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Potential utilization of municipal solid waste in landfill mining TPST Bantargebang Bekasi to become Refuse Derived Fuel (RDF) feed stock

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Abstract*. Bantargebang Integrated Waste Management Site (TPST) is a final waste processing site that accommodates waste from the DKI Jakarta Province. Most of the waste that enters the Bantargebang TPST is piled up at the dumping point in each zone, so this can lead to a new problem, namely the filling of all existing stockpile zones. One of the technologies that can be used to solve the problem of full landfill zones. One technology to overcome this problem is landfill mining. The results of the study related to landfill mining at the Bantargebang TPST were carried out to determine the potential for utilizing landfill mining waste to become RDF feedstock. Based on the study of the composition of landfill mining results carried out, the waste to be used as raw material for RDF is waste with a diameter >50 mm and which has a high calorific value.*

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INTRODUCTION

Bantargebang integrated waste management site (TPST) is a final waste processing site that accommodates waste from DKI Jakarta Province. Bantargebang TPST is managed by the integrated waste management unit (UPST) of the DKI Jakarta provincial environmental service and has been operating since 1989. Bantargebang TPST has an area of 110.3 hectare (ha) with an effective area of 81.92 ha, and the remaining 18.09 ha is used for supporting facilities such as entrances, offices, and leachate processing installations. The effective area of the TPST area is divided into five zones, namely zone 1, zone III, and zone V are still active zones to accommodate waste every day, while zone II and zone IV are inactive zones (DLH DKI, 2019). The active zone will be filled if the previous zone is full and closed. Bantargebang TPST receives 7 000-7 400 tons of waste/day.

From the results of a study conducted by the DKI Environmental Agency in 2019, the current amount of waste in all landfill zones is 6 307 028.79 m^3 (DLH DKI Jakarta, 2019b), so the estimated age of Bantargebang TPST is 43 years. This means that in the year of 2034 the Bantargebang TPST will no longer be able to accommodate waste. So action is needed to reduce waste in landfills at Bantargebang TPST (DLH DKI Jakarta, 2019b). Application of the transport and disposal method to landfills will increase pollution at landfill sites

(Wirendeni, 2020). The existence of the landfill causes several environmental problems such as global warming, acidification of water and soil, degradation of ecosystem quality, and pollution of surface water and groundwater (Zhou *et al.*, 2015).

Most of the waste that enters Bantargebang TPST is piled up at the disposal point in each zone, so this can lead to new problems, namely the fullness of the entire stockpile zone in Bantargebang TPST so that it cannot be reused for landfill area. One thing that must be done in every zone that has been filled and closed is rehabilitation to improve the environmental quality of the zone. The existing zones, there are three active zones (zone I, zone III, and zone V) and there are 2 inactive zones (zone II and zone IV) (Ministry of Environment and Forestry, 2017 in DLH DKI Jakarta, 2019b). This is done not only to restore the function of zone as land but also to allow for land reuse as a candidate for a new waste zone. Implementation of the re-utilization of old zone, which is an inactive zone, namely zone II and zone IV that has been full, the right technology is needed so that the zone to be rehabilitated has the capability of being like new land, and in operation, it will not cause losses.

One technology that can be done is landfill mining. Landfill mining operations depend on intrinsic and extrinsic parameters of the landfill. RDF's utilization is expected to reduce land, reduce GHG emissions, and reduce water bodies' pollution by leachate from landfills. However, the use of RDF to date has not shown encouraging results (Suryawan *et al.,* 2021). Intrinsic parameters are internal landfill conditions such as area, location, age, type, and waste composition. Meanwhile, extrinsic parameters are external conditions such as the availability of suitable technology, economic constraints, and social conditions. These two parameters influence each other and are equally important (Wahyono *et al.*, 2019).

The results of studies related to landfill mining at the Bantargebang TPST, especially in zones IV that have been carried out previously, show that landfill mining activities can provide benefits, namely in providing land that can be reused and also the potential for utilizing mining waste. Management of the closed heap zone can also be carried out by changing the function of the embankment into green open land and can be used as a recreational park. Management of landfills by reprofiling can improve aesthetics and increase the safety of embankment slopes. The management of all landfill zones in the Bantargebang TPST is one of the efforts to improve and optimize the existing landfill land (Mahyudin, 2017).

In carrying out this study, it is necessary to collect primary and secondary data in several stockpile zones that can provide an overview of the recommendations for the management of the stockpile zones in the Bantargebang TPST, both management with landfill mining technology, reprofiling, as well as the transfer of function/reuse of existing landfill land is no longer operating. MSW stockpiles in the Bantargebang TPST cannot be used as an alternative fuel directly in the cement industry because the condition of the waste entering the TPA is heterogeneous waste which will affect the combustion process in the cement industry. In order to be used as an alternative fuel in the cement industry, segregation must be carried out to separate waste that still has an economic value, such as metals, soil, and rock minerals (inert) which can be reused as a landfill cover and waste that has no economic value in the form of organic waste, and non-organic such as wood and rubber (Tchobanoglous dan Kreith, 2002).

Highly biomass in the composition of waste in Indonesia makes RDF production as an alternative for urban waste management. Refuse Derived Fuel (RDF) is an alternative fuel derived from residues or materials that have a high calorific value. To obtain RDF with a high calorific value, it is also necessary to have raw materials that also have a high calorific value. Therefore, to assess the utilization of waste from the Bantar Gebang Landfill Mining (DLH DKI Jakarta, 2019b). The type of waste that has been sorted and has no economic value can be used as RDF. The utilization of waste into RDF as an alternative fuel in the cement industry not only reduces pollution caused by waste but also reduces landfill operational costs (Reza *et al.,* 2013).

This method is able to reduce the amount of waste that is disposed of in the Bantargebang TPST so that the utilization of waste into RDF can be an integrated part of the waste management system. The activity of utilizing MSW in RDF requires information on the specifications of waste that can be used as RDF.

Composition data from MSW that goes to the Bantargebang TPST and its production process into RDF certainly requires further data and research. Furthermore, the use of RDF in the cement industry also requires data related to the calorific value, moisture content and other chemical parameters as well as their relationship to combustion quality in the form of calorific value analysis and emission tests of each composition in the combustion process (Dianda *et al.,* 2018).

Several regions in Indonesia have also implemented landfill mining techniques as a solution to the limitations of TPST land and to utilize landfill mining waste. Areas that have implemented landfill mining are Aceh and Bali. In the city at emerging countries such as Banda Aceh, landfilling is still the main method for waste management. Moreover, the landfilling of waste was carried out without any pretreatment since the waste management alternatives mentioned above are associated with costs that are beyond economic capacities. In addition, Banda Aceh also faced a problem with available energy due to a lack of natural resources for energy production. Therefore, the refuse derives fuel (RDF) is a potential municipal solid waste treatment option which is can solve both the waste management problem and energy shortage.

Thus, the objective of this study is to produce RDF from high organic and moisture contents of MSW, characterize its properties, and investigate the composition of organic waste suitable for RDF production. The finding of this study is significant for waste management development, particularly in developing countries (Dianda *et al.,* 2018). The problem of municipal waste in Bali is also a serious problem, one of the actions taken is to process waste in a sustainable manner, namely by utilizing waste into RDF and building an RDF Plant. Before carrying out waste management into RDF, it is necessary to carry out a catastrophic test because each region has a diverse composition of waste. In Bali, processing waste into RDF can provide benefits and contribute to meeting the MSW reduction target, supporting the use of renewable energy, and reducing greenhouse gas emissions (Suryawan *et al.,* 2021).

Other studies that have been conducted on the use of waste in landfill mining have been carried out in Brazil, Russia, India, China and South Africa (BRICS). In Brazil and South Africa, 100% of the waste collected goes to landfills. In India 91%, Russia 95% and China 79% waste is dumped in landfills (Figure 1). Disposal of Municipal Solid Waste (MSW) through landfill is commonplace in low and lower middle income countries. Waste in this landfill is certainly dangerous for the environment and health. Figure 1 shows the percentage of waste generation and landfill disposal in several countries.

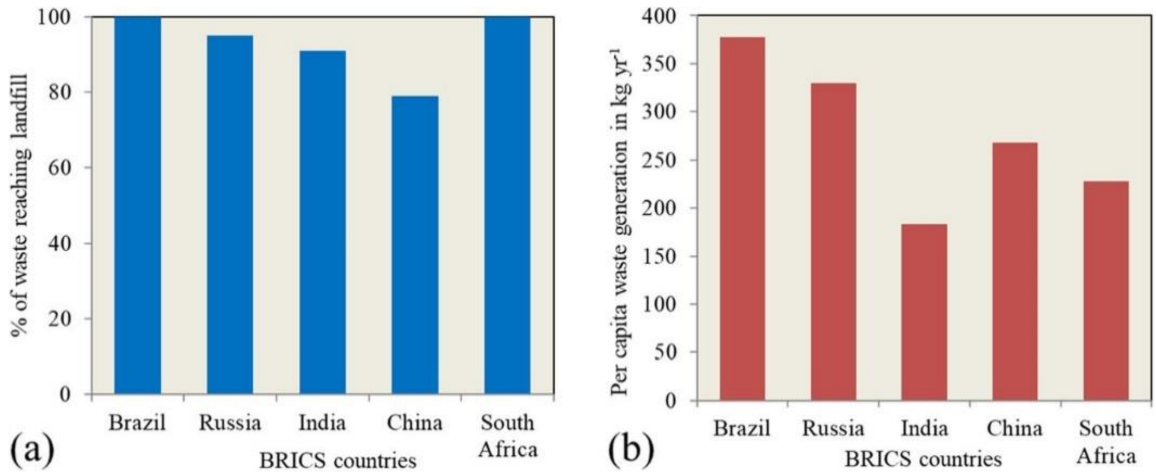


Figure 1 (a) Percentage of waste reaching landfills and (b) Per capita waste generation in BRICS countries (Source: Cheela *et al.*, 2020)

The result of the study is that the energy potential of the landfill is determined based on the physical and chemical characteristics of the waste. Moisture content and percentage of contamination increased with the increasing age of the waste. Comparing the physical chemical characteristics of landfills. Landfills can be considered as resource reservoirs for future energy generation. Reclamation of the waste material from these landfills increases the life of the landfill and reduces the usage of non-renewable energy sources in energy production. The composition and characteristics of aged waste play a key role in designing the treatment systems for waste recovered from landfills (Cheela *et al.,* 2020).

METHOD

Location and Research Time

Field research was carried out at the Bantargebang TPA, Bantargebang District, Bekasi Regency, in October until November 2018. Sample testing was carried out in the laboratory.

Data Collection

Prior to carrying out landfill mining, a field survey was conducted. Data collection methods are divided into two, namely primary data collection methods and secondary data. Primary data is done by collecting through field surveys. There are two main surveys that must be carried out, namely the survey of land measurements (topography) and soil investigation. After the survey results are obtained, then the analysis of the piece of land and the bearing capacity of the soil can be carried out. From the analysis of the piece of land, the volume of cut and fill (dug and heap) of waste can be calculated, which leads to information about the need for heavy equipment and implementation time. Then, based on the analysis of the carrying capacity of the soil, it can be calculated, and the mechanics of the waste during the excavation process can be determined.

Mining Process

Landfill mining is carried out in several ways, with a specific approach based on the objectives of the activity and the characteristics of the land. The equipment used for landfill mining activities is adapted from technology already used in the mining industry, such as during construction and other waste management operations.

Equipment and Machinery

The following machines were added sequentially to increase mining complexity, excavators, conveyor belts, coarse rotating trommel screens, fine rotating trommel screens, magnets, wheel loaders, and odor control sprayers. Excavators or loaders are used to mine landfill material and place the mining products onto a conveyor belt for further entry into the sorting machine. The sieving machine is used to separate materials based on their size. First, a large sieving machine separates materials such as tools and cloth. A small sieving machine then passes the decomposed soil fraction to leave larger or recyclable materials for collection. An electromagnet is used to remove ferrous material from the waste as it passes through the conveyor. Loaders are used to move the sorted material to trucks for further processing (re-landfilling or recycling). As for the odor control sprayer, a wheeled tractor is equipped with a cover and an arm that has a rotating sprayer. A large reservoir filled with liquid to reduce the odor generated by the excavated garbage.

Excavation and screening excavators dig up waste and move it with the help of a wheel loader which will carry the waste to a conveyor belt. The conveyor belt will deliver the waste to the sieving machine for screening. The size and type of sieve used depends on the expected final yield of the material being mined. When the materials have been separated from the sieve, they are fed to a second conveyor belt where the ferrous materials are separated due to the presence of a magnet. Mining waste samples were taken from the location, precisely in zone IV TPA Bantargebang Bekasi, where this zone is an inactive zone for 10 years. Landfill mining is carried out when cells are inactive for at least 7 years. So that the zone is potential when viewed from the age. Zone IV TPA is the zone that has the most potential for landfill mining because of its location at the corner of the road and far from the active zone, so that waste is unloading in the active zone.

Samples were taken randomly with an excavator. Waste samples from each point were taken as much as 350 kg. The total sampling points were 8 points which were carried out on four landfill applications. The waste is then filtered using a rotary screen and separated according to its size, namely diameter <30 mm, 30-50 mm, 50-100 mm, and >100 mm. The filter waste is then manually sorted into several types of waste (plastic waste, wood, cloth, rubber/leather, metal, glass, and others). Waste that has been separated is measured by weight and volume.

Data Analysis

Generated data from the calculation results were analyzed using a quantitative approach. Descriptive analysis was conducted to describe the data collected through existing standards. After that, the data is compared with the standard requirements for the utilization of landfill mining results as a substitute fuel. Non-active zone where landfill mining will be carried out in zone IV. Zone IV is a zone located at latitude coordinates: 6^{0}21'28.688"-6^{0}20'20.184"N; Longitude:106^{0}59'32.858-107^{0}00'13.258”E (Figure 2) (DLH DKI Jakarta, 2019b).

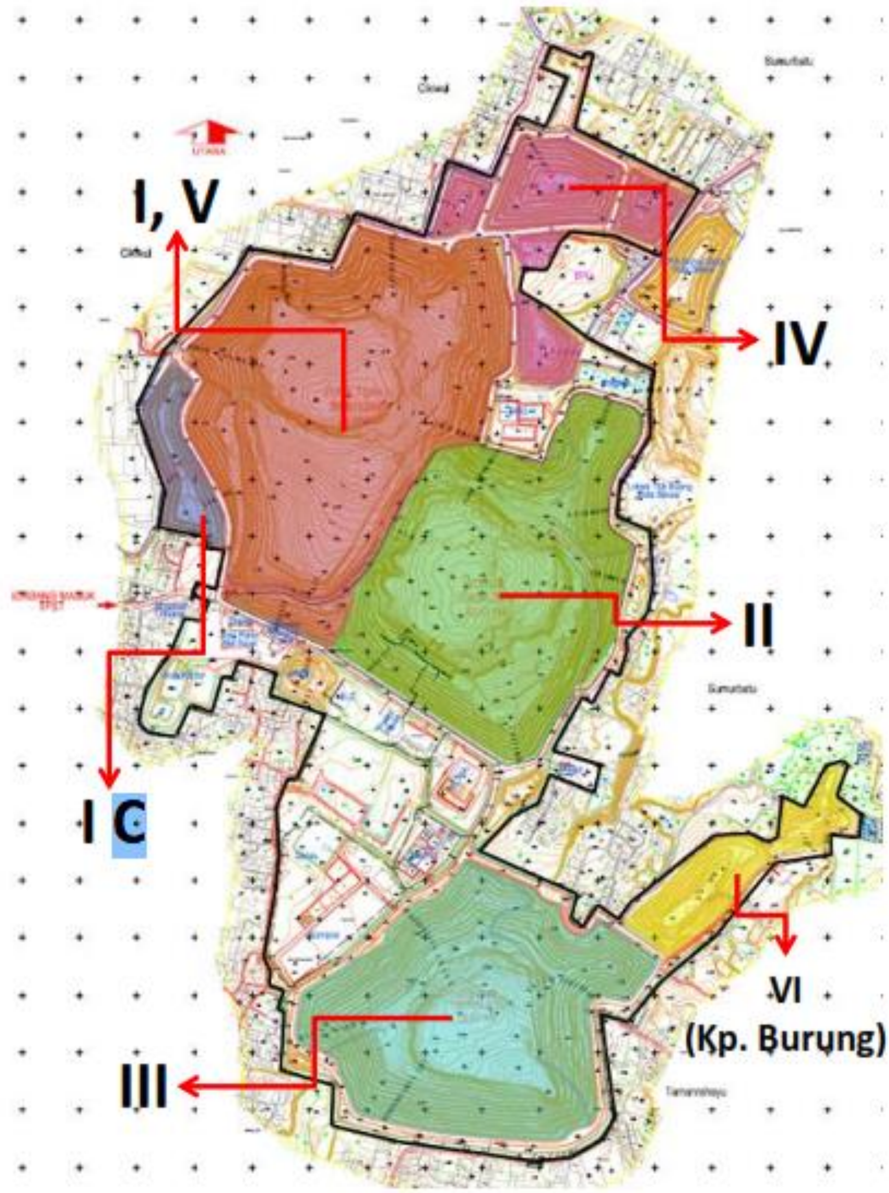


Figure 2 Municipal solid waste disposal zone at TPST Bantargebang

RESULT AND DISCUSSION

TPST Bantargebang is located in the Ciketing Udik Village, Cikiwul Village and Sumur Batu Village, Bantargebang district, Bekasi City. TPST Bantargebang started operating in 1989. The volume of waste that enters the Bantargebang TPA is an average of 6 500-7 000 tons/day, TPST Bantargebang has an initial land area of 110.3 ha consisting of an effective TPST area of 81.91% and the remaining 18.09% For infrastructures such as entrances, office roads, and leachate processing installations. TPST Bantargebang is located in a relatively bumpy area and is directly adjacent to the industrial area and residential area. The land height of the Bantargebang area is 25-100 m.

TPST Bantargebang accommodates various types of waste, which are then piled on the ground. Garbage disposal sites are categorized as open disposal systems so that they have the potential to cause environmental pollution such as air pollution (dust, odors, and greenhouse gases), as well as water and soil pollution due to leachate generated from piles of garbage. Leachate can spread on the ground surface so that it can contaminate surface water and groundwater (including well water around the landfill). The composition of the pollutants in waste water (leachate) was strongly influenced by the characteristics of the waste (organic-inorganic), age of the landfill, ease of decomposition (soluble-insoluble), characteristics of waste pile (temperature, pH, humidity), characteristics of the water source (water quantity and quality that are affected by climate and hydrogeology), soil cover composition, nutrient availability, microbes, and presence of inhibitors. Chemical composition resulting from leachate and pollutant concentrations varies for each landfill site. Table 1 below shows Waste capacity for each application in the IV landfill zone.

Table 1 Waste capacity for each application in the IV landfill zone

Number	Location	Coordinate		Capacity	Unit
		E	N		
1	Land 1	720602.6477	9297814.778	86 691.18	m^3
2	Land 2	720573.5401	9298172.934	29 995.68	m^3
3	Land 3	720935.7848	9297292.519	12 364.24	m^3
4	Land 4	720895.3478	9298401.802	11 331.08	m^3

Source: Bantargebang TPST calculation, 2018

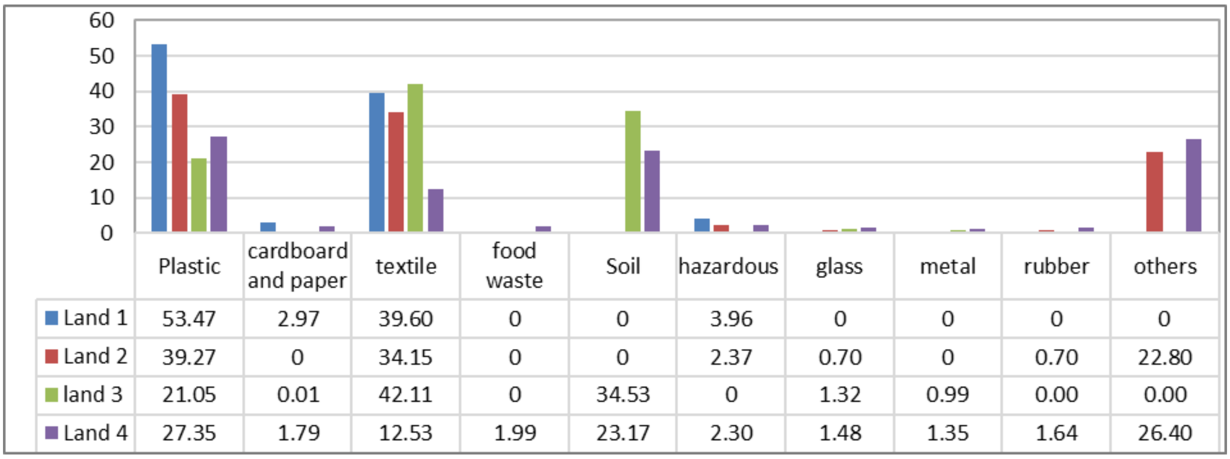
Density and Moisture Content

Garbage density is the unit weight of waste per volume. Density calculation is needed as a link between unit weight in processing units and volume units in calculating equipment and land requirements. Density measurements at 8 (eight) points in zone IV TPST Bantargebang. The density value obtained varies at each sampling point, with an average density value of 0.485 ton/m^3. This value is still within the reasonable range of density values in the landfill, which is 0.4-0.6 tons/m^3 with conventional compaction. Municipal solid waste in the Bantargebang TPST mining landfill was tested for water content. The results of the analysis of the water content that has been carried out are 48.84% w/w (DLH DKI Jakarta, 2019b).

Garbage Composition

The types of waste are divided into ten major groups, namely plastic waste, paper, textiles, food waste, soil, B3 waste, glass, metal, rubber, and others that cannot be grouped with other types because they cannot be identified both in form and type. The composition of waste based on wet weight can be seen in Figure 3.

The composition of waste based on diameter is analyzed to determine its processing potential. The grouping of waste based on diameter is based on several studies that divide composition by diameter because it can be physically observed that the remaining large waste is plastic or paper, which still has a high calorific value. On the other hand, the physical size of small waste is the result of organic waste decomposition. The recording of the percentage of waste based on its diameter can be seen in Table 2.



	Plastic	cardboard and paper	textile	food waste	Soil	hazardous	glass	metal	rubber	others
Land 1	53.47	2.97	39.60	0	0	3.96	0	0	0	0
Land 2	39.27	0	34.15	0	0	2.37	0.70	0	0.70	22.80
land 3	21.05	0.01	42.11	0	34.53	0	1.32	0.99	0.00	0.00
Land 4	27.35	1.79	12.53	1.99	23.17	2.30	1.48	1.35	1.64	26.40

Figure 3 Graph of waste composition

Table 2 Composition of waste in the landfill mining zone

Sampling Point	Trash Size Weight (%BB)				Percentage (%)
	<30 mm	30-50 mm	50-100 mm	>100 mm	
West zone I	41.46	9.761	14.63	34.15	100.00
West zone II	42.76	5.92	27.63	23.68	100.00
West zone III	46.84	12.66	24.68	15.82	100.00
West zone IV	35.07	12.69	38.81	13.43	100.00
East zone I	25.17	7.48	26.53	40.82	100.00
East zone II	28.85	8.65	44.23	18.27	100.00
East zone III	41.45	3.95	8.55	46.05	100.00
East zone IV	61.38	3.70	15.87	19.05	100.00
Rerata	40.37	8.10	25.12	26.41	100.00

Source: Bantargebang TPST calculation, 2018

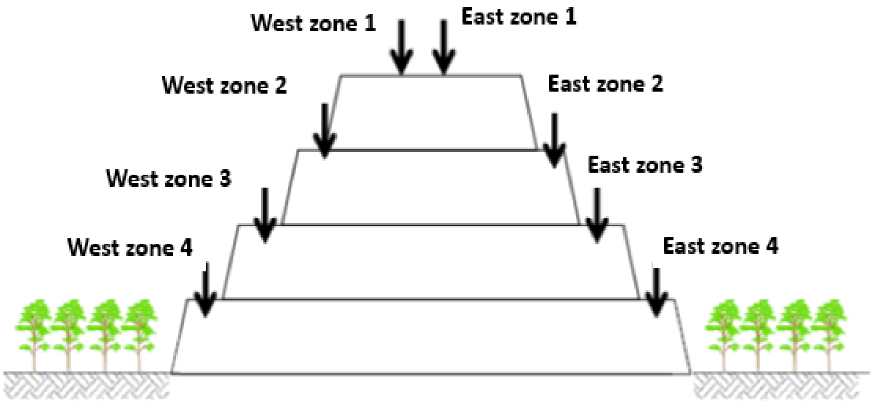


Figure 4 Landfill application in zone IV (Source: DLH DKI Jakarta, 2019b)

Diameter of the waste will be different at each stage of the landfill. This landfill stage shows the size of the waste and the physical waste from the decomposition of organic waste. In the landfill at TPST Bantargebang has four stages as can be seen in Figure 4. Based on the results of topographical measurements, height of the pile of waste from the boundary parallel to the road to the peak is 17.42 meters, with each step having a height of about 5 meters. If seen directly, the organic waste in this zone has been decomposed, as evidenced by the presence of blackish soil and very minimal odor. Remaining waste in large quantities is plastic, followed by glass, and also cloth.

CONCLUSION

Utilization of landfill mining waste is carried out by considering the processing potential and also the existing cooperation at the Bantargebang TPST. Utilization efforts are seen from the potential and target market that will be discussed, namely Refused Derived Fuel (RDF). Based on the results of the analysis carried out on the waste samples provided by the Bantargebang TPST, waste with a diameter of >50 mm. Alternative energy sources, in general, organic mass with a fraction >50 mm can be burned directly, sometimes for the fine fraction (18-50 mm) it can be used as additional fuel. Landfill mining results require a recycling equipment range tool to separate soil/compost from mixed non-organic waste. From the results of the separation, the soil/compost is further sorted into textiles, plastics, metals and glass. Sorted products from plastics and textiles can be processed into alternative fuels after drying, sizing/sizing, packaging and shipping are carried out to be sold to the industry as an alternative to fuel in the combustion process.

Good quality RDF has a high calorific value and a low concentration of toxic compounds, in this case heavy metals and chlorine (Ministry of Environment and Forestry, 2017 in DLH DKI Jakarta, 2019a). Based on the results of laboratory analysis carried out, waste with a diameter of 30-50 mm has a high water content and chloride content. This needs to be avoided in order to obtain RDF with a high heating value and low toxic compounds. Therefore, the waste that will be used as raw material for RDF is waste with a potential high calorific value, low water content, and low chloride content, namely waste with a diameter of >50 mm. Based on the analysis carried out, the following recommendations can be given regarding the treatment of zone IV TPST Bantargebang waste as raw material for RDF: a) Pretreatment is needed to reduce the moisture content, alternatives that can be done are chopping and drying mechanically; b) The use of waste with a particle diameter of >100 mm or mixing with a certain ratio of the amount of waste is more recommended because it has a high calorific value and low ash content; c) Removal of B3 materials is required to remove chlorine and other toxic compounds.

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