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Electronic Waste: Human Health and Environmental Implications

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Abstract

The science brought a revolution in the information and communication sector in the last few decades. This progress undoubtedly enhanced the quality of our living, but on the other hand, it has also created many serious problems including the large amounts of hazardous electronic waste generated. Disposal of e-waste is an emerging global environmental and public health issue in India. As this waste has become the most rapidly growing segment of the formal municipal waste stream in the world. Electronic equipment contains many hazardous metallic contaminants such as lead, cadmium, and beryllium and brominate flame-retardants, The fraction including iron, copper, aluminum, gold, and other metals in e- waste is over 60%, while plastics account for about 30% and the hazardous pollutants comprise only about 2.70%. Electronic waste (e-waste) is one of the fastest-growing waste at global level. Improper processing of e-waste renders it noxious to human health and our ecosystem. This paper provides a comprehensive review of harmful impacts of e-waste on human life and the environment. Furthermore, the review explores sustainable methods including renewable and biodegradable technologies for the effective recovery of material from e-waste and mitigating the adverse effects of electronic wastes on human health and the environment.

Keywords: Biodegradable, e-waste, adaptive strategies, recycling, sustainable approaches, hazardous waste

Introduction

The term "waste" is reserved for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations, because loads of surplus electronics are frequently commingled (good, recyclable, and non-recyclable). E-waste or electronic waste is created when an electronic product is discarded after the end of its useful life. Rapid changes in technology, reducing the initial cost of electronic devices and their systematic removal from circulation, have become a rapidly growing electronic waste crisis in the world. India is also no exception to this. In the present era, due to the rapid upgrade of electronic equipment like mobile phones, computers, television and audio sets, printers, people have started buying them at very short intervals. Parts of electronic components are often thrown away. Due to the very limited recycling process of parts, they are disposed of in total toxic conditions for health and environment in the world.

The informal processing of e-waste in developing countries can lead to adverse human health effects and environmental pollution. Lead, cadmium, beryllium, or flame retardants are among the potentially dangerous materials found in electronic trash components like CPUs. In industrialized nations, recycling and disposal of e-waste may pose a serious risk to communities and employees. As a result, considerable care must be taken to prevent both harmful exposure during recycling operations and the leakage of materials like heavy metal from landfills and incinerator ashes. The toxic effects of e-waste on both human health and the environment are exacerbated by unregulated processing. There is an urgent need for a sustainable strategy that ensures effective e-waste management while preserving the health of people and the environment[1].

E-waste has become one of the fastest growing areas of the international waste stream and is increasing at a much higher rate than all other such streams. The main problem with e-waste generated from PCs is the fact that computers are manufactured from over 1,000 different materials. Some of these materials are toxic and not only cause environmental pollution but have been linked to human health problems[2].

There is no denying the problems created by exporting e-waste, but to truly address this problem both developing and developed countries must implement comprehensive education strategies that allow local population to understand the impact of e-waste on environment from their unique point of view. It is important to consider all countries as equal participants in the problem as well as the solution. The first section of the paper provides an overview of e-waste and discusses the health implications. This is followed by a discussion on some of the innovative sustainable approaches that are being implemented to tackle the problem.

E-Waste Scenario

During the last century, Industrial revolution followed by the advances in information technology has radically changed people's lifestyle. Although this development has helped the human race, mismanagement has led to new problems of contamination and pollution. The technical progress acquired during the last century has posed a new challenge in the management of wastes. The hazardous content of these materials poses an environmental and health threat. Thus, proper management is necessary while disposing or recycling e-wastes.

Now-a-days, computer has become most common and widely used gadget in all kinds of activities ranging from schools, residences, offices to manufacturing industries. E-toxic components in computers could be summarized as circuit boards containing heavy metals like lead and cadmium; batteries containing cadmium; cathode ray tubes with lead oxide and barium; brominated flame retardants used on printed circuit boards, cables and plastic casing; poly vinyl chloride (PVC) coated copper cables and plastic computer casings that release highly toxic dioxins and furans when burnt to recover valuable metals. The lead can seep into the ground water from landfills thereby contaminating it. If the tube is crushed and burned, it emits toxic fumes into the air.

There is no generally accepted definition of e-waste and there is not a consistent list of which electronic products constitute e-waste. Previous research on e-waste has focused on items such as cell phones, computers, monitors and consumer electronics, while other researchers such as Basel Action Network (BAN) also include large household equipment as e-waste. A general definition of e-waste is 'e-waste encompasses a broad and growing range of electronic devices ranging from large household appliances such as refrigerators, air conditioners, mobile phones, personal stereos and consumer electronics to computers'[3].

Impacts on Environment and Human Health

Populations of people are living among thousands of piles of electronic scrap that when broken are emitting toxic fumes. Not only are these dump sites seriously polluting the environment but they are causing alarming increased rates of cancer, retardation and neurological disorders. These materials can also harm the environment by damaging the air and the soil. Dangerous materials such as Lead, cadmium and mercury are all found within e-waste. Lead is found in the glass of computer monitors and in printed circuit boards. If exposed to lead this could lead to damage to the central nervous system and kidneys. In addition, effects on the endocrine system have been observed, leading to serious negative effects on children's brain development.

Children are especially sensitive to e-waste exposure because of several reasons, such as their smaller size, higher metabolism rate, larger surface area in relation to their weight, and multiple exposure pathways (for example, dermal, hand to mouth, and take home exposure). They were measured to have an 8-time potential health risk compared to the adult e-waste recycling workers. Children's exposure to developmental neurotoxins containing in e-waste such as lead, mercury, cadmium, chromium and PBDEs can lead to a higher risk of lower IQ, impaired cognitive function, and other adverse effects. In certain age groups, a decreased lung function of children in e-waste recycling sites has been found. If these electronic items are discarded with other household garbage, the toxics pose a threat to both health and vital components of the ecosystem. In view of the ill-effects of hazardous wastes to both health and environment, several countries exhorted the need for a global agreement to address the problems and challenges posed by hazardous waste.

Results and Discussion

E-Waste Management Strategies

A recent investigation revealed that much of the electronics turned over for recycling in the United States ends up in Asia, where they are either disposed of or recycled with little or no regard for environmental or worker health and safety. It is estimated that 75% of electronic items are stored due to uncertainty of how to manage it. These electronic junks lie unattended in houses, offices, warehouses etc. and normally mixed with household wastes, which are finally disposed of at landfills. This necessitates implementable management measures. In industries, the management of e-waste should begin at the point of generation.

In developed countries, e-waste is often managed through formal recycling channels that involve collection centers, recycling plants, and certified processors. In the European Union, the Waste Electrical and Electronic Equipment (WEEE) Directive mandates that manufacturers take responsibility for the collection and recycling of their products[4]. Similarly, the Extended Producer Responsibility (EPR) policies in many countries ensure that producers are accountable for the disposal of their products at the end of life[5]. However, in developing countries, informal recycling practices continue to dominate due to economic factors, lack of regulation, and inadequate infrastructure. For instance, in Ghana and India, e-waste is often dismantled manually in backyard workshops, leading to exposure to hazardous chemicals and contributing to severe health and environmental impacts[6].

The government regulation and international agreements play critical role in addressing the growing e-waste crisis. Policies such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal aim to control the illegal movement of e-waste across borders and promote safe disposal[7]. Currently, pyrometallurgy, hydrometallurgy, and mechanical separation methods are the major techniques of e-waste management strategies. Although these techniques have the potential to recover valuable materials from e-waste, their effectiveness is limited by several restrictions. In particular, these methods have poor resource efficiency and environmental sustainability. The complex issues surrounding e-waste management highlight the urgent need for more advanced strategies that incorporate the ideas of sustainability and equitable resource allocation.

Sustainable Future with Biodegradable Electronics

The development of biodegradable electronics offers a promising remedy for reducing the buildup of electronic waste caused by the growing use of electronic devices[8]. Electronics manufacturing can perhaps be revolutionized by using biodegradable materials such as bioplastics and biodegradable semiconductors to create environment friendly products that naturally decompose in the environment. The long-term environmental impact of electronic devices could be significantly reduced by the use of biodegradable electronics. Research is currently being carried out to ensure that biodegradable objects function as intended for the duration of their useful lives and that they degrade steadily after disposal without harming the environment. In this context, the in-depth materials research, interactions with biological solutions, and efficient encapsulation techniques is highly significant[9].

E-Waste Recycling with Renewable Materials

Innovative approaches are urgently needed due to the global rise in the generation of e-waste, which has been fueled by the explosive growth of the electronics industry. This industry which manufactures a wide range of devices such as televisions, computers, mobile phones, video games, and iPods has quickly grown to become the largest and fastest-growing sector in the world, fundamentally altering how people live today. However, the exponential increase in the consumption of electronics has sparked a complex problem: how to manage e-waste or end of life products effectively.

In developing countries, the problem of e-waste is made worse by the influx of used electronics from developed nations. The accumulation of e-waste in less developed regions is increased greatly by the importation of out-of-date, environmentally harmful equipment from wealthy regions. Due to the lack of protection and enforcement of importation, the environment and human health are severely threatened. Studies of the release of dangerous substances into the ecosystem demonstrate the toxic impact of e-waste. The complexity of this challenge underscores the necessity for a comprehensive global approach to e-waste management.

Conclusion

E-waste management is an urgent global challenge that requires coordinated efforts from governments, industry, and consumers. Although significant strides have been made in formalizing e-waste recycling practices and improving recycling technologies, much remains to be done to mitigate the environmental and health risks posed by improper e-waste disposal. Effective policies, coupled with consumer awareness and the development of safer recycling technologies, are essential for reducing the adverse impacts of e-waste. As the global e-waste crisis continues to grow, a sustainable approach to electronic waste disposal will be crucial in minimizing its long-term health and environmental impact. We can lessen the environmental impact of electronic gadgets and preserve natural resources by reducing e-waste. The present paper provides blueprint for a balanced approach to e-waste management by adopting sustainable approach including renewable and biodegradable technologies in order to secure sustainable future.

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