E-waste: A Challenge for Sustainable Development

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Introduction

Steady technological advancement in the modern world has been making our lives easier, simpler and faster in so many ways with the progressive invention of electrical and electronic equipment (EEE) such as personal computers (PCs), scanners and televisions. The obsolescence of these forms of EEE is termed as ‘technological waste’ or ‘e-waste’ or ‘waste from electrical and electronic equipment (WEEE).’ The volume of generated e-waste has been increasing in line with economic development all over the world. According to the United States Environmental Protection Agency (USEPA), e-waste growth has significantly increased as a proportion of global solid waste generation and now comprises 8% of the total volume of current municipal solid waste (MSW). The Basel Action Network (BAN) estimated that global e-waste generation increased from 9.3 million tons (MTs) in 2005 to 50 MTs in 2012, and currently 20–50 MTs are generated every year. Furthermore, this proportion increased from 1 to 2% of total solid waste by 2010 and is increasing at an alarming rate as the fastest

Background. E-waste has been identified as the fastest growing waste stream in the world at present. Rapid socio-economic development and technological advancement are the main drivers of this trend. The hazardous chemical components of e-waste have potential adverse impacts on ecosystems and human health if not managed properly. This represents an imminent challenge to achieving sustainable development goals. Although technologically developed countries are the main source of e-product production and e-waste generation, the generated volume has also been increasing in developing countries and those in transition due to transport and transfer from e-waste source countries. Consequently, developing countries are in a vulnerable situation due to their lack of inventory data, waste management policies and advanced technology for environmentally sound management.

Objectives. This study aims to demonstrate that the present global e-waste scenarios and health hazards could prolong the achievement of sustainable development targets. This study illustrates scenarios from different perspectives and raises concerns about e-waste, identifies information gaps, and provides a basis for knowledge and awareness building and technological improvement to facilitate global long-term sustainable development.

Discussion. Total and per capita global e-waste generation has been increased along with socio-economic development. These products present a significant global challenge due to the hazardous chemicals they contain, their highly technical recycling requirements and the high overhead and costs of environmentally sound management, as well as their adverse impacts to human health. Although high-income countries are the main sources of this waste, low-income countries are experiencing an increase in e-waste due to the shifting process of both recently produced and used electric and electronic equipment (UEEE), as well as cheap management overhead costs. Consequently, they bear the greatest burden of adverse health hazards and ecosystem degradation, prolonging their achievement of sustainable development goals.

Conclusions. Sustainability is being prioritized for all development activities by integrating societal, economic, environmental, technological, cultural, and gender perspectives. Considering the adverse potential eco-toxicological impacts and diverse health effects of e-waste, an urgent global multilateral agreement is needed addressing its management (i.e., handling, storage, transportation, recycling, and final disposal), whether by land filling or incineration. Due to the global nature of the issue and the difficulty of establishing sustainable and environmentally sound processing of e-waste in low-income countries, multinational negotiation and collaboration is the only realistic solution. Furthermore, comprehensive global e-waste management and policies could help to off-set the hazards of e-waste and are the best approach for achieving sustainable development.

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-growing waste fractions. In terms of developed countries, it comprises 1% of total MSW. By 2020 however, it is expected to rise to 6%, with a range of 0.01% to 1% for developing countries with <1 kg per year, and this growth rate is exponential. Unfortunately, only 10 to 15% of this amount is managed properly, while the rest is disposed of in open landfills according to one study.

Although e-waste is omnipresent and generated everywhere, high-income countries such as the US, countries of the European Union, and Australia, Japan, etc. are considered to be the main sources of e-waste. E-waste constitutes on average 8% of total solid waste generation in these countries. Rapidly developing countries in transition such as China, Latin America and Eastern Europe will be major producers of e-products in the next ten years and will represent 1–3% of the 1636 million tons of MSW generated per year of MSW. These wastes can be classified into 26 common categories and contain more than 1,000 diverse toxic substances including heavy metals and organics, which pose adverse effects to human health and ecosystems due to improper handling and disposal.

Developing countries and those in transition are gradually being affected by this imminent toxic threat from e-waste because of their rapid movement towards technological development without the accompanying procedures, policies and infrastructure to deal effectively with the waste. In these circumstances, both recently produced and used electrical and electronic equipment (UEEE) are being consigned from their parent producers from high-income countries to low-income countries. In this case, some Asian and African developing countries, particularly India, Bangladesh, Pakistan, China, Sri Lanka, the Philippines, Benin, Ghana, the Ivory Coast, Nigeria and Liberia are the most common destinations for dumping. According to a UNEP press release, the US sold 350 million second hand computer units in 2004 and 3 billion units in 2010 to Asia and Africa. As a result, e-waste dumping has increased by 125% in Pakistan, 97.3%
of electrical and electronic appliances is so rapid that new products quickly replace existing models or make redundant, useless or nonfunctioning, thereby generating a constant source of e-waste generation. According to Mario and Casey, e-waste can be classified by its physical composition into two types as shown in Figure 1.

Electrical e-wastes are refrigerators and household appliances such as cables, bulbs, washing machines, dryers, AC units, vacuum cleaners, coffee machines, water heaters, toasters, irons etc.; plastic components are polycarbonates, polyesters, polyethylene and polypropylene; and the major oxides are alumina, silica, barium titanate, and potassium, magnesium and aluminum silicates.

E-waste Generation Globally

Industrialized and developed nations are the main producers of e-waste. According to the USEPA, the US is the largest e-waste producer in the world today, generating 3.16 million tons in 2008. In addition, 5 million tons were in storage with 2.37 million tons ready for disposal in 2009, and that represents a 120% increase from 1999. The EU generated 8.9 million tons in 2010 and that rate is increasing by 3–5% yearly, and is projected to be 12 million tons by 2020. The rapidly increasing trend of e-waste production is rising in the biggest and fastest growing economies such as China and India. China is ranked second after the US and generated 2.3 million tons of e-waste in 2010 and is predicted to have a surplus by 2020. In addition, India generated 400,000 tons in 2011. The European Union is also considered to be one of the biggest producers of e-waste. In 2010, the EU produced 8.9 million tons of e-waste. This comprised 1–3% of the total MSW in the US, a 16–28%
increase every five years, which is 3-times faster than MSW generation. A recent study found that annually, 5 to 7 million tons of e-waste is generated in the EU with a per capita of 14–15 kg and is expected to increase at a 3 to 5% annual growth rate.\(^8\)

The analysis based on the Solving the E-waste Problem (StEP) database found that a total of 51.37 million metric tons (MMT) of e-waste was generated globally in 2012.\(^28\) Among the different regions, East Asian countries are foremost (22.81%) in both total (11.72 MMT) and per capita (17.07 kg) generation, of which China (7.25 MMT) and Japan (2.74 MMT) were the major contributors. The rest of the Asian regions were also significant contributors of WEEE sources. North American countries, the USA (9.36 MMT), Canada (0.86 MMT) and Mexico (1.03 MMT), were in second position in terms of both contiguous (21.91%) and per capita (21.16 kg) generation. Europe as a whole generated 13.71 MMT with an average per capita of 17.45 kg, representing 26.70% of the global total. Oceania and African countries contributed relatively small amounts, and the Alliance of Small Island States’ (AOSIS) contribution was smaller in both total and per capita generated.\(^29\)

The analysis is shown in Figure 3.

**Emerging Markets Case Study: South Asia**

Economic development in South Asian countries has enhanced their industrialization and technological advancement daily. Consequently, the volume of e-waste generated has also been increasing with the importation of lifestyle improvement e-products. Shahriar estimated that Bangladesh generates 2.8 million tons of e-waste every year, out of which 2.5 million tons comes from ship-breaking yards.\(^30\)

Pervez and Hossain reported that 500,000 PCs were in use in 2004 and increasing at an 11% growth rate per year, and at a rate of 100% for cell phones.\(^31\) Consequently, there were 15,323 and 10,504 tons of e-waste generated from PCs and cell phones, respectively, which could be the potential sources of 30,646 tons of
In addition, India generates e-waste and also imports e-waste from developed countries. India is considered to be the second largest e-waste processing country in the world, 70% of which is originated abroad. It generates between 146,000–330,000 tons of e-waste yearly and this was expected to rise to 4,700,000 tons by 2011 based on a projected growth of 34% per year. In addition, in Sri Lanka, there are about 500,000 mobile phones and these are adding more e-waste to a market that has the potential to generate 60–65 tons annually.

According to the StEP database, in the context of South Asian countries in 2012, India was the highest e-waste producer (2.75 MMT) within the region. Pakistan generated 0.30 MMT and Bangladesh 0.18 MMT. The Maldives was found to be the lowest e-waste producer (1690 MT) with Bhutan (2821 MT) the next lowest producer. E-waste generation volume is shown in Figure 4.

On the other hand, the Maldives was the highest producer of e-waste in terms of per capita production (5.11 kg), although it was in lowest in total volume in this region. Bhutan was in the second position with 3.79 kg and Sri Lanka ranked third, generating 3.57 kg. Furthermore, per capita generations by India, Pakistan and Bangladesh were 2.25, 1.68 and 1.19 kg respectively, in contrast to their total generation. Nepal and Afghanistan were comparatively minor e-waste generators, 0.023 and 0.018 MMT, and per capita, 0.76 and 0.58 kg, respectively (Figure 5).

Impacts of E-waste
Electrical and electronic goods contain a variety of metals, many of which are toxic to humans and ecosystems. More than 60% of e-waste consists of these different metal ions and about 2.7% are toxic metals. The proper management (collecting, storage, recycling, disposing) of these wastes is important because of hazardous chemicals in the waste such as aluminum (Al), arsenic (As), bismuth (Bi), cadmium (Cd), chromium (Cr), mercury (Hg), nickel (Ni), lead (Pb) and antimony (Sb). Furthermore, the combustion of these e-wastes releases polycyclic...
aromatic hydrocarbons (PAH), brominated flame retardants (BFRs), poly-brominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins and furans (PCDD/Fs) gases that effect some or all bio-physical environments (soil, atmosphere, aquatic). Consequently, these releases adversely affect the surroundings and cause detrimental effects to human health. 

Brigden and Labunsk found that PBDEs and PBDD/Fs contaminate the surrounding soil, air and water causing a depletion of fertility and water quality, as well as acting as neuro-toxins and endocrine disruptors in infants and children. These toxic chemical compounds and persistent organic pollutants (POP) affect the environment through the ecological food chain and adversely affect human health and ecosystems. Bioaccumulation (i.e., PCBs, BFRs and several chemical elements) in the food chain affects human health, especially in pregnant and breastfeeding women. In addition, they cause endocrine disruption and this, in turn, affects the nervous system, pre- and post-natal development and genotoxicity. Dioxins may alter the methylation status of deoxyribonucleic acid (DNA). Furthermore, they also change the serum levels of mothers and newborns and are a potential hazard to maternal health and child development, as well producing hormonal effects by BFRs and thyroid-disrupting effects in developmental life stages.

The adverse impacts of e-waste on humans and ecosystems is also crucial in South Asian countries undergoing rapid economic growth, lifestyle change, socio-technical transition and transformation, which is in complete contrast to their lack of effective waste management tools. For example, in Bangladesh, only between 20% to 30% of the 3.2 MT generated e-waste each year is recycled and the rest is dumped in landfills.

There are about 120,000 poor urban people involved in the informal e-waste trade chain in Dhaka, of which 50,000 are children. The Environment and Social Development Organization (ESDO) report found that the lack of an efficient e-waste management system in Bangladesh was the cause of death for approximately 15% of the illegal child laborers employed in this sector, and 83% were found to be exposed to long term health problems. Furthermore, Chowdhury et al. found that 36.3% of 1,000 women living near the informal recycling sites experienced stillbirths in the Sylhet region of Bangladesh and 64% had hearing and/or vision.
problems. In India, more than 1 million poor people are involved in e-waste handling. In addition to these statistics, 50,000 tons of e-waste is dumped in landfills annually, ultimately contaminating the Lyari and Arabian Seas and adversely affecting marine ecosystems.

**Discussion**

The global community has converged to prioritize sustainability for all developmental activities by integrating societal, economic, environmental, technological, cultural, and gender perspectives. Accordingly, this global convergence has been working towards protecting the environment from the deterioration that occurs with rising living standards. In this vein, multilateral negotiations and cooperation play pivotal roles in the establishment of sustainable development. The ongoing emphasis on e-waste management along with other important environmental issues such as climate change and resource depletion and degradation are the most promising initiatives to achieve long-term sustainability. The rapid global economic development of recent years is leading to socio-technical transformations and changing lifestyles. Consequently, large quantities of electronic and electrical appliances are being produced, and will eventually become e-waste.

These products present a significant global challenge due to the hazardous chemicals they contain, their highly technical recycling requirements and the high overhead and costs of environmentally sound management, as well as their adverse impacts to human health. Low-income countries bear the greatest burden of adverse health hazards such as asthma, bronchitis, DNA damage, endocrine and hormone disorders, lung and liver cancers, fertility problems, genetic mutations, etc. Although high-income countries are the main sources of this waste, low-income countries are experiencing an increase in e-waste due to the shifting process of both recently produced and UEEE, as well cheap management overhead costs. In the case of India, for instance, it generates its own e-waste as well as imports waste from high income countries, and is presently the second biggest e-waste processing country. In addition, 2.2 million tons of UEEE are imported annually in Bangladesh. Necessity and cheap prices have been increasing demand volume daily. Undoubtedly, imported new and UEEE make a large contribution to industrial growth and economic development in these regions. However, as end users, low-income countries such as Bangladesh, China, India, Sri Lanka, Pakistan and the Philippines are also the final destinations for the dumping of e-waste. Furthermore, low cost recycling of e-waste, such as for a computer, which costs up to 20 dollars in the US and less than 2 dollars in Bangladesh, India and Pakistan, is ultimately exacerbating this situation.

The establishment of sustainable and environmentally sound processing of e-waste, i.e., handling, recycling, recovery, dumping or overall management practices is very difficult to implement in low-income countries. Although some initiatives have been taken by South Asian countries to regulate and import UEEE, they do not have any existing or effective laws or regulations for e-waste handling. While India has introduced legislation and adopted some important laws and guidelines (Electronic Waste Handling and Disposal) Draft Law, 2013; E-waste (Management and Handling) Rules, 2011; Management of E-Waste, Guidelines, 2008) and Bhutan as well (Waste Prevention and Management Act, 2009), no such legislation has been introduced in other affected countries such as Bangladesh, Nepal, the Maldives, Sri Lanka, Pakistan or Afghanistan. Bangladesh is classed as underdeveloped with regard to the recycling and disposal of e-waste among the e-waste generating nations and they do not have any inventory on e-waste. Similarly, Pakistan does not have any precise data or inventory on e-waste and only a very small amount of imported UEEE are usable and declared by customs as ‘waste’.

**Conclusions**

The increasing global trend of e-waste generation has come up as one of the major environmental problems and challenges for achieving sustainable development. Considering its adverse potential eco-toxicological impacts and diverse health effects, an urgent global multilateral agreement is needed addressing e-waste handling, storage, transportation, recycling, and final disposal of any residual waste, whether by land filling or incineration. As it is a global issue from the pollutant production and transportation perspectives, multinational negotiation as well collaboration is realistically the only way to achieve sustainable development goals. Formal consecutive inventory initiatives are needed in vulnerable countries such as those in developing countries in South Asia. In addition, there is a need to develop health prevention strategies focusing on e-waste by addressing susceptible groups, i.e., children, pregnant women, and socio-economically disadvantaged communities. It is also necessary to determine if there are any knowledge gaps and awareness training needs from the top to the bottom.
level. Sustainable management techniques could be included in policy implementation with a focus on knowledge and awareness building. Furthermore, economic, environmental and technological cooperation could be bolstered among the high-income producer and supplier countries of e-waste and those adversely affected by it, especially low-income countries. Comprehensive global e-waste management and policies could help to offset the hazards of e-waste and are the best approach for achieving sustainable development.

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