E-waste Estimation: A case study of Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh

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Abstract

The development of new technologies and the increasing consumption of electronic and electrical equipment have led to increase the generation of e-waste in the municipal waste streams. The present study was carried out at Shahjalal University of Science & Technology (SUST), Sylhet, Bangladesh. The aim of the research paper is to find out the amount of e-waste generated by the students of different departments of School of Applied Sciences and Technology, SUST. This study describes the current and future estimation of e-waste generated from mobile phone, laptop, desktop, pen drive, headphone, parts of computer such as keyboard, motherboard, mouse. To estimate volume of the e-waste, consumption & use (C&U) method and waste stream methods were applied. The research findings include total amount of electronic waste generated at Shahjalal University of Science & Technology (SUST), Sylhet, Bangladesh as 2494.38 kg in 2016. Linear Trend Forecasting method was applied to predict the amount of e-waste. The forecasting also showed that the amount of e-waste will increase gradually and by the year 2024 it will be 4070.62 kg which is double of the e-waste generated in 2016. It is necessary to provide essential infrastructures for separation, collection, recycling, and management of such e-waste.

Keywords
E-waste, Consumption, Stream, Forecast, Estimation.

1. Introduction

Waste from end of the life (EoL) electrical and electronic equipment, known as e -waste is the fastest-growing waste stream in the world. It contains many toxic substances which can contaminate and pollute the environment and threaten human health. At present the amount of e-waste is growing rapidly in Bangladesh. In our country, a large amount of e-waste is generated from the university students. This study estimates the amount of e-waste generated by the students of Architecture(ARC), Chemical Engineering & Polymer science(CEP), Civil & Environmental Engineering(CEE), Computer Science & Engineering (CSE), Electrical & Electronics Engineering (EEE), Food Engineering & Tea Technology (FET) , Industrial & Production Engineering(IPE), Petroleum & Mining Engineering(PME), Mechanical Engineering(MEE) departments; School of Applied Sciences and Technology, Shahjalal University of Science & Technology (SUST), Sylhet-3114, Bangladesh. This study emphasizes on mobile phone, laptop, desktop, pen drive, headphone, parts of computer such as keyboard, mouse, motherboard. Because these products contribute a major share to the amount of e-waste generated by the students and also now a days the rate of switching to electronic products is increasing day by day.

1.1 Objectives

The objectives of this study are as follows:

- To find out the amount of e-waste generated by the students of Architecture, Chemical Engineering & Polymer Science, Civil & Environmental Engineering, Computer Science & Engineering, Electrical & Electronics Engineering, Food Engineering & Tea Technology, Industrial & Production Engineering, Petroleum & Mining Engineering, Mechanical Engineering departments of School of Applied Sciences and Technology, SUST, Sylhet, Bangladesh.
- To predict the amount of e-waste from the year 2020 to 2024.

2. Literature review

This section deals with the previous research work done by different researchers of different organizations and research institutions. M.N.M, Abbondanza and R.G, Souza (2019) aimed at developing and applying a waste electrical and electronic equipment (WEEE) estimation method in a Brazilian city, by obtaining primary data that reflects the differences in WEEE generation among the various social and economic profiles in the city (Abbondanza and Sauza 2019). Siddiqua et al. (2019) tried to find information about the source of e-waste, its flow pattern and components, classifications, price changing, the process of recycling and the estimation of total amount of e-waste present in Bangladesh (Siddiqua et al., 2019). Iqbal et al. (2019) described the current and future estimation of e-waste generated from cellophane and PC in Sylhet city, Bangladesh (Iqbal et al., 2019). Santoso et al. (2019) attempted to quantitatively estimate the e-waste in Indonesia by using the population balance model (Santosh et al., 2019). Mirgerami et al. (2018) aimed to estimate the flow of e-waste in Iran in order to establish a baseline for these toxic, potentially valuable wastes (Mirgerami et al., 2018). Bahersa and Kimb (2018) tried to explicit e- waste chain and flows using the Material Flow Analysis (MFA) method (Bahersa and Kimb 2018). Park et al. (2017) discussed about the effects of e-waste on the environment and human health (Park et al., 2017). Ikhlayel et al. (2016) examined the advantages and disadvantages of five methods of estimating generation of waste from electrical and electronic equipment (Ikhlayel et al., 2016). In their research, Modified Consumption and Use methods were applied to estimate the e-waste. San et al. (2015) covered all of six mobile network operators which are doing telecommunications business in Bangladesh (San et al., 2015). Alavi et al. (2015) estimated the amount of e-waste generated by different electrical and electronics products They investigated the current status of e-waste management in Ahvaz city (Alavi et al., 2015). Kottapalle et al. (2015) tried to find out the reasons for e-waste generation and its effect on environment and human health (Kottapalle et al., 2015). Yoheeswaran et al. (2013) described the increasing rate of e-waste generation in India which is around 15% and the amount of generated e-waste crossed approximately 800,000 tons in 2012 (Yoheeswaran et al., 2013). Shagun et al. (2013) tried to focus on the effects of e-waste constituent on human health (Shagin et al., 2013). Chung et al. (2012) tried to identify the best e-waste quantification methods for e-waste estimation using case studies on China (Chung et al., 2012). Bhutta et al. (2011) tried to provide a review of the e-waste problem. Their study put forward an estimation technique to calculate the growth of e-waste (Bhutta et al., 2011).

2.1 Research Gap

The problem of e-waste disposal is a very well-known fact, and its generation is increasing exponentially every year. Many research works have been conducted by many authors regarding e-waste. A lot of research works have been carried out by many authors regarding e-waste. But a few researches have been conducted in Bangladesh.

3. Methodology

Research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. Methodology includes several methods or strategy for concluding the research.

3.1 Methodology

An action plan has been constructed so that logical and sequential progress can be made throughout the study. Action plan shown in figure.1 describes the stages involved in this study.

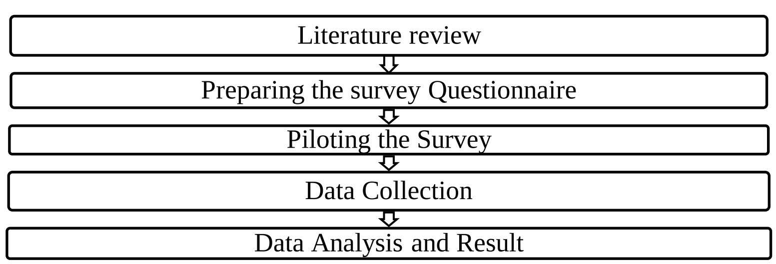

Figure 1: Action plan of this research.

Using survey research, a random population were taken from the School of Applied Sciences and Technology, SUST. Using archival method, some information related to the study that has already been answered by others was gathered from various journals and newspaper articles. So, among various types of strategy, survey research and archival method were best suited for this study purpose.

Data collection methods can be divided into two categories as Primary methods of data collection and Secondary methods of data collection. Both primary and secondary data were collected for this study. Secondary data were collected from newspapers, articles, journals etc. Primary data were collected from calculated sample of students of School of Applied Sciences & Technology, SUST through a survey-based questionnaire.

3.2 Tools and Techniques Used

Different tools and techniques that were used in this research work are as follows:

A. Sample Size

Slovin's formula is a random sampling technique formula to estimate sample size. It is used to calculate the sample size given the population size and a margin of error. When it is not possible to study an entire population, a sample is taken using a random sampling technique. Slovin's formula allows a researcher to sample the population with a desired degree of accuracy. Slovin's formula gives the researcher an idea of how large the sample size needs to be to ensure a reasonable accuracy of results. When taking statistical samples, sometimes a lot is known about a population, sometimes a little and sometimes nothing at all. Slovin's formula is used when nothing about the attributes to be experimented of a population is known. Slovin's formula is used to determine a sample size ("Slovin's Formula Sampling Techniques", 2018).

$$n = \frac{N}{(1+Ne^2)};$$

Where,

n = Sample size, N = Total Population, e = Error tolerance level.

Let, the confidence level of this study be 95 percent. Which gives e = 0.05. The students of School of Applied Sciences & Technology, SUST is approximately 2510. So, by calculating and rounding to a whole number, we get the sample size to be 345. It means that, 345 respondents need to be selected for data collection from survey questionnaire.

B. Waste Stream Method

The Quick Waste Stream Analysis informs local communities about the approximate quantity of recyclable material in their waste stream and their current recovery level for each material. Waste stream analysis is used in this research work.

- Below factors have played crucial role for choosing Waste stream analysis for estimating E-waste.
- Scarcity of proper sales data
- Availability of number of subscribers
- The time needed to gather and analyze data
- Time consuming method

Waste stream analysis does not require any sales data. Only stock data for the evaluation year and average weight of the product are required to estimate the e-waste volume in a region. The method's formula is presented in the following equation (San et al., 2016):

Total weight of products as e-waste added per year in the total waste stream =Total number of users × Average weight of products.

$$\text{Per capita amount of electronic waste generation} = \frac{Total\ Amount\ of\ Electronic\ Waste\ Generation}{Total\ Number\ of\ Population}$$

C. Consumption & Use Methods (C&U methods)

There are several methods for estimating the generation of e-waste. Each of them has its own advantages and requirements. Below factors have played crucial role for choosing Consumption and Use (C&U) method for this research work.

- Availability of consumer data
- Scarcity of proper sales data
- Rarity of e-waste inventory
- The time needed to gather and analyze data

C&U method does not require any sales data. Only stock data for the evaluation year and average lifespan is required to estimate the e-waste volume in a region. The method's formula is presented in the following equation (Ikhlayel, 2016):

$$\text{e-waste}\ (t) = \frac{\text{H(t) Nh(t) W}}{\text{L}}$$

where, H(t) = Number of households, Nh(t) = Saturation level per household, W = Average weight of electronic product and, and L = Average lifespan. The saturation level is defined as the percentage of households that owns at least one electronic product, and its maximum value is one.
The modified C&U formula to estimate e-waste in an evaluation year t, can be presented as (Ikhlayel, 2016):

$$\text{e-waste}\ (t) = \frac{\text{P(t) Np(t) W}}{\text{L}}$$

Where,
Np(t) is the number of Electrical and Electronic Equipment (EEE) owned by a person, which comprises a value lesser or greater than one. It is also known as penetration rate.
P(t) is the population
W is the weight of EEE
L is the average life of EEE

D. Linear Trend Forecasting Technique

There are several forecasting techniques. Each of them has its own feature. Below factors has been considered for choosing the desired forecasting technique for this research work

- Cost
- Accuracy
- The availability of computer software and
- The time needed to gather and analyze data and to prepare the forecast.

After considering all the above-mentioned factors linear trend forecasting technique was chosen for this research work. Linear trends show steady, straight-line increases or decreases where the trend-line can go up or down and the angle may be steep or shallow. Linear trend forecasting is used to impose a line of best fit to time series historical data. It is a simplistic forecasting technique that can be used to predict demand and is an example of a time series forecasting model. A linear trend equation has the form:

$$F_t = a + bt;$$

Where,
F_t = Forecast for period t,
a = Intercept of the line,
b = Slope of the line,
t = Specified no. of time periods from t = 0.

4. Results and Discussion

For 95 percent confidence level, the sample size was found 345. And the respondents were randomly selected from the departments of School of Applied Sciences and Technology, SUST. In this research cell phone, laptop, personal computer, pen drive, earphone, headphone, parts of computer such as motherboards, keyboard, mouse were considered. And for both newly purchased and second-hand products such as, cell phones, laptops, personal computers, computer parts such as motherboards, keyboards, mouse were particularly taken. These products are owned by almost every person aged greater than fifteen. That's why saturation level of less than or equal to one per household will result in significant error. So, the C&U method has been applied in this research.

Since the number of second-hand products users of pen drive, headphone, computer mouse, keyboard, motherboard is very low, when e-waste from second hand products is estimated, the paper deals with only mobile phone, laptop and desktop.

Figure 2 shows the estimation of electronic waste generated by the selected students from 2016 to 2019. The amount of electronic waste was estimated by using Consumption & Use (C&U) method. It shows that the newly purchased desktops generate the most of the e-waste followed by key board and headphone. The reason behind that the weight of desktop is more than others selected electrical and electronics equiment. Figure 2 also shows that the newly purchased pen drives generate the least amount of e-waste due to its lighter weight.

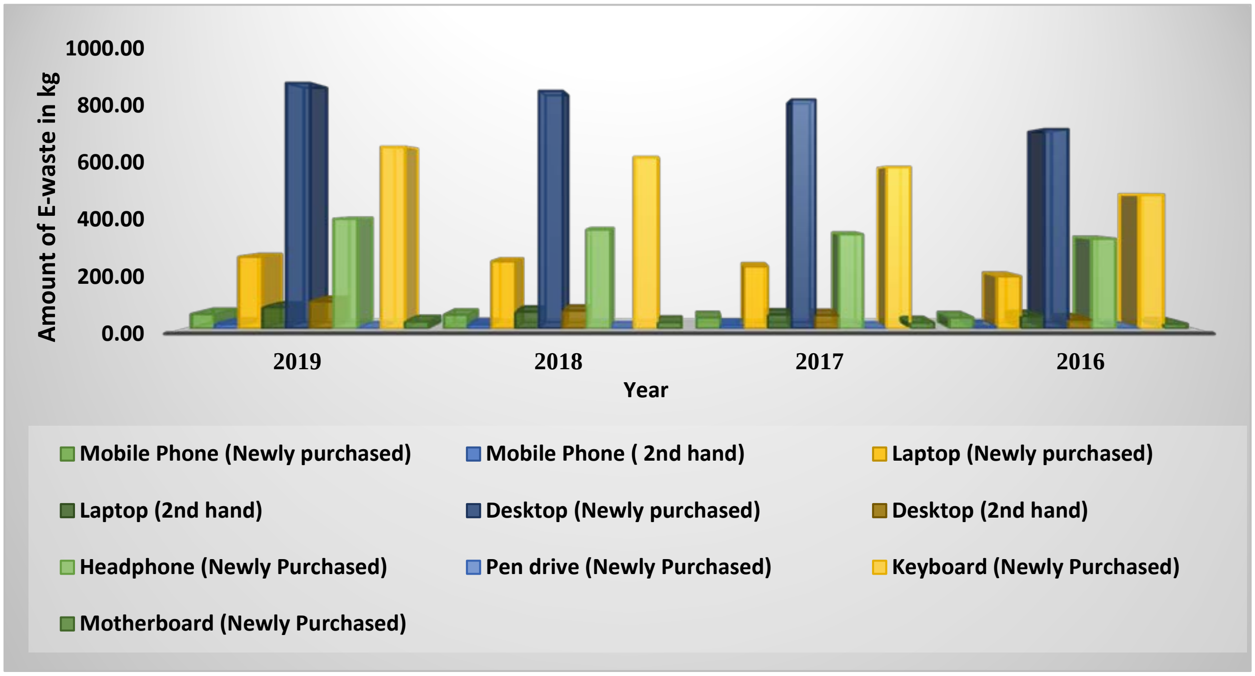

Figure 2: Estimation of different E-waste generated from 2016 to 2019.

Figure 3 shows that the maximum amount of e-waste was generated in 2019. It is also seen that the least amount of e-waste was generated in 2016. Besides, figure 3 also reveals that year by year the amount of e-waste increases gradually.

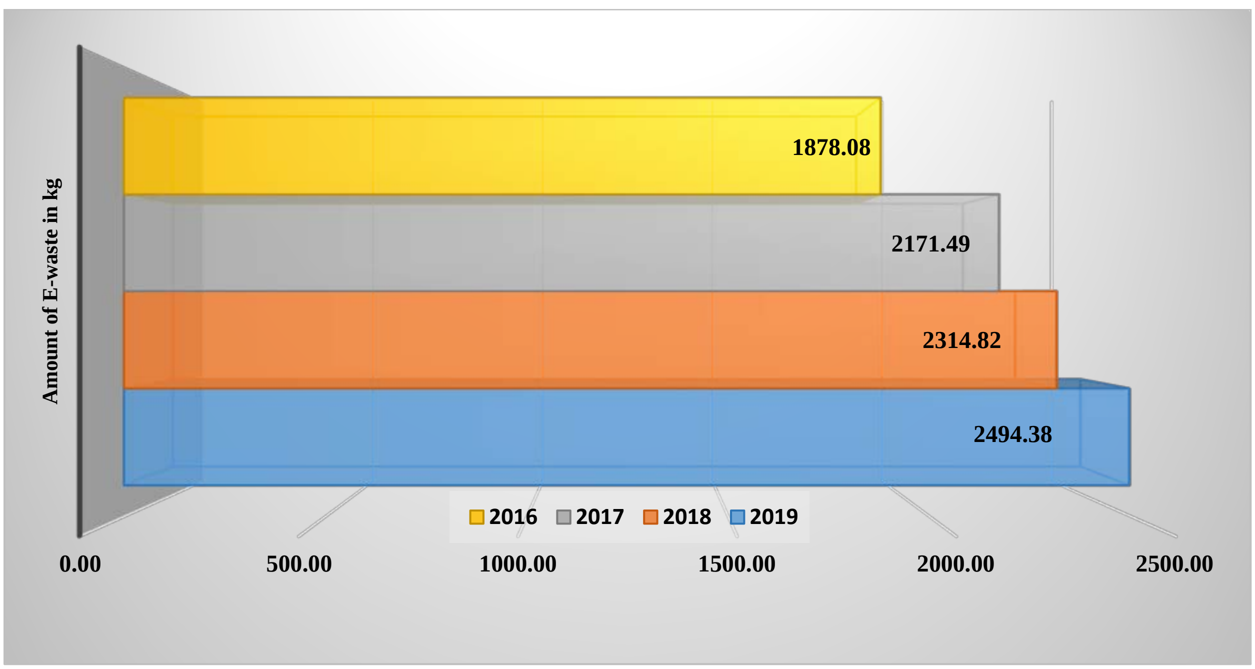

Figure 3: Total e-waste generated from 2016 to 2019.

Figure 4 shows that among all the departments of School of Applied Science and Technology, department of Computer Science and Engineering, students generate the most per-capita of e-waste (38.08 kg), followed by Food Engineering & Tea Technology (37.14 kg) and Civil and Environmental Engineering (35.31 kg). On the other hand, the students of Petroleum and Mining Engineering departments generate the least amount of e-waste (20.01 kg).

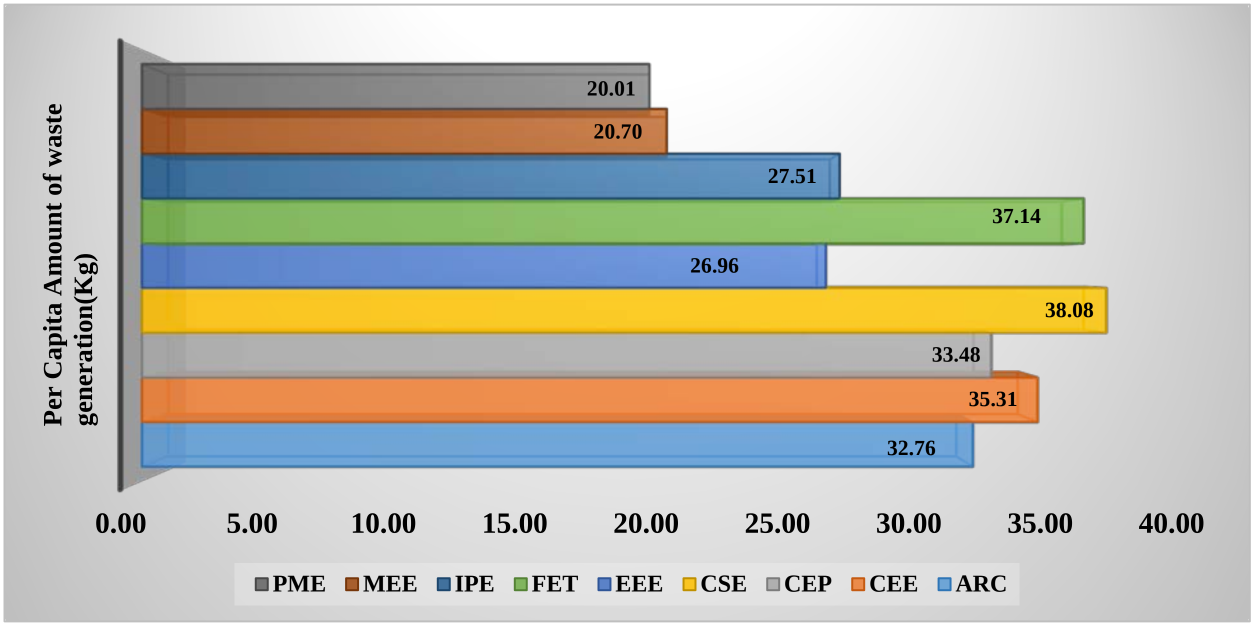

Figure 4: Estimation of per capita amount of e-waste generated by various departments.

Figure 5 shows the comparison of e-waste generated by newly purchased products (laptop, cellphone, desktop, headphone, pen drive, computer parts such as motherboard, keyboard, mouse) and 2nd hand products (laptop, cellphone, desktop). The figure 5 shows that the amount of e-waste generated from newly purchased products is more than the e-waste from second hand products from year 2016 to 2019. The reason behind this is that, normally the lifetime of first-hand products is more than second hand products. Thus, students are more interested to buy first hand products more than second hand products

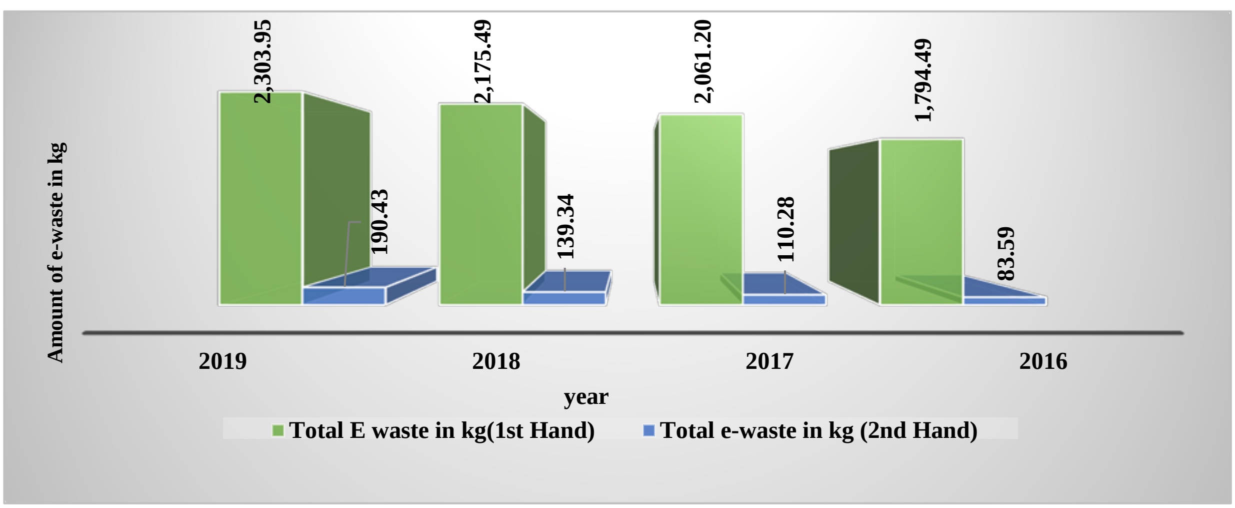

Figure 5: Comparison of total e-waste generated by newly purchased and 2nd hand products.

Figure 6 shows the comparison of e-waste generated by male students and female students. It is seen that in every year the male students generate more e-waste than the female students. Primary reason behind is that sample number of male students (196) is more than the female students (149). Secondly male students frequently change electronic products (cell phone, laptop, desktop, pen drive, earphone and headphone, mouse, motherboard and keyboard) more than female students.

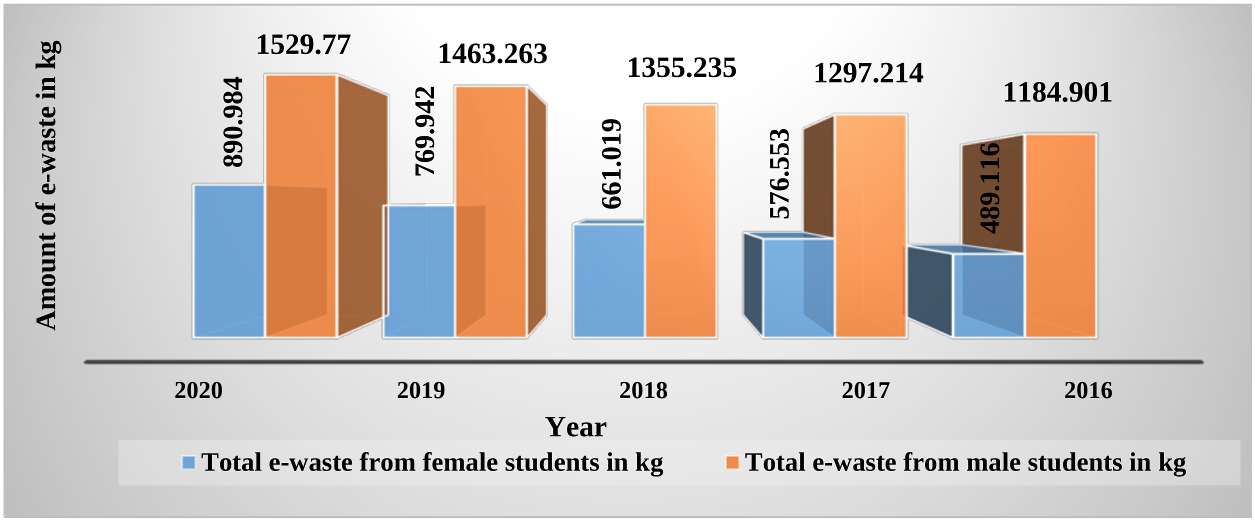

Figure 6: E-waste generated by male students & female students from 2016 to 2019 (in kg).

Figure 7 includes comparison of different e-waste from newly purchased products. It is also seen from the figure 7 that, e-waste generated from desktop is the most in each year (2016-2019). The reason behind this is that the weight of e-waste generated from desktop is more than other electronics & electrical equipment such as mobile phone, laptop, headphone, computer mouse, keyboard and motherboard. Similarly, e-waste generated from keyboard in kg is in second position. E-waste generated from pen drive is the least due to its lighter weight.

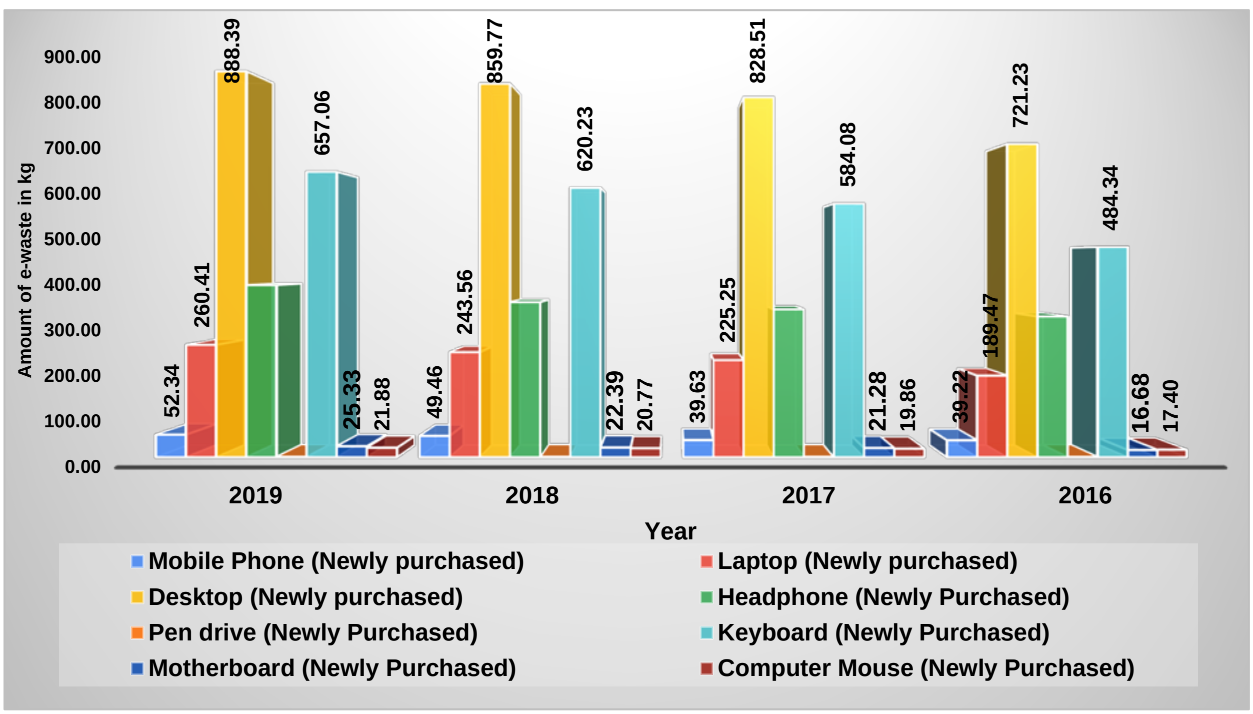

Figure 7: Comparison of different e-waste from newly purchased products.

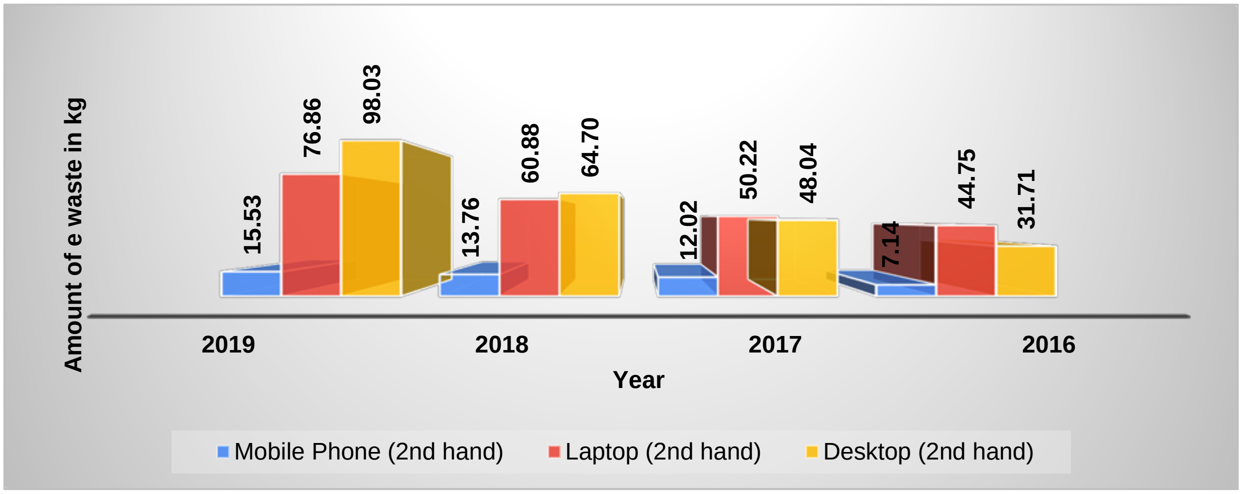

Figure 8. Comparison of different e-waste generated from 2nd Hand products.

Figure 8 shows the comparison of different e-waste from 2nd hand purchased products (mobile phone, laptop and desktop). It is also seen from the figure 8 that the amount of e-waste generated from desktop in kg is 98.03 which is the highest between the year 2018 and 2019. And also, it is seen that the amount of e-waste generated from laptops in kg is 76.86 which is in second position between the year 2018 and 2019. But the figure 8 also shows that the amount of e-waste generated from laptops in kg is 50.22 which is the highest between the year 2016 and 2017. And the amount of e-waste generated from desktops in kg is 48.04 which is in second position. The figure also states that the amount of e-waste generated from mobile phone is the least in four years (2016-2019).

Linear trend forecasting technique is used to predict the amount of e-waste generated by the students of School of Applied Sciences and Technology, SUST, Sylhet, Bangladesh. Table 1 shows the forecasted amount of e-waste generated from mobile phone, laptop, desktop, pen drive, headphone, computer parts such as mother board, keyboard, mouse from the year 2016 to 2024.

Table 1. Forecasted Amount of E-Waste generated from the selected electrical and electronics equipment.

t	Year	Forecasted amount (in kg)							
		Mobile phones	Laptop	Desktop	Head-phone	Pen drive	Computer Keyboard	Computer Mother board	Computer Mouse
1	2016	45.86	237.13	772.84	321.09	0.47	503.28	66.92	17.83
2	2017	53.47	270.94	847.67	344.42	0.53	558.71	77.35	19.26
3	2018	61.08	304.76	922.51	367.75	0.58	614.14	87.79	20.70
4	2019	68.70	338.57	997.35	391.08	0.64	669.58	98.22	22.13
5	2020	76.31	372.39	1072.18	414.41	0.70	725.01	108.66	23.57
6	2021	83.92	406.20	1147.02	437.74	0.76	780.44	119.09	25.00
7	2022	91.53	440.02	1221.85	461.07	0.82	835.87	129.52	26.44
8	2023	99.14	473.83	1296.69	484.40	0.87	891.30	139.96	27.87
9	2024	106.75	957.26	1371.52	507.73	0.93	946.74	150.39	29.30

The table 1 as shown above indicates gradual increase of e-waste. The reason behind this is the affordability of technology to mass people. Thus, it increases the penetration rate of electronic products. Also, rapid update in technology encourages customers to purchase new electronic devices even before existing one gets damaged. Thus, resulting in decreasing average lifetime of products. Furthermore, population is increasing throughout the world. If no proper solution is taken regarding e-waste management, total cumulative waste will be very dangerous to human health and environment.

5. Findings

The findings from the analysis are as follows:

- Total estimated amount of e-waste generated in 2019 was 2494.38 kg, in 2018 & 2017 it was respectively 2314.82 kg & 2171.49 kg. But in 2016 it was the least ,1878.08 kg.
- Most of the e-waste was generated by male students which is 6830.387 kg. And by female students was 3387.614kg. The reason behind this is that number of female students is less than male students. Secondly male students frequently change electronic products more than female students.
- Among all the Applied Sciences and Technology departments of SUST, CSE students generate the most per capita amount of e-waste which is 38.08 kg, followed by FET (37.14kg) and CEE (35.31kg). On the other hand, the students of Petroleum and Mining Engineering department generate the least amount of e-waste which is 20.01 kg. The reason behind is that the students of Computer Science and Engineering department use more electrical and electronics equipment than the other eight departments namely Electrical and Electronics Engineering, Industrial and Production Engineering, Chemical Engineering and Polymer Science, Mechanical Engineering, Petroleum and Mining Engineering, Civil and Environmental Engineering, Architecture and Food Engineering and Tea Technology.
- The amount of e-waste generated by desktop is more than the both newly purchased products (mobile phone, laptop, headphone and computer parts such as keyboard, mouse and motherboard) and 2nd hand purchased products (mobile phone, laptop). Because the weight of desktop is more than other selected electrical and electronics equipment.
- It is observed that for newly purchased product such as pen drive and for 2nd hand purchased products such as mobile phone, generate the least amount of e-waste due to their lighter weight.
- The forecasting indicates that the amount of e-waste generated in SUST, Sylhet increases gradually year by year. This is due to increase of electrical and electronics products by the students of School of Applied Sciences and Technology. Analysis shows that, by the year 2024, the e-waste generated from cellphone, laptop, desktop, earphone & headphone, pen drive, motherboard will be approximately 4070.62 kg which is almost double of the amount of e-waste generated from cellphone, laptop, desktop, earphone & headphone, pen drive, motherboard in 2016 by the students of SUST, Sylhet, Bangladesh.

5.1 Awareness

Another finding from the survey is public awareness. Figure 9 shows that 64% of the respondents were unaware of the negative effects of e-waste and 36% of the respondents were unaware of the negative effects of e-waste.

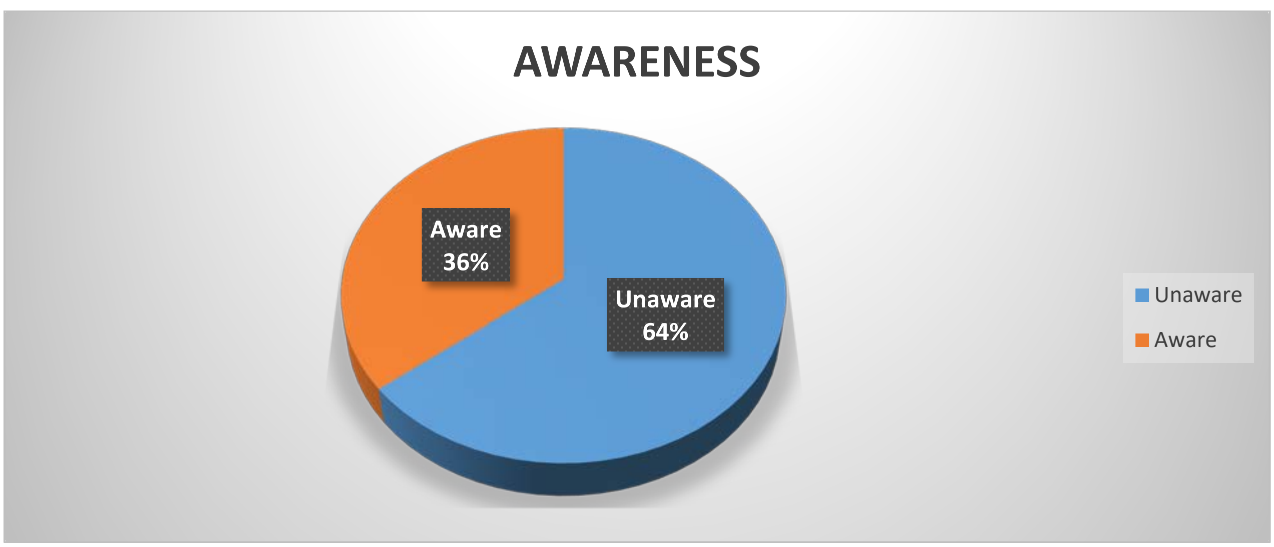

Figure 9: Public awareness regarding e-waste toxicity.

Figure 10 shows that when the respondents were asked about their knowledge on the materials used in electrical and electronics equipment (EEE), 8% students replied that they know nothing about the materials. 28% students replied that they don't have enough knowledge on EEE.

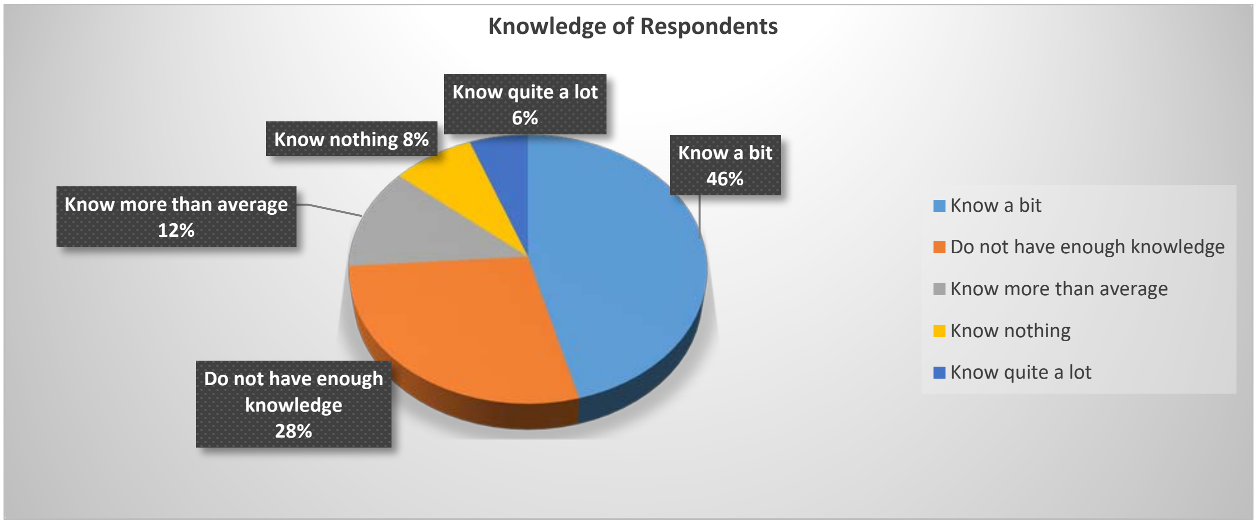

Figure 10: Knowledge of people about materials used in EEE.

6. Recommendation

- In future, this will be needed to assure that each department has different waste collector bin for solid waste and e-waste.
- At SUST every department have waste collector bin.
- But these bins are common for both solid waste & e-waste.

6.1 Responsibilities of the Government

Some responsibilities of the Government are mentioned here:

- Setting up regulatory agencies in each district.
- Providing adequate system of laws, controls and administrative procedures for waste management.
- Encouraging research into the development and standard of hazardous waste management.
- Enforcing strict regulation.
- Encouraging and supporting NGOs and other organizations.
- Exploring opportunities to partner with manufacturers and retailers ("M. Habibur Rahman et al",2011).

6.2 Responsibilities of the Citizen

Some responsibilities of the citizen are mentioned here:

- Donating used electronics for reuse.
- E-wastes should never be disposed with garbage and other household wastes.
- Be careful while buying electronic products ("M. Habibur Rahman et al",2011).

7. Future Work

For better estimation and for comparing the methods, other methods such as:

- Modified Consumption & Used method 2,
- Population Balance Method,
- Time Step Method,
- Simple Delay Method,
- Mass Balance Method,
- Approximation Method etc. can be used for estimation.

8. Conclusion

Changes in lifestyle of people, technological development and low-cost availability of electronic gadgets have led to increased consumption of electronic products. Due to high generation of e-waste and the lack of proper managing systems for this type of waste in SUST, Sylhet, it is predicted that such waste would have some adverse effects on the health of citizens and the environment as well. Therefore, it is necessary to provide necessary infrastructures for separation, collection, recycling, and management of such e-waste. E-waste volume of School of Applied Sciences and Technology, SUST, Sylhet was estimated in the study considering mobile phone, laptop, desktop, headphone, pen drive and computer parts such as mouse, keyboard and mother boards. Because these electronic products cover major portion of total e-waste volume. And also, the market of these products is expanding rapidly than other EEE. If necessary, steps are not taken for managing e-waste, cumulative volume will be much higher. For this reason, an e-waste recovery and recycling facility should be established in Bangladesh, where e-waste collected from across the country will be transported and processed.

E-waste is a serious issue at local as well as global scales. Changes in lifestyle of people, technological development and low-cost availability of electronic gadgets have led to increase the consumption rates of electronic products such as cell phone, laptop and desktop. Currently, e-waste is collected mixed with the solid waste generated in SUST. In addition, a portion of the used electronics and electric items is collected by informal sector and is sold to the secondhand materials buyer in the city. Currently there is not an integrated system for proper management of WEEE in SUST and this waste is collected and disposed of with other municipal waste. Some measures should be taken regarding this kind of waste, including a specific collection system, recycling of valuable substances and proper treatment and disposal.

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