Development and implementation of air pollution mitigation systems for animal husbandry in The Netherlands

N.W.M. Ogink, A.J.A. Aarnink & R.W. Melse
Wageningen UR Livestock Research, PO Box 135, 6700 AC Wageningen, the Netherlands, email: Nico.Ogink@wur.nl

Abstract
Being one of the most densely populated nations in Europe, and housing an economically important livestock industry, the Netherlands face the challenge to strictly control environmental impacts of livestock production on residential and natural areas. The aim of this paper is to describe the main characteristics of the approaches followed in this policy with the focus on ammonia emission mitigation. It outlines technological developments and the implementation of mitigation technology in practice, and discusses benefits and drawbacks of the followed approach, and the possibility to make use of developed mitigation options in other regions with different productions settings. Since 1980 the ammonia emission from agriculture has been reduced by nearly 50%. This major achievement can be attributed to a number of general measures related to mandatory manure storage covering, low emission manure application techniques, and the implementation of low emission housing systems. Low emission housing systems have been developed for all main animal categories. Low emission is generally reached by restricting emitting surfaces, and quick removal and drying of manure. In general ammonia emissions were reduced by 50% and more, when compared to existing conventional systems. Higher reduction levels (70-90%) can be reached by air scrubbers. All measures were tested on practical farms using standardized measurement protocols. Low emission housing systems developed in one region cannot be simply transferred to other production regions. However, most of the mitigation principles that underlie these housing systems can be successfully applied in other settings as well, if modified and adapted to local conditions.

Keywords: livestock, emission, ammonia, odour, PM10, animal housing systems

Introduction

Being one of the most densely populated nations in Europe, and housing an economically important livestock industry, the Netherlands face the challenge to strictly control environmental impacts of livestock production on residential and natural areas. Gaseous emissions of ammonia, odour, greenhouse gases and dust are a major part of this environmental impact. Livestock production is responsible for 95% of the national ammonia emission causing acidification and eutrophication of natural ecosystems, and 50% of the total emission of all acidifying compounds (EDC, 2007). Furthermore, odour emissions from animal housing and land application of manure are being increasingly considered a nuisance in densely populated countries as the scale of livestock operations expands and an increasing number of rural residential developments are built in traditional farming areas. Finally, a large number of premature deaths and health problems are associated with the emission of particulate matter (PM) (WHO, 2006), i.e. tiny solid or liquid particles that are suspended in the air (e.g. dust, dirt, soot, smoke, and liquid droplets). Approximately 20% of the primary PM10 production in the Netherlands is estimated to originate from poultry and pig operations. In order to comply with air quality regulations defined by the European Union (EU) and by national standards, The Netherlands have developed national policies for the mitigation of livestock emissions since the early 1990's. The aim of this paper is to describe the main characteristics of the approaches followed in this policy with the focus on ammonia emission mitigation. It outlines technological developments and the implementation of mitigation technology in practice, and finally discusses benefits and drawbacks of the followed approach and the possibility to make use developed mitigation options in other regions with different productions settings.

Mitigation of ammonia emission from animal production

General approach

Over the last 25 years considerable efforts were invested into the development of NH_3 abatement techniques in animal operations in the Netherlands. Since 1980 the ammonia emission from agriculture has been reduced by nearly 50%. This major achievement can be attributed to a number of general binding rules:

(a) All farmers are obliged to cover their outdoor slurry storage facilities in order to reduce emissions of ammonia and odour.
(b) Surface spreading of animal manure (application by open broadcasting) has been gradually banned by the Soil Protection Act. From 1995 on nearly all animal manure has been applied using low-ammonia-emission techniques.
(c) In a zone of 250 m around nature areas that have been labeled as vulnerable ecosystems, new livestock farms are not allowed and existing livestock farms may only expand if housing systems are applied with a very high reduction of ammonia emission.
(d) For dairy farming an agreement was made between national government and the Dutch Farmers Union that aims to reduce the nitrogen content of the feed and thus of the urine (as indicated by milk urea content) by 2010, with the aim to reduce ammonia emission from cattle.
(e) Maximum emission levels on farm level are imposed for all main animal categories in order to reduce ammonia. For every animal category maximum emission levels are listed, expressed as kg NH_3/animal place/year To comply with these maximum emission demands, low emission housing systems and/or air purification techniques have to be installed.

Especially the latter measure has a direct impact on the operation of livestock farms in practice. Since the late nineties low emission housing systems have been gradually implemented in the livestock industry. By 2010 all pig and poultry and dairy operations must comply with maximum ammonia emission levels by using low ammonia-emission housing systems. In some specific situations the transition period has been extended to 2012 or 2013.

Development of low ammonia-emission housing systems
From 1993 farmers and industry in the Netherlands were financially encouraged to develop and implement low emission housing systems on a voluntary basis. Systems with an ammonia emission reduction of 50% or higher (as compared to traditional housing systems) received a so-called Green Label award and were certified as a low emission system. This resulted in the development of a large variety of low-emission livestock housing systems, including systems for end-of-pipe treatment of exhaust air from animal houses, like air scrubbers. Over 50 Green Label awards were issued and the implementation of low-emission housing systems increased, especially in pig and poultry farming (Starmans and Van der Hoek, 2007). Later on the Green Label awarding system was terminated and followed up early 2000 by the Ammonia and Livestock Farming Regulation. This regulation includes an official list that contains all legally acknowledged low-ammonia-emission housing systems. New low-emission housing systems, including end-of-pipe techniques such as air scrubbers, are added to this list on basis of test reports, as explained in the next section.

Testing and practical verification of ammonia mitigation systems
When a manufacturer has developed a new low-ammonia housing system or scrubber system, or has redesigned an existing system and wants to market the system in the Netherlands, the effectiveness of the mitigation system must be verified. In short, the verification procedure is based on four consecutive steps:

(1) A standardized testing procedure of the system under practical farm conditions during which the ammonia emission is measured, according to a prescribed measurement protocol; or (only allowed in case of scrubber) a theoretical assessment of the design and performance of the scrubber system.

(2) Description of the essential characteristics of the system on a leaflet, and assignment of a general ammonia emission factor for this system on the regulatory list of the Ministry of Environment; the ministry is advised on this subject by an independent technical committee.

(3) Now that the system has been allowed for on-farm implementation, on each farm where the mitigation system is built it is inspected at its completion by local regulators to verify the essential hardware characteristics, as described in the environmental permit for the animal production site.

(4) Depending on the type of applied mitigation system, regular on-farm inspection and measurements related to the functioning of the system.

From this scheme it follows that the actual reduction performance of the system is tested on a limited scale before wide application as low ammonia emitting system in practice is allowed. This testing procedure for mitigation systems has recently gone through major changes, in which an intensive single farm measurement setup has been replaced by a multiple farm location test (Ogink *et al.*, 2008).

Technical principles used in low emission housing systems
Currently most low emission housing systems in pig production are based on modified pen and manure storage designs, in which the size of ammonia emitting surfaces in the pen is reduced. The most frequently applied approach in practice are based on v-shaped slurry channels below the slats, that are regularly emptied by pull and plug systems. Besides reduced emitting surface, solid floor in pens are convex shaped to stimulate fast urine drainage to the slurry storage. Other approaches are based on additional equipment, like floating cooling devices for slurry surfaces in pig housings. By cooling the boundary layer above the slurry surface the transfer of ammonia from the slurry is restricted. In general the ammonia emission can be reduced by 40-50% and more compared to the conventional housing systems with partially slatted floors.

In layer houses the conversion uric acid in manure into ammonia and its subsequent emission can be controlled by quick drying and removal of manure. For this purpose conveyor manure belts under layer cages were developed to allow direct drying and fast removal of manure. Besides the effects on emission, this approach turned out to be beneficial in reducing costs for the transport of manure to other regions, because drying leads to drastic volume and mass reduction. The manure can be dried continuously on the belts by distributing air through pipes across the manure belt. The air is drawn from the top of the animal house to make as much as possible use of the heat produced by the animals. In practice almost all low emitting layer housing systems make use of this approach, both in cage housing as in aviary housings. A variety of belt drying systems exists that mainly differ in the amount of air blown on the belt, the heat exchange system, and the frequency of removal of the manure.

In broiler production decomposition of uric acid into ammonia can be prevented through stimulating water evaporation from the litter. This can be achieved by enhanced internal air circulation. A widely applied approach is based on shafts with controllable fans inside, hanging vertically in the broiler house. Warmer air form the upper part of the house is redirected towards the litter in a horizontal circular plane. This way, enhanced air turbulence over the broilers and litter at a height of approximately 1 meter above the animals is reached. Ammonia emissions have been shown to be reduced by around 50%.

Compared to pig and poultry production only a limited number of low emission housing options are available in dairy production. Emissions in conventional cubicle houses with slats and manure storage under the slats can be reduced by replacing slats by closed floors with urine drains and scraper systems for manure removal. However their reduction performance is limited and poor cow walking characteristics of such closed floors restrict application in practice.

Development and implementation of air scrubbers
For about 25 years air scrubbers have been applied in the Netherlands in intensive livestock farming. Two main scrubbing types can be distinguished: acid scrubbers and biological scrubbers. Acid scrubbers are based on the entrapment of ammonia in acid liquid that is recirculated over a packed bed and the frequent discharge of the resulting ammonium salt solution at a concentration of about 150 g/L. Usually sulfuric acid is applied and pH is kept between 2 and pH 4. Melse and Ogink (2005) reported average ammonia removal efficiencies of 96% for farm-scale operated acid scrubbers. Reported average removal efficiency for odor was only 31% and showed a large variation. Acid scrubbers are considered as a state-of-the-art technique in cases where very high reductions of ammonia emissions are required.

In bio-scrubbers, or biotrickling filters, bacteria convert ammonia into nitrite and nitrate. Nitrogen concentrations in the water are kept below inhibiting levels by regular discharge of the recirculation liquid. The biomass is partly attached to the packed bed and partly suspended in the recirculation liquid. As compared to chemical scrubbers the discharge volume of biotrickling filters is about 8 to 10 times higher. Average ammonia removal efficiency at farm operations amounted 70%, whereas for odor removal a large variation was found with an average removal efficiency of 44%. In general, biotrickling filters have a higher odor removal potential than acid scrubbers because a wide array of odor components dissolved in the circulation water are broken down by the biomass, whereas in chemical scrubbers only part of the odor components are kept in solution due to a low pH. Scrubbers are mainly applied in pig housings with central ventilation ducts and have been applied at an increasing scale over last years, mainly because they allow scaling up of farms without violating environmental regulations. In 2008 more than 10% of all pigs were produced in housings with air purification, and this level is still increasing. Only a few examples are known where they are applied in poultry houses. The high dust content of ventilation air increases the risks of blockage of the packing bed causing high pressure drop and increased energy use. Although acid air scrubber and biological air scrubber, both single-stage scrubbing systems, were originally developed for ammonia removal only, also part of the odour and particulate matter content of the air will be removed at the same time. In the last few years also so-called multi-stage air scrubbers are applied that specifically aim to achieve significant emission reduction of odour and particulate matter (PM 2.5 and PM 10) as well. Usually in multi-stage scrubbers in each consecutive stage different compounds are removed (Melse *et al.*, 2008).

Discussion and future outlook

Ammonia emissions from animal production in general have been considerably reduced over the last 25 years in The Netherlands. This is achieved by a combination of a strict regulatory approach and large research investments in research and implementation of low emission housing systems and techniques. Key element in this approach is the presence of an independent assessment system that is trustworthy for all involved stakeholders. The application of standardized evaluation protocols, with reliable measurement and sampling methods applied on farms in practice, is essential in this process. Since the early implementation of low emission technology, the need for clear verification of techniques by inspectors on farms have been considered important. For that reasons only techniques have been admitted that could easily be verified in terms of available hardware on farm locations. This verification is especially considered important in case of air scrubbers, were malfunction may result in severe odour nuisance and high ammonia emission to natural areas. Recently, public concern raised because of examples of installations that do not operate properly, or are not operating at all. There is a general understanding among involved stakeholders that a strong improvement in monitoring of the operational performance of scrubbers is essential to ensure and regain the confidence in this mitigation technology.

Low emission housing systems developed in one region cannot be simply transferred to other production regions. However, most of the mitigation principles that underly these housing systems can be successfully applied in other settings as well, if modified and adapted to local conditions. For example restriction of emitting surfaces in pig and cattle housings and quick removal of manure can be reached in most situations. Implementation of forced drying and quick removal of manure should be feasible in different types of poultry housings. In most cases investments in low emission are not compensated by higher animal performances. However, practice has shown that extra costs can be kept to a level that keeps farmers in a competitive position, and at the same time improves sustainability.

References

EDC (2007). Environmental Data Compendium (EDC); http://www.mnp.nl/mnc/sitemap-en.html; MNP, Bilthoven, CBS, Voorburg, WUR, Wageningen, Netherlands.

Melse, R.W., N.W.M. Ogink. 2005. Air scrubbing techniques for ammonia and odor reduction at livestock operations: Review of on-farm research in the Netherlands. Transactions of the ASAE, Vol 48, No 6, pp 2303-2313.

Ogink, N.W.M.; J. Mosquera; R.W. Melse (2008). Standardized testing procedures for assessing ammonia and odor emissions from animal housing systems in the Netherlands. Proceedings of the Mitigating Air Emissions from Animal Feeding Operations Conference, May 19 - 21, 2008, Des Moines, Iowa (IA), USA.

Starmans, D.A.J.; K.W. Van der Hoek (eds) (2007). Ammonia, the case for the Netherlands; Wageningen Academic Publishers, Wageningen, Netherlands; ISBN 978-90-8686-028-9; 201 pp.

WHO, 2006. Health risks of particulate matter from long-range transboundary air pollution. Joint WHO/Convention Task force on the Health Aspects of Air Pollution. European Centre for Environment and Health Bonn Office. Available at: http://www.euro.who.int/document/E88189.pdf.