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Review Article

Evaluation of E-Waste Management and Challenges in Middle Eastern Countries

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Abstract

Middle Eastern countries are among the significant contributors to e-waste generation with challenges in handling, controlling, transporting and managing e-waste to avoid or handle its environmental and health consequences. Asia contributes 24.9 million tons (5.6 kg per capita) of e-waste generation and only 11.7% of e-waste is documented to be recycled. Middle Eastern countries contribute 2.6 million tons of e-waste (9.6 kg per capita) with only 5% of e-waste documented to be recycled. Thus, the study is carried out to revise the e-waste generated quantity, explore domestic or international legislative cooperation and understand the current document e-waste management system. The study is a review study in which data was collected exclusively from scholarly work (published) in the last 5 years. The study shows a lack of available and reliable data sources regarding e-waste generation in most countries of the Middle East. Even this, there is raising awareness of e-waste management significance among gulf-countries, but the dominant handling process of e-waste was a landfill, with small informal initiatives of recycling in minor countries. The UAE is the only country among the Middle Eastern countries that has recently participated in the Waste Electrical and Electronic Equipment (WEEE) collecting and e-waste recycling initiatives and held the largest center of WEEE management in the Middle East and has been operating since 2018. The study cited recommendations for drawing a legislation framework for e-waste management, carrying out reliable data resources for e-waste, designing and performing social awareness campaigns to increase community e-waste awareness and carrying out pilot projects for a sustainable e-waste management system.

Key words: E-waste, e-waste legislation, e-waste management, Middle Eastern countries, quantifying e-waste

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INTRODUCTION

Along with the known technology revolution, the massive production of electronic and electrical devices has increased with a huge corresponding volume of electronic waste (e-waste)¹⁻³. The e-waste is a phrase that involves all consumed electrical and electronic equipment that was discarded not for recycling, it includes numerous types of electrical and electronic devices such as computers, telephones, radios, printers, fridges, wash-machine, portable devices and any electronic devices⁴⁻⁶. A recent report on e-waste generated estimated the global e-waste per capita by 2030 to 9 kg per capita corresponding to 74.7 million tons. In the Asia region, even 11.7% of e-waste was properly recycled and processed in 2019, this recycling rate is the second-highest rate after the European recycling rate, but East Asian countries are the most responsible for increasing recycling rate with less than 1% contribution of this recycling is attributed to Middle East countries or Gulf Countries^{7,8}.

Managing e-waste has become a paramount issue internationally and locally, particularly from the health and environmental perceptions. Developing countries, such as the majority of Middle East countries, have not segregated e-waste from the regular waste types yet. Furthermore, officials and regulators lack e-waste reusing processes in the worst case, there are no regulations or facilities for e-waste in most countries, such as Oman and Qatar². Accordingly, scarce and absence of adequate e-waste management pose health threats to humans and the environment due to the chemical and organic pollutants, including toxic releases, to which humans can be exposed through thermal exposure, dust inhalation, inhalation, dermal contact and dietary intake (Ingestion)^{9,10} because e-waste consists of various physical and chemical materials. These materials are classified as hazardous substances. It thus requires an adequate and convenient recycling approach to avoid and reduce the hazardous effects on humans and the environment^{3,11,12}. In this vein, the study intends to evaluate the quantity of e-waste generated in Middle East countries and explore proposed management practices dealing with e-waste innovatively.

STUDY OBJECTIVES

The study aims to:

- Identify and estimate the amount of e-waste generated in Middle Eastern countries
- Explore e-waste regulation standards and management in Middle East countries

- Estimate the number of materials that can be recycled from e-waste in Middle East countries
- Revise innovation and alternative solutions that scholars proposed in the context of e-waste management in Middle East countries

The study contributes to explaining and estimating the e-waste issue in Middle Eastern countries by exploring the last five years of studies and scholarly works on managing e-waste, limitations and policy gaps and strengths. The significance of managing e-waste adequately has a direct impact on the surrounding health and threats. Furthermore, the significance of recycling or managing e-waste presented on the green gold, which is the potential economic gains of recycling estimated at 1.5 billion dollars annually as disclosed by the International Association of Electronics Recyclers (IAER)^{5,2,13}. The e-waste recycling can produce various paramount quantities of valuable materials such as palladium, copper, iron, gold, aluminum, platinum and silver, which can perform as an alternative resource of income. Despite the role of e-waste recycling industries that contributes to reducing environmental hazards and solving employment challenges¹⁴⁻¹⁷.

E-WASTE IN MIDDLE EAST COUNTRIES

In the last decade, the Gulf nations of the Middle East and North Africa (MENA) region significantly contributes to e-waste generation with an estimated 2.9 Mt of e-waste annually. Saudi Arabia alone is responsible for 0.9 Mt of this quantity attributed to the inappropriate and poor initiatives to handle the resulting e-waste¹⁸⁻²⁰.

According to Alghazo *et al.*², a total amount of 642 thousand tons was generated in 2014 from the Gulf Cooperation Council Countries (GCC), with an expected 120 million tons of e-waste generated in 2020 by the same countries. The United Arab Emirates annually engenders 17.2 kg of e-waste per capita, which corresponds to the highest contributors of e-waste generated among Middle Eastern countries⁵. Similarly, Kuwait is considered the biggest producer of e-waste per capita compared to the Middle Eastern countries and GCC countries since it produces 17.2 kg per capita of e-waste is equivalent to 69 thousand tons annually^{2,8}. Even though Saudi Arabia has a lower production of e-waste per capita (12.5 kg), it exceptionally contributes to generating 378 thousand tons annually⁴. In the same year, Qatar generated 16.3 kg of e-waste per capita equivalent to 32 thousand Mt per capita annually⁸. Compared to 12.9 and 14 kg of e-waste per capita in Bahrain and Oman, respectively, corresponding to 15 and 69 thousand tons annually².

In a survey of e-waste generation in Jordan, the estimated generation of e-waste was 13 thousand tons in 2018⁹. An international report disclosed a 278 kt of e-waste per capita generated in Iraq per year¹⁰. In 2014, Iraq had an estimated 3.1 kg per capita of e-waste generation with a total of 112 kt per year¹¹.

E-WASTE REGULATION AND MANAGEMENT IN MIDDLE EASTERN COUNTRIES

Gulf Council countries lack regulation or compulsory legislation to foster e-waste management practices and poor municipal e-waste management systems^{2,8,21}. For example, Kingdom of Saudi Arabia (KSA) recycles 10-15% of waste through informal private and non-profit companies or parties that reuse plastics, metals and paper extracted from municipal waste. The KSA disclosed a collaborative deal with a foreign company for recycling e-waste in 2012^{4,8,22,23}. However, many recycling activities in Bahrain involve collecting plastic, metal and paper through two private collection parties counting recycling support provided by a German company and the "Mother and Child" Welfare Society. Thus, recycling is considered a small sector in Bahrain and e-waste management practices are evaluated at an intermediate stage of modernization⁸. In terms of national legislation, Qatar is one of the foremost Middle Eastern countries that constituted a recycling law for mobile phones, started in 2009 and was compelled in 2010. The law concerns collecting and transiting mobile phone waste to Singapore for recycling purposes. In contrast, Saudi Arabia does not have any regulation system^{4,8,24}.

United Arab Emirates (UAE) classified e-waste in a technical guideline of the Center of Waste Management "Tadweer" in Abu Dhabi. The UAE also serves adequate disposal facilities for e-waste as a step toward the high responsible practice of throwing potentially hazardous products such as household waste². According to Kaddoura¹², Shahabuddin *et al.*²⁵ and Dzah *et al.*²⁶, Federal Law 24 of 1999 constitutes the basis of environmental protection and conservation. Furthermore, there are penalties on polluters to be more responsible for their illegal actions toward the environment, as well as there is support for recycling and waste reforms in the country established the Ministry of Environment and Water. The UAE recently engaged in the Waste Electrical and Electronic Equipment (WEEE) collecting and e-waste recycling initiatives exhibiting by increased equipment of e-waste management facilities and held the largest center of WEEE management in the Middle East have been operated since 2018⁸. The UAE exploited a specific-purpose facility in Dubai industrial park for collecting

and recycling e-waste with a 100 kt capacity per year¹⁰. Unfortunately, Kuwait does not include e-waste management in their comprehensive government strategy established in 2005 for the ten forthcoming years. Despite this, Kuwait is one of the biggest per capita producers of e-waste compared to GCC countries⁸. Oman, like many of the Gulf countries, does not engage in any recycling activities or legislation. The e-waste in Oman is discarded with solid waste management in either dumpsites or landfills. In terms of Yemen, until now, there is no reliable data on e-waste assessment. It may be attributed to the political status of the country^{13,27}.

In Jordan, 63.8% of e-waste was discarded with the municipal solid waste, 11.5% was granted to others, 11.4% was resold and only 6.9% was delivered to recycling, which recycling is most popular in Ma'an (3.7%), Jerash (1.5%) and Ajloun (1.4%)⁹. There are three known practices of e-waste management: Informal collection, informal recycling and landfilling. The landfills are used for disposing of hazardous materials with only one sound manufactured landfill that receives 35% of national waste. While recycled products are exported to Asian countries under the process of informal recycling. There are no formal recycling facilities in Jordan for e-waste. A pilot project conducted in Jordan for recycling mobile phones opens a promising opportunity^{14,28}. Unfortunately, there is no official and confirmed quantity of e-waste developed, stored, landfilled or recycled in the country. Jordanian government established fundamental legislation of waste management in general, but until now there is no e-waste particular legislation and technical guidance, which has not come into force yet. Furthermore, there is poor capacity, quality and infrastructure for e-waste management⁹.

In Palestine, e-waste is dumped and discarded in the three main landfills, in which e-waste was illegally imported from these regions without any adequate recycling procedure¹⁰. In Palestine, the e-waste generated was recycled and reused by informal sectors that perform domestic import hubs, in which these hubs import and process a quantity of 16-25 thousand tons per year (200-500 ton per day), gaining 25.5US\$ million and granted 1098 jobs. Hence, processing e-waste generated from Israel-occupied regions was the main informal economic activity in the West Bank, Palestine¹⁵.

Likewise, Lebanon dumped e-waste in landfills, which informal parties exported as scrap. Only a small percentage of this e-waste is formally disassembled and exported for recycling purposes. The biggest recycling challenge faced by Lebanon is the unbearable cost of recycling operations such as energy costs despite the potential threats of e-waste and its complexity¹⁰. Even this, the Iraqi Government Constituted

Table 1: Recent studies examined E-waste generation and management

Aim	Location of the study	Years	Total e-waste	E-waste management practices	E-waste regulation	Proposed suggestion	Study
Quantify and evaluate the annual e-waste generation in all governorates in Jordan and disposal practices	Jordan	2018	13 thousand tons	6.8% of e-waste is delivered for recycling by informal parties, 63.8% of e-waste dumped is discarded, 11% is granted for others and 10% resold	There is no particular regulation for e-waste	E-waste management system assigns Responsibility for the costs among producers, distributors and retailers. There is a need for practical regulatory guidance on the implementation of segregation, collection and processing of this waste stream There is a need for a social program to increase public awareness of citizenship	Hamdan and Saidan ⁹
Examines the determinants of e-waste recycling intention among young consumers in an emerging economy context by integrating habits into a prominent model that predicts people's behavior, namely, the theory of planned behavior	UAE	2019	17.2 kg per capita	-	There is a need to federal legislation of e-waste in UAE	Improving consumers' behaviors toward e-waste recycling, social rewards program and assign legislation penalties	Mahmoud <i>et al.</i> ⁵
Provide a methodological model for robust and systematic quantification	Palestine	2019	-	16-25 thousand tons processed per year informally	No regulation	/	Davis and Garb ¹⁵
Investigate the magnitude of the e-waste and the scale of the impact to the environment and health	Iraq	2019	3.1 kg per capita	There is no recycling initiative E-waste	No legislation	Increasing citizen's awareness is a first step, followed by afford suitable e-waste facilities for collection or recycling	Dawood ¹¹
Compare three international models of e-waste management to attempt to explore best management practices can be adopted in the Kingdom of Saudi Arabia	KSA	2019	378,000 tons annually	Recycling rate (10-15%), but is inadequate and managed by non-profit, private and informal parties Very low public awareness about e-waste recycling	No clear regulations on e-waste management in Saudi Arabia	Developing a sound regulatory framework to sustainably manage e-waste coupled with programs to increase consumer awareness of the importance of e-waste Proposed system is a shared responsible between manufacturers and consumers, the system has-to cover all electrical product categories, supported by a legislation declaration and ban landfill disposal of e-waste	Filimban <i>et al.</i> ⁴

Table 1: Continue

Aim	Location of the study	Years	Total e-waste	E-waste management practices	E-waste regulation	Proposed suggestion	Study
Revise the global scenario of Waste Electrical and Electronic Equipment management (WEEE)	GCC	2014	64,000 Mt	The UAE held the largest center of WEEE management. Bahrain has two private collection parties counting recycling supports provided by a German company and the "Mother and Child" Welfare Society KSA recycles 10-15% of waste through informal private parties	A poor specific law and absence of e-waste policies in KSA, Bahrain and Kuwait A promising regulation developing in UAE and Qatar	/	Mihai <i>et al.</i> ⁸
Reviews the current e-waste management practices in GCC countries including e-waste generated volume, disposal and reuse/recycle practices, forecasts e-waste production up to the year 2040 and discusses the long-term potential economic, security and environmental impact of e-waste in the GCC region	GCC	2014	642 thousand tons	Basal convention for hazardous waste management	Inadequate	/	Alghazo <i>et al.</i> ²
Valuate the environmental impacts and benefits of state-of-the-art technologies for proper e-waste handling using Jordan as a case study	Jordan	2017	/	Informal recycling practices and landfill	/	Incineration of the hazardous portion of PCBs with energy recovery is the best promising management system of e-waste accords with integrated waste management (IWM)	Ikhlaiyel ¹⁴

Legislation of Environmental Protection no. 8 in 2008, but this law has not come into force yet and there is no legislation for e-waste exclusively. Furthermore, a survey study found a weak level of awareness of e-waste risks among Iraqis¹¹.

According to the researcher's knowledge, there is no available data on Yemen and Syria for the last 5 years, which can be referred to the political status of both countries.

PROPOSED INNOVATION AND ALTERNATIVE SOLUTIONS FOR E-WASTE MANAGEMENT IN MIDDLE EASTERN COUNTRIES

Any proposed solution pertaining to an e-waste management system, should consider the community and region to accommodate with communities' awareness level and gain their trust. An international statistic showed that developing countries ranked from low-income to middle-income have 12.5 to 32.4% open dumps and 58.5 to 59% landfills for e-waste disposal¹⁴. Landfilling stationary is the worst e-waste management system regardless of e-waste materials. Thus, there is a need to innovate e-waste management systems.

A comparative study of three international models of e-waste management, namely, producer responsibility, non-producing responsibility and sharing responsibility to nominate adequate and convenient e-waste system for KSA found that sharing the responsibility of recycling e-waste between producers, collectors, recyclers and consumer is the appropriate system supported by a legislation disclosure, immediate enforcing of law, particularly, banning landfill disposal of e-waste, efficient distribution of e-waste facilities, social awareness program of the importance of e-waste and social and ethical responsibilities of citizenship toward e-waste and wide product categories coverage^{4,19}. Similar to Hamdan and Saidan⁹, who proposed a shared responsibility model of e-waste management between producers, distributors and retailers.

Ikhlayel¹⁴ proposed alternative e-waste practices using state-of-the-art technologies rather than open dumps and landfills according to Life Cycle Assessment (LCA) evaluation results considering e-waste materials, found that Incineration of the portion of hazardous waste using energy recovery is an optimal scenario of recycling cell-phone in the context of environmental health sake.

In the social initiatives, a study of consumer intention toward e-waste recycling established that the first solution toward e-waste management in UAE is enabling attitudes and habits of e-waste recycling among consumers particularly,

young through attaching e-waste recycling facilities publicity, exposure to consumers to notifications regularly on the waste packaging⁵. Similarly Nithya *et al.*²⁸, Rautela *et al.*²⁹ and Ahirwar and Tripathi³⁰, proposed a national initiative to increase public awareness of e-waste significance through collaborative activities between the Ministry of Education, municipalities and service providers.

A tabulated summary of the recent studies conducted throughout different countries in the Middle East including Jordan, UAE, Iraq, KSA and other GCC countries were shown in Table 1. The studies are targeted towards the availability of e-waste regulations including proposed suggestions for improving the e-waste management systems and are summarized accordingly. It is evident from the presented studies that the majority of Middle East countries have a profound lack of e-waste management systems. The studies mentioned in Table 1 highlighted that the majority of the constraining factors for sufficient e-waste management systems include: Low public awareness, weak regulations, inconsistent enactment, informal processing, absence of reliable data sources and poor infrastructure of collecting facilities and recycling process.

CONCLUSION AND RECOMMENDATIONS

The biggest drawback of e-waste management in Middle Eastern countries is the lack of data, leading to the failure in implementing effective recycling systems. Available data enhances the ability to estimate and quantify e-waste generation per capita per year. Unfortunately, the majority of Middle Eastern countries are still equipped with unsound e-waste management systems, while some countries have promising initiatives toward adopting efficient e-waste management systems such as UAE, KSA and Qatar. Researchers agree that there are major inhibiting factors affecting e-waste management systems in Middle East countries names, weak regulations, inconsistent enactment, informal processing, low public awareness, absence of reliable data sources and poor infrastructure of collecting facilities and recycling process. This study recommends formally quantifying the domestic e-waste magnitudes (per capita/year), allocating adequate financial resources to handle e-waste managing costs, establishing and enacting regulations, laws and policy targets with high priorities and affordable e-waste facilities. Furthermore, there is a need to establish an e-waste framework starting from collecting, transporting, recycling and disposing or exporting residues. Hence, the study suggests conducting a standardized study

plan enabling the community to attain a better awareness towards e-waste control, recycling and management. This requires cooperation between public and private sectors in countries giving opportunities for exchanging resources, infrastructure, tasks and technologies. Consequently, efficient e-waste management requires various activities and multi-level frameworks, including legislative works, social work and economic framework.

SIGNIFICANCE STATEMENT

This research highlights the lack of available and reliable data resources regarding e-waste generation and management in the Middle Eastern region. The research provides valuable insights into the needs of raise awareness toward e-waste recycling and management. The key component in reducing the impact of e-waste on human health and the surrounding environment is to enact and implement clear, applicable and enforced regulations and policy targets with high priorities. Part of this research recommendation is to formally quantify the domestic e-waste magnitudes, allocate adequate financial resources to handle e-waste management costs and affordable e-waste facilities, to create a more resilient and balanced environment.

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