Climatic Conditions and Aerial Pollutants in and Emissions from Commercial Animal Production Systems in the Netherlands

Ir. P.W.G. Groot Koerkamp and Ing. G.H. Uenk

Abstract

Research was carried out in 4 replicates of 10 commonly used animal production systems for cattle, pigs and poultry in the Netherlands. Climatic conditions, concentrations of dust and endotoxins, concentrations of ammonia, carbon dioxide, methane, and nitrous oxide (N_2O) were measured and ventilation rates and emissions were calculated. Inside climatic conditions and ventilation rates were close to what was expected or generally advised. Mean concentrations of inhalable and respirable dust varied between 0.14 (dairy cows in a cubicle house) and 11.8 mg/m^3 (broilers) and between 0.02 (dairy cows) and 1.25 mg/m^3 (laying hens with litter) respectively. Mean yearly emissions varied between 0.14 mg/h per animal for laying hens in cages and 23.8 mg/h per animal for beef cattle, while emissions from houses for sows, weaners and fatteners were 6.4, 3.3 and 6.9 mg/h per animal respectively. Concentrations of endotoxins in the air bound to dust varied according the dust concentrations. Mean ammonia concentrations were below 8 ppm in cattle houses, were between 5 and 18 ppm in pig houses and between 6 and 30 ppm in poultry houses. Mean ammonia emissions from cattle houses for dairy cows (tie houses and cubicles), beef and veal calves were 974, 2001, 686 and 522 mg/h per animal respectively. Mean ammonia emissions from pig houses for sows, weaners and fatteners were 535, 27 and 385 mg/h respectively. Mean ammonia emissions from poultry houses for laying hens (litter and cages) and broilers were 36, 6.4 and 11 mg/h per animal respectively. Methane emissions from cattle, 1010-11038 to mg/h per animal, were the highest per animal, followed by pigs (445-2406 mg/h per animal).

Keywords: Livestock Housing, Climate, Ammonia, Dust, Aerial Pollutants, Emissions

INTRODUCTION

The air within many livestock buildings seethes with a dense miasma of micro-organisms, dust particles and gases (Wathes, 1994). These aerial pollutants give cause for concern for several reasons: directly infectious and allergic diseases, multi-factorial environmental diseases, environmental acidification and global warming. There are, however, few international fiels surveys of aerial polutants in livestock buildings that have used common methods and thereby allow objective comparisons between production systems and animal species across national boundaries.

The object of this study was to undertake a large survey of the emissions of aerial pollutants within and from livestock buildings in Denmark, Germany, the Netherlands and the United Kingdom. This was carried out in an EU project under contract number PL 900703. This paper describes the results obtained in the Netherlands, considers the likely implications for human and animal health and environmental impact, and makes some recommendations for measures to control and abate pollutant emissions within livestock buildings.

MATERIALS AND METHODS

Measurements of climatic conditions and aerial pollutants were made using common methods for temperature and humidity (Rotronic sensors), airborne dust concentrations (gravimetric filtration), airborne endotoxin concentrations (in dust), ammonia (chemiluminescence NO_x analyser + NH_3 convertor) and carbon dioxide concentrations (opto accoustic analyser), ventilation rate (mass balance of CO_2 ; Van Ouwerkerk and Pedersen, 1994), wind speed and direction. Hourly values of most parameters were obtained by means of a datalogging system. Dust and endotoxins were sampled per 12 h. The survey covered 10 types of livestock housing for cattle, pigs and poultry that are in common use in the Netherlands. Four replicates of each type of building were surveyed, once in a Summer and once in a Winter. Each set of measurements was made over 24 h, staring at 6.00 h. In each building, measusrements were made in a vertical cross-section at seven locations which were representative of the location of the animals, the stockman and the exhaust of the ventilation system. An eighth location was sited outwith the building so that the ambient conditons could be recorded. In total 80 houses were measured (10 types * 4 replicates * 2 seasons). The all in-all out production systems for veal calves, weaners, finishing pigs and broilers were measured at about three quarter of the production cycle. Other housing types were measured randomly. The data were analysed by analysis of variance or tabulated straight forward. Mean levels per building type were produced.

RESULTS AND DISCUSSIONS

Table 1 summarizes the indoor and outdoor climatic condition and the ventilation rates per animal type and housing system.

Tabel 1 The minimum, mean and maximum outdoor and indoor temperature and the ventilation rate of the daily means of the four replicates in a summer and a winter situation per animal type and housing system (n=8).

Animal type and housing system	Temperature outdoor (°C)			Temperature indoor (°C)			R.H. indoor (%)	Ventilation rate (m^3/h per animal)		
	min.	mean	max.	min.	mean	max.	mean	min.	mean	max.
Dairy cows, tie house	-0.5	5.5	11.4	9.0	14.6[1]	19.0	75	168	227	305
Dairy cows, cubicle house	3.3	9.0	16.9	5.7	12.2[2]	20.4	83	331	838	1500
Beef catte, slats	-4.5	10.4	23.2	2.2	13.6[3]	25.3	74	150	355	614
Veal calves, slats (pens)	2.3	12.0	23.5	14.5	19.1[4]	26.3	73	82	103	135
Sows, boxes	5.8	10.8	14.5	19.0	20.2[5]	21.8	63	30	58	100
Weaners, partly slats	7.2	12.8	16.0	22.0	24.5[5]	27.0	52	3.8	13	24
Fattening pigs, partly slats	-3.1	7.9	23.5	18.7	22.0[5]	26.8	60	12	31	67
Laying hens, free range	3.0	10.4	18.3	16.3	20.1[5]	23.4	65	1.0	2.3	4.1
Laying hens, cages+belts	8.3	11.7	16.7	20.1	22.0[5]	23.0	60	1.2	2.3	4.1
Broilers, litter	-4.3	6.9	13.8	20.1	22.4[5]	25.0	62	0.9	1.4	2.6

[1] Mechanical ventilation, mean temperature difference house-outdoor was 9.1 °C
[2] Natural ventilation, mean temperature difference house-outdoor was 3.2 °C
[3] Natural ventilation, mean temperature difference house-outdoor was 3.3 °C
[4] Mechanical ventilation with limited temperature control, mean temperature difference house-outdoor was 7.1 °C
[5] Mechanical ventilation with temperature control at fixed or decreasing tempearture set point during production cycle

The outdoor temperature ranged from -4.5 to 23.5 °C (daily means). This effect on the indoor temperature was minimised through control of the ventilation rate. The quality of the temperature control depended on the type of ventilation system (mechanical vs. natural) and the (presence of a) temperature control system plus set points. The results in table 1 were in good agreement with generally advised figures and indicated that the research was carried out on farms with representative management under varying outdoor conditions.

The mean concentrations of inhalable dust in cattle houses were low (0.5 mg/m^3) compared the levels in pig and poultry houses (1.1-11.8 mg/m^3). In several cases occupational exposure limits, which vary between 3 and 10 mg/m^3 for different countries, were exceeded. The air in houses with laying hens and broilers houses on litter contained excessive high concentrations of dust, especially compared to the concentration in houses with battery cages. The concentration of respirable dust varied with the concentration of total dust and the contribution was between 9 and 20%. The concentrations found in this study were generally in good agreement with other results obtained in the Netherlands and abroad. The emissions of respirable dust per animal decreased with the live weight of the animals.

Tabel 2 The estimated concentration of inhalable and respirable dust (mean and c.v.) per animal type and housing system. The relative part (%) of the respirable fraction and the emission are also given (n=112).

Animal type and housing system	Inhalable dust		Respirable dust			
	Concentration		Concentration			Emission
	(mg/m^3)	c.v. (%)	(mg/m^3)	c.v. (%)	(%)	(mg/h per animal)
Dairy cows, tie house	0.34	31	0.05	43	15	11.0
Dairy cows, cubicle house	0.14	49	0.02	67	14	15.6
Beef catte, slats	0.37	27	0.07	36	19	23.8
Veal calves, slats (pens)	0.25	34	0.05	42	20	5.3
Sows, boxes	1.1	19	0.12	32	11	6.4
Weaners, partly slats	3.4	19	0.30	30	9	3.3
Fattening pigs, partly slats	2.8	18	0.25	30	9	6.9
Laying hens, free range	8.4	19	1.25	30	15	2.3
Laying hens, cages+belts	0.68	21	0.07	37	10	0.14
Broilers, litter	11.8	20	1.14	29	10	1.6

Table 3 shows the concentration of endotoxin in the air of the 10 housing systems. The concentrations in the air from both dust fractions varied according the dust concentrations in the air. The concentrations in poultry houses with litter were again again extremely high. Comparison of these results with other research is difficult due to the different methods of

Tabel 3 The mean concentrations of endotoxine in the air (ng/m^3 lucht) as found in inhalable and respirable dust. per animal type and housing system. The relative part of the endotoxine concentration in respirable dust is also given (n=16).

Animal type and housing system	Inhalable dust	Respirable dust	
	Concentration (ng/m^3)	Concentration (ng/m^3)	Contribution (%)
Dairy cows, tie house	12.0	1.2	10
Dairy cows, cubicle house	5.5	0.4	7
Beef catte, slats	11.3	1.4	12
Veal calves, slats (pens)	95.0	6.5	7
Sows, boxes	65.1	2.2	3
Weaners, partly slats	351.2	32.6	9
Fattening pigs, partly slats	121.8	9.3	8
Laying hens, free range	273.0	15.2	6
Laying hens, cages+belts	21.4	1.6	8
Broilers, litter	427.0	44.8	11

analysis. However, Preller (1995) showed that higher concentrations of endotoxins in het air have negative effects of the health of pit farmers. The concentrations found in this research in pig and poultry houses confirmed this concern and possiblities to improve the working conditions should be investigated.

Mean carbon dioxide concentrations in the summer were below 1000 ppm (0.1 vol.%) for naturally ventilated houses for cows and beef cattle, and below 2000 ppm for the other housing systems. Concentrations were higher during the winter than during the summer and in some cases exceeded the level of 2000 ppm. However, no negative health effects were expected from these levels, nor for the animals, nor for the farmers.

Tabel 4 The estimated concentration and emission of ammonia (mean and c.v.) per animal type and housing systems (n=1344). The maximum concentration is given between brackets.

Animal type and housing system	Ammonia concentration (ppm)		Ammonia concentration c.v. (%)	Ammonia emission Measured (mg/h per animal)	Measured c.v. (%)	Dutch standard (g/animal place.year)	Dutch standard (mg/h per animal)
Dairy cows, tie house	5.7	(14)	27	974	24	3000 [1]	657
Dairy cows, cubicle house	3.8	(13)	26	2001	24	8800 [1]	1930
Beef catte, slats	2.9	(11)	26	686	24	8100	925
Veal calves, slats (pens)	7.7	(47)	27	522 [3]	24	2500 [2]	184
Sows, boxes (dry/nursing)	17.8	(43)	27	535/-	24	4200/8300	505/1053
Weaners, partly slats	4.6	(22)	31	26.6[3]	28	600	76
Fattening pigs, partly slats	18.2	(60)	26	385 [3]	23	2500	317
Laying hens, free range	29.6	(73)	26	36.0	24	315 [2]	38
Laying hens, cages+belts	5.9	(17)	30	6.4	27	35	4.2
Broilers, litter	11.2	(50)	27	11.2[3]	24	50	7.6

[1] Based on 190 days during the Winter

[2] Expected value in the new Directive on ammonia emissions

[3] Measurements were made at three quarter of the production period; the standard includes the lower emission during the first half.

The mean concentrations of ammonia in the 10 housing systems were generally below 25 ppm, but the single measurements often exceeded this level, as indicated by the maximum values and the coefficient of variation (table 4). The emissions of ammonia from houses for dairy cows (cubicles), sows and laying hens (free range) were close to the standard normative Dutch values as given in Anon (1996) (1930, 505 and 38 mg/h per animal respectively). Measurements made in houses for veal calves, fattening pigs and broilers were made at three quarter of the production cycle and were a little higher than the normave values due to the increased ammonia emission during the production period. The higher emission from tie houses for dairy cows could be attributed to the higher emission during the Summer, which is not included in the normative value. Lower emissions from houses for weaners than the normative value, as in this research, was also found by Aarnink *et al.* (1995). The measured emission from houses with battery cages for laying hens was probably based too much on the higher emission during the end of the manure handling period (weekly removal of belt manure).

Tabel 5 The estimated concentration and emission of methane (mean and c.v.) per animal type and housing systems.

Animal type and housing system	Methane concentration (ppm)	Methane emission (mg/h per animal)	c.v. (%)
Dairy cows, tie house	33.7	5009	34
Dairy cows, cubicle house	20.3	11038	34
Beef catte, slats	21.1	6142	37
Veal calves, slats (pens)	13.3	1010	35
Sows, boxes	50.7	2406	48
Weaners, partly slats	60.5	445	29
Fattening pigs, partly slats	55.4	1269	37
Laying hens, free range	4.9	6.5	29
Laying hens, cages+belts	4.5	6.4	29
Broilers, litter	2.5	2.3	34

The emissions in Table 5 were not corrected for the background concentration of methane. This concentration was measured a few times only and found to be about 2.4 ppm. In the case of poultry houses this was a substantial part of the concentration found in the house. The methane emissions from houses with dairy cows and beef cattle, 97, 44 and 53 kg/year per animal, were well within the range reported by Johnson and Ward (1996). However, the lower emission from tying stalls as compared to cubicle houses was remarkable because it could be assumed that these cows had more or less the same diet. The emission from houses for dry sows and fattening pigs were close to those measured by Groenestein (1997), while emissions from weaner houses in this study were were about three times higher. The methane concentrations found in poultry houses were similar to those found in the United Kingdom (Sneath *et al.*, 1996).

Detectable levels of N_2O (detection limit about 0.4 ppm) were found in houses for laying hens with litter only, but not in all of them (mean 0.50 ppm, maximum 1.69 ppm). This resulted in a mean emission of about 0.92 mg/h per animal.

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