Investigation of Electronic Waste Generation: A Case Study of Soc Trang City, Vietnam

Tran Thi Kim Hong, Lam Trong Nhan, and Nguyen Thanh Giao

***Abstract*—In recent years, the advent of new electronic devices has spurred an increasing amount of e-waste, which is one of the fastest-growing municipal waste streams. However, research on e-waste in Vietnam is limited, especially in the southern provinces. The study was conducted to assess the current generation and volume of e-waste in Soc Trang city, Soc Trang province, Vietnam. The data were collected by interviewing 200 households. The results recorded 36 types of electronic devices that were classified into seven groups: lighting devices (2,021 pcs), heat exchangers (1,236 pcs), entertainment devices (1,221 pcs), large-sized devices (857 pcs), small-sized devices (851 pcs), office equipment (275 pcs) and medical equipment (73 pcs). The dominant devices were LED lights (1,185 pcs), smartphones (704 pcs), and electric fans (637 pcs). The average lifespan of relatively high-end appliances ranges from 3.8 to 18 years. The amount of e-waste generated in the study area was estimated at 1,065,382 pcs. The average volume was approximately 1,757 tons/year, with a generation rate of about 12.8 kg/person/year. Most of these devices are collected, sorted and sold by the households. It is recommended that effective e-waste management measures should be appropriately implemented to prevent adverse environmental and health impacts.**

***Index Terms*—E-Waste, household, Soc Trang city, toxic element, device.**

I. Introduction

Currently, the world has entered a new industrial revolution. Advanced manufacturing is associated with unprecedented breakthroughs in science and technology. Accordingly, the era of modern technology will connect people with more digital devices, such as smartphones, laptops, smart TVs, and other home electrical appliances. However, the rapid improvement in design and performance has shortened their useful life [1], [2], consequently discarding a large amount of electronic equipment every year. Former studies reported that e-waste is one of the fastest-growing types of urban waste in the world [3], [4]. Indeed, the global volume of e-waste in 2019 was 53.6 million tons [5], a 21% increase from 2014's (41.8 million tons) [6]. Asia has generated the highest volume of e-waste with 24.9 million tons [5]. Over the past decades, many previous studies confirmed that e-waste is a type of hazardous waste. According to Morf *et al*. [7], more than 1,000 different compounds were detected in the composition of e-waste. In fact, there are countless toxic substances such as lead, mercury, arsenic, cadmium, and chromium (IV) [8]. In Vietnam, e-waste is only collected by independent scrap collectors. Recycling of this waste only stops by dismantling and separating for the recovery of metals only [9]. Currently, some craft villages in the North of Vietnam, with manual methods, have obtained some major metals, including copper (Cu), iron (Fe), lead (Pb), and aluminum (Al). The performance, however, is very low and poses hidden risks of negative impacts on surrounding ecosystems and human health in the recycling areas [4], [9]-[11]. Former studies showed that soil samples collected in handicraft villages had higher concentrations of heavy metals than those in soil samples collected in the vicinity [10], [12]. The concentrations of cadmium (Cd), chromium (Cr), Cu, nickel (Ni), and manganese (Mn) in water samples taken from wells around the recycling area exceeded the allowable thresholds for groundwater standards [13]. In addition, direct exposure to e-waste during the collecting, sorting, and recycling processes has accumulated metal concentrations of arsenic (As), zinc (Zn), Cu, Cr, and cobalt (Co) in the hair and nails of the elders in the recycling area [13]. Moreover, long-term exposure to this hazardous waste would cause human health problems such as acute and chronic poisoning, affecting the nervous system, digestion, immunity, and even death [11], [14]. More dangerously, people are unaware of all the detrimental effects of e-waste on the environment and public health [9], [15]. Several people have never heard or known the concept of "e-waste".

Soc Trang city is an urban area directly under Soc Trang province, Vietnam. It is considered the economic, political, cultural - social, and national defense - security center of the province. Soc Trang city is currently being invested and strongly developed in all aspects to achieve the goal of being a grade II city in 2022 [16]. Rapid development has resulted in a continuous increase in the volume and composition of solid wastes, including e-waste. Therefore, the management of solid waste. However, the study on e-waste in Soc Trang province is unavailable. Therefore, this study was carried out to investigate the composition and generation rate of the e-waste in Soc Trang city, Soc Trang province, Vietnam. The findings in this study could be used for planning appropriate management solutions for e-wastes in the study area.

II. Materials and Methods

A. Interviewing Households

The study interviewed 200 households in five wards (denoted as Wards 2-6) in Soc Trang city, Soc Trang

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province, Vietnam. The questionnaire was designed and used in this interview. The locations, areas and populations of the surveyed wards are given in Table I.

TABLE I: BRIEF INFORMATION ON THE SURVEYED WARDS

Site	Code	No. of HH	Coordinates		Survey location characteristics		
			Latitude	Longitude	Area (km^2)	Households	People
Ward 2	VT1	40	9.59505	105.95819	5.88	6,550	30,896
Ward 3	VT2	40	9.58629	105.97578	7.5	5,508	24,636
Ward 4	VT3	40	9.60209	105.99063	5.5	3,287	13,299
Ward 5	VT4	40	9.62300	105.98372	28.35	4,039	17,585
Ward 6	VT5	40	9.61046	105.97108	2.16	2,977	13,434

*HH: households

B. Estimating the Amount of e-Waste

The study estimated the amount of e-waste in the whole study area by the approximation method previously described [17], assuming that the market is saturated. Accordingly, the amount of electronic equipment generated is equal to that being used. The total amount of electronic equipment being used at Soc Trang city was calculated according to the following equation:

$$X = D \times E$$

In which, X is the total number of electronic devices in use at Soc Trang city (pcs); D is the population of Soc Trang city in 2020 (person); E is the usage rate of each type of equipment (pcs/person).

E = Total amount of e-watse/no. of persons

C. Estimating the Volume of e-Waste

The volume of e-waste generated is estimated based on the generation coefficient and the population of the whole Soc Trang city in 2020. Accordingly, the generation coefficient is calculated using the below equation:

$$K = (M/S) / T$$

In which, K is the coefficient of generation of e-waste in Soc Trang city (kg/person/year); M is the total average weight of the 36 surveyed devices (kg); S is total population surveyed (person); T is the average lifespan of 36 surveyed devices (years).

Since all devices recorded at the survey sites are still in operation, the study will assume that the useful life of these devices is equal to their average lifespan. The average total mass of the surveyed devices (M) is calculated using the following equation:

$$M = \sum(A_1 \times I_1 + A_1 \times \mathrm{I}_1 + A_1 \times I_1 + ... + A_n \times I_n)$$

where, M is the total average weight of the surveyed devices (kg); A is the average mass of the type of equipment to be calculated (kg); I is the quantity of equipment to be counted (pcs);

The average mass of the type of equipment to be calculated (A) is determined by looking up the average mass specifications provided by the manufacturer. Thus, the volume of e-waste generated throughout the Soc Trang city in 2020 was calculated using the following equation:

$$F = K \times D$$

where, F is the volume of e-waste generated throughout the Soc Trang city area (kg/year); K is the coefficient of generation of e-waste in Soc Trang city (kg/person/year); D is the population of Soc Trang city in 2020 (person).

III. RESULTS AND DISCUSSION

A. Current Status of Using Electronic Devices

1) Group of lighting devices

Fig. 1 showed that LEDs were the most used in lighting equipment, accounting for 58.6%. The fluorescent lamps accounted for 20.4%, while compact lamps, flashlights and incandescent lamps accounted for 14.1%, 6.6% and 0.3%, respectively. The place with the highest rate of using lighting devices was recorded at Ward 2, with 456 pcs (accounting for 23%), followed by Ward 2 and Ward 6 with 421 pcs (accounting for 20.8%). Ward 3 was recorded with 403 pcs (accounting for 19.9%). Fewer were found at Ward 4 with 369 pcs (accounting for 18.3%) and Ward 5 with 363 pcs (accounting for 18%). Several previous studies reported that the composition of lighting devices contains many toxic substances, such as iron, copper, lead, zinc, aluminum, arsenic, chromium (VI), mercury, phosphorus, and barium, which potentially impact the environment and public health [4], [9]-[11], [18].

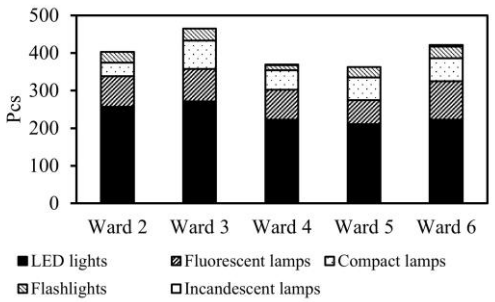

Fig. 1. The number of lighting devices in Soc Trang province*) Group of heat exchangers.*

The numbers of heat exchangers in use are shown in Fig. 2. The dominant devices were air conditioners accounting for 28.6% (353 pcs), refrigerators occupying 20.4% (252 pcs), rice cookers taking 19.3% (239 pcs), hairdryers accounting for 14.3% (177 pcs), and electric stoves occupying 9.87% (122 pcs). The remaining devices with the ratios of less than 5% were hair straighteners (with 57 pcs accounting for 4.61%), ovens (with 32 pcs accounting for 2.6%), and microwave ovens (with 4 pcs accounting for 0.3%). The current use status in the surveyed wards showed that the place with the highest number of users was Ward 3 with 279 pcs (accounting for 22.6%), followed by Ward 6 with 260 pcs (accounting for 21%). Wards 2 and 4 were only different in one device (250 and 251 pcs, respectively), accounting for 20.3 and 20.2%, respectively. Ward 5 was 196 pcs, accounting for 15.9%. According to Tran and Stefan [19], air conditioners had the highest annual growth rate during 2014-2020 in Vietnam by 21%.

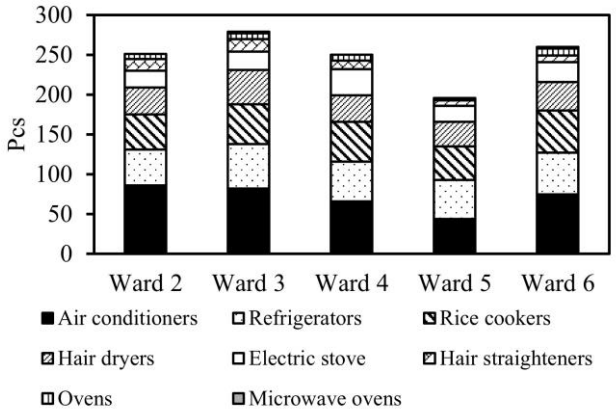

Fig. 2. The current use numbers of heat exchangers.

2) Group of entertainment device

Fig. 3 presents the current use of entertainment devices. At the top of the list of home entertainment devices were smartphones accounting for 57.7%, followed by smart TV/LCD 19.3%, general phones 10% and other devices (0.2% to 6.1%). Karaoke speakers, cameras, and music players accounted for 6.1%, 4.3%, and 1.2%, respectively. Others (game consoles, cassette players, radio, DVDs and amplifiers) accounted for 1.5%. As presented in Fig. 3, the number of devices used in each ward is relatively different. Specifically, the number of devices recorded in Wards 5 and 4 were predominant, accounting for 21.3% and 21.4%, respectively. The findings of entertainment devices used in Wards 6, 3 and 2 accounted for 20.7%, 19.2% and 17.4%, respectively. The number of mobile phones and TV put on the domestic market in Vietnam is estimated from 3,498-3,714 and 14,848-44,442 thousand units in Vietnam during 2014-2020 [19]. It can be seen that over half of interviewed households possess smartphones which can be because of the wide range of prices of these devices. This helps people easy to purchase a smartphone compared to the past.

3) Group of large-sized devices

As shown in Fig. 4, electric fans were the most used among the large-sized devices at the study sites, with 637 pcs (74.3%). The number of the remaining appliances was much smaller, with 188 pcs of washing machines (22%) and 32 pcs of vacuum cleaners (3.7%). The overall results revealed that there was a difference in the usage rate at the survey sites. The place with the most large-sized device was Ward 3 with 183 pcs (accounting for 21.4%), followed by Ward 4 (176 pcs), Ward 6 (171 pcs) and Ward 5 (163 pcs) with the proportions of 20%, 19.1%, and 19%, respectively. In Korea, the number of washing machines kept rising from 1,302-1,481 thousand units during 1995-2005 [20]. Meanwhile, the higher usage rate of the washing machine is estimated in Vietnam from 3,140-8,294 thousand units from 2014-2020 [19].

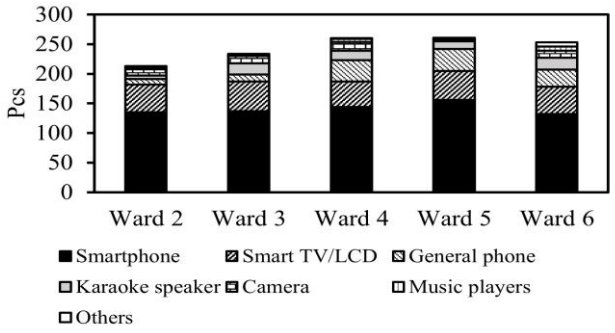

Fig. 3. The figure for entertaining devices.

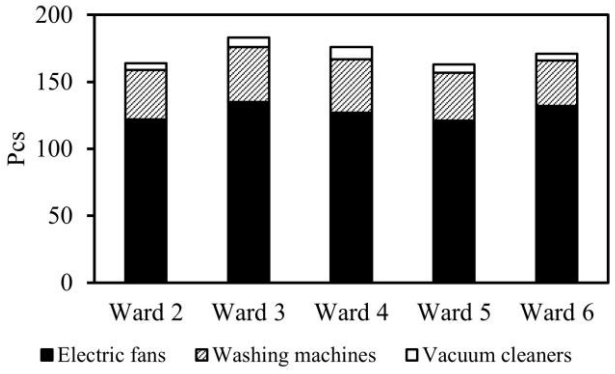

Fig. 4. The number of large-sized devices.

4) Group of small-sized device

Fig. 5 presents the number of the small-sized devices in the study area. The number of power banks was dominant, accounting for 46.7%. The next abundant device was the camera with 23.7%, the blender with 20.6% and the battery driller with 9%. The places with the highest usage rates are Wards 3, 6, 2 and 4, accounting for 22.6%, 21.8%, and 21,4% and 20.9%, while Ward 5 accounted for only 13.3%.

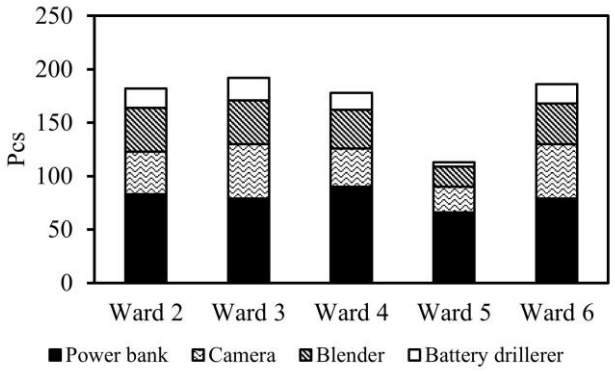

Fig. 5. The number of small-sized devices.

5) Group of office devices

The number of office devices is illustrated in Fig. 6. The laptop, printer, and PC were the three main office devices in the study areas. Specifically, laptops ranked first in devices with the number of 175 pcs (accounting for 63.6%), printers with 53 pcs (accounting for 19.3%) and PCs with 47 pcs (accounting for 17.1%). Of the five surveyed wards, Ward 4 had the highest usage rate with 63 devices (accounting for 22.9%), Ward 2 was lower with 60 pcs (accounting for 21.8%), Wards 3 and 5 had the same number of devices of 52 pcs (accounting for 18.9%) and Ward 6 with 48 pcs accounting for 17.5%. According to Tran and Stefan [19], the number of PC in the domestic market is estimated to reach over 6,200 thousand units in Vietnam in 2020.

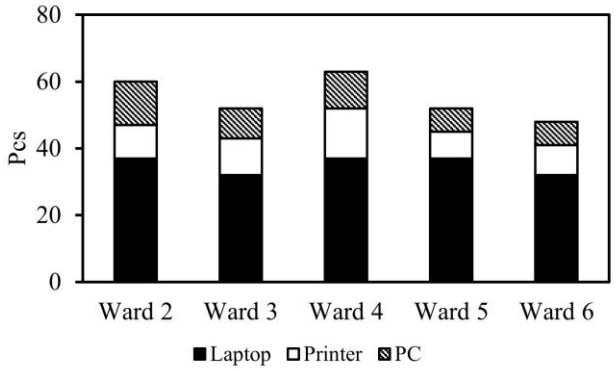

Fig. 6. The number of office device.

6) Group of medical devices

The number of medical devices being used in each ward is presented in Fig. 7. The group of medical devices had only 02 devices, including blood pressure monitors and massage machines. Blood pressure monitors accounted for 67.1% (49 pcs), and massage machines occupied 32.9% (24 pcs). The number of devices used the most was found in Ward 6, accounting for 27.4% (20 pcs), followed by Ward 3 with 17 pcs (23.3%). Wards 4, 2 and 5 had14 pcs (accounting for 19.2%), 13 pcs (accounting for 17.8%) and 9 pcs (accounting for 12.3%), respectively. Because these devices are typically expensive, not many households have access to these products.

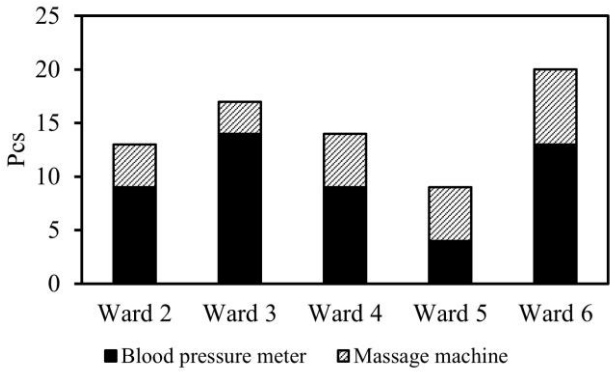

Fig. 7. The number of medical devices.

B. Device Usage Time

During the study period, all devices were found to be in good working condition and had not been discarded. Therefore, the study assumed the usage time as the life of the device. The service life of the equipment is divided into: under one year, from one to less than five years, from five to less than ten years, and over ten years, as given in Table II.

TABLE II: THE AVERAGE LIFESPAN OF THE SURVEYED DEVICES

Name of device	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6	Mean
Less than 1 year						
LED light	0	0	0	0	0	0
Fluorescent lamps	0	0	0	0	0	0
Compact lamps	0	0	0	0	0	0
Flashlights	0	0	0	0	0	0
Incandescent lamps	0	0	0	0	0	0
From 1 to 5 years						
Phone	4.9	3.9	4.3	4.2	4.3	4.3
Karaoke speaker	4.5	4.1	3.8	3.7	3.7	4.1
Blood pressure meter	4.3	3.6	3.4	3	3.6	4.0
Smartphone	4	4.1	4.1	4.1	4	3.6
Video gamer	4	3	4	0	3	3.6
Vacuum cleaner	3.6	3.7	3.7	2.5	3.8	3.5
Electric stive	3.3	3.7	4	2.7	4.1	3.1
Camera	3.2	2.9	3.1	2.7	2.8	2.9
Battery driller	3.1	2.5	3.4	2.5	4	2.9
Massage machine	3	3.3	2.2	2.8	2.9	2.8
Power bank	2.8	3.2	2.9	2.8	2.8	2.8
Music player	2	0	1.8	3	2	1.9
Hair straighteners	1.8	1.5	1.5	1.3	2	1.8
Hair dryer	1.7	2.1	1.7	2	2.2	1.6
Microwave oven	0	4	0	0	3.5	1.5
From 5 to 10 year						
Amplifier	0	0	0	8	9	3.4
DVD	0	0	0	8	9	3.4
Radio	0	0	0	0	7	1.4
PC	6.4	7.3	7.2	7	7.3	7.0

Name of device	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6	Mean
Washing machine	6.5	5.9	6.5	5.5	6.3	6.1
Refrigerator	6.4	5.4	6.4	5.6	6.1	6.0
Smart TV/LCD	5.9	5.6	6.1	5.8	6.2	5.9
Rice cooker	5.8	5.6	5.9	6.1	6	5.9
Blender	5.7	5.9	5.9	4.8	6.1	5.7
Printer	5.3	5.6	5.9	5.9	5.8	5.7
Oven	5	5.6	4.6	6.3	5.3	5.4
Camera	3.9	5.9	4.9	4.7	5.2	4.9
Air conditioner	5.5	4.7	4.6	4.2	4.8	4.8
Electronic fans	5.1	5	4.6	4.1	4.4	4.6
Laptop	3.8	4	5.2	4.1	4.4	4.3
Above 10 years						
Cassette player	18	11	0	0	10.5	7.9
Mean	3.6	3.4	3.1	3.3	4.2	3.5

Of the 36 surveyed devices, the cassette players were used the longest, ranging from 10.5 to 18 years. The place with the longest life was Ward 2 (18 years). In the group of 5 to 10 years, DVD and amplifiers were the two devices with the longest use time (from 8 to 9 years). However, the number was very small, only four devices were recorded in Wards 5 and 6. Besides, PC was also a type of device with a very long time of use (6.4 to 7.3 years). The locations recorded a long time of use were Wards 3 and 6 (both 7.3 years), followed by Wards 4, 5 and 2 with a period of 7 years, 7.2 years and 6.4 years, respectively. The life expectancy of PCs in the study area was 2.4 years higher than that in the northern provinces mentioned in the study by Cam *et al*. [17]. The equipment with the next longest use time was the washing machine (5.5 to 6.9 years), where the most used time was Wards 2 and 4 (both 6.5 years), followed by Wards 5, 3 and 5 with 6.3, 5.9 and 5.5 years, respectively. The life expectancy of washing machines in this study was much lower than that of the Philippines (average 11 to 14 years) and Japan (8 years) [21]. The refrigerator was also an appliance with a rather long service life (5.4 to 6.4 years), but still lower than Japan (10 years) and the Philippines (10 to 15 years) [21]. Among the surveyed sites, the refrigerators in Wards 2, 4 and 6 had the longest usage time (6.1 to 6.4 years), while Wards 3 and 5 were shorter (5.4 to 5.6 years). 2 out of 36 devices with roughly equal lifespan were Smart TV/LCD (5.6 to 6.2 years) and rice cooker (5.6 to 6.1 years). Printers and blenders also had roughly equal usage times. The usage time of the printer at all survey points did not have much difference (5.3 to 5.9 years). In contrast, the usage time of blenders was different between the wards in which Ward 6 had the longest time of use (6.1 years), and the shortest was Ward 5 (4.8 years). Devices such as cameras, air conditioners, electric fans, and laptops also had an average use time of 4.3 to 4.9 years.

Some of the popular devices, such as cellphones, smartphones, blood pressure monitors, and karaoke speakers, were in the group of devices with the use period from 1 to less than 5 years. Mobile phones had the usage time of 3.9 to 4.9 years, and there was not much difference between the survey sites. Karaoke speakers and blood pressure monitors had nearly the same usage time. Specifically, the use time of karaoke speakers was from 3.7 to 4.5 years, while the blood pressure monitor was insignificantly lower from 3 to 4.3 years. Due to many changes in models and operational features, smartphones had a relatively short lifetime, with an average of 3.6 years. The average usage time of this device in Wards 3, 4 and 5 was 4.1 years, and that in the others was 4 years. However, the lifespan of cellphones and smartphones in this study was two years higher than in the northern provinces [17]. Game consoles only serve a small portion of consumers; thus, the number of these devices was small, and their lifespans were also relatively low, with an average of 3.6 years). The popular devices with relatively low lifespans were cameras (2.9 years), power banks (2.8 years), hairdryers, and hair straighteners (1.5 to 1.6 years). Finally, lighting devices had the shortest lifespan (ranging from 2 to 6 months) because their continuous operations have shortened their serving lives (Table III). According to interviews, households often have to replace the light bulbs in their house, sometimes changing 2 to 3 bulbs a month and sometimes every 6 or 7 months, the bulbs that are damaged have to be replaced. According to the lifespan parameters given by manufacturers, most lamps have a lifespan of 750 hours and up to 100,000 hours for some types of LEDs. However, it is often damaged before this expected time of the manufacturers.

TABLE III: THE AVERAGE LIFE OF LAMPS

Name of device	Average Lifespan (hours)
Incandescent lamp	750 – 1,000
Halogen lamp	2,000 – 3,000
Metal halide lamp	7,500 – 10,000
Fluorescent lamp	15,000 – 20,000
High pressure mercury lamp	16,000 – 24,000
High pressure sodium lamp	15,000 – 25,000
Super bright LEDs	45,000 – 55,000
Internal inductive LED light	60,000 – 75,000
External inductive LED light	85,000 – 100,000

C. Estimate the Amount of e-Waste

Based on data collected from 200 households (842 people) at five survey sites, the study calculated the usage rate of 36 types of devices. The results revealed that the usage rate ranged from 0.002 to 1.4 pcs/person, as shown in Table 4. The population recorded in the Soc Trang city area of 137,290 people. The study has estimated the total amount of e-waste for the city under the assumption of a saturated market (Table IV).

TABLE IV: NUMBER OF HOUSEHOLD ELECTRONIC DEVICES BEING USED IN SOC TRANG CITY

Name of device	No. of devices (pcs)	No. of device per person (pcs/person)	Total amount (pcs)
Group of lighting devices			
LED light	1,185	1.4	193,217
Fluorescent lamps	413	0.5	67,341
Compact lamps	284	0.3	46,307
Flashlights	134	0.2	21,849
Incandescent lamps	5	0.01	815
Total			329,529
Group of heat exchangers			
Air conditioners	353	0.4	57,557
Refrigerators	252	0.3	41,089
Rice cookers	239	0.3	38,969
Hair dryers	177	0.2	28,860
Electric stove	122	0.1	19,892
Hair straighteners	57	0.1	9,294
Ovens	32	0.04	5,218
Microwave ovens	4	0.005	652
Total			201,531
Group of entertainment devices			
Smartphone	704	0.8	114,789
Smart TV/LCD	235	0.3	38,317
General phone	123	0.1	20,055
Karaoke speaker	74	0.1	12,066
Cameras	53	0.1	8,642
Music players	15	0.02	2,446
Video console	7	0.01	1,141
Cassette players	4	0.005	652
Radio	2	0.002	326
DVD, amplifier	2	0.002	326
Smartphone	2	0.002	326
Total			199,086
Group of large-sized devices			
Electric fans	637	0.8	103,864
Washing machines	188	0.2	30,654
Vacuum cleaners	32	0.04	5,218
Total			139,736
Group of small-sized devices			
Power bank	397	0.5	64,732
Camera	202	0.2	32,937
Blender	175	0.2	28,534
Battery driller	77	0.1	12,555
Total			138,758
Group of office devices			
Laptop	175	0.2	28,534
Printer	53	0.1	8,642
PC	47	0.1	7,663
Total			44,839
Group of medical devices			
Blood pressure meter	49	0.06	7,990
Massage machine	24	0.03	3,913
Total			11,903
Total			1,065,382

The total amount of e-waste generated in Soc Trang city area was estimated at 1,065,382 pcs. The lighting appliances had the largest number (329,529 pcs), with a dominance of LED lights (193,217 pcs). The second highest was heat exchangers with 201,531 pcs, in which air conditioners, refrigerators, rice cookers, hairdryers and electric stoves ranged from 19,892 to 57,557 pcs. The remaining equipment was under 10,000 pcs. Due to the high demand for entertainment, the number of entertainment devices was also very large (199,086 pcs). Smartphones, televisions, cellphones and karaoke speakers had outstanding numbers of 114,789 pcs, 38,317 pcs, 20,055 pcs and 12,066 pcs, respectively. Meanwhile, the remaining devices had a smaller quantity, ranging from 326 to 8,642 pcs. Among the

large-sized devices (139,736 pcs), electric fans were the equipment with the largest number (103,864 pcs), followed by washing machines (30,654 pcs) and vacuum cleaners (5,218 pcs). Moreover, small-sized devices also had a relatively large generation rate (138,758 pcs). The power bank had the largest number (64,732 pcs), followed by the camera (32,937 pcs), blenders (28,534 pcs) and battery driller (12,555 pcs). Because it only serves the needs of a small number of people, two groups of office and medical devices had a relatively low rate of generation compared to other groups. The e-waste generation dramatically increased from 1.9 kg per capita to 3.7 kg per capita during 2014 – 2020 in Vietnam [19].

D. Estimate the Volume of e-Waste

From the technical data provided by the manufacturers, the study calculated the average weight of each type of device was from 0.02 to 37.5 kg. The results of the total volume of these studied devices are given in Table V. The total volume of e-waste generated at Soc Trang city was 1,757 tons/year, and the generation rate was estimated at 12.8 kg/person/year. It can be deduced that if there are no measures for proper collection and treatment, it will cause a very serious impact on the environment and public health since several toxic compounds, mainly heavy metals and macromolecular organic substances, in e-wastes [9]-[14]. Thus, local environmental managers need to have appropriate separation, collection, treatment, and management strategies for e-wastes in the study area. More studies on the generation of e-waste between urban and rural areas are needed for efficient management agenda.

TABLE V: THE VOLUME OF HOUSEHOLD ELECTRONIC DEVICES BEING USED IN SOC TRANG CITY

Name of device	No. of devices (pcs)	No. of device per person (kg/person)	Total volume (kg)
Group of lighting devices			
LED light	1,185	0.18	213
Fluorescent lamps	413	1.30	537
Compact lamps	284	0.12	34
Flashlights	134	0.22	29
Incandescent lamps	5	0.02	0,08
Total			813
Group of heat exchangers			
Air conditioners	353	32.1	11,314
Refrigerators	252	36.5	9,198
Rice cookers	239	2.9	681
Hair dryers	177	0.6	106
Electric stove	122	2.2	273
Hair straighteners	57	0.2	13
Ovens	32	7.3	234
Microwave ovens	4	11.1	44
Total			21,663
Group of entertainment devices			
Smartphone	704	0.176	124
Smart TV/LCD	235	6.9	1610
General phone	123	0.12	15
Karaoke speaker	74	26.5	1961
Cameras	53	0.33	17
Music players	15	0.06	1
Game console	7	0.6	4
Cassette	4	3	12
Radio	2	0.64	1
DVD, Amplifier	2	1.95	4
Smartphone	2	12.5	25
Total			3,774
Group of large-sized devices			
Electric fans	637	3.65	2,325
Washing machines	188	37.5	7,050
Vacuum cleaners	32	2.85	91
Total			9,466
Group of small-sized devices			
Power bank	397	0.24	93
Camera	202	0.3	60
Blender	175	3.25	569
Battery driller	77	1.78	137
Total			859
Group of office devices			

Name of device	No. of devices (pcs)	No. of device per person (kg/person)	Total volume (kg)
Laptop	175	2	341
Printer	53	6.1	323
PC	47	7.5	352
Total			1,016
Group of medical devices			
Blood pressure meter	49	0.13	6
Massage machine	24	0.75	18
Total			24
Total			37,615

IV. Conclusions

The study focused on the current status of using electronic appliances via interviewing 200 households in five wards in Soc Trang city. The results recorded all 36 types of electronic devices were divided into seven groups. The group of lighting devices had the largest number with 2,021 pcs (30.9%), followed by heat exchangers with 1,236 pcs (18.9%), and the entertainment device group with 1,221 pcs (18.7%). The large- and small-sized device groups had 857 pcs (13.1%) and 851 pcs (13%), respectively. The office device group had 275 pcs (4.2%), and the medical device group had 73 pieces (1.2%). Out of a total of 36 devices recorded, LED lights outperformed the rest with 1,185 pcs, followed by smartphones with 704 pcs and electric fans with 637 pcs. In addition, some common appliances such as fluorescent lights, power banks, air conditioners, compact lights, refrigerators, rice cookers, smart TV/LCDs, cameras, washing machines, hairdryers, blenders, lights batteries, popular mobile phones, and electric stoves were 413, 397, 353, 284, 252, 239, 235, 202, 188, 177, 175, 175, 134, 123 and 122 pcs, respectively. The remaining devices had quantities under 100 pcs. The appliances with the longest service life were cassettes, DVDs, and amplifiers, ranging from 8 to 18 years. All lighting devices had a lifespan of less than one year. The average lifespan of 36 devices was calculated to be 3.5 years. The estimated results showed that the total number of e-waste generated in Soc Trang city was 1,065,382 pcs, with the dominance of lighting devices (329,529 pcs). The lowest amount of e-waste generated was medical devices (11,903 pcs). The generated volume was estimated to be approximately 1,757 tons/year, averaging 12.8 kg/person/year. It can be seen that high potential e-waste generation is estimated in the region. Thus, more comprehensive studies on the generation of e-waste between urban and rural areas are needed for efficient management strategies to prevent the e-waste crisis.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Dr. Tran Thi Kim Hong and Dr. Nguyen Thanh Giao designed the research and methodologies; Mr. Lam Trong Nhan conducted the research, analyzed the data and drafted the manuscript; Dr. Tran Thi Kim Hong and Dr. Nguyen Thanh Giao revised and finalized the manuscript; all authors had approved the final version.

References

[1] H. Y. Kang and J. M. Schoenung, "Used consumer electronics: A comparative analysis of material recycling technologies," in *Proc. 2004 IEEE International Symposium on Electronics and the Environment*, 2004, pp. 10–13.

[2] D. T. Huong, "Research on evaluating the potential of e-waste recycling and valuable metal recovery from discarded electronic circuit boards," Master of Science Thesis, Vietnam National University, Hanoi, 2013, pp. 1-99.

[3] C. M. Ohajinwa, P. M. V. Bodegom, M. G. Vijver, and W. J. G. M. Peijnenburg, "Health Risks awareness of electronic waste workers in the informal sector in Nigeria," *International Journal of Environmental Research and Public Health*, 2017, vol. 14, no. 8, pp.1-12.

[4] X. Zeng, H. Duan, F. Wang, and J. Li, "Examining environmental management of e-waste: China's experience and lessons," *Renewable and Sustainable Energy Reviews*, 2017, vol. 72, pp.1076-1082.

[5] V. Forti, C. P. Baldé, R. Kuehr, and G. Bel, "The global e-waste monitor 2020: Quantities, flows and the circular economy potential," *United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA)*, 2020.

[6] C. P. Baldé, F. Wang, R. Kuehr, and J. Huisman, "The global e-waste monitor – 2014," *United Nations University, IAS – SCYCLE*, 2015.

[7] L. S. Morf, J. Tremp, R. Gloor, F. Schuppisser, M. Stengele, and R. Taverna, "Metals, non-metals and PCB in electrical and electronic waste — Actual levels in Switzerland," *Waste Manag*, 2007, vol. 27, pp. 1306–16.

[8] G. Gaidajis, K. Angelakoglou, and D. Aktsoglou, "E-waste: Environmental problems and current management," *Journal of Engineering Science and Technology Review*, 2010, vol. 3, pp. 193-199.

[9] N. T. Hien and T. P. Thao, "E-waste recycling activities in Vietnam and some recommendations," *Journal of Science and Technology*, 2019, vol. 53, pp. 101-106.

[10] H. T. Hai, H. V. Hung, and N. D. Quang, "An overview of electronic waste recycling in Vietnam," *Journal of Material Cycles and Waste Management*, 2015, vol. 19, pp. 536-544.

[11] D. N. Perkins, M. B. Drisse, T. Nxele, and P. D. Sly, "E-waste: A global hazard," *Annals of Global Health*, 2014, vol. 80, no. 4, pp. 286-295.

[12] M. Someya, G. Suzuki, A. C. Lonas, M. T. Nguyen, F. Xu, H. Matsukami, A. Covaci, H. T. Le, H. V. Pham, S. Takahashi, S. Tanabe, and H. Takigami, "Occurrence of emerging flame retardants from e-waste recycling activities in the northern part of Vietnam," *Emerging Contaminants*, 2016, vol. 2, no. 2, pp. 58-65.

[13] T. T. Thao, N. M. Ha, B. D. Cam, and D. Q. Trung, "Evaluating the level of heavy metal pollution in groundwater and heavy metal accumulation in the hair and nails of residents at the e-waste collection and recycling area," *Journal of Analytical Chemistry, Physics and Biology*, 2014, no. 20, pp. 111-119.

[14] S. Sivaramanan, "E-waste management, disposal and its impacts on the environment", *Universal Journal of Environmental Research and Technology*, 2013, vol. 3, no. 5, pp. 531-537.

[15] A. E. Olowofoyeku, "Knowledge, attitude and practices of e-waste workers in owode-onirin scrap market, kosofe local government area, langos state, Nigeria," *J. Appl. Sci. Environ. Manage*, 2020, vol. 24, no. 8, pp. 1315-1320.

[16] Soc Trang People's Committee, "Thematic report on the current state of urban environment in Soc Trang province," Department of Natural Resources and Environment of Soc Tran province g, 2020, pp. 1-99.
[17] B. D. Cam, D. Q. Trung, C. X. Quang, N. X. Thung, C. X. Quang, D. V. Huong, and N. Han, "Summarization report: Scientific and technological tasks for state management of environmental protection," Vietnam National University, Hanoi, 2013, pp. 1-102.
[18] A. Pariatamby and D. Victor, "Policy trends of e-waste management in Asia," *Journal of Material Cycles and Waste Management*, 2013, vol. 15, pp. 411-419.
[19] C. D. Tran and S. P. Salhofer, "Analysis of recycling structures for e-waste in Vietnam," *Journal of Material Cycles and Waste Management*, 2013, vol. 20, pp. 110-126.
[20] H. Yoon and Y. C. Jang, "The practice and challenges of electronic waste recycling in Korea with emphasis on extended producer responsibility (EPR)," in *Proc. the 2006 IEEE International Symposium on Electronics and the Environment*, May 2006, pp. 326-330.
[21] N. T. T. Huyen, "Research and application of computational methods to determine the amount of household e-waste to forecast the emissions of some typical household appliances in Vietnam by 2025," Master Thesis, *Institute of Environmental Science and Technology, Hanoi University of Science and Technology*, 2014, pp. 1-200.

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