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Regional Case Study

Evaluating Household Solid Waste Sampling: Is an Eight-Day Consecutive Method Necessary? A Preliminary Study

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Abstract

Household solid waste sampling is a critical part of solid waste management planning, as the results determine the design of the required infrastructure. However, the method suggested by the Indonesian national standard requires time and high costs, as it must be carried out for eight consecutive days. Hence, it is necessary to evaluate this requirement and design a more efficient sampling design without compromising the results. The study conducted solid waste sampling for 16 consecutive days from 31 middle-income households in Jakarta, the Capital City of Indonesia, resulting in a pool of 16 consecutive daily averages of solid waste generation per capita data. From this pool, we generated: (1) solid waste generation per capita from eight consecutive days, (2) six consecutive days, (3) four consecutive days, and (4) eight non-consecutive days data. The results showed that the average of solid waste generation per capita for datasets (1), (2), (3), and (4) are 0.505 (± 0.022) kg/day/cap, 0.495 (± 0.044) kg/day/cap, 0.501 (± 0.035) kg/day/cap, and 0.492 (± 0.02) kg/day/cap consecutively, indicating the same estimates of solid waste generation per capita can be achieved by four scenarios.

Keywords: Municipal waste; sampling method; days required; data experiment

1. Introduction

Population and economic growth, along with lifestyle changes, result in an increase in municipal solid waste (MSW) generation. According to a study, the total global waste generation was predicted to reach 46 billion tonnes by 2050 (Maalouf and Mavropoulos, 2023). In 2019, urban areas in Indonesia generated 105,000 tons per day of MSW, and was estimated that the number will rise to 150,000 tons per day by 2025(World Bank, 2019). Consequently, the availability of MSW management services plays an important role in preventing environmental pollution. However, according to the national waste management information database, of 35,833,450.64 tons of MSW generated in 2022, only 63% was managed whereas the remaining was either burnt, buried, or discharged to water bodies illegally (Ministry of Environment and Forestry of Indonesia, 2023). The data shows that significant MSW management infrastructure developments based on thorough and appropriate planning are still deemed required.

Determining the appropriate waste management system is critical and needs to be adapted to the amount and characteristics of MSW generated in the planned area. Furthermore, the calculation of

MSW generation along with the analysis of composition is an important factor in determining an appropriate management system (National Standardization Agency, 1994). The operation of an MSW management system related to the collection, transportation, and monitoring of the system requires data on MSW generation in the area being managed (Suyasa and Budiarsa, 2020). Estimating MSW generation based on household MSW sampling is one of the common methods in Indonesia. Various studies attempted to evaluate and optimize the method of household MSW sampling. (Terashima et al., 1984) recommended a stratified sampling approach based on bulk density for estimating the physical characteristics of MSW. Another study also suggested that the minimum sample size of MSW for physical characterization is 81.25 kg to ensure representativeness (Paul and Daniel, 2007). Some other studies found that housing type significantly affects the waste composition and the stratified cluster sampling approach is the most optimum for the representativeness of MSW sampling results (Dangi et al., 2008; Edjabou et al., 2015). Moreover, variations of sample sizes and weights are reported to play major roles in precision in MSW composition analysis (N. and M., 1988). Studies that evaluate the importance of the number of sampling days, however, are still few even though it critically affects resources needed for MSW sampling.

At the current time, the procedure is regulated in SNI 19-3964-1994 which suggests the sampling campaign to be conducted for eight consecutive days. This procedure was proposed to capture the daily fluctuation of MSW generation which is heavily influenced by household activities. However, several factors, such as human resources, weather, and transportation, can influence the complexity of the sampling campaign. For example, if heavy rain occurs during one of the sampling days or an accident takes place during sample collections, the campaign might be disrupted and needs additional time to complete the sample collections. The MSW sampling procedure in the standard of several countries and from several published studies does not specify eight days as the sampling duration (Table 1). According to American Standard Testing and Materia (ASTM) and European Commission (EU), suggest that MSW sampling be conducted in seven days (ASTM, 1998; European Commission, 2004). In a study on waste analysis in Nusa Dua, Bali, the sampling was carried out for 3 days whereas in Ethiopia, the sampling was carried out for 7 consecutive days (Mame et al., 2021; Widyarsana et al., 2022). In Vietnam, a study conducted sampling for 4 days at the waste collection location in Da Nang (Vetter-Gindele et al., 2019). Likewise in Egypt, the sampling which took place in three villages was conducted for five consecutive days (Emara, 2023).

Table 1. Sampling duration in various standards and studies.

Country	Sampling Duration (days)	Sources
Indonesia (standard)	8	(National Standardization Agency, 1994)
ASTM (standard)	7	(ASTM, 1998)
European Commission (standard)	7	(European Commission, 2004)
Indonesia (study)	3	(Widyarsana et al., 2022)
Ethiopia (study)	7	(Mame et al., 2021)
Vietnam (study)	4	(Vetter-Gindele et al., 2019)
Egypt (study)	5	(Emara, 2023)

In this study, we attempted to answer a question: How would the waste generation per capita be different if they are determined by samplings that are conducted for less than eight consecutive days, and what if the sampling is not conducted in consecutive manners? It is deemed important to answer those questions, as the MSW sampling procedure could be designed more efficiently if it turned out the results between eight days and less than eight days sampling have no significant differences. In the current time, studies foccusing on the evaluation of number of sampling days to the solid waste generation per capita estimates, are very limited. Thus in this study, we conducted data experiments and combinations based on MSW sampling for 16 consecutive days in 31 middle-income households located in Jakarta, the capital city of Indonesia. Furthermore, statistical and probability analysis was performed to answer those questions.

2. Methods

In this study, we combined real MSW sampling data with experimental data technique based on statistical tests to evaluate the importance of MSW samling in eight consecutive days. Figure 1 shows the flow diagram of this study.

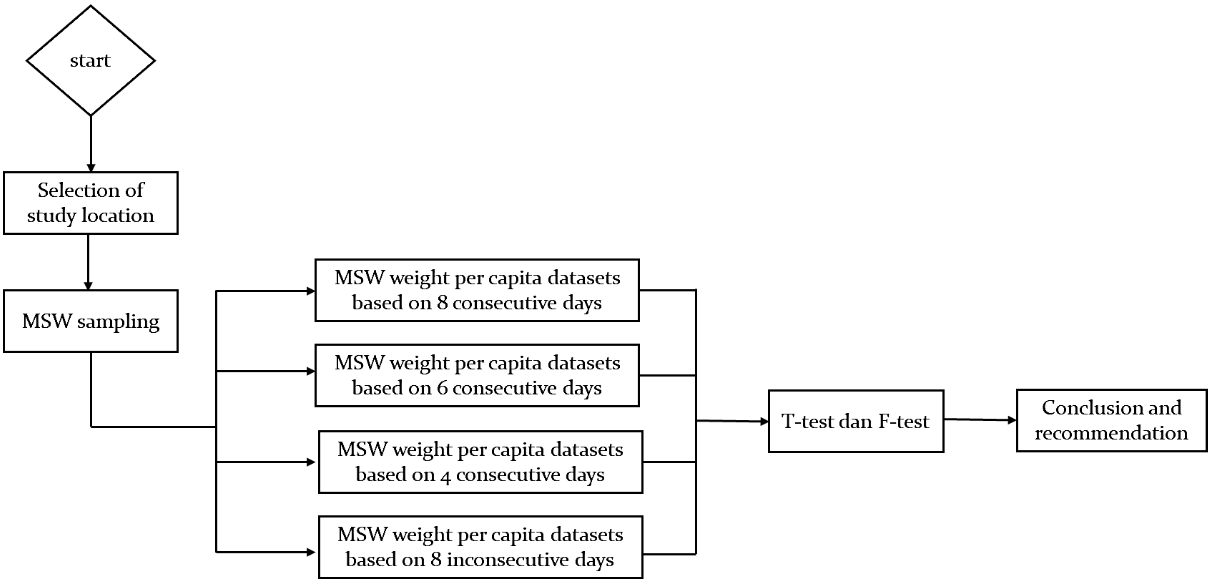


Figure 1. The flow diagram of the study

2.1. MSW Sampling

In this study, we targeted middle income housholds which represent 66.35% of the population in Indonesia. Hence, the MSW sampling was carried out in Jagakarsa Village, Community Unit No. 5, Jakarta which represents the middle income residentiala area (Figure 2). Number of samples were deterimined by the following equation (1), suggested in a SNI 19-3964- 1994.

$$S = C_d \sqrt{P} \tag{1}$$

Where S is number of samples, Cd is the urban-rural coefficient, and P is number of population. As Jagakarsa Village, Community Unit No. 5 is inhabitated by 11,952 people, using equation 1, it was required 31 samples. The number of households as the study object is determined based on the SNI 19-3964-1994 calculation method. The sampling was carried out over 16 days starting from April 3 to 18, 2023 to estimate the MSW mass and volume generation as well as its composition. Each house collected its daily waste into plastic bags with a volume of 40 liters that had been provided. Then, the collected sample was transported at 14.00 WIB to be taken to the collection point which was designated to be the location for measuring waste generation and composition at around 15.00 WIB. Every day the plastic will be replaced with a new one for sample collection the following day.

The instruments and supplies used to measure waste generation and composition following SNI 19-3964-1994 are a 20 cm x 20 cm x 100 cm box, equipped with a height scale to measure MSW volumes, scales 0 – 5 kg and Scales 0 – 100 kg, and a 1.0 m x 0.5 m x 1.0 m box equipped with a height scale.

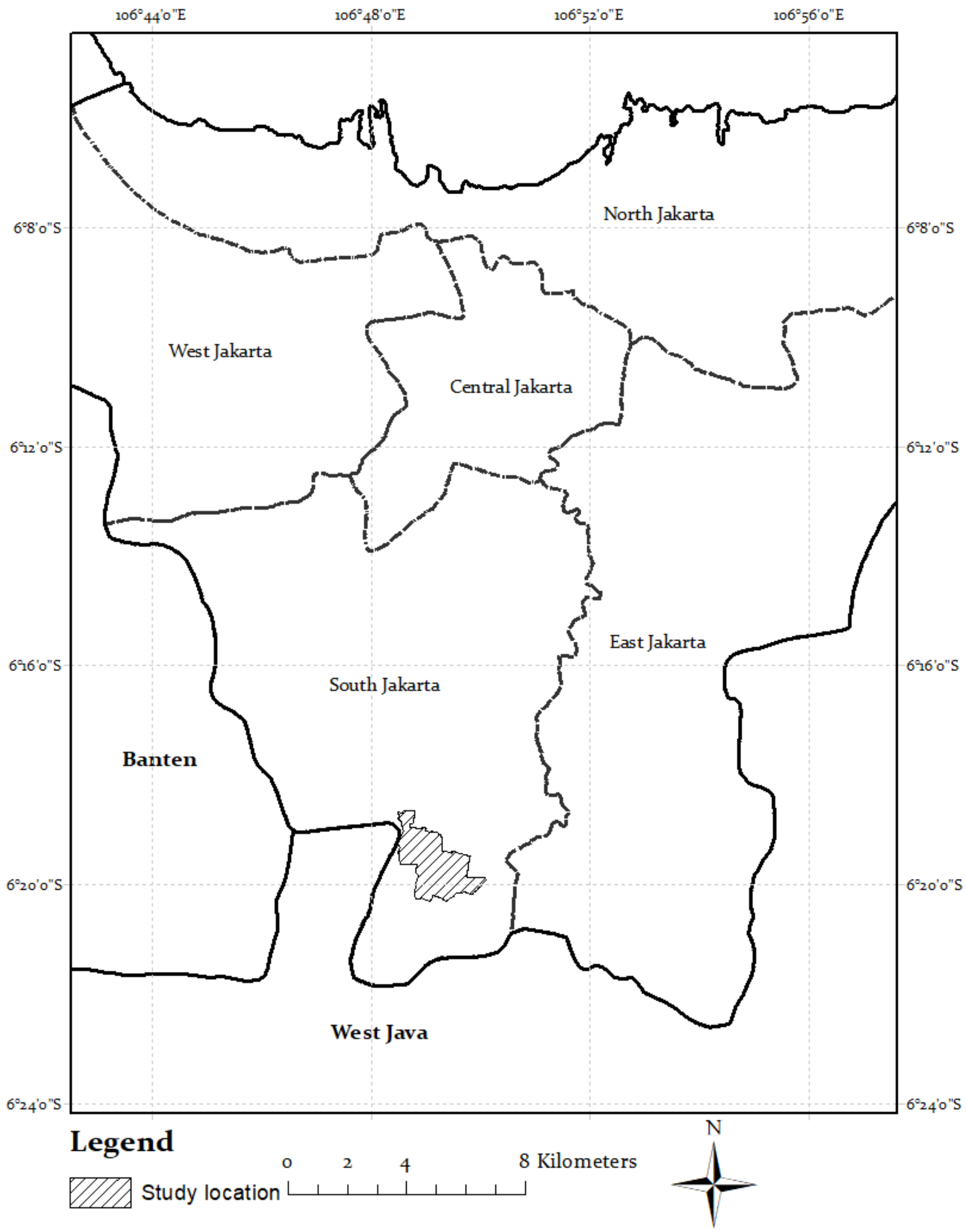


Figure 2. The map of study location

2.2. Estimation of MSW generation

For calculating the average MSW volume, series of formulas suggested by SNI 19-3964-1994 were used equation (2):

$$\overline{V} = \frac{\sum_{i=1}^{i}\sum_{k=1}^{k}\frac{V_{ik}}{n}}{i \times k} \quad (2)$$

Where $\overline{V}$ (L/person/day) is the total daily average of volume per capita of MSW collected from k number of households for the sampling duration of i days, V_{ik} (L/day) is the volume of MSW collected from household k in day i, and n is number of members in household k.

For calculating the average MSW mass, firstly, the following formula was used equation (3):

$$\bar{w}_i = \frac{\sum_{k=1}^{k} \frac{w_{ik}}{n}}{k} \tag{3}$$

Where $\bar{w}_i$ (kg/person/day) is the daily average of weight of MSW collected from *k* number of households on day i, w_{ik} (kg/day) is the volume of MSW collected from household k, and n is number of members in household k. Then, the total daily average of MSW weight $\bar{W}$ (kg/person/day) can be calculated by the following equation (4):

$$\bar{W} = \frac{\sum_{i=1}^{i} \bar{w}_i}{i} \tag{4}$$

2.3. Analysis of MSW Composition

After measuring the mass and volume of MSW samples, we also measured the percentage of each component in the composition of an MSW sample. The household waste sample components measured were categorized into several compositions. Based on (Damanhuri and Padmi, 2019), the composition of residential waste was categorized as: paper, glass, ceramics, metal, plastic, leather, rubber, wood, textiles, organic waste, others (electronics, stone, etc.). The percentage of each waste category was calculated by the following equation (5) as suggested in SNI 19-3964- 1994 .

$$w_j = \frac{\sum_{i=1}^{i} w_{i,j}}{\sum_{i=1}^{i} w_i} \tag{5}$$

Where w_j is the total MSW weight for category *j*, $w_{i,j}$ is the MSW weight for category *j* on day *i*.

2.4. Data Experiment

As previously mentioned, the sampling duration conducted in this study was 16 days which was aimed to maximize the repeated measurements and replications to ensure valid conclusions (Kenny, 2019). This data experiment consisting of two analyses:

a. Impact of sampling duration on the average waste generation,
b. Impact of consecutiveness on the average waste generation.

Of 16 days of sampling duration, we created a pool of 16 consecutive daily averages of MSW weight per capita $\bar{w}_i$ (equation 2), and we assigned a number to the average MSW mass corresponding to its sampling day, following equation (6):

$$\bar{w}_1, \bar{w}_2, \bar{w}_3, \ldots, \bar{w}_{16} \tag{6}$$

2.4.1. Impact of Sampling Duration on the Total Daily Average Waste Generation

To perform the analysis of the impact of sampling duration on the average waste generation, we developed three scenarios: (1) The total daily average MSW weight per capita datasets constructed from eight consecutive days of data. This scenario represents the procedure suggested by SNI and was set as a baseline to be compared with other scenarios, (2) datasets based on six consecutive days data, and (3) datasets based on four consecutive days data. For building data sets, we propose the following methods: For scenario (1), from the pool of 16 consecutive daily averages of MSW weight per capita data, nine combinations of the total daily average of MSW weight (Equation 3) can be created such as:

$\bar{W}_{8-1}$ was calculated from the average of $\bar{w}_1, \bar{w}_2, \bar{w}_3, \ldots, \bar{w}_8$

$\bar{W}_{8-2}$ was calculated from the average of $\bar{w}_2, \bar{w}_3, \bar{w}_4, \ldots, \bar{w}_9$

$\bar{W}_{8-3}$ was calculated from the average of $\bar{w}_3, \bar{w}_4, \bar{w}_5, \ldots, \bar{w}_{10}$

to

$\bar{W}_{8-9}$ was calculated from the average of $\bar{w}_9, \bar{w}_{10}, \bar{w}_{11}, \ldots, \bar{w}_{16}$

For scenario (2), from the pool of 16 consecutive daily averages of MSW weight per capita data, 11 combinations of the total daily average of MSW weight (Equation 3) can be created such as:

$\bar{W}_{6-1}$ was calculated from the average of $\bar{w}_1, \bar{w}_2, \bar{w}_3, \ldots, \bar{w}_6$

$\bar{W}_{6-2}$ was calculated from the average of $\bar{w}_2, \bar{w}_3, \bar{w}_4, \ldots, \bar{w}_7$

$\bar{W}_{6-3}$ was calculated from the average of $\bar{w}_3, \bar{w}_4, \bar{w}_5, \ldots, \bar{w}_8$

to

$\bar{W}_{6-11}$ was calculated from the average of $\bar{w}_{11}, \bar{w}_{12}, \bar{w}_{13}, \ldots, \bar{w}_{16}$

For scenario (3), from the pool of 16 consecutive daily averages of MSW weight per capita data, 13 combinations of the total daily average of MSW weight (Equation 3) can be created such as:

$\bar{W}_{4-1}$ was calculated from the average of $\bar{w}_1, \bar{w}_2, \bar{w}_3, \bar{w}_4$

$\bar{W}_{4-2}$ was calculated from the average of $\bar{w}_2, \bar{w}_3, \bar{w}_4, \bar{w}_5$

$\bar{W}_{4-3}$ was calculated from the average of $\bar{w}_3, \bar{w}_4, \bar{w}_5, \bar{w}_6$

to

$\bar{W}_{4-16}$ was calculated from the average of $\bar{w}_{13}, \bar{w}_{14}, \bar{w}_{15}, \bar{w}_{16}$

The normality of the waste generation per capita was confirmed by the chi-square test and results from each scenario were analyzed by using the F test for variance comparison and independent t-test for mean comparison(Walpole, 2022).

2.4.2. Impact of Consecutiveness On The Total Daily Average Waste Generation

For analysis of the effect of consecutiveness, we compared the total daily average of MSW weight calculated from 8 consecutive days of sampling and with ones calculated from eight non-consecutive days (Scenario 4). To perform this analysis, we used the result from scenario (1) in the previous section to represent the data from eight consecutive days and created 30 random combinations from 16 consecutive daily averages of MSW weight per capita, $\bar{w}_i$. The number of sets selected is considered to have met the minimum sample set of day sequences for data processing analysis (Walpole, 2022).

$\bar{W}_{R-1}$ was calculated from the average of $\bar{w}_4, \bar{w}_{13}, \bar{w}_{11}, \ldots, \bar{w}_9$

$\bar{W}_{R-2}$ was calculated from the average of $\bar{w}_{10}, \bar{w}_5, \bar{w}_{12}, \ldots, \bar{w}_1$

$\bar{W}_{R-3}$ was calculated from the average of $\bar{w}_1, \bar{w}_9, \bar{w}_{13}, \ldots, \bar{w}_2$

to

$\bar{W}_{R-30}$ was calculated from the average of $\bar{w}_6, \bar{w}_1, \bar{w}_{12}, \ldots, \bar{w}_9$

Results from the two datasets were analyzed by using the F test for variance comparison and the independent t-test for mean comparison.

3. Result and Discussion

3.1. MSW Generation

Based on the sampling results, the average total weight of the collected MSW was 60.185 kg. Figure 1, shows that the total weight of household waste in RW 05, Jagakarsa Village fluctuated with the highest total weight of household waste being 76.820 kg on the 15th day which was on Monday. Meanwhile, the lowest total weight of household waste was 40.430 kg on the 13th day which was on Saturday. The total weight of household waste obtained for 16 days fluctuates because it was influenced by the daily activities carried out by each family member in each household. The sampling time which coincided with the month of Ramadan also affected the total weight of waste because community activities were different from the normal daily routines. Indonesian people who have a habit of visiting relatives also influenced the increase in the total weight of daily waste because of the breaking of the fast together with extended family, relatives, or friends at home. According to the Ministry of Environment and Foresty of Indonesia, the MSW generations in Ramadan are relatively fluctuates with the average difference of 20% more MSW were generated (Anugrah, 2023). After the calculation, the standard deviation value of the total weight of the waste was obtained, which was 9.421. This standard deviation value is still smaller than the average total weight of the waste, which is 60.185 kg, indicating the data distribution is still said to have no major deviations. Based on the chi-square test results, we confirmed that the data are distributed normally.

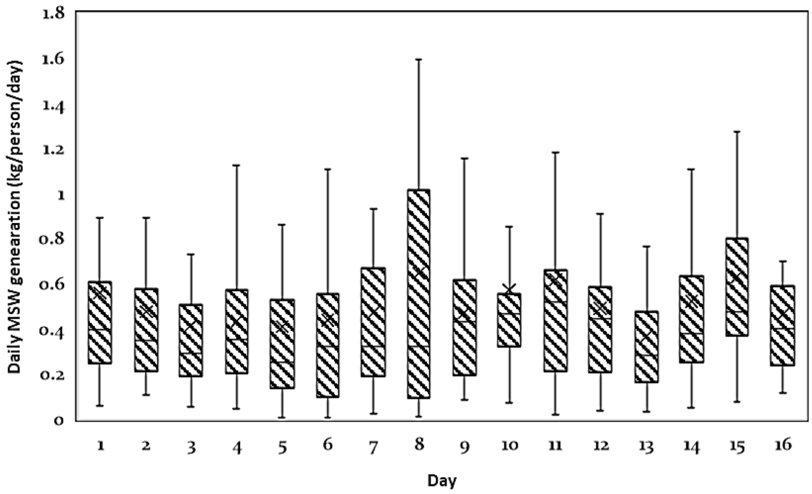


Figure 3. The daily fluctuation of the total daily average of MSW weight over 16 days period

Figure 3 shows the daily fluctuation of the daily average of MSW weight over 16-day periods. The daily average was in the range between the largest being 0.648 kg/person/day and the smallest being 0.369 kg/person/day whereas the median was in the range between 0.282 to 0.478 kg/person/day indicating some extreme values were found at the right end of the distribution. The standard deviations were in the range of 0.28 to 0.51 kg/person per day indicating the spread of the data was about 50%. Based on the calculations, it can be determined that each person at the study object location produces MSW with an average of 0.500 kg/person/day over 16-day periods. It also can be seen in Fig 3 that the 16 days sampling captured two cycles of weekly MSW generation. The pattern of the generation is repeated at every eight days with the lowest generation was in day 3 and day 13. This pattern shows that the waste generation is highly influenced by specific daily household activities (Shofi et al., 2023).

Compared to the range of the total daily average of SWM weight suggested by SNI 19-3983-1995, the value obtained in this study was higher which is 0.50 kg/person/day. Meanwhile, the range suggested by SNI 19-3983-1995 was between 0.35 kg/person/day to 0.40 kg/person/day. The difference might be caused by some houses having more family members than houses in general. The sampling time which was in Ramdhan can also influence the increase in waste generation because cooking and purchasing activities increase and produce more waste. A study in Magelang suggested that the generation of waste produced by low-income residents is 0.27 kg/person/day, medium-income is 0.28 kg/person/day, and high-income is 0.36 kg/person/day (Widodo; Ribut, Lupiyanto;Donan, 2010). That said, based on several latest studies on waste generation across Indonesia, the range of MSW generation per capita is in the range of 0.28-0.547 kg/person/day (Aulia et al., 2024; Irmawartini et al., 2023; Shofi et al., 2023; Widyaningsih & Hermurti, 2017), indicating that the waste generation obtained in this study is still in the range of those obtained from other previous studies. This implies that the value of MSW generation per capita taken from 16 days has the same range with those obtained from eight days in other studies.

There is a strong association between the total average daily MSW weight with the economic level of the waste producers. The fact that the study location is in South Jakarta with a relatively higher economic level in Indonesia might explain the large amount of MSW generation. The total daily average of MSW weight at the study location also has a value that is almost the same as the waste generation generated at the Tenggarong, East Kalimantan, with the weight of the waste generated being 0.544 kg/person/day (Setiawan et al., 2022).

Table 2. The composition of MSW generation in the study location over 16 days period

No.	Composition	Average Weight (Kg/day)	Percentage
1	Food and leaves	7.124	49%
2	Paper	1.925	13%
3	Wood	0.000	0%
4	fabric	0.215	1%
5	rubber/leather	0.000	0%
6	plastic	2.278	16%
7	metal	0.482	3%
8	glass	0.745	5%
9	Others (Hazardous)	1.686	12%
Total		14.454	100%

Table 2 shows the composition of MSW generation in the study location over 16 days. The largest amount of waste generated was food waste which reached a total of 113.99 kg during the 16 days of the study or a percentage of 49% of weight. The weight of waste generation from food waste and leaves always had the highest percentage compared to other waste categories during the research. This is because the predominant activities at the study object location are mostly domestic so the most waste produced is left over from household activities. These results is also confirmed in other previous studies conducted in other megacities in Indonesia, Bandung and Surabaya (Puspita and Ainun, 2023; Wahyuni Maulidia and Kokoh Haryo, 2024). Plastic is the waste category with the next highest percentage of generated MSW with a total of 16% weight of total MSW. Online shopping activities and consumption of packaged food increase the percentage of plastic waste produced in households. A study in South Korea suggests that the raise of onlie shopping activities increased the plastic waste generation up to 4.8 times (Kim et al., 2022). The last type was wood and rubber/leather waste with the total weight generated during the 16 days being 0 kg or 0% weight.

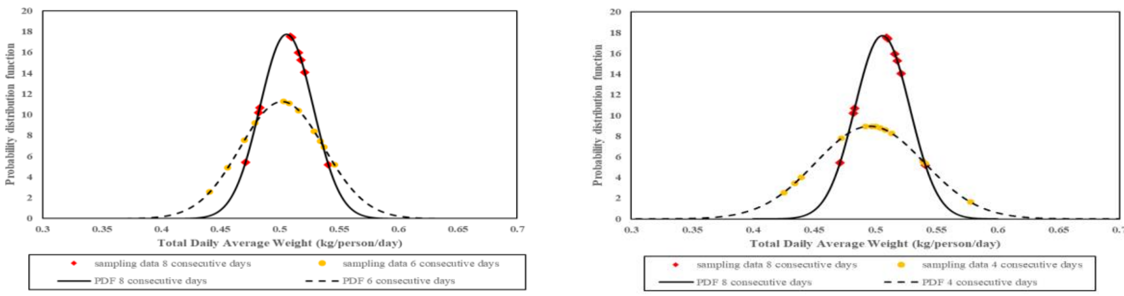
The weight of food waste and leaves always has the highest percentage compared to other waste categories during the 16 days of sampling. This is because the activities carried out at the study object location are mostly domestic waste. Plastic waste is the waste category with the next highest percentage of weight generated with a total of 16% of the total waste categories produced. Online shopping activities and consumption of packaged foods increase plastic waste generated in households. In addition, some residents have grocery stores so a lot of plastic food packaging waste is found. Household waste in the categories of wood, rubber, and leather is the waste that is least often found during the study period. The low category of this waste is because on average the community in the RW 05 area of Jagakarsa Village is not an industrial actor that produces waste in the form of wood, rubber, or leatherp.

3.2. Impact of sampling duration on the total daily average waste generation

From scenario (1) which uses daily averages of MSW weight from 8 consecutive days and resulted in 9 combinations of total daily averages of MSW weight, we found the range of total daily averages of MSW weight from 0.471 kg/person/day to 0.541 kg/person/day, with an average of 0.505 kg/person/day and standard deviation of 0.022 kg/person/day. Meanwhile, we found that scenario (2), which is based on daily averages of MSW weight from six consecutive days, resulted in 11 combinations of total daily averages of MSW weight with the range from 0.44 kg/person/day to 0.54 kg/person/day. The average obtained from scenario 2 is 0.5 kg/person/day. For scenario (3), based on daily averages of MSW weight from four consecutive days and resulting in 13 combinations of total daily averages of MSW weight, we obtained the range between 0.42 kg/person/day to 0.57 kg/person/day, with an average of 0.49 kg/person/day and standard deviation of 0.044 kg/person/day.

Comparisons between total daily averages of MSW weight constructed from eight consecutive sampling days (scenario 1) versus six sampling days (scenario 2) and 4 sampling days (scenario 3) are shown in Figures 4a and 4b. Figure 4a shows the difference bewteen the distrbution of total daily avaerages of MSW weight constructed from scenario 1 and 2. The black continuous line shows the distribition of scenario 1 whereas the dotted line shows the distribution of scenario 2. It can be seen that the peak of both distribution are around 0.5 kg/person/day, impliying little differences obtained from the two scenarios. The same results also can be seen in Fig 4b whereas the peak of distribution obtained from scenario 1 (continuous line) is adjacent to that of scenario 3 (dotted line). However, we can see that in Fig 4b, the deviation of scenario 3 distribution is wider than the scenario 1 distribution. This shows that fewer number of sampling days cause larger variability eventhough the slightly different averages were obtained (Walpole, 2022).

To quantify the difference between scenarios, the F test for variance comparison and independent t-test comparison was performed for Scenario (1) vs Scenario (2) and Scenario (1) vs Scenario (3). There was no significant difference in variance (p=0.105) and mean (p=0.77) was obtained between scenario (1) and scenario (2). On the other hand, whereas no significant difference in mean (p= 0.49) between scenario (1) and scenario (3), a significant difference of variance (p=0.03) was observed. The results may indicate that the total daily averages of MSW weight constructed from 4 days consecutive sampling days could not capture the variability of daily MSW generations. In contrast, the total daily averages of MSW weight constructed from 6 days consecutive sampling days were able to explain both the center tendency and variability of the MSW generation as well as those constructed from 8 consecutive sampling days.The difference between variability of scenario 2 and 3 distributions may due to the effect of waste generation during weekend and weekdays as reported in several previous study (Aulia et al., 2024; Shofi et al., 2023). The peak of MSW generation is typically occured during weekend wehereas the lowest is usually obtained in the middle of the week. In scenario 3, as total daily average MSW weight values are based on four days data, there are higher chances that the weekend data are not included. In contrast, as data of six days were used in scenario 2, it is certain that at least a day in the weekend is included in the calculations.



(a) (b)

Figure 4. Comparisons between total daily averages of MSW weight constructed from 8 consecutive sampling days versus 6 sampling days (a) and 4 sampling days (b).

3.3. Impact of consecutiveness on the total daily average waste generation

The analysis was performed by comparing results from scenario (1), representing the data from 8 consecutive days, and scenario (4), representing the total daily averages MSW generation constructed from randomly selected eight non-consecutive days data (30 combinations). Figure 5 shows the difference bewteen the distrbution of total daily avaerages of MSW weight constructed from scenario 1 and 4. The black continuous line shows the distribition of scenario 1 whereas the dotted line shows the distribution of scenario 4. It can be seen that the peak of scenario 4 is in the left of scenario 1 peak. These difference showed that the total daily average MSW weight values from scenario 4 is smaller than those of scenario 1. As the range of the total daily average MSW weight from scenario 4 was between 0.45 kg/person/day to 0.54 kg/person/day with an average of 0.492 kg/person/day and a standard deviation of 0.02 kg/person/day, certainly smaller than values obtained from the scenario 1 (average of 0.505 kg/person/day and standard deviation of 0.022 kg/person/day). That said, based on the F test for variance comparison and independent t-test, there was no significant difference in variance (p=0.34), and mean (p=0.056) was obtained between scenario (1) and scenario (4). These results indicate that the consecutiveness in MSW sampling does not affect the center tendency and variability of the MSW generation compared to those constructed from eight consecutive sampling days. As mentioned in the previous section, the total daily average MSW weight values are heavily influenced by the variability between weekend and weekdays data since the MSW generation is larger during weekends than during weekdays (Ermayendri and Mualim, 2023; Nethaji Mariappan et al., 2018). Hence, as long as the weekends data is included in the the total daily average MSW weight calculation, consecutiveness manner of the data is only slightly affect center of tendency of the distribution.

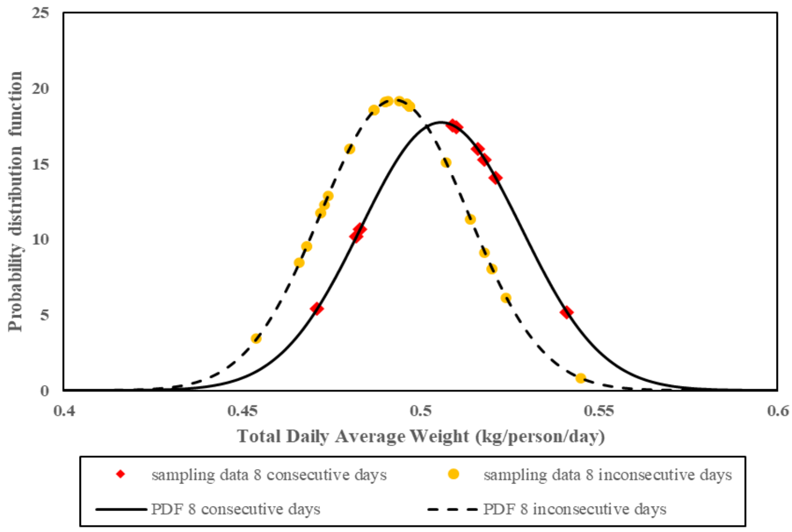


Figure 5. Comparisons between total daily averages of MSW weight constructed from 8 consecutive sampling days versus 8 non-consecutive sampling days

3.4. Implication of The Study

The study showed that the total daily averages of MSW weight estimated by MSW sampling conducted on six consecutive days, four consecutive days, and eight non-consecutive days are not significantly different from those estimated by sampling conducted on eight consecutive days. These results imply the possibility of conducting MSW sampling for less than eight days as required in SNI 19-3983-1995, which obviously will reduce the required time, cost, and resources. However, to formally reduce the sampling time, more comprehensive studies are needed as various uncertainties remain. Those uncertainties are: (1) the sampling campaign was carried out in Ramadhan month. As we suggested in previous sections, the timing may affect the amount of MSW generation. This is consistent with the report in Makkah suggesting that MSW generation during Ramadan increases significantly, reaching up to 3,000 tons per day compared to 1,800–2,000 tons per day in the regular month(Mashat and Arabia, 2014). It was also recorded that under normal conditions, the waste entering the Benowo Landfill (TPA Benowo) in Surabaya reaches around 1,500-1,600 tons per day. This amount increases by 100-200 tons per day during the month of Ramadan (Anugrah, 2023). However, although the total daily averages of MSW weight obtained in this study is slightly higher that the value recommended in sni 19-3964-1995, the value is still in the range of previous studies conducted in normal days in Indonesia day (Aulia et al., 2024; Irmawartini et al., 2023; Shofi et al., 2023; Widyaningsih & Hermurti, 2017). Having said that, we still recommend further studies conducted in a normal month to confirm the consistency of the results of our study. (2) the MSW samples were collected from middle-class housing areas. According to (Liu et al., 2019), areas or households with a higher economy class tend to generate more MSW due to larger expenditures. In this study, the average expenditure per capita is 2.7 millions Indonesia Rupiah per month, whereas in national level, the average expenditure per capita is 1.03 millions Indonesia Rupiah per month (Statistical Agency of South Jakarta, 2024). This shows that further studies need to be conducted in lower and upper-class housing areas to confirm whether the same results with this study could be obtained. (3)) The MSW samples were collected from domestic activities only. The MSW generation from non-domestic sources such as public facilities, factories, offices, or markets could have seasonal variability (Raharjo et al., 2019). Thus, the study should be replicated in non-domestic sources to confirm the possibility of MSW sampling for less than 8 days.

4. Conclusion

The total dailay average of MSW weight in Jagakarsa Village, Jakarta obtained from the 16 days of sampling duration was of 0.5 kg/person/day, whereas the value obatained from eight, six and four days were 0.505 kg/person/day, 0,5 kg/person/day, and 0.49 kg/person/day, respectively. The total MSW generation is dominated by food waste and leaves with a total of 49% and an average weight of 7.124 kg/day. Meanwhile, other categories of waste composition have results of 16% plastic waste category, 13% paper/cardboard category, 12% other waste category, 5% glass category, 3% metal, and 1% cloth. /Textiles, and 0% wood and rubber/leather categories. The result of this study indicates that conducting sampling for four consecutive days, six consecutive days and eight non-consecutive days did not influence the central tendencies of the total daily average of MSW weight compared to those calculated based on sampling for eight consecutive days (following SNI 19-3983-1995). These findings may initiate the development of a more efficient method for MSW sampling in Indonesia. However, more future studies are still needed to improve the understanding of the impact of sampling duration and consecutiveness on the MSW generation in larger areas, across different economic, educational, and behavioral of waste producers.

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