The Effect of Demographic Factors on Waste Generation and Heavy Metal in Illegal Landfill at Malaka Regency, East Nusa Tenggara Province

Leonarda Sofiani Rame¹, Widiatmaka², Arief Hartono² and Irman Firmansyah³

¹Study Program of Natural Resources Management and Environmental, Graduate School Bogor Agricultural University, Baranangsiang Campus, Bogor, Indonesia
²Departement of Soil and Land Resources, Bogor Agriculture University, Bogor, Indonesia
³System Dynamics Center, Indonesia

E-mail: leonardasofianirame36@gmail.com

Abstract. The population growth has led to a significant increase in the amount of waste every year. Meanwhile, several demographic factors influencing waste generation in Malaka Regency include an absence of a final landfill. This has caused the illegal dumping of waste which leads to various environmental problems. Therefore, this study aims to (I) analyze the effect of demographic factors on waste generation (II) determine the level of heavy metals and the chemical properties of the soil in the illegal landfill. In this study, the demographic factor sampling was conducted in all districts using a questionnaire to obtain each household sample and waste was weighed directly with the Stratified Random Sampling method. Also, soil samples at the landfill site were obtained through field observation and composite sampling. The results showed that age, gender of each family head, income, occupation, latest education, and the number of family members had a significant effect on waste generation in Malaka Regency. Based on the results, the content of Pb, Cd, and Hg in the soil at different waste disposal sites in Malaka Regency had passed the standard threshold value in soil, which showed that the land had been polluted by heavy metals.

1. Introduction
The improper management of waste has caused several problems in Malaka Regency due to the absence of TPA since the regency formed ini 2013 until now (2021). Furthermore, illegal dumping of waste in several locations due to daily increase in population has led to various environmental problems.

Meanwhile, the increase of urban waste in various compositions is caused by population pressure, urban expansion, economic development, improvement in the standard of living [1], and changes in the lifestyle of residents [2]. Since the process of urban development is unstoppable, therefore, the community needs to manage its impact on environmental destruction through the implementation of sustainable waste policies [3].

Damanhuri et al. stated that the average waste generation usually varies from one region to another [4]. Previous studies showed that several factors influence household waste management behavior, which is based on country or specific region, therefore, it is difficult to have a suitable factor for each. Also, it is important to identify the drivers of household waste management behavior for specific areas...
of interest. Therefore, research on the determinants of household source segregation behavior and solid waste dump options becomes important [5-6].

A previous study conducted by Mattar et al. showed that socio-demographic variables such as occupation, education, number of household members, and income affect food waste [7]. The results showed that households in rural areas contribute less to food waste in urban areas. Also, Mintz et al. found that cultural factors influence the extent to which people are involved in recycling and minimizing solid waste [8]. Riswan et al. stated that several factors affecting waste management include education, income level, behavior towards environmental cleanliness, knowledge of local regulations, and willingness to pay waste retribution were positively correlated with household waste management [9].

There are several problems caused by improper waste management in Malaka Regency especially in locations that are used as a landfill with an increase every year. In 2020, the location of landfills reached 23 and was distributed across several villages in the regency. Therefore, the waste that is directly disposed of on the ground needs to be analyzed to determine the contamination level of the soil.

The waste buried in the ground reduces soil quality and productivity. Furthermore, after long-term accumulation, harmful substances in sewage and garbage infiltrate into the groundwater and pollute the aquatic environment, which causes serious secondary environmental pollution [10]. Hussein et al. examined soils affected by heavy metals due to waste dumping in Malaysia, stated that there are high concentrations of heavy metals especially in landfills and also in the surrounding. This influence causes a decrease in the quality of the soil around the landfill [11].

A previous study by, Akanchise et al., in Ghana, on the impact of a landfill that causes the soil to be contaminated by heavy metals showed that soil pollution due to solid waste in several locations poses residents at risk for exposure to toxic heavy metals [12]. Furthermore, studies on heavy metal contamination (Pb and Cd) in water, soil, and plants around landfills in Bangladesh were also conducted by Alam et al. The results showed that environmental conditions around the landfill were in the moderately polluted category [13]. The concentration of heavy metals (Pb and Cd) in this analysis, namely Pb was greater than Cd. Meanwhile, the results of Altarez et al., study on Pb in the soil of the Philippines's former landfill showed that there was heavy metal contamination and food chains in the area. Hence, it is recommended that the community use the right land to avoid danger in the area [14].

Therefore, this study aims to (i) analyze the influence of demographic factors on waste generation and (ii) determine the levels of heavy metals (Pb, Cd, and Hg) in the soil and the chemical properties of the soil in an illegal landfill.

2. Method
The study was conducted from June to December 2020 in 12 sub-districts of Malaka Regency, East Nusa Tenggara (NTT) Province, meanwhile, the location is shown in figure 1. In the first study, a questionnaire and a door-to-door method of weighing waste were carried out directly in 340 households (340 samples) distributed during weekdays and weekends to determine the difference in the amount of waste when people were at home and work. Meanwhile, the second study used field observation methods and soil sampling at locations of composite dumping sites for analysis in the laboratory.

The data used in the first study were primary in form of the results from weighing waste in each household with a questionnaire which contains age, gender, income, occupation, last education, and the number of family members. Meanwhile, the secondary data were in form of the 12 sub-districts population from the Population and Civil Registration Office of Malaka Regency. In this second study, the primary data include heavy metal analysis results and secondary data such as landfill location were from the PUPR and KP Department of Malaka Regency.
Figure 1. Research Location.

Moreover, the data analysis used for the first and second studies was multiple linear regression with the SPSS. The dependent variable in the first study objective was the waste generation, while the independent variables were age, gender, income, occupation, education level, and the number of family members. Furthermore, the dependent variables in the second study objective were heavy metals (Pb, Hg, and Cd), while the independent were soil pH, C-Organic, and Cation Exchange Capacity (CEC).

The location of the first study objective was carried out in all sub-districts in Malaka Regency from June to December 2020. Also, the population was 340 houses distributed across 12 sub-districts in regency using the Stratified Random Sampling method. Materials and equipment used to analyze the amount of waste generated in each household were questionnaire materials, stationery, scales, waste containers (organic and inorganic), digital cameras, gloves, nose and mouth masks, names of respondents in the 12 (twelve) sub-districts of Malaka Regency.

The second study was carried out at 10 landfill locations that were selected based on the length and the volume of waste disposal. The longer and wider the waste disposal, the more soil samples obtained at these locations. Out of the 23 landfill locations, only 10 with greater waste disposing time and locations with large enough areas were selected. The location, length of time for the waste dump and landfill area in Malaka Regency are shown in table 1.

Table 1. Location, the length of garbage dump and the area of waste land in Malaka Regency.

| Location | Village | Address | Length of time for garbage dump and the area of garbage land in Malaka Regency | Area |
|----------|---------|---------|--------------------------------------------------------------------------------|------|
| Loc.1    | Kateri  | Central Malaka | 2015 until 2017 | 3,600 m² |
| Loc.2    | Barada  | Central Malaka | 2014 until 2016 | 2,368 m² |
| Loc.3    | Barada  | Central Malaka | 2014 until 2016 | 3,526 m² |
| Loc. 4   | Kateri  | Central Malaka | 2016 until 2017 | 2,044 m² |
| Loc. 5   | Kateri  | Central Malaka | 2016 until 2017 | 2,310 m² |
| Loc. 6   | Haitimuk| Weliman  | 2018 until 2019 | 5,952 m² |
| Loc. 7   | Umanen Lawalu | Central Malaka | 2016 until 2017 | 5,561 m² |
| Loc. 8   | Lakekun | Kobalima | 2007 until 2013 | 4,879 m² |
| Loc. 9   | Lakekun | Kobalima | 2007 until 2013 | 3,753 m² |
| Loc.10   | Wehali  | Central Malaka | 2013 until 2014 | 3,404 m² |
| **Total Area**: | | | | 45,678 m² (4.56 Ha) |
3. Results and discussion

3.1. The Results of analysis of the influence of demographic factors on waste generation

The analysis on the independent variables such as age, gender, income, occupation, last education, and number of family members showed that the age of the head of the family in the study was between 23 and 80 years, the gender of the male family head was 69.1% and the female was 30.9%, the lowest income of the household was at Rp250.000.00/month (Rp: Rupiah), and the highest income was Rp35.000.000.00/month (Rp: Rupiah). Furthermore, the occupation with the highest percentage was farming at 28.5% and the smallest was DPR (Dewan Perwakilan Rakyat/House of people’s representatives) and Retired Polic with 0.3%. In this study, the types of work varied such as Fishermen, Farmers, Ojek (Taxibike), IRT (Ibu Rumah Tangga/Housewife), Bus Drivers, Retired Civil Servants, Teda Employees (Teda: Tenaga Kontrak Daerah/Regional Contract Workers), Small Entrepreneurs, Nurses, Midwives, Retired Police, Civil Servants, Police, Teachers, and DPR (Dewan Perwakilan Rakyat/House of people’s representatives). The highest percentage of the latest education was high school at 31.2%, while the lowest was Masters at 1.5%. In addition, the highest number of family members ranged from 13 to 15 people per household (22.1% of total respondents).

Based on SNI 10-3983 [15], the amount of waste generation is according to city classification with an average of 0.38 kg/person/day on weekdays and 0.52 kg/person/days weekends were categorized in the Medium City category due to a population of more than 100,000 people. Based on data from the Malaka Regency Population and Civil Registration Agency, the population in Malaka Regency in 2020 was 194,864 people. However, the weight of waste in the Medium City was not in line with SNI 10-3983-1995 because Malaka District ranged from 0.38 to 0.52 kg/person/day. Moreover, the amount of waste generation based on city classification is shown in table 2.

| Table 2. The Waste Generation based on City Classification. |
|------------------------|-------------------|-----------------|-------------------|
| Model | Coefficients* | Coefficients* | Coefficients* |
|       | Unstandardized Coefficients | Standardized Coefficients | T | Sig. |
|       | B | Std. Error | Beta | T | Sig. |
| 1 (Constant) | 0.633 | 0.522 | | 1.212 | 0.226 |
| Year (X1) | 0.001 | 0.007 | 0.010 | 0.170 | 0.865 |
| Gender (X2) | 0.129 | 0.177 | 0.039 | 0.731 | 0.465 |
| Income (X3) | 0.001 | 0.000 | 0.217 | 2.878 | 0.004 |
| Occupation (X4) | 0.007 | 0.029 | 0.023 | 0.247 | 0.805 |
| Education (X5) | -0.007 | 0.067 | -0.008 | -0.105 | 0.916 |
| The Number of Family Member (X6) | 0.122 | 0.039 | 0.168 | 3.107 | 0.002 |

* a. Dependent Variable: garbage Generation (Y)

Source: Analysis Results, 2020

| Table 3. The SPSS Output for Regression Equation Model, T-test and Beta Test. |
|------------------------|-------------------|-------------------|
| No. | City Classification | Volume (l/person/day) | Weight (kg/person/day) |
| 1 | Medium City (100,000-500,000 people) | 2.75-3.25 | 0.70-0.80 |
| 2 | Small City (20,000-100,000 people) | 2.50-2.75 | 0.625-0.70 |

Source: SNI 10-3983
Based on the results of multiple linear regression analysis, the model is: 
\[ Y = 0.633 + 0.001 X_1 + 0.129 X_2 + 0.001 X_3 + 0.007 X_4 - 0.007 X_5 + 0.122 X_6 + e \],
while constant value was 0.633. Meanwhile, the constant value showed a positive influence of the independent variables of age, gender of the head of the family, income, occupation, last education, and the number of family members.

The partial testing of the dependent variable (waste generation) was conducted to determine the effect of each independent on the dependent variable [16]. Based on these results, 2 variables that partially affect waste generation, namely the income factor and the number of family members, while the other 4 variables had no significant effect. Meanwhile, the multiple linear regression equation models and the results of the partial test of the independent variable on the dependent variable (T-test), as well as the beta test on the SPSS output are shown in table 3.

The beta test aims to determine the variables that have the most influence on waste generation in Malaka Regency, namely viewing of the largest coefficient value in the 6 variables. Based on the regression coefficient value (\( \beta \)) in the SPPS output table in table 4, it is concluded that the X3 variable (income) had a more dominant influence on the waste generation because \( \beta \) was 0.217 (greater than the regression coefficient of other variables).

**Table 4. SPSS Output for F-Test.**

| Model         | Sum of Squares | df | Mean Square | F       | Sig.  |
|---------------|----------------|----|-------------|---------|-------|
| Regression    | 65.828         | 6  | 10.971      | 5.068   | 0.000 |
| Residual      | 720.921        | 333| 2.165       |         |       |
| Total         | 786.749        | 339|             |         |       |

a. Dependent Variable: garbage generation (Y)
b. Predictors: (Constant), Total Family Member (X6), Education (X5), Gender (X2), Age (X1), Income (X3), Occupation (X4)

**Source: Analysis Results, 2020**

Furthermore, the F test was conducted to determine the effects of independent variables (X1, X2, X3, X4, X5, X6) simultaneously on the dependent variable Y (waste generation). The calculation of F-value output was 5.068 and the significance value was 0.000, which means 0.000 < 0.050 =0.05. These results showed that X1, X2, X3, X4, X5, and X6 simultaneously affected waste generation. Meanwhile, the output of the F test is shown in table 4.

3.2. The analysis results of heavy metals levels (Pb, Cd, and Hg) in the soil

Based on the results, the highest heavy metal content of Lead (Pb) was at locations 4 and 9 was 1,290.17 ppm, while the content of Pb at locations 4 and 6 were 982.11 ppm and 34.02 ppm, respectively.

Meanwhile, Pickering, stated that the threshold value of heavy metal Pb in soil was 2-200 ppm and the critical limit according to the Ministry of State for Population and Environment of Indonesia and Dalhousie was 100 ppm [22]. Based on the two standard threshold values for Pb, it is concluded that the heavy metal content of Pb in the soil in several landfill locations in Malaka Regency has passed the threshold value in the soil, which showed that the soil had been polluted. Meanwhile, the polluted areas include Location 2, 4, and 9 with a value of 163.68 ppm 1,290.17 ppm, and 982.11 ppm respectively. The results of the analysis of the heavy metal content of Lead (Pb), Cadmium (Cd), and Mercury (Hg) in garbage lands in Malaka Regency is presented graphically in figure 2.

Based on analysis of heavy metal Cd at 10 locations, the content of Cadmium (Cd) was high in 10 soil samples taken with a value of 25.82 ppm and the lowest weight was 0.47 ppm.

According to Pickering and the Ministry of State for Population and Environment of Indonesia and Dalhousie, the threshold value for the heavy metal content of Cd in soil was 0.1-7.0 ppm [17-18]. Based on the range of threshold values for Cd, it is concluded that the content of Cd at location 4 in Malaka Regency has passed the threshold value in the soil, therefore, it is highly polluted with a value of 25.82 ppm.
The analysis of heavy metal content in Mercury carried out indicated that the highest Mercury (Hg) heavy metal content in the soil at the landfill in Malaka Regency at locations 9 and 2 were 0.46 ppm and 0.43 ppm, respectively which showed that the content of Hg in the soil was relatively high. According to Darmono, the concentration of natural mercury Hg in the soil was 0.03. When compared with the results, it is concluded that the location of the landfill in Malaka Regency had also been polluted by Hg [19].

A previous study on the Mercury (Hg) and Arsenic (As) content conducted by Wang et al on Tibet landfill showed that Hg and As most pollute the soil at the sites. Furthermore, the results showed that Hg and As had the highest concentrations of 0.015 mg/kg and 66.55 mg/kg, respectively, which has exceeded the risk of soil contamination [20].

The results of heavy metal contents showed that the Pb, Cd, and Hg in the soil at 10 Locations were 296.78 ppm, 5.08 ppm, and 0.21 ppm, respectively. The average heavy metal content of Pb, Cd, and Hg at landfill locations showed that Pb > Cd > Hg. The locations of the landfill in Malaka Regency where the soil samples were obtained and analyzed for heavy metals and soil chemical properties (10 locations) are shown in figure 3.

Moreover, the relationship between soil pH, C-Organic, and Cation Exchange Capacity (CEC) on the heavy metal content of Pb, Cd, and Hg are explained using ANOVA statistical analysis. A previous study conducted by Salem et al., on the relationship between soil chemistry and heavy metals showed that there was a significant correlation between pH levels, Cation Exchange Capacity (CEC), organic matter content, and electrical conductivity of heavy metals on the land [21]. Also, a study by Cao et al., on the relationship between soil chemical properties and heavy metal content of Pb and Cd in soil and plants (Brassica napus L) using multiple linear regression statistical analysis, showed that the levels of the heavy metals in plants correlated with C-Organic, Cation Exchange Capacity (CEC), availability of Phosphorus (P), availability of Potassium (K), sand and total soil [22].

Previous studies on the Pb, Cd, and Hg content, as well as soil chemical analysis conducted on the soil at several landfills in Malaka Regency, showed that soil pH and C-Organic positively correlated with the heavy metals in garbage dump soil, while Cation Exchange Capacity (CEC) had a negative correlation. The results showed that the pH value of the soil was a factor that had the most dominant influence on the heavy metal content of (Pb), (Cd), and (Hg) in the soil at the landfill in Malaka Regency.

Furthermore, several studies have shown that landfills pollute the surrounding [23]. Heavy metal such as lead (Pb) from waste contaminates soil and groundwater, which affects health and causes inhibition of neurobehavioral development in children, anemia, kidney damage, and chronic neurotoxicity [24-25]. Meanwhile, Cadmium (Cd) from landfill cause health problems such as kidney damage and toxicity, bone disease (ostemalacia and osteoporosis), possible reproductive damage, and

![Figure 2. Heavy Metal Content: Lead (Pb), Cadmium (Cd) and Mercury (Hg) in Waste Lands in Malaka Regency.](image-url)
pulmonary emphysema [26]. Similarly, Hg from landfill cause health problems in form of impaired neurobehavioral development in children (especially methylmercury), anemia, kidney damage, and chronic neurotoxicity [27].

![Figure 3. Distribution of garbage dump and Area of garbage dump (10 Locations) in Malaka Regency in 2020.](image)

4. Conclusion

Based on the results, the average waste generation was 0.38 kg/person/day on weekdays and 0.52 kg/person/day on weekends. In addition, the results showed that age, gender of the family head, income, occupation, last education, and the number of family members had a significant influence on waste generation in Malaka Regency. However, the income factor had a more dominant influence on waste generation in Malaka Regency.

The results of heavy metal content and soil properties showed that the highest content of Pb was located at Locations 4 and 9 with a value of 1,290.17 ppm. Also, the highest content of Cd was at Location 4 with a value of 25.82 ppm, while Hg was at Locations 2 and 9 with values 0.46 ppm and 0.43 ppm, respectively. The average heavy metal content of landfills showed that the content of Pb > Cd > Hg. Therefore, these results showed that soil pH was the dominant factor that affects the heavy metal contents of lead (Pb), Cadmium (Cd), and Mercury (Hg) in the soil at the landfill in Malaka Regency.

References

[1] Li W and Achal 2020 Environmental and health impacts due to e-waste disposal in China – A review Science of the Total Environment 737 139745

[2] Gutberlet J 2017 Waste in the City: Challenges and Opportunities for Urban Agglomerations Urban Agglomeration Mustafa Ergen (IntechOpen) 72047
[3] Kwakwa P A, Alhassan H and Aboagye S 2018 Environmental Kuznets curve hypothesis in a financial development and natural resource extraction context: evidence from Tunisia Quant. Financ. Econ., 2 981–1000
[4] Damanhuri E and Padmi T 2019 Pengelolaan Sampah Terpadu (Bandung: ITB Press)
[5] Alhassan H, Kwakwa P A and Owusu-Sekyere E 2020 Households’ source separation behaviour and solid waste disposal options in Ghana’s Millennium City Journal of Environmental Management 259 2–18
[6] Adzawla W, Tahidu A, Mustapha S and Azumah B S 2019 Do socioeconomic factors influence households’ solid waste disposal systems? Evidence from Ghana Waste Manag. Res. 37 51–57
[7] Mattar L, Abiad M G, Chalak A, Diab M and Hassan H 2018 Attitudes and behaviors shaping household food waste generation: Lessons from Lebanon Journal of Cleaner Production 198 1219–1223
[8] Mintz K K, Henn L, Park J and Kurman J 2019 What predicts household waste management behaviors? Culture and type of behavior as moderators Resources, Conservation & Recycling 145 11–18
[9] Riswan, Sunoko H R and Hadiyarto A 2011 Pengelolaan sampah rumah tangga di Kecamatan Daha Selatan Jurnal Ilmu Lingkungan 9 31–38
[10] Kong L and Ma B 2020 Evaluation of environmental impact of construction waste disposal based on fuzzy set analysis Environmental Technology & Innovation 19 100877
[11] Hussein M, Yoneda K, Zaki Z M, Amir A and Othman N 2020 Heavy metals in leachate, impacted soils and natural soils of different landfills in Malaysia: An alarming threat Chemosphere, Elsevier
[12] Akanchorise T, Boakye S, Borquaye L S, Dodd M and Darko G 2020 Distribution of heavy metals in soils from abandoned dump sites in Kumasi, Ghana Scientific African 10 e00614
[13] Alam R, Ahmed Z and Howladar M F 2019 Evaluation of heavy metal contamination in water, soil and plant around the open landfill site Mogla Bazar in Sylhet, Bangladesh Groundwater for Sustainable Development 10 100311
[14] Altarez R D D and Sedigo N A 2019 Existing land use and extent of lead (Pb) contamination in the grazing food chain of the closed Carmona sanitary landfill in the Philippines Heliyon 5 e01680
[15] Badan Standardisasi Indonesia 1995 SNI 19-3983-1995 Standar Spesifikasi Timbulan Sampah untuk Kota Kecil dan Kota Sedang di Indonesia (Serpong: BSN)
[16] Ghozali I 2013 Aplikasi Multivariate dengan Program SPSS (Semarang: Universitas Diponegoro)
[17] Pickering W F 1980 Zinc interaction with soil and sediment components. In Nriagu JO. (Ed.): Zinc in the environment-Part 1: Ecological cycling (New York: John Wiley & Sons) pp 72–112
[18] Ministry of State for Population and Environmental of Indonesia dan Dalhousie, Universitas Canada 1992 Environmental Management in Indonesia. Report of Soil Quality Standards for Indonesia
[19] Darmono 1995 Logam dalam Sistem Biologi Makhluk Hidup (Jakarta: UI Press)
[20] Wang X, Dan Z, Cui X, Zhang R, Shengquan Z, Terence W, Yan B, Chen G, Zhang Q and Zhourg L 2020 Contamination, ecological and health risk of trace elements in soil of landfill and geothermal sites in Tibet Science of The Total Environment 715 136639
[21] Salem M A, Bedade D K, Al-Ethawi L and Al-waleed S 2020 Assessment of physiochemical properties and concentration of heavy metals in agricultural soils fertilized with chemical fertilizers Heliyon 6 e05224
[22] Cao X, Wang X, Tong W, Gurajala H K, Lu M, Hamid Y, Feng Y, He Zhenli and Yang X 2019 Distribution, availability and translocation of heavy metals in soil-oilseed rape (Brassica napus L.) system related to soil properties Environmental Pollution 252 733–741
[23] Li W and Achal V 2020 Environmental and health impacts due to e-waste disposal in China – A review Science of the Total Environment 737 139745
[24] Kumar U and Singh D 2014 Electronic waste: concerns & hazardous threats Int. J. Curr. Eng. Technol. 4 802–811
[25] Wu Q, Leung J Y S, Du Y, Kong D, Shi Y, Wang Y and Xiao T 2019 Trace metals in e-waste lead to serious health risk through consumption of rice growing near an abandoned e-waste recycling site: comparisons with PBDEs and AHFRs Environ. Pollut. 247 46–54
[26] Gangwar C, Choudhari R, Chauhan A, Kumar A and Singh A 2019 Assessment of air pollution caused by illegal e-waste burning to evaluate the human health risk Environ. Int. 125 191–199
[27] Shamim A, Murshed A K and Rafiq I 2015 E-waste trading impact on public health and ecosystem services in developing countries International Journal of Waste Resources 5 188