A Review on the environmental and health impacts due to electronic waste disposal in Bangladesh

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Abstract

Bangladesh is one of the main importer countries of e-waste in the world. Moreover, country also generates e-waste about 2.81 million metric tons per year. However, majority of e-waste is being dumped into the open soil, open land, or open water bodies resulting problem on environment (i.e., pollution) and human population (i.e., health). Therefore, present review summarizes the environmental and health impact due to disposal of e-waste. Poorly management of e-waste during the collection, processing, recycling, and land filling causing environmental impact followed by air pollution, soil pollution, water pollution, and degradation of the beach because hazardous compounds spread to the surrounding or environment. Furthermore, e-waste also creates lots of health problems. Humans can be exposed to e-waste contaminants by the inhalation, dietary intake, dust ingestion, and dermic contact. In north eastern part of Bangladesh, about 36.3% women who lives near recycling sites experienced the death of a baby. Again, about 15% child laborers die, and 83% child laborers are affected by long term health problem because of e-waste mismanagement practice. There are about 120,000 Bhangaries who may be exposed to e-waste contaminants more seriously. The result of the study would provide us important insight into the growing concern of e-waste and would help policy maker for designing policy measure to recycle e-waste in a hazard free manner.

Keywords: Bangladesh; E-waste; Environment; Health; Recycle

1. Introduction

Industrial countries started shipping hazardous and e-waste to lower and middle income countries during the 1970 and 1980s [1]. For example, about 250,000 tons to 1.3 million tons of e-waste have been shipped out from Europe mostly to the developing nations of west Africa and Asia [2]. Moreover, per capita of e-waste generation is increased within the lower- and middle-income countries by the rapid development of cellular and internet networks. Sometimes, political agenda (e.g., Digitalization of Bangladesh) can also motivate the generation of e-waste in a country [31]. Therefore, current e-waste generation rate has increased all over the world about 72 million tons, that is 33% more than the last decade [32].

Continuous advancements in the science and technology help us to lead comfortable lives and also create burden on the environment (e.g., pollution) and human populations (e.g., health). For example, electronic and electrical equipment make our life easier but when this e-waste is processed in hazardous and inefficient conditions, that pose environmental and health concern [2]. People who are employed in the e-waste recycling sector had a high incidence of skin damage, headaches, vertigo, nausea, chronic gastritis, and gastroduodenal ulcers [3]. More than 70% of children have blood lead...
levels above 10 μg/dL and neonates had higher levels of toxic chemicals including Pb, Cd, Cr, Ni, PBDEs in blood and placenta [4,5].

E-waste disposal not only raise human health issue but also environmental impact. It can contaminate the agricultural soil with the reduction of annual crop production or can deteriorate the surface and subsurface water ways [6]. Government of Bangladesh has taken a unique case entitled to “Digital Bangladesh” for developing the sector of information and communication technology (ICT). Therefore, e-waste is increasing with the rate of digitalization. Further, the existence of ship breaking industries are also contributing to e-waste generation and recycling problems [31].

Rapid growth of e-waste, lack of proper management and regulation, and the absence of protection of workers causing e-waste derived environmental and health hazards in Bangladesh. However, surprisingly there have been no intensive studies in Bangladesh to calculate the e-waste derived environmental and health hazards. Given this situation, present study gives an overview to estimate environmental and health impact due to disposal of e-waste. This study would be helpful for the policy maker.

2. Definition and categories of e-waste

Electrical and electronic debris popularly known as e-waste (electronic waste). E-waste can be defined as the old, or end of life or discarded appliances, that fail to work or suffer from functional defects during its production [7]. E-waste can be classified into 10 categories based on the directives of 2012/19/EU (https://ec.europa.eu/environment/waste/weee/index_en.htm). It is one of the most widely conventional classifications (Table 1).

3. E-waste generation scenario

3.1. E-waste generation scenario around the world

Currently, the world is experiencing the significant e-waste growth, that is very alarming ecological delinquencies. Around the world, about 20 to 50 million metric tons of e-waste is originated every year and nearly 75 to 80% of that is exported to developing countries predominantly Africa, and Asia for recycling and disposal [9]. China and India are the main importer of e-waste. Besides, Pakistan, Ghana, Bangladesh, Nigeria, and Kenya are another e-waste importer country [10].

According to USEPA, global generation of e-waste is increasing annually with the rate of 5 to 10% [34, 35] because of the frequency of purchasing unnecessary EEE items are high [32], and the short life span of the electrical equipment [11,12]. During the last few decades, e-waste has gained the most alarming concern in both developed and developing countries in the world. E-waste growth has an increasing trend from 2005 to 2017 around the world which is shown in Fig.1.

![Figure 1 Trend of e-waste around the world](image)
### Table 1 Categories of e-waste [8]

| Category | Characteristic | Example |
|----------|----------------|---------|
| Category (C01) | Bulky household appliance | Microwaves, refrigerators, freezers, clothes dryers, washing machines, electric cooking stoves, dishwashers and electric fans, hot plates and air conditioners. |
| Category (C02) | Small household appliance | Coffee machines, toasters, tooth brushing, vacuum cleaners, grinders, haircutting appliances, drying and shaving. |
| Category (C03) | ICT and telecommunication equipment | Minicomputers, mainframes computer, personal computers, notebooks, laptops, printers, telephones, cell phones and IP phone. |
| Category (C04) | Consumer equipment and photovoltaic panels | Video recorders, video cameras, radios, stereo recorders, televisions, musical instruments, audio amplifiers etc. |
| Category (C05) | Lighting equipment | Straight and compact fluorescent lamps and high-intensity discharge lamps, LED, solar panel. |
| Category (C06) | Electrical and electronic tools (with the exception of large scale stationary industrials tools) | Drills, saws, sewing machines, soldering irons, equipment for turning, milling, grinding, drilling, making holes, folding, bending, or similar processing of wood and metal. |
| Category (C07) | Toys, leisure and sports equipment | Toys, leisure equipment, and sporting goods: electric trains or racing car sets, video games, and sports equipment with electric elements. |
| Category (C08) | Medical device (with the exceptions of all implanted and infected products) | Ventilators, craniological device, nuclear analyzers, radiotherapy equipment, all types of dialysis equipment. |
| Category (C09) | Monitoring and control instruments | Smoke detectors and thermostats, heating regulators etc. |
| Category (C10) | Automatic dispensers | Solid products, food and drinks related electrical device, all electronics device that mechanically deliver various products, cold or hot bottles. |

#### 3.2. E-waste generation scenario in Bangladesh

It is very popularly known as Bangladesh is one of the major e-waste import countries. Apart from this, the country also produces about 2.81 million metric ton e-waste annually [14,21]. The total generated e-waste in Bangladesh per year can be summarized in Table 2.

Table 3 reveals the volume of some key sources of e-waste generation from different electrical and electronic product with respect to Bangladesh.

During the last 15 years, Bangladesh is developing in the sector of information and communication technology (ICT) since the declaration of digital Bangladesh as a part of government’s “Vision 2021” to rapidly improve the education, health, and the financial situation of the population by infrastructure building and employment of digital technology. Then, ICT sector produces huge number of e-waste. Dhaka and Chottogram are the two largest stake holder for collecting and managing of e-waste respectively [8].

Since our country is becoming digitalized in the near future, the usages of electronic equipment will increase with a great speed [21]. This jumping in electronics consumption will led to e-waste disposal, repair, and recycling. Over and above, Bangladesh is home to the second largest ship breaking industry in the world which generates more e-waste than consumer electronics [15].
Table 2 Sources of e-waste in Bangladesh [14]

| Sources of e-waste                      | Amount of e-waste (Million metric ton/year) |
|----------------------------------------|--------------------------------------------|
| Electric charged vehicle               | 2.5                                        |
| Television                             | 0.17                                       |
| Computer                               | 0.035                                      |
| Mobile phone                           | 0.005                                      |
| CFL bulb                               | 0.0005                                     |
| Mercury bulb                           | 0.0001                                     |
| Thermometer                            | 0.009                                      |
| Other medical and dental wastes        | 0.09                                       |
| Total                                  | 2.81                                       |

Table 3 Volume of different e-waste in Bangladesh [14]

| Sources of e-waste                      | Volume of e-waste (pieces) | Time duration         |
|----------------------------------------|----------------------------|-----------------------|
| Computer                               | 2,103,687                  | From 1971 to 2010     |
| Mobile phone                           | 24,932,160                 | From 1971 to 2010     |
| CFL bulb                               | 5,253,313                  | From 2006 to 2010     |
| Thermometer                            | 610,295,237                | From 1971 to 2010     |
| Medical and dental equipment           | 167,844 (for each doctor)  | From 2001 to 2010     |
| Ilegal dumping of e-waste in the landfill threatens the soil contents and affecting the crop production as well [2].
4.3. Water pollution

When the dumped e-waste is seeping into the soil then our groundwater will be contaminated by poisons such as arsenic. It has been observed that a large amount of lead ions is dissolved from broken glass which contains lead. Like many other developing countries, Bangladesh is one of the most common ground for recycling of e-waste. Very often, these e-waste is improperly managed creating blockages in water runoff channels [16]. If discarded e-waste materials are percolating into the soil, then aquifer of water can be polluted with poisonous substances [18]. Different types of plastic elements from computer, mobile, refrigerator are dumped into the river which obstacles the free flow of water and reduce the level of oxygen. This is very common scenario for the rivers of Bangladesh, predominantly in and around the city.

4.4. Degradation of the beach

Every year Bangladesh legally import a significant number of scrap ships. These ships are broken down in the ship breaking yards. At the time of ship breaking, a large number of heavy metals and toxic pollutants are released into the environment, for example, oil spills on land and in water bodies. Besides, illegal import and trade off e-waste is happening in Bangladesh by importers to make profits. Consequently, e-waste vulnerability of Bangladesh is increasing rapidly [16].

Table 4 A potential environmental hazard of e-waste component [2,19]

| E-waste component | Process used | Potential environmental hazard |
|-------------------|--------------|-------------------------------|
| Cathode ray tubes (used in TVs, computer monitors, ATM, video cameras, and more) | Breaking and removal of yoke, then dumping | Lead, barium and other heavy metals leaching into the ground water and release of toxic phosphor |
| Printed circuit board (image behind table-a thin plate on which chips and other electronic components are placed) | De-soldering and removal of computer chips; open burning and acid baths to remove metals after chips are removed | Air emissions and discharge into rivers of glass dust, tin, lead, brominated dioxin, beryllium cadmium, and mercury |
| Chips and other gold-plated components | Chemical stripping using nitric and hydrochloride acid and burning of chips | Polycyclic aromatic hydrocarbons (PAHs), heavy metals, brominated flame retardants discharged directly into rivers acidifying fish and flora. Tin and lead contamination of surface and groundwater. Air emissions of brominated dioxins, heavy metals and PAHs |
| Plastics from printers, keyboards, monitors, etc. | Shredding and low temperature melting to be reused | Emissions of brominated dioxins, heavy metals and hydrocarbons |
| Computer wires | Open burning and stripping to remove copper | PAHs released into air, water, and soil |

5. Health impacts

In the previous sections environmental impacts of e-waste such as air pollution, soil pollution, water pollution, and degradation of the beach have been discussed. Besides, these environmental impacts e-waste also creates lots of health problems. Humans can be exposed to e-waste contaminants by the inhalation, dietary intake, dust ingestion, and dermic contact. These contaminants e-waste fluxes from producers to receivers and ultimately to humans (Fig.2).
Figure 2 Pathways of e-waste from different sources that expose humans [19]

5.1. New born baby’s health

E-waste moves into new born baby’s health through the food consumption from mother. It has been calculated that 6-month-old breastfed infants who live near e-waste recycling sites are consumed e-waste associated with PBDEs about 57 times higher than the infants who live in control areas due to high maternal exposures level [20]. Inhalation is another important route of intake to e-waste for the new born babies. As body functional system (i.e. central nervous, immune, reproductive, and digestive system) are still developing so exposure to contaminants substances may hamper further development causing unchangeable damage [16]. In north eastern part of Bangladesh, about 36.3% women who lives near recycling sites experienced the death of a baby [21].

5.2. Children’s health

There are about 50,000 (fifty thousand) children in Bangladesh are working in the e-waste collection and recycling process. Of them, 40% (i.e. 20,000) children are working in ship breaking yards [18]. In our country about 15% child laborers die because of e-waste mismanagement practice. Moreover, 83% child laborers of this sector are affected by long term health problem [2,16]. Children those who are living near the e-waste recycling sites likely to become more affected by the contaminants through inhalation during their outdoor play time [22]. Again, children those who are living near the e-waste recycling sites also appear to have poorer neonatal behavioral neurological assessment scores, poorer temperament scores, and lower intelligence quotient (IQ) because of lead levels are increasing in the blood [31]. Due to improper management of e-waste nearly 30 million children, women, and non-formal workers are exposed to heavy metals, for example, lead, mercury, cadmium, zinc and chromium, PCB, dioxin, and furan [23].

5.3. Pregnant women

After new born babies and children’s pregnant women are more vulnerable to e-waste contaminants. Pregnant women may face spontaneous abortions, premature birth, fetal loss, thyroid development, abnormal thyroid function, neurobehavioral disturbances, gene toxicity, low birth weight, and congenital malformations due to their exposure to various POPs (e.g. PBDEs, PCBs, PFOA), and PAHs [3,16,24]. Higher contaminant levels in fetal tissues are found in pregnant women those who are living near the e-waste recycling sites or involved in e-waste recycling activities during their pregnancy. Again, pregnant women may exposure from family members who are working in the e-waste collection or recycling sectors [31].
5.4. Impacts on workers

There are about 120,000 Bhangaries (E-waste recycling workers) who may be exposed to e-waste contaminants more seriously [33]. When original e-waste elements are degraded hazardous compounds e.g. dioxins are formed resulting severe health problems of the workers [37]. Sometimes skin and blood of workers are infected by e-waste or by infected wounds. Contact with sharp objects resulting wounds. During metal separation from landfill and incineration operations different types of chemicals are coming out. These chemicals are responsible for eye and respiratory infections [16]. Incineration operators may exposure to chronic respiratory diseases include cancers. Apart from open incineration, improper dismantling techniques for recovering metals followed by copper, aluminum, and iron also creates great risks to the workers. Likely, breaking of CRT monitors using stones, hammers, heavy metal rods and chisels for recovering copper, steel and plastic casings may result in the inhalation of hazardous cadmium dust and other pollutants by the workers. Handling of heavy containers causing bone and muscle disorders. Moreover, occupational accidents e.g. burns occur at the waste disposal sites or from chemicals explosions [16].

5.5. Diseases due to heavy metals

E-waste is the major source of several heavy metals (e.g. mercury, lead, cadmium, chromium, zinc etc.) When these heavy metals are kept unprocessed and open to the environment causing numerous human diseases including cancer, nerves breakdown, asthma, hearing problem, infant mortality, visual problem, kidney, disable baby birth, brain disorder, liver and lung damage as well [16]. Different E-waste generated metals and their human health risk have been summarized in Table 5.

| Compositions of e-waste | Impacts on health |
|------------------------|-------------------|
| Lead                   | Damage to central and peripheral nervous systems, blood systems and kidney damage; Affects brain development of children |
| Chromium               | Asthmatic bronchitis; DNA damage; Lung cancer; Kidney and liver damage |
| Cadmium                | Toxic irreversible effects on human health; Accumulates in kidney and liver; Causes neural damage and teratogenic; Bone fracture; Lung damage; DNA damage; Central nervous system damage, Cancer etc. |
| Mercury                | Chronic damage to the brain; Respiratory problems |
| Plastics including PVC | Burning produces dioxin which evolves reproductive and developmental problems; Interference with regulatory hormones and damage of immune system |
| Antimony               | Annoyance of the creature’s skin, eyes, lungs |
| Bismuth                | Skin problems as well as depression |
| Gallium                | Breathing problems; Throat irritation; Pain on chest |
| Cobalt                 | Vomiting; Loss of vision; Heart issue; Thyroid damage; Causes of Asthma |
| Nickel                 | Lung Cancer; Nose cancer; Heart disorders |
| Iron                   | High risk of lung cancer |
| Silver                 | Brain damage; Kidney, eye, lung, and liver associated problems |
| Selenium               | Abdominal pain; Fever, heart, and muscle problems; Bronchial asthma; Diarrhoea; Enlarged liver; Burning bronchitis; Sore throat |

6. Conclusion

Bangladesh imports e-waste from developed countries and also generates e-waste. However, this e-waste is collecting, processing, and recycling into the open environment without proper safety of the workers causing environmental and health problem. When e-waste burns it generates smoke that contains both poisonous gases and heavy metals (lead, cadmium and mercury). Dumping of brominated flame retardant plastic and cadmium in the land fill may polluted the
soil as they leach into the soil and ground water. These environmental contaminations can result in exposure to residents in the surrounding areas.

In addition to, e-waste contaminants can bio accumulate in human tissues and organs. Higher contaminant levels were found in children’s blood and serum samples those who live at or near e-waste recycling sites compared to those children who are living far from the e-waste recycling site.

E-waste contaminants can also be found in placenta, breast milk, indicating that pregnant women, fetuses, and young infants are also vulnerable to e-waste exposure. Health workers may be exposed to e-waste contaminants more seriously. Long term exposure to e-waste contaminants can damages the nervous system, kidneys, bones, and the reproductive systems as well.

So, taking initiatives by importers, recyclers, government and awareness build up among people is crucial to ensure safe handling of e-waste and reduce adverse impact of e-waste on residence. Most of lab based research focused on risk associated with e-waste on health such as newborn babies, children and pregnant women. As well as research conducted on e-waste generated material such as lead, chromium, cadmium, mercury, plastics including PVC, antimony, bismuth, gallium, cobalt, nickel, iron, silver, selenium and its possessed risk on human health has been taken place in developed countries. Authentic research on impact of e-waste on different environmental component such as air, soil, water has been articulated in this paper has also been taken place in developed countries too. So, it is crystal clear that there is significant research gap in developing country regarding impact of e-waste on health and environment. Bangladesh is not an exception. Considering limited resources and scope research focused on e-waste can be conducted in Bangladesh.

Compliance with ethical standards

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Disclosure of conflict of interest
There is no conflict of interest among the authors.

Statement of ethical approval
The Study follows proper ethical procedures.

References
[1] Bakhiyi B, Gravel S, Ceballos D, Flynn MA, Zayed J. Has the question of e-waste opened a Pandora’s box? An overview of unpredictable issues and challenges. Environ Int [Internet]. 2018; 110(August): 173–92.
[2] Masud MH, Akram W, Ahmed A, Ananno AA, Mourshed M, Hasan M, et al. Towards the effective E-waste management in Bangladesh: a review. Environ Sci Pollut Res. 2019; 26(2): 1250–76.
[3] Xu X, Yang H, Chen A, Zhou Y, Wu K, Liu J, et al. Birth outcomes related to informal e-waste recycling in Guiyu, China. Reprod Toxicol [Internet]. 2012; 33(1): 94–8.
[4] Huo X, Peng L, Xu X, Zheng L, Qiu B, Qi Z, et al. Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. Environ Health Perspect. 2007; 115(7): 1113–7.
[5] Guo Y, Huo X, Li Y, Wu K, Liu J, Huang J, et al. Monitoring of lead, cadmium, chromium and nickel in placenta from an e-waste recycling town in China. Sci Total Environ [Internet]. 2010; 408(16): 3113–7.
[6] Sepúlveda A, Schluep M, Renaud FG, Streicher M, Kuehr R, Hagelüken C, et al. A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from China and India. Environ Impact Assess Rev [Internet]. 2010; 30(1): 28–41.
[7] Kumar A, Holuszko M, Espinosa DCR. E-waste: An overview on generation, collection, legislation and recycling practices. Resour Conserv Recycl [Internet]. 2017; 122: 32–42.
[8] Khan MAR, Saadat AHM. Status of Electronic Waste Generation in Bangladesh: Int J Innov Sci Res Technol. 2019; 4(8): 918–26.

[9] Golev A, Schmeda-lopez DR, Smart SK, Corder GD, Mcfarland EW. Where next on e-waste in Australia? Waste Manag [Internet]. 2016.

[10] Garlapati VK. E-waste in India and developed countries: Management, recycling, business and biotechnological initiatives. Renew Sustain Energy Rev [Internet]. 2016; 54: 874–81.

[11] Nie X, Fan C, Wang Z, Su T, Liu X, An T. Ecotoxicology and Environmental Safety Toxic assessment of the leachates of paddy soils and river sediments from e-waste dismantling sites to microalgae, Pseudokirchneriella subcapitata. Ecotoxicol Environ Saf [Internet]. 2015; 111: 168–76.

[12] Tian J, Chen M. Assessing the economics of processing end-of-life vehicles through manual dismantling. Waste Manag [Internet]. 2016; 56: 384–95.

[13] Wath SB, Vaidya AN, Dutt PS, Chakrabarti T. Science of the Total Environment A roadmap for development of sustainable E-waste management system in India. Sci Total Environ [Internet]. 2010; 409(1): 19–32.

[14] Awasthi AK, Zeng X, Li J. Comparative Examining and Analysis of E-waste Recycling in Typical Developing and Developed Countries. Procedia Environ Sci [Internet]. 2016; 35: 674–81.

[15] Rabbi HR, Rahman A. Ship Breaking and Recycling Industry of Bangladesh; Issues and Challenges. Procedia Eng [Internet]. 2017; 194: 254–9.

[16] ESDO. Magnitude of the Flow of E-waste in Bangladesh. 2014; 1–40.

[17] Ramachandra TV SVK. Environment Ally Sound Options for E-Wastes. Envis J Hum Settlements. 2004.

[18] Islam MN. E-waste Management of Bangladesh. Int J Innov Hum Ecol Nat Stud. 2016; 4(2): 1–12.

[19] Robinson BH. E-waste: An assessment of global production and environmental impacts. Sci Total Environ [Internet]. 2009; 408(2):183–91.

[20] Leung AOW, Chan JKY, Xing GH, Xu Y, Wu SC, Wong CKC, et al. Body burdens of polybrominated diphenyl ethers in childbearing-aged women at an intensive electronic-waste recycling site in China. Env Sci Pollut Res. 2010; 17: 1300–13.

[21] Alam M, Bahauddin KM. Electronic Waste in Bangladesh: Evaluating the Situation, Legislation and Policy and Way Forward With Strategy and Approach. Present Environ Sustain Dev. 2015; 9(1): 81–101.

[22] Song Q, Li J. A systematic review of the human body burden of e-waste exposure in China. Environ Int [Internet]. 2014; 68: 82–93.

[23] ESDO. E - waste : The Bangladesh Situation. 2010; 1–36.

[24] Wu K, Xu X, Peng L, Liu J, Guo Y, Huo X. Association between maternal exposure to perfluorooctanoic acid (PFOA) from electronic waste recycling and neonatal health outcomes. Environ Int [Internet]. 2012; 48: 1–8.

[25] Grant K, Goldizen FC, Sly PD, Brune MN, Neira M, van den Berg M, et al. Health consequences of exposure to e-waste: A systematic review. Lancet Glob Heal [Internet]. 2013; 1(6): e350–61.

[26] Spalvins E, Dubey B, Townsend T. Impact of electronic waste disposal on lead concentrations in landfill leachate. Environ Sci Technol. 2008; 42(19): 7452–8.

[27] Tsydenova O, Bengtsson M. Chemical hazards associated with treatment of waste electrical and electronic equipment. Waste Manag [Internet]. 2011; 31(1): 45–58.

[28] Fu J, Zhou Q, Liu J, Liu W, Wang T. High levels of heavy metals in rice (Oryza sativa L.) from a typical E-waste recycling area in southeast China and its potential risk to human health. 2008; 71: 1269–75.

[29] Leung AOW, Duzgoren-Aydin NS, Cheung KC, Wong MH. Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in southeast China. Environ Sci Technol. 2008; 42(7): 2674–80.

[30] Song Q, Li J. A review on human health consequences of metals exposure to e-waste in China. Environ Pollut [Internet]. 2015; 196: 450–61.
[31] Aich N, Kordas K, Ahmed SI, Sabo-Attwood T. The Hidden Risks of E-Waste: Perspectives from Environmental Engineering, Epidemiology, Environmental Health, and Human–Computer Interaction. In Transforming Global Health. 2020; 161-178.

[32] Namias J. The future of electronic waste recycling in the United States: obstacles and domestic solutions. Columbia University. 2013.

[33] Ahmed FRS. E-Waste Management Scenario in Bangladesh, Department of Environment, Government of Bangladesh [Internet]. 2011.

[34] Shamim A, Mursheda AK, Rafiq I. E-waste trading impact on public health and ecosystem services in developing countries. J Waste Resour. 2015; 5(4): 1-8.

[35] De Souza RG, Climaco JC, Sant’Anna AP, Rocha TB, do Valle RD, Quelhas OL. Sustainability assessment and prioritisation of e-waste management options in Brazil. Waste management. 1 Nov 2016; 57: 46-56.

[36] Sansotera M, Navarrini W, Talaeeemashhadi S, Venturini F. Italian WEEE management system and treatment of end-of-life cooling and freezing equipments for CFCs removal. Waste management. 1 Jun 2013; 33(6): 1491-8.

[37] Brigden K, Labunska I, Santillo D, Johnston, P. Chemical contamination at e-waste recycling and disposal sites in Accra and Korforidua, Ghana. Greenpeace International, Amsterdam. 2008.