Measures against Ammonia Release in a Floor Housing System for Laying Hens

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ABSTRACT

How age of hens, storage time of manure, ventilation rate, ventilation technique and bedding materials affect concentration and release of ammonia in a floor housing system for laying hens have been carried out at the Department of Agricultural Biosystems and Technology (JBT) research station Alnarp Södergård during two 433 and 464 days long production batches. A climate chamber was equipped with a floor housing system. The housing system contained a bedding area, a manure bin area with manure conveyors below a draining floor and laying nests that placed close to an end wall.
The age of the hens had no influence on the release of ammonia. However, the age had an effect on the amount of manure stored in the bedding which influenced the release of ammonia.

The investigations clearly showed that long time storage of manure in a manure bin will cause a rapid increase in ammonia concentrations. The ammonia concentration exceeded the hygienic threshold limit value of 25 ppm after about 7 days storage of manure in a manure bin.

The release of ammonia from the bedding was compared with the release from manure stored in the manure bin. The increase in release of ammonia from the bedding was considerably lower than from manure stored in the manure bin below the draining floor. The major reason why the release increased more rapidly from manure stored in the bin was probably that the major part of the manure was left on the elevated draining floor above the bin.
It was possible to keep the ammonia concentration below the hygienic threshold limit value when manure was removed daily in the bin below the draining floor. Housing systems with elevated draining floors should therefore be equipped with manure systems that enable frequent removal of manure.

Ammonia concentration decreased when ventilation rate increased. However, the decrease did not correspond to the increase in ventilation rate because of an increased release of ammonia.
Ammonia release was also investigated when using six different bedding materials, namely; gravel, clay pellets, peat, wood shavings, chopped straw and chopped paper. The ammonia release between the materials were differed in a factor of two. The lowest release occurred with chopped paper or peat as bedding materials. However, using peat resulted in dirty eggs resulting in a poor classification of the eggs. The highest release occurred with gravel or clay pellets as bedding materials.

Keywords: Ammonia, release, bedding, manure age, layer hen, manure storage, ventilation

1. INTRODUCTION

Regarding laying hens, floor housing systems are being re-established in Sweden since animal welfare legislation stipulates that systems for laying hens must include laying nests and perches and provide access to bedding. Compared to traditional cage systems, the air in floor housing systems may be more polluted with ammonia since this gas is emitted from large exposed surfaces of manure and litter.

Ammonia is produced by decomposition of nitrous compounds in the manure. It has been reported that temperature, manure or litter pH and moisture content, ventilation rate and air velocity around the manure affect the amount of ammonia release in poultry houses beside factors like animal weight, stocking density, size of manure area exposed, time for exposure of manure before removal (Carr et al, 1987; Gustafsson, 1988; Gustafsson & von Wachenfelt, 2004; von Wachenfelt, 1993; 1994). Ammonia releases from laying hens have in experiments been shown to increase with air temperature and with the water content of the litter (Groot Koerkamp et al., 1999). In experiments with chickens, increased levels of relative air humidity resulted in increased litter moisture and caking, and generally also in increased ammonia levels (Weaver and Meijerhof, 1991).

Ammonia produced in animal production may affect the animals, the workers as well as the ecosystem.

In poultry housing, ammonia is considered the most harmful gas (Carlile, 1984). The hygienic threshold limit values for ammonia for animal welfare (Swedish Board of Agriculture, 2003) but also for occupational safety and health (Swedish National Board of Occupational Safety and Health, 2000) of 25 ppm are often exceeded in floor housing systems for laying hens with long time storage of manure in bins below draining floors (von Wachenfelt *et al*., 2002).
Charles & Payne (1966) showed that a concentration of 100 ppm ammonia caused reduced release of carbon dioxide and respiration from laying hens. The breathing frequency decreased between 7 and 24 % at this concentration.

Ambient ammonia levels of 50 ppm for prolonged periods irritate respiratory airways and predispose poultry to respiratory infections and development of lesions of keratoconjunctivitis of the eye is associated with ambient ammonia levels above 60 ppm (Hauser, 1988).

A reduced rate of bacterial clearance from the lungs was measured in turkeys exposed to 40 ppm of ammonia (Nagaraja, 1984). Excessive mucous production, matted cilia, and deterioration of normal mucociliary apparatous were found in turkeys exposed to ammonia concentrations as low as 10 ppm for 7 weeks (Nagaraja, 1983).

During the last half century, an increased nitrogen deposition due to atmospheric ammonia has been detected. This has had a stimulating effect on vegetative growth. The role of ammonia in soil acidification and on other ecological effects has therefore attracted greater attention during recent years. Atmospheric ammonia causes acute toxic injuries to vegetation close to the source and contributes to the large scale nitrogen eutrophication and acidification of ecosystems by long range atmospheric transport of ammonium.

The most important source of anthropogenic ammonia in Europe is agriculture, mainly from animal production and fertilizer application (ECETOC, 1994; Fangmeier *et al*., 1994; Ferm, 1998). The contribution from agriculture is on average 92 % (ECETOC, 1994) and about 25 % of the nitrogen in animal excretion is lost to the atmosphere in Western Europe (Ferm, 1998). One of the sources is exhaust air from poultry houses.

As ammonia, which is mainly emitted from animal manure, is a great contributor to nitrogen deposition, much work has to be concentrated on finding release-reducing measures in agriculture.

There is therefore a need to reduce the levels of ammonia concentration and release. The major reason for high ammonia concentrations in floor housing systems is the large amount of stored and exposed manure in the buildings in relation to number of birds housed.

The objective of the investigations were to determine the influence of age of hens, manure storage time, ventilation rate, ventilation technique and type of bedding materials on ammonia concentrations and release.

2. MATERIALS AND METHODS

2.1 Housing System

The investigations were carried out in a climate chamber equipped with a floor housing system, Figure 1. The chamber was surrounded by a temperature controlled air space where the air temperature and supply air temperature to the chamber were varied between 0 and º16 C.

The total area of the chamber including walking alleys was 87 m^2 and the area where the laying hens were kept was 47 m^2.

The housing system contained a bedding area, a draining floor above a manure bin with manure conveyors below and laying nests which were placed close to one of the walls. The bedding area was 1.5 m wide. The rest part of the floor which was 3.0 m wide was elevated to a height of 0.6 m and equipped with a draining floor of slatted plastic sheets.

Normally manure is stored under draining floors during whole production periods. In this investigation two parallel motor driven conveyors were placed below the draining floor to remove manure from the bin.

Feed troughs, drinking nipples and perches were placed in the manure bin area with the draining floor.

Between 333 and 392 Lohmann Selected Leghorn layers were kept in the system during two production batches. The density of hens varied between 7.1 and 8.3 hens per m^2 available floor area. The layers were fed *ad libitum* from automatic feed conveyors. The metabolisable energy content of the feed was 11.2 MJ/kg.

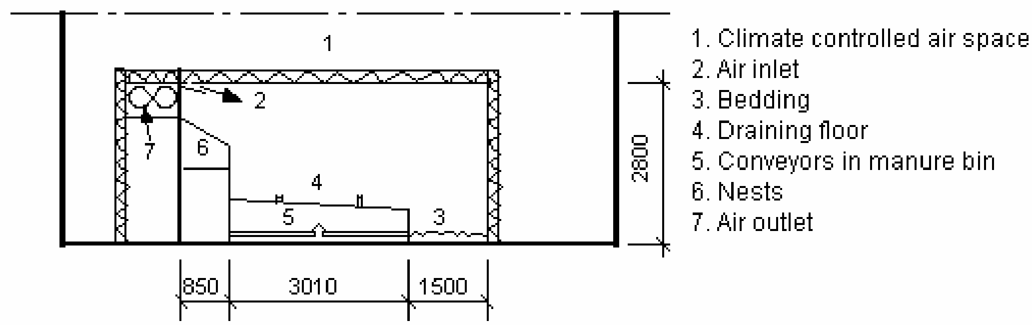


Figure 1. The climate chamber equipped with a floor housing system. Distances are expressed in mm.

2.2 Ventilation and Climate Control

Mechanical ventilation was provided by a negative pressure system (Figure 1). Air inlets in the ceiling provided the chamber with supply air from the climate controlled area surrounding the chamber. An exhaust fan removed air either at roof level or at floor level close to the manure conveyors via a slit in a duct below the laying nests.

The temperature inside the chamber was kept at a constant level of 20 - 21 °C during each trial. The ventilation rate could thereby also be kept constant. The constant air temperature was maintained by controlling the amount of extra heat from heat pipes in the chamber.

The ventilation rate was manually regulated with a damper in an exhaust air duct. The ventilation rates were set to values ranging from about 0.9 m^3 h^{-1} hen^{-1} up to 6.8 m^3 h^{-1} hen^{-1}. After adjustment of the damper the ventilation rate in the duct was determined with a hot wire anemometer (GGA- 65P, Alnor Instrument CO, Skokie, Illinois, USA) in five positions in the cross section of the exhaust air duct. Temperatures and ventilation rates were kept to specific set point values for three or four days in order to get steady state conditions during days used for evaluations.

2.3 Measurements

Ammonia concentration in the exhaust air duct was recorded using an infrared (IR) spectrophotometer, (Miran 203, Foxboro Analytical, UK) connected to a data logger and a computer. A zero gas filter containing activated charcoal was used every week to set the zero level. The measuring range was 0 -50 ppm and the accuracy of the instrument was ±5% at the full scale deflection according to the manufacturer. Data was recorded each minute and daily averages were used for evaluation.

Ammonia was also measured at two occasions for each trial by the use of colorimetric detection tubes (KITAGAWA precision gas detector AP- I, KOMYO RIGAKU KOGYO K.K., 8-24, Chuo-Cho 1 – Chome, Meguro- Ku, Japan) in the mornings before removal of manure in the following places: exhaust air duct; in the middle of the chamber in the breathing zone of humans 1.5 m above the floor and in the breathing zone of hens 0.3 m above the floor. The measuring range was 0 - 50 ppm and the accuracy ± 5 % of full scale deflection according to the manufacturer.

During trials when manure was stored on the conveyors, measurements were done in the middle of the day.

The ventilation rate was calculated from air velocities measured two times per trial in 5 positions of the cross section of the exhaust air duct (ϕ 400 mm) by using a hot wire anemometer (GGA- 65P, Alnor Instrument CO, Skokie, Illinois, USA).
Ammonia release was calculated from measured concentrations in exhaust air and ventilation rates.

2.4 Investigations

230 different set ups were investigated. Each set up was kept for 3 or 4 days. The last day before a change of a set up was used for evaluation of the set up.

2.4.1 Sources

The total ammonia release from the chamber was determined as:

$E_{exhaust} = q^* \rho^* C$

where

$E_{exhaust}$ = total release of ammonia in exhaust air, mg/h

q = ventilation rate, m^3/h

ρ = density of ammonia, kg/m^3 air

C = concentration of ammonia, ppm

2.4.2 Age

The influence of age of the hens on ammonia release was investigated during two production batches which were 61 and 66 weeks long.

2.4.3 Storage of Manure

The conditions when manure is stored in a bin below a draining floor were simulated by storing manure on the conveyors for several days at constant ventilation rates and temperatures during five trials. The release from the manure conveyors was determined by measuring the increase in ammonia release when manure was stored on the conveyors.

The influence of increasing storage of manure in the bedding area was investigated during two periods with daily manure removal from the conveyors. Measured ammonia release was then mainly from the bedding.

2.4.4 Ventilation

The influence of ventilation rate was determined at constant air temperature at varying ventilation rates.
Two different locations of air outlet were investigated namely: at roof level or through a narrow slit close to the manure conveyors.

2.4.5 Bedding Materials

New bedding materials were provided at the start of each flock. Six different bedding materials were investigated namely; gravel, clay pellets, peat, wood shavings, chopped straw and chopped paper.

3. RESULTS

3.1 Storage Time of Manure

The age of the hens had an effect on the amount of manure stored in the bedding which influenced the release of ammonia.

During the first 50 days of the housing periods there was an increase in ammonia release due to accumulation of manure in the bedding, Figure 2**.** After this initial period the increase in ammonia release levelled off.

At ventilation rates in the range of 0.95 – 1.6 m^3 hen^{-1} h^{-1} the increase in ammonia release was 0.032 – 0.037 mg hen^{-1} h^{-1} for each day of accumulation of manure in a bedding of gravel. This increase was independent of the location of the air outlet.

Storing of manure in the manure bin caused a rapid increase in ammonia concentrations in all trials. Ammonia concentrations in exhaust air; breathing zone of humans 1.5 m above the floor and breathing zone of hens 0.3 m above the floor during a trial when manure was stored in the bin is presented in Figure 3. The lowest concentrations occurred in the exhaust air which indicates that the air in the room was not perfectly mixed.

After about 7 days storage of manure in the manure bin the room and exhaust ammonia concentration increased from about 10 ppm (from bedding) to the hygienic threshold limit value of 25 ppm.

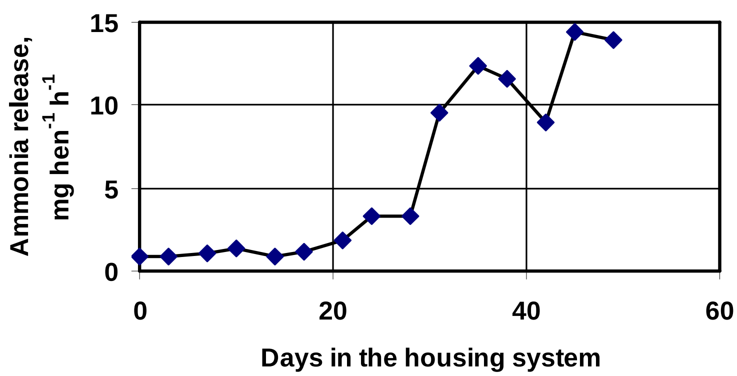


Figure 2. Increase in ammonia release the first part of a housing period at a ventilation rate of 1.01 m^3 hen^{-1} h^{-1} at high exhaust location, daily removal of manure from conveyors and with a bedding of gravel.

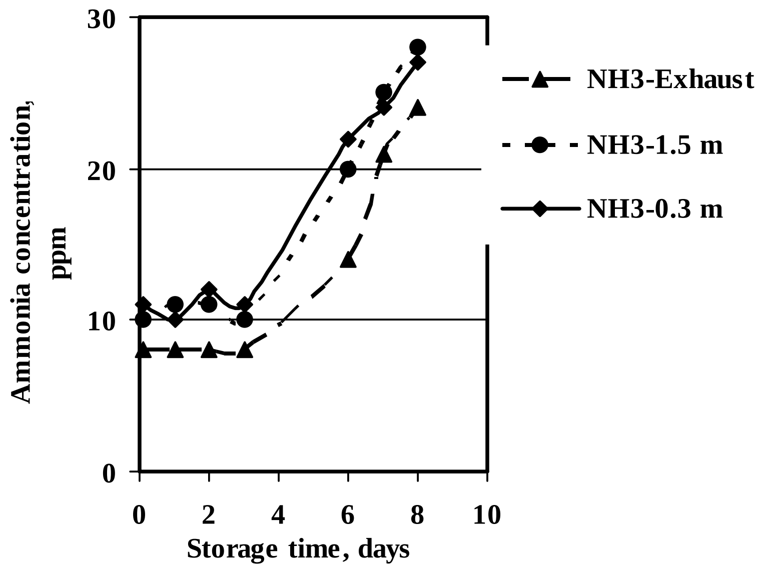


Figure 3. Increase in ammonia concentrations in exhaust air; 1.5 m above the floor and 0.3 m above the floor when manure was stored in the bin at a ventilation rate of 2.2 m^3 hen^{-1} h^{-1}.

It was possible to keep the ammonia concentration below the hygienic threshold limit value when manure was removed daily in the bin.

The increase in ammonia released in the exhaust air when manure was stored in the bin was analysed with linear regression as $E_{exhaust} = a + b \cdot x$, where x is storage time in days. The results from these analyses are presented in Table 1. The slope b gives a measure of the average daily increase in ammonia release caused by manure storage in the bin below the draining floor. The increase in ammonia release varied between 1.03 and 3.23 mg hen^{-1} h^{-1} day^{-1} when manure was stored in the bin.

Table 1. Linear regression of ammonia release in the exhaust air, $E_{exhaust}$, as function of storage time of manure in the storage bin when gravel was used as bedding material. $E_{exhaust} = a + b \cdot x$. x is storage time in days

Trial, No	Ventilation rate, m^3 hen^{-1} h^{-1}	a, mg hen^{-1} h^{-1}	b, mg hen^{-1} h^{-1} day^{-1}	r
1	1.03	-3.34	1.46	0.92
2	1.22	5.40	1.03	0.98
3	2.20	8.26	3.20	0.94
4	2.21	7.92	2.28	0.94
5	2.06	5.02	3.23	0.98

The increase in ammonia released from the bedding was also analysed as function of age of the bedding with linear regression as $E_{exhaust} = a + b \cdot x$ at two different ventilation rates (1.10 and 6.13 m^3 hen^{-1} h^{-1}) when manure was removed daily from the bin. Results from these analyses are presented in Table 2.

The increase in release of ammonia from the bedding varied between 0.0096 and 0.064 mg hen^{-1} h^{-1} day^{-1} during the trials. The high ventilation rate caused the highest increase in ammonia release, probably because of increased air movements around the manure surfaces.

A comparison with the release when manure was stored in the bin (Table 1) showed that the increase in release from the bedding was considerably lower than from manure which was stored in the bin.

The major reason why the release increased more rapidly from manure stored in the bin was probably that the major part of the manure was left on the elevated draining floor.

Table 2. Linear regression of ammonia release $E_{exhaust}$ from the bedding as function of storage time of manure in the bedding. $E_{exhaust} = a + b \cdot x$. x is storage time in days

Trial, No	Ventilation rate, m^3 hen^{-1} h^{-1}	a, mg hen^{-1} h^{-1}	b, mg hen^{-1} h^{-1} day^{-1}	r
1	1.10	4.2	0.0096	0.59
2	6.13	-2.1	0.064	0.63

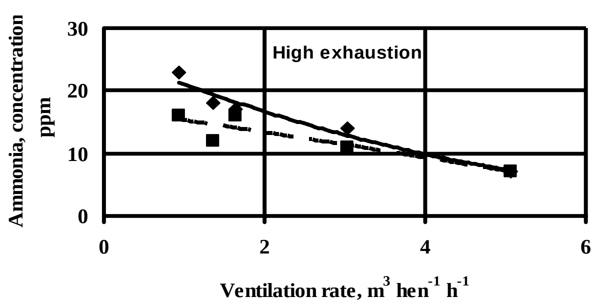
The release per unit exposed area was analysed for manure stored on the conveyors as well as in the bedding. At increased storage time the release from manure stored in the bin increased with 15.2 - 47.7 mg m^{-2} h^{-1} day^{-1} at 1.1 and 6.13 m^3 hen^{-1} h^{-1} ventilation rates. Manure stored in the bedding caused an increase in ammonia release in the range of 0.28 – 1.88 mg m^{-2} h^{-1} day^{-1}.

3.2 Ventilation Effects

The influence of ventilation rate on ammonia release and concentration was investigated at daily manure removal with conveyors and at about 20 ºC air temperature. Gravel was bedding material. The influence of ventilation rate was investigated with two different locations of the air outlet; at roof level or with a narrow slit in connection to the manure conveyors.

Ammonia concentration decreased with increasing ventilation rate, Figure 4. Exhaust connection to the manure conveyors reduced ammonia concentration in the room compared to high exhaustion at ventilation rates higher than 2 m^{-3} hen^{-1} h^{-1}.

However, the decrease in ammonia concentration was not proportional to the increase in ventilation rate. The reason was that ammonia release increased with increasing ventilation rate, Figure 5.



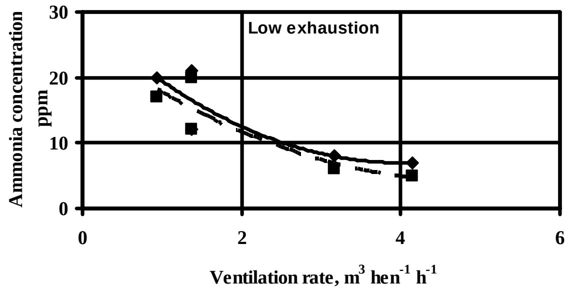


Figure 4. Ammonia concentrations in the breathing zones of humans (solid line) and hens (dashed line) at different ventilation rates at high and low exhaust locations and with a bedding of gravel.

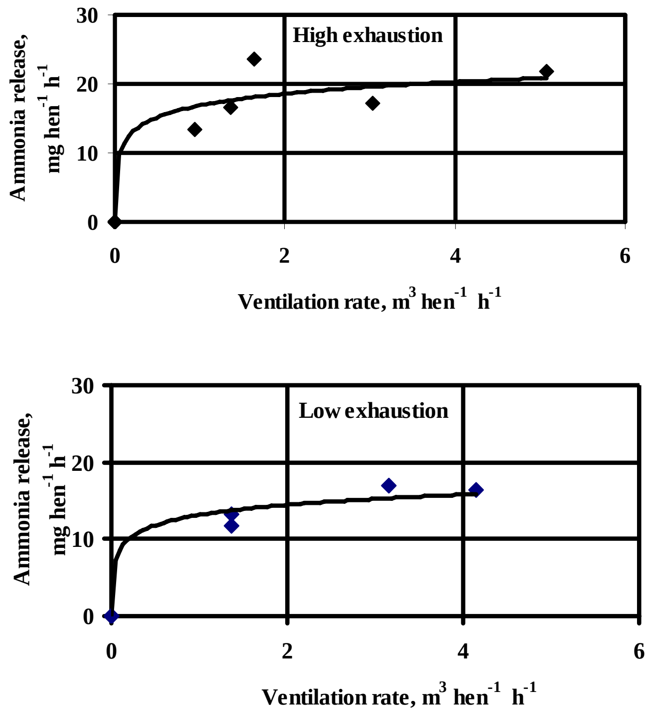


Figure 5. Ammonia release, $E_{exhaust}$, at different ventilation rates at high and low exhaust locations and with a bedding of gravel.

3.3 Bedding Materials

Ammonia release was investigated when using six different bedding materials when the ventilation rate was in the range of 1.04 – 1.13 m^3 hen^{-1} h^{-1}. The release was investigated during 14 days from the supply of the bedding materials. The results are presented in Table 3. The ammonia release among the materials were differed by a factor of two. The lowest release occurred with chopped paper and peat as bedding materials. However, using peat resulted in dirty eggs and a poor classification of the eggs. The highest release occurred with clay pellets or gravel as bedding materials.

Table 3. Total ammonia release (mg hen^{-1} h^{-1}) with different bedding materials. Ventilation rate in the range of 1.04 – 1.13 m^3 hen^{-1} h^{-1}

Bedding material	Average mg hen^{-1} h^{-1}	Minimum mg hen^{-1} h^{-1}	Maximum mg hen^{-1} h^{-1}
Gravel	12.6	10.8	13.5
Wood shavings	10.7	7.2	16.2
Clay pellets	13.7	12.0	15.0
Peat	7.3	3.7	10.1
Chopped straw	8.4	7.1	9.6
Chopped paper	6.0	5.0	7.4

4. DISCUSSION

The investigations have shown that the release of ammonia was very high when manure was stored for longer periods in a bin below a draining floor. The release from the bedding was considerably lower than from the bin. The reason why the release was high from the bin was probably that the major part of the manure was left there.

The release of ammonia increased very rapidly when manure was stored in the bin. The ammonia concentration exceeded the hygienic threshold value of 25 ppm for animal welfare as well as for occupational safety and health after 7 days storage of manure in the bin. Long time storage of manure in bins is therefore not recommended.

It was possible to keep the ammonia concentration below the hygienic threshold value when manure in the bin was removed daily. It is therefore recommended that bins below draining floor in floor housing systems for laying hens should be equipped with equipment that enables frequent manure removal.

Increased ventilation rate had a diluting effect on ammonia concentration. However, the dilution did not correspond to the increased ventilation rate because of an increased release of ammonia from the manure, probably caused by increased air movements around the manure surfaces.

Exhaust of air via connection to the manure conveyors reduced ammonia concentration in room air to some extent at ventilation rates higher than 2 m^3 hen^{-1} h^{-1}. It was relatively easy to construct an exhaust air channel below the nests.

Low release of ammonia occurred with chopped paper or peat as bedding materials. However, using peat resulted in dirty eggs and a poor classification of the eggs.

5. CONCLUSIONS

The following conclusions can be drawn from the investigations:

- Long time storage of manure in a manure bin below draining floor creates high release of ammonia
- Ammonia release from a manure bin is higher than from beddings
- Low release of ammonia occurs with chopped paper or peat as bedding materials
- Increased ventilation rate reduce ammonia concentration but increase the amount of ammonia released
- Exhaust of air via connection to manure conveyors reduce ammonia concentration**.**

6. REFERENCES

Carlile, F.S. 1984. Ammonia in poultry houses: A literature review. World Poultry Science 40:99- 113.

Carr, L. E., F.W. Wheaton and L.W. Douglas. 1987. Empirical models to determine ammonia concentration from broiler chicken litter. *Transactions of the ASAE* 33(1): 260-265.

Charles, D. R. and C.G. Payne. 1966. The influence of graded levels of atmospheric ammonia on chickens. *British Poultry Science* 7:177 – 198.

ECETOC. 1994. Ammonia releases to air in western Europe. European Centre for Ecotoxicology and Toxicology of Chemicals, Report 62, Brussels. Belgium, 196 pp.

Fangmeier, A., A. Hadwiger-Fangmeier, L. van der Eerden and H-J. Jäger. 1994. Effects of atmospheric ammonia on vegetation - a review. *Environ. Pollut.* 86, 43-82.

Ferm, M. 1998. Atmosperic ammonia and ammonium transport in Europe and critical loads: a review. *Nutr. Cycl. Agroecosys.* 51, 5-17.

Groot Koerkamp, P. W. G., L. Speelman and J. H. M. Metz. 1999. Litter composition and ammonia release in aviary houses for laying hens: Part II, modelling the evaporation of water. *J. of Agr. Eng. Res.* 73(4): 353-362.

Gustafsson, G. 1988. Air- and heat balances in animal houses. Swedish University of Agricultural Sciences. Department of Farm Buildings. Report 59. Lund, Sweden. (In Swedish). 385 pp.

Gustafsson, G. and E. von Wachenfelt. 2004. *Begränsning av luftföroreningar vid inhysning av golvhöns (Limitation of air pollutants in housing of laying hens in floor systems). Rapport 129*. Alnarp, Sweden: Swedish Univ. Agric. Sciences, Dept. Agr. Bios. and Technology. (In Swedish).

Hauser, R.H. and D.W. Folsch. 1988. Measures for measuring ammonia in poultry houses: review and approved practices. J. of Vet. Med. 35: 579- 593.

Nagaraja, K.V. 1983. Scanning electron microscope studies of adverse effects of ammonia on trachal tissues of turkeys. *Am. J. Vet. Res*. 44:1530- 1536.

Nagaraja, K.V. 1984. Effect of ammonia on the quantative clearance of E. coli. Am. J. Vet. Res. 45:392-395.

Swedish Board of Agriculture. 2003. SJVFS 2003:6. Statens jordbruksverks föreskrifter om djurhållning m.m. (Directions from the Swedish Board of Agriculture about animal management in agriculture etc.). Jönköping, Sweden: Swedish Board of Agriculture. (In Swedish).

Swedish National Board of Occupational Safety and Health. 2000. *AFS 2000:3. Hygieniska gränsvärden och åtgärder mot luftföroreningar (Occupational exposure limit values and measures against air contaminants). Statue book of the Swedish National Board of Occupational Safety and Health.* Solna, Sweden:Swedish Work Environment Authority. (In Swedish).

von Wachenfelt, E. 1993. Air contamination in poultry production systems. 4th European Symposium on Poultry. Edinbourgh, September 18-24, 1993. Edinburgh

von Wachenfelt, E. 1994. Modern techniques give less air pollutions in broiler houses. Proceedings: XII World Congress on Agricultural Engineering, Milan August 29-September 1, 1994, pp 590-598. CIGR. Merelbeke. Belgium.

von Wachenfelt, H., K. Odén and S. Gunnarsson. 2002. *Värphöns i lågbeläggningssystem (Laying hens in low density floor systems). Specialmeddelande 237.* Alnarp, Sweden: Swedish Univ. Agric. Sciences, Dept. Agric. Bios. and Technology. (In Swedish).

Weaver, W. D. and R. Meijerhof. 1991. The Effect of Different Levels of Relative-Humidity and Air Movement on Litter Conditions, Ammonia Levels, Growth, and Carcass Quality for Broiler-Chickens. *Poultry Science* 70(4): 746-755.