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DESIGN OF END OF WASTE DISPOSAL WITH SANITARY LANDFILL METHOD

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ABSTRACT
Final Disposal Site (FDS) is a place where waste reaches the final stage in its management. In realizing the need for waste disposal facilities and infrastructure, precise calculations are needed so that the land provided for the FDS can accommodate all the waste. The landfill design method with Sanitary Landfill, is a standard method used internationally where the covering of waste with a layer of soil is carried out every day so that the potential for disturbances that arise can be minimized. However, there are still many cities in Indonesia that have not implemented this system because of the difficulty in calculating the land area requirements and landfill cover needs. The purpose of this paper is to provide an example of a waste landfill design with a Sanitary Landfill system so that it can be used as an example of calculations by other landfills. The waste that enters every day is distributed and compacted into a layer of waste cells in a work area of the landfill. Cell density is determined by the volume of solid waste in the FDS. The planned dimensions of the waste cell will greatly affect the service life of the land. The results of this study indicate that if the waste produced is 1,194,399.50 m3 and the FDS is designed to meet ten years' needs, with a heap height of up to 20 m, an area of 2.3 ha is required. Cell dimensions: 6.00 m wide, 0.85 m high, 10.61 m long, and the required soil cover when the soil solid factor is 1.15 is 22.56 m3 / day.

Keywords: *Garbage, Landfill, Soil.*

1. INTRODUCTION

Final Disposal Site (FDS) is a place where waste reaches the final stage in its management. In realizing the need for facilities and infrastructure for final disposal sites (FDS) for garbage, it is necessary to calculate precisely so that the land provided for the landfill can accommodate all the waste. Sanitary Landfill is a standard method used internationally in which waste covering with soil layers is carried out every day so that potential disturbances can be minimized. This method is recommended to be applied to large and metropolitan cities since 2014 through the Ministry of Public Works. The Directorate General of Human Settlements of the Ministry of Public Works has targeted 250 final waste disposal sites (FDS) in Indonesia to have implemented a sanitary landfill (SLF) system. However, according to the Directorate General of Human Settlements of the Ministry of Public Works, to implement the SLF system, a fairly large amount of funds is needed because it requires spare land and a large enough soil for waste processing, so a calculation is needed to plan the amount of land requirements and the need for cover soil.

1.1. Related Work

In Diponegoro Journal Of Social And Political Of Science 2016, p. 1-13 http://ejournal-s1.undip.ac.id/index.php/ Elli Yoana Susanti and friends write that the final waste processing at FDS Jatibarang in practice uses the Controlled Landfill system because the Sanitary Landfill system cannot work as well as should be. This is due to the inadequate separation of waste from sources, an increase in waste generation, inadequate budget realization, and weather factors. Another research on Sanitary Landfill was conducted by Manar, S.IP, M.Si in the East Jakarta area with the title Modified Waste Management by Sanitary Landfill in Cakung District, East Jakarta, which concluded that waste processing with a modified Sanitary Landfill can reduce the amount of waste to the FDS. The modification here means that only organic waste is processed. So, waste sorting has been carried out before the garbage arrives at the FDS. In 2017, Hasbullah and friends wrote about the Analysis of Waste Management in the city of Subulussalam about Analysis of Waste Management in the City of Subulussalam, which also recommended the Sanitary Landfill system.

1.2. Research Contribution

Many cities in Indonesia have not implemented this system because of the difficulty in calculating land area requirements and landfill cover needs. In the last five years there have been several studies on Sanitary Landfill, but no research has yet calculated the land requirements and landfill requirements for this system. The purpose of this study is to provide an example of how to calculate land requirements and landfill requirements for the Sanitary Landfill system.

1.3. Paper Structure

The following sections of this paper are organized as follows: Section 2 describes the background, scope, and objectives of this research. Section 3 describes the methodology used in this study. Section 4 contains the theories that will be used as a basis for discussion of the research. Section 5 is the conclusion of the discussion results as well as contains recommendations relating to the results of the discussion.

2. BACKGROUND

One of the infrastructures that is important in supporting the function of the city is the solid waste sector. It takes careful planning because it is one of the important services that must be provided by a city, in addition to the big impact it will cause. Final Disposal Site (FDS) is a place where waste reaches the final stage in its handling, from the container at the source through the collection, transfer, transportation, processing and disposal processes. Garbage in the landfill must be isolated safely so as not to cause disturbance to the surrounding environment. In order for this security to be achieved properly, it is necessary to provide adequate facilities and proper treatment.

With the planning of land area for final disposal sites (FDS), the amount of land needed and cover soil can be estimated so that the waste management system can run optimally. The scope of the design of this FDS is the design of land area requirements and landfill cover needs.

So the aim of this paper is to provide an example of the design of an FDS with a Sanitary Landfill system so that it can be used for the calculation of landfills in other areas.

3. METHODOLOGY

The method used in this research is a descriptive quantitative method through literature study and field observations. The data collected is arranged based on the logic of the existing rationale so that this research is easily understood by the reader. The data used is secondary data obtained from literature studies, articles and journals. This research analysis focuses on literature analysis and compares the objectives of this study with other studies on sanitary landfills that have been conducted.

The calculation of waste generation production will use a general waste generation rate of 2.00 liters/person/day, and an increase of 0.02 liters/person/day per year. Service level is 60% and is planned to increase by 1% per year.

4. ABOUT WASTE

The amount of waste in a city is determined by several factors, including: population growth, level of economic development, agriculture and per capita income of the population.

The method of final waste disposal:

4.1. Open Dumping

Open disposal is a simple disposal method, where waste is only spread out at a location, left open without security and left after the location is full.

4.2. Controlled Landfill

This method is an improvement from open dumping where periodically the buried waste is covered with a layer of soil to reduce the potential for environmental disturbances that may arise. In its operation, garbage leveling and compaction are also carried out to increase the efficiency of land use and the stability of the pile on the surface of the FDS.

4.3. Sanitary Landfill

It is the standard method used internationally in which the covering of waste with a layer of soil is carried out every day so that potential disturbances can be minimized. This method is recommended to be applied to big cities and metropolitan areas. To improve the quality of the landfill to meet sanitary landfill standards, it must be done in stages starting from a controlled landfill gradually increasing from year to year, in accordance with the city government's strategic plan. With careful planning and professional construction and operation design, landfills can save costs effectively and are environmentally acceptable.

4.4. FDS Location Requirements

Given the large potential for causing disruption to the environment, the selection of a landfill site must be done carefully and carefully. In SNI 03-3241-1994, regarding the procedures for selecting a FDS location, namely:

- not a geological prone area (fault area, landslide-prone, earthquake-prone, etc.), not a hydrogeological area (an area with a groundwater depth of less than 3 m, the type of soil is easy to absorb water, close to water sources)
- not a topographic prone area (slope of land should be <20%)
- not an area prone to flight activities (minimum distance from the airport is 1.5-3 km)
- not a protected area/area
- not a flooded area with a return period of 25 years.

4.5. Cover Soil

The frequency of covering the garbage with the soil is adjusted to the method/technology applied. In the sanitary landfill system, closure is done every day, while a controlled landfill is recommended every 3 days. The purpose of land closure is:

- To cut the life cycle of flies, especially from eggs to flies
- Prevent rat breeding
- Reducing rainwater infiltration which will form leachate
- Reduces pollution and odors by isolating generated gases
- Increase the stability of the embankment surface
- Improve environmental aesthetics.

4.6. Kinds of Cover Soil

4.6.1. Daily Ground Cover

Daily ground cover is carried out after the thickness of the waste has reached a predetermined thickness, or cover soil is carried out after one day of waste disposal work is completed. Cover soil on the given day can be removed depending on the environment or the nature of the waste.

4.6.2. Intermediate ground cover

Intermediate ground cover, carried out when the garbage disposal is very advanced, is different from the same daily cover soil, the intermediate ground cover uses soil layers for garbage collection vehicles to cover soil. The aim is to remove rainwater from the stockpiled area over a relatively long period.

4.6.3. Final ground cover

Final ground cover is carried out when part or all of the garbage disposal is complete. The purpose of cover soil at the top layer is to improve the landscape, use the land, and reduce water seepage.

What must be considered in cover soil is to ensure the amount of cover soil by taking into account the ratio of the amount of soil in a solid-state and in a loose state. Cover soil type is soil that is not impermeable, and the period of cover soil must be adjusted according to the disposal method. For sanitary filled landfill cover soil is done every day, while for controlled landfill cover soil can be done periodically.

The terms of the cover soil phase for sanitary landfill consists of:

- daily cover soil (15-20 cm thick)
- coverage between 2-4 layers of daily cells (30-40 cm thick)
- Final cover soil of 50-100 cm thickness (depending on the designation of the former FDS).

4.6.4. Requirements For Land Area And Landfill Capacity

The landfill should be able to accommodate waste disposal for a minimum of 5 years of operation. The capacity is influenced by:

- the methods used
- bottom depth of the landfill
- fill height
- volume of waste removed
- compression
- the ability to reduce the volume of waste at the source.

The age and area requirements for the landfill are calculated using the formula:

$$L = V.350 / T.1,15 \qquad (1)$$

Information:
L = Area of land needed each year (m2)
V = Volume of solid waste (m3/hr)
V = A / E
A = Volume of waste to be disposed of
E = rate of compaction (kg/m3), average 600 kg/m3
T = the height of the planned landfill (m)
1.15 = ground cover ratio.
Calculation of total land area requirements:

$$H = G \times I \times J \quad (2)$$

Information:
• H = total land area (m2)
• G = area of land per year
• I = land age (years)
• J = ratio of total land area to effective land area (min. 1,2).

4.6.5. Cell Arrangement

The garbage that enters every day is spread and compacted into a layer of garbage in the work area of the landfill. Cell density is determined by the volume of solid waste in the FDS. The planned dimensions of the waste cell will greatly affect the service life of the land. This concerns how to handle the waste that enters the FDS. Proper handling of waste in the landfill increases the service life of the landfill. The division of the land into several work zones will facilitate the overall management of the land, besides being able to record the amount and type of waste that enters the working area. Filling, spreading and compaction of waste are carried out in layers to increase the density of waste. It is hoped that good compaction will increase the stability of waste and reduce the danger of landslides. Daily cells are arranged in stages starting from the bottom to flat then moving upward layer by layer. In the sanitary landfill system, the shortest period is daily, meaning that one cell is part of the land used to collect waste for one day. In controlled landfills, one cell is to accommodate the waste for 3 days, or 1 week or the shortest operating period possible. Proper handling of waste in the landfill increases the service life of the landfill. There are several things that must be considered in making cell dimensions, including:

• The division of land into several work zones will facilitate the overall management of the land, besides being able to record the amount and type of waste entering the working area.

• Filling, spreading and compaction of waste in layers to increase the density of waste. It is hoped that good compaction will increase the stability of waste and reduce the danger of landslides.

• The final result of the landfill is planned to form terraces. The formation of terraces can reduce erosion and accelerate the flow of water over the surface of the overburden so as to minimize infiltration.

• Daily cells are arranged in stages from bottom to flat then move up layer by layer.

The factors that need to be considered in cell regulation are:

• Cell widths should be within 1.5 - 3 times the machine blade width for more efficient machine operation.

• Maximum cell thickness of 1.2 m. Too large a thickness will reduce the stability of the surface and too thin will cause waste of overburden.

• The cell length is calculated based on the volume of solid waste divided by the width and thickness of the cell.

• 1: 3 slanted side ratio

4.6.6. Cover soil requirements

Cover soil has very large uses, including for:
• prevent the trash from flying and flowing out
• prevent odors
• prevent the emergence of insects that disturb health
• prevent fires
• keep the environment beautiful.

Cover soil between layers is soil covering the garbage after the garbage reaches a height of 0.85 meters and has been compacted.

Cover soil criteria are as follows:
• The landfill density is 0.6 ton/m3
• Cover soil thickness 15–20 cm

Cover land can come from cliff cuts, excavated land at the location, or land taken at the FDS location.

5. DISCUSSION

5.1. Waste Volume Projections

The calculation of waste generation production is 2.00 liters/person/day, and increases by 0.02 liters/person/day per year. Service level is 60% and increasing by 1% per year. The results of the calculation of waste volume projections from 2019 to 2028 are presented in graphical form as in Figure 1.

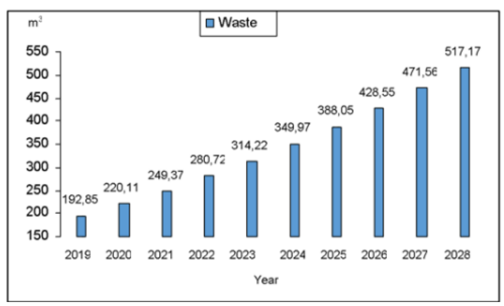

Figure 1. Graph of estimated waste generation from 2019–2028.

5.2. Calculation of Land Requirements for FDS

Land needs and capacity based on the calculation of the volume of incoming waste, the height of the planned pile, and the depreciation of waste, are calculated according to the following conditions:

The waste enters FDS-X in 2019 = 192.85 m3/day.

The cell height is planned for example 8.00 meters for each year

The average compaction rate is 600 kg /m3.

The initial density of waste is 250 kg /m3.

The need for landfill area per year is:

$$L = \frac{Vx350}{T} \times 0.70 \times 1.15$$

V = A x E

Information:

L = The area of land required each year (m^2)

V = The volume of solidified waste (m^3/hr)

V = A/E

A = The volume of waste to be disposed of

E = Compaction rate (kg/m^3), average 600 kg/m^3

T = The height of the planned landfill (m)

1,15 = ground cover ratio

V = 192.85 m3 / hr x = 77.14 m3/day

L = x 0.70 x 1.15 = 2.717 m2/year

2. Total land area requirements

H = L x I x J

H = total area of land (m2)

L = area of land a year

I = Age of land (years)

J = The ratio of total land area to effective land area 1.2

H = 2,717 m2/year x1x1,2

= 3,260 m2/yr = 0.33 Ha/year.

The relationship between cell height per 8 meters and land area can be seen in Figure 2-7.

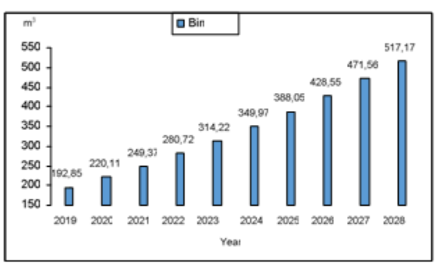

Figure 2. Graph of relationship between planned height of cells (8 m) and total land area.

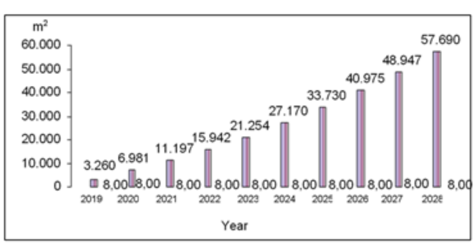

Figure 3. Graph of relationship between planned height of cells (12 m) and total land area.

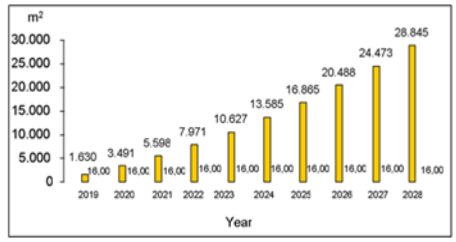

Figure 4. Graph of the relationship between planned cell height (16 m) and total land area.

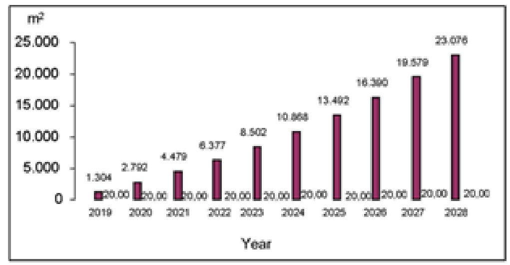

Figure 5. Graph of the relationship between cell height plans (20 m) and total land area.

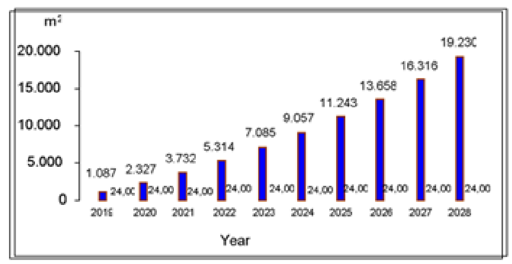

Figure 6. Graph of the relationship between plan height of cells (24 m) and total land area.

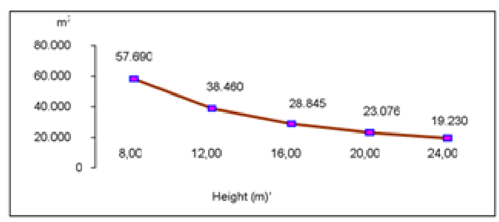

Figure 7. Graph of the relationship between cell height plans (8, 12, 16, 20, 24 meters) and Total Land Area.

The daily cell count (see figure 8) is as follows:

Cell criteria

- Cell width 1.5 - 3.5 times the blade width
- Maximum cell height of 1.20 m
- 1: 3 slanted side ratio
- Length = (volume of solid waste) / width x height

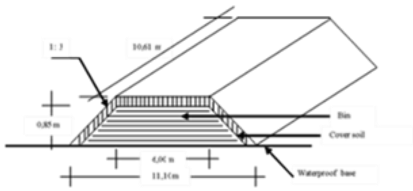

Figure 8: Daily cell unscaled sketch.

Cell dimensional plan is:
• 1: 3 slanted side comparison
• Width = 2 x 2.4 blade = 4.8 ~ 6.00 m
• Cell height = 0.85 m
• Cell length = (volume of solid waste) / (width x height)

$$= \frac{115{,}71M^3}{[6{,}00+11{,}10]/2*(0{,}85)} = 10.61$$

meters

Calculation of Cover Land Requirements
Overburden between layers is soil cover of waste after reaching a height of 1m after compaction (see Fig. 9). Cover land is taken from cliff cutting, excavated land at the FDS location and land have taken at the FDS location. The criteria for cover soil are as follows:
• Closing is done every day
• Soil types are not impermeable
• Slope ratio of 1:3
• Cover soil thickness 15 - 20 cm.

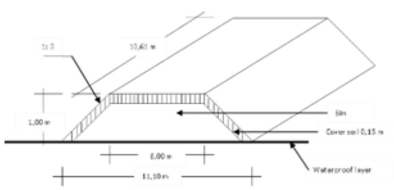

Figure 9. Cover Soil Plans Unscaled Sketch

The calculation of cover soil is as follows
• Slope ratio 1: 3
• Top width = 6.00 m
• The cross-sectional area of the cell cover
= [6.00 + x 2] x 0.15
= (6.00 + 6.32) = 12.32 m2
= 12.32 x 0.15 = 1.85 m2
• Cover soil requirement in 2019
= 1.85 m2 x 10.61m
= 19.62 m3 / hr
• Solid factor for soil 1.15 = 19.62 m3 / hr x 1.15 = 22.56 m3 /day.

From the example of the calculation results in 2019, then for the following years, figures 10 and 11 are shown in the graph of the relationship between the need for cover soil and the daily and annual waste.

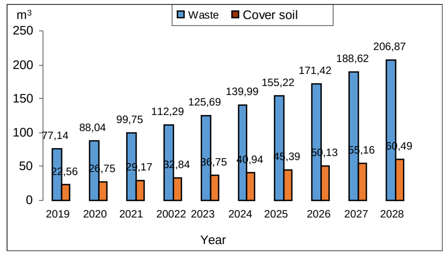

Figure 10. Graph of relationship between cover soil requirement daily with waste entering FDS.

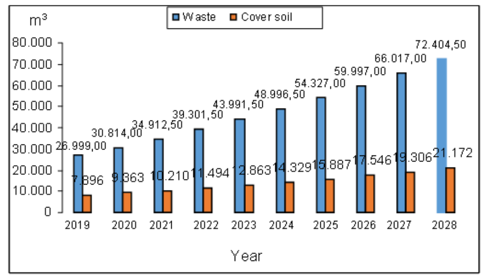

Figure 11. Graph of relationship between annual requirements cover soil with annual waste entering FDS.

5.3. Excavated Soil Calculations

FDS cliffs are slanted so that they don't collapse easily, so excavation is carried out at certain elevations. The excavated land is used to hoard waste in daily cells. The need for excavated land based on the complete cross-section of the figure is written in table 1.

Table 1. Excavated Soil Calculations

Number	Section	Excaveted soil Volume (m^3)
1	A-B	16.743,75
2	B-C	22.325,00
3	C-D	44.837,50
4	D-E	31.375,00
5	E-F	31.150,00
6	F-G	2.798,75
Amount		149.230,00
Minus landfill		835,00
Total Amount		148.395,00

5.4. Calculation of Final Cover Land Requirements

Final closure is carried out at the top layer of the landfill to improve the appearance of the landfill, use the land that has been used up, and to reduce the volume of leachate. The final soil requirements in the ten-year plan with a cover thickness of 0.60 meters are:

The land area in the planning = 23,076 m^2
So the land required for ten years = 23,076 m^2 x 0.60 m
= 13,846 m3.

5.5. Analysis of Overburden Demand and Availability

Based on the need for cover soil during the ten-year planning amounting to 139,709 m3, and the need for watertight layers of: 18,982.50 m3 and final cover soil for: 13,846 m3, the total requirement is:
139,709 m3 + 18,982.50 m3 + 13,846 m3 = 172,537.50 m3.

If the excavated land or pieces of land in the landfill location will be reused, then the shortage of land is only: 172,537.50 m3–148,395.00 m3 = 24,142.50 m3.

5.6. Land Age Calculation Of FDS

The age of the landfill is calculated to estimate how long it will take for the said FDS to be fully operational before closing. Based on the results of the division of zone 1 to zone 5 and consisting of 16 blocks that have been described previously and by using the cranyon method as a landfill method, the calculation of FDS can be calculated from each block as can be seen in Figure 12.

For example: in block 1 with a waste volume of 2,700 m3 divided by (cell height 1.00 m x cell width 8.55 m x cell length 10.61 m) = 20 days and so on as shown in Figure 12.

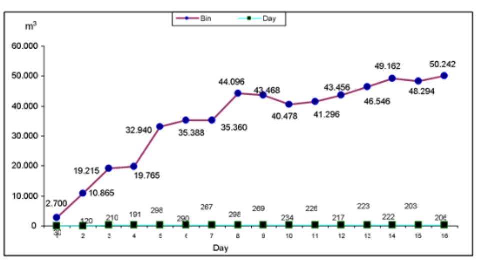

Figure 12. Graph of relationship between waste volume and number of days.

So the total number of days from blocks 1 to 16 is 3,505 days, rounded up to 10 years.

6. CONCLUSION

This research resulted in conclusions as follows:

1. The amount of waste generation is 2.00 lt / or per day and an increase is planned for 0.02 per year with a population in 2019 of 966,335 service people 60% and an increase every year is planned at 1% / year, as well as composting and recycling by 25%, in In the next ten years, the amount of waste generated by garbage will be 1,194,399.50 m3 or 477.766,28 m3.
2. The need for landfill area obtained from the design with each height can be seen in Figure 13.

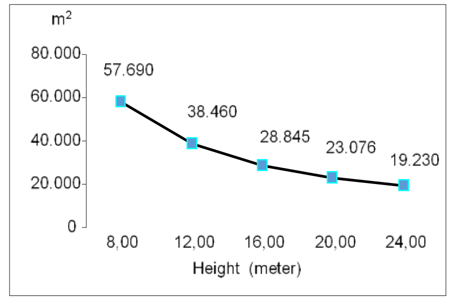

Figure 13. Graph of the relationship between the planned stockpile height and the total land area

3. The filling time for days from blocks 1 to 16 is 3,501 days, or about 10 years. The land required for garbage collection is 2.3 ha or for a service period of 10 years.
4. Cell cover soil with a thickness of 0.15 m = 139.709 m3. Soil for an impermeable layer (0,30mx2)=18.395 m3. Final cover soil requirement with thickness 0,60 m = 13.846 m3. So the total land requirement is 172.537,50 m3.
5. Ex-excavated soil that can be used for a cover as well as a waterproof soil layer of = 148.395 m3, so there is a land shortage of 24.142,50 m3.

7. RECOMMENDATION

This research only plans the availability of land area requirements and cover land, while an FDS must be equipped with other facilities such as leachate ponds, guard posts for weigh bridges and others.

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