# Controlling Computers and Electronics Waste:
## Toward Solving Environmental Problems

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*Abstract*— Environment problem becomes an essential issue associated modern life in this century. Advancement in electronic production and cost reduction in the last few decades leads to rapid growing of computers and electronic productions (e-devices). This was associated with flood of advertisements which affect customer's decision on buying new products regardless of their real needs. Although e-devices improved human life but it created a serious environmental problem called e-waste. Millions of tons of e-waste generated worldwide yearly, which is more toxic and harmful than normal household garbage. E-waste contains toxic heavy metals including arsenic, antimony, lead, mercury, nickel and zinc. Increasing consumption of e-devices in developing countries and transferring e-waste from developed to developing countries make the problem worst. So we need an innovative and creative engineers and effective recycling system to produce eco-friendly products that are easier to recycle and handle in their end-of-life. Several developing countries in Asia, Africa and Latin America still suffer from lack of advance recycling and disposal treatment experience. Workers in recycling are exposed to hazardous chemicals and material when braking e-products and extracting its valuable contents besides the polluting of water, air and soil. This paper studying the e-waste status and proposes a framework for guidance solution to control and eliminate e-waste, protecting workers and environment in developing world as step toward green environment.

***Keywords- Computer waste, e-waste, e-waste recycle, green environment.***

## I. FUNDAMENTAL FOR COMPUTER AND ELECTRONIC DEVICES

Laptops, PC computers, mobiles, TVs, communication equipments, and house-held devices become essential part to facilitate all aspects of human life at home, office, public and private area. These products and equipments are almost used in industry, education, healthcare and medicine, communications, security, information systems, agriculture and food industry, trading, military, entertainment, services, and other fields. Current situation shows that billions of computers and electronic devices are produced and consumed yearly but on the other hand, life of hundreds of millions of such devices is ended. This leads to a big environmental problem called an E-Waste.

Literatures show that: In 2006 US produces about 139 million of portable communication devices, 34 millions of TVs and display units, and 24 millions of PCs [1]. In Eastern Europe [2]; electronic devices produced and marketing in 2005 included: 776 million of lamps, 44 million of large household devices, 48 million of PCs and laptops, 32 million of TVs. On the other hand if we look at Asian countries especially the two most population countries we find that: China sold about 14 million PCs in 2005, 48 million TVs [3]. India installed about 5 million PCs in 2006, which is contributing to the 25% compounded annual growth rate in the Indian PC industry [4]. We have to know that both growth rate and market sales are increasing yearly. GSM Association estimates that 896 million mobile phone handsets were sold in 2006 worldwide [5].

Electronics TakeBack Coalition summarizes the available statistics related to electronics sales in US and global world that was offer by Garner market research firm, Displaysearch market research firm, EPA a US environmental protection agency, IDC market research firm, and iSupply market research firm. This offers a support for researcher to quantify the e-waste problem. The results can summarize as: global sales for computers-PC and laptops is 350 millions in 2010 and 353 millions in 2011, tablets (include e-readers) is 72.7 millions in 2010 and 103.4 millions in 2011, All Televisions is 247 millions 2010 and 248 million in 2011, LCD TVs is 195 millions in 2010 and 206 millions in 2011, all Cell phones is 1.211 billion in 2010 and 1.59 billion in 2011, smart phones is 304.7 millions in 2010 and 491.4 millions in 2011, and Iphone is 47 millions in 2010 and 93 millions in 2011 [ 6-10].

Based on US environmental production agency (EPA) report on electronics waste management in US through 2009 which was published in may 2011; the total of electronics products (in units and in short tons) at end-of-life, in storage, and in use in 2009 are shown in table 1. Current market culture shows that a reasonable ratio of people affected by advertisements or announcements and buying new electronic equipments regardless of damage of their old devices. This leads to increase the e-waste and consequently an environmental problem occur. The available data about e-waste internationally is insufficient since many countries still not have such data and not well implemented the suitable future estimation techniques as well as many countries and organization try to hide the data related to electronic equipments that are used in military and sensitive fields.

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Table 1: Products at end-of-life, in storage, and in use in 2009 [10]

| (1980–2009) | Computers M units | Computer displays M units | Hard-copy devices M units |
|---|---|---|---|
| Total sold | 857 | 653 | 471 |
| In use | 325 | 191 | 167 |
| Total in storage | 70.5 | 40.2 | 41.4 |
| At end-of-life | 462 | 422 | 262 |
| | Keyboards & mice M units | TVs M units | Mobile devices M units |
| Total sold | 1670 | 772 | 1660 |
| In use | 368 | 312 | 812 |
| Total in storage | Not Estimated | 104 | 57.8 |
| At end-of-life | 1310 | 356 | 789 |

To have clear idea for the situation of electrical and electronic equipments in developing countries in (Asia, Africa, and Latin America); Tables (2) summarize results of some available studies and statistics about the quantity (Metric Tons / Year) of EEE put in the market, stock of EEE. Summary is based on Literatures [11- 30].

Table 2: Stock (installed base) of EEE in metric tons/year

| **Country** | **year** | **PCs** | **Mobile** | **TV** |
|---|---|---|---|---|
| **South Africa** | 2007 | 99200 | 3400 | 189900 |
| **Kenya** | 2007 | 21300 | 610 | 22600 |
| **Morocco** | 2007 | 67500 | 3400 | 151000 |
| **Senegal** | 2007 | 3100 | 410 | 15000 |
| **Peru** | 2006 | 70000 | 880 | 92300 |
| **Colombia** | 2006 | 57300 | 3000 | 146400 |
| **Mexico** | 2003 | 300000 | 4500 | 750000 |
| **India** | 2007 | 425000 | 27000 | 1904600 |
| **China** | 2007 | 1324800 | 59200 | 11975300 |

## II. COMPUTER AND ELECTRONIC DEVICES WASTE (E-WASTE)

To understand and estimate e-waste problem we have to investigate the reports, statistics and studies published by different agencies, organizations, or researcher. LR shows that e-waste generation and growth in high ratio across the entire World. Even the figure of 50 million tons of generated electronic waste (Waste of Electric and Electronic Equipment – WEEE) is amazing; estimates have revealed that this amount will double in the next decades. To get a better idea of existing amount of electronic equipments disposed of on worldwide level; we need reports (facts) that are issued based on series of data and statistics providing by several committees or organizations such as Computer TakeBack coalition [31] and Basel Action Network-BAN [32]. BAN is the world's organization focused on confronting the global environmental injustice and economic inefficiency of toxic trade (toxic wastes, products and technologies) and its devastating impacts. Estimates have revealed that this amount will double in the next decades.

The EPA report also shows another important data in table 3, which represent the Rate at which used electronics are collected for recycling relative to the total weight of each product ready for end-of-life management, 2006 to 2010. This offers an important indication for the big challenge of e-waste problem that requires a real solution.

Table 3: e-product recycling rate (ready for end-of-life) (2006 to 2010) [6]

| year | Computers | displays | Hard copy devices | Keyboards and mice | TVs | Mobile | Tot |
|---|---|---|---|---|---|---|---|
| 2006 | 33% | 21% | 37% | 7% | 16% | 6% | 22% |
| 2007 | 36% | 24% | 38% | 7% | 17% | 7% | 24% |
| 2008 | 38% | 26% | 35% | 7% | 16% | 11% | 24% |
| 2009 | 38% | 29% | 34% | 8% | 17% | 8% | 25% |
| 2010 | 40% | 33% | 33% | 10% | 17% | 11% | 27% |

The following table 4 shows e-waste quantity (item) production, dispose, trash, and recycling for year 2010 according to EPA report published in may 2011 [6].

Table 4: E-Waste items (Trashed or Recycled) in 2010

| **Products** | **Total disposed (M unit)** | **Trashed (M unit)** | **Recycled (M unit)** | **Recycling Rate %** |
|---|---|---|---|---|
| Computers | 51.9 | 31.3 | 20.6 | 40% |
| Monitors | 35.8 | 24.1 | 11.7 | 33% |
| Hard copy devices | 33.6 | 22.4 | 11.2 | 33% |
| Keyboards and Mice | 82.2 | 74.4 | 7.830 | 10% |
| Televisions | 28.5 | 23.6 | 4.940 | 17% |
| Mobile devices | 152 | 135 | 17.4 | 11% |
| **Total** | 384 | 310 | 73.7 | 19% |

UN University's estimations indicate that current e-waste arising across the twenty seven members of the European Union amount to around 9 million tons yearly; global figure are estimated to be around 40 million tons yearly [2]. To help in solving such problem we need an effective collection and treatment processes for e-waste. Treatment processes of e-waste aim at either removing the dangerous items or at separation of as much as possible of the main recyclable materials (e.g. metals, glass and plastics), but achieving both objectives is desired. The eastern Europe have limited data availability on amounts of e-waste collected and treated through "official" e-waste system channels, it is clear that the management of significant proportions of e-waste currently go unreported [2]. E-waste problem is one of the big challenges for human life currently and in the future especially in the developing countries since some of developed countries (US, EU countries) send their e-waste to the developing countries. The global study of current situation of e-waste in developing countries in Asia, Africa, East Europe, and Latin America shows the urgent need for advanced and innovative technologies or tools [11] to overcome such

crises. The increasing warning reports on the e-waste situation in countries such as China, India, Pakistan, Peru, Mexico, Brazil, Nigeria, and Ghana [12-15] as well as other countries raising the need for such innovative solutions. The technology exists embodied in machinery and equipment and un-embodied in blueprints, technical instructions, manuals etc [16, 17]. The term "technology" reflects four different dimensions as summarized by Hillebrand [18]: technical hardware, know-how, organization, and product. So; there is a need for great efforts to prepare comprehensive and innovative solution to solve environmental problems. To have clear idea for the recycling situation of electrical and electronic equipments in developing countries in (Asia, Africa, and Latin America); Tables (5) summarize results of some available studies and statistics about the quantity (Metric Tons / Year) of the E-waste generated. Summary is based on Literatures [28- 47].

Table 5: Quantity of e-waste generated in metric tons/year

| **Country** | year | PCs | Mobile | TV |
|---|---|---|---|---|
| **South Africa** | 2007 | 19400 | 850 | 23700 |
| **Kenya** | 2007 | 2500 | 150 | 2800 |
| **Morocco** | 2007 | 13500 | 1700 | 15100 |
| **Senegal** | 2007 | 900 | 100 | 1900 |
| **Peru** | 2006 | 6000 | 220 | 11500 |
| **Colombia** | 2006 | 6500 | 1200 | 18300 |
| **Mexico** | 2003 | 47500 | 1100 | 166500 |
| **India** | 2007 | 56300 | 1700 | 275000 |
| **China** | 2007 | 300000 | 7000 | 1350000 |

With consideration of the rapid growth of production and consumption of EEE as well as the generated waste [48]; we can understand the real e-waste problem that the world will face in the future, which requires great effort to find a suitable solution. Based on the above; we can summarize our finding from literatures related to E-waste as:

a) E-waste generation is growing faster than any other type of municipal waste on a global level. Each citizen from industrialized countries produces about 20 Kg. of e-waste yearly.
b) Almost US e-waste (80%) is exported to developing countries, China and India as principal destinations.
c) Most of the materials (70%) from electronic components can be recycled but 25% can be recovered, and just 3% would be wasted.
d) US e-waste recycling rate reaches 12.5% in comparison to 32% for other types of waste.
e) Most of the obsolete electronic devices and computers (75%) stored in a household.
f) 22% of all mercury consumed on a worldwide level is used in manufacturing of electronic equipment.
g) Lead contained in electronic waste represents 40% of all the lead existing in landfills.
h) A metric ton of computer e-waste contains more gold than that recovered from 17 gross tons in the ore extraction process.

## III. Electronic Devices and Resources used

Electronic devices are essential driver for the development of demand and prices for a number of metals based on highly growth rates of electronic devices such LCD-TVs and monitors, MP3 players, electronic toys and digital cameras, as shown in Table 1. For example, electronics make up for almost 80% of the world's demand of indium (transparent conductive layers in LCD glass), over 80% of ruthenium (magnetic properties in hard disks (HD)) and 50% of antimony (flame retardants). Some metal price increases over the last years since it is directly connected to the developments in the electronic industry. The monetary value of the annual use of important "electrical and electronic equipment metals" represents USD 45.4 billion at 2007 price levels [24 -26]. The environmental impact/footprint of the primary metal production is significant, especially for precious and special metals which are mined from ores in which the precious and special metal concentration is low. Considerable amounts of land are used for mining, waste water and sulfur dioxide SO2) are created and the energy consumption and CO2 emissions are large. For example, to produce 1 ton of gold, palladium or platinum, CO2 emissions of about 10,000 tons are generated [27]. Table 3 reflected the CO2 emission associated with producing the main metals used in EEE.

Table 6: CO2 emissions of primary metal production [27]

| **Important EEE metals** | **Demand for EEE t/a (2006)** | **primary production [t CO2/t metal]** | **CO2 emissions [Mt]** |
|---|---|---|---|
| Copper | 4500000 | 3.4 | 15.30 |
| Cobalt | 11000 | 7.6 | 0.08 |
| Tin | 90000 | 16.1 | 1.45 |
| Indium | 380 | 142 | 0.05 |
| Silver | 6000 | 144 | 0.86 |
| Gold | 300 | 16991 | 5.10 |
| Palladium | 32 | 9 380 | 0.30 |
| platinum | 13 | 13954 | 0.18 |
| Ruthenium | 6 | 13954 | 0.08 |
| CO2 total [t] | | | **23.4** |

Although e-waste treatment associated with large emissions of hazardous substances but there is a good effort spend in some developing countries to implement effective technologies in recycling e-waste. UNEP report in 2009 [49] shows that; environmental footprint and gas emissions of electrical and electronic devices (TVs, computer, fridge, Air conditions, and others) may reduce significantly if recycling treatment are done properly and high ratio of components reused. Different reports and studies show that a wide range of e-waste components made of metals, plastics and other substances. A mobile phone can contain over 40 elements from the periodic

table including base metals like copper (Cu) and tin (Sn), special metals such as cobalt (Co), indium (In) and antimony (Sb), and precious metals including silver (Ag), gold (Au) and palladium (Pd).

Literatures [50-52] and studies show that one ton of handsets phone (without battery) may contains: 3.5 kg Ag, 340 g Au, 140 g Pd as well as 130 kg Cu. Furthermore, the Li-ion battery of a phone contains about 3.5 g Co. The leverage of 1.2 billion mobile phones sold globally in 2007, this leads to a significant metal demand in total. PCs and laptops, the use of more common metals such as iron in electronics is considerable: about 6 kg iron/steel for a desktop PC means 930,000 tons are used to manufacture the PCs sold in 2007. The combined 2007 unit sales of mobile phones and personal computers already add up to 3% of the world mine supply of Au and Ag, to 13% of Pd and to 15% of Co.

The inappropriate waste management/recycling generate significant hazardous emissions, with severe impacts on health and environment [49]. In this context, three levels of toxic emissions have to be distinguished:

a) Primary emissions: Hazardous substances that are contained in e-waste (e.g. lead5, mercury, arsenic, polychlorinated biphenyls (PCBs), fluorinated cooling fluids etc.).
b) Secondary emissions: Hazardous reaction products of e-waste substances as a result of improper treatment (e.g. dioxins or furans formed by incineration/inappropriate smelting of plastics with halogenated flame retardants).
c) Tertiary emissions: Hazardous substances or reagents that are used during recycling (e.g. cyanide or other leaching agents, mercury for gold amalgamation) and that are released because of inappropriate handling and treatment.

The UNEP report in 2009 for steps to solve e-waste problems shows that; it needs to be understood that legislative approaches to restrict the use of hazardous substances can address only primary emissions and partly secondary emissions. However, even the "cleanest/greenest" products cannot prevent tertiary emissions if inappropriate recycling technologies are used. The latter is the biggest challenge in particular in developing and transition countries such as India, China, Mexico, Peru, etc., where the e-waste recycle treatment is still inefficient ("backyard recycling" with open sky incineration, cyanide leaching, "cooking" of circuit boards etc.) and lead to dramatic effects on health and environment [53-57] .

Jan Krikke [58] in his research work (Recycling e-Waste: The Sky Is the Limit) shows that; China is the recipient of about 70 percent of the world's end of- life electronics. The country has developed a huge e-waste recycling cottage industry and the result has been dramatic. The city of Guiyu near Hong Kong, known as the world's e-waste capital, is an ecological disaster zone. Workers burn printed circuit boards over charcoal to recover usable computer chips, soak the boards in acid to extract gold, and dump the waste in the Lianjiang River. They open CRTs with hammers to harvest the copper yokes. These crude recovery methods release massive quantities of mercury, cadmium, and other toxins into the environment. Around 80 percent of the children in Guiyu suffer from lead poisoning. According to the Guangzhou (Canton) Institute of Geochemistry, Guiyu has the highest concentration of dioxins ever measured. India and Africa, and other destinations for end of life electronics, have similar ecological disaster zones. Several international treaties regulate the trade in toxic waste, but corruption, broad interpretation of the rules, and fraud are fueling the trade. This human health and environmental problems are sample results of the inappropriate way of recycling and e-waste treatment.

## IV. Computer and Electronic Devices Waste: Reviewing Discussion

Based on the data collected from different literatures and studying several resources, statistics, and reports published by UN and other organization and researchers; this paper introduces different dimensions of the computer and electronic devices waste problem and its effect on human and environment. Reviewing discussion can be summarized as:

- The production of computers and electronic devices is increased tremendously compared to other products.
- The procurement habit or behavior of significant ration of people affected by advertisement, announcements and social aspects rather than real needs.
- The changes or enhancement to new release is small and within short time, which means affected customers to buy the new product periodically.
- The e-waste is increasing rapidly and become significant factor of total waste, which has harmful affect on human health and environment.
- The computer and electronic devices consists of tens of heavy metals, which can be dangerous on people and environment (air, water, soil).
- The recycling ratio of e-waste components is still represented small portion the total w-waste.
- Many of developed and industrial countries export their e-waste to the poor and developing countries instead of treating in their countries.
- The e-waste recycling treatment and technology is still inefficient, especially in developing countries.
- China, India, and some other developing and poor countries in Asia, Africa, and Latin America become the hub for e-waste recycling. So people in these countries will suffer more in the future.

- Many people works in recycling suffers from poising and other diseases because of the inappropriate treatment of recycling and extracting the metals and other equipments since most of their work is manually.
- The lack and weak of implementing rules and regulations for proper way of exporting and treating e-waste as well as corruption, and fraud trade; This leads to have big hidden disaster in future which can pollute soil, air, and water.
- Lack of training and educating of people to know how to deal with e-waste and proper recycling process.

## V. RECOMMANDATIONS TO CONTROL COMPUTER AND ELECTRONIC DEVICES WASTE

Based on our reviewing discussion this paper proposes set of recommendation to control or overcome e-waste problems. The recommendations have to integrate educational, environmental, industrial, religious, cultural, ethical, informational, and financial aspects. The following is a summary of these recommendations:

- Enriching all educational programs and curricula with material to show e-waste status, its harmful impact on environment, human health and life, and suitable solutions.
- Supporting academic institutions with all needs to perform advanced research to control e-waste and perform efficient recycling.
- Offering training centers to train organizations and people working in e-waste on the latest and innovative technology to collection, recycling, and treatment of e-waste.
- Reactivating ethical and religious principles, especially Islamic principles to spread the proper dealing between people without harming each other or the environment.
- Offering special programs on TVs, radio, Internet, and social media to educate people about e-waste harmful impact and way of controlling.
- Eliminating advertisements about new products in TVs, radio, Internet and other social media.
- Determining a minimum period of time for company to have new release of each product.
- Offering suitable education programs on all media to change the peoples' culture of procurement to be wiser, especially when their e-devices still function properly.
- Preparing strict rule and regulations to force production companies to collect their waste product and recycle it using innovative and advance technology.
- The UN and other international organizations should have active rules to force the developed and industrial countries as well as the big international and local companies to collect, recycle their product in effective and efficient way and offer continuous health checking for the people who work in e-waste recycling treatment.
- Working toward high quality e-product that has longer age and less maintenance.
- Offering more resources for doing advanced research to eliminate e-waste and having efficient recycling.
- There is a need to work hard toward green ICT and green environment.

## VI. CONCLUSION

Electronic waste is one of the essential environmental problem that face people in the last few decades. Literature analysis shows several countries in Asia, Africa and Latin America becomes e-waste hub for developed countries. Developing countries suffers from lack of proper systems of recycling and disposal treatment. This leads to increase e-waste problems in developing nations. Based on UNEP in 2009 and other studies share that informal recyclers in developing countries (China, India, Ghana, Nigeria, and Mexico) make harm for workers. They are exposed to hazardous chemicals and material when products are broken apart to extract valuable content. On the other hand the water, air and soil are also polluted, which cause a big environmental problem that should be solved.

Based on reviewing result; this paper proposes set of recommendations to eliminate and control e-waste collection and recycling treatment. Educational, environmental, industrial, religious, cultural, ethical, informational, and financial aspects are considered to solve such problem. Controlling E-waste associated with innovative solution for recycling and treatment is an essential step toward green environment.

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