Utilization of Solid Waste from Landfill Passive Zone to Treate Leachate Through A Combination of Leachate Recirculation and Bulking Agent

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Abstract

Real evidence of the Municipal Solid Waste (MSW) decomposition process is the emergence of pollutants as leachate, which has a chemical composition that is difficult to degrade (recalcitrant compounds) and causes pollution of water bodies. On the other hand, waste from the passive zone landfill is not utilized at all. The aim of this study was to determine the effect of adding solid waste from landfill passive zone as bulking agent to treat fresh leachate with a combination of the recirculation process. MSW + bulking agent (70%: 30%, v/v) was recirculated using fresh leachate with a flow rate of 1 L/min for 30 days. Reactor without recirculation and bulking agent was used as control. The leachate quality was analyzed on days 0, 3th, 7th, 14th, and 30th, while the MSW composition was controlled after being left for 365 days. The outcome of the results obtained from the experiment showed that the addition of bulking agent + recirculation accelerated the increase in leachate pH and the increment of COD reduction. On day 30th, the lowest TDS level presented 63,813.8 mg/L, the conductivity was 111,457.5 µS/cm, and the ammonia showed 72.5 mg/L produced from R3 (MSW + bulking agent + recirculation). The addition of bulking agents from passive landfill zones can reduce COD, TDS, conductivity and ammonium. On the 365th day, the water content of MSW in R3 was 76.8%, pH value get 7.7, EC value presented 43.4 mS/cm and volatile solid achieved 94.99%. The same increase occurred in the total Nitrogen at R3 from 0.23% to 0.95%. Meanwhile, the levels of P-Total and K-Total did not change significantly.

***Keywords:** leachate; recirculation; solid waste; bulking agent; COD, landfill, MSW*

1. Introduction

At pandemic COVID-19, researchers have become increasingly interested in municipal solid waste treatment. Unsustainable waste management in many developing countries makes them more vulnerable to the possible spread of the coronavirus through waste management practices. Although, the impact of the COVID-19 pandemic on the waste management system has not been still well understood [1]. The problem is exacerbated by an increase in waste products as a result of population growth and urbanization [2]. Most countries globally, including Indonesia, have chosen the sanitary landfill method [3] to treat solid waste produced by residents. Sanitary landfills are very economical in terms of exploitation and costs. On the other hand, sanitary landfills have a significant drawback in leachate production which has a chemical composition that is difficult to degrade (contains recalcitrant compounds) and causes pollution of water bodies [4,5]. The strict quality standards, required by the ministry of environment and local governments regarding environmental protection and sustainable development, emphasize the elaboration of the strategy for processing leachate to be thorough.

The landfill as a large anaerobic reactor, abundant in solid waste takes the function of a plentiful and sustainable source of methane gas [6]. For this, researchers and academics are continuously exploring various optimization strategies to increase the efficiency of anaerobic processing [7,8]. However, most of these strategies require a lot of energy and a complicated operating process. Leachate that is wasted has high levels of Chemical Oxygen Demand (COD). On the other hand, the recirculation of this COD, as a source of nutrients for methanogens, increases the contact time between bacteria and organic matter (waste), and increases methane production from MSW [9–11].

Currently, the leachate in Jatibarang Landfill comes from active zone 1 and 2. Zone 3 is the current passive zone. Managers closed the passive zone area and planted green plants on the surface [3]. COD leachate levels in Indonesia vary between 3,500 – 12,000 mg/L depending on the season. The rainy season produces lower COD, but the amount is quite abundant. For example, the Rembang TPA (final processing site) produces 40.82 m^3/day of leachate with a total active zone area of 1.4 ha and a rainfall of 2,449 mm/year. The leachate management system in Indonesia mostly consists of stabilization tanks, biological treatment and aeration [12]. In Indonesia, a leachate management system by recirculation has not been still developed. This has great potential to implement this system because several countries by now have implemented it. According to Rahmawati (2018), the characteristics of solid waste composition in Indonesia are different from other countries, so it needs a thorough and systematic investigation.

This study aims to process leachate using a combination of leachate recirculation and bulking agent based on this background. The bulking agent used comes from the passive landfill zone that is no longer operational. The quality of leachate is evaluated in-depth and systematically.

2. Method

The research was conducted at the Environmental Engineering Laboratory, Diponegoro University using an anaerobic reactor. The anaerobic reactor is made of acrylic material with a capacity of 25 liters, cylindrical shape and dark color. The reactor is equipped with leachate inlet and outlet holes, as well as with gas emission outlets. The inlet hole provide the function to enter the leachate into the reactor using a pump with a 1 L/min discharge. The leachate outlet hole (ø 5 mm) serves for leachate sampling. Gas emission will exit through outlets with a diameter of 2 mm. The gas outlets were closed during the research process and opened once a day to prevent an explosion.

In this study, solid waste and leachate were created artificially with a composition equivalent to the composition of solid waste in the active zone of the Jatibarang landfill. This is an effort to anticipate the spread of COVID-19 through Municipal Solid Waste. Bulking agents are taken from the passive landfill zone in Jatibarang, Semarang, Central Java, Indonesia. Artificial samples of inorganic substances are manually separated to ensure an average particle size of 1.0 – 1.5 cm. The percentage of each component was calculated (wt%).

Combining recirculating leachate and bulking agent aims to accelerate waste degradation, reducing leachate processing volume and improving leachate quality. This study used three reactors, namely reactor 1 (R1), as the control, where this reactor contains 5,000 g of solid waste, and no recirculation was carried out. Reactor 2 (R2) contains 5,000 g of solid waste, and the leachate was recirculated every three days. The reactor 3 (R3) contains solid waste + bulking agent with a ratio of 70%: 30% (v/v) to the total volume 5,000 g. R3 is recirculated once every three days. Once every three days, the leachate of each reactor was taken for the analysis of physical and chemical parameters. The leachate collected from R2 and R3 was recirculated with a discharge of 1 L/min until all the leachates enter back into the reactor. The study performed leachate recirculation during the study period of 30 days. During the operation, all holes were closed to ensure that the reactor conditions take place anaerobically. The quality of leachate was analyzed based on the efficiency of COD removal, TDS, conductivity, nitrate, ammonia and pH.

The leachate pH was measured using a pH meter (Walklab TI 9000, Singapore) with an accuracy of 0.01. Leachate pH measurements were carried out in the three reactors on day 1th, 3th, 7th, 14th and 30th. The closed reflux method was used to determine the COD leachate concentration. Measurement of COD and nitrate concentration was provided by using a UV vis spectrophotometer (Thermoscientific Genesys 10, USA). The concentration of NH_4^+ -N was determined using the Nessler method. Total Dissolved Solid (TDS) and conductivity were tested using conducivity-TDS-salinity meter HC9021 (Walklab, Singapore).

3. Results and discussion

The results and the most important biological reaction that occurs in the solid waste decomposition process was the conversion of organic matter to gas and leachate. The most important chemical reactions were the dissolution and suspension of MSW materials and products of biological processes as well as oxidation reduction reactions that affect the solubility of metals and metal salts [14].

3.1. The effect of leachate recirculation on pH.

Anaerobic decomposition generally goes through four stages. First, a decrease in pH due to the production of volatile fatty acids (VFA) during the hydrolysis and acidogenesis processes[15]. In this study, the pH value decreased from the third day, both in the reactors R1, R2 and R3 (Figure 1 a). This was an indication that the process of hydrolysis and acidogenesis had taken place[15]. On the third day, the pH value at R1 was 5.9, R2 of 5.8 and R3 6.23. The presence of the recirculating leachate + bulking agent as much as 30% in R3 produces a higher pH than the ones with and without recirculation. The bulking agent functions as a leachate buffer for the pH not to drop drastically. These results indicate that the bulking agent had a larger buffer capacity to maintain the pH value[16]. Cooked and stable compost can be used as a pH buffer because it increases nitrogen availability[17].

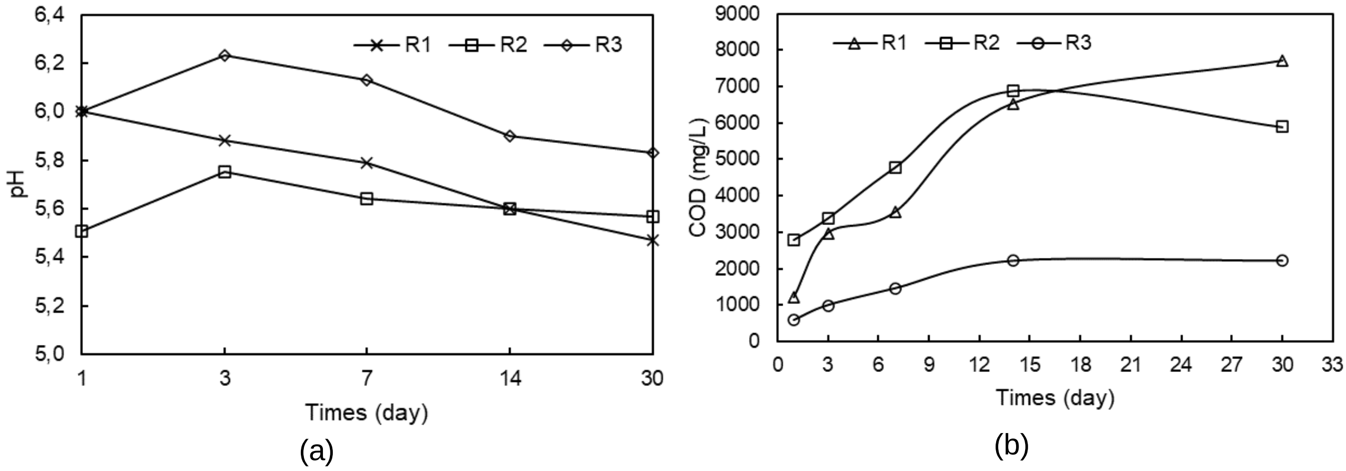


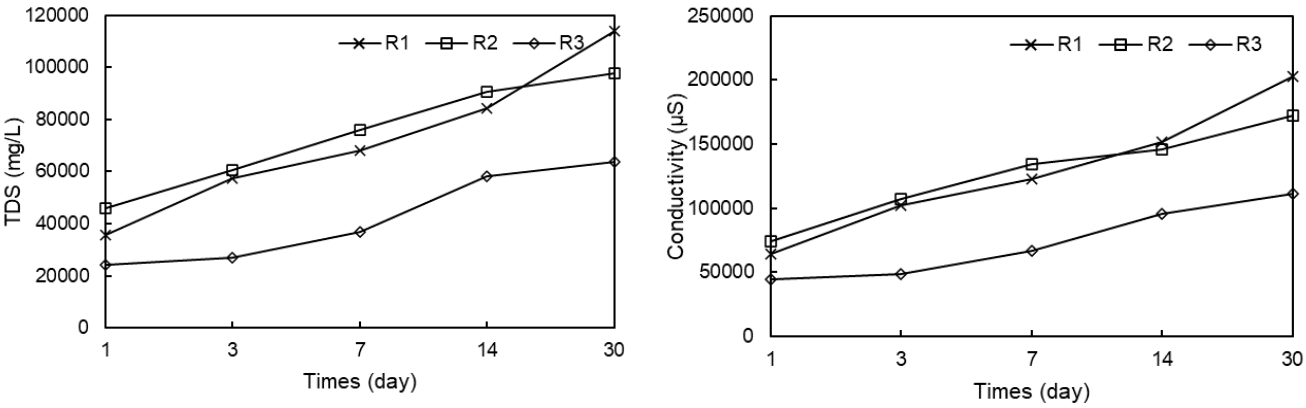
Figure 1: The pH values (a) and COD concentrations (b) of leachate generated from R1, R2, and R3 at 30 days

3.2. Effect of leachate recirculation on COD concentration.

COD is an important parameter for determining the amount of organic and inorganic material in water. COD concentration is used to estimate oxygen demand through oxidative degradation of the organic compounds presented in the leachate. This oxidative degradation was carried out chemically using a strong oxidizing agent such as dichromate or permanganate [18]. The results showed that the COD value increased significantly from the third day to the 14th day and was stable in the 14th to 30th day range. On the 30th day, COD concentration in R3 was much lower than in the other reactors (Figure 1b). The COD in R3 was 2,216.7 mg/L, while R1 was 7,700.0 mg/L and R2 was 5,891.7 mg/L. The presence of a bulking agent significantly reduces COD levels in the leachate.

3.3. Effect of leachate recirculation on TDS concentration and conductivity.

A high TDS concentration is usually associated with a high ion concentration, which increases the conductivity of the liquid. Sulfate and chloride anions are the main anionic contributors to TDS [19]. TDS levels and conductivity are shown in Figures 3a and 3b. TDS levels and conductivity have increased from day to day. R3 produces a lower TDS and conductivity levels than both R1 and R2. The lowest TDS level was 63,813.8 mg/L and the lowest conductivity level was 111,457.5 μS resulting from R3.



(a) (b)

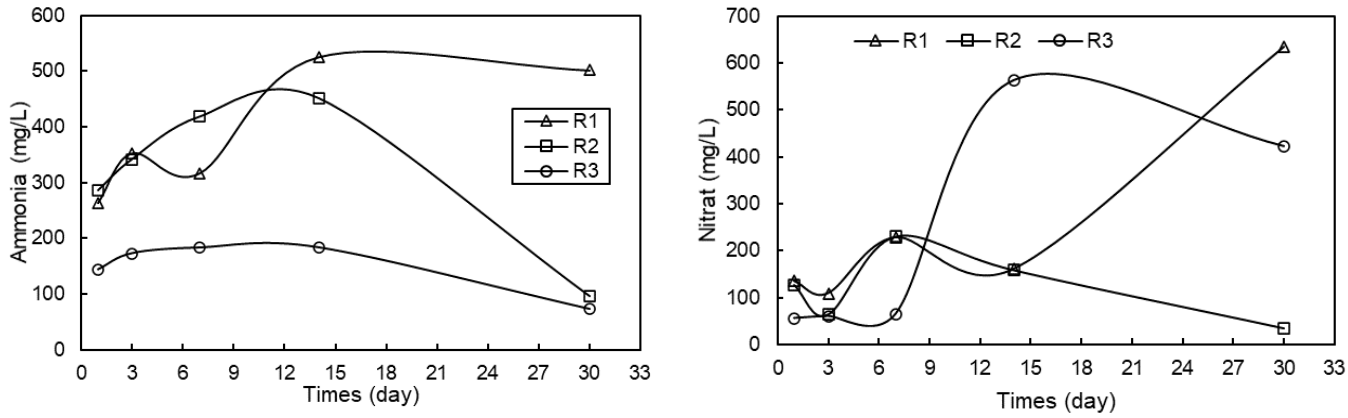
Figure 2: The concentration of TDS (a) and conductivity (b) of leachate generated from R1, R2, and R3 at 30 days

3.4. Effect of leachate recirculation on ammonia and nitrate concentrations.

Based on Amlinger and Top [20,21] The presence of $N\text{-}NH_4^+$ in leachate comes from the MSW ammonification process, namely the transformation of organic nitrogen compounds (humus-R-NH_2) into $N\text{-}NH_4^+$ (stage 1), then ammonification stage 2, where NH_3 becomes $N\text{-}NH_4^+$ based on equation (1) and (2).

Ammonification stage 1:	$\text{humus-R-}NH_2 + H_2O \longrightarrow NH_4^+ + R\text{-}OH$	(1)
Ammonification stage 2:	$\uparrow NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$	(2)
Nitrification stage 1:	$2NH_4^+ + 3O_2 \longrightarrow NO_2^- + 2H_2O + H^+$	(3)
Nitrification stage 2:	$NO_2^- + O_2 \longrightarrow NO_3^-$	(4)
Denitrification:	$NO_3^- + 10^e + 12\,H^+ \longrightarrow N_2 + H_2O$	(5)

Figure 3a is a graph of ammonia and nitrate levels in R1, R2 and R3 generated during the 30 days of the study. On the first day, R1 did not undergo recirculation resulting in ammonia levels of 262.7 mg/L, while R2 and R3 experienced one-time recirculation to produce leachate with ammonia levels of 286.0 mg/L and 143.7 mg/L, respectively. Based on this value, the bulking agent in R3 was able to reduce ammonia levels in the leachate. The pattern of ammonium levels was almost the same in all reactors. The increase in ammonia occured from the third to the 14th day, while on the 30th day it decreased compared to the 14th day. At the end of the study, the lowest ammonia level was produced by R3 at 72.5 mg/L. Based on Figure 3b, R3 produced a leachate with nitrate levels of 56.5 mg/L, while R1 and R2 get a production of 135.8 mg/L and 127.1 mg/L, respectively. The increase in nitrate was quite sharp from R3 on day 14th, where the nitrate level reached 563.0 mg/L. At the end of the study, the lowest nitrate level was produced by R2 with 35.0 mg/L.



(a) (b)

Figure 3: Ammonia (a) and nitrate (b) concentrations of leachate generated from R1, R2, and R3 at 30 days

3.5. Long term quality of municipal solid waste

This research analyzed changes of long-term MSW composition after being left for a period of 365 days. The characteristic of municipal solid waste at 365 days are shown in Table 1. The water content showed a largest increase in R3 from the initial water content of 32% to 76.8%. This increase was due to the leachate recirculation process and the addition of the bulking agent. We take samples at the bottom of the reactor. The increase in water content comes from water bound to solid waste at the top. As a result of the decomposition process, the water undergoes leaching and flows through the MSW by gravity. As a result, there is a buildup of water at the bottom of the reactor. This is in accordance with other studies [22], where the recirculation aims to increase the water content of solid waste. The pH of the waste on day 365th ranged from 7.1 to 7.7. The EC value multiplied a significantly increased from 6.9 mS/cm to 13.8 mS/cm, 35.8 mS/cm, 43.4 mS/cm for R1, R2 and R3 respectively. Volatile solids (VS) are the solid fraction remaining after sample dried, weighed and ignited at 600°C [23]. The volatile solids experienced a significant increase, especially in R3, where the value raised from 54.3% to 94.99%, while VS in control reactor were 62.10%. This indicated that the amount of volatile solids on R3 was more than in R1. Danlami Yavini et al. [24] stated that the VS content is an indication of the level of degradation. Meanwhile, Rukmini [25] stated that the changes in volatile solids content indicate the speed of organic matter conversion. So, the organic matter conversion rate at R3 was greater than that of R1 and R2. The same increase occurred in the total nitrogen at R3 from 0.23% to 0.95%. Meanwhile, the levels of K-Total did not change significantly, P-Total increased significantly.

Table 1: Characteristics of municipal solid waste at 365 days

No	Parameters	Unit	Result			
			A	R1	R2	R3
1	Water content	%	32.0	44.2	63.2	76.8
2	pH	-	5.8	7.1	7.7	7.38
3	EC	mS/cm	6.9	13.8	35.8	43.4
4	Volatile Solids	%	54.3	62.10	72.70	94.99
5	Organic C	%	12.5	5.49	7.49	25.93
6	N-Total	%	0.23	0.38	0.408	0.952
7	P-Total	mg P_2O_5/100 g	0.003	0.007	0.027	0.031
8	K-Total	mg K_2O/100 g	0.012	0.017	0.014	0.036

A - Sample of solid waste at 0 days
R1 - Sample of solid waste without recirculation at day 365th
R2 - Sample of solid waste+recirculation at day 365th
R3 - Sample of solid waste+recirculation+bulking agent at day 365th

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4. Conclusions

The aim of this study was to determine the effect of adding solid waste from landfill passive zone as bulking agent to treat the fresh leachate produced in the landfill with a combination of recirculation processes. The pH value was decreased from the 3th day, both in reactors R1, R2 and R3. On day 30th, R3 produced a higher pH than R1 and R2. The bulking agent on R3 functioned as a pH buffer, so that the pH value of the leachate did not drop drastically. The bulking agent had a larger buffer capacity to maintain pH value. The COD concentration in R3 was much lower than in the other reactors (2,216.7 mg/L), while R1 was 7,700 mg/L and R2 showed 5,891.7 mg/L. At the end of the study, the lowest TDS level was 63,813.8 mg/L, the conductivity get a value of 111,457.5 µS, and the ammonia level was 72.5 mg/L in R3. The addition of a bulking agent from the landfill passive zone can reduce levels of COD, TDS, conductivity and ammonium. Municipal solid waste parameters increased for a long time. Water content in R3 increased from the initial water content from 32% to 76.8%. The pH on day 365th ranged from 7.1 to 7.7. EC value increased from 6.9 mS/cm to 13.8 mS/cm, 35.8 mS/cm and 43.4 mS/cm for R1, R2 and R3, respectively. Volatile solids in R3 increased significantly from 54.3% to 94.99%. The same increase occurred in the total Nitrogen at R3 from 0.23% to 0.95%. Meanwhile, the levels of P-Total and K-Total did not change significantly. The implication of this research is that MSW in the landfill passive zone can be used to treat fresh leachate. Leachate will not come out into the water body, so that pollution to the environment due to leachate can be minimized.

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Využití pevného odpadu z pasivní zóny skládky do upraveného výluhu kombinací recirkulace výluhu a objemového činidla

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Souhrn

Skutečným důkazem procesu rozkladu tuhého komunálního odpadu (TKO) je vznik znečišťujících látek ve formě výluhu, který má chemické složení, které se obtížně odbourává (odolné sloučeniny) a způsobuje znečištění vodních útvarů. Na druhou stranu odpad z pasivní zóny skládky není využíván vůbec. Cílem této studie bylo zjistit účinek přidání pevného odpadu z pasivní zóny skládky jako objemového činidla pro úpravu čerstvého výluhu s kombinací procesu recirkulace. TKO + objemové činidlo (70 % : 30 %, obj./obj.) bylo recirkulováno pomocí čerstvého výluhu s průtokovou rychlostí 1 l/min po dobu 30 dnů. Reaktor bez recirkulace a plniva byl použit jako kontrola.

Kvalita výluhu byla analyzována ve dnech 0, 3, 7, 14 a 30, zatímco složení TKO bylo analyzováno po ponechání po dobu 365 dnů. Výsledky získané z experimentu ukázaly, že přidání plnidla + recirkulace urychlilo zvýšení pH výluhu a zvýšilo pokles CHSK. V 30. den byla nejnižší hladina TDS 63813,8 mg/l, vodivost byla 111457,5 S/cm a amoniak byl 72,5 mg/l vyrobený z R3 (TKO + plnidlo + recirkulace). Přidání objemových činidel ze zón pasivních skládek může snížit CHSK, TDS, vodivost a amonium. V 365. den byl obsah vody v MSW v R3 76,8 %, pH bylo 7,7, EC hodnota byla 43,4 mS/cm a těkavá pevná látka byla 94,99 %. Ke stejnému nárůstu došlo u celkového dusíku na R3 z 0,23 % na 0,95 %. Mezitím se hladiny P-Total a K-Total výrazně nezměnily.

***Klíčová slova:** výluh, recirkulace, TKO, CHSK, skládka*