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Digital Solutions for Sustainable E-Waste Management

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[1] ***Abstract*—: E-waste or electronic trash is one of the most difficult and rapidly expanding issues. E-waste is made up of old or end-of-life electronic appliances such as computers, laptops, televisions, freezers, and other items that are discarded by their owners when broken or of no use. It contains a number of hazardous constituents that have a negative impact on the environment and human health if not properly managed. Some studies show that the illegal import and export of e-waste is done as per the estimates of the Directorate General of Foreign Trade, illegal import of e-waste in the country stands at about 50,000 tons annually. This paper presents an overview of e-waste and its potential impacts on health and environment together with management strategies used in certain countries, and discusses the adoption of digital innovations are essential for achieving sustainable, efficient and environmentally responsible e-waste management worldwide. Digital technologies improve e-waste tracking, reuse, recycling techniques, processing, and promoting circular economy goals and ensuring better health and a cleaner environment.**

***Index Terms*—E-waste or electronic waste, Environmental impact, Health risk, Management strategies, Recycling techniques, Digital solutions.**

I. INTRODUCTION

When an electronic product is thrown away after its useful life is over, it produces electronic trash, or e-waste. The growing consumption of electronic goods due to the Digital Revolution and innovations in science and technology, such as bitcoin, has led to a global e-waste problem and hazard. And the processes of dismantling and disposing of electronic waste in developing countries led to a number of environmental impacts. Liquid and atmospheric releases end up in water bodies, soil, groundwater and air and therefore in land and sea animals.

The Department of Industrial Research, which studied the status and potential for e-waste in India in February 2009, said a symbiotic relationship between the formal and the informal sector were crucial. “The informal sector’s role in collection, segregation and dismantling e-waste needs to be nurtured to complement the formal recyclers as supply chain partners. They should take on the higher technology recycling processes.

A. E-waste Source

The composition of e-waste differs from product to product. Broadly it consists of a diverse range of materials which includes ferrous and nonferrous, metals, plastics, glass, wood and plywood, printed circuit board, rubber, ceramics and other items. Iron and steel constitute 50% of the e-waste, plastics 21%, nonferrous metals 13%, and the rest other constituents. Nonferrous metals consist of metals such as copper, aluminum and precious metals such as gold, silver, platinum, palladium, etc. The presence of elements such as lead, mercury, arsenic, cadmium, selenium, hexavalent chromium and flame retardants beyond the threshold limit in e-waste classifies them as hazardous waste.

Constituents	Content (% wt/wt)	References
Metals	28.00 - 60.60	Widmer et al. 2005; Zhou et al. 2009
Iron and steel	8.00 - 50.00	Ilyas et al. 2010; Pant et al. 2012
Non ferrous:	1.00 - 13.00	Pant et al. 2012; Widmer et al. 2005
Aluminium	0.75 - 4.70	Ilyas et al. 2010; Widmer et al. 2005
Copper	13.00 - 34.49	Tuncuk et al. 2012; Yamane et al. 2011
Nickel	0.0024 - 2.63	Yamane et al. 2011;Yang et al. 2009
Zinc	0.16 - 8.20	Ilyas et al. 2010; Zhang and Forssberg 1997
Lead	0.99 - 4.19	Iji and Yokoyama 1997
Gold	0.008 - 0.10	Sum 2005; Guo et al. 2009
Silver	0.20 - 0.33	Sum 2005; Guo et al. 2009
Plastics	20.60 - 23.00	Widmer et al. 2005; Zhou et al. 2009
Flame retardant	5.30	Widmer et al. 2005
Non flame retardant	15.30	Widmer et al. 2005
Glass and Ceramic	2.00 - 33.00	Widmer et al. 2005; Yuan et al. 2007
Wood and plywood	2.60	Widmer et al. 2005
Rubber	0.90	Widmer et al. 2005
Others	4.60 - 16.00	Pant et al. 2012; Widmer et al. 2005

Nearly 28% metals are abundant non-ferrous metals such as Cu, Pb, Zn, Ni, Sn, etc., while precious metals like Au, Ag, Pd and Pt are 10 times higher than that of mineral ores deposits, are generally present in waste PCBs (Huang et al. 2009; Li et al. 2007; Yang et al. 2009). High concentration of substances such as polyhalogenated organics, polychlorinated biphenyls, BFRs, heavy metals present in e-waste may contaminate the environment with their bioaccumulation in organisms and biomagnifications in food chain and thereby pose serious risks to humans and the environment unless properly managed (Barontini and Cozzani 2006; Deng et al. 2007; Ni et al.

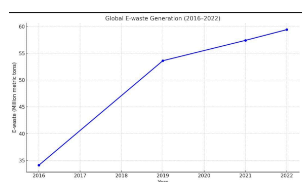
Fig. 1.1 Composition Of E-waste

B. Global E-waste Production

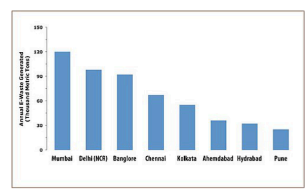
A UN report estimates that the worldwide generation of e-waste is around 30–50 million ton/annum. Nearly 50–80 percent of e-wastes collected are exported for recycling E-waste recycling and disposal in China, India and Pakistan are highly polluting due to the release of toxic chemicals. The lack of responsibility on the part of federal government and electronics industry, consumers, recyclers and local governments toward viable and sustainable options for disposal of e-wastes.

One study of environment effects in Guiyu, China found the following:

Airborne dioxins – one type found at 100 times levels previously measured Levels of carcinogens in duck ponds and rice paddies exceeded international standards for agricultural areas and cadmium, copper, nickel, and lead levels in rice paddies were above international standards, Heavy metals found in road dust – lead over 300 times that of a control village’s road dust and copper over 100 times. India saw the highest 163 per cent growth globally in generating electronic waste from screens, computers, and small IT and telecommunication equipment (SCSIT) between 2010 and 2022, according to a United Nations Trade and Development (UNCTAD) report. Annually, computer devices account for nearly 70 percent of e-waste, 12 percent comes from the telecommunication sector, 8 percent from medical equipment and 7 percent from electric equipment. The government, public sector companies, and private sector companies generate nearly 75 percent of electronic waste, with the contribution of individual households being only 16 percent



(a) Global



(b) India

Fig. 1.2 E-waste Production

II. PROBLEM OF E-WASTE MANAGEMENT

While e-waste recycling is a source of income for many people in India, it also poses numerous health and environmental risks. More than 95 percent of India’s e-waste is illegally recycled by informal waste pickers called kabadiwalas or rad-diwalas (scrap traders). These workers operate independently, outside of any formal organization which makes enforcing e-waste regulations difficult-to-impossible. Recyclers often rely on rudimentary recycling techniques that can release toxic pollutants into the surrounding area.

Residents living around the e-waste recycling sites, even if they do not involve in e-waste recycling activities, can also face the environmental exposure due to the food, water, and environmental contamination caused by e-waste, because they can easily contact to e-waste contaminated air, water, soil, dust, and food sources. In general, there are three main exposure pathways: inhalation, ingestion, and dermal contact.

The primitive methods used by unregulated backyard operators (e.g., the informal sector) reclaim, reprocess, and recycle e-waste materials expose the workers to a number of toxic substances. Processes such as dismantling components, wet chemical processing, and incineration are used and result in direct exposure and inhalation of harmful chemicals. Safety equipment such as gloves, face masks, and ventilation fans are virtually unknown, and workers often have little idea of what they are handling.

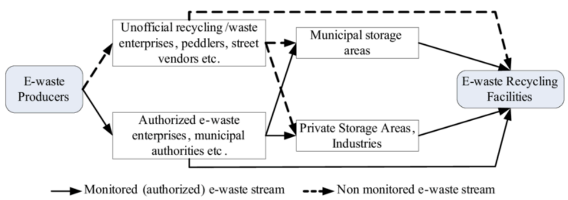


Fig. 2 E-WASTE PRODUCER AND FACILITATOR

III. OBJECTIVE AND SCOPE

Recycling can greatly reduce the leakage of toxic materials into the environment and militate against the exhaustion of natural resources. However, it needs to be encouraged by local authorities and through community education. For that we are trying to use digital management by creating a platform and teach them e waste recycling techniques and locations where formal and legal disposal of e waste will be done.

Improper management of e-waste is resulting in a significant loss of scarce and valuable raw materials, such as gold, platinum, cobalt and rare earth elements. As much as 7 percent of the world's gold may currently be contained in e-waste, with 100 times more gold in a ton of e-waste than in a ton of gold ore.

The primary aim of this project is to design and implement a practical digital system that supports individuals and communities in the responsible management of electronic waste. The project seeks to simplify the process of identifying e-waste, guide users on proper disposal methods, and connect them with authorized collection centers. By promoting correct recycling habits through a user-friendly platform, the project strives to minimize the environmental and health risks associated with informal e-waste handling.
This initiative covers the development of an interactive web-based dashboard accessible to the general public. The solution will provide educational resources on e-waste hazards, a searchable map of verification.

FIG. 3 FUTURE SCOPE

IV. GLOBAL SCENARIO OF E-WASTE MANAGEMENT

Internationally, to control E-waste management, several laws and legal frameworks have been enacted. Many nations have enacted their own legislation to limit and regulate the dangers of E-waste, such as:

In China, the Administration of Control of Pollution Caused by Electronic Information Products, which was founded in February 2006, regulates total E-waste.
In the United Kingdom, waste electrical and electronic equipment is governed by UK legislation, which was formed in 2007 after being enacted by parliament.

In 1992, the treaty was ratified by a total of 179 nations (Aston et al., 2010). After following years of discussion, the European Union proposed a new global initiative in 2016 to regulate hazardous waste imports by putting them into three categories: prohibitive, notification controlled and green listed. All hazardous wastes were banned from entering African countries after being suggested in 1991 and becoming law in 1998 (Thakur et al., 2020).

India has been the first country in South Asia to have a special E-waste law in place since 2011. The E-Waste Handling Rules created criteria for garbage transportation, storage, and recycling, as well as the concept of extended producer responsibility (EPR).

In 2016, the regulations were updated to establish a 'Producer Responsibility Organization' (PRO) to help with electronic trash collection and recycling. One option for addressing the E-waste problem is to improve regulation and implementation.

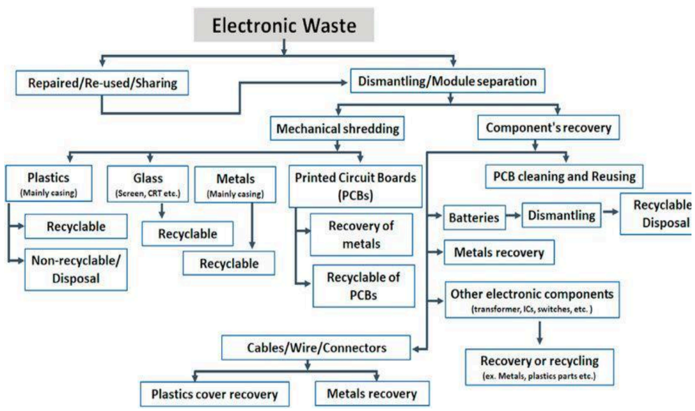


Fig. 4 E-WASTE MANAGEMENT

Fig. 5 Workflow

V. SOLUTION AND WORKFLOW

The U.S. Environmental Protection Agency encourages electronic recyclers to become certified by demonstrating to an accredited, independent third-party auditor that they meet specific standards to safely recycle and manage electronics.
Two certifications for electronic recyclers currently exist and are endorsed by the EPA.

The two EPA-endorsed certification programs are Responsible Recyclers Practices (R2) and E-Stewards.
And we are trying to create a platform in which we will use techniques such as awareness and education, guided disposable steps, collection center locator, user incentive and tracking and Support for Informal Sector Transition.
With our digital solution key features include e waste identification, educational resources, collection locators, guided disposal process, rewards and user satisfaction.
The workflow would appear as follows, first there would be user login and authentication after which they can select whether the waste needs to be disposed or recycled. We would then provide information regarding the carbon emission account to the item and provide location to the recyclers for proper disposal of the waste. If the waste could be recycled, step by step recycling procedure would be provided for it and according to the amount of waste recycled, and its contribution in environment protection rewards in the form of credits or badges would be given.

VI. RESULT AND BENEFITS

Recycling options for managing plastics from end-of-life electronics are of three types.

Chemical recycling

Mechanical recycling

Thermal recycling

Any recycling process involves dismantling, that is, removal of different parts of e-waste containing dangerous substances such as PCB, Hg, separation of plastic, removal of cathode ray tube (CRT), segregation of ferrous and nonferrous metals and printed circuit boards. with help of platform you know if recycling is dangerous or not and how to do it safely We are creating a user centered design so that there will be user interaction and educational support as we are using ai chatbot you can ask any question and interact while as expansion of these project we try to add a learn and teach option in which you can teach what you know of disposal techniques and earn badge when someone watch that video and with that badge you can learn watching someone's video so learn and teach method and with mapping integration user can know disposal area you can also report an issue of someone doing illegal recycling or dumping areas then with client data storage you get rewards.

VII. CONCLUSION

As consumers, we can extend the life of our electronic devices by repairing and recycling them whenever possible. Producers should prioritize designing products for durability, ease of repair, and recyclability. Several initiatives exist where producers collect discarded electronic equipment and reuse the materials.

According to the most recent studies, the informal sector handles the great majority of E-waste, endangering the environment and human health, especially in developing nations. Despite the passage of legislation governing E-waste management and disposal, several developing countries, such as India, have failed to implement effective formal recycling systems. So, by this platform we are aiming to change these by help of digital solution we can improve efficiency, accessibility, user motivation and adoption of this platform can reduce illegal dumping, toxic exposure and informal recycling lower the health risk and empowering the environment.

E-waste is a serious problem at both local and global scales. E-waste problems appeared initially in developed countries and now extend widely to other countries around the world.

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