



PHYSICAL AND CHEMICAL CHARACTERISTICS OF GASEOUS EMISSIONS FROM CATTLE MANURE AND THEIR ODOUR INTENSITY

A. S. Yuwono¹, A. H. Tambunan², Desrial², S. Dohong³, D. Setyaningsih⁴ and Y. C. Wirasembada¹

¹Department of Civil and Environmental Engineering, Bogor Agricultural University, Indonesia

²Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Indonesia

³Department of Animal Production and Technology, Bogor Agricultural University, Indonesia

⁴Surfactant and Bioenergy Research Centre (SBRC) – LPPM, Bogor Agricultural University, Indonesia

E-Mail: arief.sabdo.yuwono66@gmail.com

ABSTRACT

Gaseous emission from fresh manure in a cattle feedlot located in Bekasi municipality, West Java Province, Indonesia is planned to be raw material for biogas production in order to substitute a part of electricity energy need in a local household scale. To enable an engineering design of the facility to convert biogas to be electrical energy as well as to ensure the sustainability of the energy supply system, physical and chemical characteristics of the gaseous emission from the fresh manure was carried out. The objectives of the research are to describe the physical and chemical characteristics of the gas emitted from cattle manure and to measure the odour intensity of the existing ambient air in the inner area of the cattle feedlot as well as in their surrounding areas. Physical parameters include temperature, relative humidity, enthalpy, and specific volume, whereas chemical parameters cover Methane (CH₄), Carbon Monoxide (CO), Carbon dioxide (CO₂), Oxygen (O₂), Hydrogen (H₂), Nitrogen (N₂), and two odorous gases, i.e. Ammonia (NH₃) and Hydrogen sulphide (H₂S). The gaseous samples were taken two times per day (6 AM in the morning; 6 PM in the evening) within two days campaign. Laboratory analyses were conducted according to the national standard methods (SNI) in an accredited laboratory. Odour intensity was also measured by using an odour judge panel consisting of seven well trained odour panellists. Result of the analysis show that methane concentration of the emitted gas is 13% and the majority of the gas was nitrogen (59%). The concentrations of the odorous gases inside the feedlot were much higher than the national standard limit, whereas outside of the feedlot was below the standard. Odour intensity perceived by the panellist indicated that the average score inside the feedlot was -2.3 [unpleasant], whereas the outside one was 0.0 [neutral].

Keywords: biogas, cattle manure, feedlot, methane, odour, physical-chemical characteristics.

1. INTRODUCTION

A number of researchers have been conducting experiments on cattle manure management including aspects of life cycle analysis [1; 2; 3], their global warming impacts [4; 5; 6], energy aspect [7; 8; 9], gaseous emissions [10; 11], as well as their harmful environmental impacts as indicated in researches conducted by Capper and Cady (2011) [12], Varel *et al.* (2011) [13], Cardoso (2012) [14] and Graux *et al.* (2012) [15].

In this research, cattle feedlot located in Bekasi Municipality, West Java Province, Indonesia is currently facing negative image due to its odorous emission into the environment. However, their worker are mostly local people and therefore, this environmental nuisance is nowadays concerned as a common problem that is almost no objection. Nevertheless, on the other side, the cattle feedlot has a potential as a source of energy based on the fact that cattle manure contains methane (CH₄) which is known as the most important component of biogas.

The feedlot was occupied by about two thousands (2000) cattle ranging from 300-900 kg weight where the biggest part of them is in between 300-600 kg/head. Generally the average manure production is about 8% of the live weight which is similar in this case to 24-72 kg/head. Therefore, if the average of the cattle weight is 500 kg/head, then the total production of the manure from this feedlot was about 80 tons/day. The emerging harmful

environmental problems thereof include odour, dust emission, community perceptions, and within certain extend, as a source of flies for the surrounding community. In this research, a number of basic environmental aspects were assessed to describe both positive and negative aspects of the feedlot, i.e. their potential as energy source as well as the negative impacts such as odour nuisance in the environment. The objectives of the research were as follows:

- To describe the physical characteristics of the gas emitted from cattle manure consisting of parameters such as temperature, relative humidity, enthalpy, humidity ratio, enthalpy, dew point temperature and specific volume.
- To describe the chemical characteristics of the gas emitted from the cattle manure including parameters of ammonia (NH₃), carbon monoxide (CO), carbon dioxide (CO₂), Oxygen (O₂), hydrogen (H₂), hydrogen sulphide (H₂S), nitrogen (N₂) and methane (CH₄) content.
- To measure the odour intensity of the existing ambient air in the inner area of the cattle feedlot as well as in their surrounding areas.



2. MATERIALS AND METHOD

The experiment campaign was carried out in-situ in the area of the cattle feedlot (Figure-1) located in Bekasi Municipality, West Java Province, Indonesia in July 2016. The tool that was used to collect the emitted gas from manure is a transparent containment that was made from 3 mm thick acrylic sheet and equipped by a valve to flow the sampled gas.

Gas samples were collected twice per day (at 6 AM and 6 PM) from three (3) sampling points for 2 days. Before measurement, the containment was let in vacuum condition for 1 hour. Physical parameters of the samples were obtained by direct measurement on the spot, where as

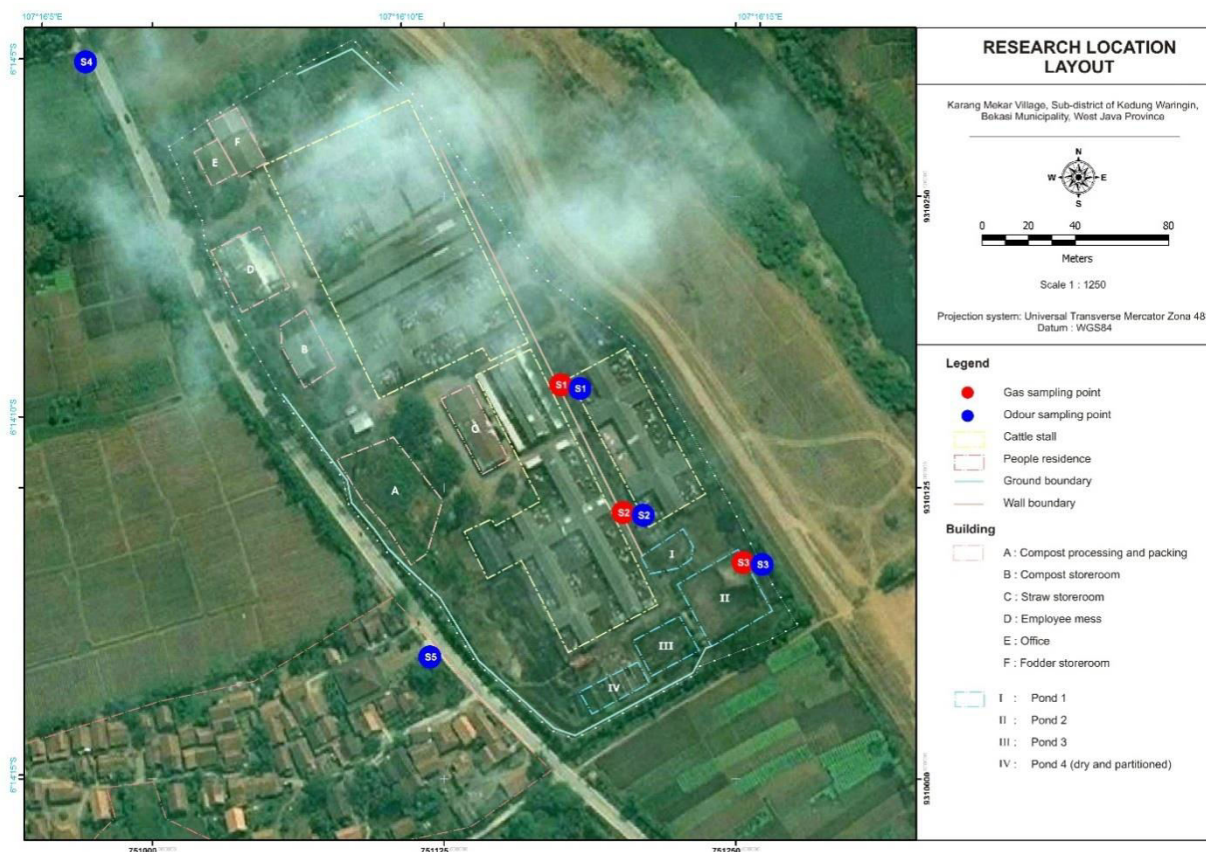


Figure-1. Sampling points (S_1 , S_2 , and S_3) of the gaseous emission in the cattle feedlot area.

chemical parameters were obtained by using laboratory analysis of the gas samples. Physical parameter measurement and gas sampling process in the field are shown in the Attachment.

Odour intensity measurement was conducted by using an odour panel (team) consisted of 7 members. The odour score of any object under concern was calculated after a quantitative assessment given by each member of the odour panel. The final odour score of any object was obtained by averaging all scores given by each odour panel. In general, all research procedures are depicted as a flowchart in Figure 2, while the materials and methods are presented in Table-1.

3. RESULTS AND DISCUSSIONS

The general condition of the research location is described briefly as follows:

- During stall cleaning activity, the produced manure is removed from the stall floor to the drainage pit (200 meter long) and then flows to the retention ponds. The

flowing process of the manure, however, is not swift enough. Therefore, some efforts such as raking or harrowing the solid fraction of the manure are necessary to make the manure flow.

- There are three retention ponds in this feedlot of which can store manure ± 800 -2000 m³. Based on observation, the manure characteristics was different between manure in the pit and in the retention pond. At the first 100 m of the pit, the physical condition of the manure was bright and being dominated by gas bubbles on the surface. In next 100 m, the colour was darker and less gas bubbles. The similar condition was encountered in the retention pond. The different characteristics could be due to the long detention time from pit to the pond (about 1 day).

The manure in the feedlot was predicted has high potential methane gas. This was based on observation that indicated many gas bubbles founded

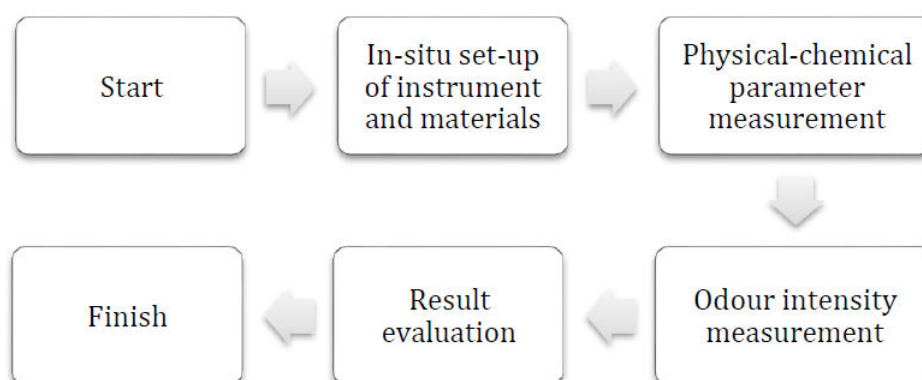


Figure-2. Flowchart of the experiment.

Table-1. List of the tools/instruments and methods used to measure the physical characteristics of the gaseous emission

No.	Parameter	Tools/instruments	Methods
1	Temperature	Wet bulb and dry bulb thermometer	A pair of wet bulb and dry bulb thermometer was placed in an acrylic containment on the surface of the manure. The temperature was recorded manually.
2	Relative humidity (RH)	Wet bulb and dry bulb thermometer; Psychrometric chart	The RH was obtained by plotting the pair of the wet bulb and dry bulb temperature on psychrometric chart.
3	Ammonia (NH ₃)	Containment; Tedlar bag	SNI 19-7119.1-2005
4	Carbon monoxide (CO) and Carbon dioxide (CO ₂)	Containment; Tedlar bag	Gas analyzer
5	Oxygen (O ₂), Hydrogen (H ₂), Nitrogen (N ₂), Methane (CH ₄)	Containment; Tedlar bag	In house Method OWI-GE3 based on Method 3C-USEPA: Determination of CO ₂ , CH ₄ , N ₂ , and O ₂ from stationary sources.
6	Hydrogen sulphide (H ₂ S)	Containment; Tedlar bag	SNI 19-4844-1998
7	Odour	Odour judge panel; human being nose	Direct odour scoring in the range of [-4 – 4] based on the perceived odour

- in the pit surface and the retention ponds. In order to get representative and optimal results, the measurement was conducted in three (3) sampling points with 2 repetitions (morning and evening) per day for each point. Sampling point determination was based on visual observation on manure characteristic differences. First sampling point (S₁) was located in the pit at 100 m distance from the stall, the second (S₂) was in the next 100 m from the first one and the last (S₃) was in the edge of retention pond.

3.1 Physical parameters

Physical parameters include wet bulb temperature (T_{wb}), dry bulb temperature (T_{db}), relative humidity (RH), enthalpy (h) and specific volume (v). All of these parameters were obtained based on temperature observation and interpreted by using psychrometric chart. The results are shown in Table-2.

The result shows that the flowing manure in the pit and retention pond emitted a huge amount of water vapour. This causes relative humidity of the ambient air above manure surface closes to the maximum value, i.e. saturation. This high relative humidity, however, was

encountered especially in the morning, instead of evening. Generally, this could be caused by optimum activity of methanogenic bacteria which work in mesophilic temperature (20-45°C) [16]. The reaction products of methanogenesis in the manure are methane and water vapour as following reaction below [17]:

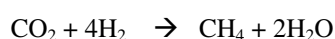


Table-2 also indicated that higher enthalpy was obtained from the air samples taken during evening session. Solar radiation that was gained by ambient air during daytime are then stored and accumulated which implied on the total energy contained by air as indicated by higher enthalpy (92.5 and 128.5 kJ/kg) of the air sampled in the evening. The reverse process is the release of energy during night time as indicated by lower value of the enthalpy (65.4 and 73.8 kJ/kg) which was sampled during morning session. There is a general guideline as well that the higher temperature, the higher enthalpy and specific volume. The latest indicated that solar radiation implies on the increase of air volume per unit of dry air mass.



3.2 Chemical parameters

Product reaction from organic matter is not only methane, but also including NH_3 , H_2S , CO_2 , and H_2 [18]. In this research, therefore, all of these parameters were measured and added to physical parameters aforementioned. Chemical characteristics were obtained by gas sampling inside the containment and then being tested in a nationally accredited laboratory. The result of the laboratory analysis will be an important basis in order to determine whether the emitted gases from the feedlot is feasible to be processed further as raw material to produce biogas as a kind of household fuel as well as a basis to develop a purification system to improve the quality of the gas as a source of energy. The result of the laboratory analysis on chemical characteristics during the first day and second day are shown in Table-3 and Table-4, respectively.

Result of the laboratory analysis shows that nitrogen is the most dominant substance (Figure-3). This is proven by more than 50% of gas content which was generated from manure are nitrogen, either in the morning or evening as well. The second and third most important gases fraction are methane and oxygen which contribute in average about 13% and 4% of all measurements, respectively. With this amount of methane, the feedlot is potential for a biogas installation establishment. The methane content of the emitted gases from this feedlot, however, is relatively low compared with some other findings which is normally about 50%. One possibility of influencing factors on the amount of methane emission from cattle is the quality of the feed. Research conducted by Pinares-Patino *et al.* (2016) [19] concluded that

Table-2. Result of physical parameters.

Sampling point	T_{db} [°C]	T_{wb} [°C]	RH [%]	h [kJ/kg]	v [m ³ /kg]
First day (July 31, 2016) morning					
S ₁	21.5	21.5	100	63.0	29.4
S ₂	23.0	23.0	100	68.5	31.7
S ₃	22.0	22.0	100	64.8	30.1
Average	22.2	22.2	100.0	65.4	30.4
First day (July 31, 2016), evening					
S ₁	29.5	28.5	93	92.5	41.5
S ₂	29.0	29.0	100	95.0	41.5
S ₃	29.0	29.0	100	90.0	39.8
Average	29.2	28.8	97.7	92.5	40.9
Second day (August 1, 2016) morning					
S ₁	24.0	24.0	100	72.5	33.0
S ₂	25.0	25.0	100	76.5	35.0
S ₃	24.0	24.0	100	72.5	33.0
Average	24.3	24.3	100.0	73.8	33.7
Second day (August 1, 2016) evening					
S ₁	35.0	34.0	94	122.5	52.0
S ₂	35.5	35.0	100	128.0	53.0
S ₃	36.0	36.0	100	135.1	55.0
Average	35.5	35.0	98.0	128.5	53.3

Note: T_{db} = Dry bulb temperature; T_{wb} = Wet bulb temperature; RH = Relative humidity; h = Enthalpy; v = Specific volume

enhanced dietary lipids contents is an effective means of reducing CH₄ emissions from grazed pasture.

The concentration of other trace gases such as NH_3 , H_2S , CO, CO_2 and H_2 are very low, either during the first day of the measurement campaign or during the second day. Based on result on the first and second day, it

could be stated that there was no significant difference between the generated gas amounts from three sampling points. It means that manures in the pit, either in fresh condition or already stays for more than one day still produce gases in almost the same amount roughly, provided the manure notwithstanding in liquid phase.

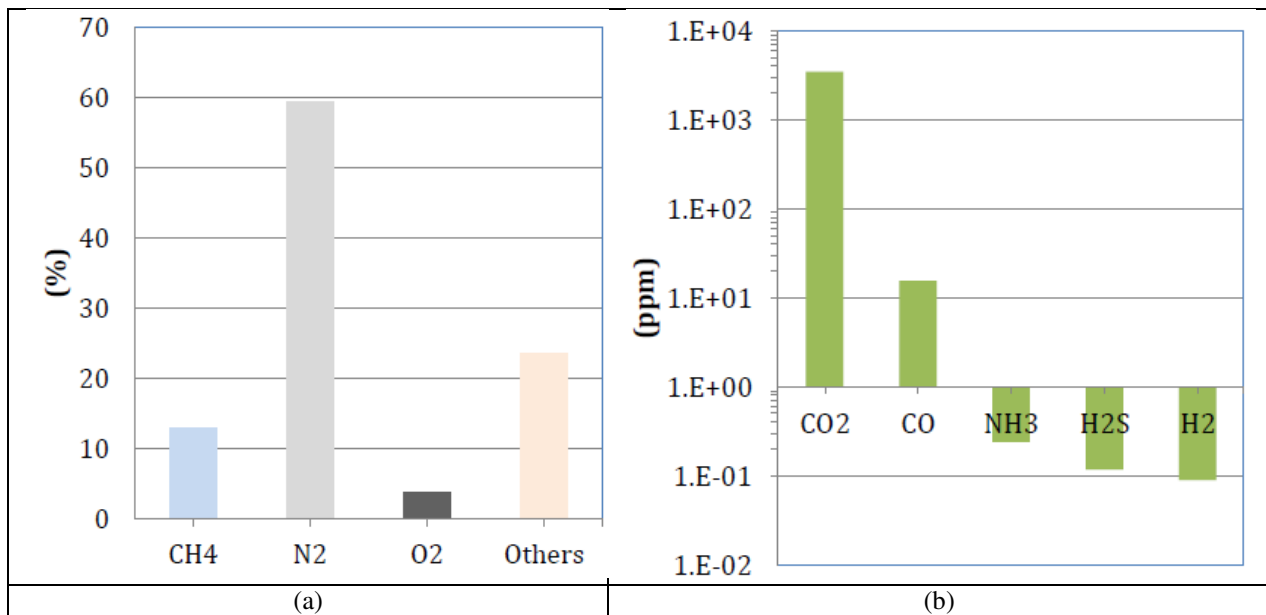


Figure-3. Composition of the major gaseous emission (a) and trace gases (b) from the cattle manure.

Table-3. Result of laboratory analysis on chemical characteristics during the first day.

No.	Parameter analysis	Unit	Day 1 - Morning			Day 1 - Evening			TL*
			S ₁	S ₂	S ₃	S ₁	S ₂	S ₃	
1	Ammonia (NH ₃)	ppm	0.336	0.180	0.213	0.200	0.261	0.238	2.0
2	Hydrogen Sulphide (H ₂ S)	ppm	0.576	0.066	0.017	0.020	0.020	0.007	0.02
3	Carbon dioxide (CO ₂)	ppm	1198	1200	5056	5753	4658	2968	-
4	Carbon Monoxide (CO)	ppm	35	5	< 1	10	12	< 1	-
5	Oxygen (O ₂)	%	3.30	3.74	3.87	3.82	3.92	3.89	-
6	Hydrogen (H ₂)	%	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09	-
7	Nitrogen (N ₂)	%	50.90	57.80	63.20	60.50	61.70	61.30	-
8	Methane (CH ₄)	%	15.00	8.28	12.10	16.40	13.80	12.30	-

* Note: TL is threshold limit according to Kep.Men.LH Number 50/1996 about Odour Threshold Standard

Table-4. Result of laboratory analysis on chemical characteristics during the second day.

No.	Parameter analysis	Unit	Day 2 - Morning			Day 2 - Evening			T.L*
			S ₁	S ₂	S ₃	S ₁	S ₂	S ₃	
1	Ammonia (NH ₃)	ppm	0.136	0.264	0.281	0.161	0.297	0.166	2.0
2	Hydrogen Sulphide (H ₂ S)	ppm	0.006	0.277	0.011	0.014	0.466	0.037	0.02
3	Carbon dioxide (CO ₂)	ppm	1191	1193	2122	8272	1156	1152	-
4	Carbon Monoxide (CO)	ppm	3	8	<1	7	34	1	-
5	Oxygen (O ₂)	%	3.37	3.24	4.04	3.8	3.75	3.98	-
6	Hydrogen (H ₂)	%	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09	-
7	Nitrogen (N ₂)	%	52.80	51.50	62.90	59.90	58.60	62.20	-
8	Methane (CH ₄)	%	12.80	9.22	15.20	12.40	12.30	13.00	-

* Note: TL is threshold limit according to Kep.Men.LH Number 50/1996 about odour threshold standard



3.3 Odour intensity

Odour quantification was conducted to measure odour intensity or odour sense inside and outside of the feedlot quantitatively. The result of this measurement will be used as basic foundation to proof whether some complains from the people living in the surrounding area meet the regulation standard, i.e. Decree of the State Minister of Environmental Affairs (Kep.Men.LH) Number 50/1996 pertaining on Standard of Odour Intensity. The measurement was conducted by involving a team consisted of seven (7) well-trained and independent odour panellists. The odour was scored by [-4 up to +4] range

indicating that “-4” is for bad or unpleasant odour, whereas “+4” is intended for good or pleasant odour [20].

The measurement series were carried out in a clear weather day in the middle of August 2016. Variations of measurement result could be encountered due to weather condition, such as speed and direction of the local wind. The measurement sampling location was divided into six points of which three (3) points are located inside the feedlot (S_1 , S_2 and S_3) whereas the rest points (S_4 , S_5 and S_6) are located around the cattle feedlot, i.e. in the people living area. The odour intensity sampling points were shown in the Figure-1. The result of odour intensity in the ambient air is depicted in Figure-4.

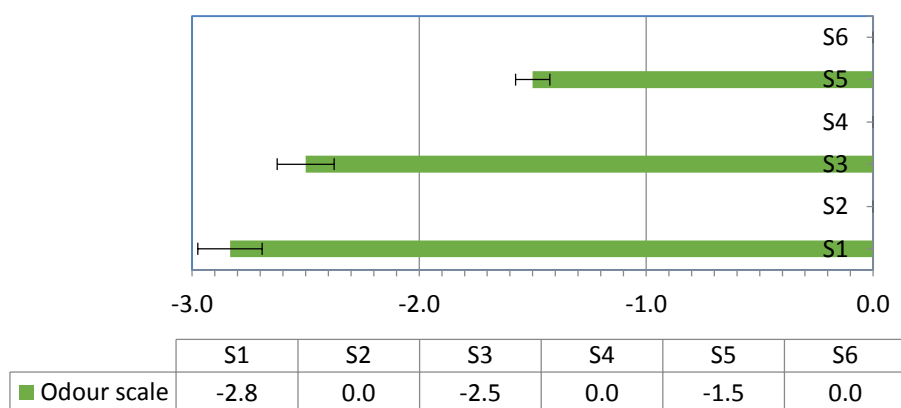


Figure-4. Odour intensity of ambient air inside (inner) and outside (outer) of the cattle feedlot.

Figure-4 shows that high odour intensity was found merely inside of the feedlot. The odour sources in the ambient air in fact are not merely from cattle manure, but also generated by straw fermentation process and fodder stacks. In the area outside of the feedlot, however, there was no unpleasant odour originated from the feedlot at all as indicated by the odour score of the outside points (S_2 , S_4 and S_6) which is only 0.0 in average. It means that all of the panellists perceived no unpleasant odour in the areas outside of the cattle feedlot. A greenbelt along the border of the cattle feedlot constructed of bamboo tree that was combined with the blowing wind improves the dispersion of unpleasant odour from the feedlot into the ambient air. This finding indicates also that if there would be any unpleasant odour perceived by anyone in the ambient air, that could originate from any sources other than cattle feedlot such as household solid wastes, domestic wastewater, any clogged sewerage system, etc.

4. CONCLUSIONS AND SUGGESTIONS

Conclusions that can be withdrawn from the research are as follows:

A. Physical characteristics of the gas emitted from the cattle manure pit and retention pond have been described. The average dry bulb temperature (T_{db}) was in between 22.2-35.5 °C whereas the wet bulb

temperature (T_{wb}) was 22.2-35.0 °C. The relative humidity was very high, i.e. 97.7-100 %.

- B. The chemical characteristics of the gas emitted from the cattle manure including parameters of ammonia (NH_3), carbon monoxide (CO), carbon dioxide (CO_2), Oxygen (O_2), hydrogen (H_2), hydrogen sulphide (H_2S), nitrogen (N_2) and methane (CH_4) content have been described where the concentration of the most important gas for biogas production (methane) was merely 13% on average.
- C. The odour intensity of the existing ambient air inside the area of the cattle feedlot was maximum -2.8, whereas in the surrounding areas was merely zero (0.0).

Suggestions that can be formulated from the research are as follows:

- a) Observations on the odour intensity should be carried out in a longer period and should be based on the local prevailing wind record of the area under concern. The longer the observation, the more accurate and better odour scale that can be obtained.
- b) The existing minister decree pertaining on the odour threshold value is possible to be improved by using the result of the human being odour panel. This is based on the fact that any complain of the presence of unpleasant odour is claimed by people living in the surrounding areas.



ACKNOWLEDGEMENT

The research was conducted with financial support from The Ministry of Research, Technology and Higher Education (RISTEK DIKTI), Republic of Indonesia, under BOPTN research grant scheme organized by The Institute of Research and Community Empowerment (LPPM) of Bogor Agricultural University (IPB). Authors wish to thank all field research assistants (Ms. Rahmafriti Arum Sabarina, Ms. Andita Dwi Sefiani, Mr. Yoga Armando, Mr. Ario Wisnu Wicaksono, Ms. Andini Ginawati Gunawan, Ms. Rika Purnamasari, Ms. Nauratul Aslah) from Dept. of Civil and Environmental Engineering IPB, field technicians and laboratory analysts in Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP). Authors are deeply indebted to Mr. Asri, Mr. Jeplin and all of company commissioners and directors for their permit and helpful services.

REFERENCES

- [1] Rotz CA, F. Montes and DS. Chianese. 2010. The carbon footprint of dairy production systems through partial life cycle assessment. *J. Dairy Sci.* 93: 1266-1282.
- [2] Aguirre-Villegas, HA, TH. Passos-Fonseca, DJ. Reinemann, LE. Armentano, MA. Wattiaux, VE. Cabrera, JM. Norman and R. Larson. 2015. Green cheese: partial life cycle assessment of greenhouse gas emissions and energy intensity of integrated dairy production and bioenergy systems. *J. Dairy Sci.* 98: 1571-1592.
- [3] Zhang, Siduo, Xiaotao Tony Bi, Roland Clift. 2015. Life cycle analysis of a biogas-centred integrated dairy farm-greenhouse system in British Columbia. *Process Safety and Environmental Protection.* 93: 18-30.
- [4] Ghafoori, E, Peter C. Flynn, and M. David Checkel. Global warming impact of electricity generation from beef cattle manure: A Life Cycle Assessment Study. Mechanical Engineering Department, University of Alberta, Edmonton, Canada.
- [5] Cota, OL, Darcilene Maria de Figueiredo, Renata Helena Branco, Elaine Magnani, Cleisy Ferreira do Nascimento, Luiza Freitas de Oliveira. 2014. Methane emission by Nellore cattle subjected to different nutritional plans. *Trop Anim Health Prod.* 46: 1229-1234
- [6] Junior, C. Costa, CEP. Cerri, CD. Dorich, SMF. Maia, M. Bernoux and CC. Cerri. 2015. Towards a representative assessment of methane and nitrous oxide emissions and mitigation options from manure management of beef cattle feedlots in Brazil. *Mitig Adapt Strateg Glob Change.* 20: 425-438.
- [7] Davydov, MS, MG. Berengarten and SI. Vainshtein. 2010. Improving the energy efficiency of anaerobic fermentation of cattle wastes. *Chemical and Petroleum Engineering.* 46(11-12): 640-643.
- [8] Zheng X and Nirmalakhandan N. 2010. Cattle wastes as substrates for bioelectricity production via microbial fuel cells. *Biotechnol Lett.* 32: 1809-1814.
- [9] Eigenberg, Roger A., Bryan L. Woodbury, Brent W. Auvermann, David B. Parker and Mindy J. Spiehs. 2012. Energy and Nutrient Recovery from Cattle Feedlots. *ISRN Renewable Energy.* Volume 2012, Article ID 723829, 5 pages. DOI: 10.5402/2012/723829.
- [10] Costa JR, Ciniro, Changsheng Li, Carlos EP Cerri and Carlos C Cerri. 2014. Measuring and modeling nitrous oxide and methane emissions from beef cattle feedlot manure management: First assessments under Brazilian condition. *Journal of Environmental Science and Health, Part B.* 49: 696-711.
- [11] Ramin M and Huhtanen P. 2012. Development of equations for predicting methane emissions from ruminants. *J. Dairy Sci.* 96: 2476-2493.
- [12] Capper JL and RA Cady. 2011. A comparison of the environmental impact of Jersey compared with Holstein milk for cheese production. *J. Dairy Sci.* 95: 165-176.
- [13] Varel, VH, JE. Wells, WL. Shelver, CP. Rice, DL. Armstrong and DB. Parker. 2012. Effect of anaerobic digestion temperature on odour, coliforms and chlortetracycline in swine manure or monensin in cattle manure. *Journal of Applied Microbiology.* 112: 705-715.
- [14] Cardoso, Luis Alfaro. 2012. Environmental and economic impacts of livestock productivity increase in sub-Saharan Africa. *Trop Anim Health Prod.* 44: 1879-1884.
- [15] Graux, Anne-Isabelle, Gianni Bellocchi, Romain Lardy, Jean-Francois Soussana. 2012. Global warming potential of French grassland-based dairy livestock systems under climate change. *Reg Environ Change.* 12: 751-763.



- [16] Leven L, Eriksson ARB, Schnurer A. 2007. Effect of process temperature on bacterial and archaeal communities in two methanogenic bioreactors treating organic household waste. *Journal of Federation of European Microbiological Society (FEMS)*. 59: 683-693.
- [17] Yasin MNH, Maeda T, Hu Anyi, Yu Chang-Ping, Wood TK. 2014. CO₂ sequestration by methanogens in activated sludge for methane production. *Journal of Applied Energy*. 142: 425-434.
- [18] Dhadse S, Kankal NC, Kumari Bharti. 2012. Study of diverse of methanogenic and non-methanogenic bacteria used for the enhancement of biogas production. *International Journal of Life Sciences Biotechnology and Pharma Research*. 1(2): 176-191.
- [19] Pinares-Patiño CS, FE. Franco, G. Molano, H. Kjestrup, E. Sandoval, M. Battistotti, J. Koolaard, J. Laubach, S. MacLean. 2016. Feed intake and methane emissions from cattle grazing pasture sprayed with canola oil. *Livestock Science*. 184: 7-12.
- [20] Yuwono AS, YC. Wirasembada, J. Febrita, RA. Sabarina, AD. Sefiani. Design and Performance Test of Non Odorous and Low Maintenance (NOL) Composting Bin Prototype. *International Journal of Applied Environmental Sciences (IJAES)*. 11(5): 1192-1212.

ATTACHMENTS

