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Association between Socioeconomic and Demographic Factors with Electronic Waste Generation in Jakarta

F.H. Adzania[1], Zakianis[1], R.A. Wulandari[1], R. Ambarsari[2], S. Fauzia[1], G.P. Aryati[1]

Key words: Correlation test, Education level, E-waste, Gender
Parole chiave: Test di correlazione, Livello educativo, Rifiuti elettronici, Genere

Abstract

Background. *Electronic waste is a continuously increasing hazardous and toxic waste in this digital era. Socioeconomic and demographic status contribute to the increase in electronic waste generation.*
Study design. *Ecological study.*
Methods. *The aim of this study was to analyze the socioeconomic and demographic factors that are related to the increase of e-waste generation in 44 sub-districts in Jakarta. Data from the Jakarta Provincial Environment Department, Statistics Indonesia, and Open Data Jakarta were used for this study. Data were analyzed using correlation tests.*
Results. *The results show that the increase in electronic waste generation is related to the male gender ($p = 0.036$, $r = 0.316$) and a moderate education level ($p = 0.038$, $r = 0.313$).*
Conclusions. *We recommend that the Jakarta Provincial Government provides electronic waste collection points in all areas; however, the area in which its population is dominated by males and has a moderate education level should be prioritized.*

Introduction

In this digital era, humans utilize more electronic goods than ever before; however, unused or broken electronic goods eventually become electronic waste. Electronic waste (or e-waste) is waste from electrical equipment, including all its components, sub-assemblies, and consumables, which are part of electronic products at the time of disposal (1). In Indonesia, electronic waste (personal computer, handphone, bulb lamp, cables, battery, etc.), is part of a specific waste containing hazardous and toxic materials that can be harmful to the environment and to human health. Thus, special treatment is

[1] *Department of Environmental Health, Faculty of Public Health, Universitas Indonesia*
[2] *Jakarta Provincial Environment Department*

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required to manage it (2). Waste management is one of the most important aspects in the field of environmental health, because it aims to protect the health of the public, which means it can be considered a promotive and preventive action that can support the protection of the health status of the community (3). Based on Government Law No. 18 year 2008, the purpose of waste management is to improve the health status of the community. Therefore, a good waste management is expected to become a part of public health.

Globally, in 2010, the amount of electronic waste was estimated at 33.8 million tons and continued to increase to 53.6 million tons in 2019; however, only 17.4% of electronic waste was properly recorded, collected, and managed (4). Similarly, in Indonesia, the amount of electronic waste amounted to 1.2 million tons in 2016 and increased to 1.6 million tons in 2019 (5, 6). The rise of electronic waste can be attributed to a variety of factors, including consumer demand, household ownership of electronic goods, and the limited duration of electronic goods, more due to obsolescence than to failure (7, 8). The average duration of usage for most consumers has dramatically decreased. For example, mobile phone usage has shrunk from three to four years to less than eighteen months. Some of the reasons an electronic item reaches end-of-life earlier are an error in items choice; or better features, aesthetics, and benefits offered by new products (7). In addition, the relationship between humans and the environment is a contributor, where human dynamics, such as social and economic factors, can produce pollutants and waste that can have an impact on the environment and on human life (9-11).

Electronic waste management in developed countries is better when compared to developing countries. In Switzerland, the amount of formally managed electronic waste increased from 75% in 2016 to 95% in 2018 (12). This favorable result is due to strict regulations, clear financial mechanisms, divisions of roles and responsibilities of interested parties, community participation, and a system and management used for waste collection with adequate facilities and infrastructures (13).

Meanwhile, electronic waste management in developing countries, such as India, is mostly carried out by informal sectors, such as scavengers and junkyards. Electronic waste in India is still mixed with other domestic waste and is eventually taken to landfills (14, 15). This is due to the existing regulations that have not been carried out optimally, the lack of supporting facilities and infrastructures for electronic waste management, and the lack of community participation (15).

In Indonesia, electronic waste management follows the old paradigm of only collecting, transporting, and disposing of waste in landfills along with other domestic waste. Only a small percentage (2%) of electronic waste is managed in the formal sector by local governments, while most electronic waste is managed by the informal sector (16, 17); however, since 2017, a program has been established to manage electronic waste from households (16). One of the provinces in Indonesia that has run a domestic electronic waste handling program is Jakarta. Electronic waste and other hazardous and toxic material (B3) waste are sorted independently by each household and then collected by officers of the Implementing Unit of the Jakarta Provincial Environment Department once per week. The collected waste is then accumulated and stored temporarily in the sub-district-scale temporary waste storage site. The waste is then transported to the city-scale temporary waste storage site and then to the Jakarta Provincial Environment Department Warehouse. The electronic waste is further managed by licensed third parties (16).

The generation of electronic waste is related to demographic and socioeconomic

factors. Population density can be associated with the generation of electronic waste (18, 19). The higher the population density is in an area, the higher the amount of electronic waste that is generated (20). Meanwhile, the productive age group (15-64 years) needs more supporting equipment, such as electronic goods, than other age groups (21). If electronic goods used by the productive age cannot be reused, it will cause a generation of electronic waste. There are several studies that show a relation between productive age and the generation of electronic waste (22, 23). The needs for electronic goods in non-productive age groups can be related to the use of electronic goods to support learning in schools (24). A study in the Netherlands shows that at least 39.4% of people over the age of 64 use electronic goods (25).

Another demographic factor associated with the generation of electronic waste is gender. Analyzing gender can provide a complex depiction of the differences between females and males, including sociocultural and lifestyle differences (26). A report from the Organization for Economic Co-Operation and Development (OECD) shows that there is a gender gap in the ownership of electronic goods in low-income and middle-income countries. On the average, the number of females who own electronic goods are 10% lower than males, which can also be related to males' generation of electronic waste (27, 28).

Level of education can also be related to the generation of electronic waste. Education, which is one factor in the human development index, can be measured using the highest year of completed school or the highest category of education obtained. Higher levels of education are often associated with a better socioeconomic status (29). People with higher education levels have the ability to purchase more electronics. A study in Pakistan shows that 81% of electronics consumers have high education levels (30). Several studies also provide evidence to support the relationship between education and the generation of electronic waste (19, 31, 32).

In addition to demographic factors, the generation of electronic waste can be related to socioeconomic factors. In general, socioeconomic factors are measured by income and employment status (29). A study from the European Union shows that unemployed people have a negative correlation with electronic waste generation (33). This result is different from a study in Poland, which shows that people who are unemployed have a strong relationship and correlation with the generation of waste (22). In addition, the proportion of slums can also be used to describe the socioeconomic characteristics of a certain population (33). Slums can represent a low socioeconomic status in the region due to limited access to education, employment, sanitation, and clean water. Generally, residents in slums do not have many secondary items, such as electronics, so the waste from electronic goods is less than that of residents not living in slums (34). This is reinforced by research, that states that the population living in slums has a negative correlation with electronic waste, which indicates that the higher the proportion of the population living in slums, the lower the waste (19).

Jakarta, the capital of Indonesia, has both demographic and socioeconomic problems. One of the problems is the high population density. The population density of Jakarta increased each year from 2017 and 2018 with 15,663 people/km^2 and 15,804 people/km2, respectively, to 15,900 people/km^2 in 2019 (35). The proportion of productive age groups in Jakarta reached 70.65% in 2019 (36), which can be one of the factors involved in the increasing electronic waste produced from this age group.

Therefore, research must be conducted related to the relationship between socioeconomic factors, such as employment status and slums, and demographic factors, such as population density, age, gender,

and education level, with the generation of electronic waste in Jakarta. The results of this study are expected to help the government identify suitable locations for electronic waste drop boxes in accordance with the socioeconomic and demographic factors.

Methods

This is an ecology study with sub-districts as its unit of analysis. The sample of this study includes 44 sub-districts in Jakarta. Data used in this study were retrieved from various sources, such as secondary data on electronic waste from Jakarta Provincial Environment Department (Permission number: 2122/-1851.84), secondary data on slums from Statistics Indonesia, and other related secondary data from Open Data – Integrated Data Portal of Jakarta Provincial Government. This study has passed the ethics review from Universitas Indonesia with License No: Ket-198/UN2.F10.D11/PPM.00.02/2021. The data were analyzed using correlation tests and are presented in table and spatial form. Electronic waste, demographic factors, and socioeconomic factors are presented in the form of mean distribution, median, standard deviation, and minimum and maximum values.

Results

Electronic Waste Generation in Jakarta

Jakarta's generation of electronic waste in 2020 has increased from the previous year. In 2019, the generation of electronic waste was 15 tons. In 2020, the generation of electronic waste from each sub-district reached more than 21 tons. Although there was an increase in electronic waste from the previous year, the number of electronic wastes in Jakarta per month in 2020 was declining, based on data from electronic waste generation (Figure 1).

Overall, Jakarta has 44 subdistricts and 267 sub-subdistricts, where the average generation of electronic waste in 2020 reached 485 kg per subdistrict. The average population density of Jakarta reached 19,875 people/km^2 in 2019, which is classified as very high because it is above 8,500 inhabitants/km^2 (37) or above 1,000 inhabitants/km^2 (38), meaning it is higher than the average population density in Indonesia of 140 people/km^2 (39). The average proportion of the productive age group in Jakarta was 72% in 2019, which is higher than the national average productive age of 68.7% (40). In addition, the average proportion of the population with higher education levels reached 17%, which also

Figure 1 - Trendline of Electronic Waste in Jakarta from January-December 2020

Table 1 - Distribution of Mean, Median, SD, Minimum-Maximum of Total Electronic Waste, Demographic Factors, and Socioeconomic Factors of Electronic Waste in Jakarta Year 2020

Variable	Mean	Median	SD	Min-Max
		N = 44 subdistricts		
Electronic waste generation (kg)	485	350	482	20-2488
Population density level (people/km^2)	19,875	19,066	11,075	2,894 – 60,625
Proportion of male population (%)	50.4	50.4	0	49.1 – 51.2
Proportion of productive age group (%)	72	72	1	68 – 73
Proportion of moderate education level (%)	59	60	4	47 – 67
Proportion of high education level (%)	17	18	6	5 – 63
Proportion of employed population (%)	40	40	3	29-43
Proportion of slum area (%)	6	3	9	0-42

exceeds the national average of only 13% (41). The average proportion of slums in Jakarta province reached 6%, which is lower than the national average of 8% (42) (Table 1).

Association of Socioeconomic and Demographic Factors with the Generation of Electronic Waste

The correlation test shows that there is a significant association between electronic waste generation and the proportion of males and a moderate education level. If there is an increase in the proportion of the male population with a moderate education level in the community, the amount of electronic waste that is generated in that area also rises. The proportion of females has a significant negative relationship, which means an increase in the female population has an impact on reducing electronic waste generation (Table 2).

Spatial Association of Social Demographic Factors with the Generation of Electronic Waste

Spatially, electronic waste generation is related to demographic factors. Spatially-related variables include gender, age, and level of education; however, population

Table 2 - Results of Demographic and Socioeconomic Factors Association Analysis with Electronic waste Generation in Jakarta in 2021

Variable	Electronic Waste Generation (n = 44 subdistricts)	
	Correlation Coefficient (r)	P value
Population density level (people/km^2)	-0.139	0.370
Proportion of female population (%)	-0.316	0.036*
Proportion of male population (%)	0.316	0.036*
Proportion of productive age group (%)	0.088	0.572
Proportion of non-productive age group (%)	-0.088	0.572
Proportion of low education level (%)	-0.078	0.617
Proportion of moderate education level (%)	0.313	0.038*
Proportion of high education level (%)	-0.206	0.180
Proportion of employed population (%)	-0.046	0.769
Proportion of un-employed population (%)	0.046	0.769
Proportion of slum area (%)	0.204	0.184

*Significant ($p<0.05$)

density has no spatial association with electronic waste generation (Figure 2).

Factors Related to Compliance with Hazardous Waste Management in Hospitals

Spatially, socioeconomic factors, such as employment status and slums, also have a relationship with the generation of electronic waste. Employed people have a better socioeconomic status than people who are unemployed. Figure 6a shows that a higher electronic waste generation was found in an area with a higher proportion of employed people. Furthermore, the spatial patterns in Figure 7 indicate that a higher electronic waste generation was found in the area with a lower proportion of slums.

Discussion

Statistical tests and spatial analyses were used for this study. Statistical tests were used to analyze the significance of relationships and the strength of relationships (43). Spatial analyses were used to analyze the pattern of a variable in a region with maps as the visualization tool. The obtained pattern can be used to compare one region with another. This pattern is obtained by combining statistical data from various sources with a specific geographic database (44). A spatial analysis is different from statistical tests because its aim is to identify independent variables that have a relationship consistent with a high occurrence of electronic waste spatially.

An increase in electronic waste generation can occur due to a variety of factors, including production in the industry due to consumer demand (7, 8, 45), dramatically decreasing duration of usage, decreasing demands (7), and affordable prices of electronic goods (7); however, affordable electronic goods are mostly produced by workers with low skills and low wages (46), which can result in producing easily damageable goods that eventually lead to a generation of electronic

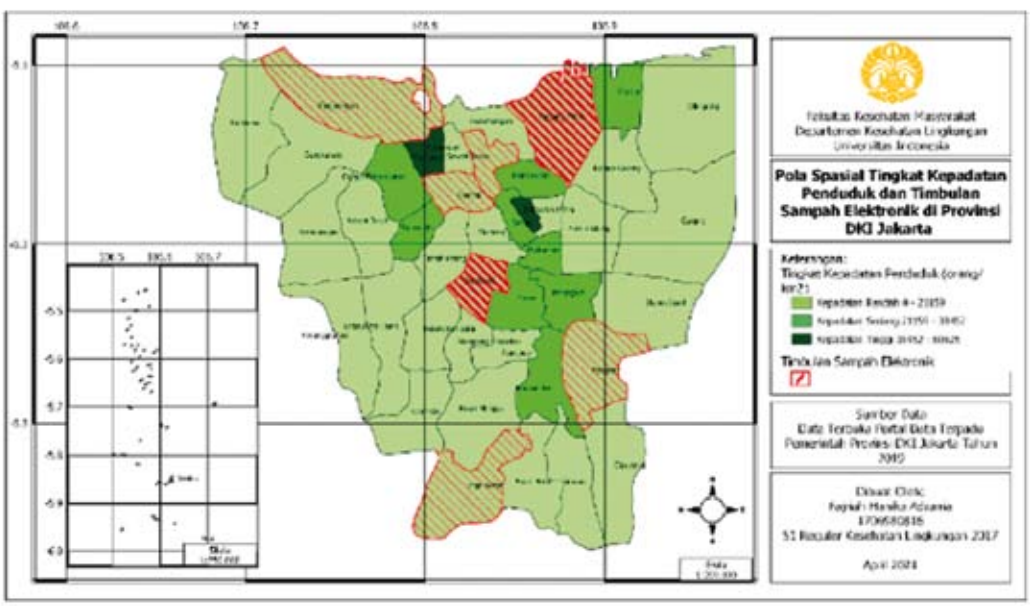
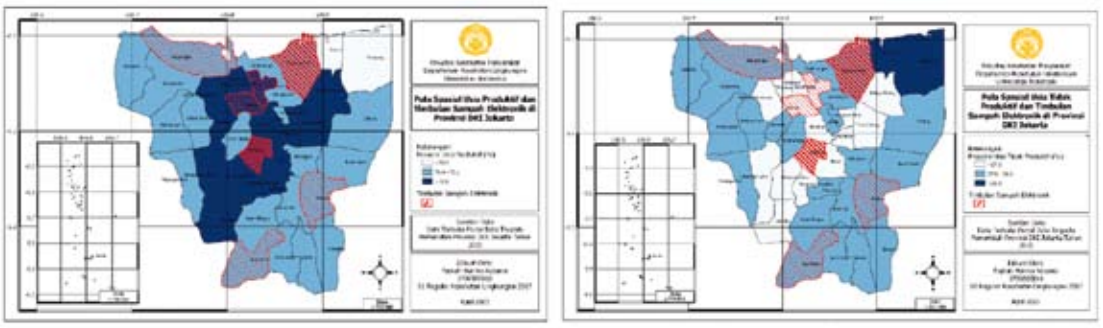


Figure 2 - Spatial pattern of population density level with electronic waste generation in Jakarta

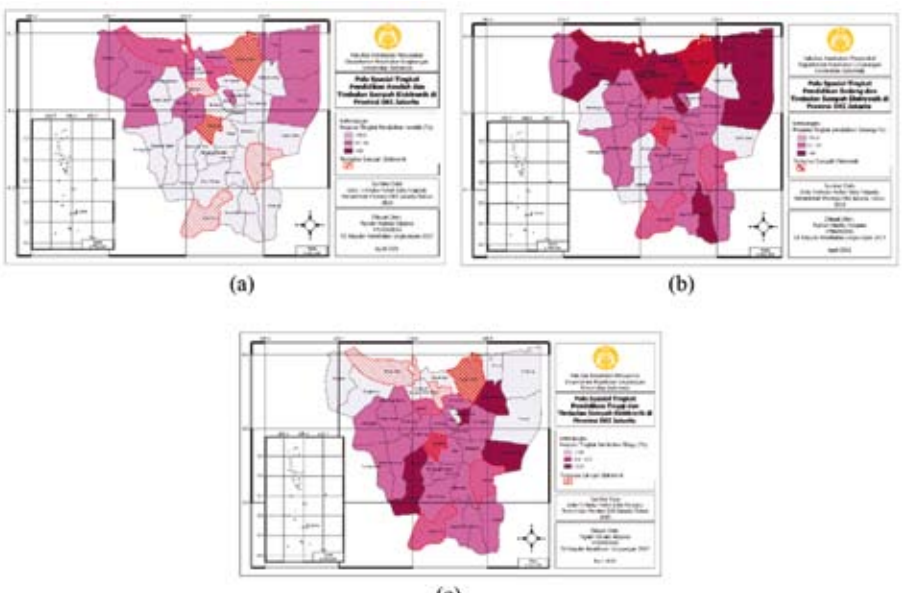
(a) (b)

Figure 3 - Spatial pattern of male (a) and female (b) population with electronic waste generation in Jakarta



(a) (b)

Figure 4 - Spatial pattern of productive (a) and non-productive (b) age group with electronic waste generation in Jakarta



(a) (b)

Figure 5 - Spatial pattern of education level with electronic waste generation in Jakarta

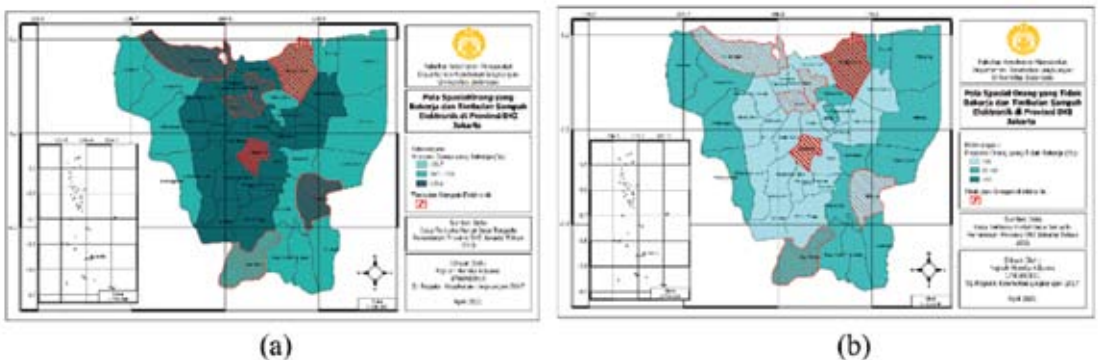


Figure 6 - Spatial pattern of employment status with electronic waste generation in Jakarta

waste. In addition, the depreciation of the duration or year of use of electronic goods contributes to the increase in the occurrence of electronic waste (7, 8, 45).

The decreased amount of electronic waste generation in 2020 could have been caused by various factors. One factor is that electronic garbage collection officers must adjust to large-scale social restriction policies due to the COVID-19 pandemic (47). Another hindering factor is the reduction in massive information and education activities for residents in Jakarta. Moreover, most of the population still disposes of its electronic waste using informal sector scavengers and collectors (48). Thus, electronic waste generation collected by the Jakarta Provincial Environment Department as the manager of the formal sector fluctuates and tends to decrease.

The results show no relation between population density level and electronic waste

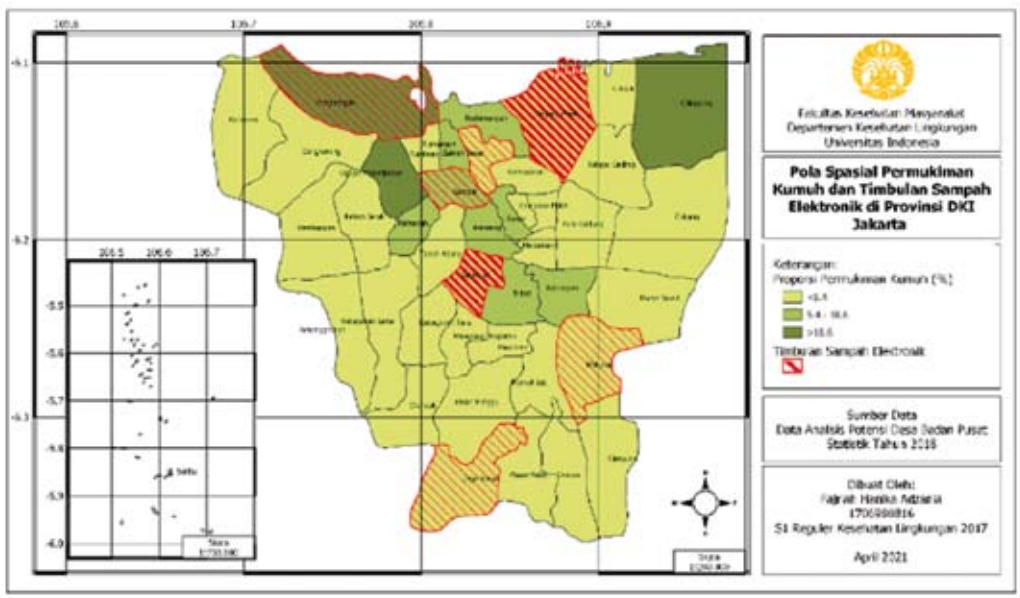


Figure 7 - Spatial pattern of slum area with electronic waste generation in Jakarta

generation in Jakarta Province. This result is in line with a previous study by Mansfield (2013) from the European Union, where it was found that electronic waste generation does not have a significant relation with the population density level (18). Population density that has no relation to electronic waste generation can be associated with vertical residences, such as apartments and residential areas inhabited by residents of Jakarta. This is because the person in charge and/or the manager of a residential area carries out waste management, including electronic waste, independently based on the Provincial Regulation of Jakarta No. 3 of 2013 on waste management and the instruction of the Governor of Jakarta Province No. 8 of 2016 on the Implementation of Independent Regional Waste Management (49, 50), which means the electronic waste from residents who live vertically with their own building managers is not being recorded by the Jakarta provincial government.

The male gender has a relationship with the generation of electronic waste. This can be related to the fact that workers in Jakarta are mostly males, and they need supporting goods, such as electronics, for their work (27, 28). In Indonesia, the labor force participation rate is dominated by males, reaching 82.41% in 2020 (51). In addition, the OECD report shows that there is a gender gap in the ownership of electronic goods in low-income and middle-income countries. On average, males have a 10% higher consumption rate of electronics than females (27, 28).

In Jakarta, the average productive age group (72%) is higher compared to the national average (68,7%) (40). There is no significant relation between proportion of the productive age group and electronic waste generation; however, there are spatial patterns in some sub-districts. The relationship of the spatial analysis patterns of productive age with electronic waste generation can be attributed to the productive age population that is classified as a labor force, which requires more supporting goods, such as electronic goods (21).

Having a moderate education level also has a significant relationship with the generation of electronic waste. This is similar to previous research conducted by Vieira (2018) in Brazil (19). A moderate education level can be significantly related to electronic waste generation because it has the largest proportion among other educational level variables. In Jakarta, the proportion of people with a moderate education level is higher than other levels, so it is likely that its residents tend to buy lower-quality electronics that are easily damaged (14, 15). If the level of education is higher, the economic ability is also higher, which results in the tendency to buy goods with a higher quality (52).

The electronics industry has been a major driver of economic growth and employment in many developing countries, including Indonesia. The electronics industry also participates in a global electronic supply chain that can provide several advantages, including domestic economic growth and increased exports; however, domestic industries are still largely dominated by assembly jobs with low-skilled workers and low wages (46), which could cause the resulting products to have a shorter life cycle, contributing to the generation of electronic waste.

The proportion of the employed population in the area has no significant relationship with electronic waste generation. This could be because those who are employed tend to buy electronics with a higher quality compared to those who are unemployed, so the durability of electronics is higher. If the life cycle is longer, the generation of electronic waste can be minimized (14, 15).

Slums have no significant relation with the generation of electronic waste. This can be attributed to the low socioeconomic status of slum residents due to limited access

to education, employment, sanitation, and clean water. In general, the residents of slum areas do not own many electronic devices, and if the goods are damaged, they would be more likely to repair a good than dispose of it and buy a new one. In addition, some of the world's slums hoard their own electronic waste and manage it informally (53, 54), resulting in a lower recorded waste generation compared to electronic waste generation from non-slum areas (19, 34).

Conclusion

Electronic waste generation from households collected by the Jakarta Provincial Environment Department reached more than 21 tons in 2020. The male gender and a moderate level of education are factors that have a significant relation with electronic waste generation, and thus the top priority of the placement of temporary waste collection sites or drop boxes in sub-districts should be for sub-districts with the highest proportion of the male population and a moderate education level, such as Penjaringan, Sawah Besar, and Gambir areas. Other factors, such as age, employment status, and slums, have a relationship with the generation of electronic waste spatially. Thus, the government can also provide temporary waste collection sites and drop boxes in areas such as Setiabudi, Makasar, Tanjung Priok, and Jagakarsa as the second priority.

Acknowledgement: Data used in this study were retrieved from various sources. This study used secondary data of electronic waste from Jakarta Provincial Environment Department (Permission number: 2122/-1851.84), secondary data of slums from Statistics Indonesia, and other related secondary data from Open Data – Integrated Data Portal of Jakarta Provincial Government.
This study has passed the ethics review from Universitas Indonesia with License No: Ket-198/UN2.F10.D11/PPM.00.02/2021.

Riassunto

Associazione tra fattori socio-economici e demografici e produzione di rifiuti elettronici a Jakarta, Indonesia

Premesse. I rifiuti elettronici sono rischiosi in quanto tossici ed il loro volume aumenta in continuazione in questa era digitale.

Disegno dello studio. Indagine di natura ecologico-ambientale.

Metodi. Scopo dello studio è l'analisi dei fattori demografici e socio-economici che si associano all'incremento della produzione di questi e-rifiuti in 44 sotto-distretti di Giacarta. Per lo studio sono stati utilizzati i dati raccolti dal Dipartimento Ambiente Provinciale di Giacarta, dall'Ente Statistico Indonesiano e da "Open Data" di Giacarta, analizzati con test di correlazione.

Risultati. È stato dimostrato che l'incremento osservato è associabile al genere maschile ($p = 0,036$, $r = 0,316$) ed al ridotto livello educativo ($p = 0,038$, $r = 0,313$).

Conclusioni. La raccomandazione che emerge dall'indagine, rivolta all'Amministrazione provincialee di Giacarta, è di predisporre a tappeto punti di raccolta dei detti rifiuti, dando comunque priorità alle aree a predominante presenza maschile dei quartieri abitati da persone di basso livello educativo.

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Corresponding author: Sifa Fauzia, Department of Environmental Health, Faculty of Public Health, Universitas Indonesia, Depok, West Java, Indonesia
e-mail: sifafauzia@ui.ac.id