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DEVELOPMENT AND TESTING OF TECHNICAL MEASURES FOR THE ABATEMENT OF PM10 EMISSIONS FROM POULTRY HOUSINGS

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ABSTRACT Emissions of PM10 have to be reduced in the Netherlands to comply with EU ambient air quality standards. Poultry industry is one of the contributors to PM10 emissions and it has to implement mitigation measures before 2012. Given the lack of effective and cost affordable technical measures an extensive research and development program has started, 2008-2011, with the objective to provide abatement technology for broiler and layer houses as soon as possible. This paper gives an overview of the results from researches carried out in 2008 and 2009 by Wageningen UR Livestock Research. Both supplying industry and poultry farmers are participating in this program. Different methods and approaches have been researched: bedding material, light schedules, oil spraying systems, ionization systems, water scrubbers, combined scrubbers, electrostatic filters, and dry filters. Most methods were first tested and optimized in small units of the experimental poultry accommodation in Lelystad. A number of methods were validated in a next step on poultry farms, where the PM10 emission was measured to establish official emission factors. From mid 2009 and on both the oil spraying system and ionization system were tested in broiler houses and they are on the edge of implementation in practice. PM10 reductions with different methods vary from no effect to levels of 60%. The paper concludes with an outlook on adequate dust abatement measures for poultry housings in the near future.

Keywords: PM10 emission, PM10 abatement, poultry production

INTRODUCTION

PM10 (dust particles with diameters equal or smaller than 10 μm) is a potential hazard to the health and welfare of humans and animals. Studies have reported serious human health effects related to PM10 and increased incidence of respiratory problems. Animal's respiratory health may also be compromised by dust. Dust from livestock houses can cause respiratory problems to people living in the vicinity of the farms, as well. High concentrations of these particles can also threaten the environment (plants and other organisms), causing vegetation stress and ecosystem alteration. Atmospheric particles are relevant to climate change issues, such as cloud formation, radiative forcing, and it can contribute to atmospheric visibility impairment.

Emissions of PM10 have to be reduced in the Netherlands to comply with EU ambient air quality standards. EU has set an ambient air quality standard for maximum PM10 concentrations. The maximum PM10 year round average was set at 40 μg/m3, and the maximum daily limit was set to 50 μg/m3 , with a maximum of 35 crossings per year. From 2010, an initial limit of 25 μg/m3 has also been set for the finer fraction of particulate matter, PM2.5 (particles with diameters equal or smaller than 2.5 μm), by the Parliament and Council of the EU. This will be binding from 2015 on.

The PM10 and PM2.5 standards are exceeded in a number of regions in the Netherlands. Livestock houses in the Netherlands are estimated to be responsible for approximately 20% of the total primary PM10 emission (Chardon and van der Hoek, 2002). Intensive poultry houses, together with pig houses normally reveal the highest concentrations of PM10. Furthermore, ammonia (NH3) emitted from livestock facilities is a main precursor for formation of secondary aerosols (PM2.5) in the atmosphere. Broilers raised on litter and laying hens in litter based housing systems are considered key contributors to atmospheric dust emissions.

Poultry industry is a major contributor to PM10 emissions in the Netherlands and is subject to a national policy program to implement mitigation measures at short term for all major sources. Given the lack of effective and cost affordable technical measures in poultry production an extensive research and development program has started in 2008 that should be completed by 2011. The objective is to provide abatement technology for broiler and layer houses as soon as possible. The research projects in this program are based on the overall ‘Plan of action: practical solutions for dust reduction from poultry houses’ (Ogink and Aarnink, 2008) which was commissioned by the Dutch Ministry of Agriculture, Nature and Food to Wageningen UR Livestock Research. This paper gives an overview of part of the results from research carried out in 2008 and 2009. The focus in this paper will be on research into bedding materials, light scheduling, oil film application and ionization techniques. In the Material and Method section an outline will be given of the research program and the generally applied dust measurement methods in underlying projects. In the Results section the findings for the four technologies will be summarized. The paper concludes with an outlook on adequate dust abatement measures for poultry housings in the near future.

MATERIAL AND METHODS

Major elements of the research and development program for dust abatement

The following issues were defined as essential requirements for the 2008-2011 program to abate PM10 emissions from poultry production (Ogink and Aarnink, 2008):

- Measures to be developed should have a substantial known PM10 reduction potential and should robust and reliable in practice.
- Measures have to be quickly developed, a number measures should be available for implementation from 2009 on.
- Measures have to be marketed as much as possible from 2009 on, this means that equipment producers are an important stakeholder of the development program
- Costs of measures have to be reasonable and acceptable for farmers

- Effective working of measures on farm must simply verifiable by regulatory authorities
- Reduction performances of measures have to be evaluated in testing and validation programmes. All measures should be assigned PM10 emission factors that can be used in regulations.
- Adverse effects on other environmental parameters or animal welfare conditions has to be avoided.

Based on a quick scan study of available reduction options the following technical approaches were elaborated in the research program:

- Application of bedding materials that may have a low potential for PM10 emission.
- Adjustment of light schedules to control animal activity and PM10 emission in broiler houses
- Reducing emissions by applying vegetable oil films on surfaces that bind dust particles (by daily sprinkling during short intervals)
- Ionization technology to bind particulate matter
- Combined air scrubbers
- Water curtains and simple water scrubbers
- Drying tunnels that utilize ventilation from the animal house
- Reducing emissions by applying water films on the litter surface
- Electrostatic devices and dry dust filters
- New concepts proposed by industry

For each option first an inventory was made of directly available technology from other agricultural and industrial sectors. This was followed by an optimization phase, if needed first on laboratory scale, followed by application on experimental farm scale, and subsequently on practical farm scale. Finally the optimized technology was examined in a test program based on a standardized measurement protocol for PM10 emission factors (Hofschreuder et al., 2008).

PM10 and PM2.5 measurement methods

Dust particles smaller than 10 μm (PM10) and particles smaller than 2.5 μm (PM2.5) were in most subprojects routinely sampled over 24 hour periods. The sampling position was close to the inlet of the ventilation shafts: at a horizontal distance of 0.5 m from the exhaust opening and at a vertical distance of 0.10 m underneath the exhaust opening. One PM10 sampler and one PM2.5 sampler were placed outside the house to measure background dust concentrations. Dust was collected on glass fibre filters (Ø 47 mm, type GF-3, Macherey-Nagel, Düren, Germany) after cyclonic separation with cyclone dust collectors (URG corp., Chapel Hill, USA). Separate cyclone dust collectors were used for PM10 and PM2.5 particles. Constant air flow pumps (Charlie HV, Ravebo Supply B.V., Brielle, the Netherlands) were used to sample the air, programmed at a flow rate of 1 m3/h. During sampling, a moisture collection vessel for condensed water was located between the pump and the cyclone dust collector to protect the mechanics and electronics of the pump. Details of these equipments are shown in Figure 1. The pumps are able to keep a constant air flow using a temperature sensor at the same position as the inlet of the cyclone dust collector. This flow can even be kept constant when the glass fibre filter is heavily loaded. The volume of air passing through the cyclone dust separator was transformed to standard conditions of 1 atmosphere and 0oC. The glass fibre filters were weighed before and after loading under standard conditions (temperature of 20°C ± 1 °C and 50% ± 5% humidity) with a Mettler balance (minimum reading 10 μg), according

to NEN-EN 14907. The difference in the weight of the filter before and after loading and the standardized air flow were used to calculate PM10 and PM2.5 concentrations of the air sampled during 24 hours.

Figure 1 Sampling equipment for PM10 and PM2.5. Photograph upper left (from left to right): inlet, PM10 and PM2.5 cyclone collector and filter holder. Photograph upper right: adapted inlet for cyclone collectors. Photograph left bottom: the constant flow pump. Photograph right bottom: a constant flow pump connected to the condensed water collection vessel

The personal exposure to PM10 during the different tests was determined using a DustTrak (DustTrak TM Aerosol Monitor, model 8520, TSI Incorporated, Shoreview, USA). The DustTrak was attached to the breast of one of the workers at a height of approximately 1.5 m. Sampling was done during a routine inspection of seven minutes per room. PM10 concentrations (mg m-3) were determined every second and one minute averages were logged in the DustTrak memory, resulting in seven values for each room.

RESULTS

In this section the major findings from the 2008-2011 program, depending on the phase and progress in the different subprojects, will be presented for the first four technical options from the program.

Type of bedding material in broiler houses

The effects of bedding material on PM10 emissions from broiler houses and the performance of broilers were examined. The study was performed in experimental broiler house that comprised two flocks with a growing period of 35 days each. This mechanically ventilated broiler house comprised eight identical climate rooms. Each room was divided into 4 pens and in each pen 565 day-old broilers were placed. At 35 days of age the broilers were delivered to the slaughter house. Feed and water were given ad libitum during the whole experiment. In this study the following bedding materials were compared: white wood shavings, chopped wheat straw, ground rapeseed straw and silage maize. In each climate room one bedding material was used. Within a flock/round each bedding material was replicated twice. PM10, PM2.5 and ammonia concentrations were measured at the ventilation shaft of the exhaust air and of the incoming air. Ventilation rate was measured by anemometers with the same diameter as the ventilation shaft. Ammonia and ventilation rate were measured continuously, whereas dust concentrations were measured during 24 h at 16, 23, 30 and 33 days of age. Beside these measurements also the performance results (e.g. growth rate, mortality, feed consumption, water consumption and feed conversion rate) and the dry matter content of the litter were determined.

From the results of this study the following was concluded:

- The examined bedding material had no statistically significant effect on PM10 emission.
- PM2.5 concentration was on average 4.8% of PM10 concentration. This percentage depended on the production stage, and is increasing with the age of the animals.
- Silage maize had a lower ammonia emission, 49-58%, compared to wood shavings, wheat straw and rapeseed.
- The use of silage maize resulted in higher energy costs (+20%).
- Bedding material had no effect on broiler performance (growth, feed conversion ratio and mortality)

The conclusion from this research was that a further elaboration of the bedding material approach on practical farm scale was not justified, as far as PM10 abatement concerns. The study however showed interesting differences in ammonia emission that could be utilized in practice. A detailed overview of this study is reported by van Harn et al. 2009a.

Light schedules in broiler houses

The effect was examined of light schedule and light intensity on fine dust emission, ammonia emission from broiler houses and on the performance and welfare of the birds. The study was performed in a mechanically ventilated broiler house that comprised eight identical climate rooms with mechanical ventilation. Each room was divided into 4 pens and in each pen 535 day-old broilers were placed. At 42 days of age the broilers were delivered to the slaughter house. Feed and water were given ad libitum during the whole experiment. Beside the control light schedules, one light schedule was based on lower light intensity, and two other on more on more frequent dark intervals, increasing the total amount of darkness. Emissions and animal performances were similarly monitored as in the bedding material study.

From the results of this study the following was concluded:

- PM2.5 and PM10 emissions were not significantly affected by the applied light schedule or intensity.
- PM2.5 concentration was on average 6.6% of PM10 concentration. This percentage depends on the production stage, and is increasing with the age of the animals
- The daily pattern of PM10 concentration is depending strongly on the light schedule
- Ammonia emissions from the broiler rooms were not significantly affected by the light schedule

The conclusion from this research was that a further elaboration of the light schedule approach on practical farm scale was not justified. Applied contrasts between light schedules had to be limited for animal welfare considerations, and were not strong enough to create significant differences in dust emission. A detailed overview of this study is reported by van Harn et al. 2009b.

Oil film application on litter surfaces

This technology is based on an oil spraying system that applies a thin layer of rapeseed oil on the bedding, thus preventing dust to become airborne. Earlier in 2007 an oil spraying system was developed and tested in broiler houses (Aarnink et al., 2008). The system proved capable of reducing PM10 and PM2.5 emissions however, a number of optimizations were needed.

In this research the following optimizations were made to the system: (a) oil was applied up from day 21 instead of day 12 of the production cycle to minimize the amount of oil applied (b) the number of nozzles per room was doubled and (c) the air and oil pressure of the system was optimized to prevent generation and emission of small (<10 μm) oil droplets. The objective of the study was to determine the effects of oil dosage (0, 8, 15 ml/m2) and application frequency (daily, once every two days) using this optimized system, on the emissions of PM10, PM2.5, ammonia and odour and on personal dust exposure, animal welfare, production and cleaning of the rooms. This study is reported in detail by Winkel et al. (2009), the main elements are summarized below.

The experiment was conducted in 6 mechanically ventilated rooms of the applied poultry research centre 'Het Spelderholt', during two production cycles. Two rooms served as controls, four as treatment rooms. In treatment rooms oil was applied at 8.00 AM up from day 21. Treatments were randomly assigned to the rooms. Rooms were identical and measured 8.3 x 16.0 m. All other aspects than the treatments applied, like ventilation, bedding, feeding, drinking, vaccination, etcetera, were identical between rooms. Per room 2675 broilers were placed (20 per m2) that were reared for 35 days up to a body weight of 1.9-2.0 kg. PM10, PM2.5, ammonia and odour concentrations were measured near the ventilation shaft of the exhaust air and of the incoming air. Ammonia concentrations and ventilation rate were measured continuously. PM10 and PM2.5 concentrations were measured gravimetrically during 24 hours on days 16, 23, 30 and 33, and optically to derive daily emission patterns.

From the results of this study the following was concluded:

- Daily application of 8 and 15 ml/m2, using this optimized system up from day 21, reduced average PM10 emission by 59 and 64% respectively and PM2.5 emission by 81 and 74% respectively. Best strategy seems daily application of 8 ml/ m2.
- The PM10 concentration is strongly dependent of the lighting scheme, with low concentrations during dark periods and high concentrations during lighting periods.
- The application of an oil film reduces personal dust exposure by 75 to 95% which is an important advantage in comparison with 'end of pipe techniques', like air scrubbers.
- The application of an oil film does not influence emissions of ammonia and odour.
- The application of an oil film does not influence production parameters.
- Application of an oil film did not influence the prevalence and severity of breast fouling, breast irritations, upper leg scratches, burning heals and foot pad lesions, of which the latter is an import improvement in comparison with the previous study.
- The cleaning of the treatment rooms took approximately a fourth of time extra in comparison with control rooms. This is an improvement in comparison with the previous study in which cleaning of the treatment rooms took about twice as much time as control rooms.

Based on this study it was concluded that the oil spraying system was ready to be tested in real farm conditions. This test started on two broiler farms in the summer of 2009. On each farm the PM10 emission from a control and a treatment barn is measured simultaneously every two months during a 24 hour period over one year. Results so far appear to be in line with the performances earlier measured. This test will be reported in 2010.

During the summer of 2008 and 2009 oil film application has also be tested on an experimental farm in two aviary housings for layers. To avoid contamination of laying nests and manure belts, application of oil has to be organized on a lower more local level in the littered areas. The first indicative research in 2008 based on local manual spraying of oil showed a potential reduction range for PM10 with an order of magnitude of 20 and 30%. However in subsequent research in 2009 with an oil sprinkler system mounted below the laying nests, these effects could not be repeated. It was concluded that local application methods of oil needed further improvement before tests on practical farms can be carried out. Reports on the research in aviary systems are in preparation, and will be published in 2010.

Ionization techniques

In ionization techniques, dust particles are loaded by devices (coronas) that emit electrical charges into the air. The loaded dust particles attach to grounded surfaces in the animal house. The principle is applied in different settings on commercial scale. From a preceding desk study it was concluded that this could be an promising approach for poultry houses.

The work in this research program focused on the performance of a commercially available air ionization system to the reduce PM10 and PM2.5, odour and NH3 in broiler houses. The experiment was conducted in four identical rooms of the applied poultry research centre ‘Het Spelderholt’, in Lelystad. In each room 2,676 broilers, a mixture of males and females, were placed at a stocking density of 20 birds per m2. Broilers were delivered at an age of 35 days and a target weight of 1,900-2,000 grams. As ionization system the “Electrostatic Particle Ionization” (EPI) system (Baumgartner Environics, Inc.) was used. The EPI system consisted of two rows of inline, negative DC ionization units running along the length of the rooms, composed of a discharge electrode (ion generator) and a grounded collection plate. These units were installed by the manufacturing company at a height of approximately 2.5 m above the litter. The ionization system was randomly assigned to 2 of the 4 rooms, while the other two rooms served as control. The experiment was done during two rearing cycles (rounds). Ventilation rates, PM10 and PM2.5 concentrations and emissions, personal dust exposure, odour and ammonia, animal production and exterior quality of the birds were measured. This research is reported in detail by Cambra et al. (2009).

On average PM10 emissions for the control and ionization rooms were 33.4 and 20.1 g/year per bird in the first round and 16.1 and 11.7 g/year per bird in the second round. At logarithmic scale PM10 dust emissions decreased on average by 34% . The reduction was not influenced by the age of the birds. The overall measured mass reduction for PM10 emission was 36%. PM2.5 emissions for the control and ionization rooms were the same in the first round, on average 1.42 g/year per bird and 0.80 and 0.58 g/year per bird in the second round. At logarithmic scale PM2.5 dust emissions decreased on average by 33%.

Continuous PM10 measurements showed a similar PM10 concentration pattern over the experiment. Concentrations of PM10 increased when lights were on, and decreased when lights were off. The cleaning of grounded collectors showed no statistically significant difference in PM10 concentrations in ionization rooms before and after cleaning, despite observed reductions of 10%, 24 h after cleaning. Personal sampling at human’s breathing height showed that ionization rooms had a mean reduction of PM10 exposure of about 30%.

There was no difference in odour, and ammonia emissions between control and ionization treatments, nor was there any effect of ionization on performance of the broilers (weight gain, mortality, feed conversion), on foot-pad lesions, on other parameters of external quality of the broilers, and on the quality of the bedding material.

Based on this study it was concluded that the ionization system was ready to be tested under real farm conditions. This test started on two broiler farms in the summer of 2009. On each farm the PM10 emission from a control and a treatment barn is measured simultaneously every two months during a 24 hour period for one year. Results so far appear to be in line with the performances earlier measured. This test will be reported in 2010.

During 2009 an ionization system has also be tested on an experimental farm in two aviary housings for layers. The fundamental difference between application in broiler houses and layer houses is that that production cycles differ substantially. Unless loaded surfaces are cleaned at regular basis, the performance of ionization in layer houses will decreases to negligible levels. From the work in the aviary housings it was concluded that automatic cleaning systems have to be developed before tests on practical farms can be carried out. Reports on the research in aviary systems are in preparation, and will be published in 2010.

OUTLOOK FOR IMPLEMENTATION OF ABATEMENT TECHNOLOGY

A wide range of different abatement technologies is evaluated in the program. They vary from approaches that affect the generation of dust particles within the animal house to approaches that are end-of-pipe treatment of ventilation air. From the start of the program there was a strong preference to develop especially measures that both improve air quality inside the animal house and reduce emissions. As was shown again in this research, air quality in poultry houses with litter must be drastically improved for the health of both workers and animals. All techniques discussed in this paper were based on decreasing dust concentrations within the barns, and therefore in theory contribute to improving working and living conditions. The program aims at developing abatement methods that differ in performance and cost level, because in practice required reduction levels differ from farm to farm, depending on the regional background concentrations. Both the bedding material approach and the light schedule approach were expected to give small reductions, but given their relatively low cost level it was considered justified to include them in the program. Results, however, showed that further testing under practical conditions should not be undertaken.

Both oil film application and ionization were successfully developed for implementation in broiler houses. The research on the experimental facilities and the first test results under practical conditions were convincing enough to be provisionally placed by regulatory authorities on the national list as acknowledged abatement methods for broiler farms. Yet is has to be realized that for successful implementation a considerable demonstration effort is required to convince farmers. For layer houses still a considerable effort has to be undertaken to develop adequate abatement methods that improve air quality in barns. So far, only water scrubbers and biotrickling filters that are modified for poultry production are available for this animal production category.

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