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

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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 in 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].

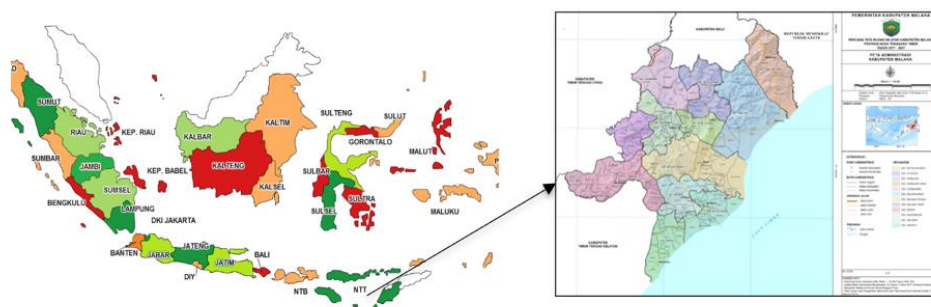
A previous study by, Akanchise et al., in Ghana, on the impact of a landfill that causes the soil to be contaminated by heavy metals showed that soil pollution due to solid waste in several locations poses residents at risk for exposure to toxic heavy metals [12]. Furthermore, studies on heavy metal 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.



Source: Malaka Regency Spatial Plant Document

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	Address		Length of time for garbage dump and the area of garbage land in Malaka Regency	Area
	Village	Subdistrict.		
Loc.1	Kateri	Central Malaka	2015 until 2017	3,600 m ²
Loc.2	Barada	Central Malaka	2014 until 2016	2,368 m ²
Loc.3	Barada	Central Malaka	2014 until 2016	3,526 m ²
Loc. 4	Kateri	Central Malaka	2016 until 2017	2,044 m ²
Loc. 5	Kateri	Central Malaka	2016 until 2017	2,310 m ²
Loc. 6	Haitimuk	Weliman	2018 until 2019	5,952 m ²
Loc.7	Umanen Lawalu	Central Malaka	2016 until 2017	5,561 m ²
Loc. 8	Lakekun	Kobalima	2007 until 2013	4,879 m ²
Loc. 9	Lakekun	Kobalima	2007 until 2013	3,753 m ²
Loc.10	Wehali	Central Malaka	2013 until 2014	3,404 m ²
			Total Area :	45,678 m ² (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 ^a					
	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	
	B	Std. Error	Beta			
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 (β) in the SPSS output table in table 4, it is concluded that the X3 variable (income) had a more dominant influence on the waste generation because β was 0.217 (greater than the regression coefficient of other variables).

Table 4. SPSS Output for F-Test.

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	65.828	6	10.971	5.068	0.000 ^b
	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].

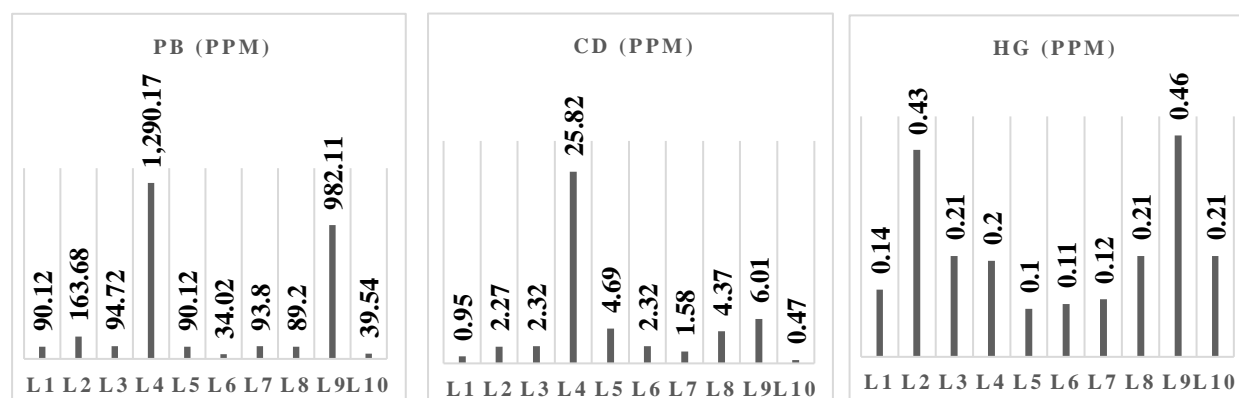


Figure 2. Heavy Metal Content: Lead (Pb), Cadmium (Cd) and Mercury (Hg) in Waste Lands in Malaka Regency.

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 (osteomalacia and osteoporosis), possible reproductive damage, and

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].

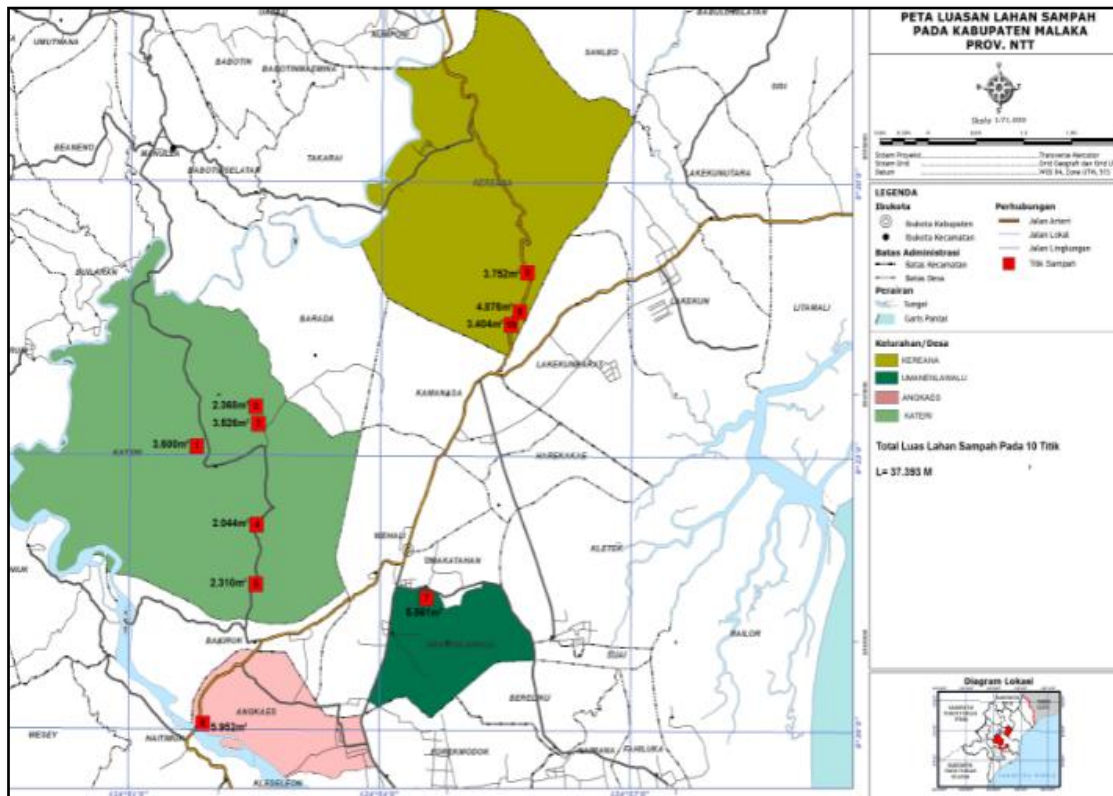


Figure 3. Distribution of garbage dump and Area of garbage dump (10 Locations) in Malaka Regency in 2020.

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.

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