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Sustainable Approach for Landfill Management at Final Processing Site Cikundul in Sukabumi City, Indonesia

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Abstract: The main problem of landfill management in Indonesia is the difficulty in getting a location for Final Processing Sites (FPS) due to limited land and high land prices. Besides, about 95% of existing landfills are uncontrolled dumping sites, which could potentially lead to water, soil and air pollution. Based on data from the Ministry of Environment (2010), The Act of the Republic of Indonesia Number 18 Year 2008 Concerning Solid Waste Management, prohibits open dumping at final processing sites and in ratification, the Local Governments have to convert the open dump sites into controlled or sanitary landfill. The Research Institute for Human Settlements has been conducting multi-year researches related to the rehabilitation of dumpsites toward sustainable landfill. The research methods are literature reviews, experiments, laboratory analysis and field observations. A pilot model of dumpsite rehabilitation was carried out in 2010 at the Final Processing Site at Cikundul in Sukabumi City, consisting of (1) mining landfill (2) construction of landfill cells in a former mining area with a semi aerobic landfill and an anaerobic landfill and (3) landfill operations using decomposed material from landfill mining as a soil cover. The purpose of the study is to develop a sustainable approach for landfill management and rehabilitation through landfill mining and implementation of semi aerobic landfill. Findings in the construction of landfill mining indicate that (1) the construction of landfill mining is constrained by leachate that is trapped in a pile of waste, therefore, the leachate needs to be pumped to leachate treatment installations, (2) the volume of waste excavation is expanding due to the high plastic content of about 26% in landfills (3) the potency of decomposed materials from landfill mining is 40–83% for landfill operations or greening.. The performance of landfill systems shows that leachate quality of semi aerobic landfill tends to be lower than that of anaerobic landfill. Gas composition at semi aerobic landfill in FPS Sukabumi shows about 6–10% CH_4 and about 15–16% O_2; for an aerobic landfill, the gas composition is about 47–57% CH_4 and about 2–3% O_2. In conclusion the concept mining landfill could be developed especially for big cities where it is difficult to find a new site for landfill or to get soil cover for landfill operation. In a sustainable approach, the excavated area can be turned into a new area for landfill cell so that the capacity of existing Final Processing Site can be expanded using the block landfill concept. The landfill should be divided into three blocks: compost block, composting block and active block. Usage of the three blocks are rotated with the intention of using solid waste on the compost block as soil material for the active block through landfill mining.

Key words: Final processing site; Landfill; Management; Sustainable.

INTRODUCTION

Based on 2010 data from the Indonesian Ministry of Environment, about 95% of final processing sites (FPS) in Indonesia were poorly managed uncontrolled dumping sites and many had reached or were soon reaching capacity. Uncontrolled dumps were associated with environmental problems such as the risk of groundwater and soil contamination, odor, air pollution (including generation of green house gases), aesthetic blight, threats to flight safety and consumption of expensive tracts of land.

Indonesian Code Number 18 Year 2008 concerning Solid Waste Management, prohibits open dumpsites at final processing sites and in ratification [1], Local Governments have to convert the open dumpsites into controlled landfill (for small and medium cities) or sanitary landfill (for big and metropolitan cities) [2]. In line with the mandate, the Research Institute for Human Settlements (RIHS) has been conducting multi-year researches on the rehabilitation of dumpsites toward sustainable landfill. A pilot project was designed in 2009 [3] at Final Disposal Site Cikundul in Sukabumi City, West Java and was constructed and operated in August-December 2010 [4] through developing an appropriate landfill model for cities in Indonesia and the rehabilitation of open dumpsites . In 2011, the research continued with its monitoring and evaluation processes [5].

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The purpose of the study is to develop a sustainable approach for the rehabilitation of dumping sites through landfill mining and implementation of semi aerobic landfill as opposed to anaerobic landfill. Compared to anaerobic landfill, a semi-aerobic landfill method has several advantages including reduction in the production of landfill gas and faster stabilization of the filled waste land [6]. In developing a sustainable approach, an alternative solution is the Block Landfill concept. In this concept, landfill area is divided into 3 blocks of operation, namely a compost block, a composting block and an active block. Usage of the three blocks is rotated with the intention of using solid waste on the compost block as soil material for waste at the active block through landfill mining. The benefits of the block landfill concept are:

- reduced expenses in buying soil cover for landfill operation
- expanded capacity of turning the Final Disposal Site into sustainable landfill
- income generation from the sale of excess compost for non-food crops
- production of biogas from area 3 R that can be used as heat energy / fuel
- recycling of non-organic materials such as plastics, rubber, metal, and glass found while sorting and sifting the compost from the composting zone
- suppression of the generation of solid waste, liquid and gas (cleaner production)
- acceleration of waste composting process

METHOD

The study material is a pilot project of a landfill model at FPS in Cikundul Sukabumi City. Methods used for data collection are laboratory analysis, field observations, and literature reviews from books, research reports and the internet, and observation study. The parameters to be analyzed are: - Solid waste composition of waste in FPS in Sukabumi

City based on organic and ianorganic waste - Soil fraction from decomposed materials from dumpsites

using sieving analysis - Characteristics of leachate from semi aerobic and

anaerobic landfill cells particularly the parameters of BOD_5 days (BOD_5) and COD

- Gas emission (for the parameters of CH_4 and O_2) at semi aerobic and anaerobic landfill cells using landfill gas analyzer type GA 2000 plus

These parameters will give a model for the reclamation of dumpsites, the potency of decomposed materials from the dumpsites as landfill cover, and the effectiveness of landfill methods using semi aerobic and anaerobic process as options for an appropriate landfill method for Indonesia.

RESULTS AND DISCUSSION

Pilot Project at Cikundul Dumpsite Sukabumi City

1) Site Description

Like most municipalites in Indonesia, the Sukabumi Local Government has been carrying out open dumping of MSW since 1994. The Final Processing Site (FPS) is located in Cikundul Sub District Situ Mekar, District Lembur Situ, Sukabumi City. The final processing site is about 8.7 Ha in size, with 470 m^3 of waste dumped per day, comprising mainly of domestic waste.

In FPS Cikundul, there is a 1000 m^2 Waste Recycling Plant with the production capacity of 10 tons per day. The products are compost, compost granules (round), waste Briquettes and fish pellets. The production of compost in 2008 was 1.92 ton/day, while in 2009; the production was 3 tons of compost per day.

The model is located at Zone I of the Final Processing Site (FPS) in Cikundul Sukabumi, The waste had been placed on the site since 1994, where it was filled up to a height of about 15 meters. The upper 3–5 meters of waste were deposited over 2008 to 2009.

2) Design of the Model

The model was designed in 2009, and was constructed and operated as a landfill cell during August to November 2010. The model of the dumpsite rehabilitation consists of : (1) landfill mining of the open dumping site involving the excavation, screening and separation of material from landfills into soil, recyclable materials and residue (2) development of the excavated area into a designed sanitary landfill cell including laying linings at the bottom and sides, and installing gas and leachate collection pipes so that the municipal waste can be disposed and managed in a proper way (3) usage of the soil fraction of excavated material as daily cover. Two cells consisting of an anaerobic landfill cell and a semi aerobic landfill cell were constructed on the dumpsite area in the Final Processing Site (FPS) in Cikundul Sukabumi city. Each cell is approximately 30 x 15 m in size, with a height of 8 m.

The construction involved the as following activities:

a) Cutting of the open dumping area of 1500 m^2, 3 m in depth
b) Excavation of the open dumping area of 900 m^2, 5 m in depth
c) Preparation of a temporary office, a stock area and a revolving cylindrical sieve
d) Handling of mined soil and waste at the stock area. The mined materials will be sieved by the revolving cylindrical sieve to obtain soil fraction to be used as landfill cover
e) Construction of an access road to the location of the pilot model
f) Construction of landfill cells - Zone A : anaerobic landfill cell and Zone B semi aerobic landfill cell.
    - The area for each zone is 450 m^2 with a length of 30 m, a width of 15 m, and a height of 8 m.
    - Construction of a base liner consisting of coarse materials/stones with a diameter of 10-15 cm; soil fractions of decomposed materials from the dumpsites with a thickness of 20 cm; geotekstil of 4 mm thickness and geomembran of 1.5 mm thickness, with a plaited mat made from bamboo layered over it.
    - Installment of piping for leachate and gas, and a connection pit.
    - The leachate collection system consists of a perforated concrete pipe with a diameter of 600 mm for semi aerobic, and 300 mm for anaerobic landfill cell. The leachate is flowed through an open drainage to the existing leachate treatment plant in FPS Cikundul.

- A vertical gas venting pipe is installed on top of a connection pit. A connection pit is used to connect the leachate collection pipes and vertical gas pipes.
- The vertical gas venting system consists of gas venting pipes (perforated PVC pipe 4 inch in diameter and protective casing made of plaited bamboo mat and gravel with a diameter of 10–15 cm that is filled between 80 cm thick pipes and casings. The holes of the pipe and bamboo allow air and gases to move in and out.

g) Operation of landfill - Total volume of solid waste disposed for the two cells is 2.365.525 kg over a period of 20 days in December 2010; making up 1182762.5 kg of waste per cell or about 5910 m^3 each cell. Solid waste came from residential areas and the market.
   - Waste is placed horizontally in layers by spreading, compacting and covering the disposal waste.
   - Each layer is 1.5 m in height after being compacted. After reaching 3 layers of 1.5 m each, it is covered with 30 cm of soil fractions of decomposed materials from the dumpsites

h) The waste is covered with 20 cm of coarse materials for drainage.

i) Final cover using 70 cm thick compacted clay is layered with 30 cm of soil fractions of decomposed materials from the dumpsites and is planted over with grass.

Obstacles in Construction: The obstacles in the construction of landfill mining in FPS Cikundul Sukabumi are 1) The leachate generated by rain water into the landfill waste is trapped in the pile of waste because the landfill is not equiped with leachate piping 2) The volume of excavated material increases about twice due to a high composition of plastic waste (about 25.65%) in FPS Cikundul.

Potency of Soil Fraction of Decomposed Materials: Data of soil fractions of decomposed materials from the dumpsites at FPS Cikundul in Sukabumi City compared with other cities such as Jember and Subang can be seen in Table 2. From sieving analysis using mesh <2 cm, it is determined that the soil fraction from decomposed materials from the dumpsites at FPS Cikundul in Sukabumi City is about 42%–83%. However, based on field analysis using screening with mesh <1 cm, the decomposed material is about 25–40%. The percentage is smaller due to several factors, particularly, in the rainy season the soil material becomes sticky and difficult to sieve.

Characteristic of Decomposed Materials: The decomposed materials/compost is still mixed with plastic. Plastic waste in FPS Cikundul is about 25.65% (Fig. 1). The compost is contaminated by heavy metal and needs adjustments of C and C/N [11]. The potency of decomposed materials in FPS Cikundul Sukabumi that can be used for soil cover in landfill operations is 40–83 %. The compost can also be used as a soil conditioner for greening, non food crop and hard crop, using mesh < 1 cm for non food crop and mesh 1–2 cm for landfill cover.

Table 1: Construction of semi aerobic and anaerobic landfill model

No	Semi aerobic	Anaerobic
1	The concept of a semi aerobic landfill is a landfill where waste goes through a decomposition process in the presence of oxygen. Additionally, the quality of leachate was improved at a much faster rate, and the generation of methane, hydrogen sulfide and other gases was significantly reduced [6]	The concept of an anaerobic landfill is a landfill where waste goes through a decomposition process in the absence of or in the presence of reduced oxygen, to maximize the generation of methane gas
2	Leachate pipe, 600 mm	Leachate pipe, 300 mm
3	A control box is placed as close as possible to the landfill cell, and there is a waterfall from landfill to control box for connection to outside air	Leachate collection pipe from landfill is connected to leachate treatment plant
4	A connection pit is used to connect the main leachate pipe with a branch pip; a vertical gas pipe is installed on top of the connection pit	The joint of the main leachate pipe with its branch is connected, thus there is no need to connect with gas pipe

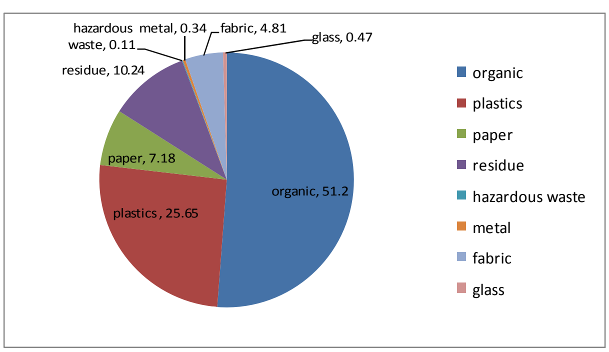

Fig. 1: Solid waste composition at final disposal site Cikundul in Sukabumi City

Table 2: Percentage of soil fraction of decomposed materials from some dumpsites

No	Location of Final Disposal Site/ Year of sampling	Fraction soil (mesh of screen diameter <1 cm)
1	FPS Tamangapa Makasar (2008)	50%
2	FPS Cicabe Bandung (2007) [7]	86.22 %
3	FPS Pasir Impun Bandung (2007)	94.69 %
4	FPS Leuwigajah Bandung (2007)	60%
5	FPS Cikundul Sukabumi (2009)	42%
6	Pilot project at Cikundul dumpsite Sukabumi City (2010)	83% (based on sieving analysis in laboratory) 40% (based on field analysis)

Quality of Leachate: Data sampling shows that leachate quality of semi aerobic landfill tends to be lower than of anaerobic landfill. The BOD_5 from semi aerobic outlet is about 256–1219 mg/L, and COD is about 394–4050 mg/L. For anaerobic landfill, the BOD_5 is about 532–1138 mg/L and COD is about 816–3750 mg/L.

Gas Composition: Gas composition of semi aerobic and anaerobic landfills in Sukabumi city compared with other models can be seen in Table 4. At the semi aerobic landfill in FPS Sukabumi, the gas composition is about 6–10% of CH_4 and about 15–16 % of O_2, while at the anaerobic landfill the gas composition is 47–57% of CH_4 and 2–3 % of O_2. This model meets the criteria that the CH_4 percentage of semi aerobic landfill should be <20% and the CH_4 percentage of anaerobic landfill should be >50% [10].

Table 3: Characteristics of leachate February-May 2011

No	Parameter	Semi Aerobic	Anaerobic	Effluent Standard Category II [9]
1	Colour (TCU)	1720-2468	2481-2529	-
2	Turbidity (NTU)	76-113	100-129	-
3	TDS (mg/L)	125-828	100-129	4000
4	TSS (mg/L)	15-18	21-54	400
5	pH	7-9.2	7.1-8.3	6-9
6	BOD_5 (mg/L)	256-1219	532-1138	150
7	COD (mg/L)	394-4050	816-3750	300
8	DHL ((μmhos/cm)	178-1210	172-1210	-
9	Nitrate (NO_3-N) (mg/L)	1.2-25.4	2.2-38	30
10	Nitrite (NO_2-N) (mg/L)	0.01-0.19	0.01-0.52	3
11	Ammonia (NH_3-N) (mg/L)	0.28-0.77	0.7-1	5

Table 4 : Comparation of CH_4 and O_2 from some landfill models

No	Landfill model	Location	Description	CH_4 (%)	O_2 (%)
1	Semi aerobic (φ 600 mm)	FPS Cikundul Sukabumi City	April-May 2011, 4 months after landfill closed, waste landfilled 5910 m^3, landfill area 15x30 m, height of waste 8 m	6–10 %	15–17%
	Semi aerobic (φ 800 mm)	FPS Cibereum Banjar City	August 2010, 8 months after landfill closed) waste landfilled 4500 m^3, , landfill area 15x30 m, height of waste 5 m	7–11%	15–17%
	Criteria of semi aerobic [10]			<20%	>6%
2	Anaerobic (φ 300 mm)	FPS Cikundul Sukabumi City	April-May 2011, 4 months after landfill closed, waste landfilled 5910 m^3, landfill area 15x30 m, height of waste 8 m	47–57%	2–3%
	Anaerobic	FDS Manggar Balikpapan	1 year after landfill closed, waste landfilled 414.000 m^3	57–66%	0.1–0.4%
	Criteria of anaerobic [10]			>50%	<6%

Developing a Sustainable Landfill: To develop a sustainable landfill, the concept of a Block Landfill can be implemented in FPS Cikundul Sukabumi city. In this concept, the landfill should be divided into three blocks: compost block, composting block and active block.

1) Compost Block:
   The old dumpsite area in FPS Sukabumi is about 5.6 Ha, operating over a long period from 1994 to 2007. 80% of it could be used as compost block and 20% as supporting infrastructure and buffer zone. The compost block is an old open dumpsite that is already stable and can be mined by sieving to get compost as a soil cover for the operation of an active block. It should be proven by testing the soil profile through drilling of the decomposed waste in the landfill at several varied depths.
2) Composting Block:
   The composting block is previously an open dumpsite that is already closed but is still in the process of composting.
3) Active Block:

The active block is a block that is being actively operated as a landfill. The alternative of a landfill system is a semi aerobic landfill that has the advantages of a lower leachate quality and methane gas emission compared to an aerobic landfill.

The operation of a semi aerobic landfill requires soil cover of at least once a week. The active block is divided by a tipping face of about 30 x 50 m. The intermediate soil cover requirement of 300 m^3 per week can be obtained from decomposed material from the mining of the compost block.

The concept should be combined with a Waste Recycling Plant. The Waste Recycling Plant can be optimized by increasing the production capacity to the optimum capacity of 10 tons/day. The capacity of production can be increased with the compost from decomposed material from the compost block. As the plastic waste composition in Sukabumi is high (about 26%), it is necessary to develop plastic recycling.

Leachate and Gas Control: The landfill is equipped with piping for leachate and gas ventilation. The leachate treatment can be optimized by recirculation towards the active block to accelerate the decomposition process in the landfill. For recirculation, leachate piping and a recirculation system are needed in order to accelerate the decomposition of landfill.

The scenario of a block landfill concept in FPS Sukabumi City can be developed as in Fig. 2.

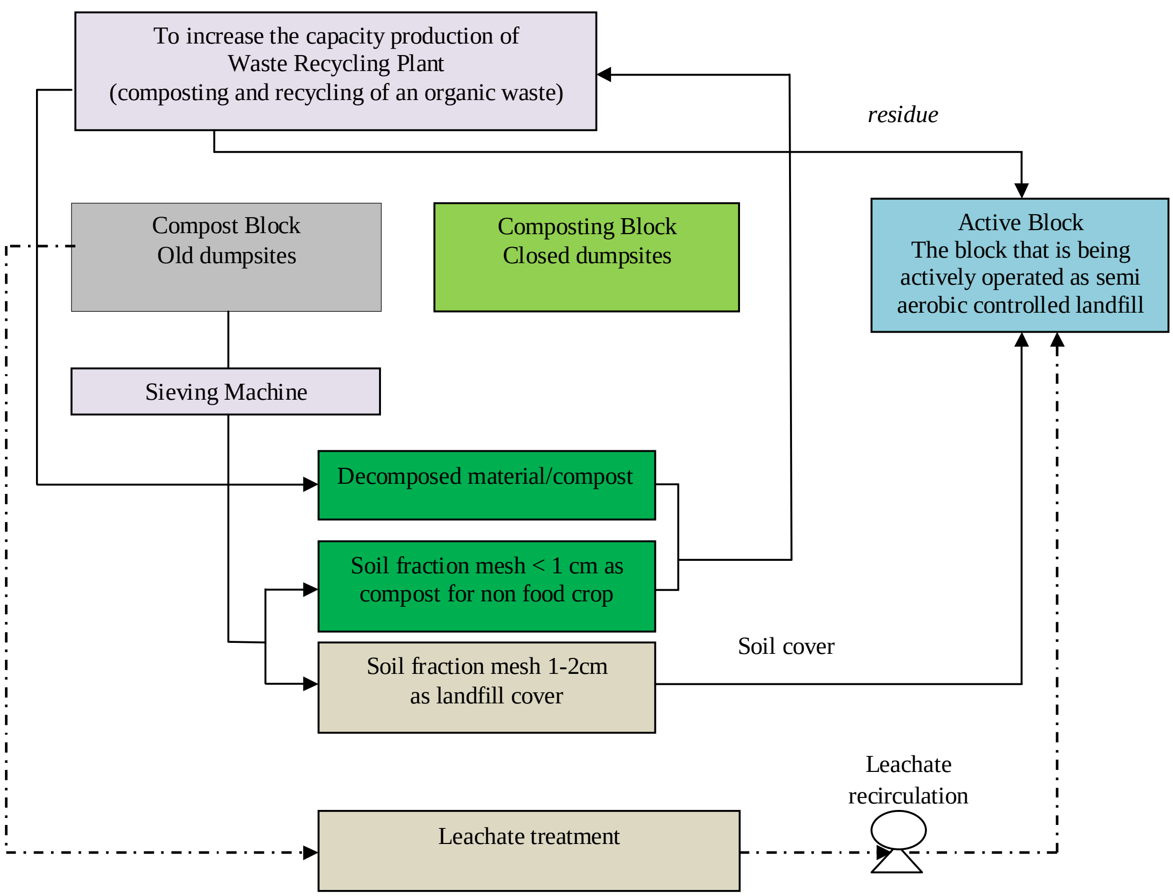

Fig. 2: Developing a block landfill concept in FPS Cikundul Sukabumi City

CONCLUSION

The obstacles in the construction of the landfill model in FPS Cikundul Sukabumi are :

a) The leachate is trapped in the pile of waste because the landfill is not equipped with leachate piping.
b) The volume of excavated material increases twice because of high the plastic waste composition in FPS Cikundul (about 25.65%). To prevent this problem, it is suggested that landfill mining should not be done during the rainy season. In addition, landfill mining needs a stock area for placement the excavated materials is needed.

The potency of soil material from landfill mining that can be sieved to get compost or soil cover for the operation of active landfill is about 40–83 %.

Data sampling shows that the leachate quality of semi aerobic landfill tends to be lower than that of anaerobic landfill. The BOD_5 from semi aerobic outlet is about 256–1219 mg/L, and COD is 394–4050 mg/L. For anaerobic landfill, BOD_5 is about 532–1138 mg/L and COD is 816–3750 mg/L.

Gas composition of semi aerobic landfill in FPS Sukabumi shows about 6–10% ofCH_4 and about 15–16% of O_2. For anaerobic landfill, the gas composition is 47–57% of CH_4 and 2–3% of O_2. This model meets the requirement that percentage of CH_4 of semi aerobic should be < 20% and the percentage of CH_4 of anaerobic should be > 50% [10].

The excavated area can be constructed as a new area for landfill cell which can expand the capacity of existing Final Processing Site. The mining landfill concept could be developed especially for big cities where it is difficult to find a new site for landfill or to get soil cover for landfill operation.

In a sustainable approach, the excavated area can be constructed as a new area for landfill cell which can expand the capacity of existing Final Processing Site using the concept of block landfill. In this concept, the landfill should be divided into three blocks: compost block, composting block and active block. Usage of the three blocks is rotated with the intention to use solid waste on the compost block as soil material for waste at the active block through landfill mining.

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