GAS EMISSION RATE FROM DIFFERENT JAPANESE OPEN TYPE PIG HOUSES WITH NATURAL VENTILATION

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ABSTRACT NH_3, CO_2, N_2O, CH_4 emissions were measured in five different naturally ventilated pig houses during summer and winter in Ibaraki prefecture, Japan as to collect inventories. The houses were a nursing hoop type house with saw dust litter on flat floor (*A-1* house), a conventional fattening house with retaining waste under floor (*A-2* house), a conventional nursing house (*B-1* house), a nursing house with retaining waste under fully slatted floor (*B-2* house) and a conventional fattening house with manure scrapers (*C* house). Results demonstrated that summer NH_3 emissions for *A-1* house, *B-1* house, *B-2* house and *A-2* house were 1.97, 2.30, 8.78 and 0.241 g d^{-1} $head^{-1}$ respectively. The winter NH_3 emissions for *A-1* house, *A-2* house and *C* house were 1.05, 49.2, and 15.2 g d^{-1} $head^{-1}$ respectively. The gas emissions were somewhat higher when the waste was retained for prolonged periods of time inside the houses.

Keywords: ammonia, fattening house, methane, nursing house, pig, ventilation

INTRODUCTION In order to evaluate environmental burden such as a global warming, and order from livestock houses, it is necessary to elucidate inventories of gas emission. In Europe, U.S. and Canada many previous studies reported ammonia emission factors and odor emission rate (e.g., Ngwabie et al., 2009; Zhang et al., 2005; Claudia et al., 2009; Guo et al., 2006; Lim et al., 2001). However, those research reports have been limited in Japan. Those objective swine housing type in above previous studies were commonly confined building. Though the confined buildings were also used in Japanese large production, many middle or small productions use open type buildings. Hoop barns which are diverted from greenhouses (pipe house) have been used in Japan because of lower capital costs and taking exercise inside. Dong et al. (2009) reported emission rates of ammonia and methane according to season. They showed that emission rates of ammonia and methane in summer was higher than those in spring. Hoop houses are influenced by weather considerably.

Specially, for naturally ventilated open type livestock houses there are not enough of data of gas emission rate. The reasons are why it is difficult to measure ventilation rate continuously in open type livestock houses and why the gas emission rate is affected by many factors, such as rearing way, weather, season, housing type and so on (Arogo et al., 2003). Leneman et al. (1998) pointed out 1) pig mass and phase of production, 2) house type and management, 3) manure storage and treatment, 4) feed nitrogen (N) content, 5) N excretion rates per pig, and 6) environmental conditions as the most important factors to influence ammonia emissions from swine production. Therefore, it is necessary to collect the inventories as many as possible each country.

The objective of this study was to collect inventories of gas emission from naturally ventilated pig houses in Japan. In this case study the gas emission rates of carbon dioxide, ammonia, methane and nitrous oxide and dust, airborne bacteria concentrations were measured for 5 open type pig houses which were a hoop nursing house of piled flat floor with saw dusts, a conventional nursing houses and two different fattening houses.

MATERIALS AND METHOD

Objective houses Objective pig houses were located in Ibaraki prefecture, Japan where has mild climate. The situations in these houses are shown in table 1 and their dimensions are shown in figure 1 ~ 5. House *A-1* was hoop type and saw dust was used for flat floor. When all pigs are moved out, the floor material is changed. The frame was covered by opaque polyethylene films. Pigs are reared hear until 110 days old. House *A-2* was open type fattening house with curtain at both side opening. Waste was retained in the pit under floor and was flowed out from the house naturally. A center room of three rooms in the house was selected for measurement. There were 14 pens in a room. House *B-1* was nursing house in which there was opening at one side. There were 5 pens. House *B-2* was reformed from a compost facility and there were ten rooms. One room was used for measurement and there were 5 pens in the room. One gable side was opened. Waste was retained under fully slatted floor and was flowed out from the house naturally. House *C* was fattening house and there were opening at both side. There were 30 pens. Scrapers removed dropped waste in the pit under floor. There were small ventilators that sacked air from the pit.

Table 1. Situations of objectives houses

Farm	House No.	Type	age	number of heads	measurement period
A	*A-1*	nursing	105 days old	44	May 2009, Feb. 2010
	A-2	fattening	from 110 to finishing	101	June 2009, Feb. 2010
B	*B-1*	nursing	from 30 to 76	93	July 2009
	B-2	nursing	from 30 to 76	90	August 2009
C	*C*	fattening	135 ~ 170 days old	277	Nov. 2008

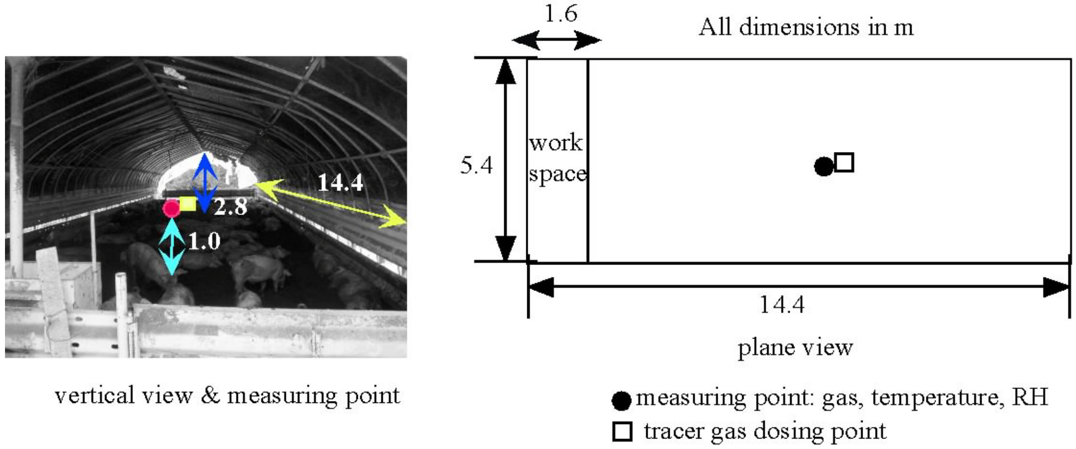

Figure 1. Objective nursing house: House *A-1*

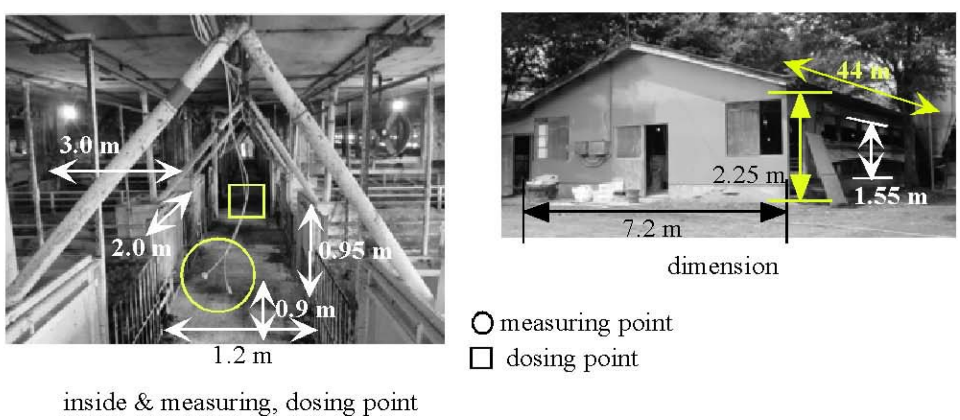

Figure 2. Objective fattening house: House *A-2*

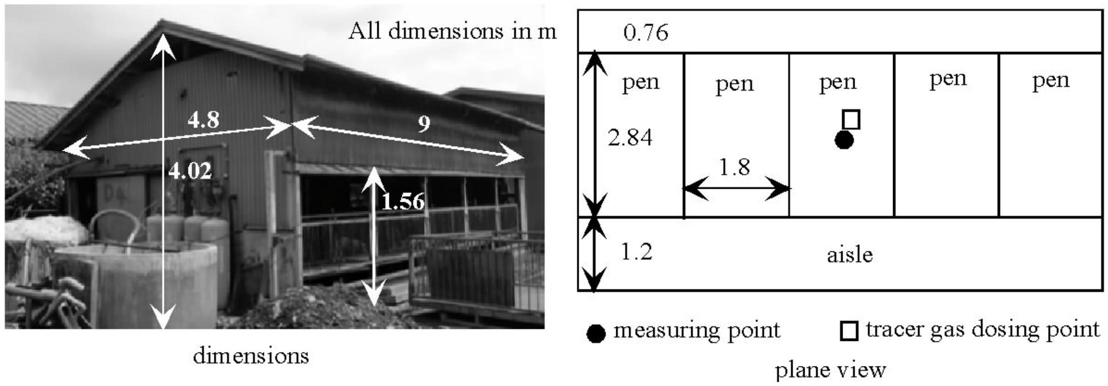

Figure 3. Objective nursing house: House *B-1*.

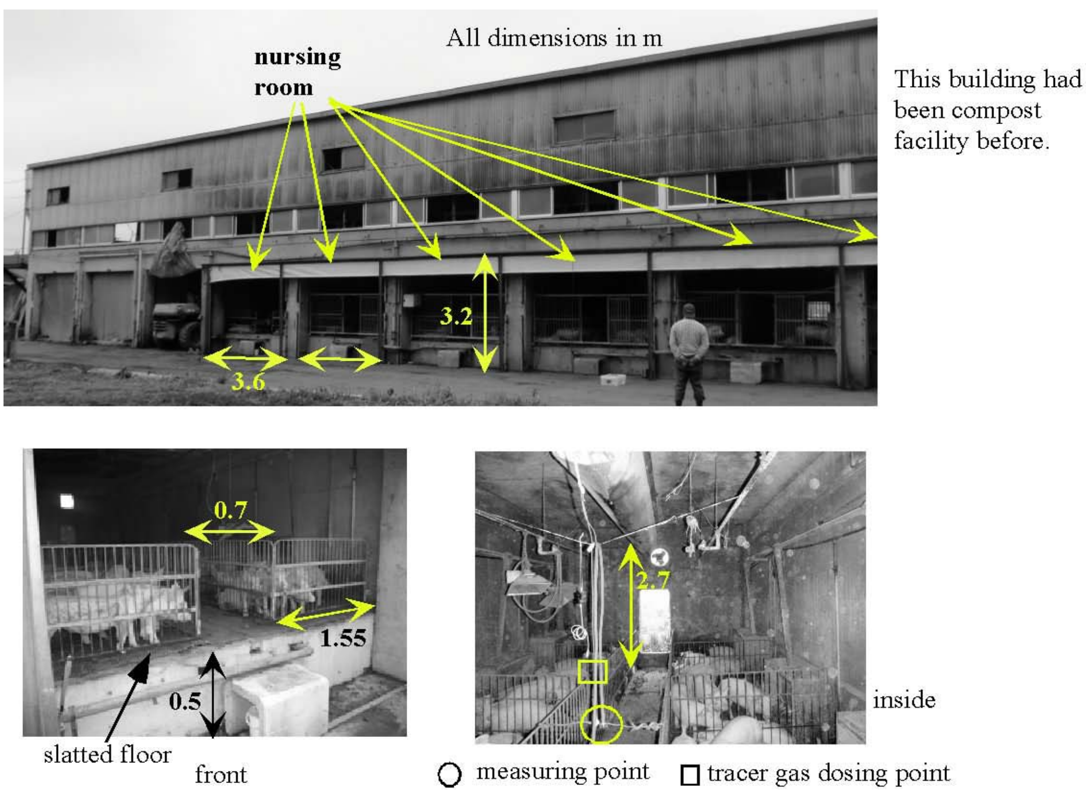

Figure 4. Objective nursing house: House *B-2*

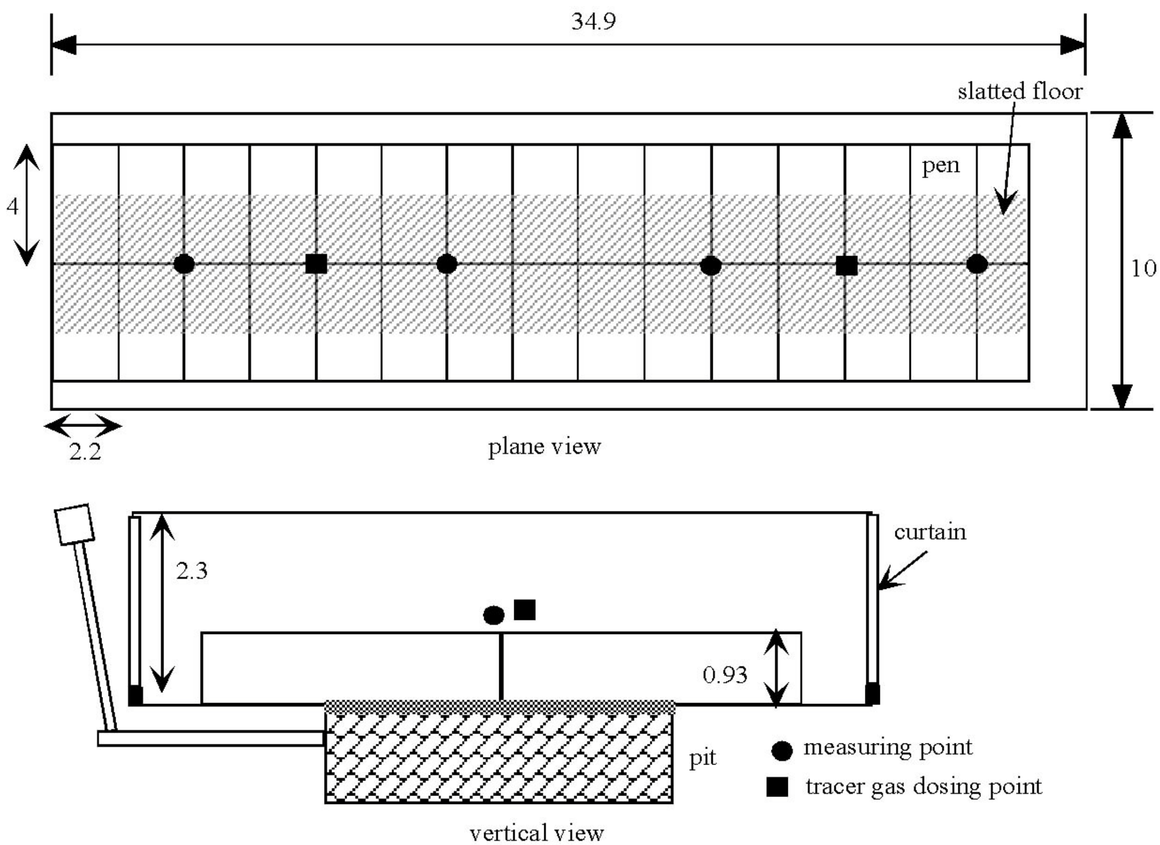

Figure 5. Objective fattening house: House *C*

Measurement Measured items were ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4), carbon dioxide (CO_2), temperature, relative humidity and ventilation rate. The gas concentration measurement system was composed of a Photoacoustic Multi-gas Monitor (Innova AirTech Instruments A/S, Denmark: model 1412) and a multipoint sampler (Innova AirTech Instruments A/S, Denmark: model 1309) with an accuracy of ± 0.1 ppm. The sampling interval was about 20 sec. Temperature and relative humidity (*RH*) were measured by a capacitor thermometer and a semi conductor relative humidity sensor and their sampling interval was 5 min (T & D co.: model RTR-53). These measuring points are shown in figure 1 ~ 5.

Constant emission method in tracer gas method was used for measuring ventilation rate. A tracer gas was sulfur hexafluoride (SF_6). The sampling interval was 20 sec. SF_6 was emitted continuously at 3.3×10^{-6} m^3 s^{-1} with a digital mass flow controller (Yamatake Co. model CMQ0020B). The locations of gas emitted point and measuring point are shown in figure 1 ~ 5. In this study ventilation rate was calculated by a derived from a discrete mass balance equation and central difference with respect to time was adopted;

$$v = \frac{P}{C_t} - V \frac{(C_{t+1} - C_{t-1})}{2\,\Delta t\, C_t} \qquad (1)$$

where: V is a volume of ventilation space, m^3; t is a time; ν is a ventilation rate, $m^3 s^{-1}$; P is generation rate of tracer gas, mg s^{-1}; C is constant gas concentration, , mg m^{-3}. An air exchange rate (*AER*) was used as an index of ventilation;

$$AER = \frac{v}{V} \times 60 \qquad (2)$$

where: *AER* is air exchange rate, h^{-1}.

RESULTS AND DISCUSSION

Temperature and relative humidity As naturally ventilated buildings are affected by outside weather, average outside temperature, relative humidity, wind speed and inside temperature during measurement are shown in table 2. Wind speed during measurement was more than 1.0 m s^{-1} and outside *RH* was high regardless of season. The different between inside temperature of *A-1* house and outside temperature was the smallest compared to those of other houses because *A-1* house was hoop type and there was no effect of insulation.

NH_3, N_2O, CH_4 and CO_2 concentrations and Air exchange rate (*AER*) Average inside gas concentrations and *AER* are shown in table 3. In *B-1* and *B-2* houses each gas concentration was higher than those in *A-1* house. The mortality in *B* farm was higher than that in *A* farm, this indicates that an inferior management conducted less environment in the house. The gas concentrations in *B-2* house were higher than those in *A-1* or *B-1* in spite of larger the *AER* in *B-2* house because gases were easily emitted from the pit under slatted floor, in which waste was retained near the floor level.

The NH_3 concentration in the fattening house of the *C* farm (*C* house) was the highest among the objective houses. The reason was why all curtains were closed completely and the sufficient ventilation rate was not obtained to remove gases. In *A-2* house (fattening house) the CH_4 concentration was apt to be higher than that in *C* house without distinction of season. As way of carrying out waste in *A-2* house was that the waste flowed naturally to outside house, the waste existed inside house always. It seems that methane fermentation was performed inside house.

Table 2. Inside and outside average temperature, relative humidity (*RH*) and wind

House & season	Inside temperature (℃)	Outside temperature (℃)	Inside RH (%)	Outside RH (%)	wind speed (m s^{-1})
A-1, summer	19.2 ± 3.1	18.4 ± 3.8	78.4 ± 14.2	82.5 ± 17.4	2.0 ± 1.0
A-1, winter	7.6 ± 4.4	2.0 ± 5.0	80.9 ± 14.3	80.7 ± 21.9	1.4 ± 1.1
A-2, summer	21.6 ± 0.9	18.8 ± 2.4	77.6 ± 2.9	89.0 ± 9.7	1.7 ± 0.8
A-2, winter	18.5 ± 2.3	10.6 ± 7.1	67.0 ± 6.7	72.4 ± 22.1	1.5 ± 1.5
B-1, summer	26.5 ± 4.0	24.9 ± 4.5	80.7 ± 6.4	88.4 ± 11.0	2.6 ± 0.8
B-2, summer	25.3 ± 1.0	22.3 ± 2.3	76.0 ± 2.9	84.3 ± 10.9	1.7 ± 0.8
C, winter	20.3 ± 1.9	6.9 ± 5.6	64.6 ± 8.6	84.3 ± 10.9	1.4 ± 1.3

Emissions of NH_3, CO_2, N_2O, CH_4 The emissions of NH_3, CO_2, N_2O, CH_4 in each house are listed in table 4. With respect to NH_3, the emission in fattening stage was larger than that in nursing stage. Usually ammonia emission in summer is higher than in winter. The case of *A-1* house was the same relationship. However, the relationship was reversed in the case of *A-2* house. The N_2O emission in *B-2* house (nursing house) was the highest among the objective houses. The reason was the same as the mentioned above section. The CH_4 emission in *A-2* house (winter) was the highest among all. The emissions of NH_3, CO_2 and CH_4 in the hoop type house were lower than those in the conventional house type.

The emission rates of NH_3, CO_2, and CH_4 in this study were lower than those of 29.4 g d^{-1} $head^{-1}$ NH_3, 2090 g d^{-1} $head^{-1}$ CO_2 and 9.3 g d^{-1} $head^{-1}$ CH_4 reported hoop type G-F swine house (Dong et al., 2009). The differences between this study and the previous study were floor type and growing stage. Though emission rate is influenced by many factors, the worst case is that waste exists long time in the house.

Table 3. Gas concentrations and air exchange rate (*AER*)

House & season	NH_3 (ppm)	CO_2 (ppm)	N_2O (ppm)	CH_4 (ppm)	*AER* (h^{-1})
A-1, summer	2.8 ± 0.7	535 ± 98	0.1 ± 0.1	6.6 ± 4.8	13.5 ± 16.8
A-1, winter	1.8 ± 1.0	731 ± 168	2.4 ± 0.9	1.1 ± 1.2	9.3 ± 5.3
A-2, summer	7.3 ± 6.9	777 ± 370	0.28 ± 0.14	28.2 ± 26.7	0.91 ± 0.62
A-2, winter	11.6 ± 4.9	1419 ± 538	0.065 ± 0.057	60.9 ± 33.2	58.6 ± 106.3
B-1, summer	3.1 ± 0.9	521 ± 27	0.27 ± 0.03	26.4 ± 3.4	25.6 ± 25.9
B-2, summer	3.1 ± 0.4	738 ± 165	0.55 ± 0.11	8.2 ± 3.1	97.6 ± 69.3
C, winter	29.9 ± 8.4	-	0.49 ± 0.11	11.3 ± 14.6	9.7 ± 4.6

Table 4. Emissions of gases g d^{-1} $head^{-1}$

House & season	NH_3	CO_2	N_2O	CH_4
A-1, summer	1.97	2.62×10^2	6.31×10^{-2}	3.49
A-1, winter	1.05	4.89×10^2	1.13	6.23×10^{-1}
A-2, summer	2.41×10^{-1}	4.18×10	0.00	8.27×10^{-1}
A-2, winter	4.92×10	9.24×10^3	2.17×10^{-1}	2.26×10^2
B-1, summer	2.30	2.88×10^2	3.77×10^{-2}	1.74×10
B-2, summer	8.78	2.33×10^3	4.08×10	0.00
C, winter	1.52×10	-	7.78×10^{-2}	6.13

CONCLUSION To collect inventories that were gas emission rates from livestock houses, NH_3, CO_2, N_2O, CH_4 emissions were measured in different naturally ventilated nursing pig houses and fattening houses during summer and winter in Ibaraki prefecture, Japan. The following conclusions were made:

- The gas emissions were somewhat higher when the waste was retained long time inside house. The handling of waste inside house was affected emissions more than pig growing stage.

- The emissions in a hoop type and saw dust litter floor were inclined to be lower than those in the conventional house type.
- The summer NH_3 emissions for the hoop type nursing house, the conventional nursing house, nursing house with retaining waste under the fully slatted floor and fattening house with retaining waste under floor were 1.97, 2.30, 8.78 and 0.241 g d^{-1} $head^{-1}$ respectively.
- The summer N_2O emissions for the hoop type nursing house, the conventional nursing house, nursing house with retaining waste under the fully slatted floor and fattening house with retaining waste under floor were 6.31×10^{-2}, 3.77×10^{-2}, 4.08×10 and 0 g d^{-1} $head^{-1}$ respectively.
- The summer CH_4 emissions for the hoop type nursing house, the conventional nursing house, nursing house with retaining waste under the fully slatted floor and fattening house with retaining waste under floor were 3.49, 1.74×10, 0 and 8.27×10^{-1} g d^{-1} $head^{-1}$ respectively.

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