Chapter 11
Sustainable Electronic-Waste Management: Implications on Environmental and Human Health

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Contents

Abstract The increasing level of Electronic-waste and its improper disposal and unsafe treatment pose significant risks to the environment and human health. They raise several challenges to the sustainable development goals. Electronic-waste is considered one of the fastest-growing pollution problems all over the world as per the United Nations environment programme estimates. This rapid growth is influenced by planned product extinction, lower prices, and change of lifestyle. Unfortunately, a major amount of Electronic-waste is recycled in the informal sector

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and results in toxic exposures to the recyclers, especially to women and children. Electronic-waste consists of valuable metals as well as environmental contaminants especially polybrominated diphenyl ether and polychlorinated biphenyls. The chemical composition of Electronic-waste changes with the innovation of new technologies and pressure from environmental organizations. As the reprocessing and recycling technologies with minimal environmental impacts are found to be expensive, rich countries export unknown quantities of Electronic-waste to developing countries, where recycling techniques including burning and dissolution in strong acids result in localized contaminations of water and food chains. This chapter deals with the generation of electronic-waste and its disposal pathways, and it especially covers the various contaminants that affect human health as well as our environment.

Keywords Industrialization · Electronic-waste · Sustainable development goals · Human health · Environment

11.1 Introduction

Due to rapid industrialization, industries have moved towards an environment with the reduction of human power and an increase in usage of electrical as well as electronic equipment. The innovation of electrical and electronic products leads the way to its usage in manufacturing and in another industrial sector. The development of faster and reliable processing technologies such as mobile phones, computers, and laptops drives consumer to use current and upgraded technology products with no longer use of older products. This development, in turn, gives a tremendous increase in the usage of electronic-waste products among consumers. Step Initiative (2014) framed a definition for Electronic-waste as follows: "Electronic waste is a term used to cover items of all types of electrical and electronic equipment and its part that have been discarded by the owner as waste without the intention of re-use."

It is considered as a fast-growing waste sector, which includes a large variety of components that include toxic as well as resourceful products. In the field of information and communication technology due to rapid advancement, substitution, and miniaturization, Electronic-waste increases day by day. Electronic-waste is also referred to as waste electrical and electronic equipment.

Baldé et al. (2015) categorized electrical and electronic equipment into six types; they are as follows:

- Temperature exchange equipment – referred to as cooling and freezing equipment. The equipment such as refrigerators, air conditioner, heat pump, and freezers will come under this category.
- Screens and monitors – monitors, laptops, tablets, and television.
- Lamps – light-emitting diode lamps, fluorescent lamps, and discharge lamps.
- Large equipment – washing machine, cloth dryers, electric stoves, photovoltaic panels, printing, and copying equipment.

- Small equipment – vacuum cleaners, microwaves, ventilation equipment, electric kettles, radio, video recorder, calculators, electronic toys, medical devices, and electronic tools.
- Small information technology and telecommunication equipment – mobile phones, global positioning system, personal computers, printers, and telephones.

The lifetime of the six different categories varies according to their quantities, economic values, and impact on environmental health if recycled improperly. The consumer mentality in disposing of the electrical and electronic equipment, as well as the recycling technologies, also varies accordingly. It is noted that in 2014, 41.8 million metric tons of Electronic-waste was produced as waste, and in near 2018 it will increase to 50 metric tons (Baldé et al. 2015). From 1992 to 2005, the lifespan of computers shrunk from 4.5 years to 2 years. This is due to the upgradation of newer and latest version with the old ones by the consumers. Unsuitable recycling makes the electronic-waste as potential environmental and health hazards. It is noted that Electronic-waste consists of 60 metals, which include copper, silver, palladium, platinum, gold, etc. These metals when recovered could reduce the demand for new metal production to some extent. The production of hazardous by-products in electrical and electronic equipment is called an informal sector of Electronic-waste. Inadequate recycling technologies and manpower were seen in terms of Electronic-waste. Unexpected exposure to Electronic-waste especially to children is found to be vulnerable. In this chapter we will be focusing on the electrical and electronic equipment, their impact to our environment as well as to health, recycling of electrical and electronic equipment, approaches in the reduction of health effects, and special attention towards the areas of improvement.

11.1.1 Electronic-Waste and Sustainable Developmental Goals

In order to end poverty and to give property assurance and protection of our planet for the next 15 years, in September 2015, the United Nations and state members adopted 2030 agenda for sustainable development. It consists of 17 sustainable development goals and 169 targets. From the goals, it is concluded that Goal 3: Good health and well-being, focuses on death rates and illness caused by hazardous chemicals and contamination of air, water, and soil. Goal 6: Clean water and sanitation and, seeks to achieve safe drinking water and to reduce pollution and dumping of hazardous waste. Goal 8: Decent work and economic growth aims at entrepreneurship, innovation, and micro-, small-, and medium-sized enterprises. Goal 11: Sustainable cities and communities focuses on per-capita environmental impact. Goal 12: Responsible consumption and production aimed at the life cycle of individual products and their release to the soil, water, and air, and on waste generation reduction by prevention, reduction, repair, recycling, and reuse. Goal 14: Life below water goes well with the management of Electronic-waste. Electronic-waste when treated improperly creates health issues and contaminates air, water, and soil, and untrained people in dismantling process provides risk to the people as well as to the

Fig. 11.1 Sustainable development goals related to environment and health

environment (Baldé et al. 2017). Representation of sustainable developmental goals highlighting the goals related to human and environmental health is mentioned in Fig. 11.1.

11.2 Electronic-Waste Tracking and Driving Trends

From 2000 to 2016, there is a rapid growth in consumption of electrical and electronic equipment. The products such as fridges, washing machines, electric furnace, and television found tremendous growth over this period. At present, the countries, which are in the economic cooperation and development organization, have a high demand for electrical and electronic equipment. Three methods are predicted (Lohse et al. 1998) for the estimation of Electronic-waste, and they are:

- The consumption and use method; it averages the household electrical and electronic equipment for the prediction of quantities of waste electrical and electronic equipment.
- The market supply method, which uses data about sales and production in the specified region.

For the first two methods, the weight and the lifetime of the electrical and electronic equipment have to be noted, and the third method is Swiss environmental agency estimates, which determines the saturated position in household, i.e. for one new appliance, an old one is replaced. This method is not applicable practically as it is not the case in all households.

The rapid expansion of mobile and broadband networks allows people to access the Internet in rural areas and areas which are unconnected previously. The heavy competition in the telecommunication market for mobile brands is a key factor for a decrease in price in electrical and electronic equipment, and this makes the baseline for the spread of electrical and electronic equipment and the Internet drastically. A single person owns more than one mobile phone, and many people use various other electronic gadgets to access internet. Due to the higher speed and upgradation to the latest technologies, the consumer changes their laptops, personal computers, television, and other devices regularly. The older equipment is considered outdated, and people are replacing it when it is not damaged or broken. For example, from analogue to digital conversion, many televisions were replaced with digital signals, which lead the way to carbon-ray-tube television invasion (ITU 2015, 2017). The UN conference on trade and development estimated in 2015:

- The e-commerce global business-to-business goes beyond US$22 trillion, and business-to-consumer exceeded US$3 trillion.
- It is concluded that 40% of enterprises receive orders using the Internet.

11.2.1 Electronic-Waste Statistics and Measurement

Over the past five decades, there is an increase in the quantity of Electronic-waste generation in the United States, the European Union, and developing countries like India and China. As per the US Environmental Protection Agency, each household uses on an average 34 electronic devices and appliances which results in the generation of 5×10^6 tons of Electronic-waste per year. In the European Union, it was estimated that each citizen generates 15 kg of Electronic-waste per year, which approximately totals to 7×10^6 tons. Electrical and Electronic-waste contributes 8% of total municipal solid waste. In developing countries, the Electronic-waste generation per capita is around 1 kg per year, and it is found to be increasing rapidly. Import of Electronic-waste from developed countries also contributes a major amount of Electronic-waste to developing countries. In the process of recycling and reuse, 50–80% of waste electrical and electronic equipment generated in developed countries are shipped to developing countries, which are against international laws (Bastian et al). When Electronic-waste is not disposed of properly, it affects our environment and living beings. In developing countries, Electronic-waste is dumped into the soil without treatment due to the lack of strict regulations and financial resources leading to the soil as well as groundwater contaminations. In India, recycling happens in the form of informal sector where people tear apart the components in the electronic equipment without any safety measures. People working in this sector are exposed to toxins 24 hours a day as they live, sleep, and cook in the same place. In Delhi, illegal and dangerous recycling practices are adopted (Tsydenova and Bengtsson 2011, Needhidasan et al. 2014).

In Baldé et al. (2015) research, Electronic-waste progress has been discussed in an accurate manner. Some of the indicators are discussed in the above publication, and they are:

- Electrical and electronic equipment market scenario
- Electronic-waste totally generated
- Recycle of Electronic-waste done officially
- Collected Electronic-waste rate

The life cycle of Electronic-waste that is from electrical and electronic equipment and the Electronic-waste management are explained in four phases, and they are as follows:

- **Phase 1**
  Using apparent consumption method or using the statistics, which are maintained from the sales to the Electronic-waste registry, market entry phase can be analysed.
- **Phase 2**
  The sold product that enters the household or to the business comes under the stock phase. Using national-level surveys in the household as well as in business, the stock phase can be analysed. The stock phase includes sales information on electrical and electronic equipment and the product residence time.
- **Phase 3**
  When the product becomes out of date to the owner, it ends up as waste. Generation of Electronic-waste becomes an important factor in Electronic-waste statistics.
- **Phase 4**
  Electronic-waste is managed using one of the following techniques, and they are:
  Official take-back system – In order to reduce the environmental impact under the national Electronic-waste legislation, designated organizations are allotted for the collection of Electronic-waste.
  Mixed residual waste collection – Consumers are directly involved in the disposal of Electronic-waste, and as an impact, the disposed Electronic-waste is made to treat with residual waste. Landfills and incineration are found to be

currently using the technique for residual waste, but for the disposed Electronic-waste, suitable techniques need to be imposed as landfill and incineration are found to release toxin leachate and air pollution that creates negative impact to our environment.

Collection outside the take-back system – In this scenario countries are divided based on the waste management procedure they follow which is developed and undeveloped. In a developed waste management system, Electronic-waste which is collected by the individual dealers is accounted, and the Electronic-waste end up locations such as metal recycling; plastic recycling is explored, and the information is not reported to the official take-back system to avoid double counting. In undeveloped countries, the process such as local dumping, export, and recovery of value-added substance is done. Fig. 11.2 Illustrates the life cycle of electrical and electronic equipment into Electronic-waste and the common Electronic-waste management scenarios

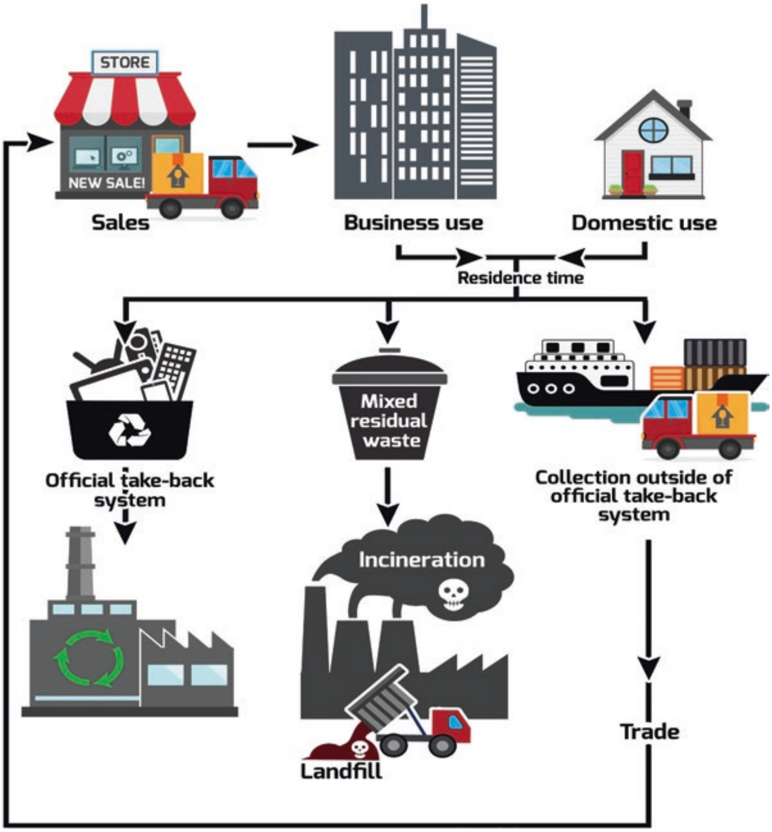

Fig. 11.2 The life cycle of electrical and electronic equipment into Electronic-waste and the common electronic-waste management scenarios

11.3 Positive and Negative Effects of Electronic-Waste

Positive Impact A research stated that (IBT 2012) 40–50 times of metals which are found to be precious are recovered from the Electronic-waste than from their native ores, and it was stated that for each year $21 billion of valuable metals are accumulated in Electronic-waste. The metals such as indium, palladium, silver, copper, and gold are often found in Electronic-waste. Forty per cent of valuable metals are recovered from printed boards (Golev et al. 2016), and it is stated that 320 tons of gold and 7500 tons of silver are used by electronic industries every year (BullionStreet 2012). In the Electronic-waste stream, notebooks, tablets, and smartphones are considered as valuable products due to the presence of high amount of precious metals (Cucchiella et al. 2015).

Negative Impact According to StEP in 2012 analysis, China and the United States contribute larger amount of Electronic-waste and waste electrical and electronic equipment with 11.1 million tons in China and 10 million tons from the United States. Now the scenario was found to be reversed from 2012 to upcoming years due to per capita average Electronic-waste trash being 29.8 kg, which is six times higher than China that figures 5.4 kg. The hazardous contaminants such as lead, cadmium, beryllium, iron, copper, aluminium and gold contribute 60% of Electronic-waste. Among those hazardous substances, lead is used in many electronic devices, which results in environmental contaminations. Children are normally vulnerable to lead poisoning more than the adults are as lead attacks the nervous system directly and it damages the human reproductive system. Cadmium affects the respiratory system, accumulates in the human kidney, and is also associated with bone disease. It causes bioaccumulation in the environment and is found to be extremely toxic to living beings. They are found in rechargeable batteries of computers. Mercury used as a lighting device like monitors and televisions affects the digestive, nervous, and immune systems. It also affects lungs, kidneys, skin, eyes and gastrointestinal tract. Symptoms, which include insomnia, memory loss, tremors, headaches, and dysfunction, are found. Polychlorinated biphenyls and mercury are seen in breast milk. In a research, which was done in China Electronic-waste, recycling processing site proves that the polychlorinated biphenyl and mercury level is seen higher in breast milk under this study (Ceballos and Dong 2016, UNU 2014). Hexavalent chromium is used in the process of a metal housing for many electrical and electronic components. Hexavalent chromium is a carcinogen, and it irritates the lung, nose, and throat. Electronic-waste with or without treatment enters into aquatic systems via leaching from dumpsites or from landfills and spreads via dust, and it enters into the human body via ingestion, inhalation, and skin absorption.

11.4 Products that Make Challenges to a Recycler

11.4.1 Solar Panel

In private as well as in industrial markets, solar panels are considered as generally known product worldwide. The polyvinyl panels installed in 1990's are on the verge of expiry which may not find a suitable recycling factility. Polyvinyl panels are based on silicon and a small number of rare earth metals such as cadmium, tellurium, indium, or gallium, which mostly ends in landfills, and 10% of polyvinyl panels are recycled in recycler's point of view. In this case, polyvinyl panels are not considered as environmental contaminants. Some researchers demonstrated that in the next few years, there will be a vast dumping of polyvinyl panels due to the installation of the massive amount of panels currently (Choi and Fthenakis 2014, Bustamante and Gaustad 2014).

11.4.2 Liquid Crystal Display and Cathode-Ray Tube Monitors

According to European Union waste electrical and electronics, cathode-ray tube and liquid crystal display technologies are considered hazardous substance. In liquid crystal display, panels and the backlights, which contain mercury, are considered as hazardous. The UK Environmental Agency in 2010 stated that "liquid crystal displays", which do not contain mercury backlights, are considered as non-hazardous. From the statement, it is concluded that key elements which make liquid crystal display a hazardous component are backlight containing mercury, and other hazardous substances are polyvinyl butyral and brominated flame retardants. It consists of three types of glass and the electron gun. As the image formation process occurs within a cathode-ray tube, it is considered as the main component in the monitor. In addition, cathode-ray tube is considered as the heaviest component comprising of 60% of the total weight in the monitor (Veit and Bernardes 2015), and it is composed of 85% of glass, which is located in the front panel (65%), funnel (30%), and neck glass (5%). Silica, alumina, lime, magnesia, boric acid, etc. (Herat 2008) are considered as main components of glass. In order to capture the escape of radiation from the tube, lead is added to the glass, and the panel glass contains barium. The lead content in the glass also makes glass as a hazardous material. The glasses in the cathode-ray tube are processed to bricks, nuclear waste encapsulation, construction aggregates, decorative tile, fluxing agent, and sandblasting medium (Guo et al. 2010a, b). The leaching of lead, barium, and other toxic materials present in the glass causes environmental risk. Leads are found to be toxic to kidneys, and its accumulation in our body affects the nervous and reproductive systems. High dosage results in haemorrhage and brain oedema. Nearly 40% of lead is from landfills, which are from electrical and electronic equipment (UNEP 2014).

11.4.3 Printed Circuit Boards

They are employed in computers as well as in electronic equipment for mechanical support, i.e. to connect the electronic components electrically by means of conductive pathways. Printed circuit systems place an essential role in all electric and electronic equipment. By means of additive and subtractive methods, circuit patterns are created. It works as a platform for mounting semiconductor chips and capacitors. The printed circuit boards contribute 3% of Electronic-waste in the overall Electronic-wastes generated. The materials such as aluminium, copper, iron and steel, lead, zinc, paper, and plastics are normally found in printed circuit boards. Metal, ceramic, and plastic compositions are found to be 40%, 30%, and 30%, respectively. Some concentrations of precious metals such as gold and palladium are found richer than their natural ores. Recycling process such as mechanical, automated, and semiautomated approaches is followed. The mechanical approach involves two steps; the first step consists of the separation of different components and materials, and the second step involves further separation and processing (Hall and Williams 2007, Guo et al. 2010a, b). In automated approach the use of image processing identifies the reusable parts in printed circuit boards by comparing the shape and labels in the database which are gathered from the manufacturers and from the reuse market. The reusable products and the hazardous components are separated in dismantling cell. The semiautomated approach is found to be flexible. The electronic components are removed by a combination of heating above the solder melting point. Semiautomated dismantling cell was connected for separating the reusable and hazardous component (Yi et al. 2007).

11.4.4 Cooling and Freezing Appliances

The release of chlorofluorocarbon is seen due to improper disposal of cooling and freezing appliances. It is reported that more than three-fractional amount of ozone-depleting substance is released from refrigerants and foams in cooling and freezing appliances. Scarp steel, compressors, cables, plastics, glass, and oil are the material compositions of refrigerators. Ferrous and non-ferrous metals account for 50% and 8% and plastics account for 20–25%. Polystyrene has high value in the secondary market and used as an insulating material in refrigerators and freezers. New cooling and blowing agents with less impact on the surroundings have to be introduced to the field of refrigerators and freezers.

11.4.5 Batteries

Batteries consist of one or more than one electrochemical cells, which are connected, in series as well as in parallel in order to produce electrical energy. The cell consists of anode, cathode, and electrolyte. Batteries play a major role in electrical

Fig. 11.3 Many people own multiple devices

and electronic devices in mobile phones, laptops, toys, cordless phones, personal computers, etc. The batteries are to be disassembled and recycled in a specific manner. Spent batteries are the secondary source of metals with high concentration levels. Metals such as cobalt and nickel are found in lesser amounts in nickel-cadmium, nickel-metal hydride, and lithium-ion batteries. Safe disposal includes landfills, stabilization, incineration and other recycling processes. Incineration of batteries is found to be expensive, and some toxins like mercury, cadmium, and dioxin are emitted during the incineration. Two main steps are involved in recycling, and they are waste preparation and metallurgical processing. Figure. 11.3 illustrates the use of multiple electronic devices by many people.

11.5 Electronic-Waste to Human Health and Environment

Electronic-waste may consist of 60 different elements, which are hazardous as well as non-hazardous in nature. Electrical and electronic equipment are considered major consumers of precious metals, and huge global demand is created due to the consumption. A simple mobile phone may consist of 40 elements from a periodic table including metals like copper (Cu), tin (Sn), cobalt (Co), indium (In), and antimony (Sb) and precious metals, which include silver (Ag), gold (Au), and palladium (Pd). One ton of phone handsets contains 3.5 kg of Ag, 340 g of Au, 140 g of palladium, and 130 kg of copper, and the remaining are filled with plastic and ceramic materials. The lithium-ion battery in the phone consists of approximately 3.5 kg of cobalt. In addition to electrical household appliances, batteries, capacitors, cathode-ray tubes, glass, etc. are considered Electronic-waste. In several countries recycling of above-mentioned Electronic-waste is done formally as well as in an informal manner. Formal recycling techniques utilize well-designed techniques and machinery to separate the useful products from the Electronic-waste in an expansive manner, and this type of formal recycling techniques does not have much impact to our environment when compared to informal recycling techniques, which are carried in underdeveloped and developing countries, which emit several pollutants in the environment. The exposure to hazardous components in the way of ingestion, skin contact, and inhalation by the mediums like soil, water, food, and air is seen. The risk of exposure is seen in workers; women and children are found to be at maximum risk due to the additional medium of exposures (maternal feeding, hand-to-mouth activities, care fewer behaviours). The exposure from the workers transfers to other family members through dermal contact, clothes, etc.; hazardous chemicals or compounds from Electronic-waste come either from the recycling process or from components of the electronic equipment. Some persistent organic pollutants such as brominated flame retardants, polychlorinated biphenyls, hexabromocyclododecane, polybrominated diphenyls, di-brominated diphenyl ethers, and polychlorinated and polybrominated dioxins are seen in Electronic-waste. Persistent organic pollutants formed during dismantling and smelting consist of polychlorinated dibenzofurans, polychlorinated biphenyls, and polychlorinated dibenzodioxins. Polycyclic aromatic hydrocarbons, which are generated during incomplete combustion of fuels like coal, gas, oil, etc., react with Electronic-waste materials and form hydrocarbons. Heavy metals such as lead, cadmium, chromium, mercury, copper, manganese, nickel, arsenic, zinc, iron, and aluminium are the results of Electronic-waste threats. Table 11.1 briefly shows various hazards caused by different components of Electronic-waste.

11.5.1 Effects on Air

Many Electronic-waste contaminants spread into the air via dust by transporting the Electronic-waste to developing countries where recycling processes are poorly regulated. In developing countries, due to informal economics, Electronic-wastes are recycled by way of dismantling and shredding with the release of a large amount of dust, which creates a respiratory problem for workers. Unregulated burning at low temperatures releases dioxins, which damages humans as well as animals.

11.5.2 Effects on Aquatic Organisms

Introduction of Electronic-waste contaminants to water bodies poses hazards to aquatic organisms. The local resident's life was affected due to dumping and other Electronic-waste recycling activities. The heavy metals such as lead, barium,

Table 11.1 Electronic-waste exposures and its potential hazards

Pollutants	Components of the electrical and electronic equipment	Effects to humans		Source of exposure	Route of exposure	References
		Temporary	Permanent			
Polybrominated diphenyl ethers	Flame retardants, electronic components	Fatigue, headache, reduced capacity of work, dizziness, irritability in combination with gastrointestinal syndromes such as diminished appetite, weight loss, abdominal pain	Neurodevelopmental toxicity, thyroid hormone imbalance, liver tumours	Air, soil, sediments, humans, wildlife, sewage treatment plant biosolids	Ingestion, inhalation, transplacental	Siddiqi et al. (2003)
Polybrominated biphenyls						
Polychlorinated biphenyls						
Polycyclic aromatic hydrocarbons	Incomplete combustion	Lung cancer		Atmosphere, surface soils	Ingestion, inhalation, and transplacental	Hussein et al. (2016)
Polychlorinated dibenzofurans, pyrene, chrysene, fluoranthene, fluorene, phenanthrene, acenaphthene, anthracene						
Heavy metals	Light-emitting diodes, doping material for Si, semiconductors, microwaves, solar cells	Cancers in lungs, bladder, and skin	Carcinogenic, chronic disease	Air, soil, and water		Kumar et al. (2017) and Grant et al. (2013)
Arsenic						
Barium	Getters in cathode-ray tube screens, plastic and rubber fillers, electron tubes	Brain, heart, liver, and lung damage		Air, water, soil, and food	Ingestion, dermal contact, and inhalation	
Cadmium	Toners, batteries, plastics, circuit boards, monitor	Birth defect and heart, kidney, and lung damage	Nephrotoxicity	Air, dust, soil, water, and food	Ingestion and inhalation	

Pollutants	Components of the electrical and electronic equipment	Effects to humans		Source of exposure	Route of exposure	References
		Temporary	Permanent			
Chromium	Data tapes, floppy disk, switches, solar	Bronchitis	Carcinogenic	Air, dust, water, and soil	Inhalation and ingestion	
Cobalt	Insulator	Thyroid damage	Vision problems, heart problems, vomiting and nausea			
Copper	Conductor cables, coils, circuitry, wiring	Liver and kidney damage, Wilson's disease	Irritation in nose, mouth, headaches, dizziness, vomiting, diarrhoea			
Lead	Cathode-ray tube screens, transistors, lasers, light-emitting diode, thermoelectrical elements,	Toxic to human, plants, and animals	Fatigue, sleeplessness, arthritis, hallucinations, vertigo, headache, hypertension			
Lithium	Lithium batteries			Air, soil, water, and food	Inhalation, ingestion, and thermal contact	
Mercury	Fluorescent lamps, alkaline batteries	Damages nervous system	Bioaccumulation, neurological and behavioural changes	Air, vapour, water, soil, and food	Inhalation, ingestion	
Selenium	Older photocopying machines as photosensitive drums	Lung tissue damage, oxidative damage in tissues	Headaches, diarrhoea			
Beryllium	Motherboard	Lung cancer, berylliosis	Headache, diarrhoea	Dust, air, food, water	Inhalation, ingestion	
Rare earth elements	Fluorescent layer	Brain, heart, liver damage	Birth defects			

mercury, lithium etc. from Electronic-waste when improperly disposed leach to the soil and reach groundwater channels. Some of the heavy metals are found to be carcinogenic, and intake of contaminated water by humans and land animals creates major health issues.

11.5.3 Effects on Soil

Toxic heavy metals from Electronic-waste enter to humans by "soil-crop-food pathway", the effects of which are birth defects and brain, heart, liver, kidney, and skeletal system damage. When computer monitors and electronics are burned, cancer-producing dioxins are released into the air, and if thrown in landfills, the toxins may leach into groundwater. Table 11.2 represents the toxic substances and their health impacts.

Table 11.2 Common toxic substances associated with electronic-waste and their health impacts

S. No	Substances	Way of exposure	Health issues
1.	Antimony	Ingestion, inhalation, skin contact	Damages the blood, kidneys, lungs, nervous system, liver, and mucous membranes
2.	Cobalt	Inhalation, ingestion	Organ damage, toxic to lungs, and carcinogenic effects
3.	Gallium	Ingestion, inhalation, skin contact	Toxic to lungs, mucous membrane, severe exposure leads to death
4.	Copper	Inhalation, ingestion	Results in death, toxic to lungs and mucous membranes, organ damage
5.	Arsenic		Skin lesions, peripheral neuropathy, gastrointestinal symptoms, diabetes, renal system effects, cancer, and cardiovascular disease
6.	Cadmium	Inhalation, ingestion	Accumulation in kidney and liver, human carcinogen, and has toxic effects on the kidney, skeletal system, and respiratory system
7.	Dioxins		Toxic and cause chloracne, damage immune system, interfere with hormones and cause cancer
8.	Barium	Inhalation, ingestion	Short-term muscle weakness and damages heart
9.	Beryllium	Ingestion, skin contact	Carcinogenic, chronic beryllium disease, warts, etc.
10.	Chlorofluorocarbons	Contact, inhalation	Potent greenhouse gas. Direct exposure causes unconsciousness, irregular heartbeat, drowsiness, coughing, difficulty in breathing, sore throat, eye redness, and pain

Sources: Compendium (2016)

11.6 Electronic-Waste Management

In minimizing the negative effects on the environment and human health as well as to increase the recycling of Electronic-waste, Electronic-waste legislation is followed in 90 jurisdictions. European Union, Japan, and South Korea have enlightened legislation and controls, which are implemented, and some developing countries like China, India, and Brazil are taking initiating steps in implementing Electronic-waste legislation. In many countries, no regulations are followed since (Li et al. 2015). Since 2002 European Union has established some of the legislation directive on waste electrical and electronic equipment and restriction of hazardous substances such as directive on registration, evaluation, authorization, and restriction of chemical substances, and Japan also established some of the legislation like waste management and public cleansing law, home appliance recycling law, and small appliance recycling. In China, they have enacted environmental protection law of the People's Republic of China, Law of the People's Republic of China on Circular Economy Promotion, Law of the People's Republic of China on cleaner production promotion, etc. Moreover, in terms of Electronic-waste, they have enacted management regulation on the recycling of waste electrical and electronic products, opinions on strengthening the prevention and control of pollution from electronic-waste, and administrative measures for the prevention and control of environmental pollution from Electronic-waste (Zhou and Xu 2012). Developed countries are found to be different from developing countries in terms of Electronic-waste usage and disposal. The issues in developing countries are as follows (Heeks et al. 2015, Osibanjo and Nnorom 2007):

- Inadequate handling threats
- Lack of formal recycling systems
- Absence of or improper recycling legislation
- Rapid development and their Electronic-waste quantities in the information and communication sector
- The tremendous increasing rate of Electronic-waste generation
- Management issues found in component handling in Electronic-waste
- The negative impact of present Electronic-waste management strategies

11.7 Conclusion

Electronic-waste is found to be a serious issue at both local and global scales. Electronic-waste-related problems initially started in developed countries, and now it has extended to developing countries across the world. Rapid change in consumer technologies and innovations moves current technologies to extinction. If the end-of-life management of electrical and electronic equipment is not managed properly, it will result to release of toxic substances, which can contaminate our environment and threaten human health. Many studies from Electronic-waste recycling plant evidence of the release of toxic heavy metals as well as contaminants to our environment, and a major source of contaminants is seen in informal recycling sectors, and informal Electronic-waste recycling has long been accepted to lead to dangerous environmental pollution. The international health community, policy experts, and non-governmental organizations in a joint venture with the national government should create awareness among people, through the creation of policy solutions, conducting educational programmes, and setting up goals for the reduction of Electronic-waste exposure and its health effects.

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