



## E-Waste Management, Disposal and Its Impacts on the Environment

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### Abstract:

Waste electrical and electronic equipment (WEEE) is becoming major threat to the whole world. Its toxic emissions mixed with virgin soil and air and causing harmful effects to the entire biota either directly or indirectly. Direct impacts include release of acids, toxic compounds including heavy metals, carcinogenic chemicals and indirect effects such as bio magnification of heavy metals. Many private firms are involved in collecting, dismantling, separation and exporting e-wastes for recyclers. However, strict regulations are currently being followed as on approval of such firms such as e-steward certification by Basel action network in US, they also involved in public awareness programs; this review is based on collected information from various journal articles, websites including the technical note by Greenpeace international. Further, it analyzes the current progress on e-waste management worldwide.

**Keywords:** E- waste, electronic waste, recycling, waste management

### 1.0 Introduction:

Electronic industry is the world's largest and innovative industry for its kind. Every year tons of electronic items are shipped over oceans, however, after their usage time they are become a complex waste matter which consists of many hazardous heavy metals, acids, toxic chemicals and non-degradable plastics. Many are dumped, burnt or exported to recyclers. However, about 75% of e-wastes are uncertain for their use or finding ways to use them which includes refurbishment, re-manufacture and reuse their parts for repair etc. While others are junks occupying usable space at houses, apartments, firms and industries. Most e-recyclers were exporting the toxic materials such as leaded glass, circuit boards, and mercury lamps usually to China, Africa and India (Basel Action uploaded on 2013). Dismantling process takes much labor, in countries like China and some parts of India there are tones e- wastes junked and dismantled; dismantling is not only involve in unscrewing but also shredding, tearing and burning. The smoke and dust particle consists of carcinogens and other hazardous chemicals which causes severe inflammations and lesions including many respiratory and skin diseases. Circuits are burnt to hunt the valuable metals such as gold, platinum,

cadmium but the wire coat of those consists of PVC and PCB which may produce erotic smoke, and carbon particles from the toners are carcinogens, they may lead to lung and skin cancer (Kevin *et al.*, 2008). Due to the poverty some places in China such as city of Guangzhou still risking their health with e-waste full of used computers and television sets, according to the data received in 2007 about 70 % of e- waste of the world reaches China and the rest to Africa and India, due to their cheap labor they have become the world's dumping station of e- waste, in Ghana about 20% of their population are working on e-waste; they use after reconditioning them (Basel Action uploaded on 2013). Poverty is the main reason for third world countries to consume e-wastes from Europe and USA.

### 2.0 Research methodology

This work is based on collected and gathered information from Greenpeace technical note 10, 2008 and different research papers including video documentaries to figure out the following issues regarding e-wastes, sources, dismantlers, current methods of e-waste disposal, and the hazardous chemicals, heavy metals, their effects on human health and the environment, possible solutions and organizations involved.

### 3.0 Discussion

#### 3.1 Sources of e-waste

Almost every used electronic items are considered as e-waste such as discarded cellphones, cameras, CD players, TVs, radios, drills, fax machines, photocopiers, printers, toners, ink cartridges, batteries, re-chargeable batteries, digital calculators and clocks, CRT monitors, electric solders, computer mother boards, key board, industrial and house hold electronic machinery such as oven, fridge, sewing & washing machines, fan, air-conditioner, grinder, iron, heater, military and laboratory electronic equipment's, etc.

#### 3.2 Particles and their origins

Phthalates includes PVC in wire coatings and cables, di (2-ethylhexyl) phthalate (DEHP), diisononyl phthalate (DINP), Butylbenzyl phthalate (BBP), DIDP (diisodecyl phthalate) and dibutyl phthalate (DBP), (Otake *et al.* 2001, Butte & Heinzow 2002, Fromme *et al.* 2004). Chlorinated compounds such as Polychlorinated biphenyls (PCBs), PCBs are released from capacitor dielectrics, hydraulic fluids, printing inks, plasticizers and transformer oils, PCB also produced during the combustion of PVC and other chlorinated materials (Hedman *et al.* 2005, Wikstrom & Marklund 2001). Chlorobenzenes are used as solvents and intermediates of pigments and die also emitted in the combustion of PVC (Grimes *et al.* 2006).

Flame retardants include Polybrominated diphenyl ethers (PBDEs) are flame retardant additives widely used in plastic casings of electronic equipment's and as foams. Triphenyl phosphates (TPP) used as flame retardants and plasticisers in photocopy films and found in hydraulic fluids and oils TPP also found in plastic covering of monitors (Carlsson *et al.*, 1997). Heavy metals includes Lead, which is used in electrical solder, batteries, commonly used as alloy with tin, in cathode ray tube lead oxide is used in the glass, used as stabilisers in formulation of PVC. (Matthews 1996). Cadmium compounds are used in contacts, switches, solder joints, in rechargeable batteries, as stabilisers in formulation of PVC (Matthews 1996), Cadmium sulfide are used in interior surface of the CRT screens to produce illumination (Burstall 1997). Antimony is used in semiconductors, flame retardant formulations in plastics (Lau *et al.* 2001), also used in lead acid starter batteries and electrical solders (Kentner *et al.* 1995). Air of the e-waste combusting region may have

oxides of these heavy metals. Mercury is found in printed circuit boards, relays and switches, chromium is used as corrosion protectant in galvanized steel parts, Barium is found in CRT monitors, Beryllium is commonly found in circuit mother boards, (Ramachandra and Saira Varghese, 2004). Free Carbon radicles from toners of printers also another form of e-waste.

#### 3.3 Impact of products from e-waste in human health

There are chances of accidents like cuts and burns during the dismantling, shredding, acid baths and incineration process, in addition, exposure to following chemicals have many long-term effects. Phthalates such as DEHP in its monomer form effects the development of testis, Butylbenzyl phthalate (BBP) and dibutyl phthalate (DBP) also hazardous to reproduction exposure to phthalates in pregnancy reduces ano-genetal index in male child (distance between anus and genitals) (Swan *et al.* 2005), DINP and DIDP (diisodecyl phthalate) effects liver and kidneys. Chlorinated compounds includes Polychlorinated biphenyls (PCBs), PCB accumulates in fishes and other organisms and undergo bioaccumulation which result in high value in top-level carnivore such as humans, PCB also absorbable via skin and inhaled or ingested causing neurotoxicity, liver damage, tumors, immunosuppression and behavioral changes, and reproductive disorders, abnormal sperms (Allsopp *et al.* 1999, Allsopp *et al.* 2001a).

Chlorobenzene causes acute and chronic effects in mammals, effects CNS (central nervous system), liver and thyroid. Increasing degree of chlorination such as tetrachlorobenzenes also affects kidneys. Hexachlorobenzene (HCB) are group 2B carcinogens it damages immune system, liver, thyroid, CNS, kidney and nervous system (van Birgelen 1998). It is also reported the bioaccumulation of HCB. Polybrominated diphenyl ethers (PBDEs) is an environmentally persistent compound, which is also reported in bioaccumulation, it causes abnormal brain development during the initial development of a fetus, it also associated with impacts on learning, memory, behavior and thyroid, oestrogen hormone systems and effecting the immune system (Legler & Brouwer 2003). When PBDEs are burnt they produce brominated dioxins/furans which are similarly hazardous. Triphenyl phosphates (TPP) are a contaminant in human blood (Jonsson *et al.* 2001),

potent inhibitor of a key enzyme (monocyte carboxyl esterase) in human blood cells (Amini & Crescenzi 2003).

Heavy metals such as lead may produce irreversible effects; it affects nervous system, blood, reproductive system and kidneys, it affects brain development in children (ATSDR 2007, Canfield *et al.*, 2003). Cadmium is a toxicant which can accumulate in tissues, exposure may affect kidneys and bones (Elinder & Jarup 1996, WHO 1992), it disrupts calcium mechanism, causing hypertension and heart diseases Cadmium oxide in fume affects the respiratory system (ATSDR 1999, Elinder & Jarup 1996, WHO 1992), in addition it is a carcinogen causing lung cancer (DHSS 2005). Antimony is a toxic compound causing dermatitis, affecting skin cells and respiratory tract and affects the immune mechanism (Kim *et al.*, 1999). It is also stated as possible carcinogen by International Agency for Research on Cancer (IARC 1989). Mercury results in respiratory and skin disorders and causing chronic damage to brain. Chromium is a known carcinogen it affects the DNA and causing asthmatic bronchitis. Barium causes damage to heart, spleen and liver also causing muscle weakness, Beryllium is a carcinogen causing lung cancer inhalation also causes chronic disease beryllicosis and resulting skin warts (Ramachandra and Saira Varghese, 2004), free Carbon radicles are carcinogens.

### 3.4 E-waste in Ghana, Africa

About 4 million tons of wastes are brought to Ghana from Antwerp and other parts of western world. Government of Ghana has signed in every international treaties but entry of e-waste is still there as the people of Ghana are not afford to purchase new electronic goods due to their poverty. And slum children and young men are used as collectors and dismantlers for cheap labor. E-wastes includes camera, computers, TVs, refrigerators, drillers and many used electronic items. They are sold for cheap price but no warranty for its usage, while unusable items are burned and dumped there (Figure 1). The river has now become a dark muddy stream rich in heavy metal wastes. Fisher men have almost lost their hopes and catch contains heavy metals which can cause long-term impact to human beings. (Dateline uploaded on, 2011).



Figure 1. Combustion of e- waste in Ghana, Africa (Dateline, 2011).

### 3.5 City of Guiyu, China and e-wastes

Guiyu was a peaceful paddy harvesting village in early days, but now it has become a junk yard of much of the electronic discards. Extraction of steel, Aluminum, plastic and Gold occurs in every corner of the village; about hundred thousand people are engaged with dismantling electronic items. After collecting the metals they simply burn the rest, the hazardous smoke spreads and causing variety of respiratory and skin diseases, they also wash vegetables here which also lead to stomach problems. Now the surface and well waters of Guiyu has become undrinkable (Figure 2), according to Basel Action Network the content of lead in river Linjaing of Guiyu is between 1.9-24mg/ L whereas the WHO border line is 0.01 mg/ L. Thus they had to wait for water from 30 km away. Open dumping of plastic, and release of dioxins, hydrocarbons and toxic brominated compounds to the soil is a common hazard, In addition circuit boards are burnt which releases fumes consisting toxic lead, tin and mercury, and toxic irritant isocyanides. It was reported water and soil consist of very high levels of lead. (Basel Action uploaded on 2013).



Figure 2. A stream polluted by e- waste in Guiyu, China (Basel Action, 2013).



A worker burning circuit board to get metals in Seelampur, India. (Keekeesocean uploaded on 2012).

### 3.6 Effect of e-wastes in India

About 80,000 people working for recycling sector, some villages such as Seelampur has scrap markets where piles of e- wastes are separated for recycling. They separate copper from wires after burning them. Plastic and PVC codes produce noxious smoke which is irritable to eyes and cause respiratory problems. In addition, acid treatment is given to isolate metals; corrosive acids also released from used batteries of cell phones and computers, according to scientists of Greenpeace recycling of a computer in India costs just 2\$ while it is 20\$ in US (Keekeesocean uploaded on 2012), not only cheap labor but also for the profit from recovered metals of circuit boards such as copper gives earning of 3 to 5 \$ per day workers are spending on dismantling e-wastes rather considering their own health (Figure 3). However, currently they are building an e-waste

recycling plant in Bengalore which was estimated as having the capacity to handle 60,000 tons of e-wastes annually. In India about 24% of e-waste was produced from Mumbai, and, Delhi, Bangalore and Chennai are 21.2, 10.1 and 9.1 respectively.

### 3.7 Current disposal methods of e-waste

Currently following methods are used to get rid of e-wastes they are Incineration, Acid baths, Landfills

#### 3.7.1 Landfills

E-wastes ending up as landfills are described as toxic time bomb. They may release to the environment after several years by natural means, and there is a possibility of leaching of wastes such as batteries releases acids and heavy metals mercury, nickel and cadmium, electronic circuits have lead, zinc, Nickel, Copper, Mercury and cadmium. These may reach the land water and reaches animals and humans, and mixes with other fresh water sources such as rivers and streams. Almost half the e-wastes of US and Australia are dumped as landfills while the rest are exported to Asia and Africa.

#### 3.7.2 Acid baths

Acid bath method is used to extract Copper, here the circuit board is submerged in to Sulfuric acid for about 12 hours to dissolve Copper then solution is boiled, precipitated Copper Sulfate is taken and remaining solution is added with scraped particles, subsequently Copper smudges are removed. Acid baths also used to dissolve the lead and in the extraction of Gold and Silver.



Dissolved copper in the acid bath turned the solution green (By Brad 2011).

### 3.8 Incineration

Incineration also includes pyrolysis; substances generated during incineration are likely to be more toxic than its ordinary form, pyrolysis heating the substance in the absence of oxygen, here the burning does not occur but the substances are converted to fumes, oils and charcoal. However, in gasification limited air is given to convert the substances into fume, ash and tar. Incineration is a commonly used method of the dispersal of e-waste in China, Africa, India and Pakistan. When heating the plastic or PVC circuit board it releases erotic fume consists of Polycyclic aromatics (PCA), polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) which are known carcinogens and gases such as carbon monoxide, sulfur dioxide, nitrogen oxides. Smoke also consists of minor quantities of oxides of following heavy metal residues antimony, lead, thallium, arsenic, copper, manganese, mercury and nickel, reminder ended up in the ashes.



End products of pyrolysis from circuit boards, mixture of metals and non-metals in the 1<sup>st</sup> and 2<sup>nd</sup> bag whereas 3<sup>rd</sup> bag consist of metals and 4<sup>th</sup> bag consist of only non-metals (from left).

### 3.9 Safe methods for disposal of e-waste and managing authorities

Most safe method is recycling materials including metals and reusing them, which includes industry wide system for the collection of e-wastes. Implementing proper rules to make following as mandatory wearing protective masks and gloves and safety glass when dismantling and avoid easy methods of extraction such as incineration which results harmful fumes, avoid dumping and avoid using acid baths, and implementing strict rules against dumping e-wastes in landfills as it could leach out towards ground water or may be released after long time. Implementing proper storage system for collected and extracted e-wastes until it is reused as products, strengthen the implementation

of agreed legislations of Basel convention and implementing potent laws to prevent political invasions or pressures. Take action against unapproved illegal e-waste collectors and dismantlers, encourage research scientists in finding alternatives to hazardous chemicals and carcinogens, banning the electronic products with hazardous ingredients, monitoring the transportation of e-wastes within the state municipal limits as well as ports and harbors. Consulting with manufactures e-waste processors, environmental groups such as NRDC, Basel Action Network (BAN) have created a certification system for recycling, refining and refurbishing companies known as e-Stewards. E-steward certification assures the recyclers keep up the standards which allow the recycling process in a way that protects workers health and the environment. BAN also maintains a list of companies which are permitted to act as subscribed e-stewards (NRDC 2012), in 2010 the first certified standard was announced. And NRDC, BAN and other advocates are currently working on ensuring the strong implementation of the laws against e-waste exporters (NRDC 2012). Moreover, In many states of US have implemented the system to make electronic manufactures to take responsibility for their products, Thus, electronic manufactures are given great responsibility to collecting the products after their use and recycling them. It is also important to educate the public on handling and disposal of e-waste through awareness programs.

### 4.0 Conclusion:

It is confirmed that the public awareness and co-operation of manufactures are essential for the advancement of e-waste management system. And also it is the responsibility of governments to allocate sufficient grants and protecting the internationally agreed environmental legislations within their borders. Licensing of certification like e-stewardship may ensure the security to prevent illegal smugglers and handlers of e-waste. Basel Action Network is now working at their best to stop or control trans boundary e-waste movements, they also involved in conducting public awareness programs to enlighten the world community and opening research areas to find better methods or alternatives. As e-wastes are the known major source of heavy metals, hazardous chemicals and carcinogens, certainly diseases related to skin, respiratory, intestinal, immune, and endocrine and

nervous systems including cancers can be prevented by proper management and disposal of e-waste.

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