Parameters of income level and season to determine the rate of household solid waste generation

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Abstract. Household solid waste is the most significant part of municipal solid waste. This research is a case study that proves the effect of economic and climate conditions on solid waste generation rate. The research location is Palembang, Indonesia (2017), with one year's dry and rainy seasons. This study has more variation in measuring the level of waste generation than previous studies. This study has proven an influence between income levels and climatic conditions on the rate of municipal solid waste generation. Based on the experience of measuring solid waste in the sample, many important aspects have not been analysed and affect the solid waste generation rate. Therefore, more variables are needed for similar research in the future to obtain results that are closest to the conditions in the field.

1. Introduction

The household solid waste consists of organic and inorganic waste originating from household activities and is considered useless and must be managed not to damage the environment and protect government assets (Indonesian National Standard/SNI, T-13-1990-F). Miezah et al., 2015 [1] explained that the sources of solid waste in developing countries mostly come from households (55-80%), followed by commercial areas, markets, roads, industry, and other institutions (10-30%). Household solid waste needs special attention because it is crucial for city growth [2].

The solid waste generation rate in each region is undoubtedly different. Many studies on measuring the rate of household solid waste generation consider aspects of family characteristics (income level, education, and lifestyle). In several studies, the rate of solid waste generation in low-income areas is higher than in high-income areas, especially in organic solid waste composition. According to Zia et al., 2017 [3], proper solid waste management is impossible because factual data on the rate of solid waste generation with the rate level, composition, and factors that affect both, are not always available. Measuring solid waste generation rate with family and seasonal characteristics in one period/year will produce high accuracy. Solid waste characterization studies can be used as a basis for further research on optimal solid waste management plans. This research is a case study analysis to prove the effect of household income level and season on solid waste generation rate in Palembang. The sample measurement method is based on the Indonesian National Standard (SNI) guidelines. The city of Palembang, Indonesia, as a developing country, has 1.6 million inhabitants spread over 16 districts with an area of 400.61 km. The city of Palembang has problems in solid waste management services, including a less than optimal management operational system, limited-service budget, lack of

community involvement, improper selection of handling technology, and so on. Strategic planning is needed to optimize municipal solid waste management services, especially those from household solid waste. As a basis for this planning, it is necessary to study the rate of solid waste generation to determine the characteristics of household solid waste.

According to SNI 19-3964-1994, organic solid waste is food waste and garden plant residues. The inorganic solid waste consists of plastic waste (PET, LDPE, and PP) from wrapping/packaging residue, plastic bottles, paper, rubber/leather, metal, glass, others, etc. "Other" waste is waste that cannot be grouped because it is in a mixed condition. The sample for measuring household solid waste comes from three categories of houses according to the Law of the Republic of Indonesia (Number 01/2011), namely permanent, semi- permanent, and non-permanent houses. According to the Central Statistics Agency (BPS), these three categories of houses are related to household income levels: high income for permanent houses, middle income for semi-permanent houses, and low income for non-permanent houses. High-income families are income > 2.5 million IDR/month, middle-income families are income around 1.5 - 2.5 million IDR/month, and low-income families are income < 1.5 million IDR/month. Palembang has a city temperature between 23.4°-31.7° Celsius. Annual rainfall ranges from 2,000 mm-3,000 mm. Indonesia is a tropical country with two seasons in one year, namely the dry and rainy seasons, influenced by the monsoon climate. The dry season is at its peak in April to September. The rainy season is at its peak between October-February. Based on the references regarding the season time at the study area, collecting solid waste during the dry season is from 10 to 18 August 2016 and during the rainy season from 5 to 12 December 2016.

2. Results and Discussion

Palembang city consists of 16 districts with different land areas and population densities. The determination of the proportion of the number of family samples in each district came from three groups of samples following the SNI 19-3964-1994 guideline as shown in Table 1. According to BPS data for Palembang (2016), the number of low-income residents is the least, and high-income residents are the most. Table 1 provides a detailed sample size for each district in each sample group. The most significant samples came from the Kemuning district and the least from the Bukit Kecil district. The number of samples originating from high income is 200 families, middle income 175 families, and low income 48 families. The selection of sample locations in each district begins with determining and recording the home addresses of the three household groups [4]. Then survey the household addresses as a step to verify the feasibility of the sample location plan.

Figure 1. Solid waste weight sample measurement (a) permanent/high income; b) semi-permanent/middle income; c) non-permanent/low income

Table 1. The number of samples.

	Districts	Number of families	Number of samples*			Total samples
			1	2	3	
1	Ilir Barat II	14,414	8	7	2	17
2	Gandus	19,535	10	9	2	21
3	Seberang Ulu I	27,648	15	13	4	32
4	Kertapati	30,321	16	14	4	34
5	Seberang Ulu II	28,744	15	13	4	32
6	Plaju	20,429	11	10	3	24
7	Ilir Barat I	21,536	11	10	3	24
8	Bukit Kecil	7,825	4	4	1	9
9	Ilir Timur I	9,408	5	4	1	10
10	Kemuning	30,013	16	14	4	34
11	Ilir Timur II	37,153	20	17	5	42
12	Kalidoni	29,96	16	14	4	34
13	Sako	22,812	12	11	3	26
14	Sematang Borang	9,054	5	4	1	10
15	Sukarami	35,204	19	16	4	39
16	Alang-Alang Lebar	31,491	17	15	4	36
Palembang city		375,547	200	175	48	424

*1 = sample of permanent housing/high-income
2 = sample of semi-permanent housing/middle-income
3 = sample of non-permanent housing/low-income

Figure 1 is documentation of solid waste measurements in three groups of family samples. Solid waste measurements were carried out for eight consecutive days in the dry and rainy seasons. Organic solid waste is weighted from inorganic solid waste using different colored plastic bags and weighed using a digital scale. Table 2 is a recapitulation of the average solid waste weight measurement results in both seasons in each district. Kemuning produces the most organic solid waste in the dry season and Ilir Timur II in the rainy season. Plaju produced the highest paper waste in the dry season and Ilir Timur II in the rainy season. Kemuning produced the highest PET and LDPE plastic waste in the dry season, Ilir Timur II and Bukit Kecil in the rainy season. The highest PP plastic in both the dry and rainy seasons was Ilir Timur I. The highest amount of other waste was from Kemuning in the dry season and Ilir Timur I in the rainy season. Kemuning is a district with a very high population density category, according to BPS, 2016 [4]. Ilir Timur I and Ilir Timur II are trade and office areas so that businesspeople or traders dominate the source of household livelihood. Plaju and Bukit Kecil are the centers of educational institutions both at the secondary and advanced levels to dominate students and college students. Table 2 shows that household activities are almost not produced glass, rubber, and leather waste. As for iron and non-iron metals, waste is generated in the rainy season and very little in the dry season. Types of organic waste, plastic (LDPE, PET, PP), and others dominate the composition of household solid waste in both seasons in each district.

Table 2. Recapitulation of the solid waste weight measurement result.

Districts	Dry season								
	Average weight (gram/person/day)								
	Organic (Leftovers)	Papers	Rubber & leather	Glasses	Iron & non-iron metals	Plastics			Others
						PET	LDPE	PP	
1	117.91	1.53	0.00	0.00	**2.69**	13.71	3.74	10.33	2.03
2	65.12	0.64	0.00	0.00	0.00	5.04	0.47	11.38	5.23
3	55.17	0.45	0.00	0.00	0.08	3.29	2.15	2.24	4.78
4	75.60	1.86	0.00	0.00	0.00	8.60	3.44	8.33	4.29
5	87.82	4.22	0.00	0.00	0.48	9.53	5.79	7.55	19.06
6	97.56	**21.97**	0.00	0.00	0.34	11.52	7.51	7.77	9.92
7	103.55	1.21	0.00	0.00	0.24	14.27	4.37	5.67	4.09
8	207.52	6.94	0.00	0.00	0.24	19.87	6.60	11.22	0.04
9	206.67	4.03	0.00	0.00	0.24	9.51	3.49	**26.37**	8.70
10	**254.00**	8.56	0.00	0.00	0.76	**29.20**	**9.90**	24.56	**19.75**
11	115.15	1.52	0.00	0.02	0.00	8.18	3.66	8.09	6.93
12	81.75	0.48	0.00	0.00	0.00	7.71	5.97	8.79	2.98
13	117.32	6.91	0.00	0.00	0.94	11.96	8.70	15.07	19.13
14	58.74	0.66	0.00	0.00	0.00	10.62	1.87	3.80	7.00
15	66.85	0.96	0.00	0.00	0.00	2.85	0.09	1.88	4.55
16	78.12	0.80	0.00	0.00	0.00	2.73	0.02	2.04	5.25
Average	111.80	3.92	0.00	0.00	0.38	10.54	4.24	9.69	7.73
Rainy season									
1	292.67	8.26	0.00	0.00	6.81	49.73	11.04	6.74	7.11
2	404.35	0.00	0.00	0.00	0.00	56.76	12.79	8.86	1.52
3	472.90	6.71	0.00	0.00	7.82	96.34	9.59	3.68	15.58
4	476.60	3.99	0.00	0.00	7.71	70.26	25.75	9.75	6.71
5	232.48	8.16	0.00	0.00	4.51	27.89	10.07	13.92	12.31
6	248.75	0.00	0.00	0.00	0.00	84.98	6.02	3.80	0.00
7	155.42	3.28	0.00	0.00	2.84	83.75	10.82	4.35	5.42
8	412.58	5.48	0.00	0.00	5.28	45.68	**85.58**	18.04	0.31
9	173.50	11.47	0.00	0.00	9.78	46.25	21.13	**31.45**	**30.23**
10	348.58	10.20	0.00	**0.18**	14.84	23.05	11.80	9.91	11.35
11	**814.30**	**20.79**	0.00	0.03	**19.71**	**373.67**	3.30	10.97	13.24
12	690.75	0.00	0.00	0.00	0.00	201.88	17.54	1.68	0.00
13	151.32	10.09	0.00	0.00	6.36	23.38	7.44	2.05	4.06
14	423.32	1.02	0.00	0.00	1.52	157.92	2.88	6.59	11.04
15	184.67	2.99	0.00	0.00	0.00	11.89	3.67	2.76	4.00
16	264.67	13.54	0.00	0.00	1.51	65.12	11.59	9.60	2.82
Average	359.18	6.62	0.00	0.00	5.54	88.66	15.69	9.01	7.86

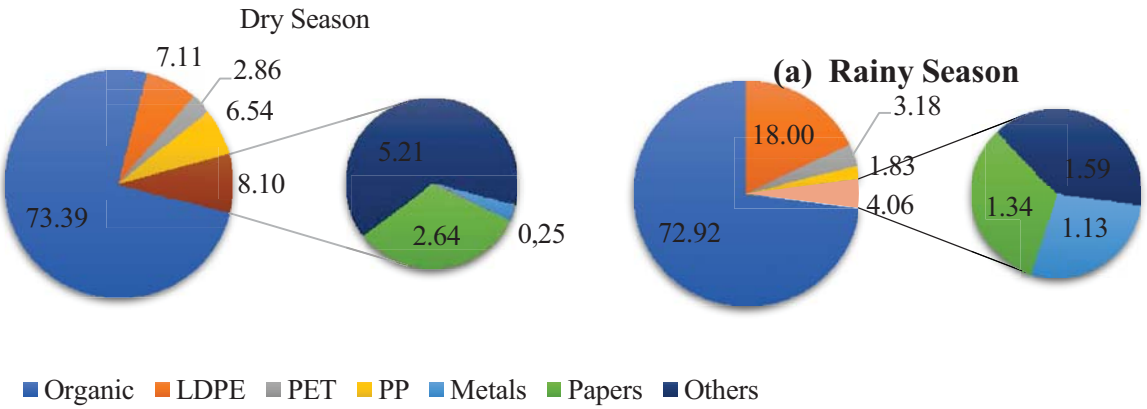


Figure 2. Percentage of solid waste weight based on season.

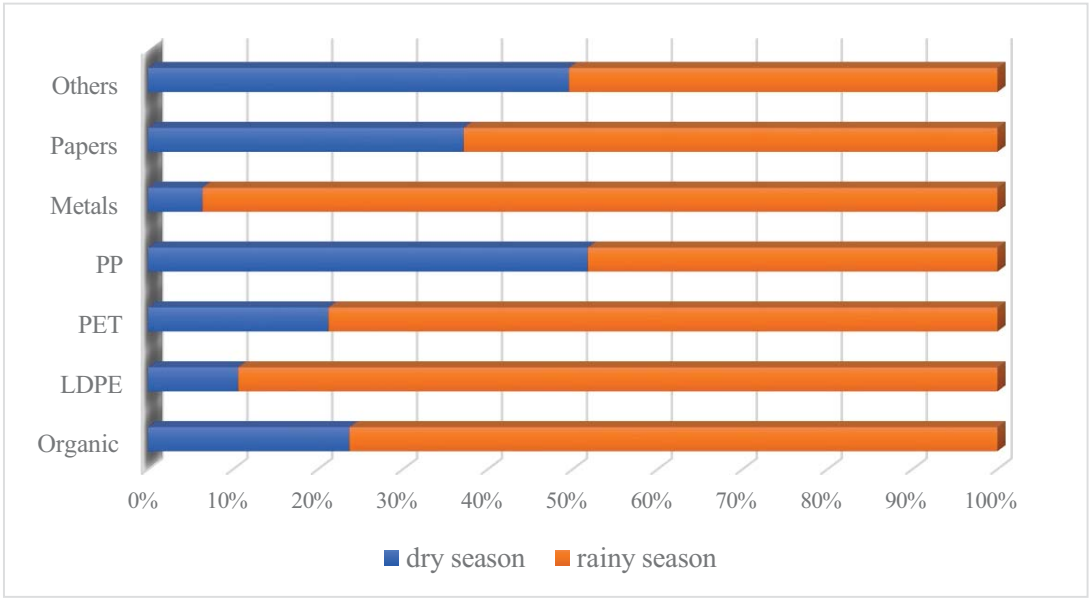
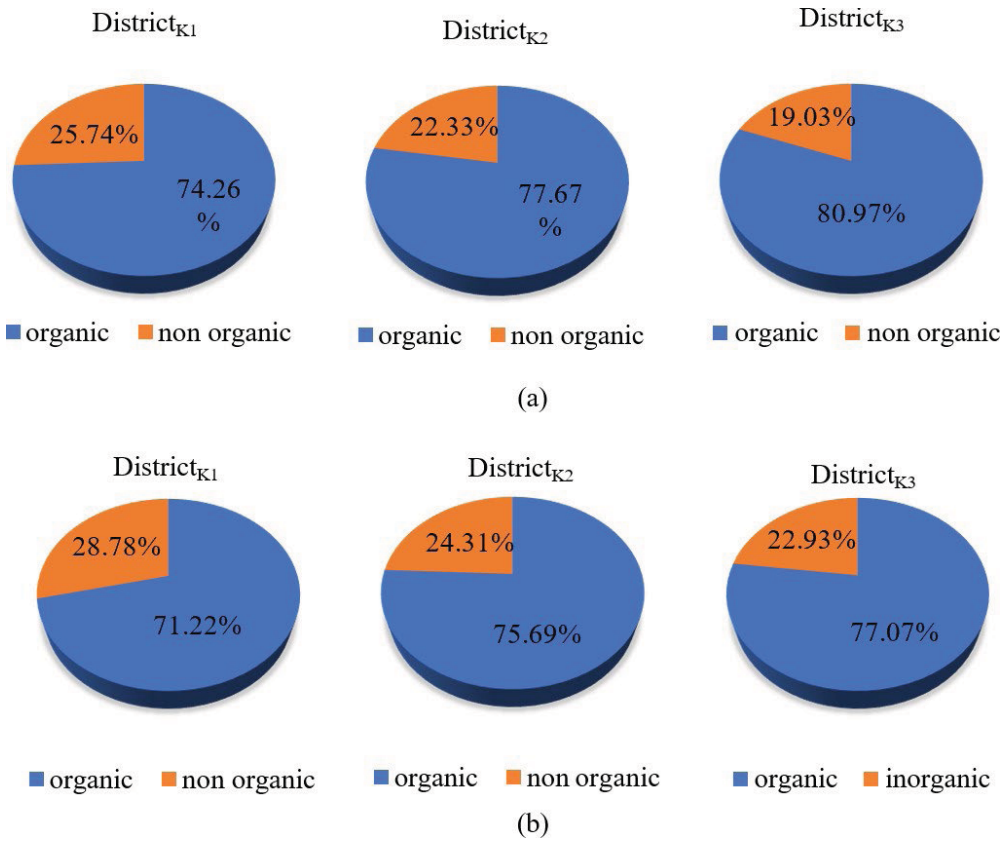


Figure 3. Comparison of solid waste weight composition in the two types of seasons.

Figure 2 shows the percentage of solid waste composition in each season. In the dry season, the composition of organic solid waste is 73.39% of inorganic waste. In the rainy season, it is not much different. The composition of organic solid waste is 72.92% of inorganic waste. The composition of LDPE waste is very high in the rainy season, while PP waste is higher in the dry season. LDPE waste comes from plastic packaging/food packaging, and PP waste comes from plastic containers for drinks, medicines, or ready-to-eat.

Figure 4 is a comparison of solid waste composition in the two seasons. Organic solid waste in the rainy

season is very high compared to the dry season. Likewise, metals, papers, others, and plastic waste from LDPE and PET types are primarily generated in the rainy season. In Indonesia, during the rainy season, there is an increase in seasonal fruit types such as durian, rambutan, mango, etc. It can be associated with increased organic solid waste in the rainy season. Remains of plastic and metal as food packaging containers increase in the rainy season due to seasonal fruit consumption. The composition of other solid waste in the two seasons is not much different



Note
District$_{K1}$ = group of permanent housing/high-income
District$_{K2}$ = group of semi-permanent housing/middle-income
District$_{K3}$ = group of non-permanent housing/low-income

Figure 4. Weight composition diagram of solid waste; (a) dry season (b) the rainy season.

Figure 4 presents the composition of organic and inorganic solid waste in each season's three housing/income groups. Organic solid waste is more dominant than inorganic solid waste in each housing/income group in both seasons. The non-permanent/low-income groups generated the highest organic solid waste composition in both seasons and the lowest by the permanent/high-income group.
Table 3 shows the weight of organic and inorganic solid waste in both seasons in the three income groups. The

measurement results show that the highest organic solid waste is produced by the permanent/high- income group, which is 3.45 kg/person/day in the rainy season. The permanent/high-income group produces metal, paper, other, and plastic solid waste (LDPE and PET) is produced more by the permanent/high-income group in the rainy season. PP type waste is produced mainly by the semi- permanent/middle-income group in the rainy season.

Table 4 presents the average solid waste generation rate in each sample group. The permanent/high-income group produced the highest organic solid waste was produced by the permanent/high-income group, which was 2.08 kg/person/day. The semi-permanent/middle-income group, which was 1.29 kg/person/day, and the non-permanent/low-income group, which was 1.27 kg/person/day. The permanent/high-income group produced the highest inorganic solid waste, namely 0.88 kg/person/day, the semi-permanent/middle- income group, 0.62 kg/person/day, and the non-permanent/low-income group, namely 0.47 kg/person/day. Thus, the permanent/high-income group became the highest organic and inorganic solid waste producer in the research location.

Table 3. Solid waste generation rate (gram/person/day) in the dry and rainy season.

Solid waste type	$District_{K1}$		$District_{K2}$		$District_{K3}$	
	Dry	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**
Organic	702.89	3,450.01	956.79	1,631.66	967.44	1,571.93
LDPE	68.13	846.13	99.10	401.96	70.84	310.15
PET	27.26	167.53	45.20	64.99	29.67	65.76
PP	27.26	86.87	90.55	42.09	55.77	25.47
Metals	1.56	65.07	0.38	23.50	3.95	6.53
Papers	13.67	98.83	31.14	8.85	38.51	9.39
Others	55.41	102.61	78.86	18.39	57.26	7.90
Total	936.54	4,817.05	1,302.02	2,191.44	1,223.44	1,997.13
Average	2,876.8		1,746.73		1,610.21	

Table 4. Average of solid waste generation in each type of sample.

Districts	Samples	Weight of solid waste (kg/person/day)		Composition of solid waste (%)	
		Organic	**Inorganic**	**Organic**	**Inorganic**
$District_{K1}$	200	2.08	0.88	71.22	28.78
$District_{K2}$	175	1.29	0.62	75.69	24.31
$District_{K3}$	48	1.27	0.47	77.07	22.93
Average in Palembang		1.55	0.66	74.66	25.34

Analysis of the solid waste generation rate measurement in this study using the Homogeneity Test aims to determine whether the sampling data come from a homogeneous population or not or has the same variance. The homogeneity test was carried out with the Levene test and the F test by first determining the hypothesis of the sample group and season as follows:

H_o= It is estimated that the solid waste weight for three groups of house samples is the same by significance.
H_1= It is estimated that the solid waste weight for three groups of house samples is different by significance.
H_o= It is estimated that the solid waste weight for both seasons is the same by significance.
H_1= It is estimated that the solid waste weight for both seasons is different by significance.

Levene test results presented at the Sig. If less than 0.05 (Sig. <0.05), then Ho is rejected; in other words, the weight of solid waste for the three groups of houses is significantly different. The Sig. is less than 0.05 (Sig. <0.05), so Ho is rejected, or it can be concluded that the weight of solid waste for the two seasons is significantly different.

The results of this study indicate that the level of household income affects the rate of waste generation. The research conducted by Senzige et al., 2014 [5] states that the rate of waste generation per capita is influenced by socioeconomic status. Research by Okalebo et al., 2014 [6] in Kenya concluded that with increasing social status in the sample the rate of solid waste generation also increased, especially in the organic solid waste component, the type of work could also influence the composition and weight of the solid waste generation rate. Another result of Nyankson et al. (2015), their study is that there is a positive relationship between the level of income and solid waste generation.

In this study, the organic composition of household solid waste is the most dominant of the other types of inorganic solid waste. Research showing the same results was carried out by Binxian Gu et al. (2017) in China and Nyankson et al. (2015) in Sekondi-Takoradi Metropolis, Ghana. Windraswara & Prihastuti (2017) conducted a study on the measurement of household solid waste in Semarang, Indonesia, which also uses SNI 19-3964-1994, but only focuses on the type of permanent housing. Their study results obtained the weight of solid waste an average of 0.28 kg/person/day with samples from 10 families, and the composition of the organic fraction was 53%. Whereas in this study, the weight and composition of solid waste households in permanent housing was 1.48 kg/person/day and 70.27% with a sample of 200 families in the dry and rainy season.

Table 5. Comparison of research results with other studies in Palembang City.

Comparison variables	Current study	Authors		
		Jimmyanto et al (2017)	**Ananda et al (2019)**	**Pratiwi et al (2019)**
Number of samples (families)	383	120	3 unit residential	2 pilar of neighbor
Sample category (Income level)	• low income • middle income • high income	• low income • high income	-	-
Season category	Dry and rainy	-	-	-
Method	**SNI 19-3964-1994**			
Time of research	2017-now	2017	2019	2019
Measurement time	8 days	3 days	7 days	2 days
Average waste weight (kg/person/days)	• 2.88 from high income • 1.75 from middle income • 1.61 from low income	• 0.91 from high income • 0.79 from low income	0.7255	0.46

As is known, the composition and rate of generation of solid waste will be very different in each region. Therefore, the approach of research results with research in the exact location is a priority for comparing the accuracy of research results. Table 5 shows several studies regarding solid waste weight in the same area (Palembang city) in 2017 and 2019 with the same measurement method based on SNI 19-3964-1994. The difference lies in the number of samples and measurement time.

Research by Jimmyanto et al., 2017 [7] differentiates the sample based on the level of family income consisting of high income and low income with a total sample of 120 people. The result of weight solid waste measurement is 0.91 kg/person/day from the high-income level and 0.79 kg/person/day from the low-income group. In comparison, research by Ananda et al., 2019 [8] and Pratiwi et al., 2019 [9] with a sample based on the proportion of the population and not based on income level obtained slightly different results, namely 0.73 kg/person/day by Ananda et al. with a measurement time of seven days and 0.46 kg/person/day by Pratiwi et al. with a measurement time of two days.

This study has more variation in measuring the level of waste generation than previous studies. The variation lies in the type of sample consisting of three kinds (level of family income and type of housing, and in the two existing seasons. The measurement procedure follows the guidelines of the Indonesian National Standard (SNI) as a whole. The measurement results show a weight of solid waste that is different from previous studies. The weight of solid waste in high-income, middle-income, and low-income families is 2.88 kg/person/day, 1.75 kg/person/day, and 1.61 kg/person/day.

3. Conclusion

This study has proven an influence between income levels and climatic conditions on the rate of municipal solid waste generation. Based on the experience of measuring solid waste in the sample, many important aspects have not been analyzed and affect the solid waste generation rate, including knowledge, habits/lifestyle, and environmental influences. Measuring the rate of municipal solid waste generation from several similar studies indicates that the number of samples and variations in research variables can affect the measurement results. Therefore, more variables are needed for similar research in the future to obtain results that are closest to the conditions in the field.

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