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Current Status of the Electronic Waste Problem in Egypt

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KEYWORDS:
Environment, e-waste in Egypt, Electronic waste management, M SW, Solid waste.

***Abstract*—Huge amounts of e-waste is generated yearly. It contains valuable metals such as copper aluminum and nickel, and precious metals such as gold, silver palladium and indium. However, it has serious hazards impacts on health and environment. E-waste management becomes essential to recover the valuable and precious metals, and protect health and environment. Egypt is a significant market for electric and electronic products that ends as e-waste and in the top of African countries in e-waste generation.**

The amount of EEE put on Egyptian market is 1069 kt with increasing rate of 10.44%; while the generated e-waste is 586 kt in with increasing rate of 5.71%. The increase in EEE put on the market is almost 3.6 times the increase in population, while the increase e-waste generated is almost double the increase in population. In average, the e-waste generated is almost 58.7 % of the amount of EEE put on the market. The generated e-waste per capita, is 5.84 kg/capita at increasing rate of 2.66%. The e-waste generated in Egypt is about 20.1% that of the African continent, while the population in Egypt is about 8.6% of Africa.

In fact, Egypt has no serious national programs and regulations to handle e-waste properly, and e-waste activities are dominated and controlled by garbage traders and waste collectors.

I. INTRODUCTION

Globally, huge amounts of electric and electronic equipment EEE are put in the market yearly. This creates huge waste stream of EEE [Khan et al. (2020)]. E-waste is defined as any item of EEE and its parts that have been discarded by the owner as waste. Egypt is a significant market for electrical and electronic products due to its high population. Computers contribute 27% of the consumer electronics market. Mobile cells and Audio-video devices contribute 63% and 10% respectively. The market growth rate was estimated to be 13% by 2013 [NSWMP (2011)].

Abdelbasir et al. (2018) reported that Egypt is the top of African countries in e-waste generation with an amount of 0.586 million tons in 2019. Egypt lacks serious national programs and regulations to deal with e-waste effectively. E-waste activities are dominated by garbage dealers and waste collectors. This private sector handles some of the waste but concentrates mostly on circuit boards that are collected and shipped abroad [El-Nakib (2012)]. The Egyptian e-waste is informally managed and controlled by garbage traders and waste collectors. Successful e-waste management activities are market driven and self-organized. In Egypt, it has been estimated that about 20% of e-waste is locally recycled, and the rest goes directly to uncontrolled landfills, causing serious impacts on health and environment.

Proper collection and recycling e-waste in controlled ways

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and facilities results in keeping safe and clean environment, and restore economic benefits from the recovery of valuable and precious metals and creating employment opportunities [Asante et al. (2019)]. Electronic waste management in Egypt is a challenge issue. Alameer (2014) reviews the management of e-waste in the Middle East and proposed a guiding framework for the national policies in regards to this growing problem, Abdallah (2014) analyzed e-waste management practices in both high income and low income. As most of developing low income countries, Egypt does not have e-waste precise data or firm regulations to control e-waste activities. That is the major problem. Abdallah (2014) developed a roadmap for sound e-waste management in Egypt.

Egypt is a huge, significant market for consumer electronic equipment and devices [CAPMAS (2019)]. The country's share is continuously growing. The market growth rate was expected to be 13% by 2013 [Mohamed (2019)]. Soliman and Boushra (2017) estimated the e-waste generated in Cairo area, and presented the amount of each material in the collected e-waste and the method of management. The largest volume generated is the PCBs and Plastics respectively. This could suggest that recycling of these two streams are feasible industries in Egypt. However, they have stated that exportation of PCBs and lithium batteries is the most suitable due to the technology required for material recycling. Whereas local recycling for plastics, metals and glass is available. The United Nations Environmental Program, [UNDP Egypt (2015), (2016)] shows that the increase in the generation rates of e-waste in Egypt is due to the increase in household's consumption, use of computer users, television sales, and mobile phone users. Mobile cells have the highest increasing rate item of municipal solid waste (MSW) in Egypt.

Shakra and Awny (2017) studied the e-waste in information and communication technology (ICT) equipment with particular emphasize on mobile phones. The study discusses the potentials and threats of mobile waste, and the significance of different recycling phases to adopt efficient and effective mobile waste recycling system. Anjani et al. (2020) review the conflicts of e-waste operations in developing countries. They recognized shortfalls that constrain effective electronic waste management, especially in the developing countries. Ikhlayel (2018) studied integrating management of e-waste with municipal solid waste MSW. Both systems share common collection, sorting, transporting, treatment and disposal technologies. This improves handling the e-waste in developing countries.

Mohamed (2019) discussed the status of e-waste in Egypt, and developed guidelines for sustainable e-waste management. This help in establishing e-waste activities framework in Egypt, and the proper financing system. Similarly, Tarek and El-Haggar (2019) reviewed e-waste in Egypt, and proposed guidelines for the sustainable management based on the international regulations and guidelines, especially for developing countries as Egypt. In the review given by Abdelbasir et al. (2018), presented the valuable and hazards contents of different PCBs. Various recycling techniques to recover high economic value metals from e-waste are discussed. Pyro-metallurgical, hydrometallurgical, or bio-hydrometallurgical and physical separation methods are considered.

Allam and Inauen (2009) studied e-waste management practices in the Arab Countries. The results indicate that there is no formal e-waste sector, and the private sector enterprises are active in Egypt and United Arab Emirates (UAE). Printed circuit boards contains valuable and precious metals in high concentrations. The concentrations of the non-metallic constituents like fiber glass and resins are also high. [Kaya (2016)]. Massive amounts of PCBs are wasted, results in up cycling PCBs waste rejects into a composite material, This achieves economic benefits and make use of e-waste recycling rejects and realize sustainable [Soliman and Boushra (2017)].

Studies on e-waste sustainable management have attracted many researchers worldwide in recent years. Ismail and Hanafiah (2020) reviewed previous studies on e-waste issues to provide a survey for sustainable management progress and recommendations. They found that there is significant increase in research studies to evaluate e-waste generation.

In Egypt, municipal solid waste (MSW) is an annoying problem. El Gazzar and Gomaa (2018) investigated the issues of MSW management, which affects sustainable development of the country. MSW activities and management system are evaluated. They reviewed waste management experience in other developing countries, and concluded that MSW management system promotes sustainability, also help in conserving raw material resources and safe the environment

Ibrahim and Mohamed (2016) carried out a study to improve solid waste management in Egypt. They formulated plan to achieve sustainable management of solid waste in Egypt. Zaki (2014) updated the Egyptian country report on MSW management, issued by SWEEP-Net in July 2010. It covers data and analysis of the SWM in Egypt, highlighting challenges and constraints. Literature review shows that Egypt does not have e-waste precise data or regulations, which is the major problem. The e-waste problem in Egypt is not very well assessed.

The object of this work is to study and state the current situation of e-waste problem in Egypt; the generation and collection rates, as well as the management, compared to the situation in the African continent and Middle East. Possible recommending for better management will be given. Research methodology considered depends on collecting and analyzing e-waste data available in related reports and articles.

II. SOLID WASTE ISSUE IN EGYPT

Electronic waste is a part of solid waste problem. So it is convenient to start with solid waste studies. Solid waste is defined as the discarded solid materials generated from residential, industrial and commercial activities. Ibrahim and Mohamed (2016) stated that waste management in Egypt as for most developing countries is highly drastic and difficult.

There is no clearly-defined strategy for efficient management of solid waste. This has dangerous environmental risks as well as considerable economical loss. In Egypt, solid waste is frustrating and irritating problem everywhere. It has negative, harmful, and serious effects on health, and environment

Egypt generates escalating amounts of solid waste, that signifies sever source of pollution that causes hazards impacts on health and environment. Population growth amplifies the load on urban infrastructure which are overloaded. Shortage of the technical and financial resources, to handle solid waste activities are found. An activity involves generation, collection, recycling and disposal. Proper solid waste management is achieved by implementing legislations, enforcing regulations, and recycling. It is essential to have infrastructures and facilities for efficient handling, and recycling [Abdallah et al. (2020)]. In Egypt, solid waste is currently disposed in dump sites that mostly have no crucial potentials for recycling, processing, or reuse.

The major problem in the Municipal Solid Waste (MSW) is the wet organic waste, which is not collected, forms about 60% of the total waste in Egypt. The generated MSW is normally estimated by governorates as rates per capita. The Waste Management Regulatory Authority (WMRA) published a report on the annually generated solid waste in Egypt for the years 2001, 2005, 2009, and 2012. [Saber, (2013)].

TABLE (1):
SOLID WASTE GENERATION IN EGYPT (M TON/YEAR) [37]

Solid waste type	20011	20052	20093	20124
Municipal Solid Waste (MSW)	14.5	17	20	21
Agricultural Waste	23.5	27.5	26	30
Industrial Solid Waste	4. 25	4.75	6.2	6.0
Medical and Hazardous Waste	0.12	0.15	0.24	0.28
Construction and Demolishing Waste	3.5	4.6	3.9	4.0
Waterway Cleansing Waste	20	30	30	25
Sludge	1.75	2.o	3.0	3.0
Total Solid Waste Generated (Mt)	63.37	84	89.34	89.28

[1] (EEAA (2001)), [2] (EEAA (2005)), [3] (SWEEP Net (2010)), [4] (SWEEP Net (2014)),

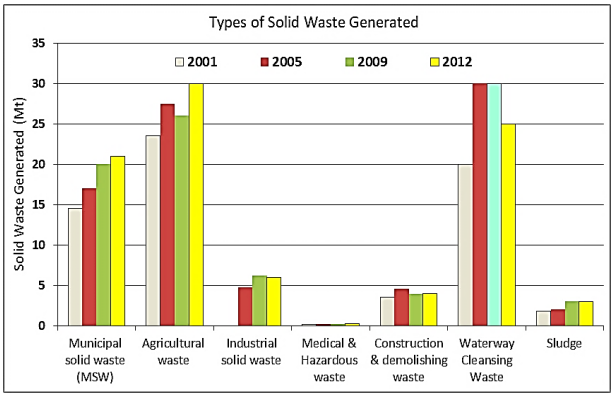

Figure (1) Types of Solid Waste generated in Egypt (Mt) during years 2001, 2005, 2009, and 2012

Table (1) and Figure (1) present the estimated data of the generated wastes, based on EEAA figures for the years: 2001, 2006, 2009 and 2012. They show that the total solid waste generated in the above mentioned years are 67.12, 86, and 89.28 Mt, respectively. The most dominant waste types are municipal solid waste (MSW), agricultural waste (AW), and waterway cleansing waste (WCW) with values in the range of 15-30 Mt/year. Agricultural waste is estimated as 23 million ton/year, that can be used as energy source .The lowest is for medical waste (MW) with a value less than 0.3 Mt/year that needs careful disposal to avoid its dangerous effects. Construction and demolition waste (CDW) is almost 3.5-4.6 Mt/year, and industrial waste (IW) is in the range 4.0–6.0 Mt/year. Good assessment of municipal solid waste management is given in the Annual Report for Solid Waste Management in Egypt, (2013) [Saber (2013)].

2.1 Municipal Solid Waste Generation and Composition

The daily generation of municipal solid waste (MSW) in Egypt is estimated as 0.3 to 0.8 kg//capita by the Egyptian Environmental Affairs Agency (EEAA), this increases yearly at rate of 3.4%. In addition, there is 6.2 million ton/year of industrial waste that includes 0.2 million ton of hazardous waste. MSW covers residential waste, commercial waste, street sweepings waste, contents of litter containers, and market cleansing waste.

Figure (2a) shows the daily generated MSW at different Governorates. In 2012, the total MSW generated is estimated as 57,020 tons/day which is equivalent to 20.8 Mt/year and 253.16 (kg/capita) [Zaki et al, (2013)]. The composition of MSW depends on people's culture, economic level and development, climate conditions, and energy sources. Waste contents are also affected by collection methods, and the way of disposed. MSW of Low-income countries have the highest proportion of organic waste. MSW of high income countries are characterized by the presence of paper, plastics, and other dry materials make up the highest proportion, while organic waste percentage is very low. The composition of the MSW in Egypt, consists 56% Organic waste, 2% Metal, 4% Glass, 13% Plastics, 10% Paper/Cardboard, and 15% Others waste.

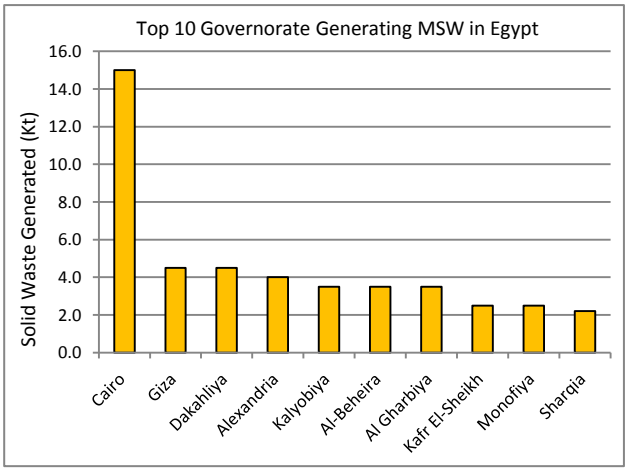

Figure (2a) Top 10 Governorates that generate the highest MSW per daily. Data from [47]

The estimated values of the generated MSW at different Egyptian regions are given by Elfeki et al. (2015), as 47% in Greater Cairo, 31% in Delta, 10% in Upper Egypt, 7% in Alexandria & Matruh, and 5% in Canal & Sinai (as shown in Figure (2b)).

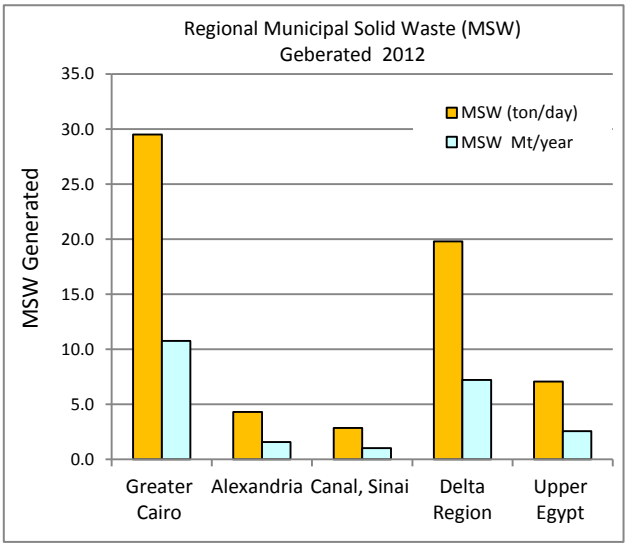

Figure (2b) Daily and Yearly Regional Municipal Solid Waste (MSW) Generated 2012, Date from [21]

Estimates of the annual MSW generation and collection coverage over 2001-2012 are summarized in Table (2). These estimates were based upon the generation rates in rural and urban areas and the Egyptian population in rural and urban areas. Abdel Gawad (2015) stated that there is no official or published data for MSW generation rate. According to [Zaki et al. (2013)] MSW covers residential waste, commercial waste, street sweepings, contents of litter containers, and market cleansing. From Table (2), it is clear that MSW yearly generation exceeds 20 million tons, but collection coverage is almost 60% in urban areas and 20% in rural areas.

TABLE (2)
MUNICIPAL SOLID WASTE GENERATION IN EGYPT
[ABDEL GAWAD (2015)] [4]

		2001[1]	**2005[2]**	**2009[3]**	**2012[4]**
Population (million)		64.7	71.2	78.2	83.2
Percentage of population (%)	Urban	40.0	40.0	42.9	43.0
	Rural	60	60	57.1	57.0
MSW generation (kg/day/capita)	Urban	0.8	0.8	0.7-1.0	0.7-1.0
	Rural	0.3	0.3	0.4-0.5	0.4-0.5
MSW (Mt/year)		14.8	17.0	19.7	21.0
MSW collection coverage (%)	Urban	30-60	n.m.	40-90	50-75
	Rural	n.m.	n.m.	0.0-35	0.0-30

2.2 Waste Collection, Treatment and Disposal

In Egypt, about 18.5 million m^3 of solid waste were collected. The primary method of waste collection is the street sweeping. They usually collect the daily left municipal waste. MSW Collection is the responsibility of local municipalities. The collection rate is around 60% in urban areas and about 20% in rural areas [EEAA (2011)].

In Cairo and big cities; waste collection is subcontracted to local garbage collectors and, in recent years, to private local and multinational companies. They collect, sort and sell recyclable materials. There is great necessity to establish a strategic framework that includes local garbage collectors. Most of the collected waste (81%) is being disposed in open dumps, while the other portions are divided into landfilled, composted, and other recycling activities. Egypt has about 53 MSW Compost plants and 52 sanitary landfills.

2.3 Wastes to Energy in Egypt

In 2012, Egypt generated 89 Mt of solid waste (SW); more than 60% are organic. Solid waste has high economic value that can be reused, recycled, and used as a source of energy. These benefits will be lost if SW is simply disposed into landfills. Waste-to-Energy (WTE) is thought to be a good solution to conserve energy sources and solve part of waste disposal problems [Shahat (2016)]. Unfortunately, waste to energy generation has low priority in Egyptian energy policy. There is no estimate for the share of waste in energy production. Huge amounts of organic waste are produced yearly in Egypt, which are considered as organic carbon-based energy source, El-Sheltawy et al. (2016).

Biogas activities are one of waste to energy techniques. In Egypt, it is just small-scale projects. Studies show that Egypt could produce 40% of its electricity consumption from biogas, if the organic waste were fully exploited, and produce a substantial amount of fertilizers [Abou Hussein and Sawan (2010)]. The potential sites for large biogas projects are large cattle and dairy farms, villages, food processing industries, solid organic municipal waste treatment sites, and sewage treatment sites [El Zayat et al. (2015)].

Refuse derived fuel (RDF) is another waste to energy technique. *RDF* is possible to be used as alternative fuel in existing boilers, gasifies, and fluidized bed combustors. It can be burned as an auxiliary fuel with other fuels such as coal or wood. *RDF* is used as a feedstock to produce methane gas. The most possible use of RDF is in cement and brick kilns. It is already be used as an alternative fuel in cement industry, saving fossil fuels. RDF is now being supplied to cement plants of Arabian Cement Company in Egypt and Helwan Cement Company in Egypt to be used instead of fossil fuels.

Pyrolysis is the most popular waste to energy technology in Egypt. In Egypt, thousands of old pyrolysis systems are in full use to produce bio-char. The old pyrolysis is uncontrolled and has dangerous impact health and environment. Recently efforts are being to rehabilitate old plants to control their operation and to avoid the drawbacks of old technology [El-Sheltawy et al. (2016)].

III. ELECTRONIC WASTE IN AFRICA

More than 53.6 Mt, (7.3 kg/capita) of e-waste were globally generated in 2019 [Forti et al. (2020)]. Out of this value Africa generated 2.9 Mt which is 2.5 kg/capita. Undoubtedly, African's economy is growing very fast, which resulted in increasing the consumption of EEE, and the amount of e-waste generated. Owing to the inadequate infrastructure for e-waste management, and the improper way of e-waste handling, hazardous substances are released that risks the humans and the environment.

Table (3) presents the e-waste data in Africa during years 2015-2019, as given by The Global E-Waste Statistics Partnership (GEWSP) [Balde et al. (2017)]. It presents the data of EEE put on African market as total (Mt) and per capita (kg/capita). It also includes the data of e-waste generated as total (Mt) and per capita (kg/capita) (Figures (3a and 3b)). The table presents the data of WEEE formally collected under collected and regulated by environmental protection laws.

TABLE (3):
DATA OF EEE PUT ON AFRICAN MARKET AND E-WASTE GENERATED DURING YEARS 2015-2019 DATA from [28]

	2015	**2016**	**2017**	**2018**	**2019**
Population (million)	1045.5	1069.9	1098.7	1124.9	1151.8
EEE Put on Market (kt)	3559.0	3837.0	4102.0	4262.0	4409.0
EEE Put on Market (kg per capita)	3.4	3.59	3.73	3.79	3.83
E-waste generated (kt)	2383.0	2515.0	2650.0	2780.0	2905.0
E-waste generated (kg per capita)	2.28	2.35	2.41	2.47	2.52
E-waste formally collected (kt)	26.00	26.00	26.00	26.00	26.00
E-waste collection rate (%)	1.00	1.00	1.00	1.00	1.00
E-waste Imported/ Exported	n/a	n/a	n/a	n/a	n/a

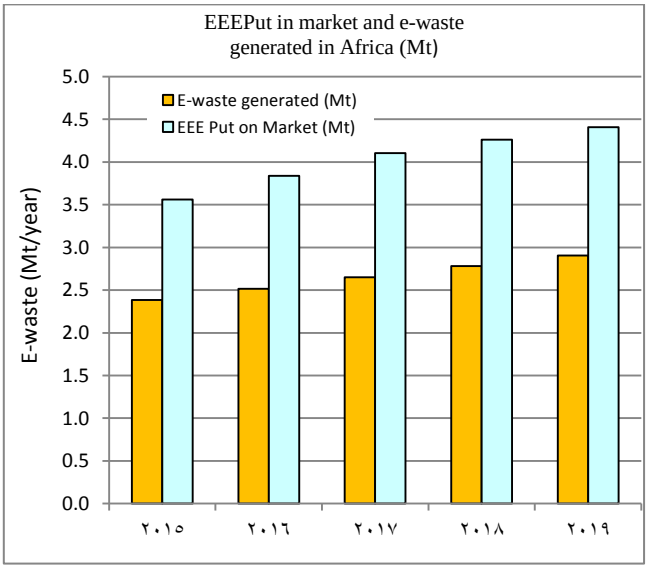

Figure (3a) EEE put on African market and e-waste generated (kt) during years 2015-2019 Data from [28]

The data of EEE and e-waste in Africa, show that the population in Africa increases from 1045.49 (million) in 2015 to 1151.77 (million) in 2019. The yearly rate is 26.57 million (2.54%). The electronic equipment "EEE" put on African market increases from 3.559 Mt in 2015 to 4.409 Mt in 2019 at a rate of 212 kt (5.97%). While the e-waste generated increases from 2.383 Mt in 2015 to 2.905 Mt in 2019 at a yearly rate of 130.5 kt, that represent yearly increase of 5.48%. This clearly demonstrate that the rate of increase in EEE put in the market and the e-waste generated is more than double the increase in population. It has been also shown that, in average, e-waste generated is 65.6% of the EEE put on African market.

Figure (3b) presents the EEE Put on African market and the generated e-waste per capita. It shows that EEE put on market per capita increases from 3.40 kg/capita in 2015 to 3.83 kg/capita in 2019 at rate of 2.53%, while those for e-waste generated per capita increases from 2.28 kg/capita in 2015 to 2.52 kg/capita at a rate of 2.1%. E-waste formally collected is almost 26.0 kt, and the collection rate is only 1.0%. In summary, in 2019, Africa's population is 1152 (millions), and the e-waste generated is 2.9 Mt and 2.5 kg/capita.

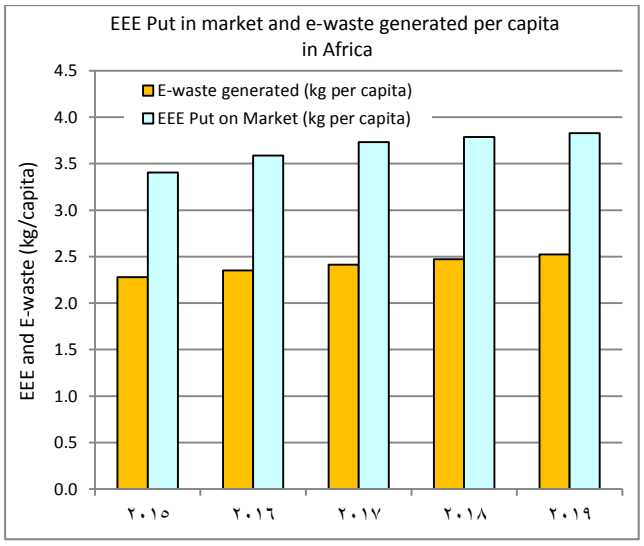

Figure (3b) EEE put on Egyptian market and e-waste generated per capita (kg/capita) during years 2015-2019 Data from [28]

Table (4) presents the data of the different sub-regions. It shows that Northern Africa of 240 million in population is the highest in e-waste generation with 1.3 Mt and 5.4 kg/capita, Western Africa of 382 million is the second with 0.6 Mt and 1.7 kg/capita, the lowest is Middle Africa of 80 million with 0.2 Mt and 2.5 kg/capita.[Forti et al (2020)]

Figure (4a) presents the top 10 countries in Africa generating e-waste in 2019 (kt). It shows that Egypt is the highest e-waste generating by 586 kt yearly. It is followed by Nigeria and South Africa by 461 kt and 416 kt. Figure (4b) presents the values of the top 12 African countries generating e-waste per capita in 2019 (kg/capita). This shows that Egypt ranked the eleventh as e-waste generated per capita with 5.9

kg/capita, while Seychelles is in the top with 12.6 kg/capita. It should be noted that e-waste activities are dominated by small business informal sector, and limited recycling facilities are found in few African countries, such as Egypt, South Africa, and Morocco.

TABLE (4)
AFRICAN SUB-REGION E-WASTE DATA Data from [27]

Sub-region	e-waste generated	e-waste collected	Population
Eastern Africa	0.3 Mt 0.8 kg/capita	1.3% 0.004 Mt	383 (Million)
Middle Africa	0.2 Mt 2.5 kg/capita	0.03% 0.0001 Mt	80 (Million)
Northern Africa	1.3 Mt 5.4 kg/capita	0% 0 Mt	240 (Million)
Southern Africa	0.5 Mt 6.9 kg/capita	4% 0.02 Mt	67 (Million)
Western Africa	0.6 Mt .7 kg/capita	0.4% 0.002 Mt	382 (Million)

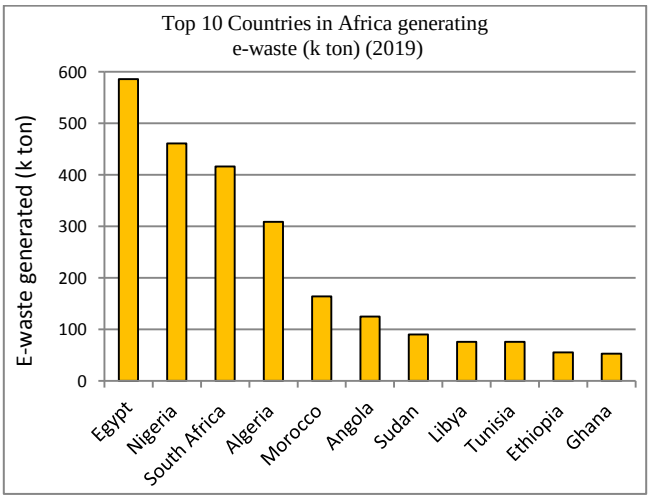

Figure (4a) Top 10 countries in Africa generating e-waste (kt) In (2019) Data from [27]

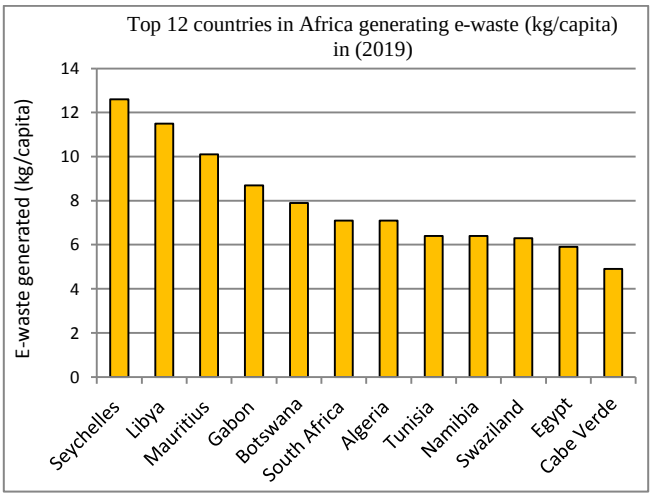

Figure (4b) Top 12 countries in Africa generating E-waste per capita (kg/capita) (2019) Data from [27]

The major shortfalls of e-waste management in Africa are the shortage of public awareness, absence of policy and legislation to control activities, lack of effective collection systems, poor equipped and uncontrolled recycling operations, that pollutes the environment, shortage of adequate recycling facilities, and limited financing of hazardous waste control activities.

IV. Electronic Waste in Egypt

In 2019, about 1.1 million tons of electric and electronic equipment "EEE" have been put on the Egyptian market, and 0.586 million tons of e-waste are generated. This makes Egypt largest electric equipment market and e-waste generation. The country's share will continue to grow like most of developing countries. Significant amounts of e-waste components is disposed in uncontrolled landfill sites. Wire burning to recover copper, acids extraction to retrieve precious metals polluted the environment. Therefore, huge efforts are greatly needed to manage e-waste in Egypt, where informal uncontrolled e-waste activities are widely practiced [Nnorom and Osibanjo (2008)]. In countries like China, India, Pakistan, Nigeria, and Ghana, similar behaviors are found, that endangering health and environment.

Precise data and knowledge of the e-waste generated is most important for planning proper management and understanding e-waste material flow [Alavi et al. (2015)]. The Global E-waste Statistics Partnership (GESP) monitors the e-waste issues over time, and produces e-waste statistical data on global, regional and countries levels. Table (5) presents the statistical data of the electronic equipment and devices "EEE" put on Egyptian market, and the e-waste generated in Egypt as given by (GESP)

TABLE (5)
DATA OF EEE PUT ON EGYPTIAN MARKET AND E-WASTE DURING YEARS 2015-2019 DATA from [28]

	2015	2016	2017	2018	2019
Population (million)	92.44	94.45	96.44	98.42	100.39
EEE Put on Market (kt)	754.0	833.0	896.0	1005.0	1069.0
EEE Put on Market (kg per capita)	8.16	8.82	9.29	10.21	10.65
E-waste generated (kt)	477.0	504.0	532.0	559.0	586.0
E-waste generated (kg per capita)	5.16	5.34	5.52	5.68	5.84
E-waste formally collected (kt)	n/a	n/a	n/a	n/a	n/a
(%) E-waste collection rate	n/a	n/a	n/a	n/a	n/a

Table (5) presents the statistical data of EEE and e-waste generated in Egypt in years 2015-2019, as given by The Global E-Waste Statistics Partnership (GEWSP) [Balde et al. (2017)]. They show that, Egyptian population increases from 92.44 (million) in 2015 to 100.39 (million) in 2019 with annual increasing rate 1.99 million (2.15%).

The "EEE" devices put on Egyptian market also increases from 754 kt in 2015 to 1069 kt in 2019 at a rate of 78.75 kt (10.44%). While the e-waste increases from 477 kt in 2015 to

586 kt in 2019 at annual increasing rate of 27.25 kt (5.71%). This clearly shows that the increase in EEE put on the market is almost 3.6 times the increase in population, while the increase the electronic waste generated is almost double the increase in population. It has been also shown that in average, the e-waste generated is almost 58.7% of the EEE put on the market.

Figure (5a) presents the data of EEE put on Egyptian market, and the e-waste generated in total amounts (kt), while Figure (5b) presents the same data per capita (kg/capita). The reported data of EEE put on market per capita increases from 8.16 kg/capita in 2015 to 10.65 kg/capita in 2019 (3.11%). While e-waste generated per capita increases from 5.16 kg/capita in 2015 to 5.84 kg/capita at annual rate of 2.66%. There are no data available for the e-waste formally collected, collection rate, and e-waste imported or exported.

These data shows that the EEE put on Egyptian market is about 51.7% that of Northern Africa, and 22.5% that of Africa. The e-waste generated in Egypt is about 43.9% that of Northern Africa, and 20.1% that of the African continent, while the population in Egypt is about 8.6% of Africa

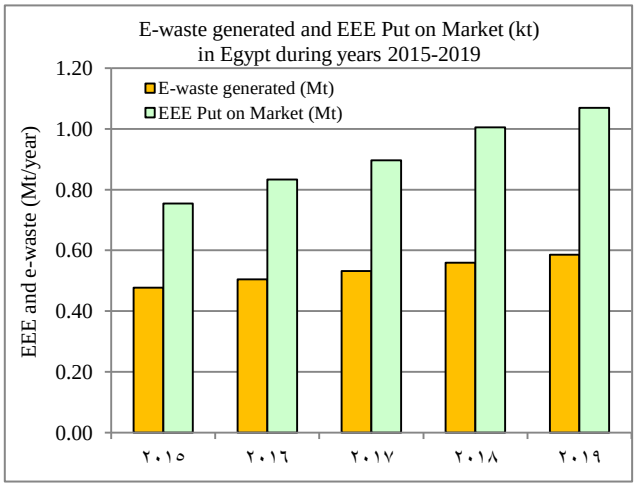

Figure (5a) E-waste generated and EEE Put on Market (kt) in Egypt during years 2015-2019 Data from [28]

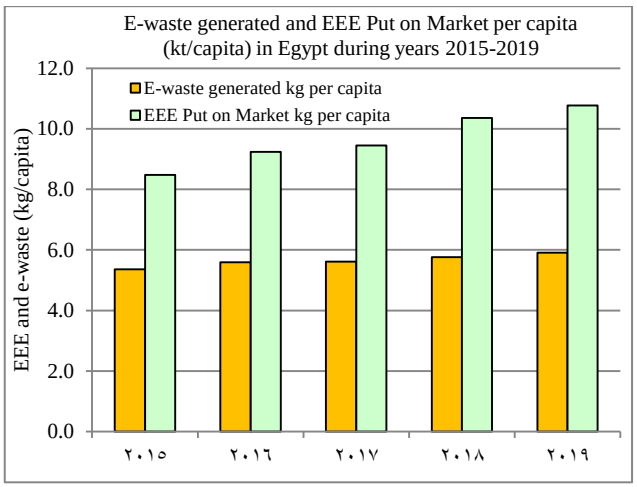

Figure (5b) E-waste generated and EEE Put on Market per capita (kg/capita) in Egypt during years 2015-2019 Data from [28]

WEEE may be broadly classified as Household appliances, Information and Communication Technology equipment (ICT), Consumer electronics, and other equipment. Generally, statistical data shows that, the contribution of household appliances category is almost 50% of the total e-waste generated, this followed by ICT equipment that contributes 30%. Each of consumer electronics category and other electronic waste share with 10%.

E-waste contains many materials of high economic value, but also it may present health and environmental threats, if not properly managed. At the same time, e-waste recycling provides one of the most important secondary raw materials sources. Waste from information and communication technology (ICT) equipment constitutes significant amounts of valuable fractions.

Recycling of printed circuit boards (PCBs) waste is the most economic activity. PCB contains valuable, precious and rare metals, as well as hazardous materials, that makes recycling very essential. PCBs are only 5–10% of the e-waste weight, but they constitute up to 80% of the recovered economic value.

Small and large household appliances contain low-grade PCBs. In contrast, information and communication technology (ICT) waste generally contain high-grade PCBs [Chi et al. (2011)]. On the other hand, the quantity of waste from (ICT) equipment is high. Owing to the rapid development of ICT technology, e-waste increases rapidly with high rates [Dwivedy and Mittal (2012)]. In addition to that the reduced life span of the ITC equipment resulted in increased consumption and increased waste amounts.

TABLE (6)
ICT EQUIPMENT PUT ON MARKET IN EGYPT DURING 2016
Data from [18]

	(a) In Weight (kt)					
	Mobile	**Teleph.**	**Desktop Computer**	**Laptop**	**CRT Monitor**	**LCD Monitor**
Personal	9.40	6.24	0.00	0.00	0.00	0.00
Households			82.92	13.54	69.67	16.14
Enterprises		24.24	262.58	84.90	74.79	99.73
Government Sector		0.96	5.58	0.85	2.38	1.85
Sub Total	9.40	31.44	351.07	99.29	146.85	117.72

	(b) In Number of Units (million unit)					
	Mobile	**Teleph**	**Desktop Computer**	**Laptop**	**CRT Monitor**	**LCD Monitor**
Personal	94.02	6.24	0.00	0.00	0.00	0.00
Households			8.38	3.87	4.94	3.43
Enterprises		24.24	26.52	24.26	5.30	21.22
Government Sector		0.96	0.56	0.24	0.17	0.39
Sub Total	94.02	31.44	35.46	28.37	10.42	25.05

Table (6) and Figure (6) present the ICT equipment put on the market from Mobiles, Telephones, Desktop PCs, Laptop PCs, CRT Monitors, and LCD Monitors in Egypt [EcoConServ (2016)]. Figure (6b) presents the number of

units of ICT equipment put on Egyptian market in 2016. The highest share comes from mobile with 94 million units, followed by Desktop Computers. Telephones and Laptops are with almost 35.5, 31.5 and 28.4 million units, respectively. The lowest number of units is for CRT monitors with 10.4 million units. Table (7) presents the ICT Equipment Put on market and the e-waste mass flow in Egypt during 2016.

TABLE (7)
ICT EQUIPMENT PUT ON EGYPTIAN MARKET AND THE E-WASTE MASS FLOW DURING 2016 Data from [18]

ICT equipment	Installed EEE		e-waste mass flow	
	[tons/year]	[%]	[tons/year]	[%]
Mobile	9,402	1	2,351	3.55
Telephone	31,441	4	2,620	3.96
Desktop PC	351,073	47	29,256	44.19
Laptop PC	99,294	13	9,929	15.00
CRT Monitor	146,854	19	12,238	18.49
LCD Monitor	117,720	16	9,810	14.82
Total	755,784	100	66,204	100.0

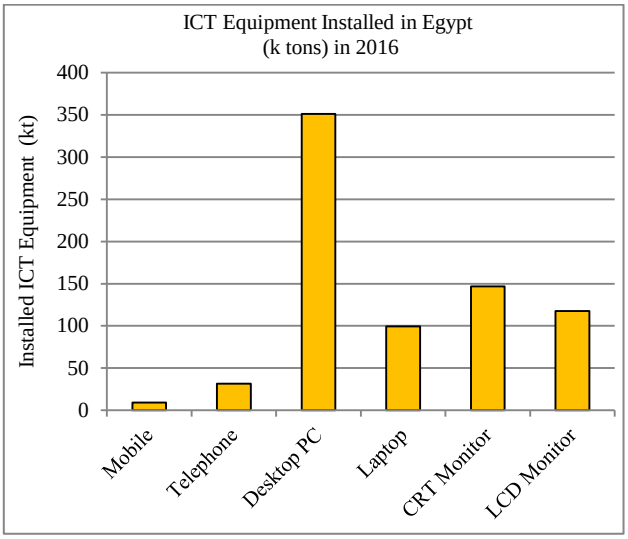

Figure (6a) ICT Equipment Put on market (kt) in Egypt during 2016

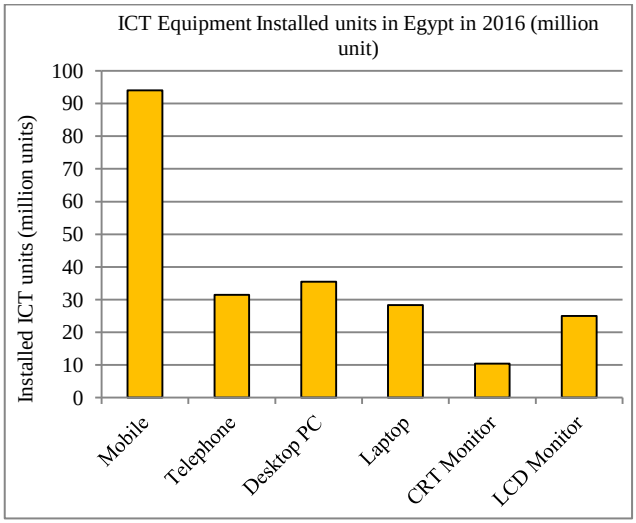

Figure (6b) ICT Equipment units Put on market (million units) in Egypt during 2016 Data from [18]

V. E-WASTE MANAGEMENT IN EGYPT

The sources of e-waste are mainly from Governmental sectors, Corporate companies, Households, Non-governmental organizations (NGOs), Private enterprises, and Small and medium business. The flows of e-waste in Egypt are in three stages. The first is the collection stage, which is controlled by the small private sector, waste collectors and street sweepers. The next stage is the dismantling and sorting, that is carried out in formal and informal sectors. The third stage is the further recycling and metal recovery activities. This may requires exporting some items (PCBs and batteries) abroad for advanced processing and material recovery.

Egypt is the highest e-waste generation country in Africa, generating more than 20% of e-waste generated in African countries. Egypt has no proper infrastructure for e-waste management. Improper handling of e-waste materials will cause serious impacts on health and environment. Meanwhile, Egyptians are not aware of the environmental protection, and the discarded electronic products may find their way as second-hand use and finally scraped. Thus, proper handling of e-waste is essential in Egypt, and recycling activities is an economically promising industry [Dahroug (2010)].

Earlier studies by Allam (2009), Dahroug (2010), SWEEP (2010) reviewed e-waste issues in Egypt. They show that selling of the consumption of ITC equipment and devices increased above 20 times in 8 years. Also the consumption of televisions sets (TVs) and satellite receivers increased but with lower rate. In spite of the increase in e-waste, there is a limited investment for recycling activities [El-Hadary (2011)].

Egyptian Minister of Environment [Egypt Today (2020)] stated that the ministry started developing legislation for e-waste management. It aims to convert the informal sector to an official sector to insure the safe disposal of electronic waste. The project is carried out in cooperation with the United Nations Development Program (UNDP). Efforts are underway to implement E-Tadweer application, which enables citizens to get rid of their e-waste items and gain incentives. This coincides with the announced strategy to safe handling of e-waste and agriculture leftovers. There is coordination with the ministry of Telecommunications on a strategy to safe handling of the e-waste. Accordingly, citizens will not dispose e-waste in the trash cans.

VI. CONCLUSIONS AND RECOMMENDATIONS

Egypt generates significant amount of e-waste yearly, which is 20% of the African continent. In spite of this huge amount, Egypt lacks serious national programs and regulations to manage e-waste. E-waste activities are carried out by small business private sector, and the management is controlled by garbage traders and waste collectors.

In this work, the study of e-waste problem in Egypt gives the following conclusions:

- Egypt is the highest e-waste generating country in Africa by 586 kt yearly, followed by Nigeria and South Africa, but not the top in e-waste generated per capita with 5.9

kg/capita. Between Arab countries, Egypt is ranked as the second after Saudi Arabia that generated 595 kt, but per capita, Egypt is ranked as the twelve in e-waste generation.

- Egypt annual increasing population rate is almost 2.15%, while the annual increase in e-waste generation is 5.71% that is almost double the annual increase in population. In average, e-waste generated in Egypt is about 20% that of the Africa, while the population is about 8.6%.
- In 2016, the amount of ICT equipment put on Egyptian market was 755 kt. The amount of ICT e-waste mass flow was almost 66.2 kt/ year. Only 2.4% of the total generated ICT e-waste was collected.
- Egypt has no proper infrastructure for the management of e-waste. Improper handling of e-waste will cause serious impacts on health and environment. Thus, proper handling of e-waste is essential in Egypt, and recycling activities is an economically promising industry.

The following recommendations are proposed to help in solving e-waste problem and to develop proper management system to safe health and environment

- Carry out and develop formal systems for e-waste monitoring and field data collection to provide accurate detailed data for e-waste in Egypt, as a basis for e-waste management industry.
- Develop national regulations and legislations to efficiently control the flow of e-waste, proper handling activities and recycling operations
- Develop an accreditation system for the informal sector involved in e-waste activities, to ensure proper handling and control of e-waste flow and processing
- Develop sustainable e-waste management model to be applied by the informal sector that includes collection, transportation, recycling, and exporting or disposal.

AUTHORS CONTRIBUTION

Corresponding Author: Hesham Sakr, contributed in the Conception or design of the work, proposed the methodology, He carried out problem data collection, analysis and interpreted the results. Finally drafting the article and prepared for publication

Co-Authors: Prof Mohamed G. Saafan, proposed the problem to be investigated and supervised the work, share in interpreting the results, revise and approve the article for publication.

Co-Authors: Dr M. Saraya, contributed in discussing and interpreting the results, and in revising the article

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REFERENCES

[1] Alameer, H. (2015) Integrated Framework for modelling the Management of Electronic Waste in Saudi Arabia.: [Online]. Available: http://vuir.vu.edu.au/32316/1/ALAMEER%20Hasan%20-%20Thesis.pdf

[2] Abdallah, L., (2014), "E-waste Management in Egypt: Opportunities and Hazards", 10th International Conference on The Role Of Engineering Towards A Better Environment Intelligent Environmental Engineering: From Vision to Action, 15-17 December, 2014 Alexandria, Egypt

[3] Abdallah M; Arab M; Shabib A; ElSherbiny R; ElSheltawy S, (2020); Characterization and sustainable management strategies of municipal solid waste in Egypt, Clean Technologies and Environmental Policy (2020) 22:1371–1383, [Online]. Available: https://doi.org/10.1007/s10098-020-01877-0

[4] AbdelGawad A.M. (2015), "ASSESSMENT OF MUNICIPAL SOLID WASTE SYSTEM IN ASYUT GOVERNORATE, EGYPT", Proceedings Sardinia 2015, Fifteenth International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy; 5 – 9 October (2015) © 2015 by CISA Publisher, Italy

[5] Abdelbasir, Sabah M; Hassan, Saad S M; Kamel, Ayman H; Seif El-Nasr, Rania (2018), "Status of electronic waste recycling techniques: a review", Environmental Science and Pollution Research (2018) 25:16533–16547, https://doi.org/10.1007/s11356-018-2136-6

[6] Abou Hussein Shaban D and Sawan Omaima M (2010), "The Utilization of Agricultural Waste as One of the Environmental Issues in Egypt (A Case Study)", Journal of Applied Sciences Research 6(8):1116-1124 (2010)

[7] Alavi N, Shirmardi M, Babaei A, Takdastan A, Bagheri N, (2015). Waste electrical and electronic equipment (WEEE) estimation: a case study of Ahvaz City, Iran. J. Air Waste Manag. Assoc. 65, 298–305.

[8] Allam H (2009) E-waste management in the Arab region: status and opportunities. Centre for Environment and Development for the Arab Region and Europe

[9] Allam, Hossam and Inauen, Simon (2009), "E-Waste Management Practices in the Arab Region", Centre for Environment and Development for the Arab Region (CEDARE), P.O. Box 1057 Cairo 11737, Egypt

[10] Anjani, R K; Gautam, S; and Shu, C.M, (2020), "Inconsistencies of e-waste management in developing nations – Facts and plausible solutions", Journal of Environmental Management 261:110234 (May 2020), DOI: 10.1016/j.jenvman.2020.110234

[11] Asante K A, Amoyaw-Osei Y, Agusa T (2019), "E-waste recycling in Africa: risks and opportunities", Current Opinion in Green and Sustainable Chemistry April 2019, DOI: 10.1016/j.cogsc.2019.04.001

[12] Balde, C.P.; Forti, V.; Gray, V.; Kuehr, R.; Stegmann, P. The Global E-Waste Monitor 2017: Quantities, Flows and Resources; United Nations University, International Telecommunication Union, and International Solid Waste Association: Geneva, Switzerland, 2017.

[13] CAPMAS (2019) Central Agency for Public Mobilization and Statistics. Egypt in Figures. http://capmas.gov.eg/Pages/Publications.aspx?page_id=5104&Year=23332Chi, X;

[14] Streicher-Porte, M; Wang, M Y and Reuter, M A (2011), "Informal Electronic Waste Recycling: A Sector Review with Special Focus on China", Waste Management 31(4):731- (2011), DOI: 10.1016/j.wasman.2010.11.006

[15] Chi, X; Streicher-Porte, M; Wang, M Y and Reuter, M A (2011), "Informal Electronic Waste Recycling: A Sector Review with Special Focus on China", Waste

[16] Dahroug S (2010), BCRC-Egypt and e-waste activities in the Arab region. Basel Convention Regional Centre for Training and Technology Transfer for Arab States in Egypt, BCRC-Egypt

[17] Dwivedy M; Mittal R.K. Future trends in computer waste generation in India. Waste Manag. 2010, 30, 2265–2277.

[18] EcoConServ (2016), "Assessment of WEEE Management in Egypt", Submitted by: EcoConServ , This report prepared by EcoConServ environmental solutions (local consultancy firm). Environmental Solutions 12 El-Saleh Ayoub St., Zamalek, Cairo, Egypt 11211. Draft Report 2 08/09/2016 As above Emad Raouf II Draft Report 3 15/12/2016.

[19] EEAA, (2011), EEAA, Egyptian Environmental Affairs Agency (EEAA), Annual Report, (2011), http://www.eeaa.gov.eg

[20] Egypt Today (2020), [Online]. Available:

https://www.egypttoday.com/Article/1/98320/Egypt%E2%80%99s-Minister-of-Environment-CBE-governor-discuss-support-for-ways
[21] Elfeki Mohamed, and Tkadlec Emil, (2015), "Treatment of municipal organic solid waste in Egypt", J. Mater. Environ. Sci. 6 (3) (2015) 756-764) ISSN : 2028-2508 CODEN: JMESCN
[22] El Gazzar R F, and Gomaa B, (2014), "Municipal Waste Management in Egypt: An Investigation Study of Collection and Generation Process in Alexandria City", Egypt, International Journal of Scientific & Engineering Research, Volume 5, Issue 6, June-2014 1204 ISSN 2229-5518 IJSER © 2014 http://www.ijser.org
[23] El Zayat, Mohamed; Hassan, Mohamed G; Taylor, Christopher l and El Haggar, Salah (2015), "Feasibility of Biogas Utilization in Developing Countries: Egypt a Case Study", Austin Chem Eng. 2015;2(2): 1017
[24] El-Hadary H (2011). For industrial waste treated - recycled - safe disposal. Egyptian National Cleaner Production Centre: Cairo
[25] El-Nakib I (2012) Reverse Logistics: A Comparison of Electronic Waste Recycling Between Switzerland and Egypt. Global Conference on Operations and Supply Chain Management - GCOM 2012, ISBN No: 978-967-5705-06-9
[26] El-Sheltawy S.T., Al-Sakkari E.G. and Fouad M. (2016) "Modeling and Process Simulation of Biodiesel Production from Soybean Oil using Cement Kiln Dust as a Heterogeneous Catalyst" The 31st International Conference on Solid Waste Technology and Management, Philadelphia, PA, USA
[27] Forti V, Baldé C P, Kuehr R, and Bel G, (2020), "The Global E-waste Monitor 2020. Quantities, flows, and the circular economy potential", Publisher: UNU/UNITAR SCYCLE, ITU, (July 2020), ISWAISBN: 978-92-808-9114-0, [Online]. Available: https://www.researchgate.net/publication/342783104_The_Global_E-waste_Monitor_2020_Quantities_flows_and_the_circular_economy_potential
[28] GEWSP, The Global E-Waste Statistics Partnership, [Online]. Available: https://globalewaste.org/country-sheets/
[29] Ibrahim M I M and Mohamed N E (2016), (2016), "Improving Sustainability Concept in Developing Countries Towards Sustainable Management of Solid Waste in Egypt", Procedia Environmental Sciences 34 (2016) 336 – 347, [Online]. Available: https://doi:10.1016/j.proenv.2016.04.030,
[30] Ikhlayel Mahdi (2018), "An integrated approach to establish e-waste management systems for developing countries", Journal of Cleaner Production, Volume 170, (Jan 2018), ages 119-130, https://doi.org/10.1016/j.jclepro.2017.09.137
[31] Ismail H, Hanafiah M M, (2020), " A review of sustainable e-waste generation and management: Present and future perspectives", Journal of Environmental Management 264 ((2020)) 110495, [Online]. Available: https://doi.org/10.1016/j.jenvman. (2020).110495
[32] Kaya M, (2016), "Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes", Waste Manag; 57:64-90. (2016 Nov) [Online]. Available: Doi: 10.1016/j.wasman.2016.08.004. Epub 2016 Aug 16.,
[33] Khan, Anish, Inamuddin, Muenuddin, Asiri, Abdullah M. (Eds.), "E-waste Recycling and Management, Present Scenarios and Environmental Issues", Environmental Chemistry for a Sustainable World (2020)
[34] Mohamed, Ahmed Tarek. (2019) Sustainability of e-waste Management: Egypt case study. 2019. American University in Cairo, Master's thesis. AUC Knowledge Fountain. https://fount.aucegypt.edu/etds/783
[35] Nnorom, I.C, Osibanjo, O, (2008). Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. Resour. Conserv. Recycl. 52, 843–858.
[36] NSWMP (2011), "National Solid Waste Management Program Egypt - Main Report", [Online]. Available: http://www.eeaa.gov.eg/portals/0/eeaaReports/NSWMP/1_P0122721_NSWMP_Main%20Report_December2011.pdf
[37] Saber, Mohamed (NRC) editor, (2013), "ANNUAL REPORT FOR SOLID WASTE MANAGEMENT IN EGYPT, (2013)", Volume 2: The Report Prepared by New center for Integrated studies of Land & Environment (NILE), 5, El-Ahram Street, Heliopolis, Cairo, Egypt, Published by: Ministry of State for Environmental Affairs National Solid Waste Management Program (NSWMP)
[38] Shahat, F. (2016). "Investigating the use of solid waste as alternative fuels in Egypt", Master's thesis, the American University in Cairo, AUC Knowledge Fountain. https://fount.aucegypt.edu/etds/581
[39] Shakra Hoda, and Awny Mohamed, (2017), "A model for E-Waste Recycling System Case Study in EGYPT", International Journal of Engineering and Management Research, Volume-7, Issue-3, May-June 2017, Page Number: 338-345, www.ijemr.net ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962,
[40] Soliman, F. and Boushra, M. (2017) Mapping of Informal Sector Involved in E-Waste Collection. SECO, Retrieved from http://web.cedare.org/wp-content/uploads/2018/11/MAPPING-OF-INFORMALSECTOR.pdf
[41] SWEEP (2010) The regional solid waste exchange of information and expertise network in Mashreq and Maghreb countries: country report on the solid waste management in Egypt. SWEEPNET
[42] SWEEPNET (2010) Country Report on the Solid Waste Management in Egypt. The Regional Solid Waste Exchange of Information and Expertise Network in Mashreq and Maghreb Countries. SWEEPNET, Cairo.
[43] Tarek A. and El-Haggar S. (2019) Sustainable Guideline for Developing the E-Waste Sector in Egypt. Journal of Environmental Protection, 10, 1043-1071,doi: 10.4236/jep.2019.108062
[44] Tarek Zaki (2014), "COUNTRY REPORT ON THE SOLID WASTE MANAGEMENT IN EGYPT", The Regional Solid Waste Exchange of Information and Expertise network in the MENA region (SWEEP-Net) GIZ Office Tunis, (April 2014)
[45] UNDP Egypt (2015), United Nations Development Program, Country: Egypt (2015) Protect human health and the environment from unintentional releases of POPs originating from incineration and open burning of health care and electronic waste. EEAA Project document
[46] UNDP Egypt (2016), United Nations Development Program, Country: Egypt (2016) Assessment of WEEE Management in Egypt final report. Submitted by: Eco Canserve Environmental Solution
[47] Zaki, T., A. G. Kafafi, M. B. Mina and M. A. E.-H. Abd El-Halim (2013). Annual Report for Solid Waste Management In Egypt. Ministry of State for Environmental Affairs, New center for Integrated studies of Land & Environment.

Title Arabic:

الوضع الحالي لمشكلة النفايات الإلكترونية في مصر

Arabic Abstract:

يقوم العالم بتوليد كميات هائلة من النفايات الإلكترونية سنويا. وتحتوي هذه النفايات على معادن قيمة مثل الألومنيوم والنحاس والنيكل والمعادن الثمينة مثل الذهب والبلاديوم والفضة والاينديوم. ومع ذلك، فإن لهذه النفايات آثار ضارة وخطيرة على الصحة والبيئة. لذا فإنه من الضروري العمل على إدارة النفايات الإلكترونية بكفاءة لاستعادة ما تحتويه من المعادن الثمينة والقيمة، ولحماية الصحة والبيئة. وتعتبر مصر سوق هامة للمنتجات الكهربائية والإلكترونية التي ينتهي عمرها كنفايات إلكترونية. كما تعتبر مصر في قمة الدول الأفريقية في توليد النفايات الإلكترونية. حيث تبلغ كمية المنتجات الكهربائية والإلكترونية المعروضة في السوق المصرية حوالي ١٠٦٩ كيلوطن بمعدل زيادة سنوية ١٠.٤٤٪ في حين تبلغ كمية النفايات الإلكترونية المتولدة حوالي ٥٨٦ كيلوطن بمعدل زيادة سنوية قدرها ٥.٧١٪. بما يعني أن الزيادة في السنوية في الاجهزة الكهربائية والإلكترونية المعروضة في السوق المصرية يبلغ ٣.٦ ضعف الزيادة في عدد السكان، في حين أن الزيادة السنوية في النفايات الإلكترونية المتولدة تبلغ ضعف الزيادة السنوية في عدد السكان تقريبا. وفي المتوسط تبلغ النفايات الإلكترونية المتولدة ما يقرب من ٥٨.٧٪ من كمية المنتجات الكهربائية والإلكترونية المعروضة في السوق .

كما تبلغ كمية النفايات الإلكترونية المنتجة للفرد الواحد سنويا، هو ٥.٨٤ كجم للفرد بمعدل زيادة قدره ٢.٦٦٪. كما تبلغ النفايات الإلكترونية المتولدة في مصر حوالي ٢٠.١٪ مما يتم توليده في القارة الأفريقية، في حين أن عدد السكان في مصر حوالي ٨.٦٪ من عدد سكان أفريقيا. في الواقع، ليس لدى مصر أي برامج وأنظمة وطنية جادة للتعامل مع النفايات الإلكترونية بشكل صحيح، ويهيمن تجار القمامة وجامعو النفايات على أنشطة النفايات الإلكترونية ويسيطرون عليها.