Analysis the potential gas production of old municipal solid waste landfill as an alternative energy source: Preliminary results

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Abstract: The MSW landfill produces gas which is represent the energy resource that lost and polluted the ambient air. The objective of this study is to evaluate the potential gas production of old landfill as an alternative energy source. The study was conducted by using 10 years old waste in landfill simulator reactor (LSR). Four Landfills Simulator Reactors (LSR) were constructed for evaluate the gas production of old MSW landfilled. The LSR was made of high density poly ethylene (HDPE) has 50 cm outside diameter and 150 cm of high. The 10 years old waste was excavated from closed landfill and subsequently separated from inorganic fraction and sieved to maximum 50 mm size particle prior emplaced into the LSR. Although quite small compare to the LSR containing fresh waste has been reported, the LRS containing 10 years old waste still produce much landfill gas. The landfill gas produced of LSR operated with and without leachate recirculation were about 29 and 21 litter. The composition of landfill gas produced was dominated by CO_2 with the composition of CH_4 and O_2 were around 12.5% and 0.2 %, respectively.

1. Introduction

The Indonesian government enacted Act 18 on Waste Management in May 2008. This acts requires MSWM authorities to implement integrated waste management by considering the waste hierarchy of reduce, reuse and recycle (3Rs) [1, 2]. MSWM includes the collection, sorting and disposal at landfill site. A landfilling of MSW should be carried out in an environmentally sound manner in order to avoid impacts on humans and the environment. In addition, the act obliges local governments to close landfills that operate as an open dump no later than five years after enactment of this act. Within the same time frame, new landfills to be constructed to replace the open dump ones. The construction, operation and closure of the open dump should be carried out in accordance with the standards and regulations in force [2].

Although there are no exact number how many landfills were operated in Indonesia, the State Ministry of Environment (MoE) estimated that all districts and municipalities have at least one

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landfill. In 2006, the amount of MSW generated and collected was estimated to be about 38.5 million tons [3]. Most of it ended up at landfill sites spread across the 126 districts and municipalities, while only 7% of the waste generated and collected was recycled or composted. Furthermore, about 37% of the total MSW generated arose from major cities such as Jakarta, Bandung, Surabaya, Medan, etc.[3].

The landfilling of municipal solid waste is associates with the environment problems, such as aesthetic problems, air pollution and ground water contamination. Soil contamination is caused by leachate, a liquid which is produce of degradation organic matter including the precipitation that has percolated through a landfilled waste and leached out any soluble materials such as salt, organic and nitrogen compounds. In addition to the leachate, the MSW landfill also produces gas which is mainly methane gas (CH_4) and carbon dioxide (CO_2). These gases are classified as greenhouse gas that caused the increase of atmospheric temperature so called global warming effect. According to Pohland and Harper, 1985 [4], the quantity and composition of landfill gas formed was significantly influenced by the age of landfilled waste. At the same time, the landfills gas is represent the energy resource that lost and polluted the ambient air since most landfill does not equipped landfill gas capture facilities and subsequently use as energy source. The objective of this study is to investigate the landfill gas production of closed landfill, particularly in tropical climate region which identified by high precipitation rate by using landfill simulator and evaluate its potential as energy source.

2. Materials and Methods

2.1. Experimental setup

Four Landfills Simulator Reactors (LSR) were constructed for evaluate the gas production of old MSW landfilled. The LSR was constructed using high density polyethylene (HDPE) pipe of 50 cm outside diameter (OD), 2.5 cm wall thickness and 150 cm of high (total volume of LSR approximately 0.57 m3). The both end of LSR is equipped with lids made of similar material to LSR body. As during the degradation organic matter process, the biogas and leachate are generates, biogas and leachate outlet ports were installed at the top and bottom of the reactor, respectively. Additionally, a showerhead were installed for fresh water to simulate rainfall or leachate recirculation and distribution were also installed at the top of LSR.

The biogas outlet port was connected to the eudiometer to measure the volume of biogas generate subsequently determine its composition by using gas analyzer (Polytector G750, GFG. Inc). Whilst, the leachate outlet port was connected with U-type silicone tube to prevent ambient air enter to the LSR after the leachate drain out. An external plastic reservoir (10 liter capacity) were placed to collect the leachate produced subsequently re-circulate into the LSR. Four thermocouples have 20 cm of length were installed at 40, 65, 90 and 115 cm of bottom LSR to measure the internal temperature of LSR. A two layers blanket made of synthetic wool and aluminum foil was coverage the entire LSR surface to reduce heat transfer from

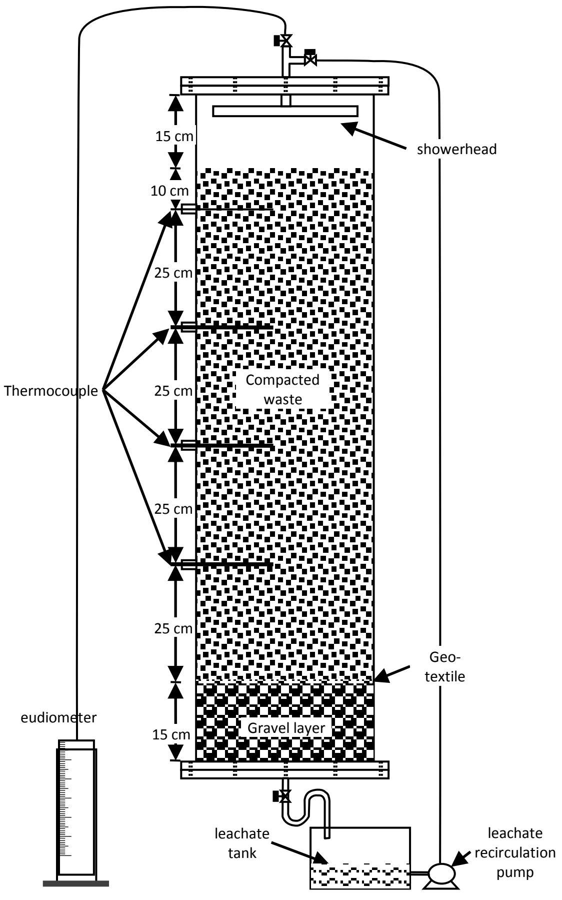

Figure 1. Experimental set up of landfill simulation reactor.

inside to the ambient air. No an electrical device has been use to maintain the internal temperature.

The LSR were filled with a 15 cm layer of sand (particle size ranged 1-2.5 cm) at the bottom followed by geo textile sheet to prevents the pore of gravel layers to be clogged by waste materials. Approximately the last 15 cm at the top of LSR was kept empty as headspace. The dimensions of the reactors are given in Figure 1.

2.2. Waste collection and preparation

The aged waste was collected from Cot Padang Nila landfill. This landfill was located at Tunong Tanjong village, Padang Tiji, Pidie district (5°26'24.3"N 95°49'10.9"E), around 86 km southeast east of Banda Aceh city. The Cot Padang Nila landfill was landfill constructed to received MSW generated from Pidie district area. This landfill has total area around 2.2 ha equipped 3 landfilling cells, treatment pound, and other supporting facilities (see Fig. 2). The Cot Padang Nila landfill was built also by UNDP after tsunami disaster in 2004 and operate immediately after completion. The aged waste was excavated from the first cell which was closed in 2012 after received around 50,000 m^3 of waste. More than 3 ton of waste was excavated to have 1 ton waste with particle size around 1 to 5 cm. Most excavated waste was inorganic matter such as plastic sheet, rubber, textile, and wood mixed with the soil. The inorganic matter was subsequently removed manually of excavated waste to easier sieving the process. The sieving of waste was carried out in two steps, first by using sieving with screen size 5 cm and followed by using sieving with screen size 1 cm. Then the sample was transported to the laboratory for emplaced into the LSR.

Figure 2. Cot Padang Nila landfill, Padang Tiji, Pidie district.

Prior emplaced into the LSR, the collected and sieved waste with maximum particle size of 5 cm was mix to homogenously and divided into four to ensure each LSR received the similar waste. The waste was placed by layers of approximately 30 cm and compacted with hydraulic press up to an apparent density of 375 kg/m^3. Finally, all LSRs was seeded with approximately 20 liters of mature leachate in order to stimulate degradation process and leaching conditions as suggested by Vroon et al., 1999 [5] and Oonk and Woelders, 1999 [6].

Two LSR (A1-A2) was operate according to the standard operating procedure described in Andreas et al., (1998) for LSR under anaerobic conditions. The fresh water was added to simulate the landfill operation with a permeable top-cover and thus the infiltration of rainwater occurred. The other two LSR (B1-B2) was also be operated under anaerobic conditions. However, contrary to LSR A1 and A2, the leachate was re-circulate to simulate landfill operation with a impermeable top-cover and thus the landfill gas capture for use as energy source. The aim this experiment is to determine the residual emission loads from the aged wastes consist of mainly moderately degradable organic compounds as the easily degradable ones have already been degraded. Hence, the landfill gas produced is resulted of the degradability of moderately degradable organic compounds, which will help to determine the ideal way to dealing with the MSW landfill that has been closed.

2.3. Sampling and Analysis
During the experiment, the volume and composition of gas produced were conducted daily basis. The gas was transferred from headspace of the LSR into eudiometer to determine the volume produced gas. The gas subsequently extracted by using portable gas analyzer (Polytector G750, GFG Germany) to determine the gas composition CH_4, CO_2, O_2 and H_2S). In addition to gas, the volume and composition of leachate produced was also determined. The measurement volume, pH and conductivity of leachate samples were carried out every day by using graduated cylinder (Iwaki, Pyrex USA), pH meter (HI9126, Hanna Instruments Inc.USA) and conductivity meter (Pinnacle 541, Corning USA), respectively. COD, NH_4, NO_3 and NO_2 content of the leachate samples were analyzed once a week according to standard methods (APHA, 2005). The heavy metals content (Fe, Cd, Cu, Pb) of the leachate was analyzed with a Atomic Absorption Spectrometer equipped with flame detector (AAS-6300, Shimadzu corp. Japan).

3. Result and discussion

3.1. Landfill gas production
Although four LSR was operated two for each operation method, the data reported here in was one for each. The two other LSR were has some leak in the beginning operation which caused the anaerobic condition has been interrupted for some days before recovered. However, after the leak was fixed, the gas production followed similar trends of other two LSR. The data reported in paper was data collected until 18 day after filling of waste.

The landfill gas was started produce one day after waste filling, this probably due to the microorganism already exist and there was no significant different the environmental condition between the landfill site and LSR. The wastes were excavated and transported from site to laboratory without any adjustment except the particle size. Hence, there was no such long time for bacteria to adapted and restart activity. However, the landfill gas produce quite low compare to the LSR containing fresh waste. The landfill gas produced was around 1.7 l/day, this amounts about a ten of landfill gas produced from LSR containing fresh waste [7]. This was caused by the aged wastes consist of mainly moderately degradable organic compounds as the easily degradable ones have been degraded. The total landfill gas produced of LSR operated with and without leachate recirculation were about 19 and 26 l, respectively (see Figure 3).

The composition of landfill gas produced was dominated by CO_2, with average CH_4 and O_2 contents were 3.7 and 0.7, respectively. The landfill gas composition was lowest compare to the typical landfill gas was reported of experiments with bioreactor landfill simulators; nevertheless biogas composition depends strongly on composition of degradable organic matter and the pH of the system [8]. The low CH_4 content in landfill gas usually occurs in the beginning of anaerobic degradation stage, where the acidogenic process take place. This condition was indicated by decreasing of pH leachate.

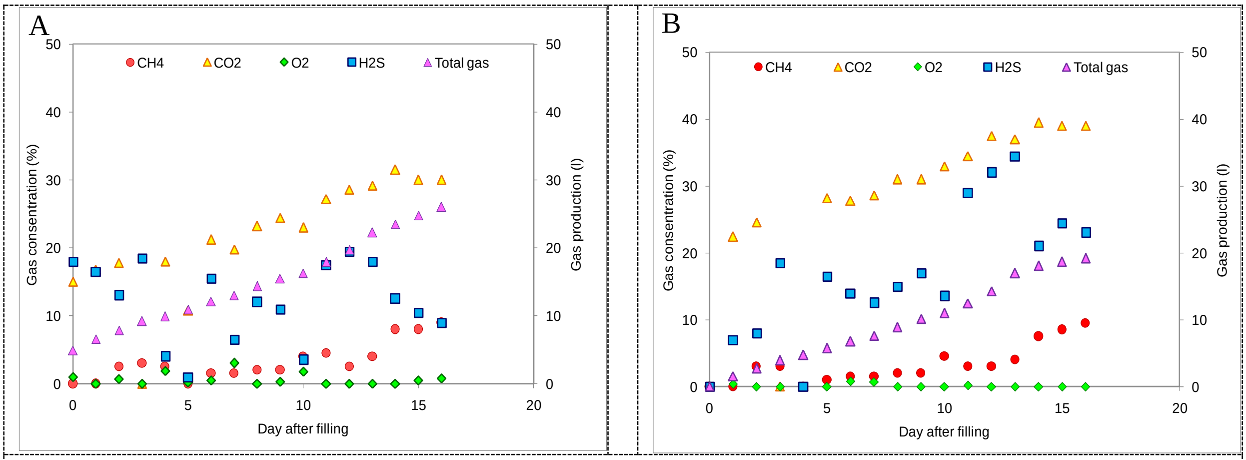

Figure 3. Landfill gas production and composition, (A) LSR operated without leachate recirculation and (B) LSR operated with leachate recirculation.

3.2. *Physical-chemical parameters*

In addition to volume and composition of landfill gas, the physical-chemical parameters also measured. The temperature inside LSR was measured by using digital thermometer which connected to the attached thermocouple has 20 cm of length. The temperature of LSR was relative constant at about 30 (± 2)^o C. There was no significant change compare to the initial condition. This might due the easily degradable organic compound has been completely degraded and the degradation of moderately degradable organic compounds was running very slow. Thus the Heat generated from the degradation of organic compounds does not increase the temperature of the LSR. The LSR temperature around the 18 day operation was about 30 (± 2)^o C. The similar trend was found to the pH value of leachate. The initial pH was around the initial pH was about 6.9 then increase to about 7.1 at day 19. For all reactors, the conductivity reached its lowest level 6.93 mS/cm at day 10 and reached its highest level 7.7 due to salt dissolved into the leachate.

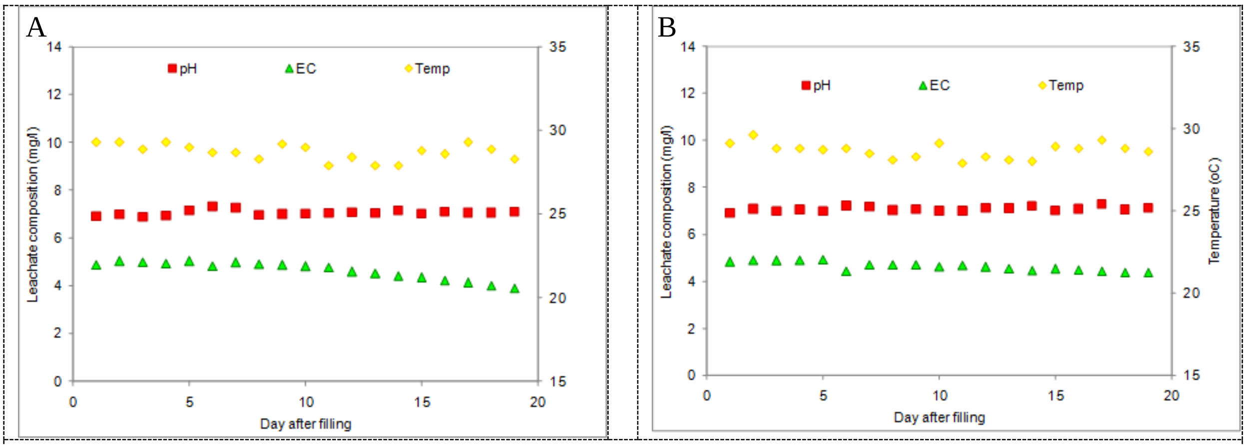

Figure 4. Physical-chemical parameters of LSR, (A) LSR operated without leachate recirculation and (B) LSR operated with leachate recirculation.

3.3. *Biological parameters*

As the leachate analysis was carried out once a week, only few data have been collected. Based on these data collected, the COD concentration has trend to decrease week to week. The COD concentration of LSR A was decreased from 799 mg/l at first week to 342 mg/l after three weeks operation, while COD concentration LSR B was decrease from 480 mg/l to be 320 mg/l (see Fig. 5). On contrary to the COD, the concentration of NO_3 of both LSR tend to increase. The NO_3 concentration of LSR A was increase from 17 mg/l to 31 mg/l, while NO_3 concentration LSR B was increased dramatically from 8 mg/l to 40 mg/l. Although the NO_3 concentration has increase tendency, but the NH_4 concentration in both LSR was observed stable. The NH_4 concentration of both LSRs were around 12.6-14.2 mg/l.

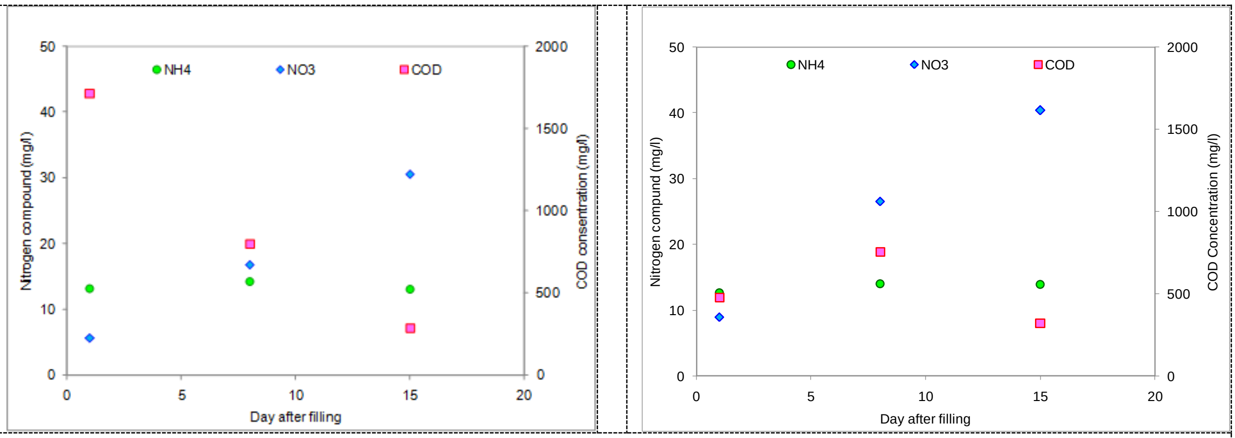

Figure 5. Biological parameters of leachate produce from landfill simulator, (A) LSR operated without leachate recirculation and (B) LSR operated with leachate recirculation.

4. Conclusion

The landfilling of municipal solid waste is associates with the environment problems, such as aesthetic problems, air pollution and ground water contamination. In addition to the leachate, the MSW landfill also produces gas which is mainly methane gas (CH_4) and carbon dioxide (CO_2) which classified as greenhouse gas that caused the increase of atmospheric temperature so called global warming effect, the landfills gas is represent the energy resource that lost and polluted the ambient air since most landfill does not equip landfill gas capture facilities and subsequently use as energy source. The aim of this study is to investigate the landfill gas production of closed landfill, particularly in tropical climate region which identified by high precipitation rate by using landfill simulator and evaluate its potential as energy source.

The landfill gas was started produce one day after waste filling, this probably due to the microorganism already exist and there was no significant different the environmental condition between the landfill site and LSR. The highest methane gas composition was found at reactor B that is about 8.5% and O_2 0.2%. Along with the length of time the waste remains in the reactor, the methane gas produced increases each day on all reactors. Leachate circulation served to keep the moisture of waste and not only can reduce water and soil pollution but also can accelerate the degradation of organic compounds and increase the methane gas production.

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