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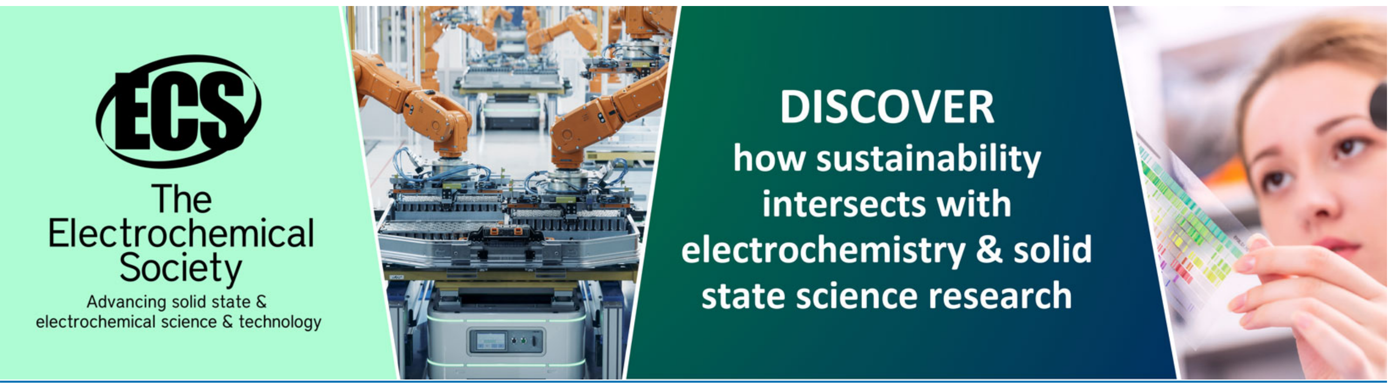

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Analysis of Potential Utilization of Landfill Materials (Case Study: Sumur Batu Landfill, Bekasi)

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Abstract. One of the efforts to overcome the critical problem of land usage for landfill and regenerate waste is to reuse the expired landfill after managing them. The purpose of this study is to determine the potential utilization of waste from landfill mining activities. At 15 sample depth points in zone 1 of Sumur Batu Landfill from 2004-2007 waste, the composition of mining landfill waste consists of 29% soil/organic fraction; 25% other waste; 23% plastic; 11% overburden; 5% diaper waste; 2% cloth; 2% wood; 1% glass; 1% rubber; and 1% metal. The particle size of the landfill waste has a diameter distribution of >38.1 mm to <2mm which is almost evenly distributed with values ranging from 9-20%. The calorific value of combustible waste is 3,569.47 kcal/kg. The chemical characteristics of the landfill soil mining fraction consisted of C-Organic 29.55%, NTK 0.65%, C/N 29.59, and Total-P 22.84%. Dosage variation of landfill mining soil fraction as a planting medium with soil used for research, respectively 1:4, 1:5, and 1:6, and soil with Bokham compost as control. The use of landfill soil fraction as a planting medium with 3 types of soil, namely clay, laterite, and acid clay causes a decrease in the growth of mung beans (Vignaradiata L.). However, the 1:4 landfill soil fraction dose gave a positive response to the physiological observations of plants compared to the other two doses of variation. The potential for landfill waste is 100,000 tons, the total cost of landfill mining activities is Rp. 25,829,996,775, and the total benefits of landfill mining activities are Rp.26,347,223,544, with the use of combustible waste to produce electricity and/or heat using an incinerator, the benefit ratio value is 1.02 which is means that the activities of the Zone 1 of Sumur Batu Landfill is feasible to carry out. Based on these data, with organic waste as the dominant waste in the Sumur Batu Landfill, the best possibility in utilizing waste is to use the waste as soil fertilizer.

1. Introduction

The handling of waste at the Sumur Batu Landfill still relies on landfills, which can have bad consequences because eventually, the landfills will be out of capacity. One of the efforts to overcome this problem is by reusing landfills that have expired. Efforts to reuse landfills begin with gas and landfill material extraction activities or usually called landfill mining. Landfill mining is the process of extracting solid materials or natural resources from waste materials that were previously dumped in the landfill [1]. Another definition of landfill mining is the excavation and removal of material from landfills for the purpose of recycling, reuse, and composting [2]. This includes the efforts to recover materials and their processing and reuse the land as a new landfill. Landfill mining studies in various countries show that different landfill conditions have different potentials related to landfill mining [3].

Waste that is operated in open dumping and has been piling up for a long time can be utilized and made into landfill mining compost by carrying out a series of activities such as excavation, the

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process of enumeration, filtering and reuse of materials [4]. Waste that dominates the composition of waste in the Sumur Batu Landfill is 58.56% of putrescible waste such as leaves and food scraps that have the potential as landfill mining compost. Passive landfills require revegetation [5]. This is done to speed up the recovery process and reduce odors in the former landfill. Soil fraction from landfill is estimated to contain high heavy metals which can affect revegetation. To determine the quality of the landfill soil fraction and improve soil quality, it is necessary to conduct research on the effect of soil type and landfill soil fraction on plant growth [6], which in this study used mung bean (Vigna radiata L.).

Landfill conditions are constantly undergoing chemical and biological degradation of degradable organic substances (such as paper or textiles) which are under aerobic or anaerobic conditions which are converted into carbon dioxide, methane and water. This degradation process can cause different potential resources available in landfill [7]. So it is necessary to analyze the composition and sieving test to determine the potential contained in the Sumur Batu Landfill. Sumur Batu Landfill waste has the potential to be reused due to the large volume of landfill and various waste compositions that are still of economic value.

2. Methodology

2.1. Preliminary Stage
At this stage, a literature study is carried out as a basis for reference and seeking knowledge about the utilization of landfill waste. Secondary data collection was obtained from the Sanitation Service of Bekasi City. The data used is an overview of the study area, the location of the landfill, the location of the landfill, and other related data

2.2. Landfill Waste Composition and Particle Size Testing
Waste sampling was selected in the passive landfill zone 1 of Sumur Batu Landfill. Sampling was carried out using a drill at one point with a depth of 15 meters and the test was divided into each meter. Then the samples were taken to the laboratory for analysis of particle composition and size. Waste samples are air-dried by turning them periodically. The sieving test was carried out to measure the size of the waste particles using five mesh screens with sizes of 38.1 mm, 25.4 mm, 12.7 mm, 4.75 mm, and 2 mm, then each size was determined by the percentage of each and the composition of the solid waste which is divided into 16 types of waste, namely soil/organic fraction, twigs/wood, PE plastic, crackle plastic, PP plastic, HDPE plastic, PVC plastic, PS plastic, glass, nappies, rubber, cloth, cans/iron, hazardous waste, soil cover, and other waste.

2.3. Measurement of Proximate Analysis and Calorific Value of Landfill Waste and Characteristic Testing of Landfill Mining Compost Fractions
This study carried out proximate measurements and ultimate analysis shown in Table 1.

Table 1. Measurement of proximate analysis, calorific value, RA_4 value, ultimate analysis, and waste metal content

Parameters	Unit	Methods
Proximate		
Water Content	%	ASTM D 2216-98
Ash Content	%	ASTM D 2216-98
Volatile Content	%	ASTM D 2216-98
Fixed Carbon	%	ASTM D 2216-98
Calorific Value	kal/gr	Bombcalorimeter
RA_4 Value	mgO_2/gr dw	OE-NORM S2027-4
Ultimate		
C-Organic	%	Walkley&Black
NTK	%	Kjeldahl
P-Total	mg/kg	Bray

Metal Content	mg/kg	AAS

Measurements of proximate analysis, particle size, calorific value, ultimate analysis (C-Organic, NTK (Nitrogen Total Kjeldahl), P-Total), metal content and RA_4 were carried out at the Solid Waste and Hazardous Waste Laboratory of Environmental Engineering Study Program of ITB.

2.4. Stage of Utilization of Landfill Mining Soil Fraction as Planting Media

At this stage the objective is to observe the utilization of landfill mining soil fraction in improving soil quality. The study was conducted using landfill mining soil fraction as a planting medium and to determine its effect on growth and metal content contained in certified mung bean (Vigna radiata, L.). Here are the steps:

1. Soil Preparation
   Preparation of soil and planting media by taking the soil determined from various points that represent the area and measuring the soil pH using a soil pH meter for the field, then the soil is air-dried, and a preliminary analysis of the soil is carried out.
2. Selection of Seeds and Nurseries
   The selection of seeds to be planted is done by soaking the seeds, the floating seeds are discarded and the sinking seeds are used when planting. Seedlings are carried out in containers containing soil media with 5 seeds planted per planting hole.
3. Planting
   The planting media consisted of three types of media, namely, media 1 (M1): a mixture of clay and soil fraction from the Sumur Batu Landfill, (M2): a mixture of laterite and soil fraction from the Sumur Batu Landfill, and (M3): a mixture of clay. acid clay and soil fraction from Sumur Batu Landfill, while for (M0): a mixture of untreated soil media, then a mixture of soil media and bokham compost as a control. Preparation of 200 grams of soil and variations in the dose of soil fraction 50 grams (1:4), 40 grams (1:5), and 33 grams (1:6). The treatment was carried out in duplicate and carried out in the Greenhouse in Solid Waste and Hazardous Waste Laboratory of Environmental Engineering Study Program of ITB. The dose of soil fraction from landfills and the three soil types is shown in Table 2.

Table 2. Variation of soil fraction mixture from landfill and soil media

Soil Types	Soil fraction/*soil-type* in Landfill				Compost BOKHAM
	K0 (blank)	K1 (1:4)	K2 (1:5)	K3 (1:6)	KK (Control)
M1 (Viscous)	M1K0	M1K1	M1K2	M1K3	M1KK
M2 (Laterite)	M2K0	M2K1	M2K2	M2K3	M2KK
M3 (Sour-Viscose)	M3K0	M3K1	M3K2	M3K3	M3KK

4. Observed Variables
   The variables observed were growth response: plant height (cm) was measured every day starting from 3 DAP (Day After Planting) to 3 WAP (Week After Planting), number of leaves (strands) and root length at 3MST.

5. Laboratory Analysis
   The parameters measured were the heavy metal content of the landfill soil fraction as a whole, 3 types of soil, mung bean plants resulting from planting using a mixture of soil media and landfill soil fraction.

2.5. Cost Benefit Analysis of Landfill Mining Activities in Zone 1 of Sumur Batu Landfill

At this stage, an analysis is carried out and a product is produced in the form of an overview of waste utilization, a budget plan, as well as operational and maintenance standards and then analyzed by Benefit Cost Ratio (BCR) analysis and conclusions are drawn from the results of the analysis. The initial analysis used categories obtained from the United States Environmental Protection Agency

(EPA). The benefit analysis falls into two main categories: benefits associated with more efficient landfill operations and benefits resulting from recycling and reusing landfill land. Cost analysis is divided into capital costs and operational costs.

3. Results and Discussions

3.1. Analysis of the Composition of Landfill Mining at Sumur Batu Landfill

Composition data is used to determine the potential utilization of each type of waste contained in landfills by knowing the weight percentage of the waste composition in question from the total weight of the sample. From the measurement data per waste composition, the average composition of each type of waste is obtained. This average is used to provide an overall picture of the composition of the waste contained in the test location, namely the Zone 1 landfill.

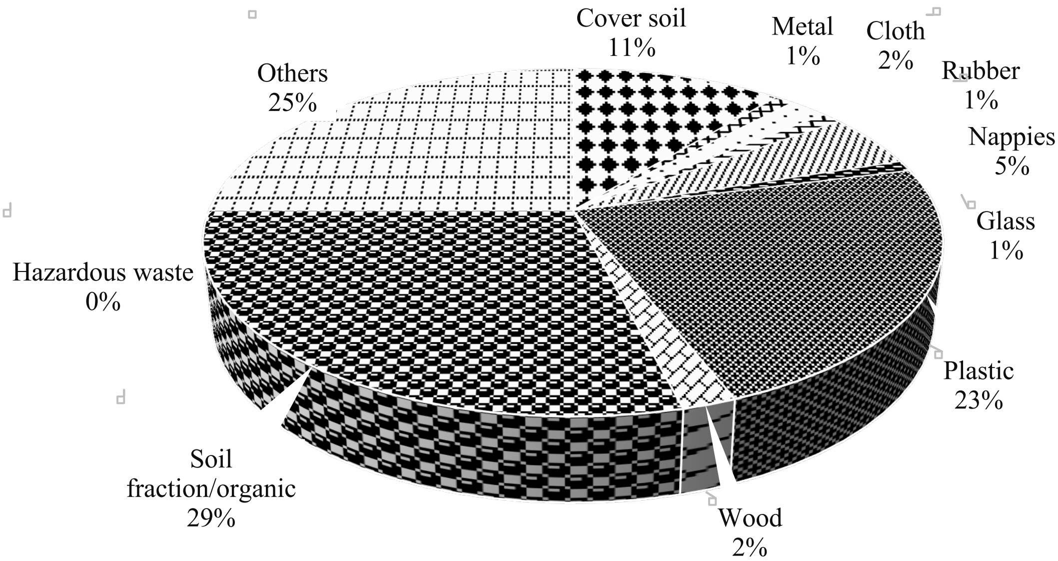


Figure 1. Composition of zone 1 landfill waste at Sumur Batu Landfill

Figure 1. shows the average composition of landfill waste in Zone 1 of Sumur Batu Landfill from the fifteen depths. Landfill Mining research at a landfill site in Belgium showed that the average content of organic fraction or "fine soil type fraction" in domestic waste from 1980-2000 was 40-60% and plastic waste was 10-25% [3]. If the definition of the fine soil type fraction from this research applied to the results of the composition of the waste heap at the Sumur Batu Landfill which is a combination of organic fractions/compost and other waste which is a combination of small material fractions that can be compared with the results obtained by the research, which is still between this range with 54%, and the percentage figure for the amount of plastic in the Sumur Batu Landfill is also still between that range with 23% [3].

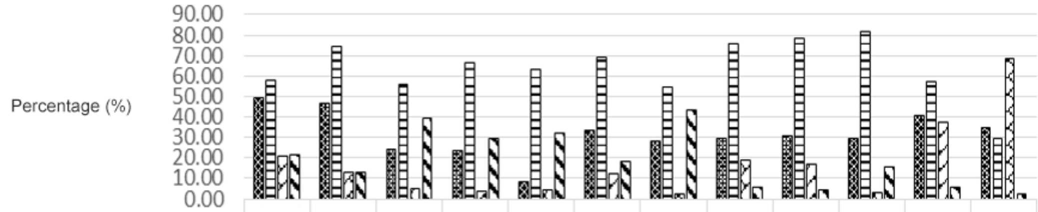
The results of the study indicate that the deeper the sampling depth, the higher the amount of organic/compost composition. The highest plastic composition is at a depth of 3 meters, which is 46.29%, while the lowest plastic composition is at a depth of 15 meters at 0.04%. The deeper the sampling depth, the lower the amount of plastic composition. This is supported by a research at the Cipayung Landfill, Depok. The results of the composition of soil/humus content are more commonly found at a depth of 4-6m from the bottom of the landfill waste pile, the plastic composition results are at a depth of 8-10m from the bottom of the landfill waste pile [8].

3.2. Size of Landfill Mining Waste in Sumur Batu Landfill

Particle size is one of the physical characteristics that need to be known in determining the processing and recycling of waste and the pre-treatment that can be carried out, especially in recycling waste into RDF and compost. In waste >38.1 mm in size, the composition of waste is more diverse than other sizes, but if accumulated, nappies and plastic each contribute the largest percentage to this size waste with values of 29.09% and 26.62%. In a 2 mm sieving, 100% of the waste that passes is only in the form of compost/fine soil type fraction. These results are also in accordance with the research conducted by Prechthai et al. (2008) who measured Landfill Mining waste with sieve sizes of 25 mm and 50 mm. At size >50 mm, there is only 14% compost/fine soil type fraction but at opening size 25 mm-50mm, the percentage of compost/fine soil type fraction increases to 47.3% [9]. The average particle size distribution depends on the sampling depth. The deeper the sampling depth, the less the amount of waste composition with a size of > 38.1 mm. Conversely, the deeper the sampling depth, the more the amount of waste composition with a size of <2mm increases. The distribution of the particle size of the waste in the Zone 1 of Sumur Batu Landfill has an almost uniform diameter distribution with values ranging from 9%-20% for each particle size tested.

3.3. Proximate Analysis, Calorific Value, and RA4 Value in Waste at Sumur Batu Landfill

In this study, a proximate analysis test was carried out as shown in Figure 2 for the zone 1 of Sumur Batu Landfill waste sample.



	Soil Fraction / Organic	Wood	Plastic PP	Plastic PE	Plastic HDPE	Plastic PVC	Plastic Bags	Rubber	Cloth	Plastic PS	Nappies	Others
Water Content (%wet weight)	49.17	46.91	24.05	23.27	8.53	33.48	28.18	29.75	30.80	29.34	40.84	34.92
Volatile Content 550 (dry weight)	57.81	74.44	56.02	66.66	63.29	69.06	54.83	75.76	78.38	81.50	57.25	29.14
Ash Content 850 (%dry weight)	20.97	12.73	4.71	3.87	4.32	12.39	2.13	18.65	17.15	3.06	37.17	68.72
Fixed Carbon (%dry weight)	21.22	12.83	39.26	29.47	32.39	18.54	43.04	5.58	4.47	15.44	5.59	2.14

Waste Composition

Figure 2. Proximate levels of landfill waste at zone 1 of Sumur Batu Landfill

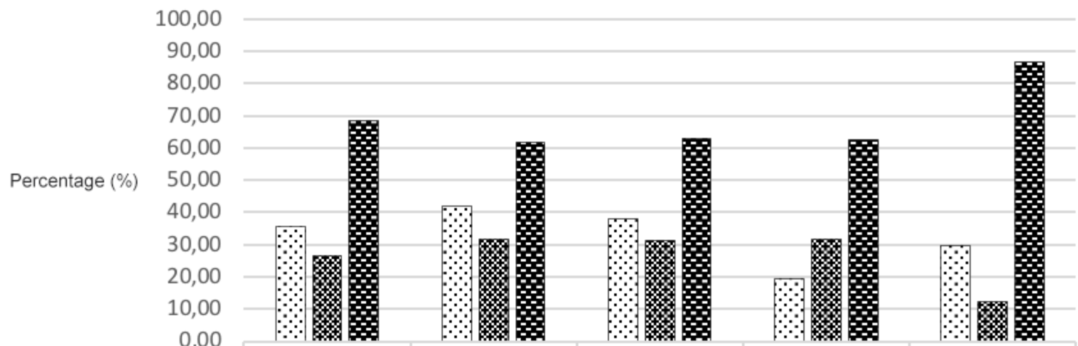
The water content of the sample is divided into two, namely waste samples before drying and after drying at a temperature of 20-30ºC. Prior to drying, waste was difficult to identify so that in some samples no specific composition was found. After drying, the water content of the sample, especially plastic, decreased by about 58%. The highest water content was found in the soil/organic fraction at 49.17% and the lowest water content value was HDPE plastic at 8.53%. Water content affects the measurement of calorific value, especially the value of LHV (low heating value). The highest volatile level is found in PS plastic at 81.50% and the lowest is in other waste at 29.14%. The composition of other waste has a low volatile content because it consists of soil-type fraction, which tends to be difficult to burn. The highest volatile content in general is plastic waste. Volatile levels greatly affect whether or not the waste is burned in the incinerator. The higher the value of volatile content, the easier it is for the waste to be burned [10]. The highest ash content was found in other waste at 68.72% and the lowest was found in plastic crackers at 2.13%. The value of ash content that is allowed as an RDF quality standard is below 20% dry weight [11]. The highest fixed carbon content is found in plastic at 43.04% and the lowest is in other waste at 2.14%. This is in contrast to the literature [10] who stated that plastic waste generally has an average fixed carbon content value of <0.1%. This may be due to the fact that the plastic waste has undergone a long-term physicochemical reaction process, and the soil fraction attached to the plastic waste.

The landfill waste fraction >50 mm consisting of the majority of paper, wood, and plastic, the calorific value obtained was 1,673 kcal/kg or higher [2]. When viewed from the substitution LHV value, the combustible landfill mining waste at Sumur Batu Landfill has a higher calorific value than that figure, which is 3,569.47 kcal/kg which meets the RDF requirements (3,105-3,821.5 kcal/kg) and incinerator combustion (≥2,200 kcal/kg).

3.4. Analysis of Sample Characteristics <2mm

The first time the proximate analysis test shown in Figure 3 was carried out for samples <2 mm from landfill zone 1 which was divided every 3 meters from a depth of 15 meters. The highest water content is at a depth of 4-6m and the lowest is at a depth of 10-12m. The highest volatile content is found at a depth of 10-12m and the lowest is found at a depth of 13-15m. The highest ash content is at a depth of 13-15m and the lowest is at a depth of 4-6m.

The ultimate analysis measurement shows that the C-Organic content is around 19.78-37.89%. The measured levels of C-Organic from excavated waste ranged from 14.6-21% and the number decreased with increasing depth. The NTK content ranges from 0.29-1.58%, the highest at a depth of 10-12 meters [9]. Based on another research, the value of NTK in waste at the Cipayung Landfill ranges from 0.53-1.8% and the number decreases with increasing depth. The C/N ratio ranges from 12.55-124.53%, the average of the five monitoring points is 63.77% which is high compared to the C/N ratio value of material <2mm at Cipayung Landfill of 44.72% [8], which indicates incomplete degradation process or low nitrogen content. P-Total levels ranged from 18.30-27.03%, the highest at a depth of 13-15m. One of the material requirements (compost or biodegradable municipal waste) as a landfill cover must be stable by showing a respiratory activity value of <7 mg O_2/gr dw [12]. The results of the analysis of compost samples from landfill mining at Sumur Batu Landfill are in the range of 0.14-1.46%, which means that the condition of the soil fraction is very stable.



	I (1-3)	II (4-6)	III (7-9)	IV (10-12)	V (13-14)
Water Content (%wet weight)	35,47	41,84	37,84	19,24	29,66
Volatile Content (%dry weight)	26,43	31,49	31,26	31,74	12,47
Ash Content (%dry weight)	68,32	61,83	62,80	62,38	86,53

Depth of Samples (meter)

Figure 3. Proximate content of soil fraction sample <2 mm in Sumur Batu Landfill

3.5. Analysis of Growth and Response of Green Bean Seed Growth

Seed germination aims to show the percentage of germination yield of plants on the planting medium. Seed germination is carried out at 1WAP (Week After Planting) by calculating the number of seeds that grow from all planting holes to the total number of seeds planted. In general, the use of landfill mining soil fraction from Sumur Batu Landfill as a planting medium with 3 types of soil causes a decrease in seed germination. This can also be compared with the research results that use the Klotok Kediri Landfill's soil as a medium for growing Trembesi plants also causes a decrease in plant growth. The application of NPK and the addition of compost can increase the ability to grow Trembesi [13].

The study was conducted using a factorial randomized block design, which consisted of 2 factors with 2 replications. The first factor is 3 types of soil, while the second factor is 3 variations in dosage of landfill mining soil fraction. The results of plant physiological observations on variations in the dose of landfill soil fraction were tested by the Anova test and Duncan's test, namely only the number of leaves that had a significant effect on the dose variation of the landfill soil fraction, while plant height and root length had no significant effect, as well as the content of heavy metals cadmium and mercury contained in the green bean plant. Types of clay and acid clay, as well as 1:4 landfill soil fraction dose gave a positive response to plant physiological observations.

3.6. Utilization Potential Analysis

Some Utilization of waste heap in zone 1 of the passive area of Sumur Batu Landfill which has a volume of 244,000 m^3 or 100,000 tonnes produces three types of waste, namely organic/compost fraction, combustible waste, recyclable waste fraction, and residue [14]. The mass balance of the landfill potential and the potential utilization of landfill waste is needed to determine the quantitative potential of material recycling which is shown in Table 3. Based on these data, with organic waste as the dominant waste in the Sumur Batu Landfill, the best possibility in utilizing waste is to use the waste as soil fertilizer.

Table 3. Mass balance of waste-to-product

No	Waste Components		Waste Weight		Utilization
	Groups	Types	%	Tonnes	
1	Organic/Compost	(12,7mm-<2mm)	67.47	67,474.07	Soil fertilizer
		>12,7mm	8.32	8,320.16	Cover Soil
2	Combustible (3.569,47 kkal/kg)	Plastic	9.97	9,970.10	• RDF (3,105-3,821.5 kkal/kg)
		Nappies	4.01	4,010.37	
		Cloth	1.88	1,881.74	
		Wood	2.11	2,105.43	• Incinerator (≥2,200 kkal/kg)
		Rubber	1.32	1,320.83	
3	Recyclable	Glass	0.16	155.51	Recycling
		Metal	0.27	270.33	
4	Others (Residue)		4.49	4,491.45	Reuse as landfill
	Total		100	100,000	

3.7. Cost Analysis of Landfill Mining Activities in Zone 1 of Sumur Batu Landfill

Cost Analysis of Landfill Mining Activities in Zone 1 of Sumur Batu Landfill is shown in Figure 4.

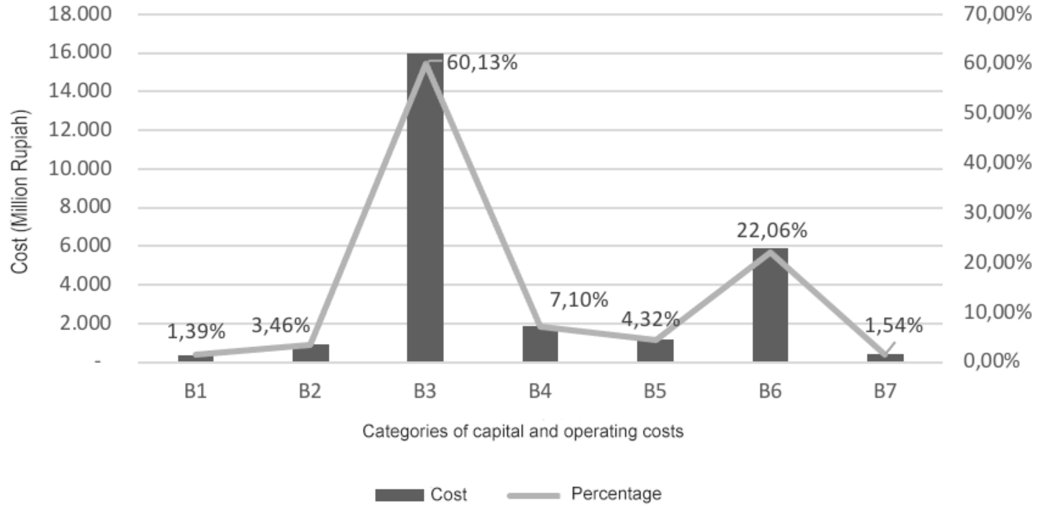


Figure 4. Comparison of cost categories from the landfill mining process in Zone 1 of Sumur Batu Landfill (Location Preparation (B1), rental or purchase of excavation and transport equipment (B2), rental or purchase of screening and sorting equipment (B3), construction or expansion of the facility material handling (B4), pre-activity research fee (B5), waste treatment fee (B6), and final waste disposal fee (B7))

The total cost of the landfill mining process in Zone 1 of Sumur Batu Landfill is Rp. 25,829,996,775 with capital costs of Rp. 18,399,295,000 and operating costs of Rp. 7,430,701,775. Based on the percentage results obtained from the total cost, the biggest cost is the cost of renting or purchasing filtering and sorting equipment by 60.13% with a price of around Rp. 16 billion. The cost analysis was obtained from the results of interviews with the Bekasi Cleaning Service, some unit cost assumptions were obtained from the research by Zhou et al. (2015) [15] which is adjusted to the Bekasi City Government Expenditure Standards for Fiscal Year 2017. In this study, with a potential waste of 100,000 tonnes assuming that the processing of 350 tonnes/day is planned for 1 year, it is known that the total Present Value Cost is Rp. 258,300/tonnes.

3.8. Benefit Analysis of Landfill Mining Activities in Zone 1 of Sumur Batu Landfill

The landfill mining process in Zone 1 of Sumur Batu Landfill with the condition of total use of combustible waste resulted in an RDF of Rp. 3,124,017,507, the total value of benefit was Rp. 24,115,860,451. In addition, the utilization of combustible waste to generate electricity and/or heat using an incinerator is Rp. 5,355,380,600, the total benefit value is Rp. 26,347,223,544, with the benefit value of landfill land reclamation of Rp. 10,050,713,800, the value of the benefit of recycling materials is Rp. 10,045. .887,337, and the value of the benefits for prevention costs obtained after the activities is Rp. 895,241,807. The analysis of the benefits of the landfill mining process in Zone 1 of Sumur Batu Landfill is shown in Figure 5.

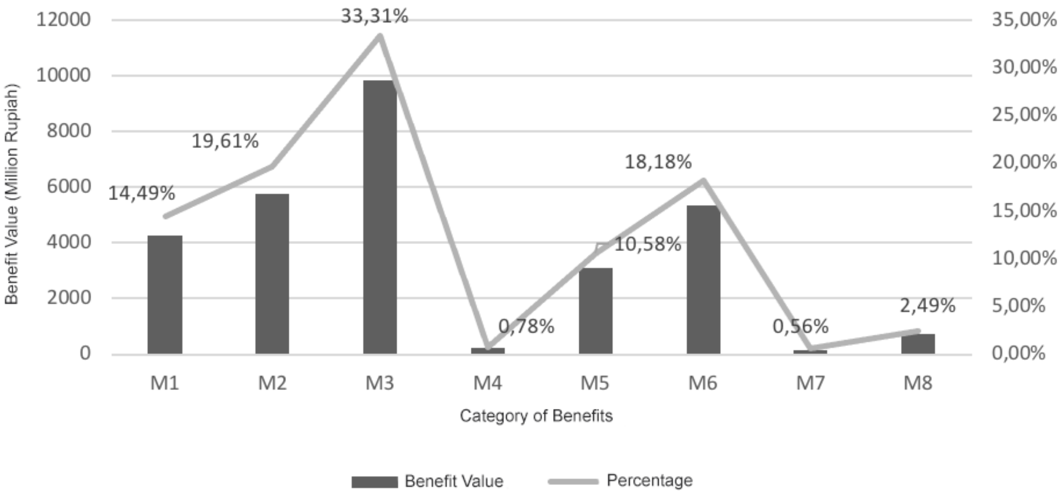


Figure 5. Comparison of benefit categories from the landfill mining project in Zone 1 of Sumur Batu Landfill (Benefits of re-availability of land (M1), benefits of availability of open space (M2), recycling of soil-type materials into overburden (M3), metal and glass recycling (M4), generate RDF from combustible waste (M5), generate electricity by burning combustible waste (M6), prevent leachate collection and treatment (M7), and prevent gas emissions from landfills (M8))

The results of the comparison of the cost-benefit value obtained by the value of the ratio of costs and benefits (B/C). Landfill mining activities in Zone 1 of the Sumur Batu Landfill show that the use of combustible waste to generate electricity and/or heat using an incinerator gives a B/C ratio value of more than 1, which is 1.02, which means that the landfill mining process in Zone 1 of the Sumur Batu Landfill is feasible to execute.

4. Conclusions

The composition of landfill waste is dominated by a combination of organic fractions/compost and other waste (54%), followed by plastic waste by 23%, and the majority of particle sizes have an almost evenly distributed diameter with values ranging from 9-20% in each particle size tested. The use of landfill mining soil fraction from Sumur Batu Landfill as a planting medium with 3 types of soil causes a decrease in seedling growth, but physiological parameters, the number of leaves have a significant effect on variations in the dose of landfill soil fraction. Potential utilization of landfill mining waste zone 1 of Sumur Batu Landfill can be implemented through waste-to-product activities (recycling of 426 tonnes of material, 19,289 tonnes of RDF/incineration production, 75,794 tonnes of soil fraction production as overburden). In a study with a potential waste of 100,000 tonnes with a planned processing of 350 tonnes/day for 1 year, the Total Present Value cost was Rp. 25.8 billion or Rp. 258.300/tonnes, and the Total Present Value Benefit was Rp. 26.4 billion or Rp. 263,472/tonnes with the condition of using combustible waste to produce electricity and/or heat using an incinerator, the cost-benefit ratio value of 1.02 is obtained, then the landfill mining activity in Zone 1 of Sumur Batu Landfill is feasible to execute, with the most feasible utilization. Based on these data, with organic waste as the dominant waste in the Sumur Batu Landfill, the best possibility in utilizing waste is to use the waste as soil fertilizer.

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