Environmental Management
https://doi.org/10.1007/s00267-020-01341-1

Estimation of E-waste Generation, Residential Behavior, and Disposal Practices from Major Governorates in Jordan

Sudki Hamdan[1] · Motasem N. Saidan[2]

Received: 8 February 2020 / Accepted: 17 July 2020

Abstract

Estimating the generation of e-waste in governorates is critically needed for sustainable and environmentally sound e-waste management in Jordan. The main objectives of the present study are to quantify and evaluate the annual e-waste generation in all governorates in Jordan and disposal practices. The present study comprises the information of e-waste as classified by the European Union Directive including six main categories (16 United Nations University key items). The survey targeted 15,883 households (12.52% females and 87.48% males), where primary data on e-waste generation and disposal methods were gathered, assessed, and quantified. Subsequently, the survey-based data collected from the study sample have been extrapolated to quantify an e-waste generation inventory for Jordan and the disposal methods using ArcGIS mapping. The study-extrapolated findings reveal that ~8,735,187 e-waste items (13 ktons) had been turned into e-waste and discarded by all households in 2018 in the 12 governorates in Jordan. Moreover, dumping of e-waste is still the dominant disposal method practiced by 58.4% of households in Jordan. The other disposal practices showed that granting of the waste EEE to others has the share of 16.6%; selling (10.7%); delivering the waste EEE for environmentally sound recycling (6.8%); and others practices represented 7.4%. Furthermore, the present study has played a vital role in e-waste awareness dissemination since the findings of the present study have been modeled and shown online by the Department of Statistics, Jordan through the link (https://arcg.is/1KzvjO). Finally, the challenges, barriers, and prospects of e-waste management in Jordan have been explored in the present study.

Keywords E-waste · WEEE · Discarded electrical and electronic waste · Disposal behavior · Waste · Jordan

Introduction

The management of waste electrical and electronic equipment (WEEE or e-waste) has currently become an emerging issue worldwide due to any reasons such as its hazardous contents (Robinson 2009; Ilankoon et al. 2018; Cucchiella et al. 2015; Islam and Huda 2020); it is recognized as the fastest-growing waste streams, for example, two to three times faster than municipal solid waste (MSW) (Awashti et al. 2018; Islam and Huda 2019; Walden 2012); and their unsafe disposal which are posing a serious environmental impacts on the ecosystem (Gu et al. 2015), especially through their illegitimate recycling (Ahmed and Panwar 2014; Ravindra and Mor 2019).

Moreover, reliable estimation of e-waste generation and disposal practices is crucial to policymakers for adequate e-waste management (Abbondanza and Souza 2019). So far, e-waste generation is estimated from EEE production and sales data, lifespan, and average weight (Oguchi et al. 2008; Matthews et al. 2014; Rodrigues et al. 2020). Several recent studies estimated the e-waste generation on national level (Masud et al. 2019; Parajuly et al. 2017; Ismail and Hanafiah 2019), while few studies reported e-waste generation estimates on city level (UNEP 2012; Baldé et al. 2015; Sajid et al. 2018).

E-waste Status in Jordan: Past to Date

The e-waste in Jordan is still a new focus of environmental concern relatively. As any other developing countries, there is a difficulty to ascertain accurate data regarding the e-waste generation, reuse, recycling, and disposal in Jordan,

✉ Motasem N. Saidan
m.saidan@gmail.com

[1] Department of Statistics, Environment Statistics, Amman, Jordan

[2] Chemical Engineering Department, School of Engineering, The University of Jordan, Amman, Jordan

Published online: 26 July 2020

mainly, because the e-waste is considered as part of the MSW. In Jordan measurement data on MSW generation and composition are available in only few selected districts, commercial and industrial areas (MoMa 2015), and refugees camps (Saidan et al. 2017a). However, estimated data based on assumptions are available in national strategy (MoMa 2015), regional reports (RSS 2011), and scientific literatures (Al-Hamamre et al. 2017; Aldayyat et al. 2019; Saidan et al. 2020). Few studies conducted by Fraige et al. (2012), Saidan and Tarawneh (2015), and Tarawneh and Saidan (2013) have investigated the e-waste generation in Jordan, in addition to the households awareness, behaviors, and willingness to participate in e-waste management in Jordan. However, to date there are no official data on domestic e-waste generation.

Jordan has a relatively high penetration of EEE usage, particularly electronic IT products. It is estimated that that 57% of the population own computers with an equal number in the hands of public and private sectors' organizations amounting to an estimated 7.3 million units. Similarly, mobile telephone usage is estimated to be 9 million and ownership of TVs is ~3 million. The e-waste World Map (StEP) data sheet estimates a per capita use of 8.8 kg/year and total annual consumption of 56,000 t of EEE (StEP 2014). Furthermore, it is estimated that the annual E-waste generation rate is 4.5 kg per person and the total generation rate is 30,000 t/year, which would be relatively high for most developing countries (StEP, 2014). Moreover, according to the data published by the SweepNet, the e-waste volume is estimated at 30,000 pieces per year (SweepNet 2014). Few research papers described the estimation of e-waste generation in Jordan, namely, cell phones, personal computers, TVs, refrigerators, and washing machines. Accordingly, the average amount of e-waste produced per capita indicates it is estimated to grow from 2.38 kg/capita in 2012 to 2.48 kg/capita in 2015 (Saidan and Tarawneh 2015).

With respect to e-waste itself, this is considered a hazardous waste under the Directive on Management, Transportation and Handling of Harmful and Hazardous Substances No: 24/2005 and is banned from disposal in landfills or otherwise as it may affect the environment. Under the current Ministry of Environment (MoE)/UNDP initiative, the development of a draft national e-waste policy and instructions for electrical and electronic waste management under the above regulation on hazardous waste has been prepared, which, however, was not approved yet, and needs to be upgraded. These documents are currently undergoing a consultation process with both government and external stakeholders, notably the private sector through the Chambers of Commerce and Industry. They provide a policy and development plan for a comprehensive control framework for e-waste that would potentially underpin an operational system of regulatory control, facilitation of required waste management infrastructure, and financing as required to address the issue. In particular, the draft policy document while somewhat aspirational provides a road map defining objectives and priorities, as well as, key areas where development work is required. These include: (1) a robust legal framework; (2) development of environmentally sound capacity and infrastructure, (3) financing and incentive mechanisms based on a variety of options involving tax incentives, "take-back" schemes options, source stewardship charges, and extended producer responsibility (EPR) programs; (4) life cycle approach EEE use and e-waste management inclusive of product composition control; (5) awareness and education of consumers and service providers; and (6) capacity building in support of the management system. The draft regulatory instructions include consideration of a dedicated consumption based charge on new EEE to fund e-waste collection and disposal as well as mandating EPR funding for some items, as well as a set of charges to be imposed on generators upon disposal of the WEEE, although it is not clear how practical or enforceable the latter may be.

The main objectives of the present study are to quantify the annual e-waste inventory and from surveyed households in all governorates in Jordan; evaluate its generation and disposal practices, and extrapolate the primary data to estimate the e-waste in all of Jordan. This present study also aims at exploring the challenges, barriers, and prospects of e-waste management in Jordan.

Methodology

Study Area

Waste management became one of the major environmental problems facing Jordan's municipal authorities, which has been aggravated over the past few years by the sharp increase in the volume of waste generated as well as qualitative changes in its composition. It is estimated that Jordan currently produces over 2.6 million tons of MSW per year (Saidan et al. 2017a, 2020; Al-Hamamre et al. 2017), with the sudden increase in Jordan's population, specifically due to the crisis in Syria, Syrians refugees constitute 46% of non-Jordanians living in the Jordan and 13.2% of the overall population (Alrabie and Saidan 2018; Aboelnga et al. (2018); Baldé et al. (2019); Al-Awad et al. 2018; Jabr et al. 2019; Al-Weshah et al. 2016; Saidan et al. 2017b, 2018; Khasawneh et al. 2019). Hence, this has put Jordan's public finances and expenditures under increasing strain, and affected the delivery of public solid waste management services (Saidan et al. 2019; Al-Addous et al. 2019). Only an estimated 5–10% of Jordan's MSW is being recycled at

Table 1 The total number of households in the governorates of Jordan

Governorate	Number of households
Amman	1,072,559
Balqa	121,953
Zarqa	312,170
Madaba	46,273
Irbid	400,103
Mafraq	118,974
Jarash	54,413
Ajloun	41,638
Karak	71,595
Tafiela	24,637
Ma'an	35,328
Aqaba	50,847

present (mainly plastic, paper, cardboard, and metals), with the rest being disposed of in landfills and open dumpsites, due to the absence of a formal recycling infrastructure and/or formal recycling activities (Saidan et al. 2017a; Saidan 2019). In the present study 12 governorates were considered, while the total number of households in these governorates is shown in Table 1.

Data Collection: Target Governorates and Procedure

In order to collect data for estimating WEEE generation in Jordanian governorates, a survey research was carried out between January and November 2019, with a sample of the households for the base year of 2018. For the first time, the WEEE questionnaire was added to the national standard survey forms, Department of Environmental Statistics, Jordan Department of Statistics, by implementing WEEE survey in the residential sector led by the Directorate of Family and Population Surveys team. The survey team was appropriately trained with previous experience in inquiries. The survey was targeting a number of 16,556 households in all 12 governorates in Jordan. However, the response rate was 95.94% of the targeted sample. Accordingly, of the 15,883 respondents (households), 12.52% were females, 87.48% were males, both were the heads of their household, 8% were illiterate respondents, and 55.93% had completed up to primary education,

In all, 11.31% had completed secondary education, and 22.11% had completed undergraduate education (diploma and bachelor degrees), and only 2.64% had completed postgraduate education (masters and PhD degrees).

The survey questionnaire is designed to collect information on WEEE disposal behaviors. Each question in questionnaire was applied to each type of EU-6 categories: 6 categories of EEE and set out in Annex III of the WEEE Directive 2012/19/EU, and 16 United Nations University (UNU) items were selected in the present study out of the 54 items of EEE developed by the UNU (Baldé et al. 2017; Shaikh et al. 2020).

The variables measured through the survey include the e-waste quantities and disposal behavior, which are then extrapolated to the population of Jordan using of ArcGIS mapping. Based on the primary data received from the preliminary survey, the present study employed a more comprehensive approach of extrapolation using adopted methodology in the Department of Statistics in Jordan, which is based on the socio-economic parameters such as gender, urbanization index, groups income levels, and the population.

Results and Discussion

Some e-waste parts have market values in Jordan associated to different e-waste component—like for instance memory cards, chargers, cardboard from mobile phones have the highest market value, followed by cardboard from other communication equipment, copper from cables, steel and aluminum from frames. Informal collectors very often dismantle by hand the wasted electronic equipment, simply dump the low-value component and sell the high value component to operators who, in turn, sell these components to international recyclers. In this way, the environmental costs are fully externalized and the income generate by the recycling of e-waste does not translate in any benefit for the environment or the society. This environmental cost must be internalized into the overall e-waste management and the sustainability of the e-waste management chain, through sound e-waste regulation establishment and enforcement. Hence, this can make the entire e-waste management chain sustainable and profitable.

The results of the present study revealed that Jordan is a throwaway society, based on the consumers' respective consumption, attitudes, and disposal behaviors (Bovea et al. 2017); e-waste (re)using and repairing patterns (Sabbaghi and Behdad 2018); and available (in)formal recycling activities.

Survey Data Collection

Data were collected via face-to-face interviews at each household. The respondents were limited to household dwellers over 18 years of age. Preference was given to the housewife and/or to the household head. In total, persons lived in the 15,883 surveyed households, with an average of 4.9 persons/household. According to Fig. 1, the most targeted households in the 12 governorates in the present study were in Amman (30%); Irbid (13%); Zarqa (12%); Mafraq (7%); Ajloun and Karak governorates per each (6%); Balqa, Jerash, and Aqaba governorates per each (5%); Madaba and

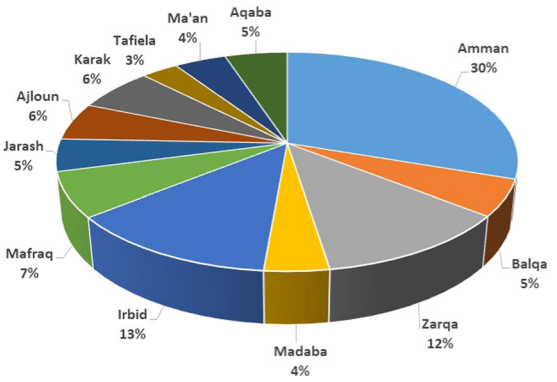


Fig. 1 Percentages of targeted and responded households distributed in the 12 governorates

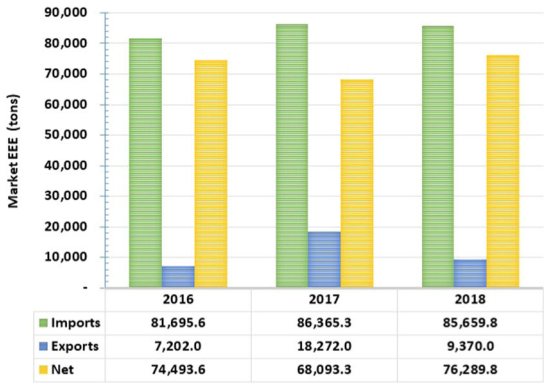


Fig. 2 Annual in-use EEE in the Jordanian market

Ma'an governorates per each (3%); and Tafiela was identified to be the least targeted governorate in the present survey with (3%).

Annual In-use EEE in Local Market

On average, a new net of 76.2 ktons of EEE are annually inserted into the market for the 2,350,490 households in Jordan in 2018, as shown in Fig. 2.

Approximately 15,776,489 of EEE items are in-use in Jordan according to the data published by the Department of Statistics in Jordan in 2019 for the base year of 2018. Hence, considering the total households in Jordan, 6.7 EEE items/household is identified as mean acquired EEE items per household. The most common types of EEE were televisions, refrigerators, and washing machine, with averages of one item/household, respectively. Other common types of EEE included smartphones, water heater (gas or electrical), vacuum cleaner, each with averages of 0.7–0.9 items/household. It is clear that refrigerator is the most common EEE items in-use (15%), then TV (14%), washing machine (14%), smart phone (14%), water heater (12%), and vacuum cleaner (10%), etc.

Surveyed Sample Data Analysis

E-waste estimation

A total of 61,748 EEE items (105 t) had been turned into e-waste and discarded by 15,883 households in the year preceding the survey (2018), as shown in Table 2. The average EEE waste generation indicators for the total households were 3.89 items/household and 6.63 kg/household. The total number of items and total weight of each category in Jordan are shown in Table 2 for the surveyed 15,883 households in the present study.

Special lamps, straight tube fluorescent lamps, and compact fluorescent lamps were the most commonly discarded EEE items, representing 34%, 30%, and 24%, respectively, of the total discarded appliances, followed by mobile phones (3%), toys (2%), and other small household equipment (2%), as shown in Fig. 3a. However, in terms of weight representation, washing machines and kitchen equipment were the most commonly discarded EEE appliances amounts, representing 49% and 34%, respectively, followed by flat display panel TVs (5%), while the other EEE categories were between <1 and 2%, as shown in Fig. 3b.

Figure 4 shows the discarded EEE percentages according to each governorate in Jordan. However, in total 16 dishwashers were discarded in Jordan in 2018, which represents 692.8 kg. The most discarded dishwashers (UNU Key 102) were generated from Amman with 31% (weight %), which represents 216.5 kg generated from the surveyed households in 2018. While Balqa and Jarash were equal to each other in terms of generated dishwashers waste with 19% (129.9 kg for each governorate), followed by Irbid (13%). Mafraq, Zarqa, and Ma'an governorates were the least discarded dishwashers' generators with 6% (43.3 kg for each governorate).

In total, 760 kitchen machines (e.g., large furnaces, ovens, and cooking equipment) were discarded in Jordan in 2018, which represents 36221.6 kg. The most discarded kitchen equipment (UNU Key 103) were generated from Irbid with 17% (weight %), which represents 6291.1 kg generated from the surveyed households in 2018. Followed by Amman with 13% (4718.3 kg), 12% in both Zarqa and Aqaba (4384.7 kg for each), and 10% Karak (3479.2 kg). Ma'an, Mafraq, and Jarash governorates were close to each other's with 9% (3336.2 kg), 8% (2811.9 kg), and 7% (2573.6 kg), respectively.

In total, 709 washing machines (incl. combined dryers) were discarded in Jordan in 2018, which represents 51,430.9 kg. The most discarded washing machines (UNU Key 104) were generated from Amman with 20% (weight %), which represents 10,301 kg generated from the surveyed households in 2018. Followed by Irbid with 16%

Table 2 Distribution of waste EEE, by category, for the surveyed 15,883 households in Jordan

UNU Key	Description	EU-6	Description	# of items	Average weight (kg)	Weight (kg)
102	Dishwashers	4	Large equipment	16	43.3	692.8
103	Kitchen equipment (e.g., large furnaces, ovens, cooking equipment)			760	47.66	36,221.6
104	Washing machines (incl. combined dryers)			709	72.54	51,430.9
111	Air conditioners (household installed and portable)	1	Temperature exchange equipment	82	26.7	2189.4
201	Other small household equipment (e.g., small ventilators, irons, clocks, adapters)	5	Small equipment	1207	0.99	1194.9
202	Equipment for food preparation(e.g., toaster, grills, food processing, frying pans)			384	3.27	1255.7
203	Small household equipment for hot water preparation (e.g., coffee, tea, water cookers)			288	1.89	544.32
303	Laptops (incl. tablets)	2	Screens, monitors, and equipment containing screens (…)	120	1.26	151.2
306	Mobile phones (incl. smartphones, pagers)	6	Small IT and telecommunication equipment	1649	0.09	148.4
309	Flat display panel monitors (LCD, LED)	2	Screens, monitors, and equipment containing screens (…)	215	5.5	1182.5
408	Flat display panel TVs (LCD, LED, plasma)			486	10.2	4957.2
502	Compact fluorescent lamps (incl. retrofit and non-retrofit)	3	Lamps	15,096	0.08	1207.7
503	Straight tube fluorescent lamps			18,386	0.11	2022.5
504	Special lamps (e.g., professional mercury, high- and low-pressure sodium)			20,977	0.07	1468.4
701	Toys (e.g., car racing sets, electric trains, music toys, biking computers, drones)	5	Small equipment	1330	0.45	598.5
801	Household medical equipment(e.g., thermometers, blood pressure meters)			43	0.18	7.8
Total				61,748		105,273.7

(8052 kg). While Zarqa, Karak, Ma'an, and Mafraq were close to each other in terms of generated waste with 11% (5585.6 kg), 10% (5150.3 kg), 9% (4642.6 kg), and 9% (4932.7 kg), respectively. Aqaba, Jarash, Tafiela, and Ajloun governorates were the least discarded dishwashers' generators with 4–6% (2466.4–2974.2 kg).

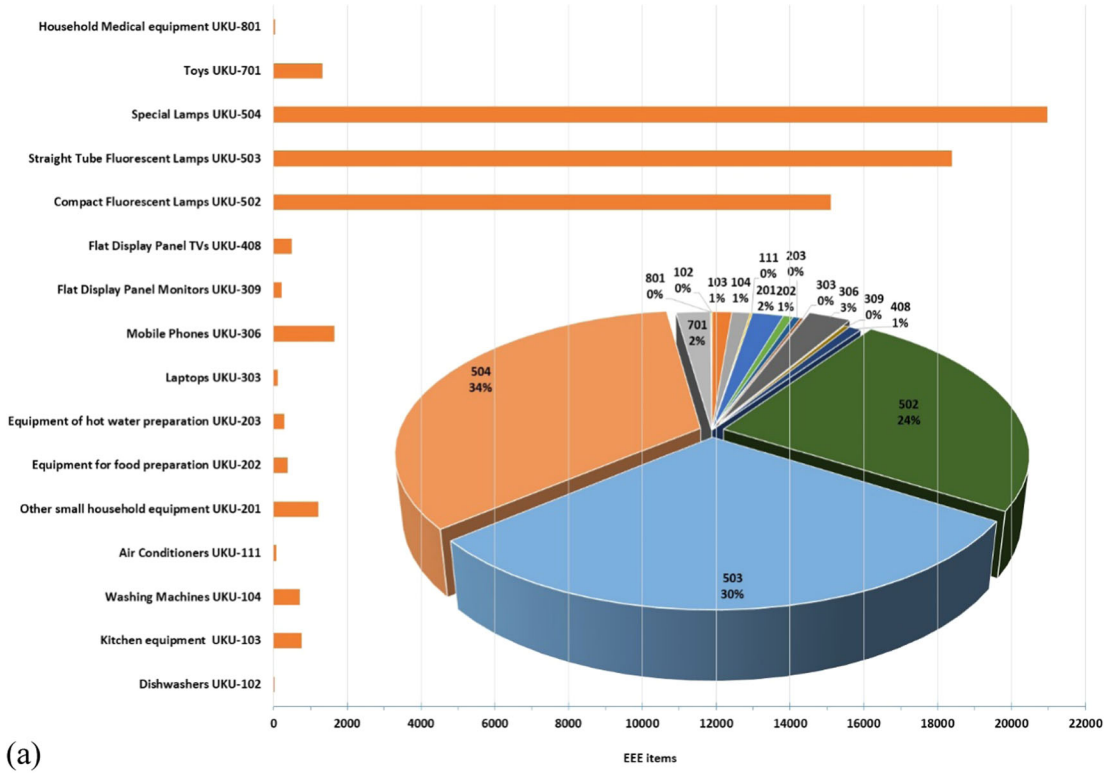
In total, 82 air conditioners (household installed and portable) were discarded in Jordan in 2018, which represents 2189.4 kg. The most discarded air conditioners (UNU Key 111) were generated from Zarqa with 34% (weight %), which represents 747.6 kg generated from the surveyed households in 2018. Followed by Aqaba with 16% (480.6 kg), and Amman with 13% (293.7 kg). While Karak, Ma'an, Ajloun, Irbid, and Jarash were close to each other in terms of generated air conditioners waste with 6% (133.5 kg), 6% (133.5 kg), 5% (106.8 kg), 4% (80.1 kg), and 3% (53.4 kg), respectively. Madaba, Mafraq, and Tafiela governorates were the least discarded dishwashers' generators with 1% for each (26.7 kg).

In total, 1207 of other small household equipment (e.g., small ventilators, irons, clocks, and adapters) were discarded in Jordan in 2018, which represents 1194.9 kg. The other small household equipment (UNU Key 201) were surveyed in the present study. The most discarded appliances from this category were generated from Amman with 18% (210.9 kg), 15% in Irbid (178.2 kg), 13% in Zarqa (157.4 kg), 12% in Ma'an (140.6 kg), and 10% in Ajloun (122.8 kg). Followed by equal percentages in both Mafraq and Jarash with 7% each (83.2–89.1 kg), and 6% for each governorate of Karak and Aqaba (67.3–76.2 kg for each).

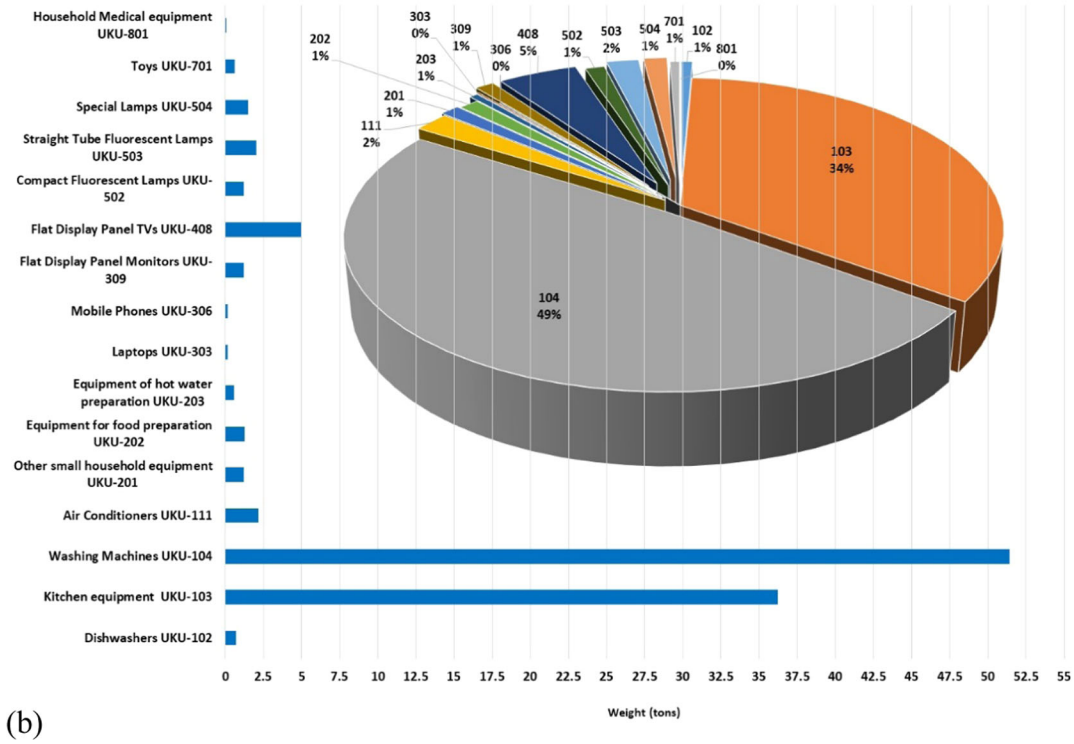
In total, 384 equipment for food preparation (e.g., toaster, grills, food processing, and frying pans) were discarded in Jordan in 2018, which represents 1255.7 kg. The most discarded equipment for food preparation (UNU Key 202) were drastically generated from the surveyed households in Amman with 66%, which represents 820.4 kg. Followed by 8% in Aqaba (104.7 kg), 6% in Irbid (81.8 kg), 5% in Ma'an (58.9 kg), and <3% in other governorates.

In total, 288 small household equipment (e.g., coffee, tea, and water cookers) were discarded in Jordan in 2018, which represents 544.32 kg. The most discarded small household equipment for hot water preparation (UNU Key 203) were generated from Amman with 37%, which represents (202.2 kg). Followed by 15% in Ma'an (81.3 kg), 13% in Tafiela (71.8 kg), and 10% in Karak (52.9 kg). While Zarqa, Irbid, and Aqaba were equal to each other in terms of generated dishwashers waste with 6–7% (34.0–37.8 kg). The percentages of this category in other governorates were 1–2% for each.

In total, 120 laptops (incl. tablets) were discarded in Jordan in 2018, which represents 151.2 kg. The most discarded laptops (UNU Key 303) were generated from



(a)



(b)

Fig. 3 Amounts and percentages of discarded EEE items: **a** in number of items and **b** in weight representation

Amman with 35%, which represents 52.9 kg, and 27% in Irbid (40.3 kg). Followed by 11% in Zarqa (16.4 kg), 9% in Karak (13.9 kg), and 5% in Balqa (7.6 kg). The percentages of this category in other governorates were 1–2% for each.

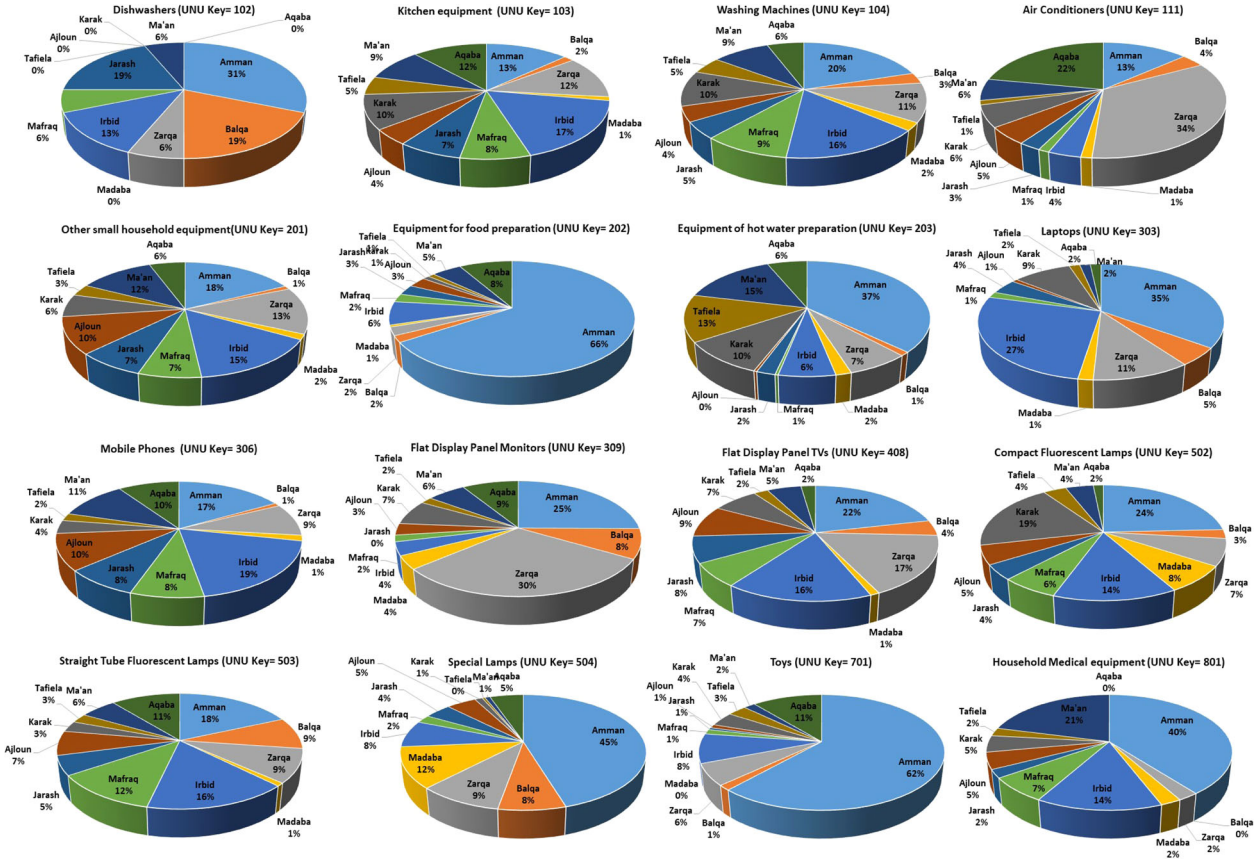


Fig. 4 Distribution of discarded EEE, by category, for the surveyed 15,883 households in Jordanian governorates

In total, 1649 mobile phones (incl. smartphones, pagers) were discarded in Jordan in 2018, which represents 148.4 kg. The most discarded mobile phones (UNU Key 306) were generated from Irbid with 19%, which represents 28.0 kg, and 17% in Amman (25.0 kg). Followed by 11% in Ma'an (16.1 kg), 10% in both Ajloun and Aqaba (15.0 kg for each), and 8% in both Jarash and Mafraq (12.2 kg for each). The percentages of this category in other governorates were 2–4% for each.

In total, 215 flat display panel monitors (LCD and LED) were discarded in Jordan in 2018, which represents 1182.5 kg. The most discarded flat display panel monitors (UNU Key 309) were generated from Zarqa with 30%, which represents 357.5 kg, and 25% in Amman (297.0 kg). Followed by 9% in Aqaba (104.5 kg), 8% in Balqa (99.0 kg), 7% in Karak (82.5 kg), and 6% in Ma'an (71.5). The percentages of this category in other governorates were 2–4% for each.

In total, 486 flat display panel TVs (LCD, LED, and plasma) were discarded in Jordan in 2018, which represents 4957.2 kg. The most discarded flat display panel TVs (UNU Key 408) were generated from Amman with 22%, which represents 1060.8 kg, 17% in Zarqa (846.6 kg) and 16% in Irbid (805.8 kg). Followed by 9% in Ajloun (438.6 kg), 8% in Jarash (367.2 kg), 7% in both Mafraq and Karak (326.4–357.0 kg), 5% in Ma'an (265.2 kg), and 4% in Balqa (214.2 kg). The percentages of this category in other governorates were 1–2% for each.

In total, 15,096 compact fluorescent lamps (incl. retrofit and non-retrofit) were discarded in Jordan in 2018, which represents 1207.7 kg. The most discarded compact fluorescent lamps (UNU Key 502) were generated from Amman with 24%, which represents 292.9 kg, 19% in Karak (230.0 kg) and 14% in Irbid (166.0 kg). Followed by 8% in Madaba (90.9 kg), 7% in Zarqa (90.4 kg), 6% in Mafraq (77.5 kg), 5% in Ajloun (63.5 kg), and 4% on average for each governorate of Tafiela, Ma'an, and Jarash (43.9, 52.7, and 63.5 kg, respectively). The percentages of this category in other governorates were 2–3% for each.

In total, 18,386 straight tube fluorescent lamps were discarded in Jordan in 2018, which represents 2022.5 kg. The most discarded straight tube fluorescent lamps (UNU Key 503) were generated from Amman with 18%, which represents 369.8 kg, 16% in Irbid (324.2 kg), 12% in Mafraq (240.5 kg), 11% in Aqaba (220.0 kg), and 9% in both Balqa and Zarqa (181.0–191.0 kg). Followed by 7% in Ajloun (138.8 kg), 6% in Ma'an (115.8 kg), and 5% in Jarash (109.1 kg). The percentages of this category in other governorates were 1–3% for each.

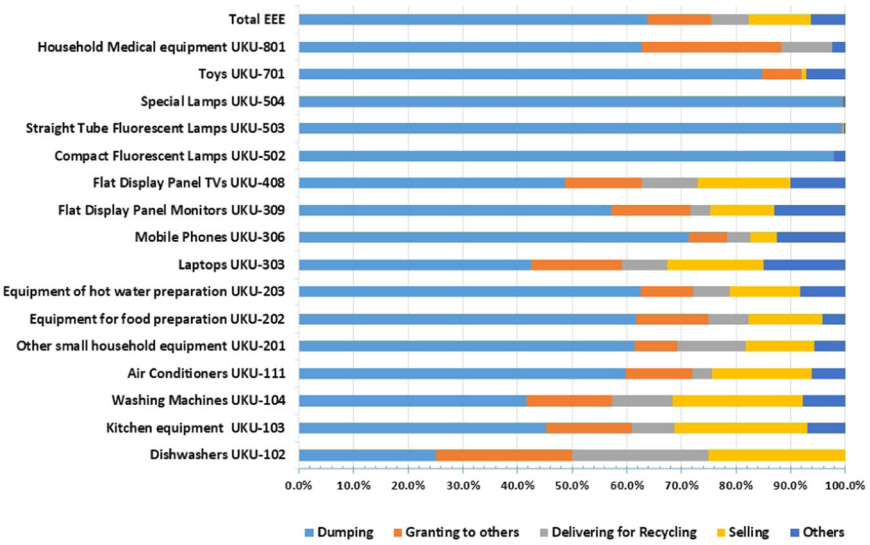


Fig. 5 Percentages of disposal methods of discarded EEE, by category, for the surveyed 15,883 households in Jordan

In total, 20,977 special lamps (e.g., professional mercury, high- and low-pressure sodium) were discarded in Jordan in 2018, which represents 1468.4 kg. The most discarded special lamps (UNU Key 504) were mainly generated from Amman with 45%, which represents 665.4 kg. Followed by 12% in Madaba (168.0 kg), 9% in Zarqa (138.0 kg), 8% in both Balqa and Irbid (109.4–111.0 kg), 5% in both Ajloun and Aqaba (68.5–77.2 kg), and 4% in Jarash (62.0 kg). The percentages of this category in other governorates were 1–2% for each.

In total, 1330 toys (e.g., car racing sets, electric trains, music toys, biking computers, and drones) were discarded in Jordan in 2018, which represents 598.5 kg. The most discarded toys (UNU Key 701) were overwhelmingly generated from Amman with 62%, which represents 368.6 kg. Followed by 11% in Aqaba (65.7 kg), 8% in Irbid (49.5 kg), 6% in Zarqa (36.0 kg), and 4% in Karak (23.9 kg). The percentages of this category in other governorates were 1–3% for each.

In total, 43 household medical equipment (e.g., thermometers and blood pressure meters) were discarded in Jordan in 2018, which represents 7.8 kg. The most discarded household medical (UNU Key 701) were mainly generated from Amman with 40%, which represents 3.1 kg, and 21% in Ma'an (1.6 kg). Followed by 14% in Irbid (1.1 kg). The amounts of this category in other governorates < 1 kg for each.

Disposal behavior

Possible disposal methods of used equipment (e-waste) in Jordan were explored in the present study. The results showed that dumping of the dysfunctional equipment was overwhelmingly prevalent in all governorates in Jordan (63.8% on average), as part of MSW. Followed evenly by granting the categories to others (11.5% on average) and selling these categories (11.4% on average). Moreover, delivering the equipment to recycling shops was practiced by households with 6.9% on average, while other methods (i.e., storage or give it away to other households as a gift without selling for reuse) were practiced with 6.4% on average

The dominant disposal methods of the categories of equipment were investigated. Figure 5 shows the most dominant disposal methods of e-waste. Hence, dumping of waste EEE is dominant in all governorates (91.7–99.0%), and for all e-waste categories, where it ranges between 25% in dishwashers and 98.9% on average for all types of lamps. Notwithstanding that the mobile phones and laptops have intrinsic values, which people tend to store them (Shaikh et al. 2020), but this was not the case in Jordanian governorates, and such waste categories were ended up in dumping sites with 71.4% and 42.5%, respectively. The second dominant disposal method was granting the categories to others, which was mainly practiced in Amman (2.1%), Irbid (1.7%), and Aqaba (1.2%). This granting to others disposal method was mostly noticed in dishwashers and household medical equipment with 25% and 25.6%, respectively. The least common granting the categories to others was noticed for all types of lamps (0.1%). The third common disposal method was selling of the equipment to local electronic equipment shops or waste collector, friends, neighbors, and family members. This selling practice is very common in governorates of Tafiela (5.9%), Irbid (2.9%), and Jarash (2.5%). The selling of the equipment was mainly found in three categories of dishwashers, kitchen equipment, and washing machines with 25%, 24.2%, and 23.8%, respectively. Followed by the selling of air conditioners, laptops, and flat display panel TVs with 18.3%, 17.5%, and 16.9%, respectively. Excluding, all types of lamps and toys, the least common selling categories were household

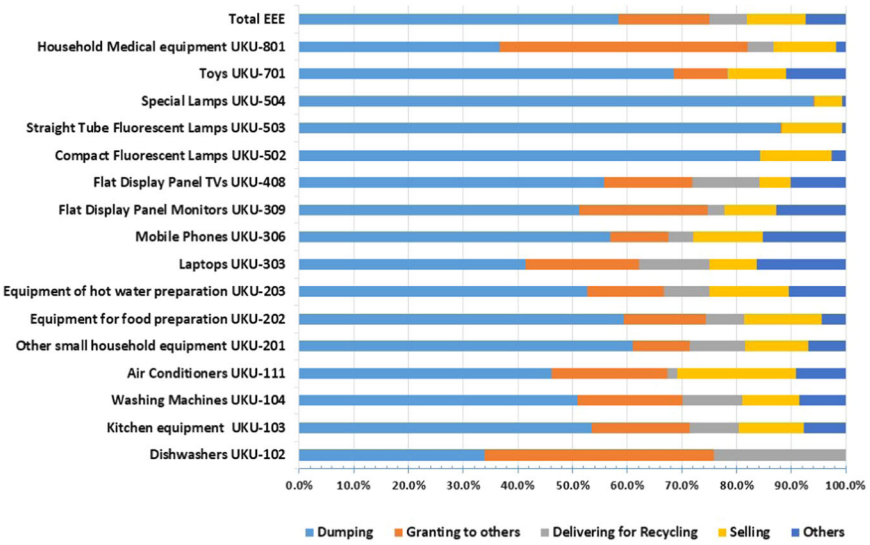


Fig. 6 Percentages of disposal methods of discarded EEE, by category, in Jordan

medical equipment (11.4%), and flat display panel monitors (11.6%). The fourth common disposal method was delivering for recycling to local dismantling for valuable parts recovery shops. These shops are normally functioning as repairing shops of EEE in general. The delivering for recycling practice was popular for all EEE in Ma'an (3.7%), Jarash (1.5%), and Ajloun (1.4%). The most common categories that were delivered for recycling by the surveyed households were dishwashers (25%), other small household equipment (12.6%), washing machines (11.1%), and flat display panel TVs (10.3%). Other disposal method of categories was the least reported method practiced by the surveyed households mainly in Zarqa (4.5%), Amman (3.6%), Tafiela (1.5%), and Balqa (1.2%). The most common categories which were disposed by other methods (i.e., storage, or give it away to other households as a gift without selling for reuse) were laptops (15%), flat display panel monitors (13%), and mobile phones (12.4%) (Fig. 6).

E-waste Inventory and Disposal Methods: Extrapolated Estimates

The extrapolated estimates of the e-waste in Jordan are shown in Table 3. A total of 8,735,187 EEE items (~13 ktons) had been turned into e-waste and discarded by 2,350,490 households in the year preceding the survey (2018), as shown in Table 3. The average EEE waste generation indicators for the total households in Jordan (after extrapolation) were 3.72 items/household and 5.72 kg/household. Furthermore, the e-waste generation per capita is relatively low when compared to other countries in MENA countries such as Egypt (5.4 kg/capita), Algeria (7.1 kg/capita), and Africa in general (on average 1.9 kg/capita) (Forti et al. 2018; Gollakota et al. 2020), as shown in Table 4. Jordan is approximately similar to the Philippines, Vietnam, and relatively higher than Cambodia, Lao PDR, and Myanmar, in the rate of e-waste generation per capita (Baldé et al. 2015, 2017; UNEP 2017; Ismail and Hanafiah 2019).

In general, most of those countries with high generation rate of e-waste per capita are having stringent institutional frameworks of EPR system on e-waste (i.e., especially South Korea, Taiwan, and Japan) (Zeng et al. 2017), or in the process to adopt the EPR system that mandates the producers to be responsible for the operations and financing of e-waste take-back and responsibility system (Garlapati 2016).

Washing machines and kitchen equipment were the most commonly discarded EEE items in terms of weight, representing 50.25% (6757 t) and 32.12% (4318 t), respectively, of the total discarded appliances, as shown in Table 3. Followed by the flat display panel TVs with 4.76% (639 t), while the other EEE categories weights were between 0.01 and <2%, which all in total represented 1731 t.

Figure 7 shows the total discarded EEE percentages according to each governorate in Jordan after data extrapolation. With 46.1%, which represents 4,029,712 EEE items, Amman ranks first in the list of e-waste generating governorates in the country, followed by Irbid with 17.6% (1,539,718 EEE items) and Zarqa with 9.4% (821,414 EEE items). Balqa and Mafraq were equal to each other in terms of generated EEE waste with 5.3% and 5.1% (466,127 and 449,777 EEE items), respectively. While the least discarded EEE percentages were in Karak (3.6%), Aqaba (3.3%), Madaba (2.8%), Jarash (2.6%), Ajloun (201%), Ma'an (1.3%), and Tafiela (0.6%).

After data extrapolation, dumping of e-waste is still the dominant disposal method practiced by 58.4% of households in Jordan. Followed by the disposal practice of

Table 3 Distribution of waste EEE, by category and households disposal methods, in Jordan

UNU Key	Description	Weight (tons)	Quantity (#)	Disposal method (quantities)				
				Dumping	Granting to others	Delivering for recycling	Selling	Others
102	Dishwashers	149.98	3464	1177	1449	838	0	0
103	Kitchen equipment	4318.65	90,614	48,529	16,148	8233	10,783	6920
104	Washing machines	6756.99	93,147	47,425	17,851	10,171	9769	7931
111	Air conditioners	159.80	5985	2764	1269	105	1302	545
201	Other small household equipment	152.65	154,196	94,121	15,922	15,816	17,850	10,487
202	Equipment for food preparation	229.05	70,046	41,545	10,499	5020	9892	3091
203	Equipment of hot water preparation	77.98	41,261	21,736	5816	3432	5963	4314
303	Laptops	23.14	18,365	7607	3803	2357	1592	3005
306	Mobile phones	19.54	217,155	123,490	23,027	10,204	27,381	33,052
309	Flat display panel monitors	159.88	29,069	14,908	6798	893	2750	3721
408	Flat display panel TVs	639.58	62,704	35,005	10,127	7665	3532	6374
502	Compact fluorescent lamps	175.21	2,190,171	1,845,730	381	82	284,601	59,376
503	Straight tube fluorescent lamps	260.03	2,366,452	2,084,610	3545	1337	261,702	15,259
504	Special lamps	221.14	3,159,196	2,970,618	7744	512	161,148	19,174
701	Toys	101.75	226,109	15,5021	21,925	270	24,135	24,759
801	Household medical equipment	1.31	7254	2661	3286	346	824	136
Total		13,446.87	8,735,187	7,496,946	149,590	67,283	823,225	198,143

granting the waste EEE to others (16.6%), then the selling practice with 10.7% share. However, others practices represented 7.4%, and delivering the waste EEE for recycling practice represented 6.8% of the households' disposal behavior in Jordan.

It is noteworthy that the 6.8% of households' responses are stressing the need of the society to have proper recycling facility with ensured environmentally sound operation. Moreover, this recycling percentage can be increased by several regulatory measures, viable collection system based on incentive scheme, and feasible business model, as discussed in section "E-waste Management Capacity: Prospects and Barriers."

For instance, the recycling facility can be a mini-hub for processing of e-waste received from different cities in Jordan and the region, and has the ability to receive quantities of e-waste and related product (i.e., branded or of a sensitive nature for assured, secure, compliant destruction through sound environmental processes).

E-waste Management Capacity: Prospects and Barriers

Jordan still faces continuing challenges and barriers related to solid and hazardous waste management. Notwithstanding that Jordan has developed an effective basic legislative and regulatory framework for waste management generally, this remains somewhat fragmented, contains gaps, and is limited in practice by enforcement capacity deficits. An integrated overall waste management policy that encompasses all critical waste streams is yet to be implemented and specifically with respect to placing appropriate emphasis on waste minimization and diversion consistent with global trends, although a solid foundation for this is emerging in the form of a National Solid Waste Management Strategy that was approved in 2015. With the exception of e-waste and other hazardous waste, this is reflected in a lack of targeted effort on specialty waste streams that could realistically be diverted with significant economic benefits. Particularly, for e-waste there remain significant capacity, quality, and infrastructure deficits that limit the effectiveness of efforts in this area. Key to having an effective overall waste management policy supporting a modern diversion strategy is the policy adoption and implementation of sustainable economic instruments and financial mechanisms to provide market-driven incentives that are endorsed and taken up by the principle stakeholders in the public and private sectors.

Moreover, at present there is no operational regulation and technical guidance on the actual management activities of e-waste that would both set minimum standards for these

Table 4 Comparison of e-waste generation per capita with countries (2014–2017)

Country	Per inhabitant generation (kg/capita)	References
Brunei Darussalam	18.1–18.3	Baldé et al. (2015, 2017), UNEP (2017), Ismail and Hanafiah (2019)
Cambodia	0.9–1.0	
Indonesia	3.0–4.9	
Lao PDR	1.0–1.2	
Malaysia	7.6–8.8	
Myanmar	0.4–1.0	
The Philippines	1.3–2.8	
Singapore	17.9–19.6	
Thailand	6.4–7.4	
Vietnam	1.3–1.5	
Africa	1.9	Gollakota et al. (2020), Forti et al. (2018)
Asia	4.2	
America	11.6	
Europe	16.6	
Egypt	5.4	
Algeria	7.1	
China	5.2	
Japan	16.6	
Jordan	1.33	Present study

activities, as well as, promote the evolution from unregulated informal activities to a modern, economically scaled and environmentally sound capability serving national needs. Hence, there is a need to have appropriate regulatory direction for e-waste management that clearly assigns responsibility for the costs something that generally involves participation of producers, distributors, and retailers. In addition, there is a need for practical regulatory guidance on the implementation of segregation, collection, and processing of this waste stream. Being hazardous waste, all stages require some form of regulation and licensing under national regulations.

A business model that is capable to sustain a financing collection and processing of e-waste is needed. This can be ensured by developing of viable e-waste diversion system in compliance with environmentally sounded management standards. Moreover, the current informal system of e-waste collection shall be progressively eliminated and integrated into the formal sector by introducing initial incentives for informal collectors, in addition to providing seed capital for environmentally sound processing of e-waste in the formal sector. This can be accomplished by some combination of an EPR system where the private sector supply chain pays and/or a system that applies state mandated incremental charges at point of sale of these products that generate a fund to cover waste management costs.

It is noteworthy that the e-waste revenue generation can be substantial when reasonable economies of scale are achieved. Jordan is a relatively small generation country with limited market for recovered resources, therefore, sustaining revenue for service providers is only likely achievable for primary processing with the components of value being exported to an international market for final processing. There will be a shortfall typically involving the collect and first transport components of the supply chain. That gap needs to be filled by an external source of revenue that ultimately ends up being reflected in the cost of sale of the originating product (i.e., waste management costs are internalized consistent with a life cycle approach). Alternatively, it could be done simply by public subsidy (government budget or external grants) but this is not generally considered an option except early in a program to demonstrate it. The mechanism which is favored by the MoE is an incremental charge collected remitted at the retail level on sales of EEE or a similar charge applied to producers/importers/distributor/retailer. Parallel to that, there is a need to support competitively selected proposal from private sector or municipal service providers to develop basic primary processing facilities, including those already entering the business. Typically, this would involve dismantling facilities inclusive of input segregation and separation into dismantling lines and accumulation of marketable materials having optimum value in onward processing. This would include equipment for steps such as mechanical wire stripping, size reduction and packaging of plastic residuals in a form suitable for recycling, and classification of printed circuit boards as a marketable commodity.

The hazardous waste management sector in general has significant shortfalls in terms of technical capacity and infrastructure. At present, there is very limited organized processing capability related to e-waste and what exists is primarily in the growing informal sector. Given the growth in generation, this situation will increase in the absence of environmentally sound collection and primary processing. Associated with this is the need for human resource technical capacity strengthening to operate new environmentally sound facilities as they become available. Moreover, it is recommended that the current limited voluntary collection system available to the public, largely based on the placement of accessible collection containers at secure but accessible locations, should be expanded and supported. In addition, more focus shall be primarily on the institutional sector but on large private sector organizations that potentially generate significant quantities. In this case, collection infrastructure would be based within large institutions such as government offices, university and military facilities, utilizing the IT

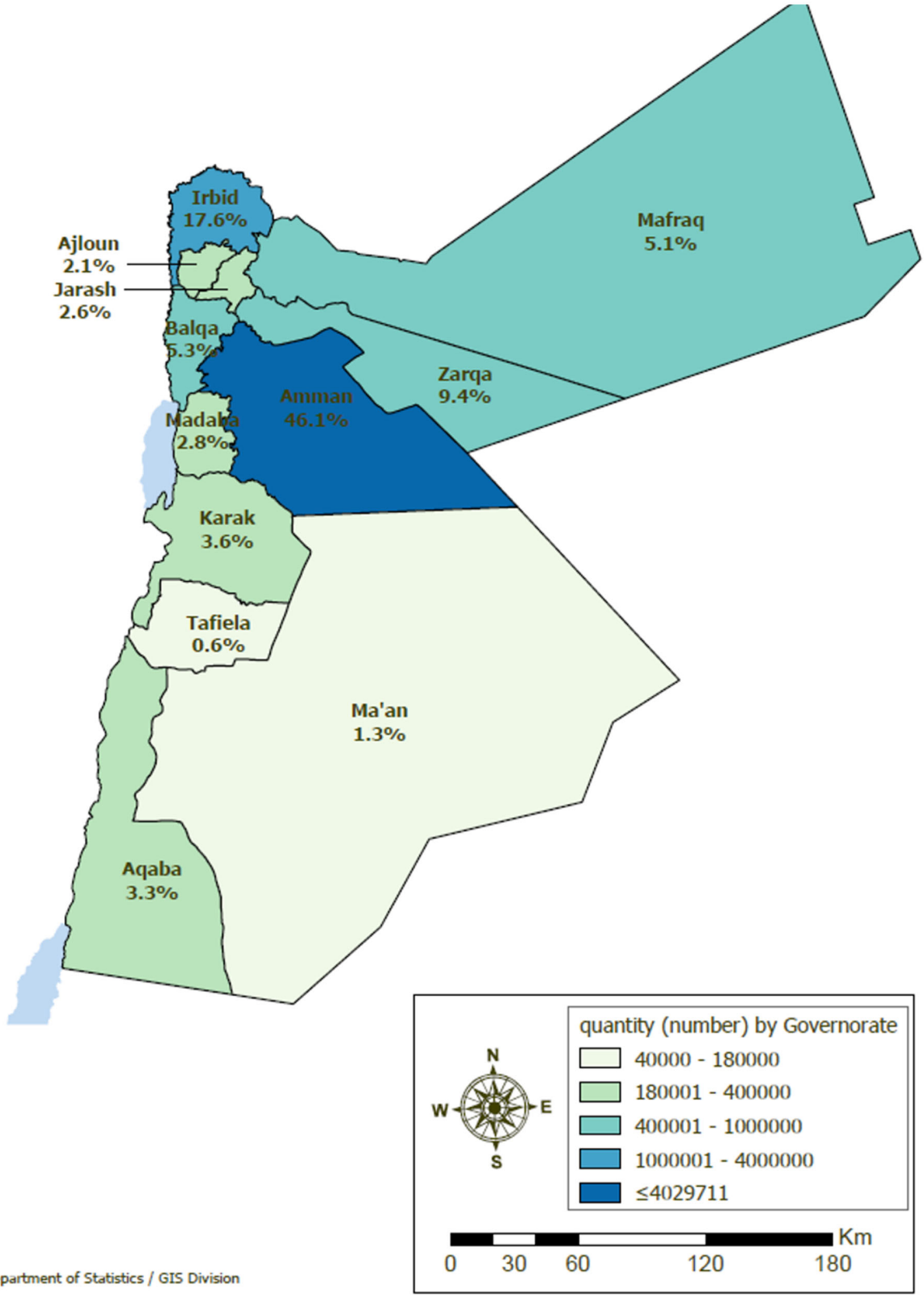


Fig. 7 Distribution of discarded EEE quantities percentages, by governorates, in Jordan using GIS mapping

equipment supply and facility management services in those organizations.

The public awareness and acceptance of the need to selectively separate and direct the e-waste to a dedicated environmentally sound system is critical for its successful implementation. This applies to the public but also across all stakeholder groups including those in the original product supply chain and service providers. Thus, additional public awareness activities are encouraged to be conducted through MoE, municipalities, and service providers, and developed and delivered in the form of conventional media and dissemination factual documents but will also utilize web-based and social media tools.

However, the present study has played a vital role in e-waste awareness dissemination since the findings of the present study have been modeled and shown online via internet-based web by the Department of Statistics, Jordan through the link (https://arcg.is/1KzvjO), as shown in Fig. 8.

Conclusions

Quantification of e-waste generation quantities and disposal methods investigation was carried out through survey of 15,883 households in 12 governorates in Jordan in the present study. The survey-based data collected from the study sample have been extrapolated to quantify an e-waste generation inventory for all of Jordan (2,350,490 households) and the disposal methods. The e-waste were considered in the study based on the European Union Directive including six main categories (16 UNU Key items) classification.

A total of 8,735,187 EEE items (~13 ktons) had been turned into e-waste and discarded by in 2018. Washing machines and kitchen equipment were the most commonly discarded EEE items in terms of weight, representing 50.25% (6756 t) and 32.12% (4318 t), respectively, of the total discarded appliances. The average EEE waste generation indicators for the total households were 3.72 items/household and 5.72 kg/household. Amman ranks first in the list of e-waste generating governorates in Jordan with 46.1% (4,029,712 EEE items), followed by Irbid with 17.6% (1,539,718 EEE items) and Zarqa with 9.4% (821,414 EEE items).

The main methods of disposal in Jordan are identified where dumping of e-waste is still the dominant disposal method practiced by 58.4% of households in Jordan. Followed by the disposal practice of granting the waste EEE to others (16.6%), then the selling practice with 10.7% share. However, others practices represented 7.4%, and delivering the waste EEE for recycling practice represented 6.8% of the households' disposal behavior in Jordan.

Moreover, the present study has played a vital role in e-waste awareness dissemination since the findings of the present study have been modeled and shown online by the Department of Statistics, Jordan through the link (https://arcg.is/1KzvjO). The analyzed data were also modeled using ArcGis mapping in order to facilitate the decision support system for the policymakers relevant to e-waste management and treatment (take-back system, sorting as source,

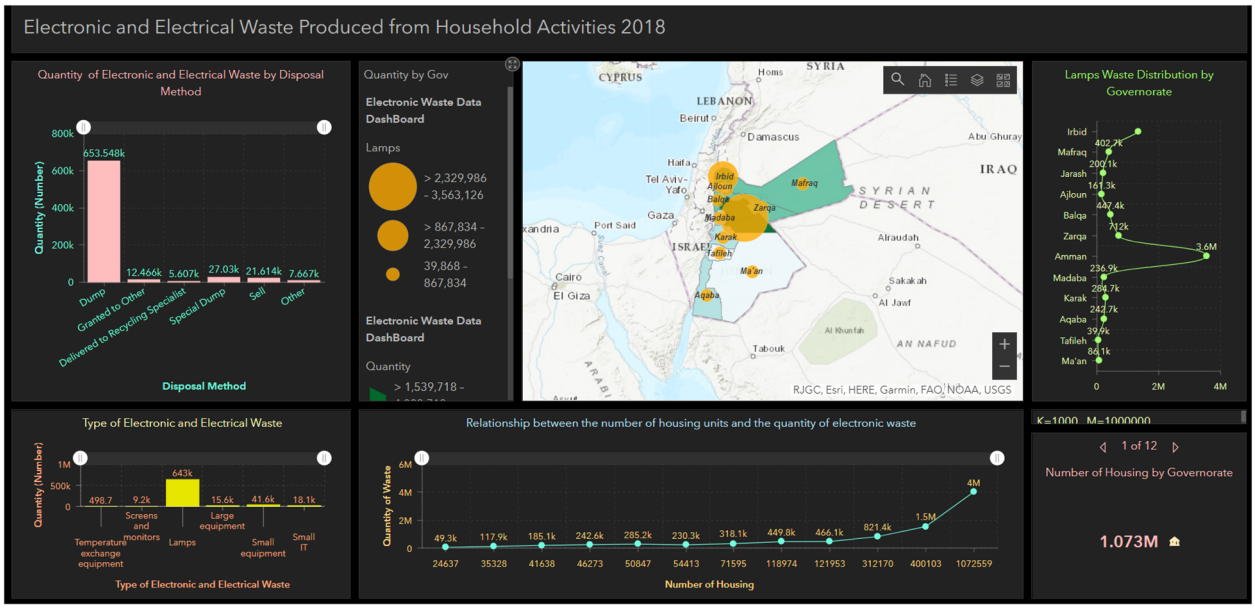


Fig. 8 Online Discarded EEE from all households in Jordan (https://arcg.is/1KzvjO)

collection, recycling and recovery facility siting, etc.), and improve the convenience on formal disposal, as well as, other suitable initiatives.

E-waste management barriers and challenges in Jordan have been discussed in the present study. A business model that is capable to sustain a financing collection and processing of e-waste is needed. This can be ensured by developing of viable e-waste diversion system in compliance with environmentally sounded management standards.

Acknowledgements The authors are thankful to the Department of Statistics, Jordan for their remarkable support during the compilation of this research data.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Abbondanza MNM, Souza RG (2019) Estimating the generation of household e-waste in municipalities using primary data from surveys: a case study of Sao Jose dos Campos, Brazil. Waste Manag 85:374–384

Aboelnga H, Saidan M, Al-Weshah R, Sturm M, Ribbe L, Frechen FB (2018) Component analysis for optimal leakage management in Madaba, Jordan. J Water Supply Res Technol 67 (4):384–396

Al-Addous M, Saidan MN, Bdour M, Alnaief M (2019) Evaluation of biogas production from the co-digestion of municipal food waste and wastewater sludge at refugee camps using an automated methane potential test system. Energies 12:32

Al-Awad TK, Saidan MN, Gareau BJ (2018) Halon management and ozone-depleting substances control in Jordan. Int Environ Agreem 18(3):391–408

Alrabie K, Saidan MN (2018) A preliminary solar-hydrogen system for Jordan: impacts assessment and scenarios analysis. Int J Hydrog Energy 43(19):9211–9223

Ahmed S, Panwar RM (2014) Technology capacity building for E-waste recycling in India: a comparison between the technology used by formal and informal sectors. In: Proceedings of the International Conference on Innovative Trends in Applied Physical, Chemical, Mathematical Sciences and Emerging Energy Technology for Sustainable Development. EXCELLENT PUBLISHING HOUSE, New Delhi, India, p 106–112

Aldayyat E, Saidan MN, Abu Saleh MA, Hamdan S, Linton C (2019) Solid waste management in Jordan: impacts and analysis. J Chem Technol Met 54(2):454–462

Al-Hamamre Z, Saidan M, Hararah M, Rawajfeh K, Alkhasawneh H, Al Shannag M (2017) Wastes and biomass materials as sustainable-renewable energy resources for Jordan. Renew Sustain Energy Rev 67:295–314

Al-Weshah R, Saidan M, Al-Omari A (2016) Environmental ethics as a tool for sustainable water resource management. Am Water Works Assoc 108(3):175–181

Awasthi AK, Cucchiella F, D'Adamo I, Li J, Rosa P, Terzi S, Wei G, Zeng X (2018) Modelling the correlations of e-waste quantity with economic increase. Sci Total Environ 613–614:46–53

Baldé CP, Wang F, Kuehr R, Huisman J (2015) The global e-waste monitor—2014. United Nations University, IAS—SCYCLE, Bonn

Baldé CP, Forti V, Gray V, Kuehr R, Stegmann P (2017) The global e-waste monitor 2017: quantities, flows, and resources. United Nations University (UNU), International Telecommunication Union (ITU), and International Solid Waste Association (ISWA), Bonn, Geneva, and Vienna

Baldé K, Wagner M, Forti V (2019) PART II—e-waste generated tool manual. United Nations University (UNU), UNU-ViE SCYCLE, Tokyo 150–8925, Japan

Bovea MD, Pérez-Belis V, Quemades-Beltrán P (2017) Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: case study in Spain. J Environ Manag 196:91–99

Cucchiella F, D'Adamo I, Koh SL, Rosa P (2015) Recycling of WEEEs: an economic assessment of present and future e-waste streams. Renew Sustain Energy Rev 51:263–272

Forti V, Balde CP, Kuehr R (2018) E-waste statistics: guidelines on classification, reporting and indicators, second edn. United Nations University (UNU), Bonn

Fraige FY, Al-khatib LA, Alnawafleh HM, Dweirj MK, Langston PA (2012) Waste electric and electronic equipment in Jordan: willingness and generation rates. J Environ Plan Manag 55 (2):161–175

Garlapati VK (2016) E-waste in India and developed countries: management, recycling, business and biotechnological initiatives. Renew Sustain Energy Rev 54:874–881. https://doi.org/10.1016/j.rser.2015.10.106

Gollakota ARK, Gautam S, Shu C (2020) Inconsistencies of e-waste management in developing nations—facts and plausible solutions. J Environ Manag 261:110234

Gu Y, Wu Y, Xu M, Wang H, Zuo T (2015) The stability and profitability of the informal WEEE collector in developing countries: a case study of China. Resour Conserv Recycl 107:18–26

Ilankoon IMSK, Ghorbani Y, Nan M, Herath G, Moyo T, Petersen J (2018) E-waste in the international context e a review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. Waste Manag 82:258–275

Islam MT, Huda N (2019) E-waste in Australia: generation estimation and untapped material recovery and revenue potential. J Clean Prod 273:117787

Islam MT, Huda N (2020) Assessing the recycling potential of "unregulated" e-waste in Australia. Resour Conserv Recycl 152:104526

Ismail H, Hanafiah MM (2019) Discovering opportunities to meet the challenges of an effective waste electrical and electronic equipment recycling system in Malaysia. J Clean Prod 238:117927

Jabr G, Saidan M, Al-Hmoud N (2019) Phosphorus recovery by struvite formation from Al Samra municipal wastewater treatment plant in Jordan. Desalin Water Treat 146:315–25. https://doi.org/10.5004/dwt.2019.23608

Khasawneh H, Saidan M, Al-Addous M (2019) Utilization of hydrogen as clean energy resource in chlor-alkali process. Energ Explor Exploit 37:1053–72

Matthews HS, McMichael FC, Hendrickson CT, Hart DJ (2014) Disposition and end-of-life options for personal computers. Technical Report. https://www.researchgate.net/publication/239514396_Disposition_and_End-of-Life_Options_for_Personal_Computers. Accessed 13 Nov 2019

Masud MH, Akram W, Ahmed A, Ananno AA, Mourshed M, Hasan M, Joardder MUH (2019) Towards the effective E-waste management in Bangladesh: a review. Environ Sci Pollut Res 26:1250–1276

MoMA (2015) Development of a national strategy to improve the municipal solid waste management sector in the Hashemite Kingdom of Jordan. Ministry of Municipal Affairs, Amman

Oguchi M, Kameya T, Yagi S, Urano K (2008) Product flow analysis of various consumer durables in Japan. Resour Conserv Recycl 52(3):463–480. https://doi.org/10.1016/j.resconrec.2007.06.001

Parajuly K, Habib K, Liu G (2017) Waste electrical and electronic equipment (WEEE) in Denmark: flows, quantities and management. Resour Conserv Recycl 123:85–92

Ravindra K, Mor S (2019) E-waste generation and management practices in Chandigarh, India and economic evaluation for sustainable recycling. J Clean Prod 221:286–294

Rodrigues AC, Boscov BEG, Günther WMR (2020) Domestic flow of e-waste in São Paulo, Brazil: characterization to support public policies. Waste Manag 102:474–485

Robinson BH (2009) E-waste: an assessment of global production and environmental impacts. Sci Total Environ 408:183–191

RSS (2011) Municipal solid waste composition analysis study. Royal Scientific Society, Amman

Sabbaghi M, Behdad S (2018) Consumer decisions to repair mobile phones and manufacturer pricing policies: the concept of value leakage. Resour Conserv Recycl 133:101–111

Sajid M, Hussain J, Iqbal M, Abbas Z, Hussain I, Baig MA (2018) Assessing the generation, recycling and disposal practices of electronic/electrical-waste (EWaste) from major cities in Pakistan. Waste Manag 84:394–401

Saidan M (2019) Cross-sectional survey of non-hazardous waste composition and quantities in industrial sector and potential recycling in Jordan. Environ Nanotech Monit Manag 12:100227

Saidan MN, Abu Drais A, Al-Manaseer E (2017a) Solid waste composition analysis and recycling evaluation: Zaatari Syrian Refugees Camp, Jordan. Waste Manag 61:58–66

Saidan M, Khasawneh HJ, Tayyem M, Hawari M (2017b) Getting energy from poultry waste in Jordan: cleaner production approach. J Chem Technol Metall 52:595–601

Saidan M, Khasawneh H, Aboelnga H, Meric S, Kalavrouziotis I, Jasem A, Hayek B, Al-Momany S, Al Malla M, Porro J (2019) Baseline carbon emission assessment in water utilities in Jordan using ECAM tool. J Water Supply Res Technol 68:460–73

Saidan MN, Abu Drais A, Linton C, Hamdan S (2020) Solid waste characterization and recycling in Syrian refugees hosting communities in Jordan. In: Negm AM, Shareef N (eds) Waste management in MENA regions. Springer International Publishing, Cham, p 281–293. ISBN:978-3-030-18349-3

Saidan M, Tarawneh A (2015) Estimation of potential e-waste generation in Jordan. Ekoloji 24(97):60–64

Shaikh S, Thomas K, Zuhair S (2020) An exploratory study of e-waste creation and disposal: upstream considerations. Resour Conserv Recycl 155:104662

StEP (2014) StEP E-Waste World Map [WWW Document]. http://www.step-initiative.org/Overview_Jordan.html. Accessed 3 Dec 2018

SweepNet (2014) Country report on the solid waste management in Jordan. SweepNet, GIZ, Amman, Jordan

Tarawneh A, Saidan M (2013) Households awareness, behaviors, and willingness to participate in e-waste management in Jordan. Int J Ecosyst 3(5):124–131

UNEP (2012) E-waste volume III: e-waste take-back system. UNEP, Division of Technology, Industry and Economics International Environmental Technology Centre, Osaka, p 146

UNEP (2017) Summary report: waste management in ASEAN countries. https://wedocs.unep.org/bitstream/handle/20.500.11822/21134/waste_mgt_asean_summary.pdf. Accessed July 3 2020

Walden JL (2012) Environmental impacts associated with current methods of re-use, recycling and reclamation of personal computers and cell phones, MSc Thesis, The University of Kansas. KS 66045, USA

Zeng X, Yang C, Chiang JF, Li J (2017) Innovating e-waste management: from macroscopic to microscopic scales. Sci Total Environ 575:1–5. https://doi.org/10.1016/j.scitotenv.2016.09.078