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Hen or manager – who is responsible for dust and ammonia in the stable?

According to EU and national regulations in Germany layers are kept not any longer in cages. There are alternatives on the market. An assessment of different keeping/management systems for laying hens with regard to individuals' health and environmental protection is required. One open question concerned is the relevance of airborne dust and ammonia. This paper deals with investigations running in two systems for keeping laying hens – aviary and German small group housing system – regarding dust and ammonia concentrations inside the stable and their emission flows. The systems vary in size, stocking density and management. First data on airborne exposure indicate differences between the housing systems investigated. The ammonia concentrations reach from less than 1 ppm to more than 20 ppm and PM4 from 0,1 to 2 mg/m³. Ammonia produced essentially by the birds' faeces. Manure management is one of the most important factors to reduce the concentration of ammonia. Dust emissions are mainly caused by birds' activity which can be influenced by e. g. the light programme.

Keywords
Laying hens, dust, ammonia, aviary, German small group housing system

Abstract
Landtechnik 67 (2012), no. 2, pp. 127–132, 6 figures, 3 tables, 10 references

Egg production in Germany has a long tradition. There are barns with a stock of 3,000 birds managed as a family business to sell their eggs in the neighbourhood. On the other side there is an egg production industry which is managed in a standardized way. They house up to 100,000 birds within each stable, sometimes three stables beside each other. They must serve the rising demand for eggs of Germany and Europe. After banning conventional cages 2010 in Germany [1] new systems must be found which fulfil the new conditions in egg production with respect to farmers' and animals' health and welfare as well with view to a possible environmental impact. But also other reasons like the needed ground for a keeping system must be considered. Aviaries and small group keeping systems give preference over floor keeping because they can use the 3rd dimension with different residential levels for the birds. That leads to higher stocking densities related to the needed ground. This fact may have an influence on air quality and airborne emissions as could be shown in previous projects [2–6].

One aim of the running project is to find out if there is an influence from the birds and from the management on the production of dust and ammonia. Resulting from these finding, management recommendations shall be worked out to reduce the content of airborne contaminants. For this purpose an interdisciplinary field study was created. This paper deals with the aspects of air quality and airborne emissions only.

Table 1 shows sources of dust and ammonia in a barn and their relevance depending on activities of man and animal increasing from "0" (no influence) up to "++" (high influence). This signature does not include any judgement.

Material and methods

During three years, from January 2010 until December 2012, about 72 stables, commercial and private farms, will be inves-

Table 1

Factors influencing air quality in the barn

Haltungsform ***Keeping system***		
Interne Quellen *Internal source*	Staub *Dust*	Ammoniak *Ammonia*
Einstreu/*Litter*	++	+
Kotbandreinigung *Manure belt cleaning*	+	++
Sandbad/*Sand bath*	++	0
Lichtprogramm *Light programme*	++	0
Management/Aktivität von Mensch und Tier ***Birds and farmers activity***		

Fig. 1

Local distribution of farms attending the field study

tigated all over the country. The stables are quite uniformly distributed in the north, the middle and the south of Germany (**Figure 1**). Unfortunately there is still a lack in the eastern states.

In general 32 aviaries and 28 small group keepings are taking part in the study up to now.

Emissions and concentrations of health related particles as well as of ammonia inside and from the stables are measured once as 24–48 h spots. Measurements inside are carried out at a central location in the stables. Emissions are determined directly in the exhaust ducts. In cases of several exhaust openings the concentration is measured in one central duct only. This value is seen to be representative to calculate the emission flow of a stable in connection with the total air flow concerned. The permissibility of this procedure could be shown in a previous project [7].

Both positions are equipped with the same type of instruments measuring ammonia and PM concentration. All instruments are adjusted against each other during every measurement. Calibration was done previously by the manufacturer with repetitions after a period of time.

Ammonia concentration is measured using a multi-gas monitor. For PM concentration mainly optical counters are used to measure the different fractions of particles whereby respirable dust (later on named PM4) for farmer's health related fraction according to DIN EN 481 and PM10 defined by DIN EN 12341 are in the focus [8, 9]. To calculate mass concentrations from the results of the optical particle counter it is necessary to know the physical density of the dust. For this purpose a pycnometer is used to determine dust density from collected samples. To separate very large particles from feathers or other materials a 100 µm sieve is used. At the same time, this allows also to get close to the definition of inhalable dust which ends with a diameter of 100 µm.

A deep problem exists for the determination of air flow. Different kinds of control strategies in stables with several ducts and fans go beyond our resources to measure directly. So the stable computer is an opportunity to get the necessary information. Mostly there is no direct data exchange available. A camcorder is used to record the actual values of air flow from the display. Additional air speed is checked by a fan wheel anemometer with own data logger. The fully equipment is listed in **Table 2**.

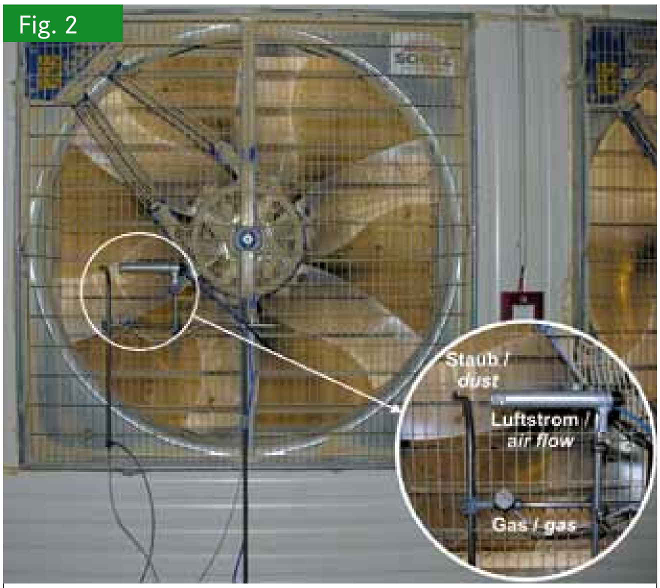
Table 2

Measuring equipment of the field study

Messgröße/*Measure*	**Messinstrument /*Measuring instrument***	**Messprinzip/*Measuring principle***
Ammoniak/*Ammonia*	Innova 1302 Multigas-Monitor/*Innova 1302 multi gas monitor*	Optoakustik/*opto acoustics*
Ammoniak/*Ammonia*	Innova 1312 Multigas-Monitor*/*Innova 1312 multi gas monitor**	Optoakustik/*opto acoustics*
12-Kanal-Überwachungssystem *Twelve-channel monitoring system*	Innova 1309 Mehrpunktsammler* *Innova 1309 multipoint sampler**	Elektroklappen/*electronic valves*
PM10, PM4, PM2,5	Grimm optischer Partikelzähler 1.108 und 1.108 *Grimm optical partical counter 1.108 and 1.108*	Streulicht/*light scattering*
Luftstrom/*Air flow*	Hoentzsch Flügelrad-Anemometer/*Hoentzsch anemometer fan wheel*	Anemonetrie/*anemometry*
Luftstrom/*Air flow*	Reventa Flügelrad-Anemometer*/*Reventa anemometer fan wheel**	Anemonetrie/*anemometry*
Dichte/*Density*	Pyknometer 50 ml/*pycnometer 50 ml*	Gravimetrie/*gravimetry*
Temperatur, rel. Feuchte *Temperature, rel. humidity*	Wetterstation/*weather station*	Pt100 und kapazitiver Sensor *Pt100 and capacitive sensor*
Temperatur, rel. Feuchte *Temperature, rel. humidity*	Tinytag Ultra*/*Tinytag Ultra**	NTC Thermistor und kapazitiver Sensor *NTC thermistor and capacitive sensor*
Luftdruck/*Pressure*	Fischer Barometer*/*Fischer barometer*	Aneroid/*aneroid*

* Messinstrumente von SMUL/equipment of SMUL.

Fig. 2



Localisation of the PM sampler in front of an exhaust opening

For emission measurements it is aspired to take the particle sample under isokinetic conditions according to VDI 2066. But sometimes it is impossible to situate the mouth of the nozzle directly in the inlet area of the exhaust duct. In these cases measurements are carried out in a distance of approximately 15 cm from the desired position as demonstrated in **Figure 2**.

All measurements are planned to be carried out in the last third of a laying period. The dates of measurement result from farm management arranging the beginning and ending of laying periods. So samples will be gathered by a more or less random procedure related to the seasons, which is, however, for force ventilated stables the dominant ambient factor that is influencing air quality and emissions. This is demonstrated for a small group keeping system by means of box plots for the ammonia concentration (**Figure 3**).

In an additional part of the project in a limited number of selected stables measurements with larger time slots of 14 days are carried out once in a quarter of a year. This offers the opportunity to adjust the results for reasons of comparison with regard to the seasons.

Results and discussion

In the following the results will be presented first for the ammonia and PM4 concentrations for one aviary and one small group keeping. After this an example for ammonia emission factors is presented for two small group housing systems with, different procedures for the manure belt cleaning.

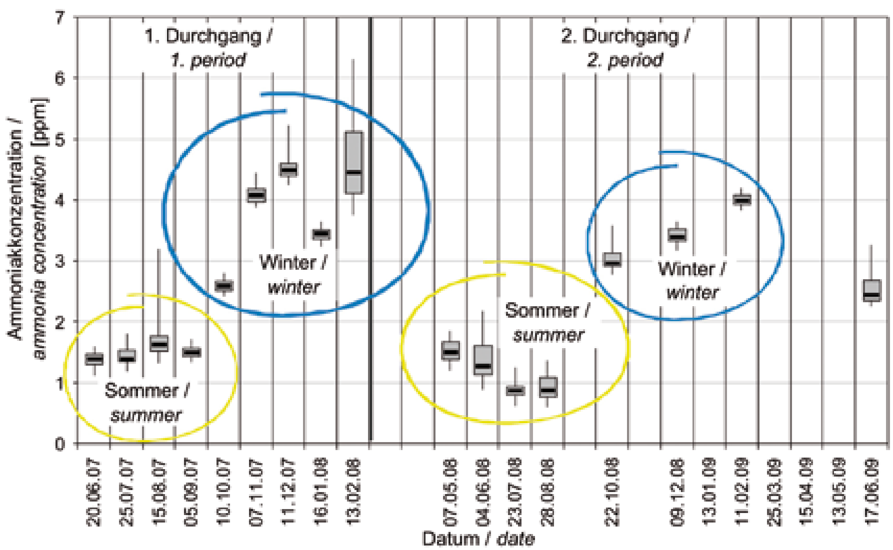
Concentrations

First data on airborne exposure indicate differences between the housing systems investigated.

Ammonia is produced by the birds' faeces. Manure management is one of the most important factors. **Figure 4** gives the 48 hours' courses of ammonia concentration in a small group keeping with 6,720 birds and in an aviary with 1,500 birds with manure belt cleaning once a week. It's significant that the concentration decreases from a relatively high level to low levels by a factor of 6. Such a great ratio between maximum and minimum concentration was also observed by Hahne [10]. It can be concluded that for an evaluation of air quality in a stable or a keeping system the concentration of ammonia must be known together with the information about the time of cleaning the manure belt.

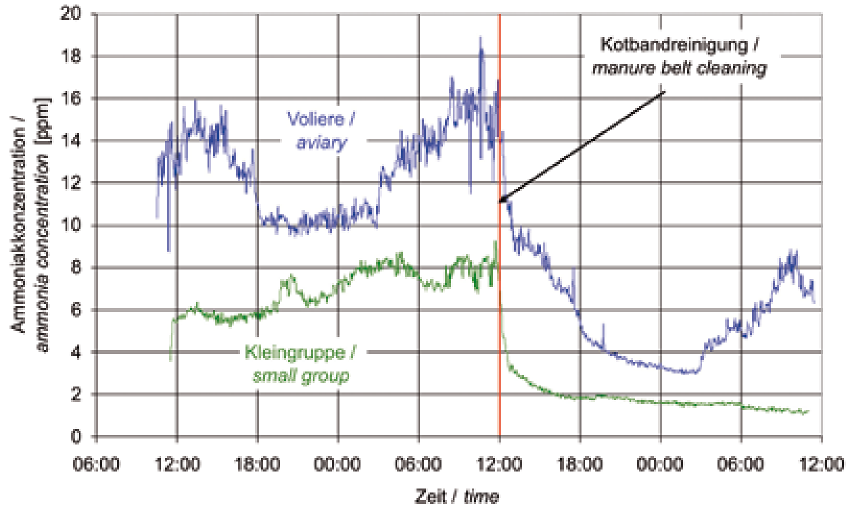
Dust concentrations are mainly caused by birds´ activity which can be controlled by e. g. the lighting programme. Further research is needed in order to improve the manage-

Fig. 3



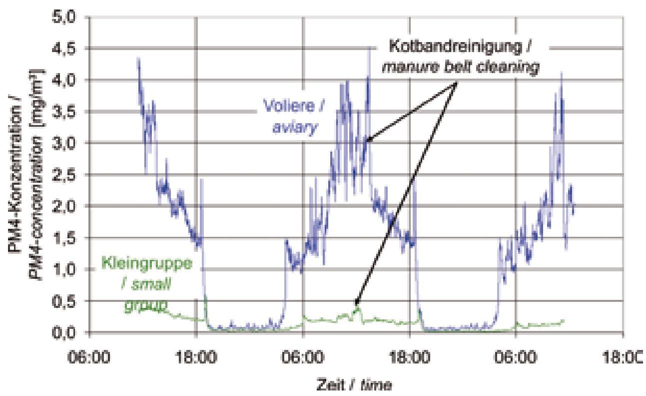
Seasonal influence of ammonia concentration in the small group

Fig. 4



48 hours' course of ammonia concentration in a small group and in an aviary

Fig. 5



48 hours' course of PM4 concentration in a small group and in an aviary

ment of different housing systems for laying hens. **Figure 5** shows PM4 inside a small group system and an aviary.

As already found in other studies the course of PM concentration follows directly the light in the stable – very low at night and on a higher level at day time. The reason is in general the activity of the birds which explains also additional peaks caused by other outside events. The values are nearly one order of magnitude higher in the aviary because of highly active, flying birds.

For some other different reasons like environmental impact other dust fractions are of interest, e.g. PM4/PM10 and PM2.5/PM10. **Table 3** gives the ratios between the fractions for the two stables. The particular proportions are similar for these both stables.

Emissions

Concentration of airborne contaminants measured inside a barn can be used for estimation of emission limited only. Nevertheless, the question arises whether if the influence of manure belt cleaning can also to be observed for the emission flow.

Figure 6 shows the ammonia emissions related to the numbers of birds. In order to obtain comparable emission factors, these are determined in two small group keepings with larger time slots. Manure belt cleaning happens once or twice a week.

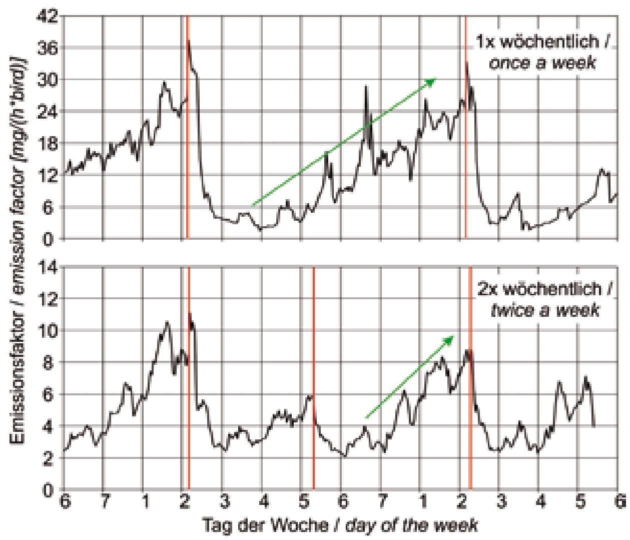
Independent from the absolute values of the emission factors the work cycle of manure belt clearance is visible. For the higher cleaning frequency, the course of time gets straightened and the ratio of maximum to minimum becomes much smaller, from approximately 9 down to the range of 3.

Table 3

PM4/PM10, PM2.5/PM10 in a small group and in an aviary

System ***System***	**Verhältnis** ***Ratio***	**Median** ***Median***	**Unteres Quartil** ***Lower quartile***	**Oberes Quartil** ***Upper quartile***
Kleingruppe *Small group*	PM2.5/PM10	0,13	0,12	0,14
	PM4/PM10	0,40	0,38	0,43
Voliere *Aviary*	PM2.5/PM10	0,12	0,11	0,13
	PM4/PM10	0,38	0,36	0,42

Fig. 6



Courses of ammonia emission factors in two small group keepings with manure belt cleaning

Conclusions

Air quality, concentration inside and emissions of ammonia and PM from stable keeping layers in small groups and aviaries are caused by the birds but can be influenced by the farmer – in a positive and in a negative way.

In one part of the still running interdisciplinary field study concentrations inside barns and resulting emissions are determined for ammonia and dust at examples of aviaries and German small group housing systems to derive management recommendations for the farmer.

Ammonia can be reduced by increasing the frequency of cleaning of the manure belts. PM can be controlled by the light programme which has an effect on the activity of the birds. High activity at day time means high PM production. More detailed statements can be given after finishing the project and using particular information of all participants.

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