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Studies on Landfill Mining at Randegan Landfill Mojokerto, Indonesia

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ABSTRACT

The study of landfill mining is conducted in order to explore an alternative of landfill waste management to be applied to Randegan landfill, Mojokerto, Indonesia. Randegan landfill has been operated since 1990 and was originally a landfill with open dumping system. Currently, a passive waste area has formed on Randegan landfill. The purpose of the study was to identify and analyze the composition and characteristics of waste in the passive zone. The measurement of waste deposit volume was made by the Total Station equipment, while the waste composition and characteristics of in each zone was done by composite method and analyzed in the laboratory. The results of previous studies on the active zone show that the average volume of garbage landfill garbage is 213.4 m^3 / day. The study of passive waste zone shows that organic soil is a major part of the waste composition, so that a process to utilize the content of soil that formed in the waste composition is required. The results of ground investigation and analysis of waste deposit composition found that the most dominant composition of waste deposit in Zone 1 Randegan landfill at 2 meters depth is soil by 51.97%; whereas at 4 meters depth, the dominant composition is of the plastic by 38.18%, and at 6 meters depth consists of plastic by 33.30%, gravel/sand by 5.37%, organics by 59.80%, metal by 1.03% and glass by 1.5%. Research in zone 2 at 2 meters depth shows that the dominant composition is soil by 40.14% and organics by 38.95%, while at 4 meters depth consists of soil by 38.09% and organics by 53.10% and at 6 meters depth consists of a plastic by 62.95% and organics by 29.60%. Researchs in zone 3 at 2 meters depth shows that the waste composition consists predominantly of organics by 44.7% and soil by 14.29%. At the 4 meters depth, the dominant is organic composition by 39.80%, while at 6 meters depth consists of soil by 25.85% and organics by 58.50%. At the 8 meters depth, it consists of soil by 32.80% and organics by 42.96%.
Keywords: Landfill mining, landfill.

INTRODUCTION

Landfilling of municipal waste has a major impact on the environment. The major risk of water contamination due to landfills is leachate and greenhouse effects of methane emissions and effects on human health. Closed landfills will remain, generating emissions to air, soil and water if further steps are not taken. The landfill may be a threat to local water resources, the reasons for decline in value of land, etc. Landfill excavation and soil remediation is a potential method for processing waste from longstanding landfills. Landfill excavation is done to recover valuable materials from landfill. One of the most valuable materials obtained from excavation of the landfill is the soil. It can be used for ground cover. As it is known that landfill contribute to most of the hazardous material disposal and reclamation of landfills is very important for the sustainable development of the environment [1].

Randegan Landfill, Mojokerto, which has a land area of 2.5 hectares, is currently operating with an open dumping method and gradually improved with the controlled landfill method. Open dumping conducted in many developing countries in Africa, Latin America, and Asia [2]. Waste management is a complex process, as it includes many technologies and disciplines [3]

Traditionally, Landfill Mining is defined as the excavation and processing of waste from active or closed landfill. Landfill Mining involves extracting, sorting, and separation from the old landfill waste into various components including soil, recycling materials, hazardous materials, and residue. This may include land mass recovery and processing of mined materials from old landfills to recover recyclable materials and increase the capacities of the new landfill for new waste in a landfill where appropriate design can be used for the accumulation of inorganic materials as inert material [1]. Various studies related to landfill mining have been done for landfill area reduction of area development in the same location or move to another place, conservation of landfill area, reducing potential sources of contamination, disposal place repair, reuse of materials generated

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from landfill mining, and reduction of the post-closure maintenance and monitoring of landfill sites cost [4]. Mining research was conducted in Kodungaiyur and Perungudi, which were some landfills near Chennai, India to evaluate the status of solid waste degradation and restore the feasibility soil fraction as compost and / or landfill cover material.

MATERIALS AND METHODS

Location of research

The study was conducted in Randegan landfill which is located in Randegan Village, Magersari Subdistrict, Mojokerto City with an area of 2.5 ha.

Research time

Research methods to determine the composition, characteristics of the waste, the garbage passive zone and soil investigation (drill logs) were performed on passive garbage zone, conducted in July 2013.

The tools used for the investigation of land use at the site are shallow drill with the following specs:

- Brace and bit using a small Iwan
- The length of the drill stank was made every 2 meters.
- Two pieces of stopcock

The retrieval of boring results using small Iwan brace and bit was done when finding the original soil conditions (not mixed with organic waste or / and organic)

The method used in this research is a field survey method which includes the identification and observation of waste in Randegan landfill. The research of landfill surveys waste and waste volume measurement methods were performed with the manufacture and installation of point helper, carpenter's level measurement, measurement of longitudinal and transverse face, and polygon measurement.

For physical and chemical characteristics of waste were done by taking samples of each waste composition as much as 2 kg for laboratory analysing. Laboratory tests done to the waste included water content, energy content of the waste, the element Carbon (C), Nitrogen (N) and phosphorus (P) of the waste. Based on the C and N value could be determined the C / N ratio of waste [5].

The results of the identification and observation of waste in Randegan landfill were analysed by quantitative sampling methods and the waste characteristics samples were analysed in Environmental Engineering Laboratory of ITS.

RESULTS AND DISCUSSION

Randegan landfill consists of three zones, namely two passive waste zones and a passive and active mixed waste zone. The active zone area that is used for waste processing currently is only ± 3000 m^2 with an average waste pile of 7.5 meters height. An active zone is a zone that still accepts new incoming garbage. Meanwhile the passive zone is already stable waste, which can be proven by soil profile testing through drilling.

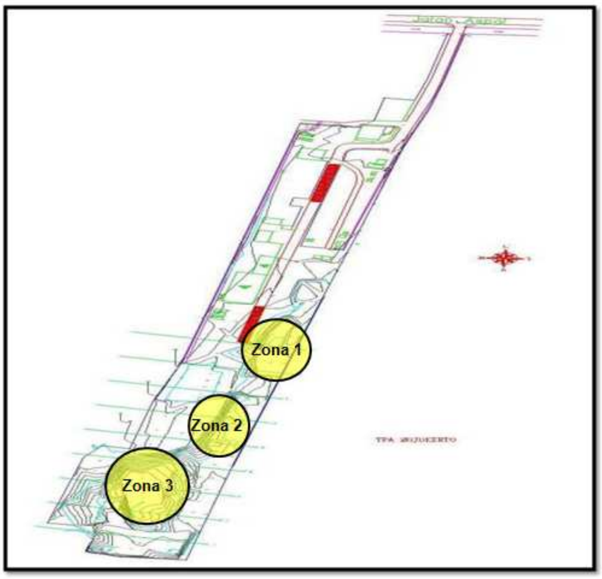

Figure 2 Waste Zone of Randegan Landfill

Passive garbage zone consists of Zone 1 with an average height of 4.0 m and Zone 2 with 3,702 meters height. Zone 3 is mixed waste zone with an average height of 7.472 m, but its function is the zone of active garbage. The waste deposit in the three zones of Randegan landfill can be seen in Table 2 below.

Table 1 Waste Deposit of Randegan Landfill

Zone	Date	Layer Depth of Waste Pile
I	June 12, 2013	5.80 meters from Surface
II	12 to 13 June 2013	6:20 meters from Surface
III	June 13, 2013	8:10 meters from Surface

Table 2 Waste Deposit of Randegan Landfill

	Zone 1	Zone 2	Zone 3	Retention Time
Area	2184.62 m^2	1613.974 m^2	5726.809 m^2	1990-2012
Height	5.80 m	6.20 m	8.10 m	
Volume	12670.80 m^3	10006.64 m^3	46387.15 m^3	

The table above shows that Zone 3 is the area of greatest waste volume. This is because the area of Zone 3 is an active zone, which is a zone which receives the waste generation of Mojokerto.

The illustration of soil investigation (drill logs) that was performed on three zones of the open dumping landfill showed a significant condition with laboratory test results for testing the composition of the waste deposit in the passive waste zone that organic soil is the major part of the waste composition, so that processing by utilizing soil content formed in the waste composition is necessary.

Table 3 Results of Waste Chemical Characteristics Analysis of Randegan Landfill

Parameters:	Zone 1				Zone 2				Zone 3				
	T = 2 m	T = 4 m	T = 6 m	Average	T = 2 m	T = 4 m	T = 6 m	Average	T = 2 m	T = 4 m	T = 6 m	T = 8 m	Average
Water Content (%)	31.7	66.34	55.75	51.26	44.15	57.77	76.94	59.62	72.59	63.56	43.98	58.89	59.76
Nitrogen (% N)	0.68	0.61	0.43	0.57	0.92	0.77	1.27	0.99	0.24	0.72	1.23	0.46	0.66
Phosphorus (% P)	0.45	0.67	0.18	0.43	0.15	0.05	0.24	0.15	0.18	0.17	0.45	0.23	0.26
Total Carbon (% C)	46.57	18.44	34.21	33.07	32.18	16.41	20.55	23.05	24.41	28.76	34.96	20.59	27.18
C / N	68.49	30.23	79.56	59.42	34.98	21.31	16.18	24.16	101.71	39.94	28.42	44.76	53.71

Source: research result, 2013

From the results of ground investigation and analysis of the composition of waste deposits made by the Laboratory of Environmental Engineering ITS garbage taken on June 25, 2013, the composition of the deposit of waste in Zone 1 Randegan Landfill at 2 meters depth consists of 21.86% plastic, 51.97% soil, and 26.17% organic. At 4 meters depth is consisting of 38.18% plastic, 6.70% gravel / sand, 26.17% organic, metal 1.33%. At 6 meters depth is consisting of 33.30% plastic, 5.37% gravel / sand, 59.80% organic, 1.03% metal and 1.5% glass.

While research in Zone 2 at 2 meters depth is comprising 40.14% soil, 20.90% gravel / sand and 38.95% organic. At 4 meters depth is consisting of 38.09% soil, gravel / sand 6.80%, 53.10% organic, 2.01% fabric. Meanwhile, at 6 meters depth is consisting of 62.95% plastics, 7.45% wood, and 29.60% organic.

Research in Zone 3 at 2 meters depth shows that the waste composition consisting of 16.53% plastic, 44.77% organic, 14.29% soil, and 24.41% stone. At 4 meters depth consists of 55.35% plastic, 39.80% organic, 3.95% soil, 0.90% stone. At 6 meters depth consisting of 25.85% soil, 58.50% organic, 9.20% stone, 0.25% metal, 5.5% paper, 0.7% glass. At 8 meters depth consisting of 32.80% soil, 42.96% organic, 6.60% stone, 14.40% metals, 3.34% paper.

Table 4 The results of physical and chemical characteristics parameters research in Randegan Landfill

Parameter	Unit	Zone 1				Zone 2				Zone 3				
		T = 2 m	T = 4 m	T = 6 m	Average	T = 2 m	T = 4 m	T = 6 m	Average	T = 2 m	T = 4 m	T = 6 m	T = \8 m	Average
Plastic	%	21.86	38.18	33.30	31.11	40.14	38.09	62.95	47.06	16.53	55.35	25.85	32.63	32.59
Soil / sand	%	51.97	0	0	17.32	0	0	0	0.00	14.29	3.95		4.56	5.70
Organic	%	26.17	26.17	59.80	37.38	38.96	53.10	29.60	40.55	44.77	39.80	58.50	46.51	47.39
Gravel /	%	0	6.70	5.37	4.02	20.9	6.80	0	9.23				0.00	0.00

Sand						0								
Metal	%	0	1.33	1.03	0.79	0	0	0	0.00			0.25	3.66	0.98
Glass	%	0	0.00	1.5	0.50	0	0	0	0.00			0.7	0.18	0.22
Cloth	%	0	0	0	0.00	0	53.10	0	17.70				0.00	0.00
Wood	%	0	0	0	0.00	0	0	7.45	2.48				0.00	0.00
Stone	%	0	0	0	0.00	0	0	0	0.00	24.41	0.90	9.20	10.28	11.20
Paper		0	0	0	0.00	0	0	0	0.00			5.5	2.21	1.93

Source: research result, 2013

The results of the study of physical and chemical characteristics of the parameters tested in Zone 1 at 2 meters depth are moisture content of 31.7%, nitrogen of 0.68% N, phosphorus of 0.45% P, total carbon of 46.57% C. At 4 meters depth, moisture content of 66.34%, nitrogen of 0.61% N, phosphorus of 0.67% P, total carbon of 18.44% C. At 6 meters depth, moisture content of 55.75%, nitrogen of 0.43% N, phosphorus of 0.18% P, total carbon of 34.21% C

In Zone 2 at 2 meters depth, moisture content of 44.15%, nitrogen of 0.92% N, 0.15% P phosphorus, and total carbon of 32.88% C. At 4 meters depth, moisture content of 57.77%, nitrogen of 0.77% N, phosphorus of 0.05% P, total carbon of 16.41% C. At 6 meters depth, moisture content of 76.94%, nitrogen of 1.27% N, phosphorus of 0.24% P, total carbon of 20.55% C.

In Zone 3 at 2 meters depth, moisture content of 72.59%, nitrogen of 0.24% N, phosphorus of 0.18% P, total carbon of 24.41% C. At 4 meters depth, moisture content of 63.56%, nitrogen of 0.72% N, phosphorus of 0.17% P, total carbon of 28.76% C. At 6 meters depth, moisture content of 43.98%, nitrogen of 1.23% N, phosphorus of 0.45% P, total carbon of 20.59% C.

Value of the carbon and nitrogen content in this study is used to determine the C / N ratio, which shows a comparison of organic substances containing nitrogen in waste [8]. C / N ratio of Mojokerto domestic waste in this study ranged from 7.7 to 15.45 Research in the Rangsit vegetable market, Thailand get C / N ratio of 40-47 with an average of 43.5. The study of urban waste in Guwahati India gets a C / N ratio of 31.0 to 38.0 [6]. Range of C / N ratio obtained was 27-100 for urban waste in Accra, Ghana. While research of waste in Boyolali Landfill, Indonesia received C / N ratio of 7.0 [7], there is a big difference in C / N ratio for the initial studies because the value of C / N ratio is highly dependent on the composition of the waste generated by local communities.

Based on the research of waste composition and characteristics in Mojokerto, the recommended waste processing method that can be done to reduce waste at the active zone is Landfill Mining.

Landfill Mining has been practiced on a limited basis throughout the United States by landfill owner and operator, driven by several factors, including the following:

1. Addressing the problem of groundwater pollution at landfills that are not equipped with linings. Waste that stored in cells that are not equipped with coating has previously been documented as a source of groundwater contamination at many landfill sites across the United States. The contamination is the result of seepage fluids that come in contact with or derived from waste materials deposited and further migration of the fluid into another ground water. Documented source of groundwater contamination at many unlined landfills are landfill gas. When addressing the issue of groundwater contamination, the preferred option, if possible is to remove the source of contamination. However, the cost of landfill mining must be weighed against the cost and effectiveness of other techniques used to address groundwater contamination such as pumps and treat option. Based on interviews conducted to the owner / engineer from the sites that have done landfill mining in the past or are currently pursuing it, reducing future obligations of the existing groundwater contamination or potential found to be the most common factors to consider landfill mining.
2. Creating new capacity for future landfilling activities.
3. Reduce the closing costs.
4. Recover recyclable materials.
5. Others. Landfill mining has also been considered to recover waste fuel that derived from the landfill for burning in waste-to-energy facilities.

Landfill Mining typically consists of three basic operations, namely digging waste, processing of excavated materials, and manage material excavated or processed. Solid waste is the first excavated using commonly used equipment in landfill surface as a backhoe or hydraulic excavator. Excavated garbage can be processed to fulfill a number of purposes, including separating the big materials, sifting hazardous materials and other unidentified waste, segregation of soil from waste, and sorting materials for recycling or used as fuel. Some common mechanical process (such as magnet for ferrous metals and electric current separators for aluminum) can be used to separate recyclable materials. Identifying and sorting of hazardous and other suspicious wastes is reported to be an integral part of most of the identified landfill mining project in this study.

The purpose of landfill mining is the most important factor when considering options of sewage treatment equipment. For example, if land recovery is the priority, then the material excavation must be filtered mechanically. Mined materials can be transmitted through the electromagnet if recovery of ferrous metals is desired. Excavated waste may not be processed at all if the purpose of the mining operation is to relocate the waste from cells that do not have coatings to waste cells that have coatings.

Other major factors that influence the choice of processing methodology are conditions and properties of the mined materials. For example, filtering soil fractions may be difficult in a landfill where there are frozen waste. Other factors that may affect processing methodology is the potential market for recycled materials. In many cases (for instance, in Naples Landfill in Collier County, Florida), recycled materials such as metal, iron, and aluminum must meet certain quality requirements in order to have value as a recycled material - additional processing to meet the standards of recycled materials represent other factors that may affect feasibility of a landfill mining project.

The cost and time to process the excavated material is also an important factor when considering treatment methods to recycle. For example, separating and recycling glass were considered in the Naples Landfill Mining Project. It was not pursued, because of poor marketing and high transportation costs. Automatic processing of mined materials from municipal waste landfill has been proposed to potentially reduce the processing cost [8].

Figure 3 presents the general flow chart of the process of empowered landfill mining. Sorting of excavated waste is an activity that are often used in landfill mining activities.

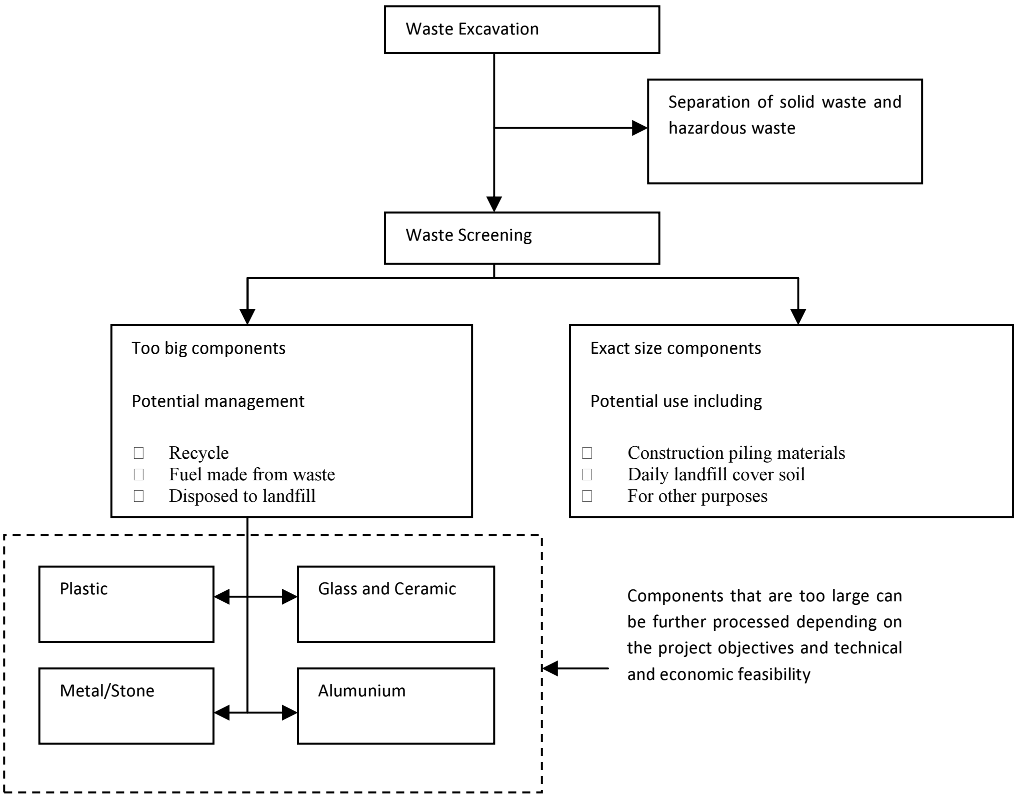

Figure 3 Landfill Mining Process

Landfill Mining is defined by Krook *et al*. [9] as "a process for extracting material or other resource-intensive nature of the waste that have previously been disposed by burying them in the ground". Although the first project was done in 1953 [4][10], but serious concern emerged in the 1990s [9]. However, landfill mining activities in the past in most cases limited to the extraction of methane, partial recovery of precious metals and / or land for reclamation, as corroborated by Krook *et al*. [9]: "So far, landfill mining has advantages primarily seen as a way to solve the problems associated with landfill management such as lack of landfill area and concerns of pollution.

Landfill Mining Approach In situ and Ex Situ

However, the mining landfill strategy is developed further. Broadly these can be divided into two main categories. First, in situ landfill mining refers to resource recovery activities (eg methane extraction and removal of contaminants from soil and water), which occurs at the site without digging landfill stored waste stream. Second, ex situ landfill mining involves the recovery of resources by partially or fully dig trash heap for further processing. Currently there are five different landfill mining management / concepts, which are described in Table 5: The Developed Landfill Mining.

Table 5 The different management / concept of Landfill Mining that are currently in development [11].

Concept	Type of Resource Recovery	Definition	Primary Reference
Already Developed Landfill Mining	Ex Situ	Discussing the different combined and integrated urban waste dumped as the second ingredient (Waste-to-Materials,, WTM) and energy (Waste-to-Energy, WTE), while meeting the most stringent ecological and social criteria.	Jones and Tielemans
Biodegradation is already (& Bio-reactors)	In Situ	Primarily developed as a cost-effective remediation measure for soil and groundwater contaminated bodies. Both contaminants and source regions treated. In connection with landfills, there is limited experience in the old landfill and abandoned	(Hoekstra *et al.*; Hoekstra and Langenhoff; Read *et al.* ; Rich *et al.*)
Continuous Landfil	In Situ	Refers to a method for minimizing the potential for contamination of landfills, with in situ remediation within one generation with using the concept of bioreactor, in landfills modern managed. Pollutants broken berbahatya not broken down into materials, issued or deposited in landfills. Risk reduction can be achieved together with methane extraction, stabilization of organic content and specific land use	
Peninbunan / Shelter naturally	In Situ	The concept that uses the properties of natural organic matter to isolate contaminated waste (natural closure) and prevent leachate contamination of deployment (natural catchment). The goal is to create a gradual, functional replacement of landfill cover soil (soil and synthetic foil) by a layer of natural living, organic materials. The principle of natural catchment is to improve conditions for natural attenuation zone by seepage from a landfill restoration or (re) constructed wetland.	(Clemens *et al*; Dijcker *et al.*)
While Shelter	In Situ and Ex Situ	Provides a relationship between ex situ and in the concept of in situ resource recovery. The concept of temporary storage that will be developed in such a way that the resource sites that are environmentally friendly and safe structural, already allow present in situ recovery of energy, soil, ground water, soil and nature, and allows recovery of ex situ materials in the future.Temporary storage place should be applicable to various types of landfill.	(Jones and Tielemans,)

The composition of reclaimed materials

Recyclable materials from municipal waste typically consist of materials such as metals, plastics, wood, rubber, and the fine fraction. Limited number of studies in the past have been marked recyclable materials from municipal waste landfill with respect to composition. Table 6 presents the average composition which can be reclaimed. Land cover and degraded organic wastes has been reported to form approximately 50 to 85% of recycled material (weight basis). It should be noted that this study was conducted at the waste with a wide range of ages.

Table 6 Composition of Mined Waste [12]

Material	**Composition (% by weight)**							
	Murphy and Stessel [8]	NYSERDA [13]	Kilmer and Tustin [14]	Earle et al. [15]	Zornberg et al.[16] (80 samples)	Jain et al. [17] (78 samples)	McKnight [18] (19 samples)	Hull et al. [19]
• **Paper** • **Plastic** • **Garden Waste** • **Wood** • **Fabric** • **Aluminiunm** • **Metal** • **Glass / Ceramic** • **Misc** • **Soil Size**	10% 7% - 5% - 2% 5% 5% 18% 50% (0.5 inch sieve)	3% 2.8% - 0.7% - - 2.5% / 1.4% 1.3% 3.8% 84.5%	- - - - - - - - 75% (1-inch sieve)	- - - - - - - - 75% - 87% (1/4 inch sieve)	- - - - - - - - > 56%	12% 13% 3% - 3% - 6% 5% - 50% (0.5 inch sieve)	18% 7% 12% - 5% - 7% 2% - 49% (1/4 inch sieve)	- - - - - - - - > 50% (1 inch sieve)

Overall the total number may not be up to 100% due to rounding.

CONCLUSION

This study concluded that there is potential for soil and organic matter which can be extracted from Randegan Landfill, Mojokerto which can be used for the benefit of landfill piling material or used as mixing ingredients of composting process.

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