Richard Hölscher and Wolfgang Büscher, Bonn

Emission Reduction in Decentralized Ventilated Pig Houses ?

Oil-aerosol Application as a Solution to Retrofit

An oil-aerosol application was tested for dust and ammonia reduction in a pig house. Its effectiveness as a retrofit solution for decentralized ventilation in pig houses was evaluated. A 68 % reduction in total dust emissions and 28 % in ammonia emissions were measured.

Dipl.-Ing. Richard Hoelscher is PhD-student, Prof. Dr. Wolfgang Buescher is head of the section „Livestock technology" at the institute for agricultural technology of the university Bonn, Nussallee 5, D-53115 Bonn;
e-mail: *richard.hoelscher@uni-bonn.de*

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Literature

Literature references can be called up under LT 06321 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

A lot of research regarding exhaust air treatment from livestock husbandry has been done since the early 70th [1]. Typically a ventilation system with one central located exhaust point was the prerequisite of the conducted trials. In the context of a PhD-thesis several concepts for emissions reduction in decentralized ventilated pig houses were developed at the Institute for Agricultural Engineering, Bonn. Two concepts out of the in total 7 theoretical solutions [2] were chosen and technically realized. The systems were installed in two typical pig houses and their ability to reduce dust- and ammonia-emissions has been observed over a complete fattening period. The results on one of the two systems will be detailed in the following. The idea to reduce the emissions of the pig house by reducing the indoor concentrations was the motivating thought of the concepts. Compared to the untreated reference pig houses the emissions of the treated pig barn – calculated by the product of the concentrations and the exhaust air volume flow- were aimed to be reduced by binding or collecting the components (dust and ammonia) already indoor. In addition to the environmental effect, positive effects on the animal health and improvements in the work environment for the staff were intended.

System

Motivated through observations on the negative long term health impact of organic dust on farmers working intensively in livestock husbandry the technology of rapeseed oil sprinkling (or other organic oil) for dust reduction have been developed 30 years ago. First trials have been done in 1985 by researchers in Denmark [3]. The method of oil sprinkling has been further enhanced in the 80th and 90th by research departments in Denmark, Canada and the US, improving the technology for the oil application and reducing the necessary amount of oil. An oil application of 5 to 40 ml per pig and day led to a reduction of indoor dust concentration of 40 to 90 % (total dust and PM10-dust). Typically the oil emulsion has been dispersed once or twice a day by field sprayer nozzles or sprinkler units with a water pressure of maximum 0.4 MPa, producing primarily droplets not aerosols [4, 5]. The dust reduction has been explained by the dust binding effect of a thin oil film on the surfaces (fences, slatted floor,…) produced by the oil sprinkling. In addition to that, some research has been done with technologies to produce oil-emulsion aerosols mainly in Germany, the Netherlands and Japan. Trials in a sawdust littered pig house using rotational nozzles showed a dust reduction by the system of 18 % given an application rate of 80 ml/m^2 per day [6]. Other research has been done using a typical evaporation cooling system working at a pressure level of 12 MPa. Dust reductions of 2 to 12 % have been measured [7]. All these authors explained the dust reduction by accelerated dust sedimentation within the pig barn caused by the forming of agglomeration units in the air.

First research with special focus on the environmental impact (reduction of dust emissions from the house) of the oil-sprinkling treatment has been done in combination with nutrition trials [8]. The original intention of the setup was to quantify the reduction of the odour- and gas-emissions. Dust-emission reduction of 95 % and ammonia-emission reduction of 38 % (explained by the adjusted nutrition) have been measured.

In general no impact on the ammonia concentration – if measured during the trials – caused by the oil sprinkling has been found.

Material and methods

The trials were set up in a way that the emissions of a typical pig house equipped with the oilmixture-aerosol-application unit could be compared with the emissions of a similar but untreated unit. Therefore a typical building for pig fattening with two compartments – independent regarding ventilation but climate-wise regulated by the same control algorithm – has been chosen. The pigs of the two compartments had nearly the same weight and were fed four times a day with a computer controlled liquid feeding system. An evaporation cooling system adapted for the purpose of the trials and realizing an area-wide treatment was used in compartment number one; the other compartment (number two) gave the reference. The oilmixture contained different types of essential oils (which were known to reduce germs and fungi) and a carrier oil. This oilmixture emulsion was applied every half hour realizing a nearly continuous indoor air treatment. The daily oil consumption sums up to 3 to 5 ml per pig.

The dust concentrations were measured with a particle counter (Grimm model 1.105) working on the principles of laser light scattering and for crosschecks in addition with a gravimetric dust sampler (designed according to VDI 2463); each with a sampling point height of 1.5 m. Ammonia concentrations were measured using a photoacoustic multigas-monitor (Innova model 1312) and for crosschecks in addition with a NDIR spectrometer (Rosemount Binos). Both instruments worked in a bypass setup, which means that a pump provided the instruments with the sample air conducted through heated PTFE-tubes.

With the exception of the gravimetric dust sampler which continuously ran 24 hours, all measurement data have been collected every minute. Additional data from the climate control unit have been stored every minute as well (temperatures inside and outside, relative humidity inside and outside, air volume flow, periods of feeding representing periods with maximum animal activity, the estimated weight of the animals and their actual quantity and the water consumption of the aerosol-application unit).

Measurements at 45, 70 and 80 kg live weight captured the whole fattening period of the pigs. Each variant in the trial set up was observed for at least three days (one iteration = 24 hours).

In general the measurements have been analysed by calculating the average value (n = 3) of the daily average (n = 1440 data points) of each trial variant. Because of the high influence of the air volume flow on the dust- and ammonia-concentrations the emission-mass-flow per livestock weight (emission rate) was always calculated by comparing the systems with the following equation:

$$\text{Quellstärke} = \frac{\text{Massenkonzentration} * \text{Luftvolumenstrom}}{\text{Tieranzahl} * \text{Tierlebendgewicht}} \left[\frac{\text{mg}}{\text{GV min}}\right]$$

Results

Typically dust emission rates of pig houses show a characteristic shape in the course of the day dominated by the animal activity [9]. An example for such typical intraday emission rates is given in *Figure 1*. The emission peaks during the feeding period caused by the maximum animal activity are characteristic for pig houses with the same feeding system as used in the trials. When comparing the dust emission rates of the treated compartment with the emissions rates of the untreated compartment in *Figure 1*, the reduction through the oil-aerosol-treatment gets obvious. The emission rates were generally lower even through feeding periods. The smaller but very cyclical peaks mark the time of the aerosol-application. The aerosol spectrometer detects all particles irrespective whether they are typical dust fractions or they are very small water droplets or mist. The generated data didn't represent the real dust concentration. Therefore all dust related data were analysed in such way that only the dust concentrations 15 minutes previous to every aerosol-application were taken into account for the calculation of the emission rates (leaving 720 data points each day).

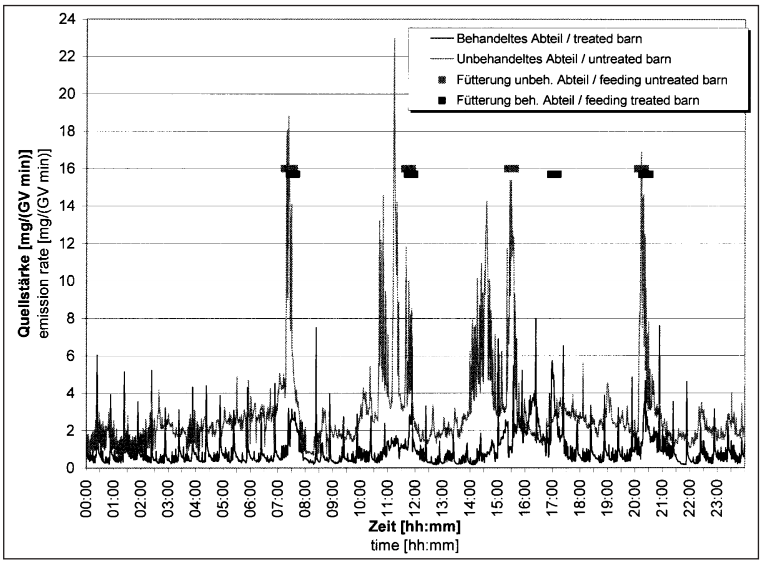

Fig. 1: Dust emission rate in the course of the day with and without aerosol treatment

In average – over all three measurement periods (> 22 days of fulltime measurements) – the oilmixture-aerosol-application led to a reduction of dust emission rates of 68 % for total dust and of 60 % for PM10-dust. The ammonia emissions were reduced by 28 % through the system. If compared with results derived from previous examinations other authors on conventional rapeseed oil application the reduction of ammonia emissions is remarkable (never observed before). Three main differences in the systems are the reason for that:

1. The technical realization of the oil-aerosol-application especially characterized by the high frequency of cycles, the very fine mist caused by the special nozzle type working on a high pressure level and the way the nozzles were placed (quantity per area, placement) was the main difference. Former systems for oil application sprayed the oil once or twice a day. The high frequency of application by day and night led to a nearly continuous air treatment.
2. The oilmixture – containing essential oils – was able to bind ammonia better then pure rapeseed oil or soy oil used in the former trials.
3. The evaporative cooling (fostered by the fine mist/aerosols) influenced the air volume flow indirectly. Reduced air temperatures therefore changed the climate control unit parameters and increased the emission reduction in addition.

Discussion

With the illustrated results of the conducted trials the suitability of the oil-aerosol-application as technical solution to retrofit a dust- and ammonia-emission reducing technology in decentralized ventilated pig houses have been proven. Next to the environmental aspect the system revealed a high capability to improve the indoor air hygiene leading to improved conditions for the livestock husbandry and a better working environment for the farmers. The concentrations of dust were reduced on average by 59 % for total dust, by 54 % for PM10-dust and by 16 % for ammonia (statistically highly significant). Veterinary findings regarding the pig lungs (performed in the slaughterhouse) tend to show less lung malfunctions of the pigs from the treated compartment (pigs were treated over the whole fattening period) compared to the ones from the reference compartment. These results were backed further by macroscopic and histological examinations of randomly taken lungs (25 from each compartment). No negative impact of the oil-aerosol-treatment has been observed. The „Institute for Hygiene and Public Health" of Bonn University conducted concentration measurement of airborne fungi. The treated compartment showed a 58 % reduced concentration of airborne fungi confirming the hygiene improving aspect.