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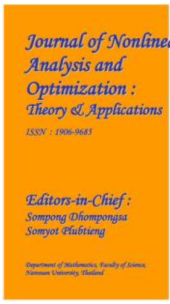

E-WASTE: AN OVERVIEW ON COMPOSITION, IMPACT OF THE RELEASED TOXIC METALS AND MANAGEMENT APPROACHES

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Abstract
In recent years the generation of E-waste has increased remarkably. E-waste is generated from the discarded electronic equipment. The toxic metals released from the e-waste are contaminated in water, soil and air from its disposal. These released metals have adverse effects on the environment. Therefore E-waste can create grave consequences for the environment if not managed properly. Now E-waste has become a matter of concern globally. In this aspect this review summarizes the composition of E-waste, impact of the released toxic metals and management approaches.

Keywords:
E-waste, Electronic equipment, Toxic metals, Grave consequences.

1. Introduction

Electronic waste or E-waste usually refers to all the items related to electrical and electronic equipment (EEE), which have been discarded by the users. E-waste or E-scrap includes the consumer and business electronic equipment that's no longer working, unwanted and nearly or at the end of their useful life [1]. The consumption of electronic items is increasing day by day due to digital innovation and revolution in science and technology. Due to advanced technology more sophisticated modern electronic goods are developing to make life easier and thereby leaving behind the old computers, laptops, televisions, cellphones, batteries and other electronic gadgets, generating E-waste [2]. In this way the generation of E-waste is enhancing dramatically throughout the world. E-waste contains many harmful and toxic components including heavy metals and metalloids like arsenic, barium, beryllium, cadmium, cobalt, chromium, copper, iron, lead, mercury, nickel, zinc and organic compounds such as dioxin, brominated flame retardants (BFRs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominateddibenzop-dioxins, dibenzofurans (PBDD/Fs), polychlorinated dibenzo-p-dioxins, dibenzofurans (PCDD/Fs), polyvinyl chloride (PVC), alternative halogenated flame retardants (AHFRs), chlorofluorocarbons, polybrominateddiphenyl ethers (PBDEs) [3]. E-waste is a topic of great concern as the toxic components present adversely affect the human and environmental health if not managed properly. Again E-waste contains some valuable and precious metals like Fe, Cu, Al, Ag, Au, Pt, Pd, La, Nd which should be recovered and utilized to conserve the natural resources [4]. Disposal of E-waste in the landfills and incineration produces a variety of toxic materials, which impact the air, water, soil and ultimately human health. A remarkable amount of heavy metals and polyhalogenated organic components are found in landfill leachates. Again incineration produces greenhouse gases, mercury and dioxins, pollutes the environment to a great extent. Therefore the improper disposal of E-waste is very dangerous to the environment [5]. It is very important to spread awareness regarding E-waste and its management, so that it can be recovered, recycled and reused. This article will give a comprehensive idea on composition of E-waste, impact of E-waste on human health and management strategies in order to achieve sustainability.

2. Sources of E-waste

E-wastes generated from electrical and electronic equipment can be categorized in two types. (i) Information technology and telecommunication equipment like computer and its accessories, monitors, printers, keyboards, central processing units, typewriters. (ii) Consumer electrical/electronic products such as mobile phones and chargers, treadmills, remotes, compact discs, headphones, batteries, LCD/Plasma TVs, i-pods, air conditioners, dryers, fridge, VCRs, Stereos, Copiers, fax machines, video games, smart watches, music system and other household appliances etc. [3].

3. Composition of E-waste

In general most of the E-waste comes from computer and its parts, mobile phones, TVs, refrigerators and washing machines. If we know the composition of E-waste then only we can find the hazardous component of E-waste and retrieve the metal from E-waste. So it is important to know about the composition of E-waste. Generally E-waste is composed of four types of materials i.e. ferrous metals, non-ferrous metals, plastic and others [6]. The material present and their concentration in E-waste depend on manufacturer, model, type of the device, technology used, age of the device etc. The metals in E-waste are present mostly in their elemental form and in some cases alloys of different metals attached with non-metallic components. E-waste contains about 70% of hazardous substances of heavy metals. This hazardous substance of E-waste is comprised of about 2-3 % of the total hazardous pollutants in the environment [4].

4. Impact of E-waste

The hazardous pollutants of E-waste cause health issues due to environmental contamination. The heavy metals present in E-waste enter into the biological system through air, water and soil and causes health hazards.

4.1 Effect of Arsenic (As): Arsenic serves an important role as a semiconductor in electronic industries. Nevertheless, its presence imposes significant health risks. Exposure to arsenic can lead to various adverse effects, including skin alterations, reduced nerve conduction, elevated diabetes risk, and an increased likelihood of cancer in the skin and other tissues [7]. Arsenic poisoning occurs when the body accumulates higher levels of arsenic, resulting in short-term symptoms such as vomiting, abdominal pain, and diarrhea. Long term exposure can lead to arsenicosis, a condition caused by the consumption of arsenic-contaminated groundwater. Arsenicosis manifests in skin issues like pigmentation and keratosis, as well as pulmonary diseases, liver disorders, neurological issues, peripheral vascular disease, hypertension, diabetes mellitus, fatigue, anemia, and cancers affecting the skin, lungs, and urinary bladder.

4.2 Effect of lead (Pb): Lead is widely used in printed circuit boards, glass in cathode ray tubes, light bulbs, televisions, mobile phones, solder, and batteries. Exposure to lead is associated with Kidney failure, central and peripheral nervous systems, damage to blood and reproductive systems, anemia, and chronic neurotoxicity.

In earlier time Pb was used as an antiknock compound [tetraethyl lead (TEL)] in petrol and it was transported into the atmosphere with the exhaust. Today the use of leaded (TEL) fuel has virtually stopped all over the world due to its toxicity. Pb toxicity in the body depends on acute and long term exposure, loss of appetite, headache, hypertension, abdominal pain, renal dysfunction, fatigue, sleeplessness, arthritis, hallucinations, and vertigo, whereas chronic exposure may lead to mental retardation, birth defects, autism, psychosis, allergies, dyslexia, weight loss, hyperactivity, muscular weakness, paralysis, brain damage, kidney damage, and may even cause death [8].

4.3 Effect of nickel (Ni): Nickel finds widespread uses in batteries, printed wiring board, housing, mobile phones, and cathode ray tubes. Lung cancer, cardiovascular disease, neurological deficits, developmental deficits in childhood, and high blood pressure are the common problems caused by Ni toxicity. Contact of Ni to skin causes skin irritation and oral exposure may lead to erythema, eczema. Studies have indicated that Ni metal dusts and some Ni compounds possesses carcinogenic properties, which may be due to facilitation of oxygen-free radical reactions by nickel oxides. The carcinogenicity of nickel compounds depends on their ability to enter cells and therefore water-soluble compounds exhibit less potency when compared to water-insoluble compounds [9]. High Ni concentrations in soil can hamper plant growth. Ni toxicity in plants include chlorosis, necrosis, and wilting. It interferes with enzymatic activity of antioxidant enzymes such as superoxide dismutase and catalase, thereby enhancing oxidative stress. It interferes with significant processes such as photosynthesis, respiration, germination, and chlorophyll synthesis [10].

4.4 Effect of Copper (Cu): The electrical components like printed wiring board, cathode ray tubes, computer chips, central processing unit, heat sinks, cables, and mobile phones are made of copper. Cu is an essential trace element required in both plants and animals for several enzymatic reactions as catalyst and cofactors. However, an excess of Cu can result in copper toxicity. The effect of environmental Cu on plants is more pronounced when compared to human and other mammals, as it is not readily bio-accumulated. Cu is relatively safe when compared to several other metals (like mercury, lead, and cadmium). In human, presence of excess Cu in system leads to production of metallothionein, which binds to Cu to form a water-soluble complex which can be eventually excreted. Further, the presence of organic and inorganic colloids in soil reduces Cu mobility and thereby the exposure of land plants to copper is reduced. However, aquatic plants are vulnerable to Cu toxicity. Studies indicate that Cu toxicity in plants depends on its bioavailability, which in turn is dependent on the physicochemical characteristics of the environment, such as pH, redox potential, soil and sediment type, water hardness, and organic content. Higher levels of Cu may result in inhibition of enzymes leading to interference in metabolic pathways. One of the major toxic effects on plants includes inhibition of chloroplast photosynthesis [11]. Excess intake of copper leads to formation of hydroxyl radical, which initiate per-oxidative chain reaction, thus degrading membrane lipids [12].

4.5 Effect of palladium (Pd): Palladium is mainly used in hard drives, circuit board components (capacitors), mobile phones, and printed wiring board. Pd is known to inhibit enzymes such as creatine kinase, aldolase, succinate dehydrogenase, carbonic anhydrase, alkaline phosphatase, and prolyl hydroxylase. Pd toxicity majorly affects mitochondria. it increases ROS production in mitochondria, collapses mitochondrial membrane potential, causes a negative effect on mitochondrial respiratory system that may lead to apoptosis [13]. Another study on rats indicated that inorganic Pd compound can significantly induce drop in diastolic and mean blood pressure and a decrease in heart rate. However, Pd bound in an organic compound does not show any significant cardio-toxicity in isolated rat hearts [14].

4.6 Effect of Mercury (Hg): It is mainly used in thermostats, sensors, monitors, cells, printed circuit boards, housing, batteries, and cold cathode fluorescent lamps. Hg is a highly toxic element. Inorganic Hg salts can cause irritation in the gut and can damage kidneys. Organic Hg salts are capable of crossing the bloodbrain barrier as they are fat-soluble and can cause neurological and behavioural disturbances [15].

4.7 Effect of Cadmium (Cd): Cd is a nonessential element and is widely used in rechargeable batteries, electroplating for corrosion resistance and in chemical industries. Cd is considered toxic and prolonged exposure can affect multiple organs such as skeletal, urinary, reproductive, cardiovascular, central and peripheral nervous, and respiratory systems. Cd is reported as a potent carcinogen [16]. It tends to accumulate in kidneys and affects excretory mechanisms.

4.8 Effect of Antimony (Sb): It is mainly used as alloy in lead acid batteries. Chronic exposure to Sb in the air at levels of 9 mg/m3 may cause irritation of the eyes, skin, and lungs. Long-term inhalation of Sb can potentiate pneumoconiosis, altered electrocardiograms, stomach pain, diarrhea, vomiting, and stomach ulcers [17]. Sb over exposure has been reported to cause adverse effects on respiratory, cardiovascular, gastrointestinal, and reproductive system [18].

4.9 Effect of Tungsten (W): Tungsten metal is used for filament in various incandescent lamps but the major part of the world production goes into the tungsten carbide bits that are used extensively in different engineering applications (gas and oil field drilling is a major consumer). W has toxic attributes similar to those of other heavy metals. These include hindering of seedling growth, reduction of root and shoot biomass, ultrastructural malformations of cell components, aberration of cell cycle, disruption of the cytoskeleton, and deregulation of gene expression related with programmed cell death [19].

4.10 Effect of Lithium (Li): The major part of the production goes into the modern batteries. Li toxicity at smaller level causes diarrhea, vomiting, drowsiness, muscular weakness, and lack of coordination. At higher levels may cause giddiness, ataxia, blurred vision, tinnitus, and a large output of dilute urine, followed by damage to multiple organs [20].

4.11 Effect of Beryllium (Be): Be finds its widespread applications in power supply boxes, computers, x-ray machines, mobile phones, and ceramic components of electronics. The severe effect of Be exposure is Berylliosis, or chronic beryllium disease (CBD), a chronic lung disease caused by sustained exposure to Be in genetically susceptible individuals [21]. In plants, Be interferes with various physiological and morphological processes resulting in reduction the plant growth. Be significantly affects seed germination, biomass, and root length [22].

4.12 Effect of Iron (Fe): Iron, because of its magnetic nature, is used in electrical motors, generators, and transformers. Fe is essential for growth and development of most organisms, but high tissue concentrations can lead to physiological imbalance resulting in liver and heart diseases, certain cancers, and immune system dysfunction. Chronic inhalation of iron oxide fumes may result in siderosis and may increase the risk of lung cancer. Fe overload can lead to oxidative damage resulting in lipid peroxidation followed by membrane impairment, mainly in mitochondria and lysosomes. Excess of Fe can result in damage to various metabolic processes, most of which are downstream effects of oxidative stress caused by Fe overload [23].

4.13 Effect of Cobalt (Co): Printed wiring board, cathode ray tubes, housing, hard drive, and mobile phones are the major sources of Co release in the environment. Co is associated with vitamin B12 and is therefore beneficial for humans. Breathing air containing high concentrations of Co can result in lung problems, such as asthma and pneumonia. High intake of Co can cause vomiting, nausea, neurological deficits, heart problems, and thyroid malfunctioning [24]. Chronic exposure to Co may lead to considerable weight loss, dermatitis, and respiratory disorders. Plants grown on soil with high levels of Co may accumulate Co, which may be passed to human consuming those plant products.

4.14 Effect of Chromium (Cr): Anticorrosion coatings, decorative hardener, data tapes, floppy disks, mobile phones are made up of chromium and thereby its disposal releases Cr. Cr is considered highly toxic and is a possible carcinogen. Toxicity of Cr depends on the oxidation state, trivalent and hexavalent states being the most prevalent ones. Hexavalent chromium [Cr(VI)] compounds are strong oxidizing agents and therefore more toxic compared to trivalent chromium. Further, Cr(III) compounds are poorly absorbed in the body, whereas Cr(VI) is absorbed by the lung and gastrointestinal tract [25].

4.15 Effect of Manganese (Mn): Printed wiring board, housing, mobile phones, and cathode ray tubes are the electrical equipment made up of Mn. Mn is required for normal development and physiological processes both in plants and animals. However, any imbalance in the Mn homeostasis leads to disease conditions. Mn deficiency has been reported to be linked to skin lesions and bone malformation (including osteoporosis), whereas an excess intake of Mn may lead to neurodegenerative diseases. Level of Mn in serum of healthy human individuals is indicated as 0.050.12 μg/dl [26].

4.16 Effect of Aluminium (Al): It is used in printed wiring board, cathode ray tubes, computer chips, hard drives, central process unit, mobile phones, connectors, power conductor in electrical industries. Due to the low cost in compared to the Cu, Al has virtually displaced Cu in power transmission fields. Al is not a necessary element for plants and animals. It is particularly harmful for nervous, osseous, and hematopoietic systems [27].

4.17 Effect of Tin (Sn): The metal is used as a protective layer (tin plating) to improve corrosion resistance in chemical industries and also as an alloy component in solder in all electronic applications, printed wiring board, cathode ray tubes, solder, liquid-crystal display screens, and computer chips. It is nonessential for life and considered to be nontoxic. Higher levels of Sn may accumulate in liver, bone, lymph nodes, and kidneys. Chronic exposure to Sn can cause liver damage, immune disorder, depression, and brain damage [28].

5. Management approaches

In order to mitigate the E-waste problem extensive research is going on into E-waste management process**.** Different methodologies have been developed for proper management of E-waste and to maintain environmental sustainability**.** In India, generally two disposal methods are carried out, which are landfilling and incineration. Unfortunately, both methods are not effective methods for treating e-waste and are extremely hazardous to the environment. Various technological solutions have been developed to improve e-waste management in India. For example, a mobile app called ‘Eco E-Waste’ enables consumers to request doorstep e-waste pickup services [29]. The e-waste management approaches and initiatives in India include, life cycle assessment (LCA), material flow analysis (MFA), Multi criteria analysis (MCA), extended producer responsibility (EPR), informal sector integration, PPPs, awareness campaigns, and technological solutions [30].

LCA is an internationally standardized tool for systematic evaluation of environmental burdens of a product or process from its origin to the final disposal. LCA is the most important tool to assess the environmental impact of waste management [31, 32]. The E-waste (Management) Rules, 2016 have made it mandatory for producers, importers, and brand owners to take back the e-waste from consumers and ensure its environmentally safe disposal [33]. These efforts aim to promote environmentally sound recycling of e-waste and mitigate the negative impacts of e-waste on human health and the environment.

6. Conclusion

E-waste is a major problem locally and globally. Initially, it was originated in the developed countries but now extended to the other countries in the world. The amount of e-waste is rapidly shooting up with the technological advancement. The e-waste is constituted with different toxic elements, which are contaminated to the environment and thereby threaten the human health. Different methodologies have been developed to mitigate the E-waste problem. A national policy EPR is an important tool to deaden the E-waste problem. Moreover it is the utmost responsibility of the user to adhere to the rules to solve the e-waste issue for environmental sustainability. Therefore the research is going on to acquaint and to develop new methodologies to solve the E-waste issue.

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