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EMISSIONS OF AERIAL POLLUTANTS FROM POULTRY HOUSES

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ABSTRACT

For a better understanding of the present emissions of aerial pollutants from livestock production an extensive research project was started. The objective of this project was to provide emission figures that can be used to establish emission factors for aerial pollutants. Within this paper results from dust and ammonia emissions from broilers, layers floor housing, layers aviary housing, broiler breeders, and turkeys are reported. From the results it was concluded that the necessity of this study is shown by the high differences between measured PM10 emissions in this study and the emission factors estimated by conversion from total dust emissions in a previous study. Results show that PM2.5 contribution to PM10 is generally low (5 to 8%), except for turkeys where it was 47%.

KEYWORDS. dust emission, ammonia emission, poultry

INTRODUCTION

In 2005 the European Union (EU) has set limits for maximum fine dust concentrations in the outside air. Mean yearly concentrations of particles smaller than 10 µm (PM10) should not exceed 40 $\mu g/m^3$ and daily mean PM10 concentrations should not exceed 50 $\mu g/m^3$ for at least 330 days per year. In 2008 a new EU guideline was formulated for particles smaller than 2.5 µm (PM2.5). Mean yearly PM2.5 concentrations in the outside air should not exceed 25 $\mu g/m^3$.

Besides traffic and industry, livestock production significantly contributes to fine dust emissions in The Netherlands. To reduce these emissions its important to first determine the actual emissions of fine dust. Until now, fine dust emission factors were based on dust emission data from an extensive EU project (Aerial Pollutants) collected in the period from September 1993 until November 1995 (Takai *et al.* 1998; Groot Koerkamp *et al.* 1996). However, within this project inhalable dust (~PM50) and respirable dust (PM5) were measured and not the requested PM10 and PM2.5. By Chardon and Van der Hoek (2002) conversion factors were estimated to calculate PM10 and PM2.5 emissions from inhalable dust emissions within this EU project. Because of the indirect and tentative basis of the dust emission factors, an update was requested.

In The Netherlands, especially some poultry farms are exceeding the EU threshold values. Therefore we started the update of the emission factors on poultry farms. Besides dust emissions, the emissions of ammonia from animal houses are important, as well. In the year 2013 all livestock houses in The Netherlands should be implemented with a low ammonia emitting system. For that reason, in this study we did not only look at dust, but also at emissions of ammonia.

The objective of this study was to update dust emission factors for poultry houses in The Netherlands. The following poultry houses were investigated: broiler houses, floor houses for layers, aviary houses for layers, broiler breeder houses, and turkey houses. Furthermore, in all these houses emissions of ammonia were determined, as well.

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MATERIAL AND METHODS

General design

The study was done in 4 broiler houses, 4 floor houses for layers, 4 aviary houses for layers, 2 broiler breeder houses, and 2 turkey houses. Dust and ammonia emission measurements in the different houses were performed according to the protocols described by Hofschreuder *et al.* (2008) for dust and Ogink *et al.* (2010) for ammonia. These measuring protocols prescribe for each location six 24 h measurements, evenly spread over the year and spread over the production period. According to these protocols the number of locations per defined housing system should be four. In this way for such a system 6 x 4 = 24 measurements are obtained. Because of budget reasons and the smaller contribution to dust emissions in The Netherlands it was decided to limit the broiler breeder and the turkey houses to two locations.

Housing

In Table 1 the main characteristics of the different housing systems are given.

Table 1. Main characteristics of the different poultry housing systems in this study

Category	Animal density	Production cycle	Housing	Bedding	Feed	Ventilation
Broilers	22 – 24 broilers/m^2	6 – 7 weeks	Floor with bedding	Wood shavings	Automatically distributed crumbles and pellets	Side inlet, end wall outlet
Layer floor	8.8 – 9 layers/m^2	18 – ±75 weeks	Floor with bedding, slatted hopper (with manure belt at 2 farms), laying nests	Wood shavings (3 farms or sawdust (1 farm); 2 farms also some alfalfa	Automatically distributed crumbles and pellets	Side inlet, end wall outlet
Layer aviary	17 – 18 layers/m^2	18 – ±75 weeks	Floor with bedding, aviary system with manure belts, laying nests	Sand (1 farm), wood shavings (3 farms)	Automatically distributed crumbles and pellets	Side inlet, end wall outlet
Broiler breeder	7.7 – 8.5 birds/m^2	20 – 60 weeks	Floor with bedding, slatted hopper, laying nests	Wood shavings	Automatically distributed meal, crumbles and pellets	Tunnel
Turkey (cocks)	3.0 – 3.4 turkeys/m^2	4, 5 – 21 weeks	Floor with bedding	Wood shavings	Automatically distributed crumbles and pellets	Natural ventilation with curtains

Measurements

<u>Dust</u>

The following dust samples were taken during the measurement days during 24 h:

- Duplicate 24 h samples of the exhaust air and a single 24 h sample from the incoming air of particles smaller than 10 µm (PM10);
- Duplicate 24 h samples of the exhaust air and a single 24 h sample from the incoming air of particles smaller than 2.5 µm (PM2.5).

PM10 and PM2.5 concentrations from the exhaust air were measured near the outlet ventilators, but far enough that the airspeed was not higher than 1.0 m/s. Figure 1 shows the dust sampling equipment. The equipment for gravimetrically sampling of PM10 and PM2.5 is based on the standard reference samplers for outside air (NEN-EN 12341 1998; NEN-EN 14907 2005). The difference between the reference samplers for outside air and the used ones is that the impactor pre-separator has been replaced by cyclones (URG corp., Chapel Hill, US) to separate the larger particles from the aimed ones. This was done, because of the vulnerability of the impaction plate, especially for sampling PM2.5, for overloading (Zhao et al. 2009). The air flow through the samplers was 1 m^3/h and was drawn with a constant flow pump (Charlie HV, Ravebo Supply, The Netherlands). For details on the sampling procedure see Zhao *et al.* (2009). Dust was collected on glass fibre filters wit a diameter of 47 mm (type MN GF-3, Macherey-Nagel GmbH & Co., Düren, Germany). Before and after sampling dust filters were weighed under standardized conditions (20 ± 1°C; 50 ± 5% relative humidity), following the standard (NEN-EN 14907 2005). According to the study of Zhao *et al.* (2009) PM10 concentrations measured with the cyclones need to be corrected with the following regression lines to be comparable with the reference impaction method for the outside air:

For X < 223 µg/m^3: Y = 1.09 X

For X > 223 µg/m^3: Y = 0.83 X + 57.5

Where: X is the concentration measured with the cyclone; Y is the calibrated concentration.

Figure 1. Sampling equipment for PM10 and PM2.5. Left (from left to right): air inlet (Ravebo Supply bv, Brielle, The Netherlands), PM10 and PM2.5 cyclones, filter holder; Right: construction of the air inlet (adapted European inlet).

Ammonia

Ammonia concentration was measured with the so-called wet chemical method. In this method the air is sucked at a constant flow by a pump through a critical capillary (1.0 L/min) and through an impinger with 100 ml of nitric acid solution (0.05 M). Ammonia in the air was trapped by the acid. To wash all the ammonia from the air a second impinger with acid was placed in series of the first one. A third impinger without solution was placed in series to trap possible solution that was carried with the air. After sampling for 24 h, ammonia in the acid solution was determined spectrophotometrically; together with the volume of the acid solution the total amount of trapped ammonia was calculated. Both the incoming and the exhaust air were sampled in duplicate.

Ventilation rate and climate

Ventilation rate was determined with the CO_2 mass balance method (Pedersen et al. 2008). For this purpose the incoming and exhaust air was sampled for 24 h and CO_2 concentrations in these samples were determined with the gas chromatograph. The CO_2 production from the animals (including from manure) was calculated from CIGR calculation rules (Pedersen et al. 2008; CIGR Working Group on Climatization of Animal Houses 2002). From these data the average 24 h ventilation rate was calculated as follows:

$$V = \frac{CO_2 - production}{[CO_2]_{out} - [CO_2]_{in}}$$

Where: V is ventilation rate (m^3/d);

CO_2-production is CO_2 production from animals and manure (m^3/d);

$[CO_2]_{out}$ is CO_2 concentration in exhaust air (m^3/m^3);

$[CO_2]_{in}$ is CO_2 concentration in incoming air (m^3/m^3).

Depending on the way the CO_2 production is calculated (per animal house or per animal) the ventilation rate of the animal house or per animal is calculated.

Data analysis

Emissions were calculated by multiplying the daily mean ventilation rate with the difference in daily mean concentrations between the exhaust and incoming air. From the daily mean emission data the yearly emissions per animal were calculated. For broilers and turkeys first means per two weeks production period were calculated, followed by averaging all these periods (3 two-week periods in broilers and 10 two-week periods in turkeys). This was done because the data were not totally balanced over the growing period. Emissions of the first 4 to 5 weeks of turkeys (when they were in the rearing house) were estimated by linear extrapolation. In turkeys measurements were only done in houses for cocks. Hens are grown during a shorter period than cocks (16 versus 20 weeks). To estimate the mean yearly emission factors it was assumed that during the first 16 weeks of the growing period emissions of hens were the same as for cocks.

RESULTS AND DISCUSSION

Dust emissions

In Figure 1 PM10 and PM2.5 dust emissions during the production cycle of the different categories of birds are given. From these graphs it can be seen that dust emissions strongly increase during the growing period of broilers and turkeys. For the layers there was no clear pattern during the production cycle. For broiler breeders dust emissions seemed to decrease during the production cycle. This might be due to the decreasing ventilation rate at both farms during the production cycle, especially after day number 120, ventilation levels decreased to very low level, because of low outside temperatures.

In Table 1 the mean PM10 and PM2.5 emissions in g per animal per year are given. The estimated PM10 emission factors in The Netherlands from a previous study were 65, 61, 61, 99, and 214 for broilers, layers floor, layers aviary, broiler breeders, and turkeys, respectively (not corrected for inoccupation). From Table 1 it can be seen that the determined PM10 emission factors in this study for broilers, broiler breeders and turkeys differed considerably from the previous factors. The previous emission factors for poultry were all based on measurements of inhalable dust in broiler houses and in layer floor houses. The lower emission factor determined for broilers within this study might have been due to the fact that within the EU project, on which the previous factors were based, the measurements were all done in the second half of the growing period. This might explain the lower emission factor determined in this study. The previous emission factor for turkeys was based on an extrapolation from broilers, which might explain the lower emission factor for turkeys in this study, as well. The emission factors for layers are quite comparable with the previous ones. For broiler breeders the emission factor determined within this study was also a lot lower. Both farms within this study were very similar in dust emissions. This might be due to the fact that both farms started the new production period in spring (end of April and beginning of June). Measurements at two other farms with a different start moment should show whether the emission was related to the start moment of the farms in this study.

From Table 1 it can be calculated that the contribution of PM2.5 particles to PM10 in mass was 7, 5, 6, 8, and 47% for broilers, layers floor, layers aviary, broiler breeders, and turkeys, respectively. The high contribution of PM2.5 to PM10 in turkeys, compared to the other categories, is remarkable. At this moment we don’t have a clear explanation for this difference.

Ammonia emissions

For ammonia the emission pattern during the growing period for broilers and turkeys was a lot less clear than for PM10 and PM2.5. For ammonia a lot more variation was visible at similar moments in the production period. Differences in environmental conditions, temperature and humidity, might have played a significant role in this variation. The ammonia emissions for layers in floor housing, layers in aviary housing and broiler breeders did not show an increasing or decreasing pattern during the production period. Although there was a large variation, the emissions stayed approximately at the same level. The present ammonia emission factors for broilers, layers floor housing, layers aviary housing, broiler breeders, and turkeys are 98, 328, 57/94 (depending on type of aviary system), 667, and 716 g/year per bird, respectively. Although there are some differences of the calculated yearly emissions in this study and the present emission factors, the relative differences are a lot smaller than for PM10.

Table 1. Mean emissions of PM10, PM2.5, and ammonia (in g/year per animal). Standard errors of the mean (n=4 farms, except for broiler breeders and turkeys, where n=2) are given between brackets.

Animal category	PM10	PM2.5	Ammonia
Broilers	26.8 (8.2)	2.0 (0.7)	88 (18)
Layers floor housing	87 (16)	4.2 (0.7)	419 (41)
Layers aviary housing	67 (7)	4.0 (0.4)	134 (42)
Broiler breeders	49 (1)	3.8 (0.2)	524 (7)
Turkeys	95 (29)	45 (19)	1040 (98)

CONCLUSIONS

From this study the following can be concluded:

1. The high differences found in measured PM10 emissions in this study and the emission factors estimated by conversion from inhalable dust emissions in a previous study show the necessity of this study.
2. PM2.5 contribution to PM10 is generally low (5 to 8%), except for turkeys where it was 47%.

Acknowledgements

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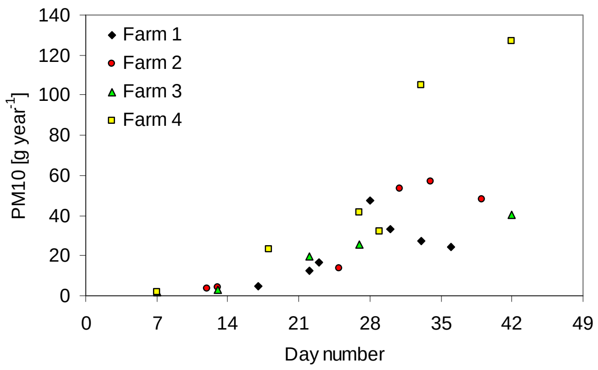
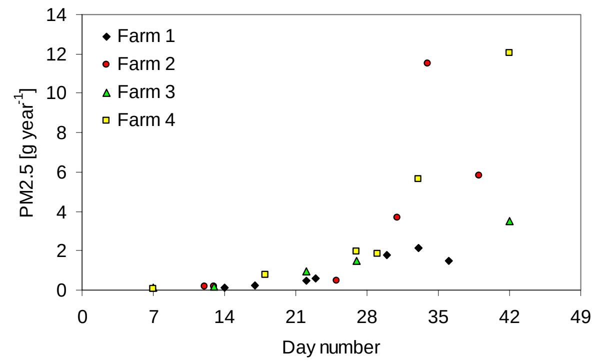
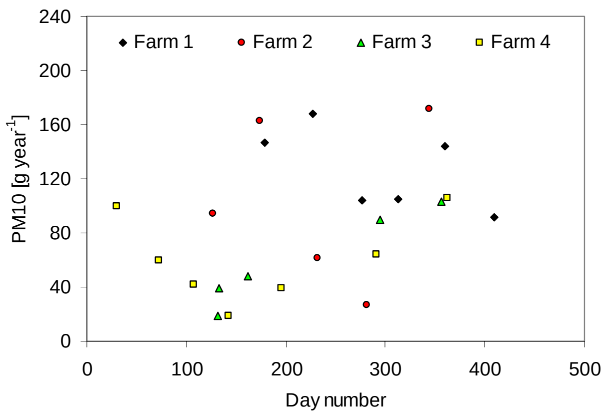
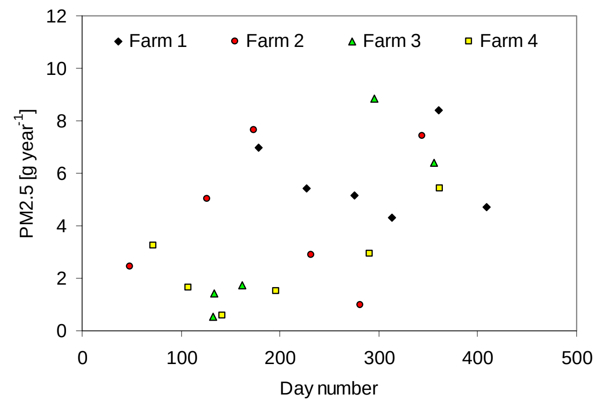
Broilers



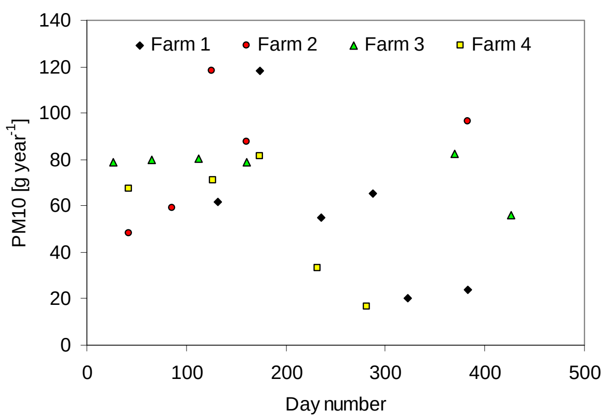


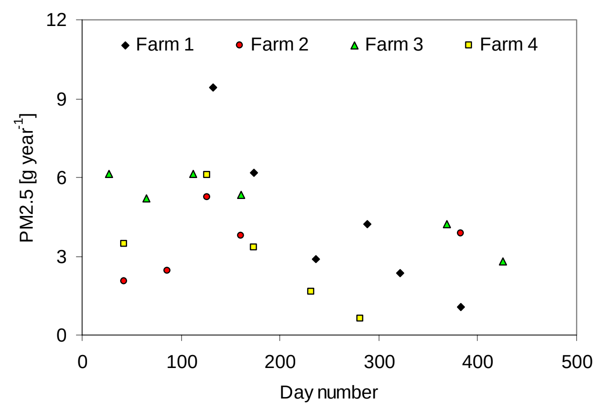
Layers floor



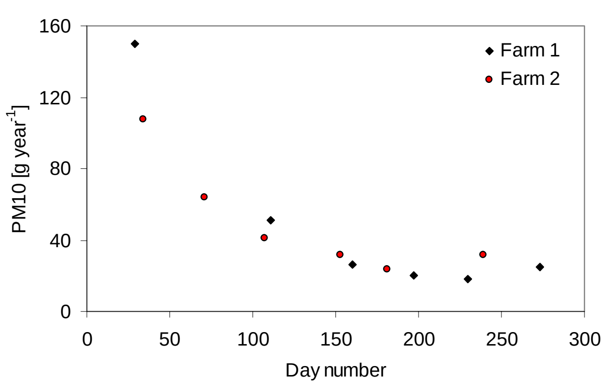


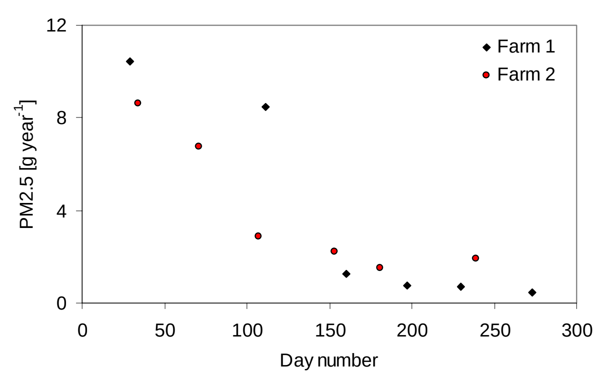
Layers aviary





Broiler breeders





Turkeys

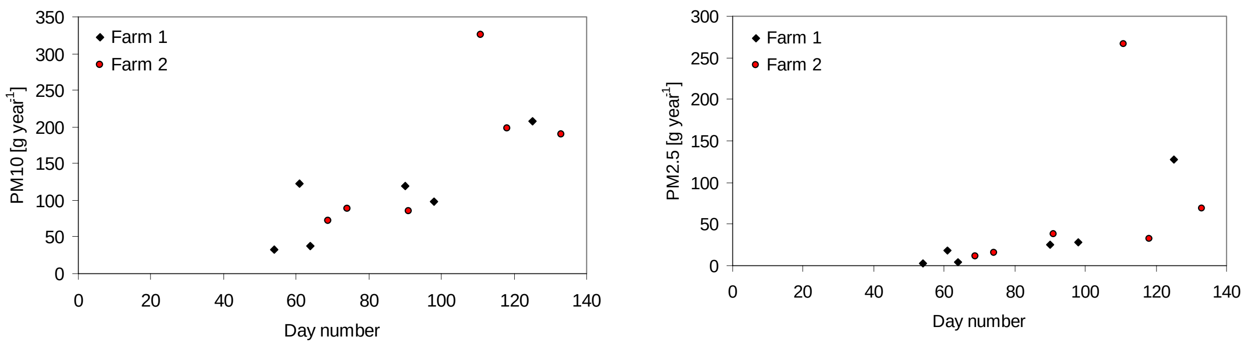


Figure 1. Emissions of PM10 (left graphs) and PM2.5 (right graphs) during the production cycle (day number after start) of broilers, layers floor housing, layers aviary housing, broiler breeders, and turkeys, in g/year per animal.

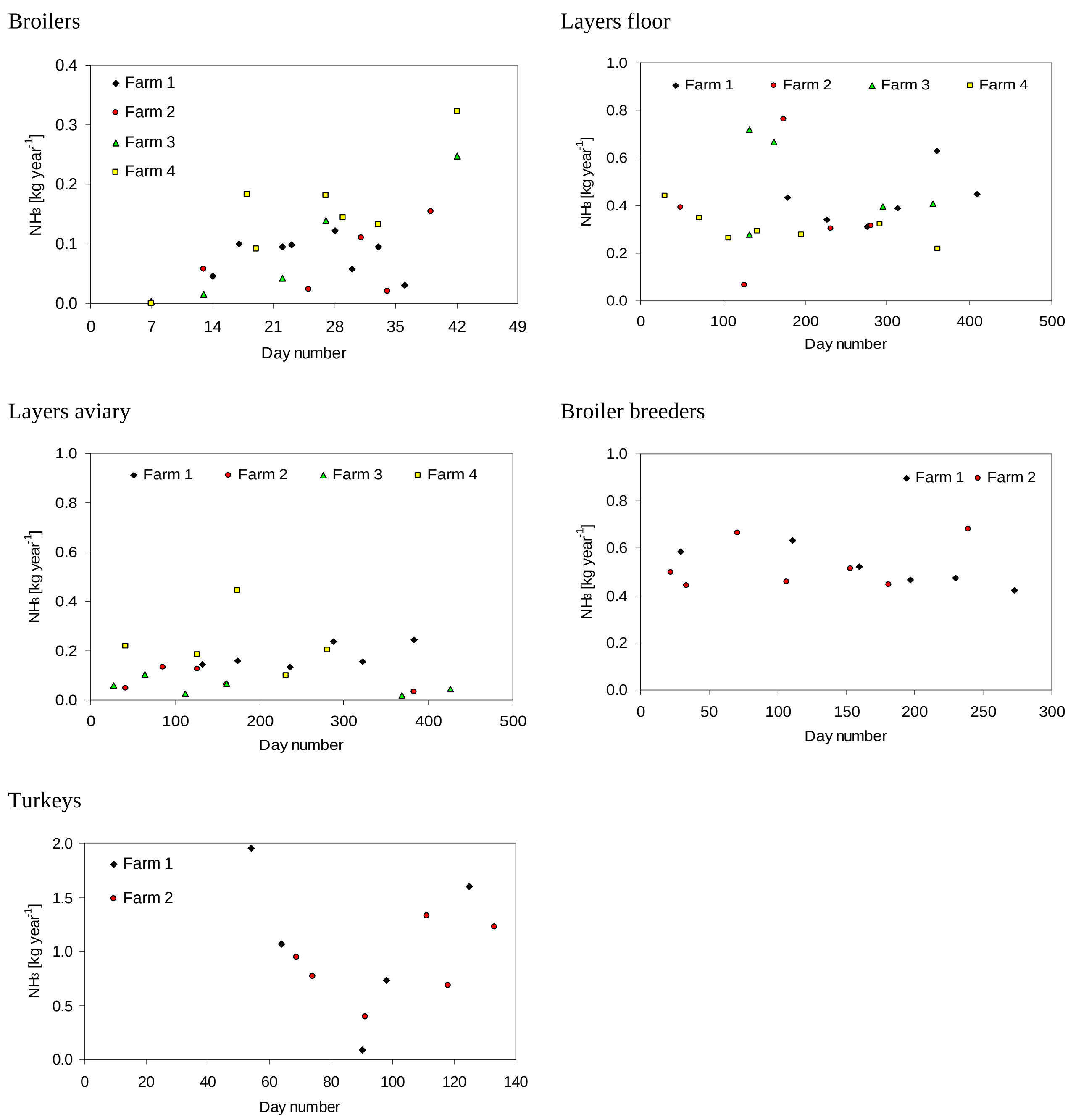


Figure 2. Ammonia emissions during the production cycle (day number after start) of broilers, layers floor housing, layers aviary housing, broiler breeders, and turkeys, in kg/year per animal.

REFERENCES

1. Chardon, W.J. and K.W. Van der Hoek. 2002. Berekeningsmethode voor de emissie van fijn stof vanuit de landbouw., 35. Wageningen: Alterra / RIVM.
2. CIGR Working Group on Climatization of Animal Houses. 2002. *Heat and moisture production at animal and house levels., 4th Report of Working Group on Climatization of Animal Houses.*: CIGR Working Group.
3. Groot Koerkamp, P.W.G., G.H. Uenk and H. Drost. 1996. De uitstoot van respirabelstof door de Nederlandse veehouderij. Instituut voor Milieu- en Agritechniek: Instituut voor Milieu- en Agritechniek.
4. Hofschreuder, P., Y. Zhao, A.J.A. Aarnink and N.W.M. Ogink. 2008. Measurement Protocol for Emissions of Fine Dust from Animal Housings. Considerations, draft protocol and validation. Animal Sciences Group. Lelystad: Animal Sciences Group.
5. NEN-EN 12341. 1998. Luchtkwaliteit - Bepaling van de PM 10 fractie van zwevend stof - Referentiemethode en veldonderzoek om de referentiegelijkwaardigheid aan te tonen van meetmethoden. Nederlands Normalisatie-instituut. Delft: Nederlands Normalisatie-instituut.
6. NEN-EN 14907. 2005. Ambient air quality - Standard gravimetric measurement method for the determination of the PM2,5 mass fraction of suspended particulate matter. Nederlands Normalisatie-instituut. Delft: Nederlands Normalisatie-instituut.
7. Ogink, N.W.M., J.M.G. Hol, J. Mosquera and H.M. Vermeer. 2010. Bouwstenen van het meetprotocol NH_3-emissiemetingen in de veehouderij. Animal Sciences Group. Wageningen: Animal Sciences Group.
8. Pedersen, S., V. Blanes-Vidal, H. Joergensen, A. Chwalibog, A. Haeussermann, M.J.W. Heetkamp and A.J.A. Aarnink. 2008. Carbon dioxide production in animal houses: a literature review. *Agricultural Engineering International: CIGR Ejournal* Manuscript BC 08 008, Vol. X.
9. Takai, H., S. Pedersen, J.O. Johnsen, J.H.M. Metz, P.W.G.G. Koerkamp, G.H. Uenk, V.R. Phillips, M.R. Holden, R.W. Sneath, J.L. Short, R.P. White, J. Hartung, J. Seedorf, M. Schröder, K.H. Linkert and C.M. Wathes. 1998. Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. *J. Agric. Engng Res.* 70:59-77.
10. Zhao, Y., A.J.A. Aarnink, P. Hofschreuder and P.W.G. Groot Koerkamp. 2009. Evaluation of an impaction and cyclone pre-separator for sampling high PM10 and PM2.5 concentrations in livestock houses. *Aerosol Science* 40:868-878.