Analysis of e-waste components at a computer service center of Makassar City

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Abstract. E-waste is a waste of electronic devices where its number of generation continues to increase in the world. However, improper processing of e-waste in developing countries, such as Indonesia, especially from computing devices, can lead to adverse human health effects and environmental pollution. Therefore, the aims of this study are to determine the generation, composition, material flow, and management of e-waste of computer devices produced by 19 stores in a computer service center of Makassar City. Analysis of this study is based on Indonesian Government Regulation No. 101 of 2014 on the Management of Hazardous and Toxic Waste. The results of this study showed that the generation of e-waste from a computer service centre was 4.340 kg/store/day with 60.34% of plastic, 23.88% of metal, 7.81% of metal and plastic, 4.18% of metal and rubber, 3.62% of glass and 0.17% of rubber. Material flows of e-waste generation in the computer service centre are divided into sold to e-waste collectors, kept in stores, brought back by customers, and disposed of, with 38.69%, 30.75%, 26.55%, and 4.01%, respectively. Moreover, specific e-waste management needs to be done by segregating the e-waste from other types of waste by arranging waste transport time and providing a special disposal site.

1. Introduction

The number of population and the level of economic growth of the community affect the use of electronic devices. For people living in metropolitan cities, especially those supported by many educational facilities, the use of computer devices has become familiar. Most people already have computer devices to support their daily activities. Currently, laptop usage is used instead of the computer because of its practicality, light, and easy to carry. Therefore the number of users continues to increase. In 2010, the number of laptop usage in Indonesia was about 32.46% (2.18 million units). Based on Indonesia Government Regulation PP No. 101/2014, electronic waste or e-waste is included in hazardous and toxic waste, where hazardous and toxic wastes are substances, energies, and/or other components due to their nature, concentrations and/or quantities, either directly or indirectly, can pollute and/or damage the environment, and/or endanger the environment, health, as well as the survival of human beings and other living beings [1].

Sources of e-waste generation in Indonesia come from various activities include health, education, food, transportation, communication, environmental processing, culture, household and others. Electronic equipment commonly used in such activities, including computers, medical devices, industrial machinery, electronic transport systems, communication devices, refrigerators, lamps and washing machines. The import of used electronic goods into Indonesia becomes the source of a pile of e-waste material, which mainly consists of mobile phones and computers [2]. In addition, according to the United Nations Framework Convention on Climate Change (UNFCC), by recycling raw materials
from discarded electronics, natural resources are conserved, and air and water pollution caused by hazardous disposal are avoided. Recycling e-waste from landfills reduces methane emissions, which are 25 times more potent than carbon dioxide at trapping heat in the atmosphere. More than 17 tons of e-waste is collected each year, preventing the release of carbon dioxide and other greenhouse gases. E-waste that is not recycled contributes to about 4.25% of the greenhouse emissions [3]. Previous researches showed that methane (one of the greenhouse gases) emissions and concentrations were 2.44 – 18 Gg/year and 12 – 425 ppm in Tamangapa landfill-Makassar City, respectively [4,5]. All type of waste was disposed of in Tamangapa landfill, including the E-waste.

This study was conducted in a computer and electronic devices sales and services center in Makassar city, South Sulawesi of Indonesia based on the previous research [6]. This previous research entitled Identification of e-Waste Material from Computer Device in a Computer Service Centre of Cimanggis Depok city concluded that researchers in electronic devices have to be carried out in many areas to describe the e-waste management and its impact on the environment. Therefore, it is necessary to analyze the e-waste material of computer peripheral from a computer service center in Makassar city. This study will provide useful inputs as a basis for consideration of the planning and design of waste management systems. The objectives of this study are to determine the amount of e-waste generation, composition, material flow, and its management from a computer service center of Makassar city.

2. Methodology
This study was carried out by observation, interview, and sampling in 19 stores of a computer service center. In data analysis, this study used a quantitative approach with data obtained from the sampling process and statistical data in correlation studies based on surveys and quantifiable case study support materials. These data included the amount of generation and composition of E-waste of computer devices obtained from store activities.

2.1. Study site
This study was conducted in the largest computer service center in Makassar city, named Computer City. Computer city has many computer stores, up to 26 computer peripheral sales stores with 19 stores, including computer repair services. From these repair activities, electronic waste (e-waste) was produced from damaged or non-reusable computer equipment, where the amount of this generation will affect the amount of e-waste in Makassar city.

![Figure 1. Computer service center of Makassar City.](image)

This study was located in Computer City, the largest computer service center at Jalan Pengayoman in Makassar City. This study site has a total area of 2,500 m2, which consists of four floors and a basement. Ground floor, first floor, and second floor are intended for buying and selling activities of electronic devices and services. Half part of the third floor is used for buying and selling activities, and another part is used as a canteen, prayer room, and management office.
2.2. Data collection

Types of required data, its description, and method of data collection could be seen in table 1.

| Required Data                                      | Description                                                                 | Data Collection Method                      |
|---------------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------|
| General description of Computer City, a computer service centre in Makassar City | • General description of the study site, operational data, and location of the study site (map).  
• General data of study object: numbers, area, operating hours, and number of the consumer of the stores | Literature and Interview                    |
| Current waste management system of computer service centre in Makassar City Variable | • Current waste collection and transport system  
• E-waste management  
• E-waste generation  
• E-waste composition  
• Percentage of recyclable E-waste and cannot be recycled  
• Characteristics of E-waste generation related to hazardous and toxic waste | Literature, Interview and Field Survey  
Sampling, Calculation, and Literature Analysis |

Equipment needed for sampling, namely:
• Trash bag, used as an e-waste collection container from source (stores in a computer service centre)
• Scales used to weigh the e-waste generation
• Hygiene kits, such as duster and tissues
• Personal protective equipment, such as masks and gloves

2.3. Processing and data analysis

2.3.1. E-waste generation of computer devices. Based on the weight of waste generation from each store, then summed, then summed, using the equation as follows:

\[ \text{E - Waste Generation (\( \text{kg/day} \))} = \frac{\sum \text{Weight of Ewaste generation (kg)}}{\text{day}} \]  

(1)

Based on Indonesian National Standard, SNI 19-3964-1994, daily weight data of e-waste generation was collected in the research period, which was conducted for 8 (eight) days [7]. Moreover, the average of e-waste generation (kg/day) was done to obtain the total e-waste generation from a computer device in kg/day, as follows:

\[ \text{E - Waste Generation (\( \text{kg/day} \))} = \frac{\sum \text{Weight of Ewaste generation (kg) 8 days}}{8 \text{ days}} \]  

(2)

2.3.2. E-waste composition. The e-waste composition was derived from the e-waste generation by all stores every day. Based on the data are also known component compilers. Therefore the percentage of materials composing of e-waste components could be known by using this equation:

\[ \% \text{ Weight of Material} = \frac{\text{Weight of material composition}}{\text{Weight of total EWaste}} \times 100\% \]

(3)
2.3.3. Potential of e-waste generation. The potential of e-waste generation was obtained from the research data where the inventory of the components stored in each store. Inventory was applied on new and used components stored by the store in the form of component type, amount of component, and weight of the stored component. Calculation of potential E-waste generation by measuring the weight of the stored components with the following equation:

\[
\text{Total weight of stored Ewaste (kg)} = \text{Weight of Component} \times \text{Amount}
\]

(4)

2.3.4. Material flow of e-waste. Material flow is a mass equilibrium diagram of e-waste management. The management performed was: e-waste disposed to the temporary dump site, e-waste was stored by stores, e-waste brought by a consumer, and e-waste sold to collectors. Equilibrium diagrams were equipped with the weight and percentage of e-waste. The data was analyzed and compared with the flow of e-waste material obtained from previous research.

\[
\% \text{ Type of Management} = \frac{\text{Weight of material composition}}{\text{weight of total e–waste}} \times 100\%
\]

(5)

2.3.5. Management of e-waste from computer devices. An analysis was done by comparing the existing management system with integrated e-waste management. The management system was also adjusted to the number of e-waste generation and composition, where could be determined e-waste management system that effectively and efficiently so as to prevent the occurrence of environmental pollution.

The sampling equipment used was a 2 kg and 5 kg scales. The 2 kg scales were used to weigh small and light e-waste samples. A 5 kg scale was used to weigh E-waste samples which more than 2 kg. In addition, magnets were used to identify the composition of the e-waste, whether metal or non-metals. Documentation tools used during the sampling process were cameras, masks, and gloves that must be worn during sampling.

Table 2. Detailed data of each store.

| No. | Name of the Store | Area (m²) | Operating Hours | Services | Average of Repair per Day |
|-----|-------------------|-----------|-----------------|----------|--------------------------|
| 1   | Store No.1        | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 2   | Store No.2        | 3 x 4     | 09.00 – 20.00   | Laptop repair | 5 – 7                   |
| 3   | Store No.3        | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 4   | Store No.4        | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 5   | Store No.5        | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 6   | Store No.6        | 3 x 4     | 09.00 – 20.00   | Laptop, computer, and mainboard repair | 3 – 5          |
| 7   | Store No.7        | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 8   | Store No.8        | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 9   | Store No.9        | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 10  | Store No.10       | 4 x 10    | 09.00 – 20.00   | Laptop, computer, and printer repair | 5 – 8        |
| 11  | Store No.11       | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 12  | Store No.12       | 3 x 4     | 09.00 – 20.00   | Laptop repair | < 5                     |
| 13  | Store No.13       | 3 x 4     | 09.00 – 20.00   | Laptop, computer, and CPU repair | < 5            |
| 14  | Store No.14       | 3 x 4     | 09.00 – 20.00   | Printer repair | < 5                        |
| 15  | Store No.15       | 3 x 4     | 09.00 – 20.00   | Laptop, computer, and printer repair | < 5            |
| 16  | Store No.16       | 3 x 4     | 09.00 – 20.00   | Laptop, computer, and printer repair | < 5            |
| 17  | Store No.17       | 3 x 4     | 09.00 – 20.00   | Computer repair | < 5                  |
| 18  | Store No.18       | 3 x 4     | 09.00 – 20.00   | Printer repair | < 5                        |
| 19  | Store No.19       | 3 x 4     | 09.00 – 20.00   | Laptop, computer, and printer repair | 5 – 7        |
The study was also conducted by interviewing the store owner about the service of the store. The data collected were the store area, store operating hours, store-provided services, and the average of repair by the store per day. The following is the detailed data of each store from the interview result in table 2. The data shows the store area, the operating hours, and the services provided differently. Therefore, it could be used to analyses the amount of E-waste generation.

3. Result and discussion

3.1. E-waste generation
Based on the study result, e-waste generation, from each store per day for 8 days was 33.092 kg with average E-waste generation per day of 4.340 kg/day. From the data, it could be seen that there were days where the value of E-waste generation is 0 kg because on that day, the computer service center not produce E-waste or closed. Based on the data obtained through interviews with store owners noted that Store No. 10 offers complete repair service, including a laptop, computer, and printer. This can lead to E-waste generation of Store No. 10 more than other stores. Fluctuation in the average of e-waste generation per day, as seen in figure 2., shows that there is a deviation of the values. Therefore, these influence factors will be tested by using multiple regression statistics with "Backward Elimination" in SPSS 22 as an independent factor in merging the two results as a dependent factor.

**Table 3. Linear regression test result.**

| Model | R | R² | Adjusted R² | Std. Error of the Estimate | R² Change | F Change | df₁ | df₂ | Sig. F Change |
|-------|---|----|--------------|---------------------------|-----------|---------|-----|-----|--------------|
| 1     | 0.903³ | 0.815 | 0.792 | 1.1899625 | 0.815 | 35.242 | 2 | 16 | 0.000 |

a. Predictors: (Constant), Store Area (m²), number of repairs  
b. Dependent Variable: Total e-waste generation (kg/store)

Table 3 shows the amount of correlation or relationship (R) is 0.903 with a coefficient of determination (R²) of 0.815, where the influence of independent variables (the number of repairs and store area) to the dependent variable (e-waste generation) is equal to 81.5%.

3.2. E-waste composition
The e-waste component was generated from the stores in computer service centre. The E-waste component consists of various types of computer components, such as ICs, keyboards, motherboards, capacitors, and so on. The following were some of the e-waste components produced by the stores in
Based on the e-waste composition data of its component type, the largest amount of e-waste was the computer case, and the smallest was the regulator. The computer case was made of plastic. One type of plastics, which were widely used in the manufacture of a computer case, is polycarbonate [8]. The advantages of polycarbonate material in the computer case are resistance to thermal, impact, and transparent. In hot conditions, polycarbonate could emit the main ingredient Bisphenol-A, which could be harmful. The smallest e-waste composition was the regulator. The regulator component was in the mainboard component, if it was damaged, some other components could be separated from the mainboard to be reusable. According to the research, the component of mainboard contained metal, which could pose a danger [9]. The composition of e-waste components based on materials, in this study, could be seen in figure 3.

![Figure 3. Percentage of e-waste based on composition.](image)

The data obtained show that 63% of the composition of e-waste generation is plastic, while the smallest is rubber only reaches 0.17%. Based on data from UNEP, 50% composition of e-waste compiler from the computer device was iron and steel (metal) [10, 11, 12]. While in this study, the metal composition was 24%. Differences in results obtained were due to data obtained in the e-waste study was very diverse. This might be due to differences in study sites, where electronic equipment components were damaged differently despite the same type of electronic device. Therefore, the composition of one location of e-waste could be different from other locations.

3.3. Material flow of e-waste and its management

The material flow calculation was done on the whole sample for 8 days using equation 5. The purpose of the calculation of this material flow was to know the management of the e-waste generation, where it could be disposed of, stored for reuse, sold to collectors, or could be returned to consumers. Figure 4 shows the different types of management carried out in this study site, i.e., e-waste carried by consumers, e-waste stored, e-waste sold to collectors, and e-waste disposed of with guidance lines explaining the amount of e-waste managed on each behavior management. The material flow diagram also comes with the potential to be e-waste disposed of, i.e., e-waste brought by consumers and e-waste stored. E-Waste brought by consumers was considered the potential to be e-waste disposed of due to a lack of knowledge of e-waste recycling. While e-waste stored was considered to be potential as e-waste disposed of, if it is unused so it could be damaged.

E-waste management that could be applied was to provide a waste bin, which was divided into three types of waste (organic, inorganic, and e-waste) and arranging waste transportation schedules in accordance with the type of waste. Waste bins need to be provided at each temporary dumpsite, which was divided into three according to the three types of waste based on the sorting. Therefore, waste
could be separated for recycling purposes and e-waste did not mix with other waste so as to reduce the risk of harm.

![Diagram of e-waste material flow and management]

**Figure 4.** The material flow of e-waste and its management.

### 4. Conclusion

Based on the study result, it can be concluded that the weight of e-waste generation from a computer service center with 19 repair stores, amounting to 33,092 kg with an average weight per day of 4,340 kg/store/day or 0.278 kg/m²/day. Moreover, the detail of e-waste composition from a computer service center with 19 repair stores: 60.34% plastics, 23.88% metals, 7.81% metal and plastics, 4.18% metals and rubber, 3.63% glass and 0.17% rubber. The material flow of e-waste in this study contained 4.01% of e-waste disposed of, 30.75% e-waste stored, and 26.55% of e-waste brought back by consumers. This management behavior is considered to be lacking in the effort of recycling e-waste components. Therefore, the amount of e-waste is still quite a lot.

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