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EVALUATION OF METHANE AND CARBON DIOXIDE EMISSION DECREASE THROUGH WASTE COMPOSTING

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Abstract

The organic waste disposal under anaerobic conditions emits Methane, which causes increased global warming. This study attempts to find the emission factor in windrow waste composting systems from two sizes of gathered organic waste piles. Designed to compare two groups of composting piles, one pile consisted of 500 kilograms of waste originating from local authorities while the other amounted to 250 kilograms of waste collected from households. With six piles of each type, aeration was done by manual turning and emissions were sampled in closed flux chambers and analyzed by gas chromatographs. A control experiment, modeling landfill sites, was set up in a one x one x one meter hole. Results from the experiment showed that emission ratios from the 500 kg was 1.3613 x 10^{-3} g CO_2-eq kg^{-1} wet waste, and 1.3427 x 10^{-3} g CO_2-eq kg^{-1} wet waste from the 250 kg experiment. The 500 kg experiment decreased emissions by 0.059185 g CO_2-eq kg^{-1} wet waste and the 250 kg experiment, emissions decreased by 0.059206 g CO_2-eq kg^{-1} wet waste when compared to the control group. In summary, pile size has no effect on emission ratios. Statistical testing found no significance difference between emissions from the 500 kg compared with the 250 kg. This study tells us that massive landfill or waste composting is difference effect.

Keywords: organic waste; composting waste; windrow system; greenhouse gas; emission factor

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Introduction

Greenhouse gases in the waste sector have increased continually over the years. A National report prepared by Office of Natural Resources and Environmental Policy and Planning (ONEP) in 2010 indicated that greenhouse gas emissions in the waste sector had increased by 6.7 percent per year from 2000 to 2004 (ONEP, 2010). Most of these emissions were from Methane produced from the digestion of organic matter under anaerobic conditions (G.J.Farquhar, 1973). Methane has a global warming factor 25 times the factor for carbon dioxide (IPCC, 2007) and there has been a steady increase by one to two percent per year (IPCC, 1997).

Results of the Anderson (2010) study reveals that Methane emitted from household composting was 0.4-4.2 kg Mg^{-1} wet waste (B. A. Andersen J. K., et al, 2010) and from windrow composting it was 2.4±0.5 kg Mg^{-1} wet waste (B. A. Andersen J. K., et al, 2010). Boldrin's study (2009) regarding the emission rate for organic waste composting found that net greenhouse gas emissions amounted to 300 kg CO_2-eq Mg^{-1} wet waste (Boldrin, 2009).

However, the degree of inconsistency of data in the analysis of greenhouse gas emission from landfills by taking secondary data produce high levels of uncertainty, in the range of $\pm$130.3%. In general, an evaluation usually uses mean values from IPCC which may lead to inconsistencies (ONEP, 2010). Therefore, it is necessary to establish greenhouse gas emission values for composting which are appropriate and proper values for Thailand.

Methods

Population and sampling

In this study, population refers to waste that was collected at Khon Kaen University (KKU), with a actual production rate of 28.7 Mg per day, including organic waste of 30.88% or 8.86 Mg per day (KKU, 2012). Only organic waste from waste trucks, houses, school vegetables, and fruit from canteens and leaves and branches from gardening were selected for use.

Sampling from waste trucks took place for one week until organic waste of 4.5 Mgs or about 50% of the daily rate of organic waste was collected. Over holiday and working days during that time, kept food waste from volunteer restaurants was then mixed with leaves and vegetables to obtain a C:N in the range of 30-35 : 1 (PCD, 2009).

A trial study was set up consisting of two types: experiment and control. The experimental group was set up to accommodate two sizes of waste piles: 250 kg and 500 kg compost piles. The experiment group was set up in the open land. There were six piles of each type. The control group was setup in two holes, each one x one x one meter, and used for the burial of organic waste to simulate a landfill site. Four flux chambers were placed above each hole to collect emitted gas. The ambient temperature of this study was between 25–39 °C and was surveyed in October and November.

Machines and devices

Gas emission trapped (E_{gas}) with closed flux chambers, as in (Beck-Friis, 2001), (Börjesson, 1997), (Livingston, 1995), (C. Scheutz, et al, 2003) and (C. Scheutz, et al, 2007) were used as the device for a given volume ($V_{chamber}$) and calculated as follows. Emitted gas, is proportional to the concentration increase (dC_{gas}) per elapsed time (dt), or concentration changes ($dC_{gas}\ dt^{-1}$), and volume.

$$E_{gas} = \frac{dC_{gas}}{dt} x \left(V_{chamber} \right)$$

During composting, three gas samples were collected per week before turning. Which took one to two days before sampling. Gas sampling takes around five to eight minutes, 24 samples (eight weeks, three samples per week per chamber: Monday, Wednesday and Friday). Then to find out the gas emission from the compost for the total time of the experiment, means integration for gas quantity of measurement duration and sum gas quantity until end of composting. Emission ratios are in the unit of gram gas kilogram^{-1} wet waste:

$$EF_{gas} = \frac{\sum \left(\int_{t1}^{t2} E_{gas} dt \right)}{wet \quad waste}$$

A flux chamber was set up on top of the compost, which is the best position to collect gas emissions (B. A. Andersen J. K., et al, 2010), one to two chambers were used per compost pile depending on compost size (two chambers for 500 kg and one chamber for 250 kg). The chambers trapped all gas that emits from the compost.

Composting preparation process

The use of the turned pile windrow system, which is a popular system in both households and local administration organizations, was used since it takes less time than anaerobic types, which have odor problems and emit Methane. Devices that are not complicated and require low investment were used (U.S.EPA., 2010) , (Coker, 2006). The process of finding for emission value from composting is as figure 1.

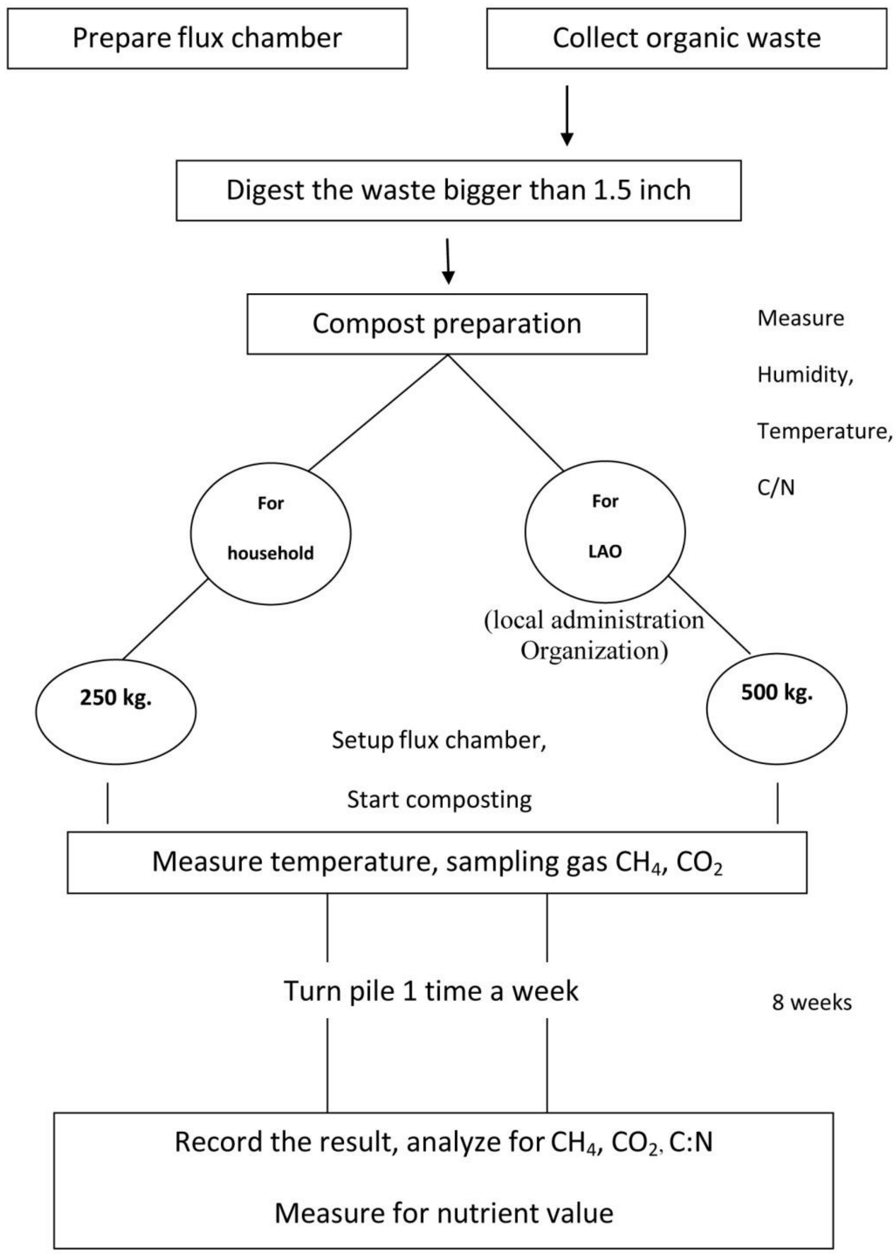

Figure 1: The process of emission value experimentation from composting.

Waste composting preparation process: random collection of waste from waste trucks, then separation of only decomposable organic waste such as food waste. Vegetable waste larger than 1.5 inches should be taken to a digester machine then mixed with leaves. Each pile of compost was mixed with 20% kitchen waste, 40% dry leafs and 40% vegetables, which are the main components of organic waste.

Data collection

The composting time takes around four to five weeks to measure CH_4 and CO_2, then continues for two weeks which is required for incubation and to set conditioning time. Sampling for compost before and after composting to analyze the C:N ratio. Sampling emission of gas from compost in the flux chamber to analyze for CH_4 and CO_2.

Sampled gas will be put in gas storage tube and then analyzed in a gas chromatograph (Shimadzu 2014 model), that uses a thermal conductivity detector. There are 24 gas samples were taken from each pile to analyze the difference between average gas concentrations in both types of compost. Independent t-test $n<30$ was used to test for the difference between the average gas quantity that is emitted from each of the two experiments.

Result

Compost sampling Result

After the preparation of compost, compost material was sampled for analysis and the results are as table 1.

Table 1: Initial analysis result

Compost size	Result		
	Humidity (%)	Temperature (^oC)	C:N
250 kg	63	35	33
500 kg	67	40	35

Compost was sampled for analysis by combining the 250 kg and 500 kg to compare with the compost properties set out by the Department of Agriculture (DOA) and the Ministry of Agriculture and Co-operation. The results are as table 2.

Table 2: Compost analysis result

Parameter	Result	Range		Mean ± SD	Unit
		Min	Max		
Total Nitrogen (N)	1.76	1.6	1.94	1.76 ± 0.14	%
Total Phosphorus (P)	1.44	1.35	1.56	1.44 ± 0.14	%
Total Potassium (K)	1.56	1.44	1.66	1.56 ± 0.10	%
Organic Matter (OM)	27.28	29.78	34.59	33.67 ± 4.11	%
Electrical Conductivity (EC)	7.48	6.5	8.88	7.48 ± 0.96	dS m^{-1}
C:N Ratio	8.96:1	8.5	9.5	8.96 ± 0.46	-
pH	7.6	7.4	7.9	7.6 ± 0.2	

For compost, C:N is in the range 7-10 which is in the inert transformation group (Yingjajaval, 2011). When compared to the DOA standard. This compost was made with organic matter and completely digested (DOA, 2005). The result of CO_2 diagnosis is shown as figure 2 and CH_4 diagnosis is shown as figure 3.

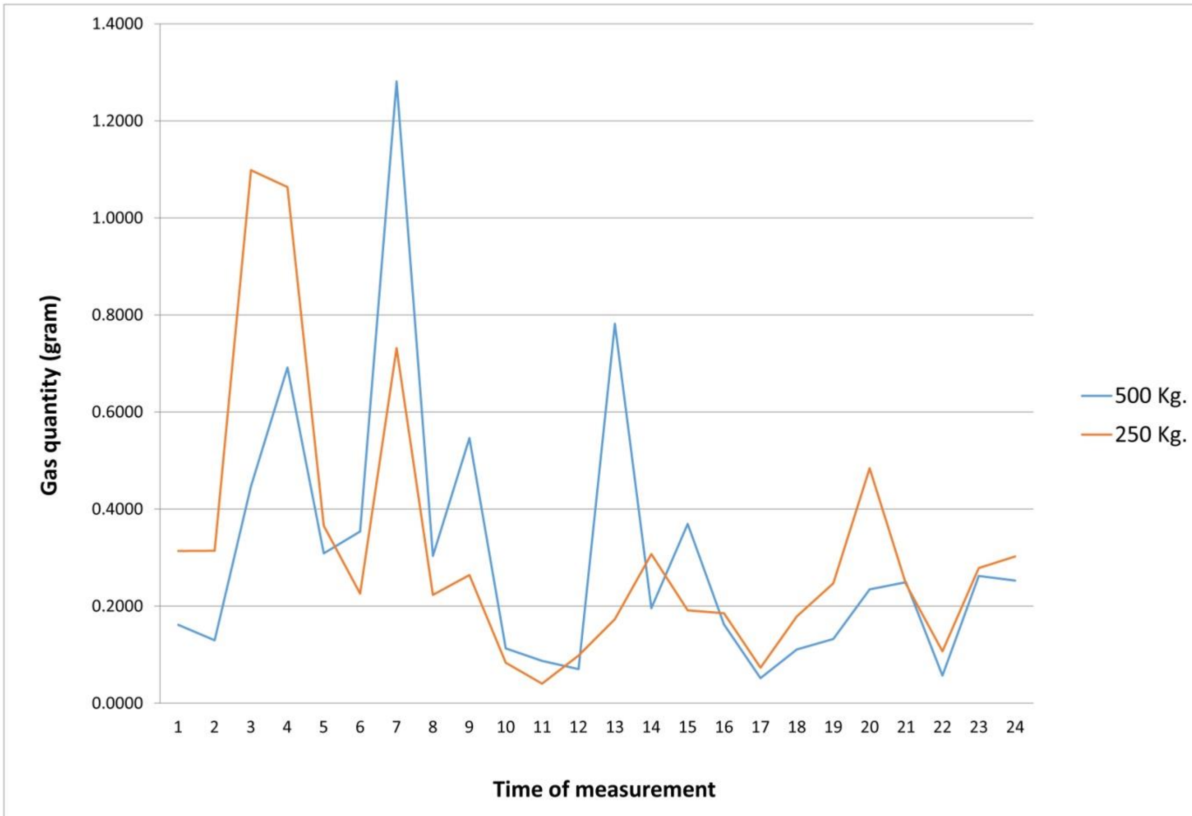

Figure 2: Graph showing CO_2 quantity of 500 kilograms and 250 kilograms

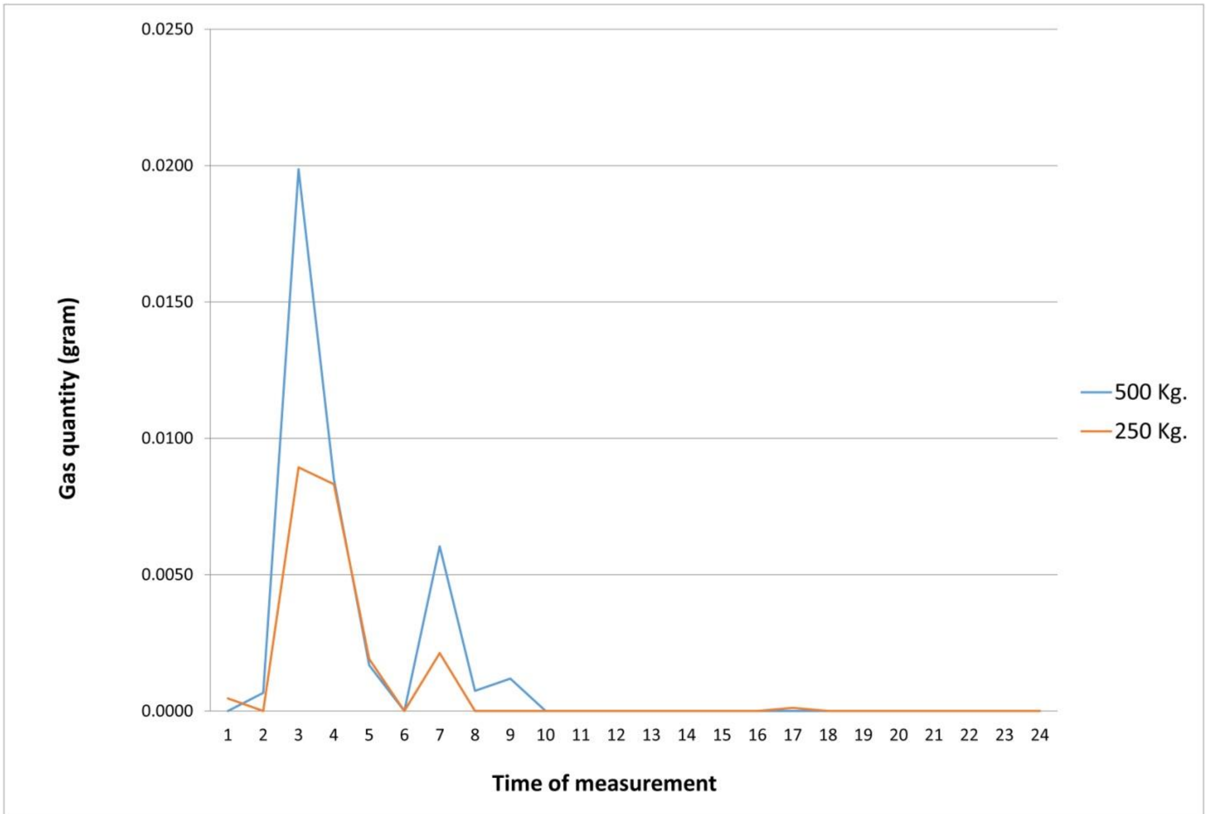

Figure 3 Graph showing CH_4 quantity of 500 kilograms and 250 kilograms

Emission rate

Emission rates from compost can be calculated by adding the CO_2 emission rate and the CH_4 emission rate of the experiment group as table 3.

Table 3: Emission rate

Experiment group	Emission ratio (g CO_2-eq kg^{-1} organic waste)		
	CO_2	**CH_4**	**Total**
500 kg	0.0012 ± 0.1941	1.3537×10^{-4}±0.0023	1.3613×10^{-3} ± 0.2036
250 kg	0.0013 ± 0.1309	7.6478×10^{-5} ± 0.0014	1.3427×10^{-3} ± 0.1870

Decreasing emission rate

This can be found by comparing the existing situation, which has no management for organic waste (control group), minus management of organic waste (composting experiment group). The result is shown as table 4.

Table 4: Decreasing emission ratio

Experiment group	Emission ratio ($g\ CO_2$-eq kg^{-1} organic waste)	Decreasing emission ratio ($g\ CO_2$-eq kg^{-1} organic waste)
500 kg	$1.3613 \times 10^{-3} \pm 0.2036$	0.0592
250 kg	$1.3427 \times 10^{-3} \pm 0.1870$	0.0592

* Control group 0.0605 ± 0.2492 g CO_2-eq kg^{-1} organic waste

Statistical analysis result

From the composting of the 500 kg, the 250 kg and the control group there were two types of emissions, CO_2 and CH_4, as well as the CO_2 equivalent of the two:

$$CO_2eq = (\text{Mean } CO_2) + (25 \times \text{Mean } CH_4)$$

Thus the experiment reveals that the mean of CO_2 and CH_4 and weighted sum of CH_4 and CO_2 in the control group have higher values than composting in the 500 kg piles and 250 kg piles but the emission values of CO_2 and CH_4 from the experiment group between the 500 kg piles and the 250 kg piles displayed no difference as table 5.

Table 5: Average gas emission ratios from composting (Unit is Kg Kg^{-1} wet waste).

Gas	Experiment	Sampling	Mean	Sd	Median	Min	Max
CO_2	500 kg	12	.00122	.00113	.00096	.00020	.00512
	250 kg	6	.00126	.00110	.00098	.00016	.00439
	Control group	8	.05119	.00758	.05141	.03614	.06625
CH_4	500 kg	12	6.43e-06	.00001	0	0	.00007
	250 kg	6	3.55e-06	9.77e-06	0	0	.00003
	Control group	8	.00044	.00025	.00044	0	.00097
CO_2+ CH_4	500 kg	12	.00136	.00133	.00096	.00020	.00563
	250 kg	6	.00134	.00129	.00098	.00016	.00514
	Control group	8	.06054	.00797	.06127	.04666	.07742

The t-test attempts to find significant emission difference when comparing the 500 kg experiment with the 250 kg experiment. It turned out that the 500 kg was able to decrease emissions by 0.0591859 g and the 250 kg was able to decrease by emissions by 0.0591859 g. Not a significant difference indeed taking measurement accuracy into account.

The 95% confidence interval is -0.00461 to +0.00457 and the difference between emission ratios in the two experiments is not statistically significant with probability 0.993 as table 6.

Table 6: Comparison of decreasing emission of composting with control group by t-test

Reduce gas	N	Mean	Std. Dev.	Mean diff.	95% CI	p-value
Control – 500 kg	24	.05918	.00160	-.00002	-.00461 to .00457	0.993
Control – 250 kg	24	.05920	.00162			
Cohen's d statistic (pooled variance) = .00630						
Hedges' g statistic = .00616						

Agreement testing by the Bland-Altman analysis reveals that decreasing emissions of 500 kg compared to 250 kg indicates little difference; the maximum and minimum values are between 0.002 and -0.002 so this difference has no statistical significance (p-value = 0.693)

Discussion

The study found that emission values of CH_4 and CO_2 are very low, which can be explained due to 1) compost size 2) turning pile and 3) ventilation. Compost sizes in the experiment were 0.5-1.0 meters in width and 0.5-1.0 meter in height (PCD, 2009). Variations in compost weights were 250 kg and 500 kg respectively. These compost sizes were smaller than the standard sizes recommended by the Thai Pollution Control Department which are 2.0-2.5 in width and 1.0-1.5 height respectively . The sizes of compost used in the experiment related to waste obtained from households and local administration organizations that was subsequently separated into two groups; organic waste and general waste. In the experimental compost process the sizes of the waste piles were less than standard, thereby enabling the oxygen to permeate the compost easily, resulting in low CH_4 emissions. The turning pile rate of once a week had a positive effect on the aeration in the compost. Moreover, an experiment that was conducted in an open space with a wind blowing encouraged oxygen exchange. The ambient temperature of this study is between 25–39 °C and was survey in October and November.

Conclusion

The study's intention was to search for greenhouse gas emissions of CO_2 and CH_4 from the waste piles during the composting process. Compared to other studies this study managed to find very low emissions. The 500 kg experiment had an average emission rate of 1.3613×10^{-3} g CO_2-eq kg^{-1} organic waste (1.36 g CO_2-eq Mg^{-1} organic waste), and the 250 kg experiment had average emissions amounting to 1.3427×10^{-3} g CO_2-eq kg^{-1} organic waste (1.34 g Mg^{-1} organic waste) were found. Both values were tested for decreasing emissions by subtracting the results from a control group (0.0605 g CO_2-eq kg^{-1} organic waste (60.5 g CO_2-eq Mg^{-1} organic waste)) that was modeled on a landfill site, It achieved the same value of 0.0592 g CO_2-eq kg^{-1} organic waste (59.2 g CO_2-eq Mg^{-1} organic waste). The values are similar even though the C:N ratios are different. C:N values at the start of composting are 33 and 35 and decreased to 8.96 after composting was finished.

Limitation

However, in order to enable this method to become more widespread, it is still imperative to convince people of the necessity and importance of waste separation and of course to educate people as to its efficacy and positive impact it would have in regard to the global warming issue that we all have to face up to.

After the decomposition of compost, the compost‘s weight will decrease by about 80% of the initial weight. Thus the final compost weight will be less than when it was prepared. Compost produced from this method needs fairly diligent turning over of the piles, which would require considerable time and effort in the case of there being many piles to attend to. Some authors such as Teerapong (2011) have studied how to prepare compost without turning pile (Sawangpanyangkura, 2011). This study's recommendations are as follows: 1) Emissions should be evaluated in compost sizes of one to two Mgs to get the emission rate since that size has the standard one to 1.5 meter height and two to 2.5 width as figure 4. 2) The examination of the organic composting process should be expanded to up to three to four months in order to evaluate gas emissions, especially for Methane in the control group which will continue to be emitted.

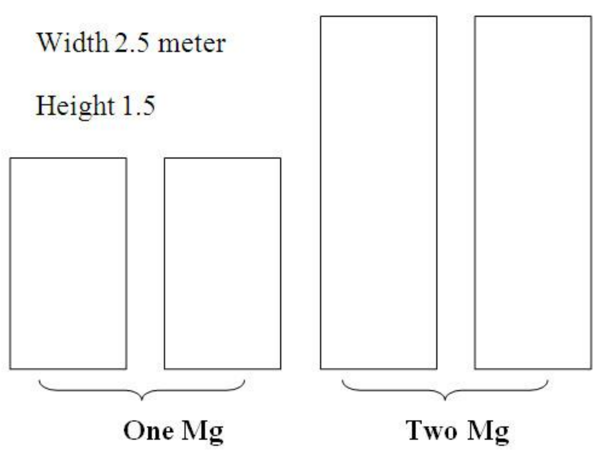

Figure 4. The further study of compost unit

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References

Andersen, J. K., B. A., Christensen, T. H. & Scheutz, C. , 2010. Greenhouse gas emissions from home composting of organic household waste. *Waste Management, 30(12):2475-82*. doi: doi: 10.1016/j.wasman.2010.07.004

Andersen, J. K., B. A., Jerker Samuelson,Thomas H. Cristensen, Charlotte Scheutz., 2010. Quantifi cation of Greenhouse Gas Emissions from Windrow Composting of Garden Waste. *Journal of Environmental Quality, 39, 713-724*.

Beck-Friis, B. G. , 2001. Emissions of ammonia, nitrous oxide and Methane during composting of organic household waste. *Uppsala: Swedish University of Agricultural Science (Doctoral Thesis)*, 331 p. .

Boldrin, A., Andersen, J. K., Møller, J., Christensen, T. H. & Favoino, E. , 2009. Composting and compost utilization: accounting of greenhouse gases and global warming contributions. *Waste Management & Research, 27, 800–812*.

Börjesson, G., Svensson, B.H. , 1997. Seasonal and diurnal Methane emissions from a landfill and their regulation by Methane oxidation. *Waste Management Research, 15:33–54*.

Coker, C. , 2006. Environmental Remediation by Composting. *BioCycle, 47(12), 18*.

DOA. , 2005. Annoucement of Department of Agriculture : Organic Compost Standard 2005. *Department of Agriculture, Ministry of Agriculture and Cooperation*.

G.J.Farquhar, F. A. R. , 1973. Gas Production During Refuse Decomposition. *Water Air Soil Pollution (1973), 2(4), 483-495*. doi: doi: 10.1007/BF00585092

IPCC. , 1997. The revised 1996 IPCC guidelines for national greenhouse gas inventories. *Reference manual*.

IPCC. , 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press. *Cambridge, United Kingdom and New York, NY, USA*(([Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)])), 996 p.

KKU. , 2012. The Model of Khon Kaen University Integrated Solid Waste Management. *National Research Council of Thailand, 04-117*.

Livingston, G. P., G.L. Hutchinson. , 1995. Enclosed-based measurement of trace gas exchange: Applications and sources of error. In P.A. Matson, R.C. Harriss (ed.)

Biogenic trace gases: Measuring emissions from soil and water. Methods in ecology series. *Blackwell Science, Cambridge(UK)*.

ONEP. , 2010. Thailand's Second National Communication under the United Nations Framework Convention on Climate Change. *Ministry of Natural Resources and Environment, Bangkok (Thailand)*. doi: 102 p.

PCD. , 2009. Composting from Solid Waste Manual. *Ministry of Natural Resources and Environment, Bangkok (Thailand), 04-117*.

Sawangpanyangkura, T. , 2011. Preliminary Study of Effect of Chimney Convection on Aerobically Decomposition in Composting without Turning. *The 7th Naresuan Research Conference, 29th-30th July(Naresuan University), Phitsanulok*.

Scheutz, C., Bogner, J., Chanton, J., Blake, D., Kjeldsen, P. , 2003. Comparative oxidation and net emissions of CH4 and selected non-Methane organic compounds in landfill cover soils. *Environmental Science & Technology, 37:5150–5158*.

Scheutz, C., Bogner, J., Chanton, J., Blake,D., Morcet, M., Aran, C., Kjeldsen, P. , 2007. Atmospheric emissions and attenuation of non-Methane organic compounds in cover soils at a French landfill. *Waste Management, 28:1892–1908*.

U.S.EPA. , 2010. Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source ategories : Solid Waste Disposal, Wastewater Treatment, Ethanol Fermentation. *EP-D-06-118*.

Yingjajaval, S. , 2011. Using an organic matter in corrected type. *Faculty of Liberal Arts and Science Kasetsart University , Kamphaeng Saen Campus*.