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ORIGINAL ARTICLE

# An analysis on e-waste generation in Chandigarh: quantification, disposal pattern and future predictions

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**Abstract**

In this study, an assessment of e-waste management in Chandigarh, India was done. A structured questionnaire based survey was used to know about various socio-economic characteristics. Based on the results, the quantification of, equipment wise, e-waste generation and their distinctive disposal patterns were acquired. Future, e-waste generation was also estimated using an approach investigated by Gesellschaft für Technische Zusammenarbeit and Manufacturer's Association of Information Technology (GTZ-MAIT). The total amount of e-waste generation from households of Chandigarh was found out to be 3276.47 tons/annum, which was equivalent to 3.1 kg/capita/annum. It was also found that most of the e-waste generated was from the use of Electrical and Electronic Equipment (EEE) such as Mobile phones, Laptops, Cameras, Washing machines, Air conditioners, Heaters, Geysers, LEDs and LCDs. Moreover, taking the annual GDP growth rate of India into account e-waste generation from households was estimated to reach 9565.1 tons/annum by 2020. Among the various disposal channels "selling as scrap" was the most favored one among the respondents to discard the used EEE. Therefore, it can be concluded from the survey that informal sectors or scrap dealers are very active in e-waste collection as they are aware about the profitability from its dismantling and recycling.

**Keywords** E-waste management · Quantification · Electrical and electronic equipment · Disposal channel · Survey · Recycling

## Introduction

Rapidly evolving advancements in IT industry introduces pristine electronic equipment into the global market. Consequently after every few months most of the electronic equipment become obsolete and their prices fall. In Indian society, after every week on an average two computers become obsolete. This supports lifetime of 50 weeks to a computer [1]. At this obsolescence rate and regular abatement in the prices of electronic equipment, they start falling within the budget of larger population. Subsequently, the consumption of such Electrical and Electronic Equipment (EEE) increases. Similar scenario has been observed in Indian society as well and the share of IT sector in Indian GDP has increased from 1.2% in 1998 to 7.5% in 2012 [2]. Although, this exponential growth in IT sector has been the reason for enhancement in economic growth of India yet it has troubled it by introducing a new waste stream of e-waste.

Any waste that was either once a part of EEEs or itself consists of electronic components is known as e-waste [3]. E-waste embodies a broad range of abandoned EEEs generated from homes as well as industries such as: air conditioners, televisions, computers, refrigerators, mobile phones, MP3 players, laptops, tablets, etc. The prompt generation of such e-waste has also encouraged e-waste recycling industry because Waste EEEs (WEEEs) comprise lucrative metals such as gold, silver, copper, platinum and palladium. In developed countries, where e-waste recycling is maintained by formal sectors, the quantification and assessment of e-waste generation is carried out precisely. However, in developing countries, where e-waste recycling is dominated mainly by informal sector, quantification of e-waste is a very bewildering task

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[4–6]. In such countries, the rate of generation of e-waste is dispersed and information about the dumping of e-waste from developed nations is also not available [7]. Therefore, in such countries it is of utmost importance to collect the data on e-waste generation, collection, dumping and various kinds of recycling processes being performed.

Comprising 17.3% of world's population, India has been a forerunner in IT revolution. In India, the gross turnover of electronics market had jumped from US$ 11.5 billion in 2004 to US$ 32 billion in 2009, making it one of the fastest growing electronics market worldwide [8]. Moreover, due to the high obsolescence rate in India, e-waste is also being dumped into the municipal landfills. Therefore, it is necessary to carry out e-waste inventory assessment in India, before setting e-waste legislative policies. But due to diversity in Indian societies it is advisable to apply state wise assessment of e-waste generation and quantification.

It is with this objective that an attempt has been made to quantify the e-waste generation in the Union Territory (U. T.) of Chandigarh, India. After a brief review of various existing approaches such as, the 'Time step', the 'Carnegie Mellon', the 'Market supply' and the 'Consumption and Use' methods, the lattermost, after some modifications, has been found most suitable for the quantification of e-waste in Chandigarh. This approach can assess the e-waste inventory from pre-disposal indicators and it also requires knowledge about the flow of e-waste because of which disposal routes of different EEEs were also analyzed.

## Study area

For the present study, the geographical region considered was U. T. of Chandigarh, India (30.74°N, 76.79°E; area = 114 km$^2$). As per Indian census 2011, Chandigarh had population of 1,055,450 with total number of households of 235,061 [9]. Moreover, because of the existence of Rajiv Gandhi I.T. park, teaching institutions and various colleges/universities at its peripheries, this city has been a temporary residency for youngsters. Subsequently, youngsters have attracted numerous suppliers of electronic gadgets in the city. This city is also a capital of two major Indian states: Punjab and Haryana, therefore, numerous government offices of different sectors are also located in the city. In other aspects such as planning, architecture and waste disposal, this city is well managed and legislations are also up-to-date. But no material flow analysis and quantification of e-waste has been done in the city so far, which could prove to be problematic in coming years. Therefore, during 2013–2014, we choose this city for the e-waste quantification.

## Approach and methodology

The approach followed, for the quantification of e-waste in Chandigarh, is divided into two sections: (1) data collection and analysis—in which preliminary and questionnaire based survey was conducted and analyzed and (2) E-waste quantification using Consumption and Use method—in which amount of e-waste generation was estimated for the present as well as future conditions. Using results from both the steps, disposal channels for different WEEEs were also estimated. The flowchart of the methodology followed, in this study, is shown in Fig. 1.

### Preliminary survey

After deciding the study area, the first step followed in quantification of e-waste was to attain an outline about the material flow of e-waste in the city. Therefore, a preliminary survey was conducted to gain a glimpse of the location of various stakeholders in the city. These stake holders involved in the life cycle of e-waste were surveyed through personnel interviews. The various sections of stakeholders interviewed were: retailers, service centers, rag pickers/door to door garbage collectors, second hand/repair shops, scrap dealers.

### Questionnaire based survey

After getting a glimpse about the material flow of e-waste in the city, an elaborated door to door survey was also conducted during January, 2014, using a house hold questionnaire. The main objective of the questionnaire based survey was to collect data for assessing: (1) average life time of the EEEs; (2) socio-economic characteristics of the respondents and households; (3) purchase/use/disposal pattern of EEEs and (4) EEEs consumption and Inventory.

For in depth analysis of the effects of different societies on e-waste generation, various socio-economic factors related to the respondents were included in the questionnaire. These parameters were chosen on the basis of the quantification method (i.e., Consumption/use method) to be used in the study, as results from this survey were going to affect the purchase/use/disposal pattern of various EEEs.

The information collected from this survey was considered for developing the purchase/use/disposal pattern of various EEEs used in households of Chandigarh. Household income and dwelling size, after being validated using Analysis of variance (ANOVA)—SPSS (version 16.0), were set as the basis for discretion in establishing the product wise purchase/use/disposal pattern for households.

Based on the E-waste inventory analysis and surveys conducted, the purchase/use/disposal pattern was developed.

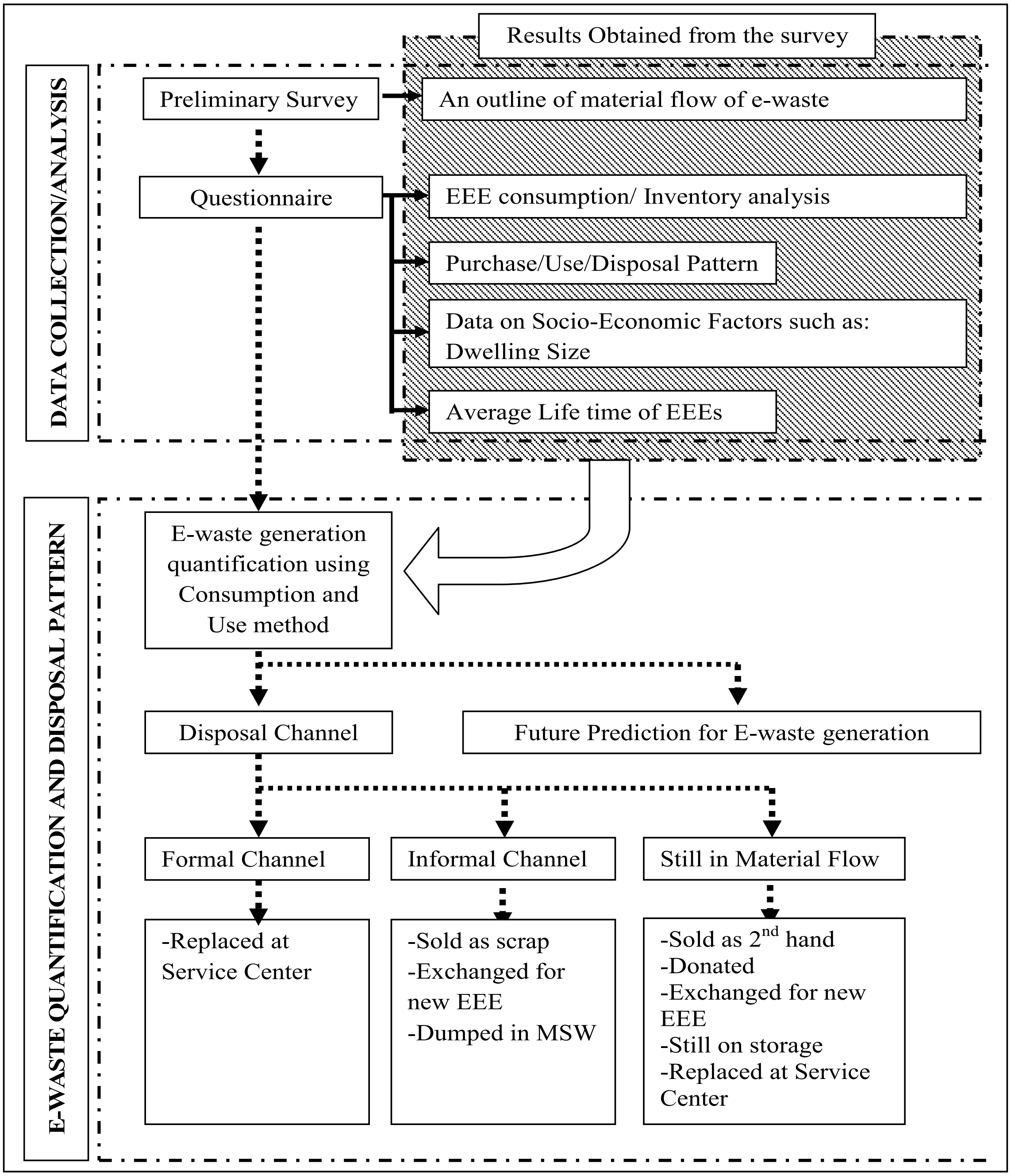


**Fig. 1** Methodology followed for the e-waste quantification

After collecting all the information from survey, a review of various e-waste quantification methodologies was done, as shown in Table 1.

These methods use basic parameters such as EEE sales data, stock data for households and commercial establishments and average lifetime. Market Supply Method, which assumes that all EEE sold in a particular year become obsolete after a fixed average lifetime, set the base for development of all these methodologies. This method had been used, in various countries such as China, India, Nigeria and Chile, for e-waste quantification [13–15]. However, the lack of time, requirement of collection of data on e-waste industrial generation and large EEEs inventory made this methodology unsuitable for the present study.

Among other quantification methodologies ‘Consumption and Use’ or ‘Approximation 1’ method, as described by the UNEP E-waste Inventory Assessment manual, is less time consuming. The various parameters utilized in this study

**Table 1** Mathematical formulae for e-waste inventory assessment [10]

| Method | Limitations | Pros |
|---|---|---|
| Time step method | 1. Ambiguity in household saturation and industrial stock levels<br>2. Storage of WEEE is not considered | 1. Easy calculations<br>2. Efficient for saturated markets |
| Market supply method | 1. Subjectivity of Average life of EEEs<br>2. Assumptions about average life for disposal of EEE<br>3. Can't be used for dynamic market | |
| Carnegie Mellon method | 1. Requirement of sales data in the initial stage<br>2. In depth knowledge of material flow is required | 1. More accurate material flow |
| Approximation 1 (consumption and use) | 1. Assumption of mean life span<br>2. Fit only for saturated markets | 1. Accurate results when data is available |
| Approximation 2 | 1. Fit only for saturated markets<br>2. Cannot be used where storage of e-waste and second hand usage is considered | 1. Best fit for conducting initial assessment<br>2. Low range of input data is required<br>3. No need of previous years data |

for the estimation of e-waste generation at an instantaneous time, (t), can be explained by Eq. 1:

$$\text{E-waste}(t) = [\{\text{Stock private}(t) + \text{Stock industry}(t)\}/\text{average lifetime of EEE}] \quad (1)$$

where, stock private = number of households × saturation level of households/100 = population/average size of household × saturation level of the households/100, stock industry = number of work places × saturation level in the industry/100 = number of employees/number of users per appliance × saturation level in the industry /100.

Household characteristics and awareness level, which helped in calculation of average life time for various EEEs.

Variation in possession of number of EEEs and average lifetimes for households of different sizes and different economic levels restrict the use of same inventory and lifetimes for a society as whole. To overcome this limitation, a parameter based on dwelling sizes, defined by number of rooms in the house, was used. Dwelling size was used as a parameter instead of household income, which seems more dominating factor, because actual census statistics were available for dwelling size only. Using this approach, e-waste generation at time (t), can be calculated as described by Eq. 2:

$$\text{E} - \text{waste generation } (t) = \sum \left[ \left\{ (\text{number of dwellings})_{j,i} \times (\textit{satutation level of household})_{j,i} \right\} / \text{average lifetime}_i \right] \quad (2)$$

where, $i$ = Dwelling Size; $j$ = Type of EEE.

Saturation level of household/industry was estimated using the average number of units possessed by a particular household/industry, respectively. Stock data can be calculated from census data, traders/manufacturers associations and market research agencies, while average lifetime can be assumed or estimated from the already available data on EEEs active, passive and storage life. According to UNEP 2007, this method can be applied only in such nations where the difference between saturation levels and usage life times is not substantial and where there is a presence of limited disposal routes and formal collectors [10].

In this study, Consumption and Use method was chosen for the quantification of e-waste as it is not a time consuming method and with some modifications it could be made applicable in Chandigarh city, where income level is higher as compared to per capita income of India. Consumption and Use method was modified by including parameters such as reuse, storage, refurbishing and disposal into municipal solid waste (MSW) as used in 'Carnegie Mellon Method'. Moreover, various socio-economic factors have also been included in the survey such as: Respondents characteristics,

## Results and discussion

### Trade value chain

While conducting the preliminary field study two types of scrap dealers were identified. One type of scrap dealers (Referred: Type 1, in this study) dealt with general waste such as paper, plastic and metal, and another type (Referred: Type 2, in this study) were those who dealt specifically with e-waste. All the information gathered from preliminary survey was collaborated and epitomized as a trade value chain, shown in Fig. 2.

### Responses to questionnaire

A sample size of 400 households was decided for the survey, but we were able to achieve response rate of 69.20%. About 4.1% of the respondents left the survey in-between

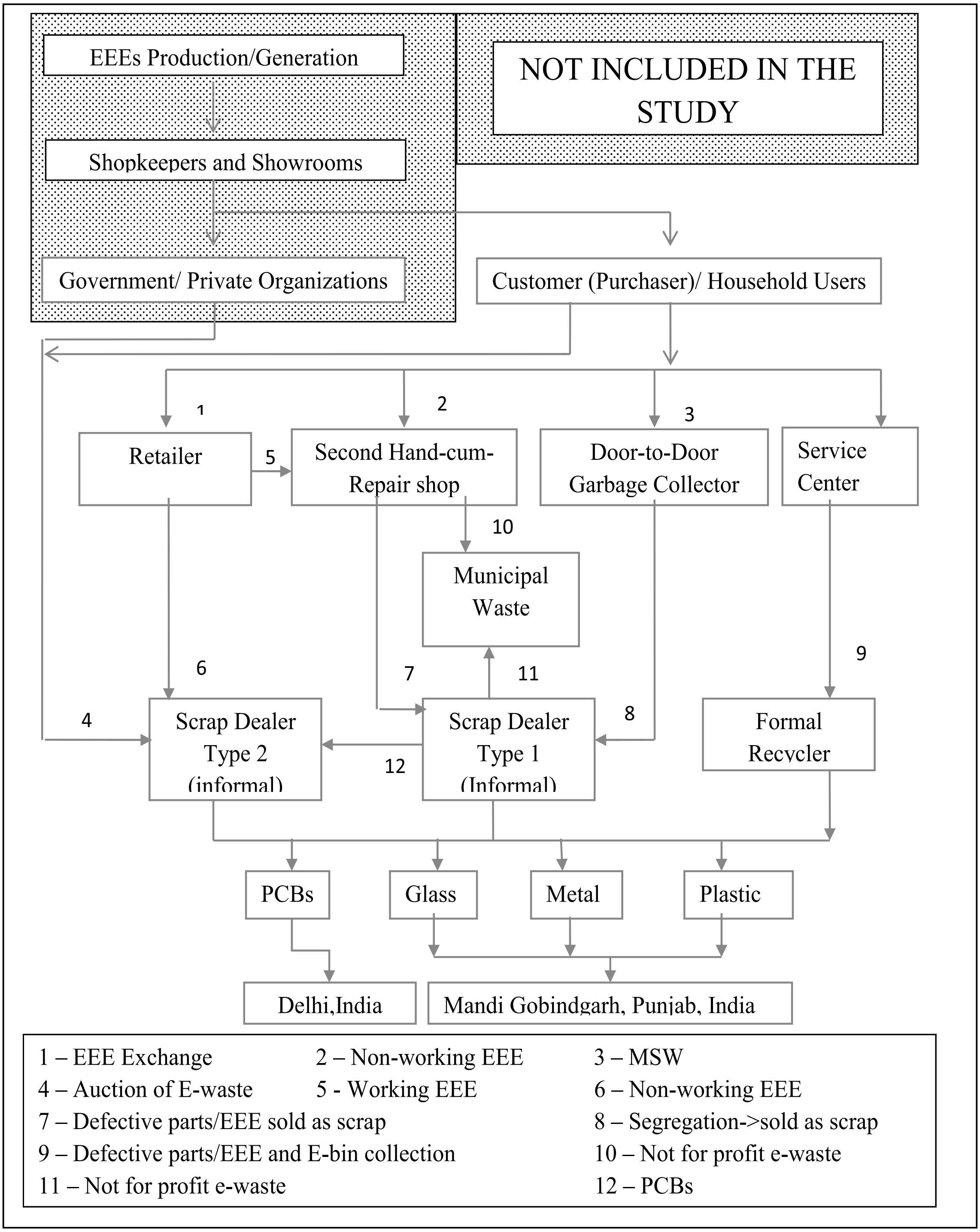


**Fig. 2** Trade value chain constructed after preliminary survey

and 30.75% refused to participate. A Complete scenario about respondent's participation in filling the questionnaire is shown in Table 2.

As the study concentrates on the households of different income levels, the chances of getting variability in the results were obvious, as shown in Table 3.

**Table 2** Survey Response Rate

| Approached households | Did not participate | Incomplete Entries | Completed |
|---|---|---|---|
| 400 | 123 | 24 | 253 |

**Table 3** Results from the survey conducted using questionnaire

| Main topic | Sub topic | Parameters selected | Output (%) | | |
|---|---|---|---|---|---|
| Respondent's characteristics | Gender | Male | 59.68 | | |
| | | Female | 40.32 | | |
| | | | M* | F* | H* |
| | Education of the respondent and family Head's Education | Less than metric | 19 | 43 | 47 |
| | | Metric | 6 | 13 | 27 |
| | | Secondary | 9 | 15 | 9 |
| | | Diploma | 8 | 1 | 15 |
| | | Graduation | 51 | 21 | 78 |
| | | Post graduation | 48 | 9 | 67 |
| | | PhD | 10 | 0 | 10 |
| Household Characteristics | Family members | Less than or equal to 3<br>4 to 6<br>More than 6 | 64<br>146<br>43 | | |
| | Dwelling type | Permanent<br>Rented | 196<br>57 | | |
| | Dwelling size (number of rooms) | 1/2/3/4/5/6 & 6+ | 73/36/40/31/28 & 45 | | |
| | Income | Low (less than 2 lakhs)<br>Medium (2 to 5 lakhs)<br>High (more than 5 lakhs) | 79<br>47<br>127 | | |
| Awareness about E-waste | What is e-waste?<br>Environmental Hazards of E-waste?<br>What are E-waste rules, 2011?<br>Use EEE Exchange Offer?<br>Know E-waste Bin location?<br>Use of E-waste Bin ever?<br>Know about e-waste pick-up service? | | BG*<br>2<br>5<br>0<br>22<br>0<br>0<br>0 | AG*<br>24<br>46<br>5<br>61<br>17<br>5<br>1 | |
| Choice of e-waste collection method | Permanent collection center | | 18 | | |
| | Retail stores | | 26 | | |
| | Regular kerb-side pick up | | 9 | | |
| | Scheduled pick up when needed | | 6 | | |
| | Permanent collection + scheduled Pick up | | 39 | | |
| | Retail store + scheduled pick up | | 61 | | |
| | Curb side pick up + scheduled pick up | | 9 | | |
| | Unable to answer | | 85 | | |
| Storage of E-waste | Back up | | 85 | | |
| | Attachment | | 24 | | |
| | Do not Know | | 94 | | |
| | Do not Store | | 50 | | |

*_M_ male respondents, _F_ female respondents, _H_ head of the family,_BG_ below graduation, _AG_ above graduation

The results from the survey revealed the information about the various characteristics of the respondents such as: gender, qualification and family head's qualification. Almost all of the respondents involved in the survey were within the age group of 20–50 years. Respondent's gender distribution has shown the similar trend as that of Indian demographic gender distribution, with the male respondent's percentage slightly higher than that of India and Chandigarh's male percentage [9]. Disparity in the qualification levels among two genders of the respondents was also noticed. Approximately, 50% of the respondents were having higher qualifications and most of them were male. Qualification level of the head of a family was also chosen as a parameter as most of the rules of the house, are regulated by the heads. According to the study, approximately 60% of the heads of the families had attained higher qualifications.

Information about household characteristics also plays a crucial role in the quantification of e-waste, therefore, information about the family size, dwelling type and its income level was also collected through the survey. Household size was determined based on number of members in the household. As per the survey, average number of family members per household was 4.90. Actual range of the number of members lied between 1 and 16. Most of the respondents participated in questionnaire were staying in their own houses. Dwelling size was given weightage in this study as its results were also used in the preparation of e-waste inventory and its quantification. Usage of the number of EEEs by the family also depends on its income level, therefore, the families were also asked about their annual income. About 50% of the respondents were having family income in high (more than 5 Lakh) income category.

After comparing three parameters (Dwelling type/Size/Household Head's Education) with household Income, following conclusions were made:

1. Low income households were found majorly residing in single room houses (89.87%) with the family head's education lesser than or equal to metric level (86.07%). 30.37% of the low income households had rented dwelling type. The results were not astonishing, as in most Indian societies similar relationship can be found between income/household size and qualification level.
2. Medium income households majorly resided in 2 room dwellings and 44.7% of them had a rented accommodation. Graduates (40.42%) formed the highest percentage of the medium income category. It is not a disparity, as while staying in metro cities like Chandigarh, if anybody wants to buy a house he/she has to be in high income category, therefore, most of the respondents of other income categories reside in rented flats or compartments. Moreover, graduates serving away from their hometowns do not prefer buying new properties so they stay in rented accommodations.
3. High income households were almost similarly distributed for dwelling size of 3 rooms and higher. 9.44% of them resided in rented accommodation. The house heads of high income households were graduates or having higher qualifications. With high income, everyone can attain more facilities, therefore, this scenario is justified. Moreover, higher qualification levels also bring financial stability in his/her life, therefore, this relationship has no ambiguity.

The survey findings also showed that there is a lack of awareness, among the respondents, regarding e-waste. Only 5 respondents out of 253 were aware of the e-waste rules. Moreover, the respondents with higher educational qualifications had higher awareness about e-waste. However, respondents from all the education level categories responded positively to the use of EEE exchange offers.

As per the survey, the most preferred methods for the collection of e-waste were both Retail store collection and 'scheduled pickup when needed' collection systems. Moreover, storing the e-waste has been the most favored method opted by developing nations to manage the e-waste [11]. Kerb-side pickup was least preferred method as respondents were not sure about the proper collection of e-waste by any organization.

Storage of discarded EEEs has been found as a problem in quantification and recycling. As a significant number of respondents (37.1%) said that they had stored the e-waste without any reason, therefore, it can be deduced from such storage habits of the respondents that they do not have or do not know about the opportunities for the dumping or resale of the discarded EEEs.

## Purchase/use/disposal pattern

From the results of ANOVA the null hypothesis $H_0$ and $H_1$ were rejected by statistical analysis at significance level of $p < 0.05$ and $p < 0.001$ respectively.

Where, Null hypothesis, $H_0$ = Mean ($\mu$) of EEE possessed by each household size is equal and there is no variation with increase in number of members of household, i.e.,

$$H_0 : \mu(\text{small}) = \mu(\text{medium}) = \mu(\text{large})$$

Null hypothesis, $H_1$: Mean ($\mu$) of EEE possessed by each income category is equal and no variation is seen with increase in annual income of the household, i.e.,

$$H_1 : \mu(\text{low}) = \mu(\text{medium}) = \mu(\text{high})$$

The analysis revealed stronger relation between possessions of EEE with annual income level of household, than relation between possessions of EEE with increase in size of the family. The various EEEs included in the e-waste inventory are listed in Table 4 against household income and dwelling size.

After analyzing the trade value chain, questionnaires outputs and e-waste inventory a purchase/use/disposal pattern was developed which is shown in Fig. 3.

It was observed that the EEEs sold/donated by high and middle income households were mostly in working condition. On the other hand, low income households sell the EEEs after they stop working. EEEs in working conditions are dealt by donating, selling to second hand dealers, exchanging with other working EEEs and by keeping stored. On the other hand, EEEs in non-working conditions are dealt by selling to service centers and scrap dealers, by keeping in storage and dumping in dustbins.

## E-waste inventory of Chandigarh

### E-waste generation

Table 5, describes the frequency of e-waste generated by the residents in Chandigarh. Total amount of e-waste

**Table 4** E-waste inventory possessed by different category (income based) of households

| Type | Commodity | Household Income Category | | |
|---|---|---|---|---|
| | | Low | Medium | High |
| IT and telecommunication equipment | Desktop computers | × | √ | √ |
| | Laptop computers | × | √ | √ |
| | Notebook computer | × | × | √ |
| | Notepad computers | × | × | √ |
| | Printers including cartridges | × | × | √ |
| | Copying equipment | × | × | × |
| | Electrical and electronic typewriters | × | × | × |
| | Telephones (cordless and fixed) | √ | √ | √ |
| | Mobile telephones | √ | √ | √ |
| | Answering systems | × | × | √ |
| | Modem | × | √ | √ |
| | Scanners | × | × | √ |
| | Projectors | × | × | × |
| Large household appliances | CRT | √ | √ | √ |
| | LCD | × | √ | √ |
| | LED | × | √ | √ |
| | Refrigerator | √ | √ | √ |
| | Washing machine | × | √ | √ |
| | Air conditioner | × | √ | √ |
| | Microwave ovens | × | × | √ |
| | Dishwashing machines | × | × | √ |
| Small household appliances | Vacuum cleaners | × | √ | √ |
| | Electric iron | √ | √ | √ |
| | Electric heaters | × | √ | √ |
| | Blenders | × | √ | √ |
| | Mixers | √ | √ | √ |
| | Electric geysers | × | √ | √ |
| | Toasters | × | √ | √ |
| Consumer equipment | Cameras (photo + video) | × | √ | √ |
| | DVD players | √ | √ | √ |
| | Radios | × | √ | √ |
| | Pocket music player (IPod) | × | √ | √ |
| | Game consoles | × | √ | √ |
| | Video games | × | √ | √ |

× not possessed, √ possessed

generated from households of Chandigarh was 3276.47 tons/annum, which is equivalent to 3.1 kg/capita/annum. Similar results were reported in a study conducted on e-waste quantification in China [12, 13]. In a similar study, conducted in India, the per capita e-waste generation rate of 1 kg/ capita/ annum e-waste generation was estimated which is significantly lower than that observed in present study [14, 15].This variability is due to the higher per capita income of the study area (Chandigarh) in comparison to the per capita income of India. The various EEEs enlisted in the inventory defined by E-waste rules, 2011 was found to constitute 57.37% of the total e-waste generated in Chandigarh. It can also be observed that most of the e-waste generation in Chandigarh is due to the use of some specific EEEs such as Mobile phones, Laptops, Cameras, Washing machines, Air conditioners, Heaters, Geysers, LEDs and LCDs, which are mostly used by middle/high income Households. Therefore, the results of the present study, which state that higher dwelling size is directly related to higher qualification and household income, are verified by the inventory assessment of Chandigarh. Moreover, after comparing the results from the survey, purchase/use/disposal pattern and inventory assessment, it was found that average lifetime in smaller

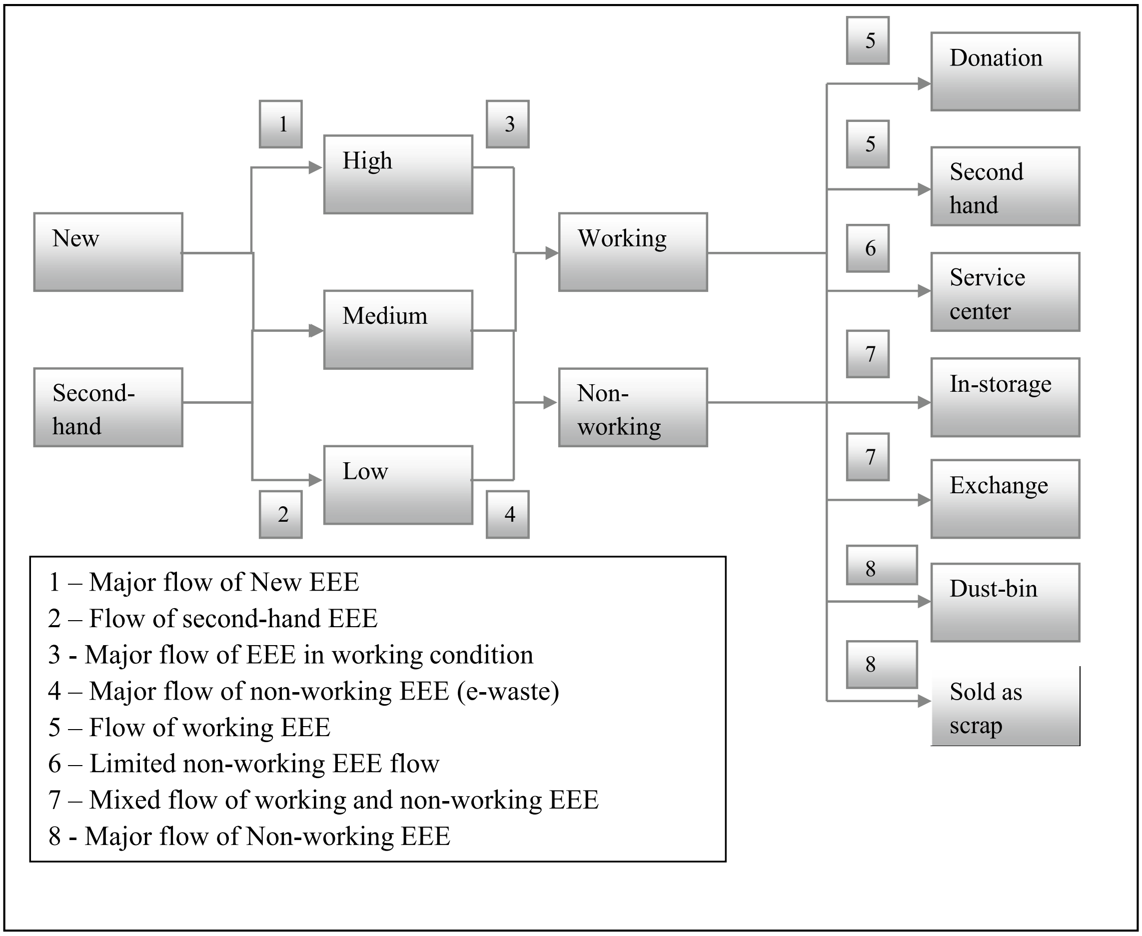


**Fig. 3** Purchase/use/disposal pattern for EEEs in Chandigarh

dwellings was lesser than larger dwellings, due to the infusion of secondary EEEs which have smaller lifetimes. Further, to validate the modifications in the 'Consumption and Use' methodology, those households which did not possess an EEE, for instance washing machine, were excluded from the e-waste assessment.

Moreover, in this study, as the data from the different business organizations could not be collected, generation of e-waste from business organizations was estimated as per the proportions proposed by Gesellschaft für Technische Zusammenarbeit and Manufacturer's Association of Information Technology (GTZ-MAIT) [16]. Accordingly, a total of 727.74 tons/annum from desktop computers and 287.61 tons/annum from laptop computers, used in business establishments, could be expected to appear as e-waste in the study area. Therefore, the final estimated total e-waste generation in the study area was estimated to be 4291.7 tons/annum.

### E-waste generation projection

GTZ-MAIT (2007) [16] estimated the e-waste generation in India for next five years based on assumption that e-waste generation will increase parallel to compound annual growth rate of India. Based on these assumptions generation of e-waste in Chandigarh was projected based on its economic growth rate indicator (i.e. GDP) till 2020, as shown in Fig. 4. In 2011, annual GDP growth rate observed for Chandigarh was 16.54%. Taking this annual GDP growth rate into account e-waste generation from households would reach 9565.1 tons/annum in 2020. Similarly, the e-waste generation growth for desktop and laptop computers till 2020 was estimated. It is also estimated that the increase in e-waste generation for the business organizations in the study area will be from 1015.3 tons/annum in 2013 to 2964.1 tons/annum in 2020. Therefore, the cumulative e-waste generation for households and

**Table 5** E-waste generation in Chandigarh from households

| | Product | Life cycle | Dwelling size category | | | | | | E-waste generation (chandigarh) (tons p.a.*) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6+ | |
| Consumer Equipment | Camera | Consumption[a] | NA | 0.29 | 1.046 | 1.591 | 1.45 | 1.81 | 10.36 |
| | | Life time[b] | NA | 3.09 | 3.96 | 4.11 | 3.86 | 4.13 | |
| | DVD player | Consumption | 0.19 | 0.29 | 0.3675 | 0.64 | 0.54 | 0.67 | 335.15 |
| | | Life time | NA | 4.28 | 4.37 | 4.69 | 4.44 | 4.61 | |
| | Radio | Consumption | NA | 0.006 | 0.09 | 0.13 | 0.12 | 0.13 | 0.64 |
| | | Life time | NA | 14.43 | 13.42 | 9.69 | 9.82 | 8.89 | |
| | Game console | Consumption | NA | 0.003 | 0.1 | 0.21 | 0.17 | 0.19 | 1.06 |
| | | Life time | NA | 2 | 2 | 2 | 2 | 2 | |
| | Video game | Consumption | NA | 0.26 | 0.21 | 0.18 | 0.18 | 0.19 | 9.55 |
| | | Life time | NA | 3 | 3 | 3 | 3 | 3 | |
| | Portable music player | Consumption | NA | 0.15 | 0.39 | 0.53 | 0.47 | 0.58 | 2.06 |
| | | Life time | NA | 2 | 2 | 2 | 2 | 2 | |
| IT equipment | Desktop computer | Consumption | NA | 0.29 | 0.51 | 0.51 | 0.52 | 0.55 | 198.14 |
| | | Life time | NA | NA | 4.99 | 5.27 | 5.15 | 5.24 | |
| | Laptop computer | Consumption | NA | 0.37 | 0.79 | 1.186 | 1.07 | 1.30 | 87.86 |
| | | Life time | NA | 4.26 | 4.07 | 3.69 | 3.84 | 3.74 | |
| | Modem | Consumption | NA | 0.07 | 0.15 | 0.26 | 0.23 | 0.29 | 12.27 |
| | | Life time | NA | 1.87 | 1.74 | 1.47 | 1.58 | 1.51 | |
| Large household appliance | Air conditioner | Consumption | NA | 0.61 | 1.71 | 2.63 | 2.32 | 2.78 | 931.17 |
| | | Life time | NA | NA | 6.21 | 6.07 | 6.17 | 6.11 | |
| | CRT | Consumption | 0.86 | 0.74 | 0.73 | 0.70 | 0.77 | 0.69 | 498.27 |
| | | Life time | 6.67 | 12.02 | 12.79 | 14.20 | 13.78 | 13.56 | |
| | LCD | Consumption | NA | 0.19 | 0.66 | 0.96 | 0.89 | 1.10 | 18.16 |
| | | Life time* | NA | 12.02 | 12.79 | 14.20 | 13.78 | 13.56 | |
| | LED | Consumption | NA | NA | 0.54 | 1.09 | 0.93 | 1.24 | 51.86 |
| | | Life time* | NA | 12.02 | 12.79 | 14.20 | 13.78 | 13.56 | |
| | Microwave | Consumption | NA | 0.04 | 0.67 | 0.91 | 0.88 | 1.09 | 263.94 |
| | | Life time* | NA | NA | 6.21 | 6.07 | 6.17 | 6.11 | |
| | Refrigerator | Consumption | 0.83 | 0.98 | 1.02 | 1.18 | 1.51 | 1.59 | 433.99 |
| | | Life time | NA | 15.85 | 16.13 | 15.92 | 16.02 | 15.96 | |
| | Washing machine | Consumption | NA | 0.03 | 0.90 | 1.03 | 1.01 | 1.1 | 15.94 |
| | | Life time | NA | NA | 11.50 | 10.28 | 10.82 | 10.48 | |
| Small household appliances | Blender | Consumption | NA | 0.02 | 0.54 | 1.08 | 1.09 | 1.22 | 83.7 |
| | | Life time | NA | 3.67 | 3.87 | 4.26 | 4.10 | 4.21 | |
| | Mixer | Consumption | 0.30 | 0.85 | 1.06 | 1.08 | 1.07 | 1.07 | 7.14 |
| | | Life time | 4.27 | 6.46 | 7.48 | 8.17 | 7.98 | 8.41 | |
| | Toaster | Consumption | NA | NA | 0.50 | 1.08 | 1.16 | 1.18 | 7.14 |
| | | Life Time | NA | NA | 8.32 | 9.08 | 8.73 | 8.82 | |
| | Electric iron | Consumption | 0.39 | 0.83 | 1.01 | 1.17 | 1.17 | 1.19 | 37.14 |
| | | Life time | 3.25 | 4.28 | 5.85 | 6.05 | 6.08 | 6.39 | |
| | Electric geyser | Consumption | NA | 0.05 | 1.38 | 2.02 | 2.17 | 3.18 | 97.23 |
| | | Life time* | NA | 6 | 6 | 6 | 6 | 6 | |
| | Electric heater | Consumption | NA | 0.06 | 1.28 | 1.69 | 1.58 | 2.25 | 28.20 |
| | | Life time | NA | 5 | 4.52 | 4.20 | 4.39 | 4.41 | |
| | Vacuum cleaner | Consumption | NA | NA | 0.41 | 0.69 | 0.72 | 0.76 | 27.38 |
| | | Life time (A) | NA | NA | NA | NA | NA | 4.56 | |
| Tele-communication Equipment | Mobile phone | Consumption | 1.50 | 3.53 | 3.27 | 3.71 | 3.53 | 3.68 | 68.6 |
| | | Life time | 1.49 | 1.84 | 1.91 | 2.15 | 2.08 | 2.23 | |
| | Telephone | Consumption | NA | 0.06 | 0.85 | 0.87 | 0.88 | 0.93 | 49.52 |
| | | Life time | NA | 11.77 | 14.58 | 15.24 | 15.08 | 15.54 | |
| Total | | | | | | | | | 3276.47 |

**Table 5** (continued)

*NA* not available

[a]Average units per household

[b]Years

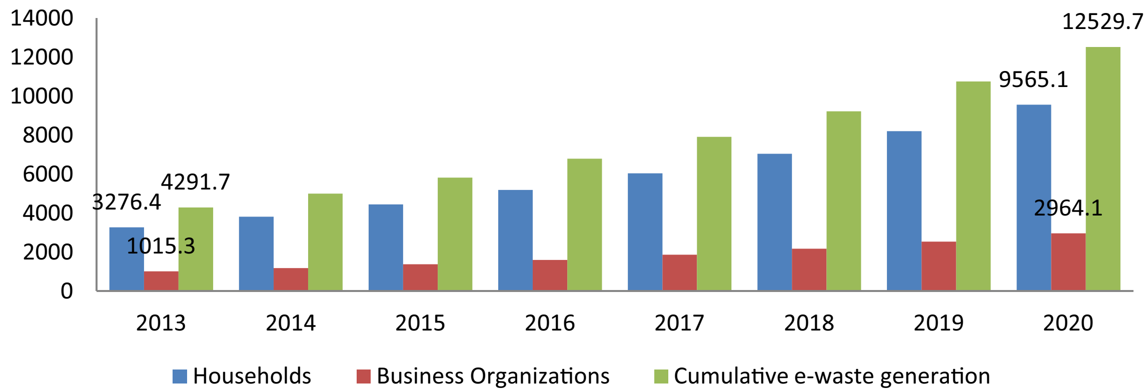


**Fig. 4** Future predictions of E-waste generation for Chandigarh

business organizations is expected to reach 12529.7 tons/annum by 2020.

## Disposal routes and e-waste inventory

In this section, discussion on comparative analysis of various disposal patterns and E-waste inventory is presented. The amount of e-waste generated from particular equipment was found using the weightage of disposal routes, estimated from survey. Then percentage weightage was obtained from the number of units disposed off through a particular disposal route. It can be observed from the Table 6 that the lack of awareness, about e-waste and its management, among the residents has affected the disposal pattern of the e-waste and storage of e-waste has been chosen as the third most favored method for the disposal of e-waste. EEEs such as DVD players, Desktop Computers, Laptops, CRTs, mobile phones and refrigerators are the ones which are stored mainly in store rooms of offices, warehouses, homes etc.

Channel of “selling as scrap” has been highly represented, for e-waste management, among the respondents. Chandigarh city has attracted a lot of e-waste scrap dealers, therefore, they are active in searching for e-waste from home to home. As scrap dealers are easily available at door steps, therefore, respondents have chosen “selling as scrap” as the best e-waste management method. Moreover, monetary benefits from this method have made it most favorable.

The study also revealed that the mode of direct exchange of used EEEs with the retailers has also been appreciated by the respondents. It is the second most favorite method of disposal of EEEs. The problem with this method is that it is availed only for few costly EEEs such as laptops, refrigerators, AC and Washing machines. These EEEs are mostly owned by high income category people and in our study their proportion is also relatively higher.

“Donation” of used EEEs to their relatives or friends has also been appreciated by the respondents. Being high/medium income category people, they sometimes hand over their outdated or to be repaired EEEs to their needful relatives, rather than selling them to gain some money. The use of second hand EEEs can be credited to the low/middle income category respondents, as higher income respondents mostly prefer buying new EEEs. Mobile phones, CRTs and DVD players are the main EEEs which are mostly sold as second material in the market.

Method of giving the used or discarded EEEs to the service centers has not been much appreciated by the respondents due to lack of awareness and unavailability of the on the door provision.

Dumping of e-waste along with solid waste is the second least chosen method. Only two equipment, mobile phones and portable music players were thrown in dustbins. Lack of awareness has been found as the major reasons among the respondents for choosing this method for e-waste management.

Similar results were obtained in studies conducted by GTZ-MAIT (2007) [16] and IMRB (2010) [17] in Delhi and Kolkata respectively. These studies identified that ‘giving away/donating’ of obsolete EEE to relative/friends and selling in second hand markets are major disposal routes.

**Table 6** Share (tons/annum) of different disposal routes for e-waste inventory

| Product | Sold as scrap | Sold as second hand | Exchanged | Donated | Dustbin | In storage | Service center |
|---|---|---|---|---|---|---|---|
| Camera | 1.6 (16%) | – | – | 0.9 (8.66%) | – | 7.8 (75.33%) | – |
| DVD Player | 95.7 (28.57%) | 95.7 (28.57%) | – | – | – | 143.6 (42.85%) | – |
| Radio | 32.6 (50.31%) | – | – | 0.1 (19.74%) | – | 0.2 (29.93%) | – |
| Game Console | 0.06 (6.06%) | – | – | 0.6 (57.57%) | – | 0.4 (36.36%) | – |
| Video Game | 2.6 (26.86%) | – | – | 3.2 (34.42%) | – | 3.7 (38.81%) | – |
| Portable Music Players | 0.4 (19.67%) | – | – | 0.2 (9.83%) | 0.03 (1.63%) | 1.4 (68.86%) | – |
| Desktop Computer | 59.9 (30.23%) | – | – | 45.6 (23.25%) | – | 86.2 (43.51%) | – |
| Laptop Computer | 27.1 (30.90%) | – | 1.6 (1.81%) | 19.2 (21.81%) | – | 39.9 (45.45%) | – |
| Modem | 2.4(20%) | – | 9.8(80%) | – | – | – | – |
| AC | 368.5 (39.58%) | – | 551.1 (59.18%) | – | – | – | – |
| CRTs | 114.2 (22.92%) | 117.4 (23.56%) | 28.5 (5.73%) | 168.2 (33.75%) | – | 69.8 (14.01%) | – |
| LCD | – | – | – | – | – | – | – |
| LED | – | – | – | – | – | – | – |
| Microwave | – | – | – | – | – | – | – |
| Refrigerator | 128.8 (29.2%) | 43.1 (9.77%) | 79.5 (18.04%) | 155.6 (35.29%) | – | 62.9 (14.28%) | – |
| Washing Machine | 3.3 (20.51%) | 1.4(8.97%) | 3.5 (21.78%) | – | – | 7.8 (48.71%) | – |
| Blender | 71.9 (85.94%) | – | – | 3.9 (4.76%) | – | 8.9 (10.71%) | – |
| Electric Geyser | 47.2 (48.57%) | – | – | 49.9 (51.42%) | – | - | – |
| Electric Heater | 16.7 (59.13%) | – | – | 2.9 (10.43%) | – | 8.6 (30.43%) | – |
| Electric Iron | 20.9 (56.19%) | – | 0.5 (1.42%) | 3.7(10%) | – | 12.02 (32.38%) | – |
| Mixer | 3.8 (53.95%) | – | – | 1.1 (15.82%) | – | 2.1 (30.21%) | – |
| Toaster | 4.9 (70%) | – | – | – | – | 2.1 (30%) | – |
| Vacuum Cleaner | 18.2 (66.66%) | – | – | – | – | 9.1 (33.33%) | – |
| Mobile phone | 8.9 (13.05%) | 14.4 (20.98%) | 7.9 (11.46%) | 12.3 (17.98%) | 3.7 (5.46%) | 19.5 (28.45%) | 1.1 (1.58%) |
| Telephone | 1.57 (3.19%) | – | 43.2 (87.23%) | – | – | 4.7 (9.57%) | – |
| Total | 1031.23 (39.6%) | 272.0 (8.56%) | 725.6 (22.83%) | 467.4 (13.45%) | 3.73 (0.12%) | 490.72 (15.44%) | 1.1 (0.03%) |

## Limitations and future research

1. Sample size was not large enough to suitably generate stable average data's so that they could be used at national level. Therefore, this study can be extended by involving all the stakeholders and on an extensive scale in a specific area to create better input data. There is also a need to conduct such surveys in Tier-I, II, III and IV cities, and then draw conclusions by comparison and aggregated analyses.
2. The E-waste inventory assessment in the study was done on the basis of household survey. E-waste generation from business organizations was based on the assumptions from previous studies. A detailed study about generation and flow of e-waste from business organizations is needed.
3. The study provided an overview of material flow of e-waste through the study area. The preliminary survey revealed that flow was profit oriented. Thus a study based on cost-benefit analysis of the e-waste flow can be carried out.
4. The material flow of EEE and e-waste through the study area is proposed by a survey and is not quantitative. Quantitative data in each flow path would help in enhancing the areas with substantial material flow.

## Conclusions

The preliminary survey revealed that, though, various entities are generating e-waste which flows through different routes; still the handlers at the end of material flow chain are informal scrap dealers/recyclers.

Majority of the respondents (89.73%) had poor level of awareness about e-waste. Higher education level respondents had better know-how of e-waste, comparatively. A significant number of respondents from each education level reported to have made use of exchange offers. Most preferred method (24.9%) for the collection of e-waste was retail store take-back and 'scheduled pick–up when needed' combined. 37.1% of the respondents were found to be in a habit of storing e-waste without any specific reason.

CRTs, Refrigerators, electric irons, mixers, mobile phones and DVD players were the major EEE in possession of each income category households. Majority of EEE possessed by medium and high income households were bought new, while second-hand possession existed majorly in low income households. Similarly, majority of the EEE discarded by high income households were in working condition, while comparatively higher percentage of EEE discarded by low and medium income households were in non-working condition. Disposal routes varied as per the product category to be discarded. Sold as scrap, second-hand, exchange, storage and donation were major disposal routes for high income households, while low income households usually discarded their products as scrap to scrap dealer.

The e-waste generation in Chandigarh was reported to be 4291.7 tons/annum. Business organization contributed 1015.3 tons/annum (23.65%) into the total e-waste generated in the form of desktop and laptop computers. Total e-waste generation from households and business organizations is expected to reach 12529.7 tons/annum by 2020. Selling as scrap was found to be the major disposal route contributing 1256.86 tons/annum of e-waste into the total amount.

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