PM and ammonia in small group keeping – emissions and air quality in a German system for laying hens

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Abstract

Cages for layers are banned in Germany since January 2010. Alternatives must be found e.g. floor keeping or aviaries. In Germany a new system, the so called small group keeping, is introduced. Groups of 28 to 60 hens are animal friendly housed with scraping area, separated nests for laying and perches for resting on a space of 890 cm² for each bird. With view to air quality inside and emission flows in comparison with other systems small group keeping has advantages for the stables investigated. Ammonia concentration is below 10 ppm (7.06 mg/m³) and respirable dust fraction below 4 mg/m³.

Keywords: Laying hens, keeping systems, small group, air quality, emissions, ammonia, PM

Staub und Ammoniak in der Kleingruppenhaltung – Emissionen und Luftgüte bei einem deutschen Haltungssystem für Legehennen

Zusammenfassung

Käfige für Legehennen sind seit Januar 2010 aus Deutschland verbannt. Alternativen müssen gefunden werden z. B. Bodenhaltung oder die Haltung in Volieren. In Deutschland wurde die sogenannte Kleingruppenhaltung eingeführt. Gruppen von 28 bis 60 Hennen leben tierfreundlich mit Scharrflächen, separaten Nestern zur Eiablage und Sitzstangen auf einer Fläche von 890 cm³ pro Henne. Hinsichtlich der Luftgüte im und den Emissionen aus dem Stall weist die Kleingruppenhaltung im Vergleich mit anderen Haltungssystemen Vorteile auf. Die Konzentrationen von Ammoniak liegen zumeist unterhalb von 10 ppm, die der alveolgängigen Staubfraktion unterhalb von 4 mg/m³.

Schlüsselworte: Legehennen, Haltungssysteme, Kleingruppe, Luftgüte, Emissionen, Ammoniak, PM

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Introduction

Two years before the entry into force of European regulations, cages for layers are banned in Germany since January 2010. Alternatives must be found e.g. floor keeping, aviaries or new systems. In Germany a new system, the so called small group keeping, was introduced since 2009 (TierschNutztV, 2009). With a decision of October12, 2010 by the Federal Constitutional Court the authorization for small group keeping systems for layers was cancelled due to formal reasons and March, 31 2012 is the deadline for amendment.

Keeping systems must follow the intentions of the society with high animal welfare requirements. Nevertheless protection of work and the environment cannot be neglected for evaluation and comparison of different systems. Groups of 28 to 60 hens are animal friendly housed with scraping area, separated nests for laying and perches for resting. In different studies recently and now the small group system is investigated and compared with floor keeping and an aviary with respect to air quality and emissions (Hinz et al., 2011; Hinz et al., 2010; Winter et al., 2009; Hinz et al., 2009). Concentration of ammonia and respirable dust (PM4) is measured inside the stable to estimate possible effects to men's and birds health and welfare. Emissions of ammonia, PM10 and PM2.5 are monitored to get an impression of possible environmental impacts.

The paper gives a description of the small group keeping system and a comprehensive view to the measuring procedures and results in examples. Finally the small group system is compared with two floor keepings and one aviary which have been investigated for three years by measurement.

Method and materials

In total over all studies measurements are carried out in different systems on commercial farms and research facilities. In two still running studies, eight stables – three on commercial farms and five experimental stables – are investigated. Project A compares four different types of layer husbandries: an aviary with integrated litter space (1); a floor keeping system with integrated litter space (2); a floor keeping system with outdoor access (3); and a small group keeping system (4). The system can keep layers in small groups of 28 to 60 birds. Because this system is a new development, project B studies influences of details given by different manufacturers of stables. The three manufacturers of the small group keeping system are marked as (4), (5) and (6). System parameters are given in Table 1. Two further stables of project B are not considered in this paper.

Table 1:
List of stables with stocking number, litter and manure management

keeping system	stocking	litter	manure management
1[1]	900	sand/wood shavings	manure belt, weekly
2[1]	8,000	wood shavings	storage inside
3[1]	3,000	without	storage
4[1, 2]	1,500	without	manure belt, weekly
5[2]	300	without	manure belt, weekly
6[2]	480	without	manure belt, weekly

[1] Project A
[2] Project B

In the centre of interest are the small group systems. Although there are creative possibilities of design and construction, the following principal requirements must be kept (TierschNutztV, 2009):

- Active area for each bird 890 cm²
- Additional scratching and sand bath area of 900 cm² per 10 birds
- Additional group nest area of 900 cm² per 10 birds
- Minimum area 25000 cm²
- Nests
- Perches

In practical use are mainly systems with stocking numbers of 40 to 60 birds. An example of a typical construction shows Figure 1.

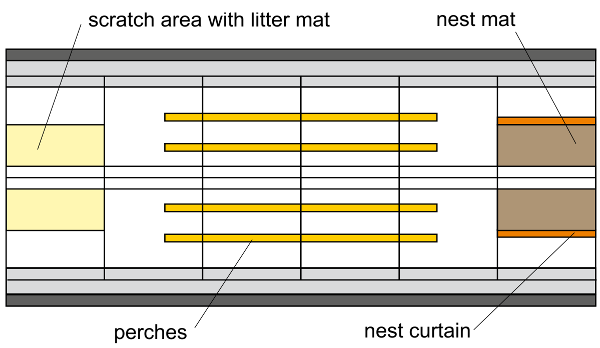

Figure 1:
A scheme of a typical small group system

In all cases the stables were equipped with manure belts and dryer. The dry manure is storage outside the stables. Also all stables are force ventilated and managed by a light programme. Some stable but not all are computer controlled (flow rate, light).

The measuring procedures and devices are nearly the same in all stables of the different studies.

To get an impression on the variations with time, daily courses are monitored. In one study additional spot measurements are carried out for one hour at noon to determine long term variation with the season and the age of birds. Table 2 shows the equipment to measure airborne concentrations and exhaust flow rate.

Table 2:
Measuring devices

contaminant	instrument	principle
ammonia	Innova 1302 multi gas monitor	opto acoustic
PM10, PM4, PM2.5	Grimm optical counter 1.105 and 1.108	light scattering
total dust	high volume sampler	gravimetry
air flow	Hoentzsch anemometer fan wheel	anemometry

The total dust sampler with pre-separator is used to collect dust for further analysis e.g. particle size analysis or imaging (Romann and Hinz, 2007).

Results and discussion

In the following examples of results are presented in two steps: first with the concern of air quality and secondly emission flows. Air quality is described by ammonia and PM4 concentration, the emissions by mass flow of ammonia, PM10 and PM2.5. PM10, PM2.5 and PM4 are calculated from the optical particle counter according to the definitions of US EPA and ISO 7708 respectively.

In contrast to ammonia, measurements of particle concentrations in gas flows must be done with the condition of an isokinetic probe, which means that flow in the exhaust opening and the sampler must be equal in magnitude and direction.

If emissions E from exhaust flows are determined by concentration c and air flow Q, c and Q must be measured simultaneously if both are fluctuating with respect to time:

$$E = \overline{c * Q} \neq \bar{c} * \bar{Q}$$

In both projects the conditions given above are regarded as accurately as possible.

Air quality

In Figure 2 a daily course of ammonia concentration is drawn. There are large differences between the systems of three producers, but the main message is that the level of concentration is very low and satisfies the wanted level of 10 ppm (7.06 mg/m³) and not only the prescribed limit of 20 ppm (14.12 mg/m³).

Figure 2 reflects the situation at one single day. Repetitions in different laying weeks (lw) are shown in Figure 3 for stable 5.

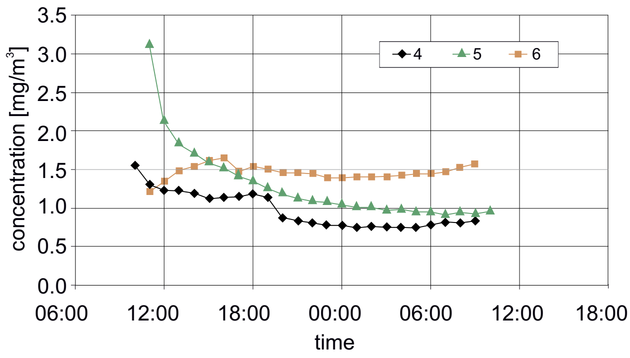

Figure 2:
Ammonia concentration in three small group keepings

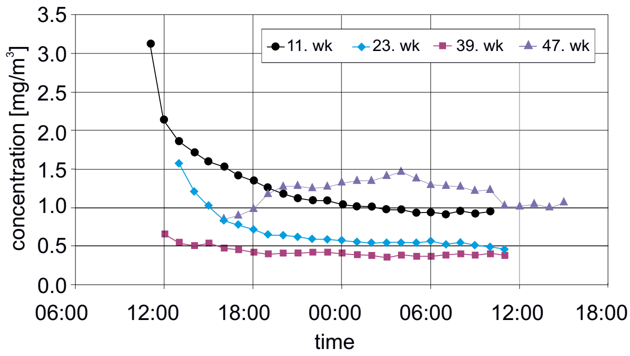

Figure 3:
Ammonia concentration, daily courses in stable 5 for different weeks

The situation is similar for the concentration of PM4, Figure 4 and 5.

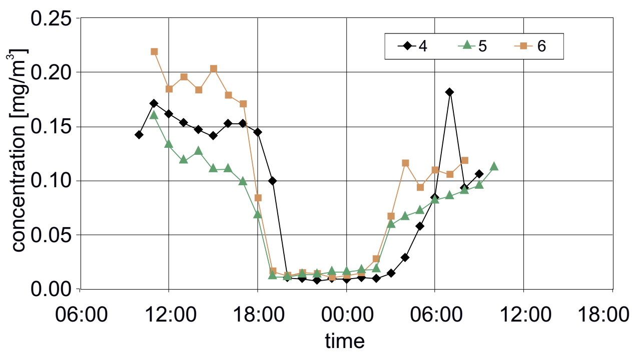

Figure 4:
PM4 concentration in 3 small group keepings

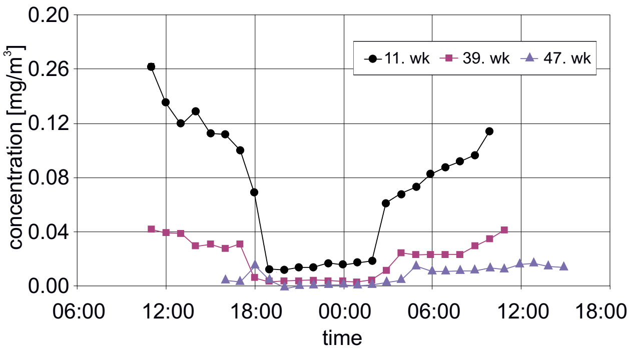

Figure 5:
PM4 concentration, daily courses in stable 5 for different weeks

In Figure 4 daily courses of PM4 concentration are drawn. There are large differences between the systems of three producers, but the main message is that the level of concentration is very low and satisfies very well the prescribed limit of 4 mg/m³.

Figure 4 reflects the situation at one single day. Repetitions are shown in Figure 5 for stable 5. It is clearly detectable that PM4 concentration is higher for younger birds than for the older ones.

The figures given above are based on 24h monitoring. To see possible seasonal influence the 1h spots of the ammonia concentration are used and demonstrated for stable 4 in Figure 6 in a box plot presentation.

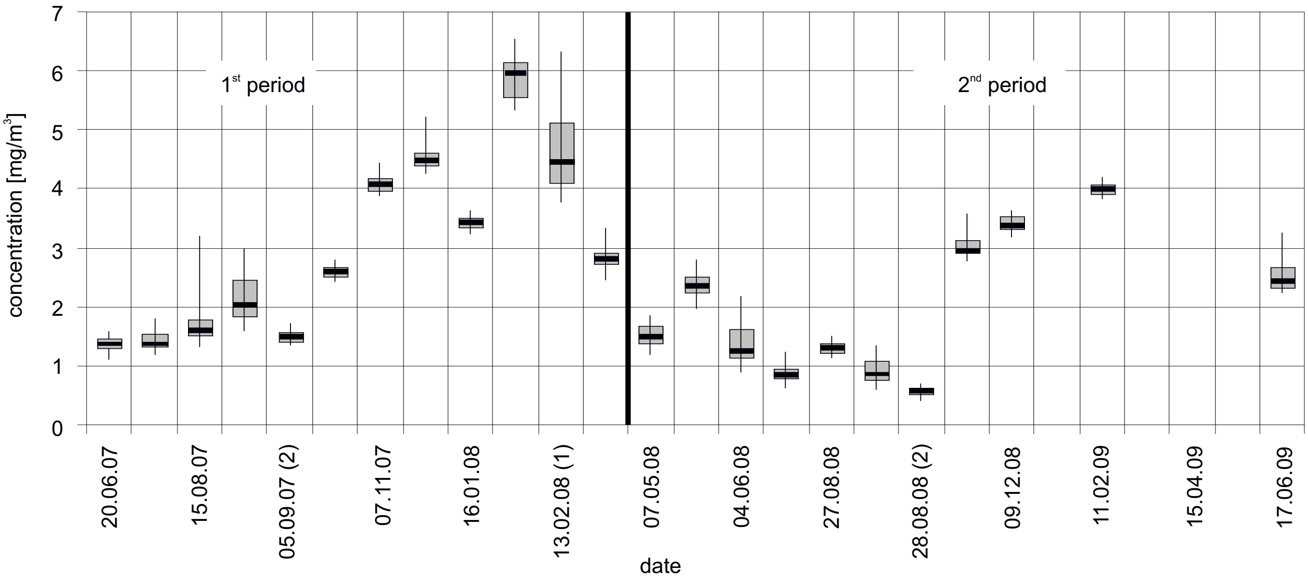

Figure 6:
Box and Whiskers plot of ammonia concentration in stable 4

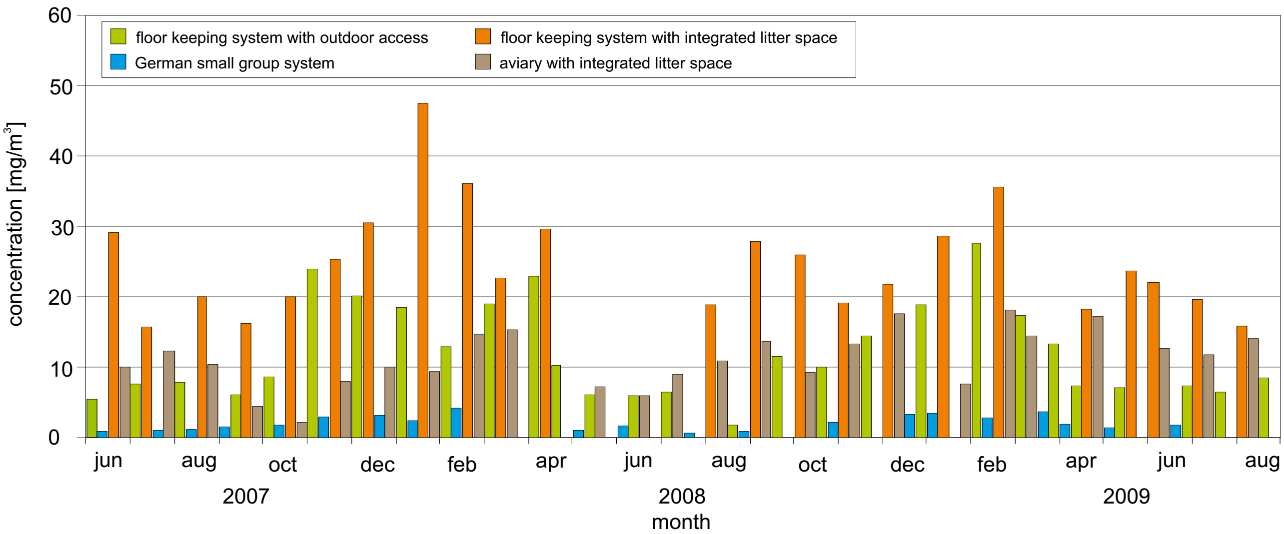

Figure 7:
Ammonia concentration for different types of alternative layer houses

The seasonable influence is obvious for both laying periods – concentration is higher in winter than in summer time, but nevertheless low over the year.

The same finding shows Figure 7 for all systems investigated in project A. But the main message is that in the small group keeping the lowest ammonia concentration is observed.

Emissions

With the typical air flows for all investigated stables of 700 to 10000 m³/h of the single stables emission flows range for 1h averages from <1 mg/(h*bird) to 180 mg/(h*bird) for ammonia and <1 mg/(h*bird) to more than 25 mg/(h*bird) for PM10.

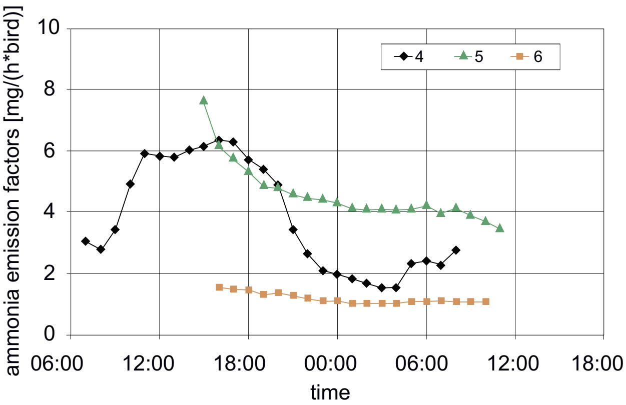

Figure 8:
Ammonia emission factors for the three small group keepings

Depending on the daily variations of concentration and air flow more or less typical courses of the emissions and emission factors are obtained. Ammonia concentrations are quite smooth (Winter et al., 2009). The time variations of emission factors follow the course of ventilation rate. Figure 8 shows this for ammonia emission factors of the three small group keepings. Ventilation rate is controlled by a stable computer in system 4 only.

As mentioned, emission is the product of concentration and air flow rate. If both are functions of time it becomes complicated to find short but representative spaces of time for comparison and evaluation of systems. System 4 in Figure 9 gives a first impression for ammonia. Figure 10 gives the emission factors of three different small group systems for PM10. It is obvious that day and night time must be distinguished.

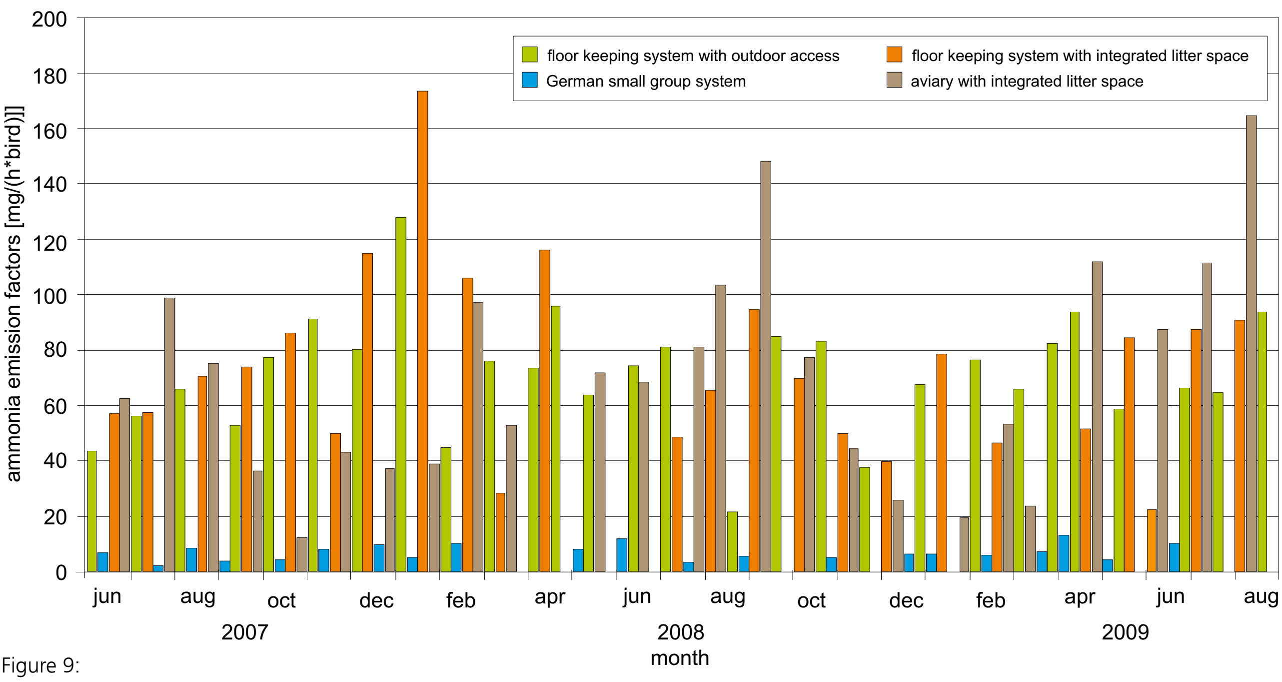

Figure 9:
Ammonia emission factors for different types of alternative layer houses

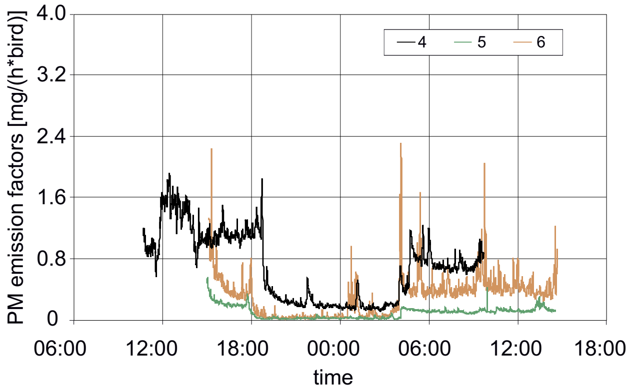

Figure 10:
PM10 emission factors for three different small group systems

Using again for comparison the description by 1 h noon spots, wide spans on different levels of emission factors are the result; cf. Table 3. The values in brackets are given in the EMEP EEA guidebook for inventory use.

Table 3:
Ammonia, PM10 and PM2.5 emission factors for the stable systems, 1h noon spots

stable	ammonia emission factor [mg/(h*bird)]	PM10 emission factor [mg/(h*bird)]	PM2.5 emission factor [mg/(h*bird)]
1	12 - 165	0.8 - 20	0.08 - 1.98
2	20 - 173	1.0 - 28	0.10 - 1.97
3	22 - 128 (20)	0.6 - 9.0 (9.45)	0.04 - 0.56 (1.95)
4	2.4 - 13.0	0.5 - 4.6 (2.0)	0.05 - 0.19 (0.22)
5	1.7 - 19.4	0.6 - 3.6 (2.0)	0.04 - 0.17 (0.22)
6	0.3 - 3.2	0.3 - 2.0 (2.0)	0.03 - 0.11 (0.22)

Summary and conclusion

A new German system for layers, the small group keeping system, is introduced. It is more animal friendly than conventional cages which are banned in Germany since January 01, 2010. A final decision on its future authorization must be made until March 31,2012.

In the centre of the study are concentration inside and emissions from different small group systems with view to ammonia and PM.

All measured values are very low with respect to wanted or given limits. Ammonia concentration did not exceed the limit of 10 ppm (7.06 mg/m³). PM4 levels are below 1 mg/m³ and far from the limit of 4 mg/m³.

The reasons for low concentration and emissions are given by no litter, the manure management with regard to ammonia and lighting strategy for PM emissions.

In comparison with other systems small group keeping has advantages with view to air quality and emissions.

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This report includes results from projects funded by the German Ministry of Food, Agriculture and Consumer Protection (BMELV) through the German Federal Agency for Agriculture and Food (BLE), it is a reviewed version of a presentation given at AgEng2010 in Clermont-Ferrand, France