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Digital Waste Recycling Applications

Kemal Yaman[*1]

[1]*Karabük University, Faculty of Economics and Administrative Sciences, Türkiye*

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ABSTRACT
This study aims to reveal the current situation of digital waste policies and practices at national and international levels by using recycled digital waste data. The study used the literature review technique as a research method. In addition, recommendations and suggestions that will raise awareness about the recycling of digital waste have been developed. Today, with the rapid development of technology, the lifespan of digital devices has shortened and the amount of digital waste has increased significantly. The disuse of computers, mobile phones, televisions and other digital devices leads to serious environmental and health problems. Since digital waste contains heavy metals and toxic chemicals, it causes soil and water pollution when released into nature in an uncontrolled manner. In addition, the burning of these wastes threatens human health by releasing harmful gases into the air. Inadequate or incorrect implementation of recycling processes can harm both the environment and recycling workers. Sustainable recycling systems should be developed to minimize the environmental impacts of e-waste. Recycling of used digital products contributes to the protection of natural resources by reducing the amount of waste. In addition, it is of great importance for manufacturers to develop policies that encourage recycling and for consumers to be aware. Some of the findings obtained as a result of the research are as follows. According to 2023 data, 50 million tons of digital waste is produced annually worldwide, 10 in China, 7 in the USA, 3 million tons in India and 847 thousand tons in Turkey.

1. INTRODUCTION

Digital waste refers to electrical and electronic devices that have reached the end of their useful life or have become idle. The rapid development of technology increases individual and institutional consumption, and this shows that the amount of e-waste has increased dramatically. If these wastes are not recycled in accordance with laws and regulations, they cause serious ecological and health problems. This study examines the environmental impacts of digital waste, addresses current management strategies, and offers solutions to make the process more sustainable.

The electrical and electronics industry is the world's largest and fastest-growing manufacturing industry, and as a result of this growth and due to rapid obsolescence or obsolescence, old and scrap electronic devices (digital waste) are the most serious solid waste problem in the world. It is stated that e-waste contains more than 1000 substances. However, to date, the industry, states, and consumers have not taken major steps to solve this growing problem in the world.

When this assessment is considered in terms of Turkey, it is understood that consumers' knowledge and awareness levels regarding e-waste recycling are limited and that facilities that can perform e-waste recycling are not sufficient.

2. MATERIALS AND METHODS

In this study, document analysis method was used. Document analysis method is seen as a comparative, observational and advantageous method in terms of addressing many criteria. Information about digital waste practices in the countries and regions examined was provided by using sources such as books and book chapters, articles, thesis and other internet databases.

3. DIGITAL WASTE

3.1. What is digital waste?

*Corresponding author
*e-mail: kyaman@karabuk.edu.tr
ORCID ID: 0000-0001-9844-4264

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In short, it is necessary to explain what types of waste materials are covered by the concept of digital waste, which we define as e-waste. Although there is no generally accepted definition on this subject, it would be more appropriate to include some widely used and adopted definitions. According to the Global E-Waste Monitoring Center 2024 report, e-waste is "all products that have circuits or electrical components and a power or battery source" [1].

The United States Environmental Protection Agency (USEPA) defines digital waste as "any electronic device that has reached the end of its useful life and is no longer used for its original purpose." [2,3]. According to another definition digital waste is described as "e-waste does not only include information and communication devices, but also all kinds of electronic devices in the home are classified as e-waste. In other words, small and large household appliances, computer hardware, telephones, headphones, etc. are also examined within this scope [3,4]. Some other definitions are as follows:

Alieva [5], defined digital waste as signifying the existence of superfluous or unessential information gathered, organized, conveyed, or retained without any discernible tactical or strategic rationale.

According to the provisions of the "Waste Electrical and Electronic Equipment Management Regulation" published in the Turkish Official Gazette dated 26.12.2022, digital waste is defined as "electrical and electronic devices and all their components, elements and consumables that meet the definition of waste in the Waste Management Regulation" [6].

In this case, digital waste should include not only digital waste but also electrical waste and their components. All components of all devices and consumables included in this definition should also be evaluated within this scope. However, it is also necessary to define what is not digital waste. According to [1] batteries and similar electrical Storage devices, electrical and electronic devices used in the automotive sector, audio and entertainment systems, satellite navigation units installed in cars, boats or aircraft, electronic devices used for military purposes, and electronic devices used in satellites are not considered within the scope of e-waste.

3.2. Environmental and Health Problems Caused by Digital Waste

Since e-waste contains more than 1000 substances, most of which are toxic [7], if it is not recycled within the framework of the relevant regulations and mixes with other wastes into the soil and water, it causes the poisoning of the soil and water resources and the deterioration of the ecosystem. E-waste that cannot be recycled has a direct impact on the environment and human health. Currently, 58 thousand kg of mercury and 45 million kg of plastic are released into the environment every year as a result of e-waste not being recycled in accordance with the regulations [1]. In addition, different minerals, especially gold, are used in the production of these electrical and electronic devices. In the production phase of these minerals, it is necessary to carry out very large amounts of excavation work compared to the raw materials obtained. For example, 3 million kg of rock must be excavated to obtain 1 kg of gold. If e-waste is disposed of without taking the necessary safety precautions, it poses serious environmental risks primarily to those who process the waste, to natural resources as a result of mixing with the soil and groundwater in the disposal environment, and to harmful gases emitted after the incineration of the waste [7].

3.3. Digital waste recycling applications

The effective management of digital waste (d-waste) is supported by various projects and applications in Europe, Africa, Japan, South Korea, Taiwan, USA and other regions are currently working with e-waste management systems to handle this type of waste stream [8]. Below are some of the important initiatives and applications carried out in some countries:

3.3.1. Europe

Kahhat et. al, [8], reported that the 25 EU Member States have been adopted community level regulations related to digital waste, which are intended to preserve, protect and improve the quality of the environment, protect human health.

Moreover, Switzerland has been successfully handling digital waste. Switzerland, for example, has two different digital waste systems. One is Swiss Association for Information, Communication and Organization Technology and Swiss Foundation for Waste Management (SENS) for household appliances. Some of the projects implemented regarding digital waste in Europa are given below.

WEEEWaste Project (Interreg Europe): The WEEEWaste project is an initiative that aims to improve the management of e-waste in 10 different regions in Europe. The countries participating in the project include the Czech Republic, Romania, Spain, Italy, Germany, Poland,

Slovenia, the Netherlands and Albania [9]. In the United Kingdom, Gabriel Kay from De Montfort University has designed a kettle that users can easily repair. This application offers a creative solution to reduce e-waste [10]. In addition, the UK government is planning to introduce regulations that will make it mandatory for online marketplaces to contribute to recycling processes [11]. Similarly, Sweden has integrated digital tracking systems in its recycling centers to monitor e-waste flow and improve resource recovery.

3.3.2. Africa

E-Waste Recycling Pilot Projects in South Africa, These pilot projects in the Mpumalanga region of South Africa are raising awareness among local people about collecting and recycling e-waste [12]. As part of the E-Waste Management Strategies in East Africa, Rwanda has established a strong legal framework for e-waste management and has established a 15,000-metric-ton recycling facility [13]. In South Africa, an initiative aimed at improving e-waste management and recycling processes has been implemented through the Sustainable Recycling Industries Program (SRI) [14].

3.3.3.USA

Currently, in the U.S. digital waste debate focuses on two main points. One is U.S. e-waste disposal in U.S. landfills and the second is U.S. e-waste exportation [9].

In the US there is not yet a broad and fixed infrastructure in place. The International Association of Electronics Recyclers (IAER) estimated that in 2003 the U.S. electronics recycling industry consisted of just over 7000 employees and annual revenue of over US$ 700 million [15].

On the other hand, a private company called Elo has launched a program that aims to recycle or reuse all digital waste collected in 18 states of the USA in accordance with federal and state laws. For this purpose, this company has started a take-back program for digital waste.

One of the most successful digital waste management applications in the USA was implemented in the state of Maine. In the first 3 years of this program, 6,406 million kg of household digital waste was collected and recycled [16].

Lilly researched the digital waste strategies of 16 American cities in 2023 and found that:

- 8 city strategies mentioned Device Renewal
- All 16 cities understood device usage and access to reliable/affordable devices
- 13 cities had Libraries providing computers and devices for community use
- 8 city strategies mentioned Device Redistribution, whereas
- 8 Other city strategies mentioned hardware repairs.

Only 2 cities mentioned E-waste management in their digital inclusion strategies [17].

4. CONCLUSION

Digital waste has become one of the fastest-growing environmental problems worldwide, and the findings of this study clearly highlight the urgent need for more effective management strategies. Although many countries have taken important steps toward recycling and regulation, the global recycling rate remains low, and the situation in Türkiye shows significant role for improvement. Strengthening public awareness, increasing the number of licensed recycling facilities, and encouraging producers to take greater responsibility are essential steps for minimizing the environmental and health risks of e-waste. A sustainable and coordinated approach at national and international levels is crucial for protecting natural resources and ensuring a healthier future for coming generations.

When the research results were summarized, the following data were obtained. According to the Global E-Waste Monitoring report, 62 billion kg of e-waste was produced in the world in 2022, with an average of 7.8 kg of e-waste produced per person. Only 22.3% of the e-waste produced is properly collected and recycled [1]. The annex of the "Management of Waste Electrical and Electronic Equipment" regulation, which entered into force in Turkey in 2022, lists in detail which wastes are considered e-waste [6]. In addition, according to the most up-to-date data from the Ministry of Environment, Urbanization and Climate Change, 23,365 tons of e-waste were collected in 2018. According to the Turkish Electronics Industrialists Association, approximately 1 million tons of e-waste is produced annually in Turkey [18]. In this case, only 2.5% of the e-waste produced in Turkey is recycled. This situation is understood to be a serious problem in terms of both the environmental risks it causes in terms of the toxic substances it contains and the environmental risks caused by the production processes of the metals used in the production of these wastes. In order to prevent this problem, first of all, consumers should be educated and

made aware, and licensed institutions and producer-importer-marketing companies should be ensured to take a more serious initiative in the recycling of e-waste.

Conflict of Interest

The author declares that there is no conflict of interest. In addition, no financial support was received.

Authors' Contributions

Study Design: KY; Data Collection: KY; Data Interpretation: KY; Manuscript Preparation: KY; Literature Review: KY Authors has read and approved the published version of the manuscript.

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