# **Population Dynamics of Microorganism and Greenhouse Gas Emission by Applying Chicken Manurein Peat Soil**

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#### ABSTRACT

Peat land accumulates organic materials and emits greenhouse gas (GHG). Agricultural activities in peat land resulted in the subsidence of peat land surface and the loss of C in the form of GHG. Appropriate management of peat land for agriculture would reduce GHG emission. This research aims to understand the microorganism population dynamics and emission of GHG due to chicken manure application in peat land. The research was conducted in the GHG Laboratory of Indonesia Agricultural Environment Research Institute (IAERI) in 2012 using peat material from Jabiren, Central Kalimantan. The experiment started by incubating peat soil for two months with the treatments of chicken manure and without manure. The incubation experiment was conducted by using paralon PVC pipe. Parameters observed included pH, Eh, bacteria population and fungi, as well as GHG flux (CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O). GHG samples were collected in a sealed containment. The research result showed that peat with chicken manure had lower bacteria population at the end of incubation; fungi population, however, increased. The application of chicken manure on peat land planted rubber trees and pineapples would reduce GHG emission by 12.8% as compared to peat without manure application.

Keywords: peat, greenhouse gas emission, microorganism population, chicken manure.

#### **INTRODUCTION**

Peat land which has different thickness and vegetation types contains different C deposit. Considering the large amount of C deposit in peat land where the ecosystem is fragile, if it was not managed properly it would cause the release of C in large amount, especially in the form of  $CH_4$  and  $CO_2$  to the atmosphere, so that it further increases GHG emission.

Based on researches conducted in IAERI in 2007; 2008; 2009; 2010 the application of ameliorants could reduce the emission of GHG by 7-47%, zeolite by 21%, Fe slag by 29%, manure by 16-31% and silicate SiO<sub>4</sub> fertilizer by 18%. Rice production increased by as much as, of dolomite by 0.3-37%, of Fe slag by 14%, of manure by 10-31% and of silicate fertilizer by 10% (Susilawati *et al*, 2011).

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Peat land that has been opened for agricultural purpose will increase GHG emission because soil pH increases so it is suitable for methanogen growth. In order to minimize the impact of tropical peat land management activities by using ameliorant application that can reduce the emission of C from peat land, it is necessary to know the effect of ameliorants on GHG emission as well as the microbial activities in peat land. This research aimed to know the microorganism population dynamics and emission of GHG due to chicken manure application in peat soil.

## MATERIALS AND METHODS

The research activity was conducted in the GHG Laboratory and the Integrated Laboratory of IAERI Jakenan, Pati, from February to September 2012. Peat soil taken from Jabiren Village, Jabiren Raya County, Pulang Pisau Regency, Central Kalimantan Province was used. Based on its level of maturity, the peat soil was categorized as

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saprogenic peat. The peat was taken at the layer depth of 25 cm for about 1 ton and then placed in a plastic bag of 20 kg and transported to the laboratory.

Peat sample was placed in a paralon PVC pipe of 21 cm in diameter and 30 cm in height and was conditioned with water content of about 66% (vol vol<sup>-1</sup>) (Husen and Agus, 2011). The treatment was given by applying chicken manure with the dosage of 4 ton ha and without manure. Before the treatment, peat sample was incubated in advance for two weeks in order to stabilize the peat soil. The application of chicken manure was conducted after the incubation period of two weeks in accordance with the treatment. Parameters observed included pH, Eh, bacteria population and fungi, as well as GHG flux (CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O). GHG samples were taken using a sealed containment. Total counts of fungal and bacterial populations were determined by the plate count method using Potato Dextrose Agar (PDA) for fungal, and nutrient agar (NA) for bacterial growth. The number of denitrifying bacteria were counted by Durham Tubes (Trolldenier, 1996) with the empirical indicators of gas bubbles formed at the end of the Durham tube and used NMS (spell for the first time) medium for methanotrophic bacteria (Hanson and Hanson, 1996).

The measurement of GHG emission from the peat sample was done in the GHG Laboratory of IAERI, Pati. GHG sampling was conducted once every seven days until 49 days. GHG sampling was done by using a 10 mL syringe in the morning (06:00 - 08:00) from paralon PVC containment. Time intervals used to take the sample were in the  $10^{\text{th}}$ ,  $20^{\text{th}}$ ,  $30^{\text{th}}$ ,  $40^{\text{th}}$ ,  $50^{\text{th}}$ , and  $60^{\text{th}}$  minutes. Subsequently, gas sample was analyzed using a gas chromatography. GHG flux was calculated using an equation as follows (IAEA, 1993).

$$E = \frac{dc}{dt} \times \frac{Vch}{Ach} \times \frac{mW}{mV} \times \frac{273,2}{273,2 + T}$$

where :

- E : Emission of  $CH_4/CO_2/N_2O$  (mg m<sup>-2</sup>day<sup>-1</sup>)
- dc/dt : Concentration difference  $CH_4/CO_2/N_2O$  per time (ppm minute<sup>-1</sup>)
- Vch : Chamber volume  $(m^3)$
- Ach : Chamber area  $(m^2)$
- mW : Molecule weight  $CH_4/CO_2/N_2O(g)$
- mV : Molecule volume  $CH_4/CO_2/N_2O$  (22,41 l)
- T : Average temperature during gas sample taking (°C)

#### **RESULT AND DISCUSSION**

The presence of microorganism in soil is very important because it plays a role in maintaining and improving soil fertility. The populations of microorganism observed are total fungi, total bacteria, denitrifier, and methanotroph bacteria. At the beginning of the research, the number of total bacteria in controlled treatment was  $3 \times 10^5$  cell g<sup>-1</sup> then increased on the  $15^{\text{th}}$  day of observation and then decreased until the end of incubation. The same happened with the treatment of chicken manure, the number decreased down to  $1.5 \times 10^5$ CFU or of peat (Figure 1). With inundation of nearly 66% of its volume, there was an increase in the number of total bacteria but then gradually decreased. As peat was disturbed and drained the level of fungi variety and bacteria tended to be less than that in natural peat.



Figure 1. Total bacteria with the treatment of chicken manure application in peat.

The populations of soil fungi and bacteria were affected by treatment with either chicken manure or control. The total number of fungi increased on the 15<sup>th</sup> day of observation, then decreased until the end of incubation time, this was due to the application of water so that it was less

aerobic. The treatment of chicken manure application could increase the total number of fungi (Figure 2), this was because the application of manure could supply C and N as nutrition for microorganisms and created a suitable condition for them to grow well.



Figure 2. The total number of fungi with the treatment of chicken manure application in peat.

The denitrification bacteria population in peat increased during incubation, the highest being on the last observation (Figure 3). The application of chicken manure caused a reduction of denitrification bacteria population. This was probably because of the peat taken from rubber and pineapple plantation has a C/N ratio lower as compared with that from people's rubber plantation and underbrush. The presence of denitrification

bacteria population was characterized by the formation of gas inside durham tube. Positive mark was given to durham tube that contains gas and negative mark to that with no gas. The presence of microorganism activities was indicated by the turbidity and the presence of gas in almost all tubes. The gas was presumed to be the result of release of microbiological process on substrate.





The number of methanotrophic population was higher in the treatment without chicken manure application (Figure 4). This was probably due to the chicken manure application caused the increase of methanogen population and eventually

triggered the development of methanotrophic. Important factor determining methanotroph population was aeration (redox potential above 10 mV), whereas methanogen required negative redox potential.



Figure 4. The number of methanotrophic bacteria at the beginning and the end of incubation with the treatment of chicken manure application in peat

The measurement of pH during peat incubation showed an increase as a result of chicken manure application. The increase of peat pH was related with the time during which the land was cultivated, ameliorant application and fertilization, as well as the height of ground water level. The longer the land was cultivated for agriculture then the more ameliorants and fertilizer were applied into the land so that peat pH further increased. Eh measurement result showed that the application of chicken manure could prevent the reduction of Eh, either in controlled peat and in that which with chicken manure treatment. This became the cause of  $CH_4$  gas production increase. The increase of pH caused the reduction of Eh, so that it was more suitable for  $CH_4$  gas production. During incubation period the value of Eh dropped, but not in the value of pH, which tended to rise. A reduction process constituted of an electron consuming process, so that it caused the value of Eh to decrease and produced OH ion, which increased pH value. All redox potential values at the beginning of observation were in the positive range, at the subsequent observation however the value of Eh dropped (Figure 5).

In an aerobic condition, methanogens then producer of  $CH_4$  was very active so that

organic material decomposition process took place very quickly. Fetzer and Conrad (1993) added that in an  $O_2$  free medium, the production of CH<sub>4</sub> could start at +50 mV. Microorganism had a good capacity to reduce redox potential (Eh).



Figure 5. pH and Eh during peat incubation treated with the chicken manure application.

 $CO_2$  flux measurement result showed a decreasing tendency with the humidification at the beginning of treatment (Figure 6). At the beginning of chicken manure application, the number of  $CO_2$  flux was higher as compared with that without chicken manure

application, this was because the humidification provided additional nutrition for fungi development and produced more  $CO_2$ . At the last observation there was a little increase in  $CO_2$  flux, either in control and treatment.



Figure 6. CO<sub>2</sub> flux from the treatment of chicken manure application in peat.

Addition of water at the onset of experiment, either in the treatment of chicken manure application and control, would produce anaerobic condition which increased CH<sub>4</sub>formation. CH<sub>4</sub> flux increased until the  $23^{rd}$  day of observation, but decreased and increased again in the following observations (Figure 7).



Figure 7. CH<sub>4</sub> flux in the treatment of chicken manure application in peat

N<sub>2</sub>O emission generally occurred in cultivated peat land, where nitrogen fertilization (such as urea, manure, or ZA fertilizer) had been intensively applied. N<sub>2</sub>O microbiological process included nitrification and denitrification. In the nitrification process  $NH_4^+$  was modified into  $NO_2^-$  and  $NO_3^$ through oxidation process (aerobic). Whereas denitrification happened in an anaerobic situation and produced NO<sub>3</sub><sup>-</sup> reduction process biochemically by heterotrophic bacteria to become N<sub>2</sub>O and N<sub>2</sub>.

 $N_2O$  gas daily flux during incubation period fluctuated significantly, ranging from 11-24 mg m<sup>-2</sup> day<sup>-1</sup> (Figure 8). Peat without the application of chicken manure produced higher  $N_2O$  flux than peat with the treatment of chicken manure application. The high  $N_2O$ flux was caused by the peat material originated from rubber and pineapple plantation which was a cultivated land whose fertilization (urea and manure) was more intensive.



Figure 8. N<sub>2</sub>O flux from the treatment of chicken manure application in peat.

GHG emission calculation result showed that the application of chicken manure in peat could increase  $CO_2$  emission, but reduce  $CH_4$ and  $N_2O$  emission (Table 1). The high  $N_2O$ emission could be caused of the peat taken from intensive plantation land in which it rich of nitrogen fertilizer residue. Global Warming Potential (GWP) from peat with the treatment of chicken manure application amounted to 19 ton CO<sub>2</sub>-e ha<sup>-1</sup> year<sup>-1</sup>, whereas control amounted to 21.8 ton CO<sub>2</sub>-e ha<sup>-1</sup> year<sup>-1</sup>. This showed that the application of chicken manure could reduce GHG emission by 12.8%.

Table 1. GHG emission and GWP in peat with the application of chicken manu
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Treatment	GHG Emission (kg ha <sup>-1</sup> )			$GWP$ (top $CO_{-0}$ )
	$CO_2$	$CH_4$	N <sub>2</sub> O	$GWP$ (toll $CO_2$ -e)
Control	1869.86	4.41	66.53	21.81
Chicken manure	2083.32	3.45	56.49	19.00

Chicken manure is rich with macro and micro nutrient elements, contains cations that can make a stable complex band with organic ligands in peat soil. Stevenson (1994) revealed that the formed complex constituted a stronger covalence band and tended to be stable, so that it was more difficult to break or exchange. The presence of formed complex could cause peat to be resistant to decomposition process, which eventually could participate in pressing the release of  $CO_2$  and  $CH_4$  into the atmosphere. Therefore, from practical benefit point of view Fe cation based amelioration substance could be used as alternative to reduce the production of  $CO_2$ and CH<sub>4</sub> gas.

For rubber plantation it was assumed that the emission value from peat decomposition amounted to 18 ton  $CO_2$  ha<sup>-1</sup> year<sup>-1</sup>. Though the equation of Hooijer *et al.* (2008) was valid for drainage depth ranging from 30-120 cm, but the emission level of 18 ton  $CO_2$  ha<sup>-1</sup> year<sup>-1</sup> based on this equation was comparable with the Jauhiainen *et al.* (2004) measurement result of 19 ton  $CO_2$  ha<sup>-1</sup> year<sup>-1</sup>. Various factors such as ground water content, fertilization, and soil temperature significantly affected the number of emission apart from the depth of peat soil water level.

## CONCLUSION

In peat that was treated by chicken manure application, the bacteria population decreased at the end of incubation, however the fungi population increased. The application of chicken manure in peat land planted with rubber trees and pineapples could reduce the GHG emission by 12.8% as compared with no-manure application.

### REFERENCES

- Fetzer S, Conrad R. 1993. Effect of redox potential on methanogenesis by Methanosarcina barkeri. *Arch Microbiol* 160: 108-113.
- Hanson R, Hanson TE. 1996. Metanotrophic bacteria. *J Microbiol Review*, 60:439-471.
- Hooijer A, Silvius M, Wösten H, Page S. 2006. PEAT-CO<sub>2</sub>, Assessment of CO<sub>2</sub> emissions from drained peatlands in SE Asia, Delft Hydraulics report Q3943.
- IAEA. 1993. Manual on Measurement of Methane and Nitrous Oxide Emissions from Agricultural, Vienna, Austria. International Atomic Energy Agency.
- Jauhiainen J, Jaya A, Inoue T, Heikkinen J, Martikainen P, Vasander H. 2004. Carbon Balance in Managed Tropical Peat in Central Kalimantan. In: Päivänen J (ed.) Proceedings of the 12th International Peat Congress, Tampere 6 - 11 June 2004. pp. 653-659.
- Stevenson FJ. 1994. Humus Chemistry: Genesis, Composition, Reactions. John Wiley & Sons, New York
- Susilawati HL, Ariani M, Kartikawati R, Setyanto P. 2011. Ameliorasi Tanah Gambut Meningkatkan Produksi Padi dan Menekan Emisi Gas Rumah Kaca. Sinar Tani, Edisi 6-2 Maret 2011 No.3400 Tahun XLI.
- Trolldenier G. 1996. Denitrifiers by MPN method. In: Schinner, F., R. Öhlinger, E. Kandeler, R. Margesin. 1996. Methods in Soil Biology. Springer, Germany. p. 28-31.