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Wastes Management Can Minimize CH_4 and N_2O Emissions from Wetlands in Indonesia

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ABSTRACT

Paddy (*Oriza sativa* L.) and Oil palm (*Elaeis guineensis* Jack) are two important crops and are potential to produce wastes which may lead to huge green house gas emissions if they are not managed properly. Open burning and conventional composting are commonly practiced by farmers and/or planters to managed agricultural wastes in Indonesia. A series of research has been carried out to elucidate (1) the reductions of CH_4 and N_2O due to incertion of a catalitic converter on burning kiln, (2) green house gas emissions from different composting techniques of oil palm field wastes, and (3) the effects of oil palm field wastes compost application in oil palm fields and of paddy field wastes biochar in integrated oil palm-paddy fields. The results showed that CH_4 and N_2O emissions from paddy field wastes (i.e., rice straw or rice husk) was lower than that from oil palm empty fruit bunch (EFB). Furthermore, insertion of a catalytic converter into pyrolysis installation reduced the CO_2, CH_4 and N_2O emissions from paddy field wastes as much as 14.5, 17.8 and 11.1%, respectively. Incorporation of EFB compost did not increase greenhouse gas emission from oil palm fields. These results suggest that biochar and EFB compost can be practiced to manage agricultural wastes in Indonesia.

INTRODUCTION

Paddy (*Oriza sativa* L.) and oil palm (*Elaeis guineensis* Jack) are two important crops and are potential to produce wastes which may lead to huge green house gas emissions if they are not managed properly. Agriculture contribute about 21.5% of CH_4 emission from Indonesia, while wastes in general contribute as much as 64.8% (Ministry of Environment, 2010). Nitrous oxide (N_2O) is the most destructive green house gas and contributes to ozone depletion (Bouwman, 1990).

It is reported that about 7.7 mill ha land in Indonesia is used for paddy cultivation, and nearly seven mill ha is used for oil palm. It is also estimated that solid wastes resulted by the two crops are nearly 12.5 mill ton annually (Hadi et al. 2014a). Wastes of paddy field are mostly in the form of rice husk and straw, while wastes from oil palm are in the forms of trunk, empty fruit bunch, and charnel. Apart from those wastes, oil palm also produces significant amount of liquid wastes. However, the liquid wastes have well been managed to produce energy (Ahmad et al. 2012).

Open burning and conventional composting are commonly practiced by farmers and/or planters to managed agricultural wastes in Indonesia. Previous researches have improved the composting process of oil palm empty fruit bunch (EFB) and the burning of rice husk while evaluating carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions during composting and burning of the two wastes. Open burning released CH_4 and N_2O as mach as 140.5-525.5 ppmv and 350.7-606.3 ppbv,

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respectively (Hadi et al. 2014a). The conventional composting may take several months for the compost got mature. The use of bacterial isolates resulted in shortening of composting time of oil palm EFB. A C/N ratio of less than 25 (as criterion for compost) has achieved less than 16 days of composting of oil palm EFB composting with bacterial isolate *Bacillus megaterium* (Hadi et al. 2014b).

Present research was carried out to elucidate (1) the reductions of CH_4 and N_2O due to incertion of a catalitic converter on burning kiln, (2) the best composting technique of oil palm field wastes, and (3) the effects of oil palm field wastes compost application in oil palm fields and of paddy field wastes biochar in integrated oil palm-paddy field.

MATERIALS AND METHODS

Paddy field wastes in the form of rice husk and rice straw were air dried to achieve about 20% moisture content. They were than burn in pyrolysis kiln (made of drum which has hole in the bottom and was equipped with smokestack on the top). Two kilns were prepared with and without catalytic converter (made of motor cycle smokestack) on their smokestack, respectively. Fire was set using small amount of fuel and increased as the fire grows. The kilns were fully filled and closed after the fire established (about 20 min after fire setting) and maintained until all material get burned (3-4 h).

Air samples were taken from the smokestack when about half of the materials had been burned and used for determination of CO_2, CH_4 and N_2O by gas chromatography. The working conditions for the gas chromatograph were as that described by Hadi et al. (2012).

To study the effect of rice husk biochars on emissions of greenhouse gases, nine plots of paddy were established at inter row of oil palm in South Kalimantan with peat soil. Rice husk charcoal was applied into three of the plots on soil surface at the rate of two ton per ha (referred as integrated oil palm-rice + biochar, **IRIAN with B** hereafter). The plots were then cultivated to rice (Oriza sativa L) of *ciherang* variety. The other three plots were also cultivated with rice without biochar (referred as **IRIAN without B** treatment hereafter). The remaining tree plots were be kept without biochar and without rice as control treatment (referred as **farmer practice** treatment hereafter). The experimental units were arranged following Randomized Block Experimental Design (Mattjik & Sumertajaya, 2002).

Two sets of open-top-mica boxes in each plot were constructed to beneath about 5 cm into the soil, one set to cover the oil palm tree and the other set to cover paddy or weeds in between oil palm tree. Capillary plastic tube was inserted to the boxes through a rubber septum in order to collect air inside the boxes. The box was equipped with a pan in order to mix the air inside the boxes prior to gas sampling.

To study the GHG emissions from different composting techniques, EFB was collected from factory of PT. Perkebunan Nusantara XIII. The EFB was chopped into 2-5 cm long and air dry at room temperature. Concorrently, *Bacillus brevis* and and *Bacillus megaterium* (Nur and Kridianto, 2009) were propagated in CMC-agar media on a shaking fermentor for 48 h and the number of cell $>10^6$. Cow dung was also collaected and stored until the time of use. Two kg of EFB was filled in open-top chamber, a box made of poly vinil carbonate with about 30 L in volume which were equipt with a pipe and a sampling port on its cover. Twenty four chambers containing EFB was prepared. The experiemntal units were placed in a green house following Randomized Block Design, with six treatments and four replications.

To study the effect of compost on emissions of CO_2, CH_4 and N_2O from oil palm fields, EFB compost produced in the previous step and weed compost prepared similarly as that of EFB compost were each spread in the planting hole or soil surface of

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mature oil palm. The plants were closed with chamber from the top at the time of gas measurements in three weeks basis. Air samples were taken at 2, 7 and 12 min after the closure of the chamber. Methane and N_2O concentrations were determined by a gas chromatograph with the same working conditions as explained earlier.

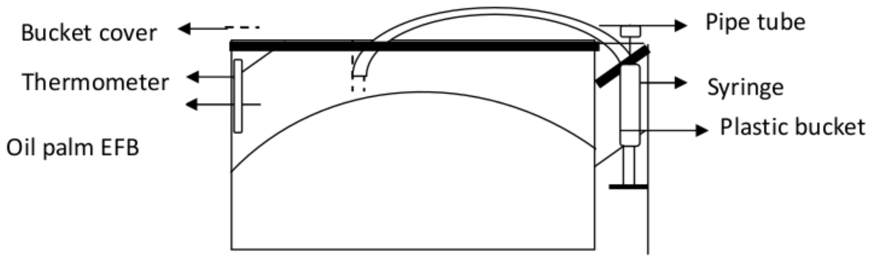

Figure 1. *Chamber* for composting

RESULTS AND DISCUSSION

Gas Emissions from Biochar Production and Application

Open burning of oil palm EFB released CH_4 and N_2O as mach as 140.5-525.5 ppmv and 350.7-606.3 ppbv, respectively. Table 1 showed that the CO_2, CH_4 and N_2O emissions of rice husk and rice straw burning in pyrolysis kiln with and without a catalytic converter. The CH_4 and N_2O emissions from paddy field wastes (i.e., rice straw or rice husk) was lower than that from oil palm EFB, probably due to the reduction of O_2 concentration in kiln during the pyrolisis of paddy field wastes. Furthermore, insertion of a catalytic converter into pyrolysis installation reduced the CO_2, CH_4 and N_2O as much as 14.5, 17.8 and 11.1%, respectively (Table 1).

Table 1. CO_2, CH_4 and N_2O emission during biochar production

Raw Material	Pyrolysis Instrument Desain	Greenhouse Gas		
		CO_2 (ppm)	**CH_4 (ppm)**	**N_2O (ppb)**
Rice Husk	No Converter	522.82	3.64	298.6
	Converter	447.02	2.99	265.2
Rice straw	No Converter	492.23	2.61	256.6
	Converter	435.05	2.20	241.1

Table 2 showed greenhouse gas emissions at conventional oil palm cultivation and those with insertion of rice with (IRIAN + B) or without biochar (IRIAN – B) treatments. Table 2 indicated that the insertion of rice in between oil palm eliminated the green house gas emissions from the field to the atmosphere, meanly due to the CO_2 uptake by rice. This was also confirmed by the fact that the above ground biomass was more in IRIAN system (26.4 and 23.2 ton/ha/year in IRIAN + B and IRAIN – B treatments, respectively) as compared to conventional oil palm by farmer (22.8 ton/ha/year). In one year cycle, the global warming potential of conventional oil palm cultivation, introduced IRIAN with biochar and IRIAN without biochar were 1,852, -3,749 and -2,384 kg $CO_{2\ equ}$/ha, respectively.

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Table 2. Summary of annual gas emissions and biomass production from conventional and integrated oil palm-paddy systems

Parameter	Unit	**Farmer practice**	**IRIAN +Biochar**	**IRIAN -Biochar**
N_2O	Emission (ug N/m^2/h)	17.99	30.92	0.28
	GWP (g CO_2 equ/m^2/y)	73306.04	125988.37	1137.15
CH_4	Emission (mg C/m^2/h)	0.01	0.01	-0.04
	GWP (g CO_2 equ/m^2/y)	10156.67	9414.86	-28446.45
CO_2	Emission (mg C/m^2/h)	3.17	-31.04	-7.58
	GWP (g CO_2 equ/m^2/y)	101663.43	-510271.18	-211126.31
Total	GWP (kg CO_2 equ/ha/y)	1851.26	-3748.68	-2384.36
Paddy and/or weed biomass	ton/ha/year	22.8	26.4	23.2

Incorporation of biochar along with the presence of rice paddy in between oil palm tree tended to improve the bulk density of peat soil (Table 3). The averaged soil bulk density in IRIAN + biocar treatment was nearly 5% higher than that of conventional treatment. The increase in bulk density of peat soil may prevent the peat material to float when the field is flooded. The floating of peat material is problem because it may lost if it is transported by stream to other places.

Table 3. Changes in soil bulk density in conventional farmer practice and introduced IRIAN systems

No	**Treatments**	**0-30 cm**	**30-60 cm**	**60-90 cm**	**Average 0-90 cm**
1	IRIAN without biochar	0.2720	0.2652	0.2721	0.2698
2	IRIAN with biochar	0.2857	0.2653	0.2789	0.2766
3	Conventional	0.2653	0.2619	0.2687	0.2653

CH_4 and N_2O Emissions from Compost Production and Application

Changes in CH_4 and N_2O emissions during the composting of oil palm EFB and weeds are shown in Figure 2. Figure 2 showed that CH_4 emissions changed temporally and varied in varies composting techniques.

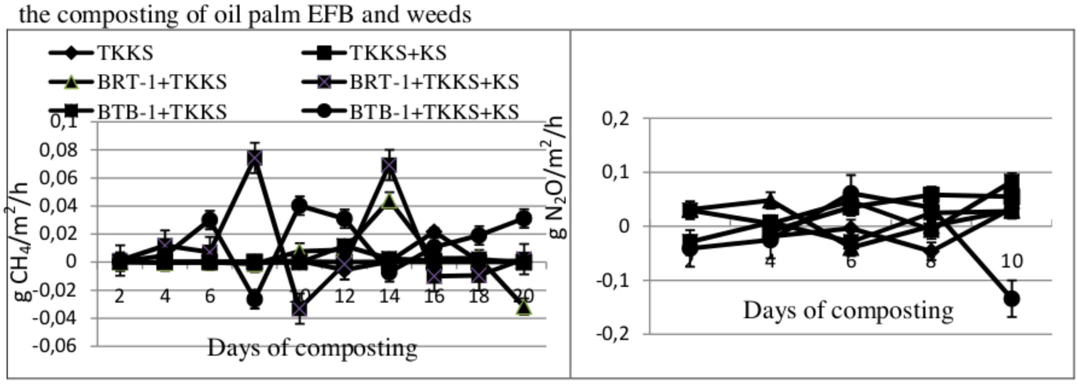

Figure 2. Methane (left) and N_2O (right) emissions during 20 days of composting by different techniques. TKKS=oil palm empty fruit bunch, BRT-1= *Bacillus bravis*, BTB-1= *Bacillus megaterium*, KS = cow dung.

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The C/N ratio of EFB after 20 days composting by bacterial isolate *Bacillus brevis* along with cow dung was 14.2 with global warming potential was 319.7 g CO_2eq m^{-2} (Table 4). The C/N ratio of conventional composting technique (control treatment) was higher than improved techniques (i.e., other treatments) (Table 4), suggesting that the losses of C from improved technique were more than that of N. Since the loss in form of CH_4-C were equal to N_2O-N (Fig. 2), the loss of C are thought through CO_2. This is in line with the statement by Mitchell that CO_2 are evolved during composting to form more stable organic matter.

Table 4. Ranking of C/N ratio, ranking of GWP and averaged ranking of diverse composting techniques

Composting technique	C/N Ratio	C/N Ranking	GWP (g CO_2 equ/m^2/y)	GWP Ranking	Averaged rank
EFB/Control	53.76	6	-52770.4	2	4.0
EFB+KS	52.76	5	-59420.3	1	3.0
BRT-1+ EFB	24.23	4	129089.8	5	4.5
BRT-1+ EFB S+KS	20.68	3	444163.0	6	4.5
BTB-1+ EFB	19.56	2	-63068.2	3	2.5
BTB-1+ EFB +KS	14.22	1	168523.1	4	2.5

Note: BTB-1=Bacillus brevis, BTB-1=Bacillus megaterium; KS=cow dung

Incorporation of EFB and weed composts did not increase greenhouse gas emissions from oil palm fields (Tables 5). A flash of CH_4 emissions as results of dumping of organic matter on soil surface reported by Inubushi et al. (2007) did not occurred in present experiment. This fact indicates that oil palm EFB and weed compost contain less simple organic chain which easily attack by methanogenic microbes.

Table 5. Calculated and Table's F values of N_2O and CH_4 emissions from old oil palm fields

Source of Variation	df	2 years old oil palm				6 years old oil palm				F Table	
		N_2O		CH_4		N_2O		CH_4		0.05	0.01
Block	3	0.56	tn	1.44	tn	0.69	tn	0.59	tn	2.89	4.44
Treatment:	11	1.81	tn	1.42	tn	1.02	tn	0.98	tn	2.09	2.84
A	3	1.11	tn	0.00	tn	2.56	tn	0.60	tn	2.89	4.44
B	2	0.32	tn	1.99	tn	0.44	tn	1.16	tn	3.28	5.31
A x B	6	2.65	tn	1.85	tn	0.53	tn	1.07	tn	2.39	3.41
Error	33										
Total	47										

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CONCLUSIONS AND SUGGESTION

It could be concluded that:

1. The use of pyrolysis installation could minimize CH_4 and N_2O emissions from agriculture waste management.
2. The application of rice husk biochar in integrated oil palm-paddy system could farther reduced green house gas emissions.
3. The use of bacterial isolate *Bacillus brevis* along with cow dung resulted qualified compost with minimum green house gas emissions.
4. The application of oil palm EFB compost did not result in increase of CH_4 and N_2O emissions from oil palm field.

These results suggest that biochar and EFB compost can be practiced to manage wastes in Indonesia.

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