Paper ID 167

Electrical and Electronic Waste Management in Sri Lanka

PKCG Panduwawala# and MB Samarakoon

Department of Civil Engineering, General Sir John Kotelawela Defence University

#chamodipanduwawala@gmail.com

.**Abstract:** E-waste or electrical and electronic waste is one of the fastest-growing waste in the world and this problem affects Sri Lanka as well. E-waste will become an emerging issue in the near future because the estimated e-waste generation in 2021 is 0.09 million tons in Sri Lanka. E-waste contains valuable compositions that have economic value when it recycled correctly. Unfortunately, Sri Lanka has not improved in e-waste recycle and e-waste management. Therefore the objectives of this research were to find out different types of e-waste generate in Sri Lanka, identify different compositions, develop an application for hazardous non-recycle composition and develop mathematical models for the weight of the composition of e-waste. The study was based on data collected from e-waste collectors. The research project reveals the hazardous, non-hazardous and recycle, non-recycle composition in selected devices are; 1G mobile phones (0.5kg), 2G mobile phones (0.235kg), 3G mobile phones (0.155kg), 4G mobile phones (0.145kg), Tv (14kg), laptops (2.3kg), computers (9kg), A/C machines (34kg), refrigerators (135.5kg), fluorescent bulbs (0.185kg), and washing machines (34kg). Average weight has to be considered because of the different types, different models, different brands for the same device. Mercury is the only non-recycle hazardous composition in these devices. The results of this research revealed the ten compositions (mercury, plastic, copper, aluminum, cadmium, silver, gold, palladium, steel and lead) found in e-waste and how to calculate them.

The study reveals the amount of weight of compositions that can be found in e-waste and which compositions can be affected by the environment. The proper e-waste management system is needed to minimize e-waste generation. E-waste recycling is necessary but should conduct in a proper manner.

Keywords: e-waste, The weight of compositions, e-waste Management

Introduction

Electrical and Electronic waste or e-waste is discarded electrical and electronic devices such as mobile phones, sim cards, batteries, Air condition (A/C) machines, Washing machines, Fluorescent bulbs, Refrigerators, Computers, Laptops, etc (Samarakoon, 2015). With the rapid development of technology, e-waste has become an environmental and health concern in developing countries. Electrical and electronic devices demand is rising day by day due to the rapid development of technology. Because of that global e-waste growth is gradually increased day by day (Shibly and Thelijjagoda, 2018). The volume of e-waste generated in the past few 8 years in million metric tons as well as the world's worst e-waste offenders in 2018 (*Outlook on per capita e-waste generation globally 2018 | Statista*, no date). When e-waste is mishandled in terms of being discarded into open dumps or burn pits rather than recycled, it creates a serious impact on the environment including groundwater, soil, air quality and the health of humans and animals since e-waste consist many types of hazardous heavy metals, acids, toxic chemicals, and non-degradable plastics (Sivaramanan, 2014). E-waste has been generated rapidly worldwide due to the high demand for electronic and electrical devices and the development of technology as well as the low recycling rate of e-waste (Samarakoon, 2015). Most of the e-waste has been generated due to poor recycling and disposal of electronic electrical devices. Because of that, e-waste becomes a major problem worldwide (Chan *et al.*, 2007). The rapid development of electrical and electronic industries and the continuous upgrading of a new version of electronic and electrical products lead to the discard more and more products of electrical and electronic, which produce large e-waste in the world (Osibanjo and Nnorom, 2007). Sri Lankan e-waste collectors are only doing dismantling the devices and send them to foreign countries like Japan, Belgium, India, and Spain. Other waste generated through the e-waste dismantling process includes glass materials sent to the glass manufacturing industry, metal materials to recycling in the steel manufacturing industry, plastic materials sent to the plastics recycling industry and non-recyclable materials are disposed of through cement kiln co-processing (Ranasinghe and Athapattu, 2020). Cement kiln co-processing means the use of waste as raw material, energy source, fossil fuel, etc (Baidya, Ghosh and Parlikar, 2016). This method is used because of the lack of facilities in Sri Lanka to recycle. Other than registered e-waste collectors, some companies like Abans, Singer and LG use the new method which is, if someone buys a new model of equipment they give a discount if they bring the old model or previous used one to them. Then they collect it and send them to either e-waste collectors or their head company. This method helps to prevent throwing those electrical and electronic devices to the open dump (Samarakoon, 2015). Basel Convention is the international treaty that was designed to reduce the movements of hazardous waste between the nation and prevent the transfer from developed to less developed countries (Frankshtein *et al.*, 1972). Electrical and electronic equipment mainly depends on the imported goods to Sri Lanka. Therefore a noticeable increase of e-waste generation can be seen in Sri Lanka in past few years (Ranasinghe and Athapattu, 2020).

Recently, lots of e-waste can be seen in the open yards. There is a possibility of leaching of heavy metals to the ground and surface water due to this open yard disposal of e-waste. Karadiyana and Gohagoda dumpsite show a higher concentration of compositions like Fe, As, Cu, Ni, Cd, Zn, Pb, and Mn (Ranasinghe and Athapattu, 2020). Sri Lanka is still far away from e-Waste management compare to other countries and still not identify all types of e-Waste generate in Sri Lanka (Samarakoon, 2015). Unfortunately, Sri Lanka has not improved in e-waste recycle and e-waste management (Ranasinghe and Athapattu, 2020). Therefore, the objectives of this research were to find out different types of e-waste generate in Sri Lanka, identify different compositions, develop an application for hazardous non-recycle composition and develop mathematical models for the weight of the composition of e-waste.

Methodology and Experimental Design

A. Methodology

The main objective of this research is to find out the weight composition of selective electrical and electronic equipment and design a mathematical model for the weight content of compositions in selected equipment which are released to the environment through e-waste.

Two types of data collection techniques were used in this case study to collect data. They were;

(1) Interviews
(2) Documents and Records

Central Environment Authority was selected to study the current situation of e-waste management in Sri Lanka. Data collection was started with six selected e-waste collectors in a way of representative of the population who registered under Central Environment Authority. The formal interview methods were used to collect data from e-waste collectors. Secondary data collection was done by using e-waste collector's company database information and reports. The main objective of this case study is to find out the generated e-waste amount from annual imports electrical and electronic items in Sri Lanka. Because of study, the average weight content was selected for each device due to different types of models, brands for the same equipment. Composition weight content was taken for mg in 1kg of e-waste in the same device. For example; Gold weight content in 1kg of mobile phones.

B. Experimental Design

The case study finding reveals the different types of e-waste generated in Sri Lanka can be found as discarded 1G mobile phones, 2G mobile phones, 3G mobile phones, 4G mobile phones, washing machines, A/C machines, refrigerators, Tv, laptops, computers and fluorescent bulbs. These items have different types of brands names, model types for the same equipment. Therefore, the weight of equipment can be varied with the types and models because of this reason average weight need to be considered. Table 1. shows the average weight of this electrical and electronic equipment and the number of equipment in 1kg. Number of equipment in 1kg is needed to find the weight of compositions of equipment imported to Sri Lanka.

(Number of item in 1kg = 1/Average weight of equipment)

Table 12 Average Weight of the equipment and number of equipment in 1kg

Equipment (x)	Average Weight in kg	Number of items in 1kg
1G Mobile Phones	0.5	2
2G Mobile Phones	0.235	4.255
3G Mobile Phones	0.155	6.452
4G Mobile Phones	0.145	6.867
Washing Machines	90	0.011
A/C Machine	34	0.029
Refrigerators	135.5	0.007
Tv	14	0.071
Laptops	2.3	0.435
Computers	9	0.111
Fluorescent Bulb	0.185	5.405

From the above findings, identify the different types of compositions in the electrical and electronic equipment that can be affected to the environment because e-waste contains toxic materials. Aluminium, plastic, copper, mercury, lead, cadmium, silver, gold, palladium and steel were identified as compositions in the electrical and electronic equipment. Table 2. shows the types of compositions and the weight of compositions (mg/kg) in e-waste.

Table 13 Types of Compositions

Equipment (x)	Weight of the Compositions (mg/kg)									
	Aluminium	Plastic	Copper	Mercury	Lead	Cadmium	Silver	Gold	Palladium	Steel
Computers(x_1)	50	230	200			0.06		0.01		70
Refrigerators (x_2)	75	100	50							50
Washing Machines(x_3)	90	240	20	0.01		0.04				370
TVs(x_4)	100	280	50			0.06	0.01	0.05	0.001	
A/C Machines(x_5)	130	150	170			1.36				460
Laptops(x_6)	16.3	465.9	43.3		5.3		0.1			
1G Mobile Phones(x_7)	50000	28000	50000	7.5	45000	10000	1500	186.5	56.9	
2G Mobile Phones(x_8)	50000	20000	50000	8	45000	10000	1572.5	187	38.4	
3G Mobile Phones(x_9)	50000	25000	50000	10	45000	10000	1630	190.9	40.1	
4G Mobile Phones(x_{10})	53448.3	25000	65000	10	46724.4	10000	1680	250	41	
Fluorescent Bulbs(x_{11})	97297.3			50000						

Results

Starting from the above findings of the composition weight of electrical and electronic equipment, mathematical models were developed. Figure 1., Figure 2., Figure 3. and Figure 4. show the relationship between the weight of the compositions in mg/kg and the types of equipment.

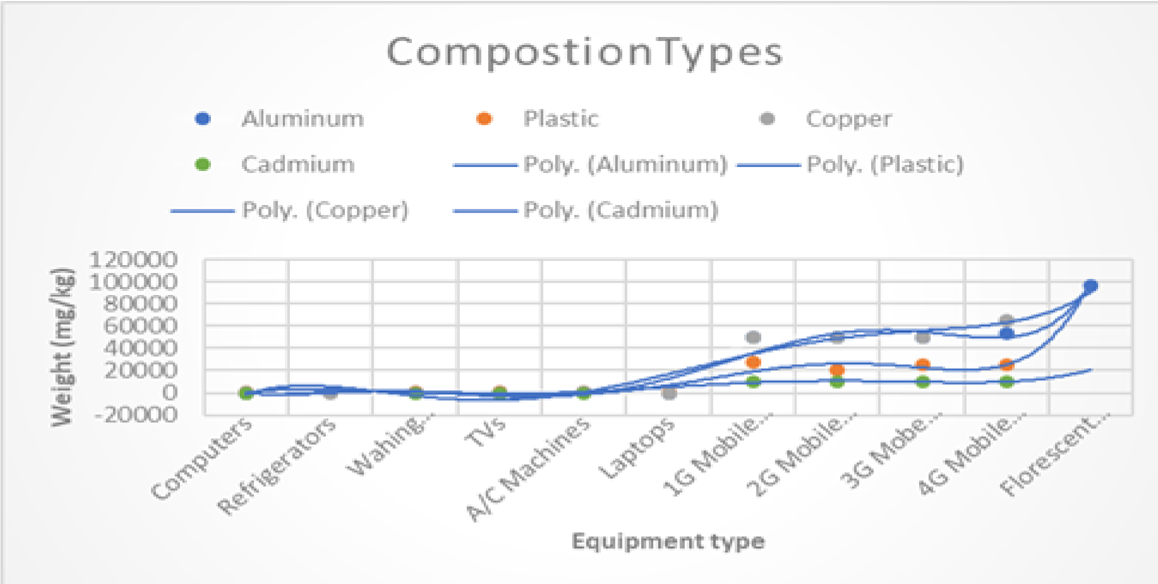

Figure 1 Aluminium, Plastic, Copper and Cadmium weight of selected electrical and electronic equipment

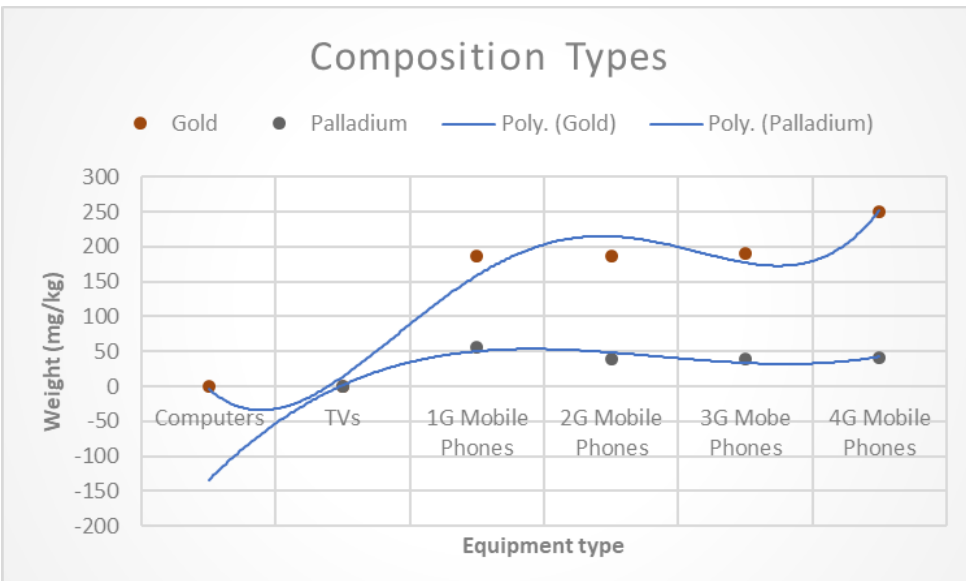

Figure 2 Gold and Palladium weight of selected electrical and electronic equipment

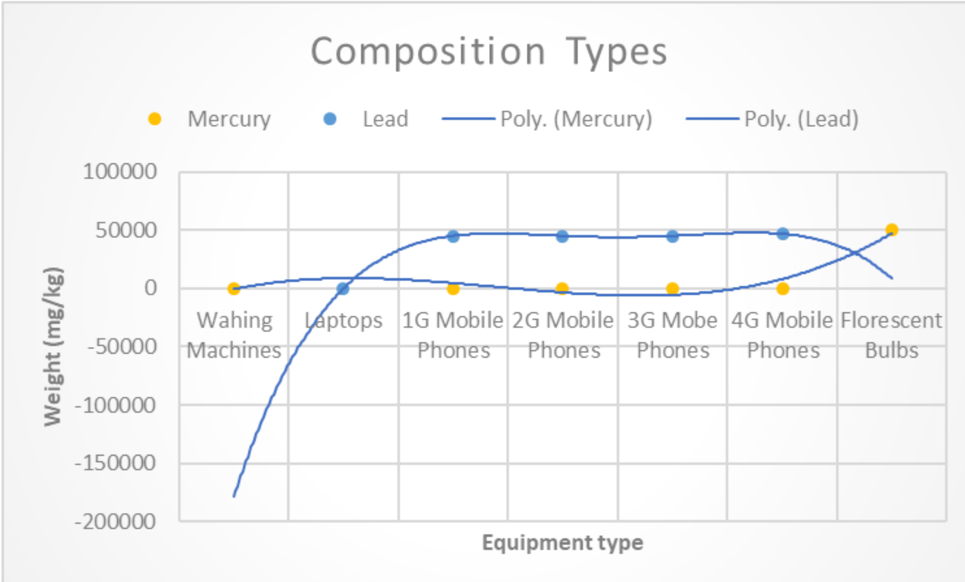

Figure 3 Mercury and Lead weight of selected electrical and electronic equipment

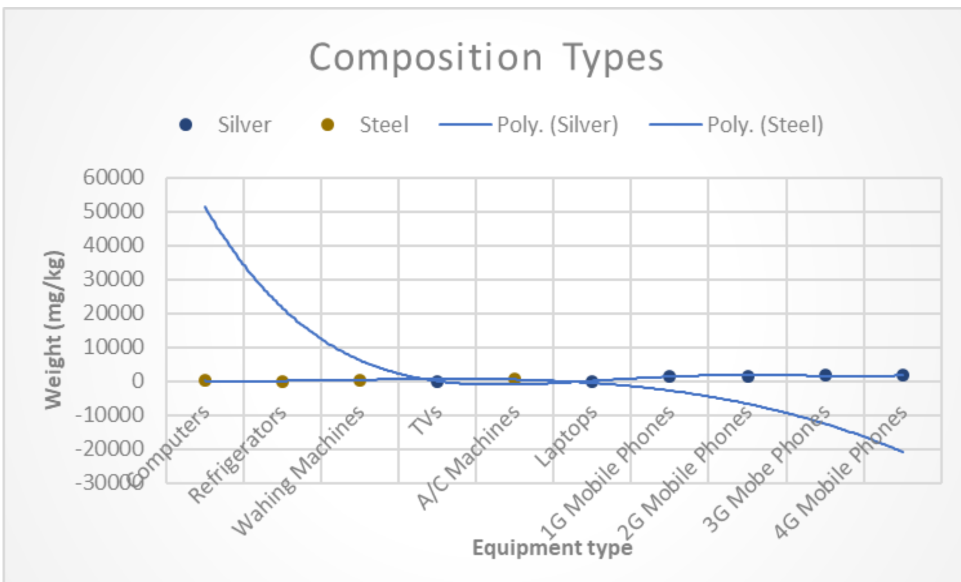

Figure 4 Silver and Steel weight of selected electrical and electronic equipment

$$y_{aluminum} = 12.575x^6 - 401.31x^5 + 4807.5x^4 -$$

Quadratic regression equations were used to develop the mathematical models to calculate the composition weight of the selected device that imported to Sri Lanka and the matrices were used to calculate the weight of the composition in the e-waste which generates from the total selected electrical and electronic equipment imported to Sri Lanka.

A. Weight Composition of Aluminium

(1)

$$\text{Weight of Aluminium} = y_{aluminum} \times \text{Weight of the equipment} \quad (2)$$

Total Aluminum Weight =

$$\begin{bmatrix} 0.999x_1 \\ 0.949x_2 \\ 0.99x_3 \\ 0.994x_4 \\ 0.986x_5 \\ 1.001x_6 \\ x_7 \\ x_8 \\ x_9 \\ 0.996x_{10} \\ x_{11} \end{bmatrix} \begin{bmatrix} 50 & 75 & 90 & 100 & 130 & 164.3 & 50000 & 50000 & 50000 & 53448.3 & 97297.3 \end{bmatrix}$$

(3)

B. Weight Composition of Plastic

$$y_{plastic} = 12.182x^6 - 393.97x^5 + 4875.4x^4 - 28956x^3 + 85556x^2 - 116690x + 55862$$

(4)

Weight of Plastic $= y_{plastic} \times$ Weight of the equipment $\times$ no. of Equipment

(5)

Total Plastic Weight =

$$\begin{bmatrix} 0.949x_1 \\ 0.986x_2 \\ 0.999x_3 \\ 0.99x_4 \\ 0.994x_5 \\ 1.001x_6 \\ x_7 \\ x_8 \\ 0.996x_9 \\ x_{10} \end{bmatrix} \begin{bmatrix} 100 & 150 & 230 & 240 & 280 & 465.9 & 20000 & 25000 & 25000 \end{bmatrix}$$

(6)

C. Weight Composition of Copper

$$y_{copper} = 37.188x^5 - 1113.7x^4 + 12045x^3 - 55517x^2 +$$

(7)

Weight of Copper $= y_{copper} \times$ Weight of equipment $\times$ No. of equipment

(8)

Total Copper Weight =

$$\begin{pmatrix} 0.99x_1 \\ 1.001x_2 \\ 0.949x_3 \\ 0.994x_4 \\ 0.986x_5 \\ 0.999x_6 \\ x_7 \\ x_8 \\ x_9 \\ 0.996x_{10} \end{pmatrix} \begin{bmatrix} 20 & 43.3 & 50 & 50 & 170 & 200 & 50000 & 50000 & 50000 & 65000 \end{bmatrix}$$

... (9)

D. Weight Composition of Cadmium

$$y_{cadmium} = 51.276x^5 - 1153.7x^4 + 9369.2x^3 - 33036x^2 + 49706x - 24995$$

(10)

Weight of Cadmium $= y_{cadmium} \times$ Weight of the equipment $\times$ No. of Equipment

.(11)

Total Cadmium Weight =

$$\begin{bmatrix} 0.99x_1 \\ 0.994x_2 \\ 0.999x_3 \\ 0.986x_4 \\ x_5 \\ x_6 \\ x_7 \\ 0.996x_8 \end{bmatrix} \begin{bmatrix} 0.04 & 0.06 & 0.06 & 1.36 & 10000 & 10000 & 10000 & 10000 \end{bmatrix}$$

(12)

E. Weight Composition of Gold

$$y_{gold} = 8.8367x^4 - 124.53x^3 + 590.32x^2 - 1015.1x + 537.73$$

(13)

Weight of Gold $= y_{gold} \times$ Weight of the equipment $\times$ No. of Equipment

(14)

Total Gold Weight =

$$\begin{bmatrix} 0.999x_1 \\ 0.994x_2 \\ x_3 \\ x_4 \\ x_5 \\ 0.996x_6 \end{bmatrix} \begin{bmatrix} 0.01 & 0.05 & 186.5 & 187 & 190.9 & 250 \end{bmatrix} \quad (15)$$

F. Weight Composition of Palladium

$$y_{palladium} = 4.3083x^3 - 42.046x^2 + 132.94x - 94.917 \quad (16)$$

Weight of Palladium $= y_{palladium} \times$ Weight of the equipment $\times$ No. of equipment (17)

Total Palladium Weight =

$$\begin{bmatrix} 0.994x_1 \\ x_2 \\ x_3 \\ 0.996x_4 \\ x_5 \end{bmatrix} \begin{bmatrix} 0.001 & 38.4 & 40.1 & 41 & 56.9 \end{bmatrix} \quad (18)$$

G. Weight Composition of Mercury

$$y_{mercury} = 1041.3x^4 - 12264x^3 + 49631x^2 - 79848x + 41638 \quad (19)$$

Weight of Mercury $= y_{mercury} \times$ Weight of the equipment $\times$ No. of equipment (20)

Total Mercury Weight =

$$\begin{bmatrix} 0.99x_1 \\ x_2 \\ x_3 \\ x_4 \\ 0.996x_5 \\ x_6 \end{bmatrix} \begin{bmatrix} 0.01 & 7.5 & 8 & 10 & 10 & 50000 \end{bmatrix} \quad (21)$$

H. Weight Composition of Lead

$$y_{lead} = 3893.3x^3 - 41221x^2 + 138314x - 100363 \quad (22)$$

Weight of Lead $= y_{lead} \times$ Weight of the equipment $\times$ No. of equipment (23)

Total Lead Weight =

$$\begin{bmatrix} 1.001x_1 \\ x_2 \\ x_3 \\ x_4 \\ 0.996x_5 \end{bmatrix} \begin{bmatrix} 5.3 & 45000 & 45000 & 45000 & 46724.4 \end{bmatrix} \quad (24)$$

I. Weight Composition of Silver

$$y_{silver} = 61.14x^4 - 886.51x^3 + 4301.1x^2 - 7478x + 3979.5 \quad (25)$$

Weight of Silver $= y_{silver} \times$ Weight of the equipment $\times$ No. of Equipment (26)

Total Silver Weight =

$$\begin{bmatrix} 0.994x_1 \\ 1.001x_2 \\ x_3 \\ x_4 \\ x_5 \\ 0.996x_6 \end{bmatrix} \begin{bmatrix} 0.01 & 0.1 & 1500 & 1572.5 & 1630 & 1680 \end{bmatrix} \quad (27)$$

J. Weight Composition of Steel

$$y_{steel} = -81.667x^3 + 630x^2 - 1298.3x + 800 \quad (28)$$

Weight of Steel $= y_{steel} \times$ Weight of the equipment $\times$ No. of equipment (29)

Total Steel Weight =

$$\begin{bmatrix} 0.949x_1 \\ 0.999x_2 \\ 0.99x_3 \\ 0.986x_4 \end{bmatrix} \begin{bmatrix} 50 & 70 & 370 & 460 \end{bmatrix} \quad (30)$$

Compositions were categorized under hazardous, non-hazardous and recycle non-recycle after finishing mathematical models for compositions. Table 3 shows the categorization of compositions.

In consonance with the table 3., Mercury is the only hazardous non-recycle composition found in the above-selected devices. Therefore, application was developed to find the weight of mercury in the e-waste of the selected device. This application was developed by using Visual basic software.

Figure 5 shows the application of Mercury Analyzer.

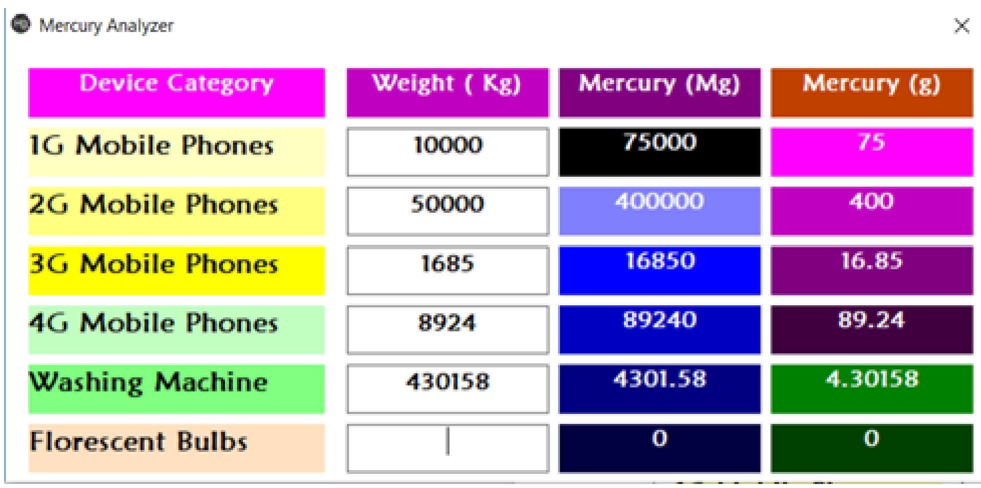

Figure 5 Mercury Analyzer

Table 14 Composition categorize under hazardous, non-hazardous, recycle and non-recycle

Device	Hazardous		Non-Hazardous	
	Recycle	Non-Recycle	Recycle	Non-Recycle
1G Mobile Phones	Silver Lead Cadmium Palladium	Mercury	Plastic Aluminium Copper Gold	
2G Mobile Phones	Silver Lead Cadmium Palladium	Mercury	Plastic Aluminium Gold Copper	
3G Mobile Phones	Silver Lead Cadmium Palladium	Mercury	Plastic Aluminium Gold Copper	
4G Mobile Phones	Silver Lead Cadmium Palladium	Mercury	Plastic Aluminium Gold Copper	
TVs	Silver Cadmium Palladium		Plastic Aluminium Gold Copper	
Laptops	Silver Lead Ferrous		Plastic Aluminium Copper	
Computers	Cadmium Antimony		Plastic Steel Copper Aluminium Gold Glass	
Florescent Bulbs	Iron	Mercury	Silicon Aluminium	
A/C Machines	Cadmium		Plastic Steel PCB Aluminium Copper	
Washing Machines	Cadmium	Mercury	Plastic Steel Aluminium Copper	
Refrigerators	Polyurethane		Plastic Steel Stainless Steel Glass Aluminium Copper	

Disscussion

There are many ways of e-waste generate in Sri Lanka. This research project is only focused on the main e-waste to generate methods in Sri Lanka. Most of e-waste contains different types of compositions and out of the aluminium, plastic, cadmium, mercury, steel, silver, lead, gold, palladium and copper were selected for this case study. Most of the e-waste contains toxic materials that effect to the environment, surface water and groundwater. Some compositions can be found as hazardous and non-hazardous and can be recycled and cannot be recycled. This research study shows the amount of weight of identified composition, that can be released to the environment within a period from the e-waste. Generally, the high amount of electrical and electronic equipment ae imported to Sri Lanka due to the use of modern technology. Therefore, it is important to have a general idea about the weight of compositions released from this equipment. Another aspect of this research is to find the amount of weight that releases to the environment by using the number of imported equipment within a known period. The number of items in 1kg of selected equipment should be substituted to find the "y" in the graphs shown in figure 1, figure 2 and figure 3. There are different types of models, brands in the electrical and electronic equipment in the present market. Therefore, the weight of the equipment may vary with the model, type and brand. This case study is used the average weight of all electrical and electronic equipment to overcome this problem. Average weight and number of items that imported to Sri Lanka with a period are used to calculate the weight of the composition. Matrix model was developed to identify the total composition weight from the all selected electrical and electronic equipment. This model helps to calculate composition weight that can affect to the environment from the e-waste. This gives an idea about the amount of weight of composition that releases to the environment from the e-waste. Mercury is the most harmful composition found in this research. Therefore, application was developed to identify the weight of mercury in selected equipment load.

Current practices of e-waste management are the collection, dismantling, reuse, recovery, and disposal. Green computing is used to minimize e-waste which is designing, constructing, running a computer system to be energy-efficient. Mainly refer to promote recyclable or biodegradability of products to reduce the use of hazardous material. Energy-saving electrical and electronic equipment should be introduced to minimize e-waste generation. Best practices of e-waste minimization are used as a 3-R concept which is Reduce, Reuse and Recycle. Reduce can be done by buying a new one if the end of the life of equipment only. Otherwise, try to repair it and use it. Same for the reuse also. Recycle can be done to recyclable materials, for example, glass parts to the glass manufacturing industry to recycle. Steel materials to steel manufacturing industries etc. Energy consumption methods can be used to minimize e-waste. Sustainable develop methods can be introduced to minimize e-waste.

Conclusion

Sri Lanka is still behind in e-waste management sector because it has not been identified all the types of e-waste in Sri Lanka. Therefore, proper e-waste management have not developed in Sri Lanka. Major types of e-waste generation devices in Sri Lanka can be identified as discarded personal computers, 1G mobile phones, 2G mobile phones, 3G mobile phones, 4G mobile phones, TV, laptops, A/C machines, refrigerators, fluorescent bulbs, and washing machines.

There are many types of compositions that can be identified in electrical and electronic devices. Major compositions can be identified as aluminium, mercury, plastic, copper, lead, cadmium, silver, gold, palladium, and steel. These identified compositions can be classified as Hazardous and Non-hazardous, Recycle and Non-recycle compositions. From this classification, mercury is the only non-recycle and hazardous composition identified from all these compositions. Developed application can be used to find out the weight of mercury inside the identified e-waste in any weight of kg.

The developed mathematical models in this research can be used to identify weight composition of selected electrical and electronic device and can be calculated weight compositions of e-waste generate in Sri Lanka from the annual imports of electrical and electronic equipment.

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Author Biographies

PKCG Panduwawala is a Sri Lankan citizen and born in Colombo, the Western Province of Sri Lanka. She is an undergraduate student of Department of Civil Engineering of General Sir John Kotelawela Defence University, Rathmalana, Sri Lanka.

Dr. MB.Samarakoon is a Senior Lecturer of Department of Civil Engineering of General Sir John Kotelawala Defence University, Rathmalana, Sri Lanka. He has obtained PhD(Japan), M.Eng.(Japan), B.Sc. Eng. (Hons) (Peradeniya) .Currently he is holding the position of Dean, Faculty of Engineering. His research interest includes Water Resource Management, Waste Water Treatment and Disposal, Solid Waste Management, Air Pollution and E-Waste Management. Dr. Samarakoon supervised Master Students and PhD students and examined undergraduate research projects.

Paper ID 354

Evaluating the Efficiency of a Traffic Signal Light over a Traffic Policeman

TWKIM Dias# and NHARS Ekanayake

Department of Civil Engineering, General Sir John Kotelawala Defence University

#ishanidias@kdu.ac.lk

Abstract: The overall effect of traffic is considered to be high, at most of the intersections when they are controlled by traffic signal lights during peak hours

. This causes lengthy queues and user inconveniences at intersections. Traffic police officers also control some of the intersections during peak hours in order to reduce this queue length and waiting time. The objectives of this research were to determine the relationship between the queue length formed and vehicular delay at peak hours, when the intersection is controlled by traffic signal lights and traffic policemen. Data was collected in two four-way intersections at Kanatta road / Dudley Senanayake Mawatha and Golumadama intersection. When the queue length was considered by 5-minute time intervals, the number of vehicles in the queue were higher with traffic signal control, compared to police controlled intersection. Further, per signal cycle queues were also counted in the said two scenarios. The observed values were furthers tested using Contingency Table analysis (Chi-square test) to assess whether the effect is statistically significance. Results showed that, queue lengths and the number of waiting hours were higher when the intersection was controlled by traffic signal lights compared to a traffic policeman. However, per cycle waiting time was significantly higher when controlled by policemen. Therefore, when a single-user point of view, the intersection delay may seem higher when controlled by a traffic policeman. However, the overall delay at the intersection is lesser with the police control.

Keywords: Traffic Signal Lights, Traffic Policeman, Intersection delay

Introduction

The invention of motor vehicle had a great impact on human lives. This lead to the development and improvement of road conditions, with increased speeds and capacities which resulted vulnerability for the road users. So the necessity of properly controlling and channelization of traffic is a significant factor for road user safety.

In the early days, human resources were used to control traffic. In 1722, the Lord Mayor had appointed three men to control traffic on the London bridge, whom considered as the world's first traffic police. The first traffic signal had been installed in 1868 in London. It has used a semaphore 'arms' together with green and red gas lamps. In 1925, first three colored traffic signal light has been installed in New York. The first ever traffic signal light in Sri Lanka has been installed at Naval and Maritime Academy in Trincomalee. Traffic signal lights are used throughout the world to reduce conflicts by time-sharing right of way (Allsop, 1971; Gerlough and Wagner, 1964; Ndoke, 2006).