Study of Remaining Service Life of a Municipal Solid Waste Landfill with the Composting Method: A Case Study in Klaten Regency

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Abstract. At Troketon’s Municipal Solid Waste Landfill (MSWLF), waste management adopts the controlled landfill method. The solid waste that enters the MSWLF of Troketon is increasing every day. Without processing, the incoming waste is directly dumped into a landfill. It causes the landfill capacity in the active zone to decrease so that the landfill’s service life decreases faster. This study aimed to calculate the capacity of the used landfill to determine the useful life of the landfill. It also aimed to compare the service life of MSWLF with the processing and composting process. This research took place from January 2019 to May 2021. This research conducted interview techniques, and literature studies. Estimating the waste generation rate projections were based on data in 2020 by using an excel program to calculate waste reduction and its service life. The average rate of the waste generation entering MSWLF of Troketon was 0.07% per year with 48% biodegradable waste composition. The results revealed that these operating landfill zones could extend their service life by composting process. MSWLF with the composting process saves capacity by 136.99 m³/day and 712 days’ longer service life than without composting.

1. Introduction
Not all cities and regencies in Indonesia have solved waste management issues in Indonesia, especially in landfills at the Municipal Solid Waste Landfill (MSWLF) [1]. Waste management includes collection, transportation, processing, and final disposal [2]. In Indonesia, most of the waste management includes storage, collection, final transportation, and landfill in MSWLF [3][4][5]. MSWLF is the final solution for waste management in a city/district [6] as it is used as an estuary for waste landfilling where the wastes are isolated safely so as not to cause disturbance to the surrounding [7][8]. The waste generated in the city/district, 69% of the waste generated from the community, is transported and stored in MSWLF [9]. Waste processing that is not optimal results in more complex waste management. The issue of waste management is reduced landfill life [10].
Reducing the volume of waste stockpiled at the landfill can extend the service life of landfills and save space in the existing landfill zones [11]. One effort to reduce waste generation is the composting process, changing or utilizing waste as raw material for compost production [12]. The composition of the waste entering MSWLF contains food/organic/quickly biodegradable wastes by 45-60% [13][14][15]. Organic waste must be reduced by more than 37% to make MSWLF optimal [16][17].

The Law of the Republic of Indonesia number 18 of 2008 (Waste Management) states that waste management is the responsibility of local governments. One of the regencies that perform waste management is Klaten Regency. The MSWLF of Troketon has been operating since October 2018. Two landfill zones have been operating using the controlled landfill method since 2018. The method backfills the landfill by compacting it after 5-7 days [18]. Waste processing at MSWLF of Troketon utilized an incinerator to burn waste. It is insufficient to reduce the amount of waste piled up in landfills since they continue to increase. It can cause an increase in the stockpiled wastes, affecting the service life of the landfill [19]. The amount of waste generated continue to increase, while the available landfill at the MSWLF of Troketon is still limited.

Currently, one zone has exceeded its capacity while the waste entering the landfill continues to increase. The landfill zone's limitation is that the existing treatment has not reduced the amount of waste that is stockpiled in the landfill. There is a need for waste management that can extend the life of the landfill [20]. Many studies related to the service life of landfills have been carried out. In 2015 a study was conducted related to the study of the useful life of the sanitary landfill method where landfills using the open dumping method were rehabilitated into controlled landfills in stages before becoming a sanitary landfill [21]. In 2018, a landfill study was conducted with waste to energy technology. The results obtained that in addition to saving the landfill's life, it was also able to process waste into fuel [19]. Waste to energy processing has not been implemented in MSWLF of Troketon because it requires a considerable investment cost. That simple technology is needed to reduce the amount of waste and extend the service life of the MSWLF. Processing that can be done is to process readily biodegradable waste into compost. In addition to reducing waste piled up in landfills, it can also produce compost products that can be used as fertilizer for soil fertility and strengthen soil structure [22]. The compost produced can be sold so that it can become regional income [23]. Therefore, this study aimed to conduct research related to the remaining service life of MSWLF of Troketon. The study was conducted by comparing the remaining useful life of the existing MSWLF (without compost processing) with MSWLF using compost processing. Subsequently, it can be recommended for the managers, especially the Department of Public Works and Spatial Planning of Klaten regency, to improve the management at MSWLF of Troketon.

2. Method

2.1 Location and time of research

In the Klaten Regency, Central Java, Indonesia conducted this research, precisely in the MSWLF of Troketon. The population of the Klaten Regency in 2020 was 1,327,577 people. The waste produced by the people of Klaten Regency is transported to MSWLF of Troketon, located in Troketon Village, Pedan District, Klaten Regency, with a land area of about 7.08 Ha. The currently operating landfill zones are zone 1 and 2, with a total capacity of 172,986 m³. MSWLF of Troketon has served 207 Waste Disposal Sites, covering 26 sub-districts in Klaten Regency since 2018. Wastes are transported using various vehicles such as dump trucks, arm roll trucks, pick-ups, and 3-wheeled vehicles. These vehicles transport waste from residential areas and commercial areas such as markets, shops, restaurants, regional institutions, and street areas. The research took place from January 2019 to May 2021.
2.2 Method of Collecting Data

The data required to characterize the study site included the population of Klaten Regency, landfill capacity, active landfill zone, infrastructure, and landfill management. Data were obtained from literature studies related to Klaten Regency and interviews with related agencies. Data related to population was obtained from the Statistics of Indonesia of Klaten Regency. In contrast, data related to waste management in Klaten Regency was obtained from the Department of Public Works and Spatial Planning of the Klaten Regency.

The first stage in this research was to project the waste generation generated in 2020. The generation projection results calculated the amount of waste generated in the landfill active zone. In addition, it also calculated the volume of waste and soil used for landfills. The results obtained the accumulation of stockpiles in landfills, which was then utilized to calculate the remaining capacity and the service life of the landfill. Figure 1 shows the research flow chart.

![Flowchart of research stages.](image)

2.3 Data Analysis and Recommendation

The calculation of the remaining service life was based on the time of data collection on January 5, 2021. Data analysis was carried out by comparing the calculations obtained with composting and without composting. The comparison is explained in the form of a description. Analyzed the results qualitatively to obtain recommendations. Can use these recommendations to improve processing at MSWLF of Troketon.

The initial stage in data analysis is carried out by calculating waste generation projections to obtain a projected landfill capacity. Data of waste generation were from the 2018-2019 weighbridge data in MSWLF of Troketon. The average data were obtained every year to be projected into the following year and estimated waste generation calculation from 2020-2025. A projected waste generation used generation data with the unit of m$^3$/day to approach the existing capacity. Subsequently, converted the generated data obtained in tons/day to m$^3$/day by dividing the weight of waste by the average density of the measurement results for two days. Conducted projection of waste generation to estimate the amount of waste generated in the future by referring to the increase in the amount of waste in the previous year, and the method utilized the following geometric equation [19]:

\[
V = V_0 \times r^n
\]
\[ P_n = P_0 \left(1 + r\right)^n \]  

in which:

- \( P_n \) = volume of waste in year \( n \) projection
- \( P_0 \) = volume of waste in the initial year of the projection
- \( r \) = average rate of increase in waste generation (%)
- \( n \) = projection time interval (year)

The waste generation calculation is used to determine the existing condition (waste generation without processing). While the calculation of the amount of waste with compost is the amount of existing waste minus the amount of waste that can be composted. The calculation of the remaining service life of the landfill can be seen in Figure 2, obtained from the remaining landfill capacity at MSWLF. Obtained the remaining capacity by reducing the existing capacity by generating accumulated waste and backfilling the waste landfill. If obtained a minus value for the remaining capacity, the remaining capacity at MSWLF of Troketon had been exhausted. It could no longer accommodate the incoming waste generation, identifying the remaining service life of that year. The remaining service life of the landfill was obtained by dividing the remaining landfill capacity by the projected daily waste generation coming in along with the need for overburden.

**Figure 2.** Remaining service life calculation.

### 3. Results and Discussions

The location of MSWLF of Troketon has complied with the requirements for selecting MSWLF location in the Regulation of the Minister of Public Works of the Republic of Indonesia Number 03/PRT/M/2013 concerning the Implementation of Waste Infrastructure and Facilities in Handling Household Waste and Other Types of Household Waste [24]. Troketon landfill has been equipped with leachate control and a buffer zone to reduce the impact of pollutants on the environment. Pollution can occur in water, soil, or air [25][26][27]. This buffer zone is in the form of a green line or fence around the landfill. The trees planted are teak to grow tall and lush with the function of a filter from odors.

Waste management at MSWLF of Troketon is divided into two after the weighbridge. Wastes transported by three-wheeled motors are processed at the Domestic Waste Processing Installation (IPSD), while those are transported by dump trucks, arm roll trucks, and pick-ups to the controlled landfills (Figure 3). Waste processing at IPSD uses a rotary screen and a sorting conveyor to sort waste and an incinerator to burn waste. IPSD can process as much as three tons of waste/day from the total waste that goes to the MSWLF of Troketon or by 0.048 %. The landfill at MSWLF of Troketon has used a controlled landfill system, and it utilizes two excavators and two bulldozers operated by four people.
The waste generated in the Klaten Regency entering MSWLF of Troketon in 2020 was 80.50 tons/day, where the average density was 0.25 m$^3$/ton. Hence, the conversion result of waste generation was 327.42 m$^3$/day. The average rate of the waste generation entering the landfill was 0.07%, so that the projected waste generation was obtained, as shown in figure 4. The projection calculation is only carried out for 5 years of MSWLF of Troketon operation starting in 2020 because it only operates with 2 zones.

The waste generation comes from domestic sectors, schools, tourist attractions, markets, health facilities, hotels, supermarkets, and industries. There were biodegradable and non-biodegradable wastes entering MSWLF. Quickly biodegradable waste included vegetable/food residues and leaf waste, while non-biodegradable waste included plastic, diapers, cloth, glass, paper, and rubber. A sampling of waste is carried out on the waste that enters the MSWLF. The waste sampling results found that the composition of waste as much as 48% is waste that is readily biodegradable (figure 5). 48% of the incoming waste can be processed into compost so that the landfill is only used to stockpile non-biodegradable waste.

Waste generation with compost is obtained from the waste generation that goes into landfills minus waste processed into compost. In this study, the percentage of waste that can be composted is 48%, based on the percentage of waste composition in the MSWLF of Troketon. The waste is stored in the active zone of the landfill. The MSWLF of Troketon has 2 zones that have been in operation since 2018. The solid waste that enters the active zone is filled with soil. The percentage of ground cover is 3% of the landfilled waste. The landfilled waste will accumulate and will reduce the landfill capacity. From the projection of waste generation, this research calculated the remaining landfill capacity to calculate the remaining service life of the MSWLF of Troketon, as shown in table 1 and table 2. can determine remaining capacity by reducing the existing capacity with accumulated waste generation. The minus remaining capacity indicated that the remaining capacity at MSWLF of Troketon had been exhausted and could no longer accommodate the incoming waste generation to identify the remaining service life of that year. Dividing the existing capacity by daily waste generation plus overburden could obtain the remaining service life with composting.

![Figure 3. Waste management flow at MSWLF Troketon.](image)

![Figure 4. The projection of waste generation with and without composting.](image)
Figure 5. The composition of the waste entering MSWLF of Troketon

Table 1. The remaining life of the landfill without composting.

| Year | Waste Generation | Waste to Active Zone landfill | Waste landfill with cover soil | Accumulation m³/year | Remaining Capacity m³ | Remaining life without compost (day) |
|------|------------------|-------------------------------|-------------------------------|----------------------|-----------------------|-------------------------------------|
| 2020 | 321.99           | 321.99                        | 1803.13 m³/day               | 1857.23 m³/week      | 96575.79 m³/year     | 41813.01 m³/day                     | 158                                 |
| 2021 | 347.31           | 347.31                        | 1944.94 m³/week              | 2003.28 m³/week      | 104170.77 m³/year    | 264.59 m³/week                      | -218                                |
| 2022 | 374.63           | 374.63                        | 2097.93 m³/week              | 2160.87 m³/week      | 112365.02 m³/year    | 307.85 m³/week                      | -568                                |
| 2023 | 404.09           | 404.09                        | 2262.90 m³/week              | 2330.79 m³/week      | 121201.14 m³/year    | 332.06 m³/week                      | -891                                |
| 2024 | 470.17           | 470.17                        | 2632.95 m³/week              | 2711.94 m³/week      | 141020.91 m³/year    | 386.36 m³/week                      | -1131                               |
| 2025 | 507.15           | 507.15                        | 2840.04 m³/week              | 2925.24 m³/week      | 152112.54 m³/year    | 416.75 m³/week                      | -1413                               |

Table 2. The remaining life of the landfill with composting.

| Year | Waste Generation with compost (48%) | Waste to Active Zone Landfill | Waste Landfill with cover soil | Remaining Capacity m³ | Remaining life with compost (day) |
|------|-------------------------------------|-------------------------------|-------------------------------|-----------------------|----------------------------------|
| 2020 | 321.99                              | 154.55                        | 167.43 m³/day                | 937.63 m³/week        | 50219.41 m³/day                 | 88169.39 m³/day                     | 641                                 |
| 2021 | 347.31                              | 166.71                        | 180.60 m³/week               | 1011.37 m³/week       | 54168.80 m³/year               | 104388.21 m³/day                    | 229                                 |
| 2022 | 374.63                              | 179.82                        | 194.81 m³/week               | 1090.92 m³/week       | 58429.81 m³/year               | 162818.03 m³/day                    | -153                                |
| 2023 | 404.09                              | 193.96                        | 210.13 m³/week               | 1176.71 m³/week       | 63024.59 m³/year               | 225842.62 m³/day                    | -506                                |
| 2024 | 470.17                              | 225.68                        | 244.49 m³/week               | 1369.14 m³/week       | 73330.87 m³/year               | 299173.49 m³/day                    | -800                                |
| 2025 | 507.15                              | 243.43                        | 263.72 m³/week               | 1476.82 m³/week       | 79098.52 m³/year               | 378272.01 m³/day                    | -1107                               |
The calculation results (table 3) revealed that the landfill capacity without composting exceeded in 2021, while will exceeded the landfill capacity in 2022. The remaining service life of a landfill with composting was 229 days in 2021, and without composting, it was already minus in 2021. The difference between composting and without composting was 712 days or equal to 1 year, 347 days. Hence, if the tracking was carried out on January 5, 2021, the MSWLF of Troketon composting can still be used until December 11, 2022, when landfill zone 3 operates in 2022. Construction of landfill zone 3 began in May 2021.

**Table 3. Conclusion analysis of the remaining useful life.**

| Capacity Landfill | Unit | Without Compost | With Compost |
|-------------------|------|-----------------|--------------|
| Year Past MSWLF capacity | year | 2021 | 2022 |
| Q day with a cover landfill in 2021 | m³/day | 285.40 | 148.41 |
| Total remaining useful life | day | 158 | 870 |

**4. Conclusion**

MSWLF of Troketon consists of 48% of biodegradable waste. The waste can process into compost. The processing waste into compost can extend the service life of the landfill. Based on the research results, the landfill's capacity used in 2021 by using compost is 148.41 m³/day and save capacity by 136.99 m³/day compared to without composting. Aside from that, the remaining service life of the landfill with the composting process is 712 days longer than the existing landfill without composting.

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