AMMONIA EMISSION AND MINERAL LOAD ON OUTDOOR YARDS OF LAYING HENS

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Abstract
The objective of this study was to determine the ammonia emission and the mineral load from outdoor yards of laying hens. Measurements were done at a commercial farm, with an outdoor yard for 3000 hens, and at an experimental farm, with two outdoor yards each for approximately 250 hens. At the commercial farm the hens had an outdoor area of 4 m^2 per hen and of 5 m^2 at the experimental farm. Ammonia emission was measured at 5, 10, 15, and 20 m distance from the animal house by the ventilated chamber technique. Mineral load on the outdoor yard was determined by weighing and analyzing the fresh droppings. The results showed decreasing ammonia emissions with increasing distance to the animal house. Per laying hen an emission from the outdoor yard was calculated of 2.0 mg/h for the commercial farm, and of 0.95 and 0.86 mg/h for the experimental farm. Estimated mineral load within 20 m distance from the animal house exceeded the maximum standard for manuring (of 170 kg N and 44 kg P per ha) by a factor 15, both on the commercial farm as on the experimental farm. It is concluded that ammonia emission from the outdoor yard for laying hens is relatively low compared to the emission from the animal house. The mineral load of the outdoor yard near the animal house is unacceptably high, and severe measures should be taken to solve this problem.

Keywords: organic farming, poultry, emission, ammonia, minerals

1 Introduction

Protection of the environment is an important goal in organic food production. One of the important goals of organic farming is closing mineral cycles. However, in this mineral cycle losses are inevitable. In organic farming of laying hens losses occur by emission of ammonia from the barn and from the outdoor yard, and by rinsing of nitrogen and phosphorous from the soil of the outdoor yard.

According to Dutch legislation (Stichting SKAL, 2004), which is a supplementation to the EU-regulation on Organic Production (1991), organic laying hens should have access to an outdoor yard from an age of 8 weeks onwards; in the winter this is from week 14 onwards. They should have daily access to a yard of 2.5 m^2 per hen. In total, from week 18 onwards, it should be at least 5 m^2, which can be given in two separate yards of 2.5 m^2 per hen. From this it can be calculated that per hectare a maximum of 2000 hens can be kept. The aforementioned EU-regulation also states that the maximum manuring standard of 170 kg N/ha per year is reached by the yearly manure production of 230 layers. With an occupation rate of 2000 layers/ha this means that a maximum of 11.5% of the manure produced should be deposited in the outdoor yard, to prevent overloading of the yard with minerals. Furthermore, overloading is only prevented under the assumption that this manure is evenly distributed over the yard and that vegetation is present to absorb the minerals.

Little is known as yet about the ammonia emission from unpaved outdoor yards. Bussink (1994) found ammonia emissions from grassland varying from 3.3 to 14.4% of the amount of nitrogen excreted via urine and faeces. For laying hens no data are available of ammonia emissions from the outdoor yard.

The objective of this study was to study the ammonia emission and the mineral load of the outdoor yard of laying hens. With this information it could be decided whether more effort should be put in reducing environmental pollution by organic laying hens.

2 Material and method

The study was performed at two locations: a commercial farm and an experimental farm, both with organic laying hens. On both locations measurements were done during a few days spread over a number of months.

2.1 Measuring locations

In Table 1 the main features of the two measuring locations are mentioned. On the experimental farm measurements were done at two outdoor yards belonging to different housing systems. In Figure 1 a schematic view of the layout of the outdoor yards is given. For an impression of the situation in Figure 2, two photos are shown of the outside yards.

Table 1. Main features of the measuring locations.

Feature	Commercial farm	Experimental farm	
Housing system	Floor housing	Floor housing	Voliere housing
Number of hens	3000	212	265
Breed of hens	Lohman Brown	Lohman Silver	Lohman Silver
Area outdoor yard	Approx. 10 000 m^2	1 100 m^2	1 500 m^2
Use of outdoor yard	From 11:00 – sunset	From 10:30 – sunset	From 10:30 – sunset
Soil outdoor yard	Sandy soil	Peaty clay mixed with sand	Peaty clay mixed with sand

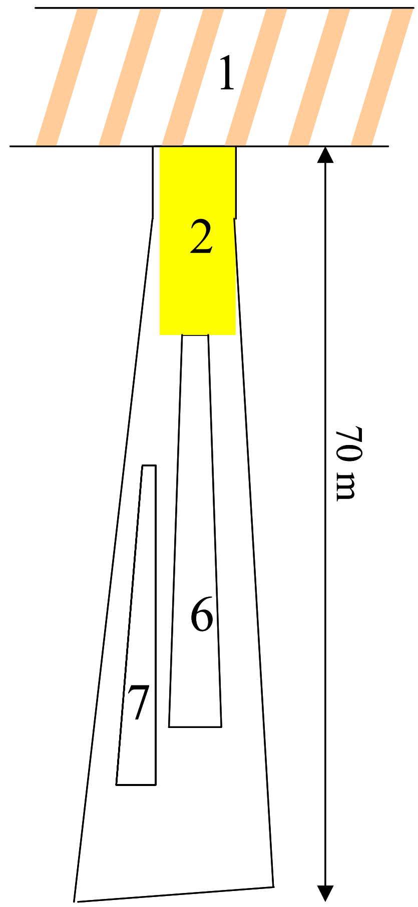

Figure 1. Layout of the outdoor yard. Left: situation at the commercial farm; Right: situation at the experimental farm. The width of the paddock at the experimental farm is different for the floor system and the voliere system, but the shape is similar. 1=poultry house; 2=measured area; 3=water puddle; 4=clump of trees; 5=vineyard; 6=bushes; 7=maize.

 

Figure 2. View of the outdoor yard at the commercial farm (left) and the experimental farm (right).

2.2 Measurements

Measurements were done at 5, 10, 15, and 20 m from the animal house at random chosen locations. From each outdoor yard the following was measured:

- Ammonia emission
- Mineral load

At the commercial farm the mineral load was determined at 30 m, as well.

2.2.1 Ammonia emission

Ammonia emission was measured at one random place each at 5, 10, 15, and 20 m distance from the animal house using a ventilated chamber (Aarnink et al., 2002) constructed of steel walls (Figure 4). The base of the chamber (0.5 x 0.8 m) was open; the sides of the chamber were 0.28 m high (including a rubber edge of 0.03 m high). The chamber covered a soil area of 0.4 m^2. Two equal fans on either sides of the chamber ensured an equal pressure in the measuring chamber to prevent air leaking. An anemometer calibrated in a wind tunnel measured the volume of air. Ventilation rate was kept at 98 m^3/h, giving an air speed of 0.22 m/s in the chamber. After the chamber was placed at the measuring location we waited for 2 min. to let the air being stabilized inside the chamber, before we started to measure. Ammonia concentrations of incoming and outgoing air of the chamber were measured with the denuder method (Figure 4). In this method a small air stream of 1 L/min is lead through a denuder during 15 min. A denuder is a glass tube of 10 cm length and 0.5 cm diameter coated inside with oxalic acid (2.5 g in 100 ml alcohol). This coating binds the ammonia in the air. The amount of ammonia absorbed in the denuders was determined in our chemical lab in triplo. The denuder test is described in more detail by Mosquera et al. (2002). In Table 2 the measuring days and the number of measurements are given.

Figure 4. The ventilated chamber for measuring ammonia emission (left) and a detail of the denuder method equipment (the arrow indicates the location of the denuder).

Table 2. Measuring dates and number of ammonia measurements in the outdoor yards of the commercial and experimental farm.

Commercial farm		Experimental farm			
		Floor housing		Voliere housing	
Date	Number of measurements[1]	Date	Number of measurements[1]	Date	Number of measurements[1]
13 May 2004	8	27 May 2004	4	27 May 2004	4
3 Aug 2004	8	28 Jul 2004	4	28 Jul 2004	4
24 Aug 2004	6[2]	3 Sep 2004	4	3 Sep 2004	4
		3 Dec 2004	4	3 Dec 2004	4

[1] To get the number of measurements per location (per distance from the animal house) this number has to be divided by 4.
[2] At 5 and 20 m one time and at 10 and 15 m two times.

2.2.2 Mineral load

On basis of the number, chemical composition and weight of the droppings at a certain area in a certain period of time an estimation can be made of the local mineral load. Measurements were done at different days in 2004 (see Table 3). Before the chickens went out in the morning rasters of 1 m^2 were randomly placed, at least one at each distance (5, 10, 15, 20, and 30 m; 30 m only at the commercial farm) to the animal house (Figure 3). At 13:30 the number of total droppings, whole droppings and trampled droppings, was counted. Only whole droppings were collected for weighing and analyses. At the commercial farm one or more rasters were additionally randomly placed at the same distances. Within these rasters the old droppings were removed before the layers went out. In that way only the fresh droppings, whole and trampled, were counted from the moment the layers went out until 13:30 h. Only whole droppings were collected for weighing and analyses. On basis of the information of total and fresh droppings on the commercial farm a conversion factor was calculated for the experimental farm to calculate the fresh produced droppings on basis of the total number of droppings. This conversion factor was 0.81. The total droppings at the commercial and experimental farm and the fresh droppings at the commercial farm were analysed for N, P, K, NH_4-N, and dry matter.

Table 3. Dates of measurements and number of measurements on droppings at the outdoor yards of the commercial and experimental farms.

Commercial farm			Experimental farm			
			Floor housing		Voliere housing	
	Number of measurements[1]			Number		Number
datum	Fresh droppings	Total droppings	Date	of meas.[2]	Date	of meas.[2]
25 Mar '04	50	0	27 May '04	4	27 May '04	4
23 Apr '04	15	10	28 Jul '04	4	28 Jul '04	4
6 May '04	15	10	3 Sep '04	4	3 Sep '04	4
13 May '04	15	10	3 Dec '04	4	3 Dec '04	4
9 Jun '04	15	10				
14 Jul '04	15	10				
2 Aug '04	15	10				
3 Aug '04	15	10				
24 Aug '04	5					

[1] To get the number of measurements per distance from the animal house this number has to be divided by 5.
[2] To get the number of measurements per distance from the animal house this number has to be divided by 4.

Figure 3. A raster at the outdoor yard to determine the number and composition of droppings.

2.3 Analyses

2.3.1 Ammonia emission

To be able to extrapolate the measured ammonia emission levels to other distances from the animal house we determined the relation between distance and ammonia emission by one-way regression analysis for each outdoor yard. The average effects of distance, temperature and humidity were determined by multiple regression analysis. All analyses were performed with the Genstat-program (Genstat Committee, 2003).

2.3.2 Mineral load

The mineral load of the outdoor yard was determined by multiplying the daily production of manure with its concentrations of N, P, and K. The daily manure production was calculated by linearly extrapolating the amount measured during the measuring period to the period the layers had access to the outdoor yard (from 10:30 – 11:00 until sunset). The mineral load was determined with the following formula:

$$ML_{i,j} = C_i * N * M * HO / HM \qquad (g/(d.m^2))$$

Where:

- $ML_{i,j}$ = the load of mineral i at distance j from the animal house (i = N, P or K in $g/(d.m^2)$; j = 5, 10, 15, 20, 30 m));
- C_i = the concentration of mineral i in the droppings (i = N, P or K in g/kg);
- N = total number of droppings in a certain area (whole and trampled droppings; in m^{-2});
- M = the average mass per dropping (in kg);
- HO = the number of hours the layers had access to the outdoor yard (from 10:30 - 11:00 until sunset; in h/d);
- HM = the time period the droppings were collected (in h).

3 Results

3.1 Ammonia emission

In Figure 4 the relation is given between the distance to the animal house and ammonia emission in mg per hour per m^2 for the commercial farm, the experimental farm with floor housing, and the experimental farm with voliere housing, respectively. The graphics show that the variation in emission is big; in some cases even a negative emission was calculated. Because also the negative values were in the range of the normal variation, these values were included in the analyses. For all outdoor yards a negative relationship was found between the distance to the animal house and ammonia emission. All regression coefficients were significantly or almost significantly different from zero (p=0,081 for the commercial farm; p=0,011 for the experimental farm with floor housing; p=0,061 for the experimental farm with voliere housing).

The multiple regression analysis showed significant regression coefficients for distance to the animal house, temperature and relative humidity on ammonia emission. The following regression line was determined:

$$Y = -3.86\ (4.8) - 0.36\ (0.09)\ D + 0.27\ (0.11)\ T + 0.10\ (0.04)\ RH \qquad (R^2 = 0.28)$$

Where: Y = Ammonia emission ($mg/(h.m^2)$);
D = distance to animal house (m);
T = temperatuur (^oC);
RH = Relative humidity (%).

This regression line shows that ammonia emission decreased with increasing distance to the animal house and increased with increasing temperature and humidity. It should be remarked that this regression line is only valid in the range of the values measured in this study (distance: 0 – 20 m; temperature: 5 – 34 ^oC; RH: 27 – 97%). Total emission was calculated by multiplying the areas at the different distances to the animal house with the average ammonia emission from

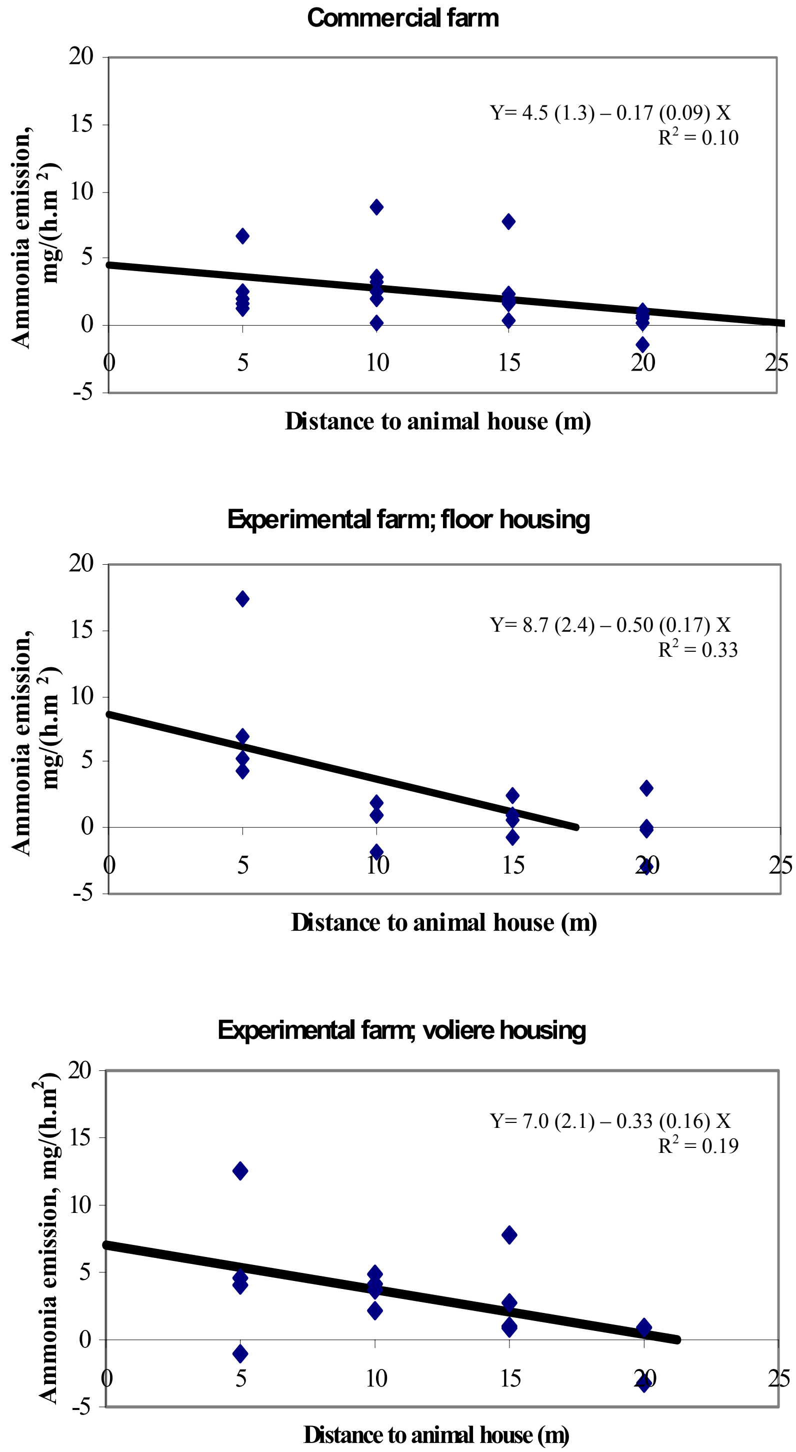

Figure 4. Relation between the distance to the animal house and the ammonia emission from the outdoor yards. The regression lines are given in the graphics with the standard errors in between brackets.

Table 4. Total ammonia emissions from the different outdoor yards in this study.

			Emission (g/h)	Emission (mg/(h.layer))
Commercial farm			6.0	2.0
Experimental farm	-	Floor housing	0.21	0.95
	-	Voliere housing	0.31	0.86

these areas, and then taking the sum of these values. In Table 4 the total ammonia emissions are given.

3.2 Mineral load

In Table 5 the number of droppings, the composition of the droppings, and the mineral load is given for the different distances to the animal house and for the different outdoor yards in this study.

Table 5. Number of fresh and total droppings per m^2 during the measuring period at the different distances to the animal house and the composition of the total droppings. In between brackets the standard errors of the mean are given.

Location	Distance to building (m)	Number per m^2 Fresh	Total[2)]	Composition of total droppings, g/kg[1)] N	P	K	NH_4-N	DM
Commercial farm	5	3.1 (0.39)	5.1 (0.78)	11.9[5)] (0.5)	3.2[5)] (0.24)	4.2[5)] (0.22)	3.9[5)] (0.39)	473[5)] (48)
	10	3.4 (0.34)	5.4 (0.69)					
	15	3.2 (0.55)	2.7 (0.65)					
	20	2.4 (0.37)	2.9 (0.82)					
	30	1.4 (0.27)	1.2 (0.48)					
Experimental farm; floor housing	5	6.5[3)]	8.0 (3.7)	12.2 (1.9)	2.8 (0.68)	7.3 (0.67)	2.8 (0.77)	443 (56)
	10	7.3[3)]	9.0 (3.5)					
	15	8.9[3)]	11.0 (3.4)					
	20	8.3[3)]	10.3 (1.9)					
	30	-[4)]	-[4)]					
Experimental farm; voliere housing	5	6.1[3)]	7.5 (3.6)	13.2 (2.5)	3.0 (0.77)	8.4 (0.76)	2.9 (0.75)	420 (53)
	10	4.1[3)]	5.0 (2.0)					
	15	10.6[3)]	13.0 (1.8)					
	20	6.9[3)]	8.5 (1.7)					
	30	-[4)]	-[4)]					

1) Composition of the total collected whole droppings. The collected droppings at the different distances were pooled to one sample.

2) The total number of droppings can be lower then the number of fresh droppings, because they were counted at different places.

3) Estimated on basis of a conversion factor of 0.81, see 2.2.2.

4) Not measured.

5) The composition of the fresh droppings at the commercial farm was 9.8 (0.3), 2.4 (0.14), 3.7 (0.20), 4.4 (0.42) and 357 (19) g/kg for N, P, K, NH_4-N and DM, respectively.

Table 6. Calculated mineral load at the different distances to the animal house and for the different locations (in g/(d.m^2)).

Location	Distance to building (m)	Mineral load, g/(d.m^2)[1]		
		N	P	K
Commercial farm	5	0.79 (0.10)	0.20 (0.03)	0.30 (0.04)
	10	0.84 (0.09)	0.21 (0.02)	0.32 (0.03)
	15	0.86 (0.15)	0.22 (0.04)	0.33 (0.06)
	20	0.62 (0.09)	0.15 (0.02)	0.23 (0.03)
	30	0.39 (0.07)	0.10 (0.02)	0.15 (0.03)
Experimental farm; floor housing	5	1.05 (0.43)	0.24 (0.10)	0.62 (0.25)
	10	1.29 (0.56)	0.29 (0.13)	0.77 (0.33)
	15	1.75 (0.68)	0.40 (0.15)	1.04 (0.41)
	20	1.69 (0.44)	0.38 (0.10)	1.00 (0.26)
	30	-	-	-
Experimental farm; voliere housing	5	0.98 (0.35)	0.22 (0.08)	0.62 (0.22)
	10	0.67 (0.13)	0.15 (0.03)	0.43 (0.08)
	15	2.17 (0.52)	0.50 (0.12)	1.38 (0.33)
	20	1.47 (0.40)	0.34 (0.09)	0.93 (0.25)
	30	-	-	-

1) The measured amount of manure during the measuring period (from 10:30 – 11:00 until 13:30) was linearly extrapolated to the period the chickens had access to the outdoor yard.

Table 5 shows that at the first 20 m from the animal house the distribution of the droppings was rather uniform, only at 30 m, measured at the commercial farm, the number of droppings was clearly lower. The N and P concentrations were comparable for the different outdoor yards. The K concentration was lower at the commercial farm and the ammonium-N and dry matter contents were higher than at the experimental farm. On the basis of data in Table 5 and the mean weight of the droppings the mineral load in g/m^2 per day was calculated in Table 6. Mean weights of droppings were 6.8 (fresh droppings), 4.3, and 4.2 g for the commercial farm, the experimental farm with floor housing, and the experimental farm with voliere housing, respectively.

In Table 7 the mineral load of the first 20 m to the animal house is recalculated to 1 ha and 1 year, to be able to compare these figures with the available standards for manuring. From this table it can be seen that the mineral load of the first 20 m of the outdoor yard is very high. The mineral load was very comparable for all three outdoor yards.

Table 7. Calculated mean mineral load of the first 20 m (measured distance from the animal house) of the outdoor yard, recalculated to kg per ha per year.

		Mineral load, kg/(year.ha)		
		N	P	K
Commercial farm		2845 (199)	709 (50)	1074 (75)
Experimental farm	- Floor housing	2637 (461)	597 (104)	1562 (273)
	- Voliere housing	2412 (408)	552 (93)	1530 (259)

4 Discussion

4.1 Ammonia emission

Ammonia emission was measured with the ventilated chamber technique. The ventilated chamber generates a constant airflow over the emitting surface. The advantage is that different measurements in time are better comparable, because it is not influenced by differences in outside wind speed. The disadvantage is that extrapolation to yearly emissions is more difficult, because the effect of variations in wind speed is not included in the results. In this study a rather low airflow rate was used of 0.22 m/s. The main reason for this was to create a higher concentration difference of ammonia in the incoming and outgoing air of the chamber. Generally, the air speed outside is higher than 0.22 m/s. Higher airspeeds generally means a higher ammonia emission from liquid manure (Aarnink and Elzing, 1998). With poultry manure a higher airspeed, in combination with a high temperature and low relative humidity, also has a drying effect and may reduce ammonia emission in that way (Groot Koerkamp et al., 1995). We expect, however, that at the outdoor yard with moderate temperatures and rather high humidity, the lower air speed in the chamber caused a lower ammonia emission. On the other hand, we only measured emissions during the day. When extrapolating these data to daily emissions the real emissions might be overestimated, because during the night there is no production of manure on the outdoor yard and the temperature generally is lower.

Taking into account the former discussion points we did recalculate our measured ammonia emission data to yearly emissions to be able to make a comparison with the emissions measured from the animal house. In that way we could make an estimate of the contribution of the outside yard to the total ammonia emission from the farm. Table 4 shows ammonia emissions of 2.0, 0.95 and 0.86 mg/h per layer from the outdoor yards of the commercial farm, the experimental farm with floor housing, and the experimental farm with voliere housing, respectively; on a yearly basis this gives emissions of 17.5, 8.3 and 7.6 g per layer. A layer house with floor housing has an ammonia emission factor of 315 g per year (VROM, 2002). For the commercial farm this means that ammonia emission from the outside yard was approximately 5.5% of the emission from the layers house; for the experimental farm with floor housing this was 2.6%. A voliere system has an emission factor of 90 g per layer per year (VROM, 2002). For the experimental farm with voliere system this means that the emission from the outdoor yard was approximately 8.4% of the emission from the layers house.

The ammonia emission per layer was approximately two times higher at the commercial farm than at the experimental farm. This might be caused by the higher manure production at the outdoor yard at the commercial farm. From the results it can be calculated that the manure production on the first 20 m from the animal house was 55 g/d per layer at the commercial farm and 25 and 40 g/d for the experimental farm with floor housing, and the experimental farm with voliere housing, respectively. The lower manure production on the experimental farm was probably caused by the fact that relatively less chickens were outside at this farm when compared to the commercial farm. Less covering in the outdoor yards of the experimental farm probably caused less chickens to go out. Another reason for the lower ammonia emission on the experimental farm might be the lower ammonium-N content of the droppings (see Table 5).

From the results it can be concluded that the ammonia emission from the outdoor yards is relatively low when compared to the emissions from the layers house. However, it can not be ignored. More measurements, spread over the year, at different air speeds, are necessary to get more accurate data on the yearly emissions from the outdoor yard of layers.

4.2 Mineral load

Data from the mineral load (Tables 5 and 6) of the commercial farm show that the manure produced was rather similar for the first 20 m distance from the animal house, but was lower at 30 m distance. At the experimental farm the manure production was not measured at 30 m, but on basis of observations it is the expectation that also at this farm the mineral load was decreasing at this distance. In paragraph 4.1 the estimated manure productions at the outdoor yards per layer per day were given. According to the handbook for poultry production (2004) the average manure production per layer per year is 75 kg; this equals 205 g/d. This means that at the outdoor yards of the commercial farm, the experimental farm with floor housing, and the experimental farm with voliere housing approximately 26, 19, and 12% of the total manure was produced at the first 20 m of the outdoor yard, measured from the animal house. This is already higher than the maximum amount calculated in the Introduction (11.5%) when the manure would be equally spread over the whole yard. In addition, because all this manure is excreted in a small area near the layers house, this causes a strong overloading with minerals in this area. In addition, in this area there was no plant cover, so all minerals added are in fact in overload, and is run off, leached to the ground water, or accumulated in the soil.

At the commercial farm the mineral load was measured in spring and summer, and at the experimental farm this was done in spring, summer, and autumn. In both cases no measurements were done in winter. From broilers it is known that they go out less during the winter (Van Harn et al., 2003), but layers are less vulnerable for cold and will go out in winter, as well. Only at rainy days, the layers will go out less. When calculating the mineral load, we linearly extrapolated the measured values during the measuring period (from 11:00 – 13:30 at the commercial farm and from 10:30 – 13:30 at the experimental farm) to the period the layers had access to the outdoor yard (from 10:30 – 11:00 until sunset). Little is known about the excretion pattern of layers during the day, but we expect a rather uniform distribution. We base this expectation on results of Hogewerf et al. (2004) who found that the number of layers in the outdoor yard was rather uniformly spread over the time period they had access to the yard. While layers eat almost during the whole day, it is reasonable to assume that manure production is evenly distributed over this time period, as well.

The estimated mineral load of (a part of) the outdoor yard is so high that this problem cannot simply be solved by management measures or extra plant cover to increase the spread of the layers over the yard. Drastic measures, like an impermeable layer under the sand or mobile barns seem to be necessary to solve this problem (Rodenburg and Van Harn, 2004). The impermeable layer, e.g. of concrete, is probably only necessary at the first 20 to 30 m distance from the animal house.

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