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Multistage exhaust air treatment for poultry farming

In spite of considerable fluctuating operation conditions a multi-stage test facility for the treatment of poultry exhaust air secured a good and reliable particulate matter reduction.
It was equipped with an initial dry dedusting unit, an acidic and a subsequent water scrubber unit. At filter loads between 1 800 and 3 600 $m^3/(m^2 \cdot h)$ a mean particle reduction efficiency (n = 149) of at least 57 % was verified for a particle diameter between 2.0 and 2.5 µm and more than 98 % for a particle diameter between 6.5 and 7.5 µm. Also 72 % of the nitrogen was separated in a useable form from the raw gas as a nitrogen balance over six month of operation showed. The considerable fluctuating ammonia emissions from the tested animal house offered a noticeable correlation with the dung removal interval.

Keywords

Exhaust air treatment, poultry farming, ammonia, particulate matter

Abstract

Landtechnik 65 (2010), no. 5, pp. 334-337, 4 figures, 1 table, 6 references

The commercial relevance of the broiler livestock becomes obvious seeing a considerable increase of broiler heads from 54.6 million (2003) to 59.2 million (2007) in Germany [1] and a per capita consumption of broiler meat which increased from 9.2 (2004) to 11.2 (2008) [2]. Also the development potential is enormous viewing the per capita consumption in the EU 27 with 17.1 and even 44 kg in North America [3]. This pleasant economic development is, however, connected with increasing environmental impacts, because poultry houses create considerable dust and ammonia emissions and odour as well. The latter may be significantly underestimated as actual investigations show [4]. The portion of poultry on total ammonia emissions by animal livestock is calculated with 15 % in 2010. Accordingly, the portion of PM10 and PM 2.5 is estimated at 29 % and 18 %, respectively [5].

Whereas several approved exhaust air treatment systems of different producers are available for pig farming, corresponding techniques are still missing for poultry farming (status: May 2010). The development of approved systems for poultry farming is therefore necessary to maintain the future economic potential of poultry farming in Germany.

Aim of the work is the development of exhaust air treatment systems for poultry farming. Comparable to the DLG signum test minimum reduction requirements of 70 % for total dust and PM10 are intended. The separation efficiency for ammonia should also be 70 % at least.

Material and methods

The investigations were conducted at a chicken house (cocks and hens) in the time period from June to December 2009. The animals were housed with 18 weeks at the end of February and kept until the end of the year. Feeding was at libitum and water was supplied with nipple drinkers. Dung removal was realized with a dropping belt once a week. The exhaust air from the chicken house was directly taken from the stable ventilator as raw gas for the test facility without any additional pre treatment.

The test facility consists of a dry operating deduster and two subsequent washing units (**figure 1**). A coarse dust removal was realized by a regenerative dust filter pad (Type HS 15, HS-Luftfilterbau GmbH, Kiel) (2). Conditioned by dust separation the pressure drop of the dust filter pad raised. Above an adjustable value (80 Pa in this investigation) the filter pad regeneration started with an external vacuum cleaner (6), which cleans the filter pad. The exhaust air from the vacuum cleaner was led back to the raw gas pipe, while the separated dust is collected in bags (9). The widely dust free waste gas was then cleaned by passing a washing wall 1 (150 mm thickness) operating with acidic washing liquid (pH < 5) (3). As filling bodies 25 mm Highflow rings (Rauschert, Steinwiesen) were used. For pH control sulphuric acid (96 %) from a reservoir (13) was used. The washing unit 1 was supplied from a separated reservoir (7) with an individual elutriation pipe (10). The pH value in washing unit 1 was controlled below 5 with concentrated sulphuric acid. After this followed a second washing unit 2, identical in construction (4) which is supplied with water from a separated reservoir (8) and also equipped with an elutriation pipe (11). The irrigation density was 4 m³/(m² • h) in washing unit 1 and 3.2 m³/(m² • h) in washing unit 2. Both water reservoirs dispose of a fresh water supply (12) and an automatic water level control. After passing washing unit 2 the clean gas is released from the test facility (5).The mean filter loading rate was 2880 m³/(m² • h).

Two aerosol spectrometers (Grimm, Ainring), identical in construction, were used to assess the particle separation efficiency. Ammonia was measured quasi online with a FT-IR spectrometer (Ansyco, Karlsruhe), nitrogen monoxide and nitrogen dioxide were also measured quasi online with an Environnement S.A. CLD chemiluminescence detector (Ansyco, Karlsruhe). For assessing the air flow an ultrasonic flow meter (Sick AG, Reute) was used. For water analyses ammonia was measured by distillation (DIN 38406 part 5). Nitrite and nitrate was measured with HPLC at 210 nm.

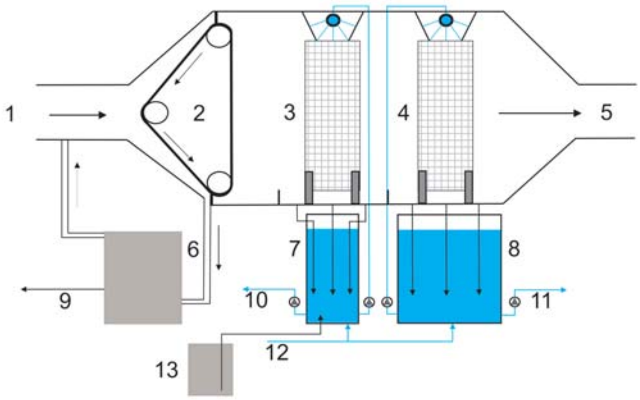
Results

The composition of exhaust air from the chicken house showed considerable fluctuations (**table 1**). High ammonia concentrations were observed in March and from October to December. In the period between July and September the average daily values in the raw gas were nearly constant below 5 ppm. The ammonia emissions showed a noticeable correlation with the weekly dust removal intervals (**figure 2**). After dung removal the NH_3 emission was very low but increased significantly till the next dung removal.

The measurements were done simultaneously in raw and clean gas with two identical Grimm aerosol spectrometers and the mean particle separation efficiency was calculated from all in all 149 measurements, each with 30 minutes measuring time. Results show a mean particle separation efficiency of at least 57 % for the 2.0-2.5 µm particle fraction and 98 % for the 6.5-7.5 µm particle fraction at filter loading rates between 1,800 and 3,600 m³/(m² • h) (**figure 3**). If bigger particles appeared in raw gas, they were separated nearly complete. The results also show some influence of the surface load on the particle separation efficiency. At low surface loads the separation efficiency decreased slightly.

A nitrogen balance from June to December 2009 with all nitrogen inputs and outputs with the exception of N_2O (gas analysis was not available then) and the nitrogen portion in the dust showed a nitrogen reduction efficiency of nearly 72 % (**figure 4**). 64.8 % of the input nitrogen was separated in washing unit 1. Another 9.4 % was separated in washing unit 2. The nitrogen separation efficiency at mean filter loading rates of 2,880 m³/(m² • h) should be improved by additional measures.

Fig. 1



Configuration of the test facility for the cleaning of poultry exhaust air (1: raw gas; 2: filter fleece; 3: scrubber wall 1; 4: scrubber wall 2; 5: clean gas; 6: fleece exhaustion; 7: water tank 1; 8: water tank 2; 9: dust removal; 10: elutriation water tank 1; 11: elutriation water tank 2; 12: fresh water supply; 13: sulphuric acid supply)

Conclusions

An effective particle reduction efficiency of at least 57 % (PM 2.0-2.5) and 98 % (PM 6,5-7.5 µm) respectively, can be secured with the described multi-stage exhaust air cleaning process at filter loading rates from 1,800 to 3,600 m³/(m² • h). A nitrogen balance over a time period of six month showed a separation efficiency of 72 %.

Literature

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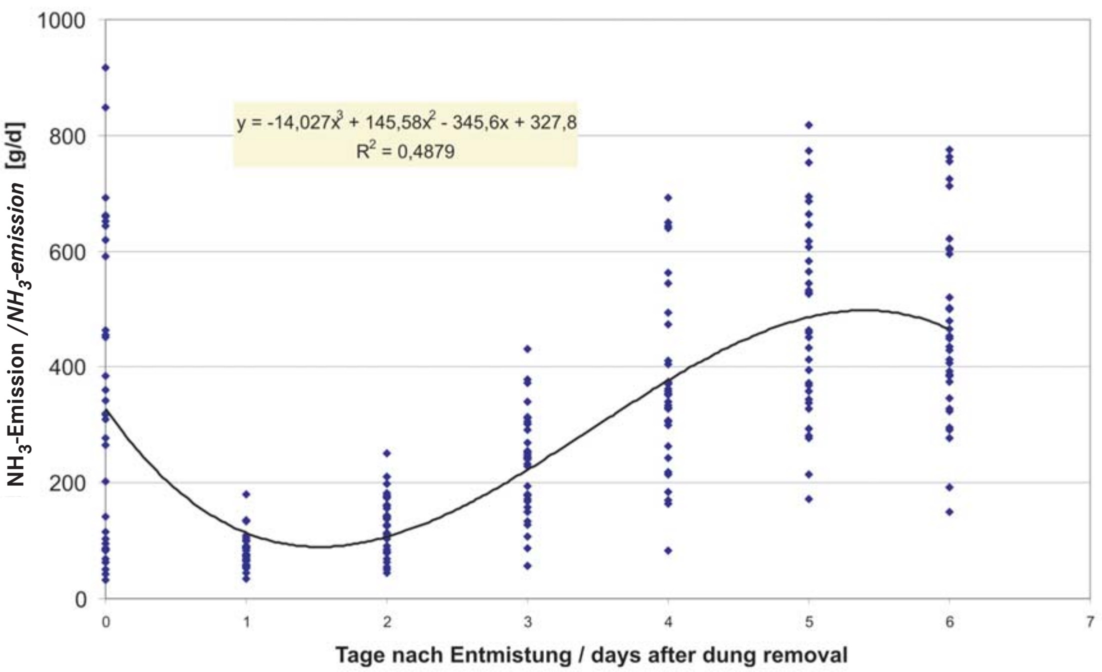
Table 1

Mean composition (n = 1 707) and fluctuation range of the chicken house exhaust air in the time period from June to December 2009

Parameter *Parameter*	**Mittelwert** *Mean*	**Minimum** *Minimum*	**Maximum** *Maximum*
Temperatur/*Temperature* [°C]	21,2	18,4	33,7
Relative Feuchte/*Relative humidity* [%]	57,9	33,5	78,2
Schwefelwasserstoff/*Hydrogen sulfide* [ppm]	1,0	0	4,9
Methan/*Methane* [ppm]	3,2	1,1	7,2
Gesamt org. Kohlenstoff/*Total organic carbon* [ppm]	2,7	1,5	5,5
Kohlenmonoxid/*Carbon monoxide* [ppm]	0	0	0,2
Ammoniak/*Ammonia* [ppm]	5,7	0	30,0
Kohlenstoffdioxid/*Carbon dioxide* [ppm]	1 055	266	3 227
Stickstoffmonoxid/*Nitrogen monoxide* [ppm]	0	0	0,1
Gesamt-Staub/*Total dust* [mg/m³][1)]	0,8	0,1	13,3

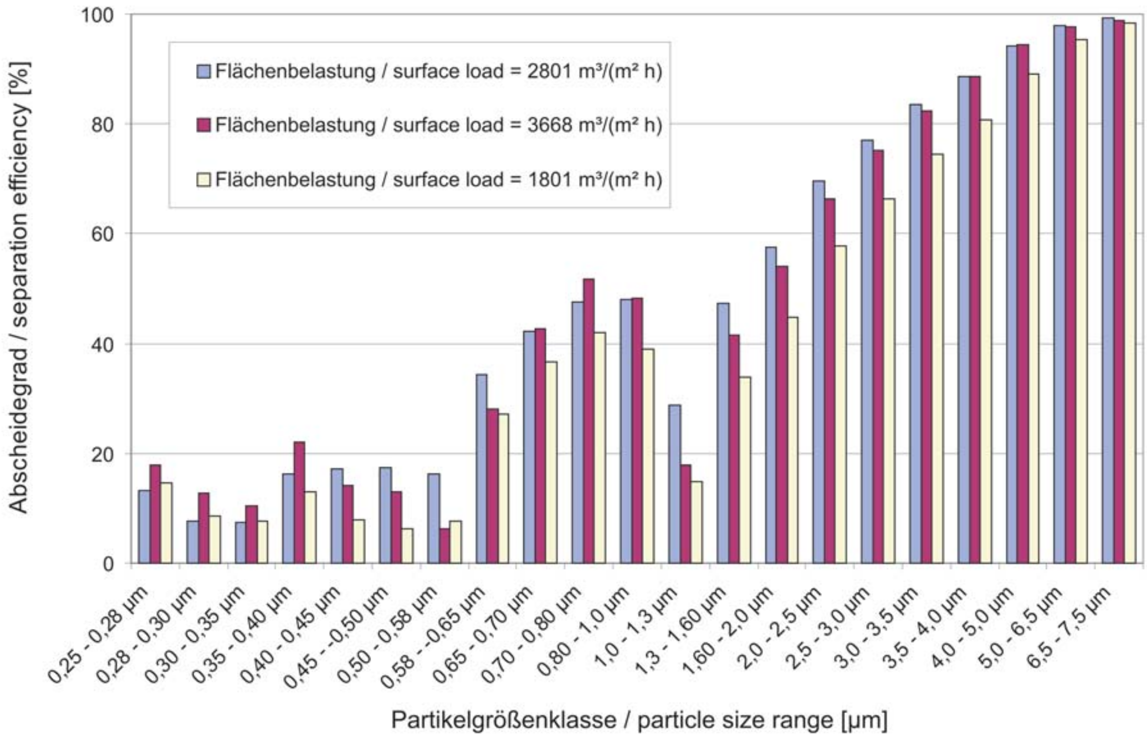
1) Laseroptisches Verfahren nach Sick/*Laser optical Sick method.*

Fig. 2



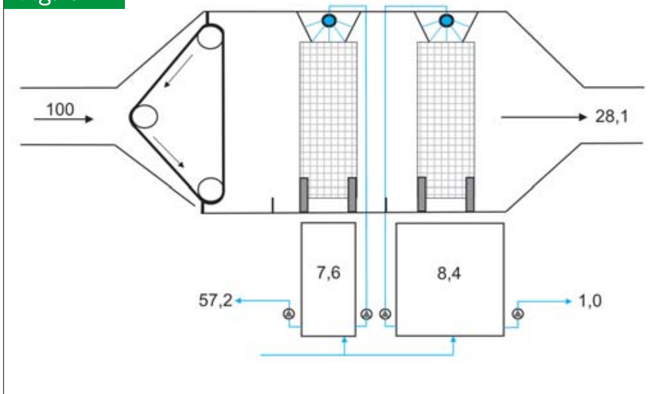
Ammnonia emissions of the chicken house against the dung removal interval

Fig. 3



Particulate matter separation efficiency of the test facility against particle size range and surface load

Fig. 4



Nitrogen flow in the test facility for the cleaning of poultry exhaust air (expressed as a percentage)