International Journal of GEOMATE, April, 2020, Vol.18, Issue 68, pp. 35 - 40
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.68.5592
Special Issue on Science, Engineering and Environment

EVALUATION OF METHANE AND CARBON DIOXIDE EMISSIONS FROM LIVESTOCK WASTE, COMPOST, AND BIOGAS SLUDGE

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*Corresponding Author, Received: 14 June 2019, Revised: 20 Nov. 2019, Accepted: 10 Feb. 2020

ABSTRACT: Livestock sector contributes to greenhouse gases (GHGs) emission especially methane and carbon dioxide gases that produced from digestive system and manure of ruminants. GHGs mitigation was conducted by cattle manure waste management through biogas and compost technologies. In this study we evaluated methane and carbon dioxide emissions from untreated and treated cattle manure in cattle farm group of Ngudi Mulyo, Yogyakarta. Test equipment that used in this study is 25-liters chamber to isolate gas emissions from naturally digested untreated and treated cattle manure for eight weeks. Gas samples were analyzed by gas chromatography (GC). The results shows that buried cattle manure produced the highest methane emission of 173100 ppm while compost from cattle manure produced of 2963.33 ppm. There is the decrease in methane emission of compost and sludge biogas from cattle manure (98.18 and 98.10% respectively) compared to fresh cattle manure. The highest carbon dioxide emission was produced by fresh cattle manure (580215.371 ppm). Conversion of cattle manure to biogas sludge and compost could reduce carbon dioxide emission of 80.85 and 86.23% respectively compared to fresh cattle manure. We concluded that cattle manure waste management by biogas and compost technologies are important role in GHGs mitigation especially in livestock sector.

Keywords: Manure, Methane, Carbon dioxide, Biogas, Compost

1. INTRODUCTION

Global warming is due to the increase in greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), chloro-fluoro-carbon (CFC), hydro-fluoro-carbon (HFC), nitrous oxide (NOx), and sulfur hexafluoride (SF_6). All of these gases, carbon dioxide and methane are the most abundant GHGs in the atmospheric. In addition, methane has 21 times higher global warming potential. One of sectors that generate methane and carbon dioxide emissions is livestock sector. In United Nations' books, Livestock Long Shadow in 2016 reported that livestock activities generate 18% from total GHGs emission [1]. Pete et al. [2] were also reported that agriculture sector included livestock sector contributes 10-12% of total anthropogenic emissions of GHGs. CH_4 contributes approximately 50% of total emissions. It means livestock have a substantial impact on climate change. Emissions of methane and carbon dioxide were produced from digestive system of ruminants and livestock waste. Based on Livestock and Animal Health Directorate [3], in Indonesia number of cattle population undergone the increase from year 2013 until 2017. A dramatic expansion livestock sector has been driven by population growth and rising income in Indonesia. But unfortunately, manure from cattle livestock is just being stockpiled in these cages. And the consequence the accumulation of cattle manure enhances GHGs emission. It's big challenges that faces livestock sector in Indonesia. Moreover it causes water and air pollution [4]. The high level of emissions opens up large opportunities for climate change mitigation through livestock action [5].

Mitigation strategic to reduce GHGs emission that generated from livestock manure is utilizing cattle manure as substitute of fossil fuel energies through biogas technology and compost as substitute of synthetic fertilizer. This is hierarchy of utilization of livestock manure for many benefits (Fig.1).

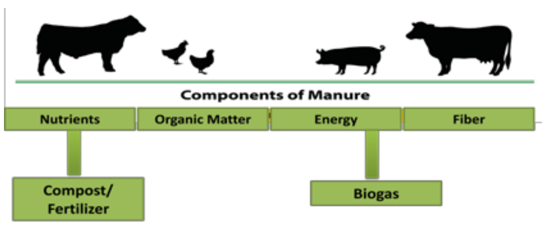

Fig.1 Benefits of livestock manure

Figure 1 showed that components of manure like nutrients and energy can be converted to fertilizer or compost and biogas respectively.

Cattle manure is the most typical forms of waste that used in as source of biogas production because its composition consists of carbohydrates, proteins, fats, cellulose, and hemicelluloses [5]. Cattle manure is suitable to be converted to biogas and compost because of its high organic content. Methane that produced from cattle manure by biogas technology through three pathways are hydrolysis, acidification and methanogenesis [6]. Hydrolysis pathway is when complex organic content in cattle manure to be converted to monomers or simple organic compounds while acidification is when organic monomers to be converted to organic acids. Last step, methanogenesis pathway, organic acids will be converted to methane by anaerobic bacteria. Livestock waste management by utilizing cattle manure to produced biogas and compost will reduce methane emission [7]-[9. Biogas is a clean, efficient, and renewable energy that substitutes coal energy [10]. Besides that, the composting of cattle manure will degrade organic content to simple compounds by microorganism. Simple organic content in compost can fulfill nutritional needs of plants [111]. Utilization of compost can substitute synthetic fertilizer because it give abundant nutrients, amino acids, and bioactive substances to plants [12].

Evaluation of methane and carbon dioxide is rare studied so in this study we evaluated methane and carbon dioxide emission from untreated cattle manure and treated cattle manure that taken from farmer group in Yogyakarta

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2. METHODOLOGY

2.1 Materials

Cattle manure that used in this study was taken from cattle farmer group of Ngudi Mulyo in Yogyakarta. In this study, we evaluated methane and carbon dioxide emissions from untreated and treated cattle manure. Sample of untreated cattle manure were taken from fresh cattle manure and 3 months buried cattle manure. Sample of treated cattle manure were taken from compost which processed for five weeks and biogas sludge which digested for one week (Fig.1).

The test equipment that used to calculate methane and carbon dioxide emissions is 25-liter chambers equipped with fan and thermometer. Each chamber is also equipped with a rubber cap above its surface to take gas sample. The design of chamber can be seen in Fig. 3 and Fig.4.

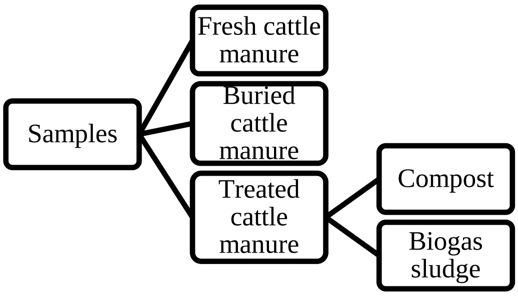

Fig.2 Samples cattle manure in evaluation of methane and carbon dioxide emissions

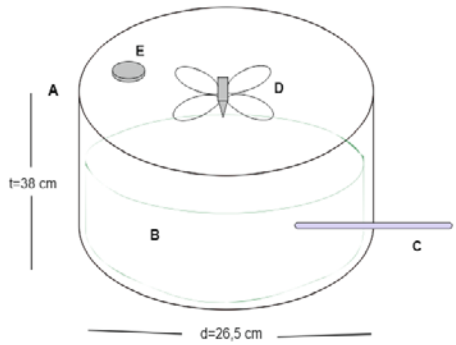

Fig.3 The design of chamber (A. chamber with height of 38 cm and diameter of 26,5 cm, B. untreated/treated cattle manure, C. thermometer, D. fan, E. rubber cap).

Fig.4 Chamber that used in evaluation of methane and carbon dioxide emissions

2.2 Methane and Carbon Dioxide Data Collection

Each of fresh cattle manure, buried cattle manure, compost, and biogas sludge was put in a 25-liter chamber. Each sample was naturally digested for 8 weeks. Gas that produced from this chamber was analyzed to calculate of methane and carbon dioxide emissions. Gas samplings were carried out in every week for 8 weeks. The time interval for each gas sampling per week are 10 minutes, 20 minutes, and 30 minutes respectively.

In addition, the fan must be turned out to make homogenized gas when gas sampling was taken by a syringe.

Methane and carbon dioxide concentration in gas samples were analyzed by gas chromatography (GC). Methane or carbon dioxide concentration was used to calculate methane or carbon dioxide flux with formula in Eq. (1) [6].

$$E\ (\frac{\frac{mg}{m^2}}{minute}) = \frac{dc}{dt}\ x\ \frac{Vch}{Ach}\ x\ \frac{mW}{mV}\ x\ \frac{273,2}{273,2+T} \quad (1)$$

Equation (1) is formula to calculate methane or carbon dioxide emission per unit of area and time (E). $\frac{dc}{dt}$ refers to difference concentration of methane or carbon dioxide per unit time (ppm). Vch is volume of chamber (m^3) while Ach is area of top chamber (m^2). $mW$is the molecular weight of gas, mV is the volume of gas molecule (22.4 liters), and T is average temperature in gas sampling (^{o}C). We conducted T-test to analyzed methane and carbon dioxide emission in ppm.

3. RESULTS AND DISCUSSION

3.1 Methane and Carbon Dioxide Emissions

In this study, methane and carbon dioxide are GHGs emission that generate from untreated and treated cattle manure. Tubiello [13] reported that methane and carbon dioxide emission are produced from cattle's digestive system and manure. Cattle have a special digestive system which there is methanogenics bacteria in their rumen that convert organic matter to be methane and carbon dioxide gases and carried out together with their manure. To reduce methane and carbon dioxide emissions, cattle manure waste could be managed by biogas and compost technology [7]-[9]. We have evaluated and compared GHGs emission from untreated and treated cattle manure. In this study we reported that management of cattle manure by biogas and compost can reduce GHGs emission. Methane and carbon dioxide total emissions of cattle manure showed in Table 1 and Table 2 respectively.

In this study, both of fresh and buried cattle manure are not significantly different in producing high methane emissions. Fresh cattle manure produced 162797.10 ppm of methane while buried cattle manure produced 173101.00 ppm. Buried cattle manure produced more methane than fresh cattle manure because when cattle manure was buried, it will make the condition increasingly anaerobic, a good condition to generate more methane gases [14]. But based on the data on Table 1, methane gas emissions from fresh cattle manure is higher significantly compared to cattle manure that converted to be sludge of biogas and compost. Compost only generated 2933.89 ppm of methane methane. It's lower than sludge biogas that generated 3070.55 ppm of methane. In compost production, the surface material was incorporated into the pile while material at the bottom so the chance of CH_4 production by anaerobic condition were minimal [15]. The turning of compost resulted in more uniform and smaller-sized aggregates makes some anaerobic microsites could have not developed inside in the pile [16] so that methane that produced from sludge biogas' higher than compost. The lower methane emission from sludge biogas and compost was revealed that this method is more environmental friendly in waste management. Amanda [9] explained that biogas sludge is product of anaerobic degradation that has lower methane gases emission because methane that produced in biogas process was utilized as resource of renewable energy. Methane is flammable gas that converted to energy for cooking or electricity especially in rural area. Utilization of cattle manure to biogas and compost was proven to be able to reduce methane emission of 98.11 and 98.18% respectively.

Table 1 Total emissions of methane from cattle manure

Sample	CH_4 emission (ppm)	
	Total CH_4	Average of CH_4
Fresh manure	162797.10	32559.4±107[a]
Buried manure	173101.00	34620.2±981[a]
Sludge biogas	3070.55	614.1±981[a]
Compost	2933.89	586.78±43,0[b]

Table 1 Total emissions of carbon dioxide from cattle manure

Sample	CO_2 emission (ppm)	
	Total CO_2	Average of CO_2
Fresh manure	580215.371	116043.8±197[a]
Buried manure	535458.552	107091.6±844[a]
Sludge biogas	111108.55	22221.6±830[b]
Compost	79888.38	15977.6±780[b]

The same phenomenon also occurred in carbon dioxide emission. Utilization cattle manure to biogas and compost reduced carbon dioxide emission significantly from 580215.371 ppm to

111108.55 and 79888.38 ppm respectively. The significant reducing of carbon dioxide or the best decrease in carbon dioxide emission in sludge biogas was caused by anaerobic condition makes carbon dioxide production can be minimized. Anaerobic condition would prefer to convert carbon content in cattle manure to methane gases compared to carbon dioxide.

In this study, buried cattle manure reduced 7.71% of carbon dioxide while cattle manure treatment by biogas and compost were able to reduce carbon dioxide of 80.85 and 86.23% respectively. This fact should be recommended to many cattle farmers in Indonesia that some of them are not capable to manage organic waste to biogas or compost. They still maintain waste management by piling up cattle manure in specific place. So, biogas and compost technologies are recommended as alternative mitigation action in reducing GHGs emission.

3.2 Methane and Carbon Dioxide Flux

Methane or carbon dioxide flux is the differences of methane or carbon dioxide concentration that produced in certain time and area units. In this study, we also investigated methane emissions from untreated and treated cattle manure. Figure 5 is methane flux from fresh and buried cattle manure, biogas sludge, and compost.

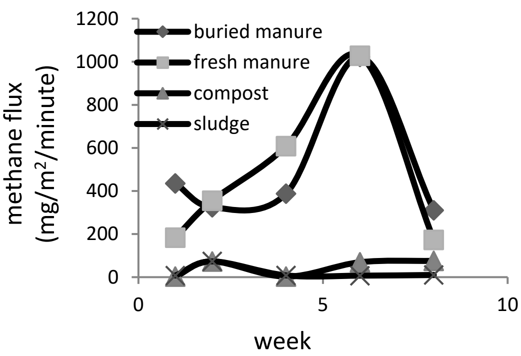

Fig.5 Methane flux of fresh cattle manure, buried cattle manure, biogas sludge, and compost

Methane flux of fresh cattle manure at the first week was 183.21 mg/m^2/minute, at the second week was 354.97 mg/m^2/minute, at the third week was 608.57 mg/m^2/minute, at the sixth week was 1027 mg/m^2/minute, and at the eighth week was 173.06 mg/m^2/minute. There was the increase in methane flux by increasing time of observation. The same trend showed by buried cattle manure. Methane flux of buried cattle manure were 435.19, 324.96, 388.15, 1022.78, 310.53 mg/m^2/minute at the first, second, fourth, sixth, and eighth week of observation. This phenomenon can be explained in this study. At first day until to 30th days naturally methanogenic bacteria started to convert organic matter in fresh and buried cattle manure to methane gases [16]. In this study, at the last week of observation (eighth week), production of methane gases was limited because the methane production was optimal until sixth week. At the sixth week, methanogenic bacteria have already multiplied to produce the highest methane gases 1027 mg/m^2/minute. After that, methane production would decrease day by day, only produced 173.06 mg/m^2/minute of methane at eighth week. This phenomenon also was explained by Lise [17] and Puspitasari [18]. Methane flux of cattle manure increased from the first until sixth week and after that, at the eighth week it would decrease.

Lower methane flux was showed by treated cattle manure of biogas sludge and compost. Methane flux of biogas sludge were 7.66, 72.23, 8.14, 7.01, and 10.29 mg/m^2/minute at the first, second, fourth, sixth, and eighth week of observation. While methane flux of compost were 2.68, 73.09, 2.64, 69.32, and 75.80 mg/m^2/minute at the first, second, fourth, sixth, and eighth week of observation. Methane flux on biogas sludge and compost were relatively stable in the eighth week. It means carbon conversion of cattle manure to biogas and compost have stopped. Lower methane flux rate in compost can be explained. By turning the compost pile, the surface material was incorporated into the pile while material at the bottom was exposed at the surface. This process makes the chance of methane production by the development of anerobic condition was minimal. Aerobic condition microorganisms prefer produce carbon dioxide than methane so that methane flux from compost is lower than sludge biogas. Moreover, aeration treatment in composting reintroduced fresh air (O_2) into the manure and activated biological activity of aerobic microorganism to degrade carbon content in manure to be carbon dioxide. This process due to turning led to a higher carbon dioxide emission of compost compared to sludge. It means most carbon content loss in the form of carbon dioxide.

Beside generating methane, carbon dioxide was also generated after one week observation. In this study carbon dioxide flux decreased with the increasing time. Figure 6 showed that carbon dioxide flux of fresh manure were 1007.36, 4824.73, 700.89, 178.01, and 254.69 mg/m^2/minute at the first, second, fourth, sixth, and eighth week respectively. The highest carbon dioxide flux of fresh cattle manure was occurred at the second week because fresh cattle manure contained high organic matter that used by microorganism to produced carbon dioxide. The decreasing of carbon dioxide flux of biogas sludge and compost were not significant for eight weeks observation. Carbon dioxide flux of biogas sludge were 282.14, 230.56, 11.07, and 5.97 mg/m^2/minute at the first, second, fourth, sixth, and eighth week respectively while carbon dioxide flux of compost were 226.11, 101.85, 60.15, 12.51, and 5.98 mg/m^2/minute at the first, second, fourth, sixth, and eighth week respectively.

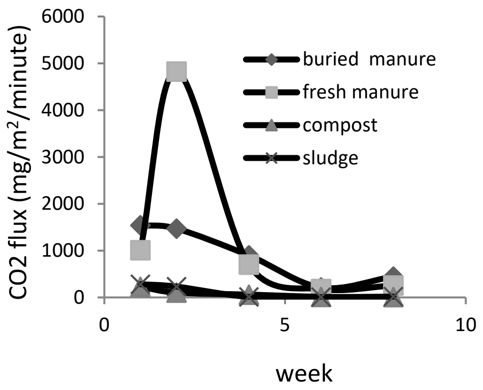

Fig.6 Carbon dioxide flux of fresh cattle manure, buried cattle manure, biogas sludge, and compost

Carbon dioxide flux of sludge and compost were relatively stable and lower compared to fresh and buried cattle manure because carbon content of cattle manure have been decomposed and converted to energy and others material content. The lower carbon dioxide flux of compost and sludge means emission rate of carbon dioxide from cattle manure can be mitigated. The fact that decomposition and stabilization of cattle manure by biogas and compost technology would emit GHGs emission also have been reported previous [7]-[9],[19]. The reduce in methane and carbon dioxide emissions from biogas that was reported by Amanda [9] showed biogas can reduce approximately 3.9% of annual GHGs emissions.

4. CONCLUSION

Based on this study, we concluded that conversion of cattle manure by biogas and compost technologies were able to decrease in methane emission at 98.11 and 98.18% respectively while carbon dioxide emission at 80.85 and 86.23% respectively. Biogas and compost technologies were proven and recommended to be one of actions in GHGs mitigation especially in livestock sector.

5. ACKNOWLEDGMENTS

The research was supported by Grant Program from Universitas Gadjah Mada, Indonesia through PTUPT program with contract number 2696/UN1.DITLIT/DIT-LIT/LT/2019. We also gratefully acknowledge the support from USAID through the SHERA program – Centre for Development of Sustainable Region (CDSR). In year 2017-2021 CDSR is led by Center for Energy Studies - UGM. Authors would like to thank for students of Faculty of Animal Science that contributed in collecting the data.

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