH [16]

Sl. No.	Source of E-waste	Constituent	Health effects
1	Solder in printed circuit boards, glass panels and gaskets in computer monitors	Lead (Pb)	Damage to central and peripheral nervous systems, blood systems and kidney damage. Affects brain development of children.

2	Chip resistors and semiconductors	Cadmium (Cd)	Toxic irreversible effects on human health. Accumulates in kidney and liver. Causes neural damage. Teratogenic.
3	Relays and switches, printed circuit boards	Mercury (Hg)	Chronic damage to the brain. Respiratory and skin disorders due to bioaccumulation in fishes
4	Corrosion protection of untreated and galvanized steel plates, hardener for steel housings	Hexavalent chromium (Cr) VI	Asthmatic bronchitis. DNA damage
5	Cabling and computer housing	Plastics including PVC	Burning produces dioxin. It causes Reproductive and developmental problems; Immune system damage; Interfere with regulatory hormones
6	Plastic housing of electronic equipments and circuit boards	Brominated flame retardants (BFR)	Disrupts endocrine system functions
7	Motherboard	Beryllium (Be)	Carcinogenic (lung cancer) Inhalation of fumes and dust. Causes chronic beryllium disease or beryllicosis. Skin diseases such as warts.

HAZARDOUS SUBSTANCES IN E-WASTE

E-waste consists of a large variety of materials [17], some of which contain a range of toxic sub- stances that can contaminate the environment and threaten human health [18]. E-waste disposal methods include landfill and incineration, both of which pose considerable contamination risks. Landfill leachates can potentially transport toxic substances into groundwater whilst combustion in an incinerator can emit toxic gases into the atmosphere. There are more than 1000 toxic substances [19] associated with E-waste, the more commonly reported substances include: toxic metals (such as barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe),lead (Pb), lithium (Li), lanthanum (La), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), silver (Ag), hexavalent chromium (Cr(VI)) and persistent organic pollutants (POPs) such as dioxin, brominated flame retardants (BFRs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs), Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and polyvinyl chloride (PVC).

EFFECT OF E-WASTE ON ENVIRONMENT

The E-waste may also pollute ground water, soil and air if not disposed properly. The heavy metals like cadmium, lead etc may leach from the waste and may pollute the ground water. When E-waste is disposed off on the ground the hazardous substances mix with the soil and lowers the pH of the soil making the soil acidified. The presence of metals like cadmium, mercury, lead causes air pollution leading to severe environmental impacts like global warming, hole in the ozone layer. Reusing and recycling the raw materials from end-of- life electronics conserve s natural resources and avoids solid waste, air and water pollution, as well as greenhouse gas emissions.

The presence of toxic substances in E-waste was recognized only within the last 20 years. There is inadequate legislation worldwide for effective management of such waste. The rapid growth of E-waste and the ineffectiveness of legislation has led to inappropriate management strategies in both developed and developing countries, leading to profound impacts on the environment. Management of E-waste by recycling and by disposal to landfills has been shown to pose significant risks to the environment [19-22] .

DEALING WITH E-WASTE

There are basically four ways in which E-waste has been treated till date , but none has been found to be fully satisfactory.

Landfilling

It is one of the most widely used methods for disposal of E-waste. In land filling, trenches are made on the flat surfaces. Soil is excavated from the trenches and waste material is buried in it, which is covered by a thick layer of soil (Fig. 4 and 5). Modern techniques like secure landfill are provided with some facilities like, impervious liner made up of plastic or clay, leachate collection basin that collects and transfer the leach ate to waste water treatment plant. The degradation processes in landfills are very complicated and runs over a wide time span. The environmental risks from land filling of E-waste cannot be neglected because the conditions in a landfill site are different from a native soil, particularly concerning the leaching behavior of metals. Mercury, cadmium and lead are the most toxic leachates. Lead has been found to leach from broken lead containing glass, such as the cone glass of cathode ray tubes from TVs and monitors. Cadmium also leaches into soil and ground water. In addition, it is known that cadmium and mercury are emitted in diffuse form or via the landfill gas combustion plant. Landfills are also prone to uncontrolled fires, which can release toxic fumes. Therefore, landfilling does not appear to be an environmentally sound treatment method for substances, which are volatile and not biologically degradable (Cd, Hg,), persistent (Poly Chlorinated Biphenyls) or with unknown behaviour in a landfill site (brominated flame retardants).

Irrespective of the current global move towards zero wastes, the number of landfills has been increasing in both developed and developing countries. While the owners of modern landfills argue that recently constructed landfills are capable of safely isolating from the environment the pollutants found in electronics [23], the presence of thousands of old landfills with no barrier and containing a mixture of putrescibles and E-wastes is of much concern. There is sufficient evidence now to demonstrate that landfills accepting electronic devices or old landfills containing E-wastes will cause groundwater contamination [24,25]. Pollutants have the potential to migrate through soils and groundwater within and around landfill sites [26]. Organic and putrescible material in landfills decomposes and percolates through soil as landfill leachate. Leachates can contain high concentrations of dissolved and suspended organic sub- stances, inorganic compounds and heavy metals. However, the concentrations of toxic substances from leachate depend on the waste characteristics and stages of waste decomposition in a particular landfill [27].

Incineration

It is a controlled and complete combustion process, in which the waste material is burned in specially designed incinerators (fig. 6) at a high temperature (900-1000 °C). Advantage of incineration of E-waste is the reduction of waste volume and the utilization of the energy content of combustible materials. Some plants remove iron from the slag for recycling. By incineration some environmentally hazardous organic substances are converted into less hazardous compounds. Disadvantage of incineration are the emission to air of substances escaping flue gas cleaning and the large amount of residues from gas cleaning and combustion. E-waste incineration plants contribute significantly to the annual emissions of cadmium and mercury. In addition, heavy metals not emitted into the atmosphere are transferred to slag and exhaust gas residues and can reenter the environment on disposal. Therefore, E-waste incineration will increase these emissions, if no reduction measures like removal of heavy metals are taken.

E-waste transportation.

Landfilling with E-waste.

Reuse of E-waste

It constitutes direct second-hand use or use after slight modifications to the original functioning equipment. It is commonly used for electronic equipments like computers, cell phones etc. Inkjet cartridge is also used after refilling. This method also reduces the volume of E-waste generation. We can use above mentioned methods for treatment and disposal of E-waste. The better option is to avoid its generation. To achieve this, buy back of old electronic equipments shall be made mandatory. Large companies should purchase the used equipments back from the customers and ensure proper treatment and disposal of E-waste by authorized processes. This can considerably reduce the volume of E-waste generation.

Incineration of E-waste.

Recycling

Monitors and Cathode Ray Tubes (CRTs), keyboards, laptops, modems, telephone boards, hard drives, floppy drives, compact disks, mobiles, fax machines, printers, CPUs, memory chips, connecting wires & cables can be recycled. Recycling involves dismantling i.e. removal of different parts of E-waste containing dangerous substances like PCB, Hg, separation of plastic, removal of CRT, segregation of ferrous and non-ferrous metals and printed circuit boards. Recyclers use strong acids to remove precious metals such as copper, lead, gold. The value of the elements obtained from recycling could be much higher if appropriate technologies are used. The recyclers working in poorly– ventilated enclosed areas without mask and technical expertise results in exposure to dangerous and slow poisoning chemicals. The existing dumping grounds in India are full and overflowing beyond capacity and it is difficult to get new dumping sites due to scarcity of land. Therefore recycling is the best possible option for the management of E-waste (fig.7). E-waste disposal methods include landfill and incineration, both of which pose considerable contamination risks. Landfill leachates can potentially transport toxic substances into groundwater whilst combustion in an incinerator can emit toxic gases into the atmosphere. Recycling of E-waste can also distribute hazardous substances into the environment and may affect human health.

Vast quantities of E-waste are now being moved around the world for recycling in developing countries using manual processes in backyards of residential properties, resulting in significant contamination of soil, water and air in these countries. Such practices have also resulted in the poisoning of many local people engaged with the recycling process.

Recycling of E-waste.

RULES AND REGULATIONS

The rules are applied to every producer, dealer, collection centre, refurbisher, dismantler, recycler, auctioneer, consumer or bulk consumer involved in the manufacture, sale, and purchase and processing of electrical and electronic equipment or components. According to the rules, the producers of electrical and electronic equipments including large and small household appliances, computers, toys, leisure and sports equipments, and medical devices shall be liable for collecting any E-waste generated during manufacture and will have to channelize the same for recycling or disposal. They will set up collection centers for E-waste generated from the 'end of life' products in line with the principle of the 'Extended Producer Responsibility' and ensure that such E-waste is channelized to a registered refurbisher or dismantler or recycler. They have to ensure that all electrical and electronic equipments are provided with a unique serial number or individual identification code for product tracking in the E-waste management system. They shall also finance and organize a system to meet the costs involved in the environmentally sound management of E-waste generated from the 'end-of life' of its own products and 'historical waste' available on the date from which the rules come into force. The producers will also have to provide contact details of dealers and authorized collection centers to consumers so as to facilitate return of E-waste.

The Rules also clearly stated the responsibilities of the consumers and bulk consumers. They have to ensure that E-waste is deposited with the dealers or authorized collection centers. They may also avail the pickup or take back services provided by the producers. As per these rules, any person operating a collection center, individually or collectively, is required to obtain authorization from the SPCB or PCC concerned. To ensure E-waste management in an environmentally sound manner, they have to make certain that the storage system is secure and that the transportation to the producer, refurbisher or to the registered recycler is safe.

Conclusions

E-waste is a serious problem at both local and global scales. E-waste problems appeared initially in developed countries and now extend widely to other countries around the world. The volume of E-waste is growing fast because of Rapid technology change, low initial cost, increased purchase power, high obsolescence rate have resulted in a fast growing problem of E waste. As about 90% of the E-waste generated in India is being consumed by the informal sector. Bringing E waste in regulatory regime alone will not solve the problem of E-waste. Educating people about how to recycle, reuse, and dispose electronics at all levels will teach them and their communities how to

behave more responsibly towards the environment.

Individual consumer should promote effective E-waste management by mitigating the role of scrap yard. Government should also take stringent actions to enforce the "E-waste (Management and Handling) Rules, 2010". Poor quality electronic gadgets which do not last long like Chinese gadgets should not be allowed in the market.

The key to success in terms of E-waste management is to develop eco-design devices, properly collect E-waste, recover and recycle material by safe methods, dispose of E-waste by suitable techniques, forbid the transfer of used electronic devices to developing countries, and raise awareness of the impact of E-waste.

REFERENCES

[1] Widmer, R., Lombard, R., 2005. E-waste Assessment in South Africa a Case Study of the Gauteng Province. EMPA, pp. 1–62. | [2] Bushehri, F.I., 2010. UNEP's role in promoting environmentally sound management of E-waste. In: 5th ITU Symposium on "ICTs, the Environment and Climate Change" Cairo, Egypt. | [3] Hicks, C., Dietmar, R., Eugster, M., 2005. The recycling and disposal of electrical and electronic waste in China-legislative and market responses. Environmental Impact Assessment Review 25, pp 459–471. | [4] Sukeshini (2013). Electronic waste : A growing Concern in Today's environment Sustainability. International Journal of Social Science & Interdisciplinary Research, Vol.2 (2), February (2013). | [5] Anwesha Borthakur and Kunal Sinha (2013). Generaion of electronic waste in India: Current scenario, dilemmas and stakeholders. African Journal of Environmental Science and Technology, Vol. 7 (9), pp 899-910. | [6] MoEF (2010) Modified draft on rules on handling E-waste, dated May 14, 2010. | [7] MoEF (2008). Guidelines for Environmentally Sound Management of E-waste (as approved vide Ministry of Environment and Forests (MoEF) letter No. 23-23/2007-HSMD; 2008. dated March 12, 2008. | [8] MPCB (2007). Report on Assessment of Electronic Wastes in Mumbai-Pune Area, Maharashtra. Maharashtra Pollution Control Board. | [9] Chan, J.K.Y., Xing, G.H., Xu, Y., Liang, Y., Chen, L.X., Wu, S.C., Wong, C.K.C., Leung, C.K.M., Wong, M.H., 2007. Body loadings and health risk assessment of polychlorinated dibenzo-p-dioxins and dibenzofurans at an intensive electronic waste recycling site in China. Environmental Science & Technology 41, pp 7668–7674. | [10] Huo, X., Peng, L., Xu, X., Zheng, L., Qui, B., Qi, Z., Zhang, B., Han, D., Piao, Z., 2007. Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. Environmental Health Perspectives 115, pp 1113–1117. | [11] Qu, W., Bi, X., Sheng, G., Lu, S., Fu, J., Yuan, J., Li, L., 2007. Exposure to polybrominated diphenyl ethers among workers at an electronic waste dismantling region in Guangdong, China. Environment International 33, pp 1029–1034. | [12] Wang, T., Fu, J., Wang, Y., Liao, C., Tao, Y., Jiang, G., 2009b. Use of scalp hair as indicator of human exposure to heavy metals in an electronic waste recycling area. Environmental Pollution 157, pp 2445–2451. | [13] Xing, G.H., Chan, J.K.Y., Leung, A.O.W., Wu, S.C., Wong, M.H., 2009. Environmental impact and human exposure to PCBs in Guiyu, an electronic waste recycling site in China. Environment International 35, pp 76–82. | [14] Zhao, G., Wang, Z., Dong, M.H., Rao, K., Luo, J., Wang, D., Zha, J., Huang, S., Xu, Y., Ma, M., 2008. PBBs, PBDEs, and PCBs levels in hair of residents around e-waste disassembly sites in Zhejiang Province, China, and their potential sources. Science of the Total Environment 397, pp 46–57. | [15] Zheng, L., Wu, K., Li, Y., Qi, Z., Han, D., Zhang, B., Gu, C., Chen, G., Liu, J., Chen, S., Xu, X., Huo, X., 2008. Blood lead and cadmium levels and relevant factors among children from an e-waste recycling town in China. Environmental Research 108, pp 15–20. | [16] Shagun, Ashwani Kush, and Anupam Arora (2013). Proposed Solution of e-Waste Management. International Journal of Future Computer and Communication, Vol. 2, No. 5. | [17] Zhang, S., Forssberg, E., 1997. Mechanical separation-oriented characterization of electronic scrap. Resources, Conservation and Recycling 21, pp 247–269. | [18] Kiddee. P., Ravi Naidu., Ming H. Wong. (2013) Electronic Waste Management approaches : An Overview. Waste Management , 33, pp 1237-1250. | [19] Puckett, J., Smith, T., 2002. Exporting harm the high-tech trashing of Asia. In: Coalition, S.V.T. (Ed.) | [20] Robinson, B.H., 2009. E-waste: an assessment of global production and environmental impacts. Science of the Total Environment 408, pp 183–191. | [21] Wong, C.S.C., Duzgoren-Aydin, N.S., Aydin, A., Wong, M.H., 2007a. Evidence of excessive releases of metals from primitive e-waste processing in Guiyu, China. Environmental Pollution 148, 62–72. | [22] Wong, M.H., Wu, S.C., Deng, W.J., Yu, X.Z., Luo, Q., Leung, A.O.W., Wong, C.S.C., Luksemburg, W.J., Wong, A.S., 2007b. Export of toxic chemicals – a review of the case of uncontrolled electronic-waste recycling. Environmental Pollution 149, pp 131–140. | [23] Swana (2004). The Environmental Consequences of Disposing of Products Containing Heavy Metals in Municipal Solid Waste Landfills. Solid Waste Association of North America, Silver Spring, MD. | [24] Schmidt, C.W., 2002. E-junk explosion. Environmental Health Perspectives 110. | [25] Yang, G.C.C., 1993. Environmental Threats to Discarded Picyure tubes and Printed Circuit boards, Journal of Hazardous Materials 34, pp 235-243. | [26] Kasassi, A., Rakimbei, P., Karagiannidis, A., Zabaniotou, A., Tsiouvaras, K., Nastis, A., Tzafeiropoulou, K., 2008. Soil contamination by heavy metals: measurements from a closed unlined landfill. Bioresource Technology 99, pp 8578–8584. | [27] Qasim, S.R., Chiang, W., 1994. Sanitary Landfill Leachate: Generation, Control and Treatment. CRC Press, The United States of America. |