ESTIMATION AND ANALYSIS OF ELECTRONIC WASTE GENERATION IN MOSUL CITY/ IRAQ

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ABSTRACT

The research aimed to study the status of electronic wastes in Mosul city as it is considered a new threat to the environment. The study involves composition, generation rate of electronic waste and its relationships with some of the creation source features. A questionnaire was prepared to collect the data, which was conducted through a 57 visits. The results showed that monitors and televi-sions represent the higher percentage among other types with a percentage of 51.4% according to weight. The electronic waste generation rate in Mo-sul city was 1.78 kg/capita/year for the period 2009-2014. It increased in families with high edu-cation level head and those with high income, while it decreased as family members increased. Addi-tionally, families in the metropolitan quarters have higher generation rate than those in the mixed quar-ters. The environmental sense of the risk of elec-tronic wastes ranged between 85.5-100% according to waste type. A regression model results showed that the education level of family head had the highest effect on the variation in electronic waste generation rate followed by quarter type and then number of family members. The research recom-mended to stop importing the electronic waste with-in the bales from China.

KEYWORDS:
Electronic waste, environmental sense, family income, electronic waste bale, regression model, Mosul city

INTRODUCTION

The electronics industry is the world's largest and fastest growing manufacturing industry. The rapid growth of electronic equipment accompanied with the rapid obsolescence of the used ones lead to the increase in electronic waste (e-waste) generation. E-waste is the fastest growing municipal wastes across the world and 20 to 50 million tons is generated globally every year[1]. Developing countries with increasing consumer base and an anticipated rise in the sales of electronic products would experience rapid economic and industrial growth along with the huge quantity of e-waste generation due to their heavy prospective demand. This will be of serious concern for these countries.[2]

Electronic waste is defined as the obsolete electrical and electronic equipment. Computers, laptops, televisions (TVs), mobile phones, digital video disc (DVD) players, printers, satellite receivers, remote controls, mobile chargers, etc. that have outlived their live and have been disposed of by their users became e-waste.

The composition of e-waste is different and complex and it may contain more than 1000 types of materials[3]. There are many reasons behind the generation of huge quantity of

e-waste. Also the useful life of all consumer elec-tronic devices is short relatively and decreasing due to rapid changes in equipment features and capabilities.[4] For example, globally the average life span of central processing units (CPU) in computers dropped from 4 to 6 years in 1997 to 2 years in 2005.[5]

Pasiecznik et al.[6] examined the behavior of local community on e-waste awareness in Poland. They explore the collection of selective waste of electrical and electronic equipment and evaluate the opinion of the individuals towards e-waste treatment.

Electronic waste differs from municipal waste and industrial waste chemically and physically. These huge quantities in addition with the fact that e-waste contains a wide range of risky compounds have turned e-waste into a universal environmental concern. Many of these materials are risky and carcinomas to human.[7]

Tang et al.[8] found that the concentration of total polycyclic aromatic hydrocarbons (PAHs) reached 1336 µg/kg in agricultural soil near the cycling plants of e-waste in Taizhou town, China compared with 466.5 µg/kg in the agricultural soils of other villages of the same town. Zhao et al.[9] established that the dietary intakes of five heavy metals for residents living in villages located in the Zhejiang province of China was 1.3 to 3.4 times higher than the provisional tolerance daily intake (pTDI) of 140 µg/day. They attributed their findings to the entrance of these metals to the food chain from e-waste. Wang et al.[10] discover that blood lead levels was significantly higher in those working in e-waste site. They concluded that work-ing in the e-waste site may be a risk factor for in-creased lymphocytic micronucleated binucleated cells frequencies. They also suggested that the his-tory of working with e-waste may be a predictor of increased blood lead levels. Muenhor et al.[11] found that the levels of polybrominated diphenyl ethers (PBDEs) in the road and floor dust from a manual e-waste dismantling facility in Thailand was signifi-cantly greater than those in resident dust. These levels range between 1200 to 43000 ng/g in the facility.

Therefore, e-waste needs a special treatment and experience in recycling to avoid its bad effects on environment and on human. Michalski et al.[12] investigated alloys fabrication from computer boards by melting.

The high labor cost and the strict environmen-tal legislation have consolidated the recycling of e-waste activities' implementation mostly in Asian countries such as China and India[13] by use of ob-solete methods and inadequate emphasis on the employees' protection.

This research aimed to indicate the quantity and composition of e-waste in Mosul city and its relationships with family income, family head edu-cation level and family numbers. Additionally a statistical model may be constructed to arrange the independent variables according to their power.

MATERIALS AND METHODS

Study site. The study was carried out in Mosul city. Mosul city is the center of Ninawah gover-norate with 1377000 inhabitants in 2014 according to statistic department in Ninawah governorate. It is located 465 km northwest of Baghdad on the banks of Tigris river. The city is separated by Tigris river into two parts, the right bank and the left bank. The quarters of the city is spread along the sides of the river which connected by five bridges. The right bank includes 91 quarter versus 160 quar-ter in the left bank.

Data collection. A special questionnaire was prepared to collect the data about the quantity and the type of e-waste in Mosul city (Table 1). The forum also includes the characteristics of the identi-fied families. These characteristics were the number of family individuals, family income and education level of family head. The data were collected for a sample of 57 families through 57 visits in different quarters of Mosul city. The sample includes nine quarters from the right bank and 23 quarter from the left bank involved in the study for five years. The data were analyzed statistically to find the percentages of e-waste constitutes. The rate of e-waste generation per capita in the year was calcu-lated. Additionally, the relationships between the rate of generation and each of family income, fam-ily head education level and number of family in-dividuals were found.

TABLE 1
The prepared questionnaire of e-waste data collection

Data Collection Forma				
Number of family individuals				
Family income (USD/ per month)	Weak (≤200)	Medium (200-800)		Good (>800)
Education level of family head	Illiterate	Read & write	Primary de-gree	University degree
Residential place	Town:		Quarter:	
The number of disposed or unused electrical standing or unused old devices for the last five years				
Device	**Number**	**Period used**	**Weight (kg)**	**Effect on Envi-ronment**
Television and Monitors				
Remote control				
Batteries				
Flash memory				
Desktop computer & Laptops				
Mobile				
Satellite receiver				
AC adaptor				
DVD player and Compact disk				
Printers				

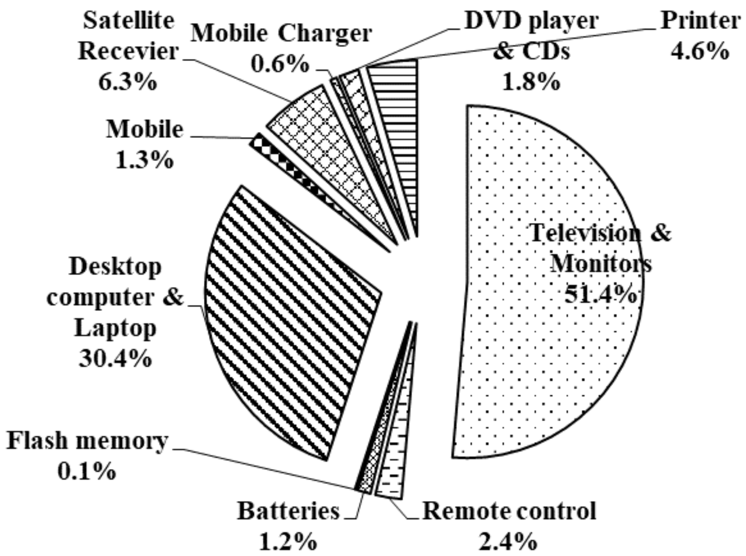

FIGURE 1
Composition of e-waste as a percentage according to type

Statistical analysis. The data were analyzed statistically using SPSS version 17 for Windows. Mean, percentage were used for data description. Spearman correlation was used to find the relationships between e-waste generation rate and the studied independent variables. Multiple regression analysis was used to construct a model of e-waste generation versus the independent variables. The results were considered statistically significant at $p<0.05$.

RESULTS AND DISCUSSION

The composition of electronic wastes according to weight in Mosul city is presented in Figure 1. Televisions and monitors constitute more than half of the e-waste by weight at a percentage of 51.4%. This percentage is more than four times that found by Widmer et al.[14] in the countries of the Organiza-tion for Economic Cooperation and Development (OECD). This can be attributed to the technological development in televisions and monitors from the old heavy type CRT to Plasma, LCD, OLED and QLED monitors with light weight and less energy consumption and less risk on eyes. Additionally, the percentage of monitors increased due to the avail-ability of cheap bale LCD monitors imported from China.

In the second order came computers with a percentage of 30.4% as people move from the desktop computers to laptops. This also can be attributed to the availability of low cost bale lap-tops in Mosul imported from China like monitors. After that came satellite receivers with 6.3%, print-ers including cartridge with 4.6%, remote control with 2.4%, DVD players and compact discs (CDs) with 1.8%, mobiles with 1.3%, small batteries with 1.2%, mobile chargers with 0.6% and 0.1% for portable flash memories.

According to the data obtained, the rate of e-waste generation in Mosul city during the study period 2009-2014 reached 1.78 kg/capita/year. This rate was lower than that in Jordan (2.48 kg/capita)[15] which may be attributed to the difference in the type of e-waste included in the study. In addition, the rate is higher than that in South Africa (1.2 kg/capita) and China (1.7 kg/capita)[16] since the lifespan of the devices is higher in these countries, also repairing and recycling is used more than other countries. On the other hand, It is less than that in Bulgaria (5.4 kg/capita) and Lithuania (6.3 kg/capita)[17]. In Europe, e-waste is produced at a rate of 14 kg/capita/year[18]. This can be attribut-ed to the fast technological development in the European countries and high family income.

The increase in the e-waste generation rate with the increase in family income level did not reach the level of significance (Figure 2). For the fami-lies with good income, e-waste generation rate reached 10.4 kg, while it was lower (8.84 kg) in those with medium income and decreased to 6.2 kg in families with weak income. This relationship is considered logic, since the families with good in-come have the ability to keep up with technological developments which increase the e-waste genera-tion.

The relationship between e-waste generation rate and number of family members is negatively significant (Figure 3), ($r=-0.408$, $p<0.01$). For families with four members and less, the rate of e-waste generation was 3.21 kg/capita/year which de-creased to 1.76 kg/capita/year in families with 5-6 members and to 1.05 kg/capita/year in families with 7-14 members. The quantity of e-waste pro-duced is divided by a larger number as the family size

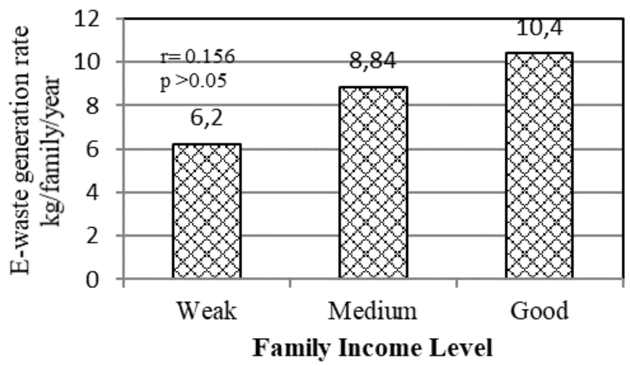

FIGURE 2
Distribution of e-waste generation rate according to family income

increase. Additionally, the recycling of devices among the members of large families is more probable. There-fore, generation rate of e-waste in large families is lesser.

The relationship between generation rate and the education level of family head did not reach the level of significance (p=0.087). It increases with the rise in family head education level (Figure 4). The rate of generation reached 2.14 kg/capita/year in the families with university degree head. It decreased to 1.27 kg/capita/year for those primary degree head and to 0.78 kg/capita/year for those with read and write family head. This variation can be related to the difference in the incentive factor among the families to keep up with the technological de-velopment in the domestic instruments and communications ones. In other words, the lifespan of the devices in families with university degree head is less than those with read and write head, which will increase the rate of e-waste generation in the former families.

When the data was sorted according to the type of quarter (Figure 5), metropolitan districts have more e-waste generation rate than the mixed ones with significant difference (p<0.05). The generation rate in metropoli-tan quarters reached 2.47 kg/capita/year versus 1.31 kg/capita/year in the mixed quarters. This difference may be attributed to the variation in the ability of the families in these quarters to follow the technological develop-ment and also to the variation of income.

A multiple regression model for e-waste generation rate as a dependent variable versus the studied inde-pendent variables showed that the education level of the family head has the highest effect on the variation in e-waste generation in Mosul city (Table 2). This is followed by quarter type and then number of family mem-bers. The income level of the family has the lowest effect on the generation rate of e-waste. The education level of the family head has more than one and quarter that for each of the number of family numbers and the quar-ter type. On the other hand, it has more than 11th time that of family income level.

The method of e-waste disposal differed ac-cording to the type. The e-wastes of low weight and low cost were disposed with the domestic wastes like remote controls, flash memories, batteries,

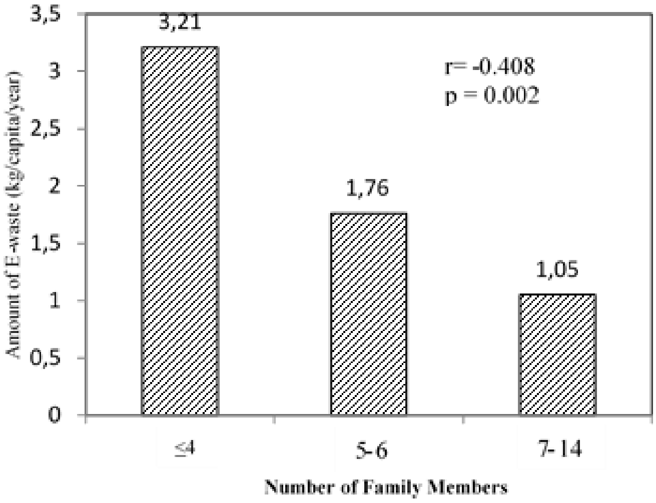

FIGURE 3
Distribution of e-waste generation according to number of family members

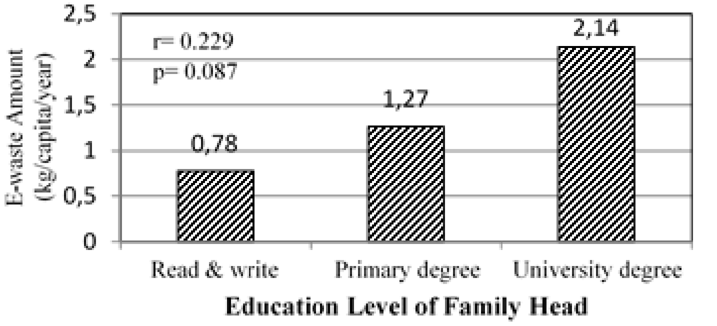

FIGURE 4
Distribution of e-waste generation according to the education level of family head

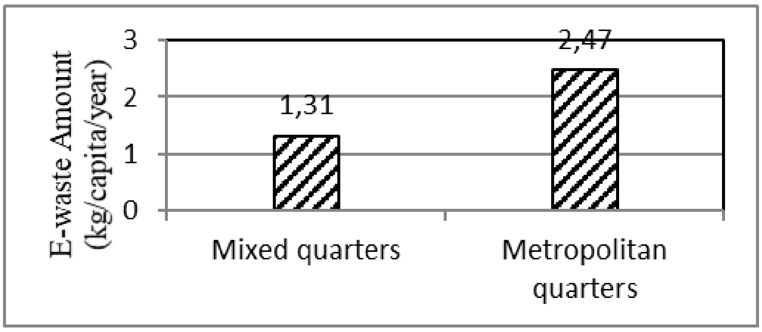

FIGURE 5
Distribution of e-waste generation rate according to quarters

TABLE 2
Multiple regression model for e-waste generation in Mosul city

Independent variables	Coefficient	Standard Error	Standardized coefficients (□□	t-value	p-value
No. of family members	-0.652	0.287	-0.560	2.27	0.027
Family income level	-0.066	0.414	-0.065	0.16	0.874
Education level of family head	0.450	0.226	0.727	1.99	0.051
Quarter type	1.031	0.479	0.575	2.16	0.036

Coefficient of determination (R^2) = 0.555, $p<0.001$

mobile chargers, and CDs (Figure 6). The percentage of e-wastes disposed with domestic waste ranged between 60.7% for flash memories to 93.75% for CDs. On the other hand, e-waste of more weight and cost like television, monitors, desktop computers, mobiles, satellite receivers and printers were saved at home at a percentage of 40.6% to 76.9%.

The questioned families shows a high percentage of environmental risk sense of e-waste in Mosul city according to type (Figure 7). The percentage of risk sense ranged between 85.5% for televisions to 100% for batteries.

The existence of valuable materials in e-waste has encouraged the studies of recycling and recovery systems in developing countries. The recycling and recovery of e-waste had been necessary as these wastes formed a load on the environment and natural resources. Additionally, recycling of e-waste prevent the release of hazardous materials to the environment and decrease the volume of e-waste which will lower the area required for landfill. In contrast, the decision of e-waste recycling must not be taken before the insurance of applying the environmental restriction on the recycling sites and the workers.

The manual dismantling of e-waste helps in recapture of recyclable materials and plastics. Conversely, the separation of the hazardous fragments require further treatment like mercury and lead containing parts: CRT-glass and LCDs.[19] For example, mercury containing parts are treated in specialized mercury recovery facilities or authorized hazardous waste incinerators having modern flue gas cleaning system.[20]

CONCLUSIONS

[1] Electronic waste became as a threat on the environment in Mosul city nowadays, since it was mixed with the municipal waste as it contains hazardous materials.

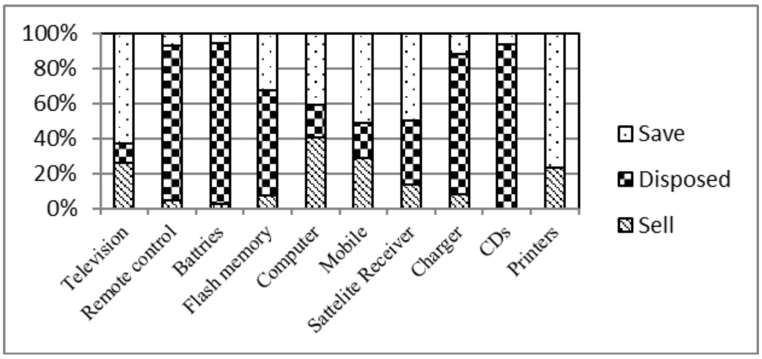

FIGURE 6
Methods of e-waste disposal in Mosul city according to type

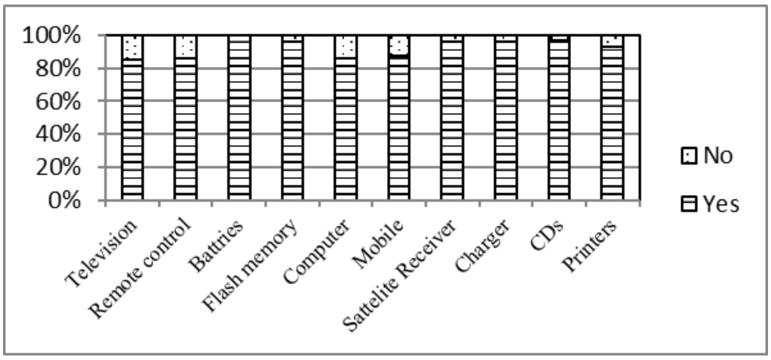

FIGURE 7
Environmental sense risk of the e-waste in Mosul city according to type

[2] Televisions and monitors represent the highest percentage among the other types of e-waste composition by weight.
[3] The average generation rate of e-waste in Mosul city for the period 2009-2014 reached 1.78 kg/capita/year.
[4] The generation rate of e-waste increases in families with head of high education level and with high income. On the other hand, it decreases in families with higher number of individuals.
[5] The metropolitan quarters shows higher generation rate of e-waste versus mixed ones.
[6] The light weight e-waste in Mosul city is disposed mixed with the home waste.
[7] The environmental risk sense of e-waste ranged from 85.5 to 100% according to type.
[8] The recycling of e-waste need to conduct a feasibility study and home sorting in addition to the availability of investment.
[9] The researchers recommend preventing the importing of e-waste bale from China.

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