Abatement, control and regulation of emissions and ambient concentrations of odour and allergens from livestock farming in the Nordic countries

P. V. Madsen[1], O. Hertel[1], T. Sigsgaard[2] J. Bønløkke[2], and K. Puputti[3]

Abstract

A survey on current practise and ongoing policy regarding abatement, control and regulation of emissions and ambient concentrations of odour and allergens from livestock farming in the Nordic countries is planned to form the basis for a common Nordic strategy in this area. Such a strategy would be an important element in reducing the number of people in the Nordic Countries exposed to odour and/or allergens as well as to other livestock related compounds health hazardous beyond certain thresholds. The project is foreseen to strengthen the knowledge exchange and cooperation between the Nordic countries and in the following phases address the urgent matter in EU. The goal of the project is to reducing the number of inhabitants in the Nordic countries that are exposed to odour and airborne allergens as well as other emissions from animal farming with possible health impact and to investigate to what extent the various countries have developed national strategies in order to control and regulate odour annoyance and allergen of dispersion from livestock farming.

Keywords: odour management, bioaerosols, emission from livestock, allergens, annoyance, regulation, health and life quality

Introduction

Thousands of different odour and bioaerosols compounds from livestock farming have been identified (Attwood P. et al. 2004). Odour from livestock farming is usually a mixture of many compounds (Avery R. et al. 2004). Some of these may enhance the effect of other compounds whereas others may eliminate each other. A number of compounds that may be difficult to detect separately might in some cases together give a strong smell. The human nose is able to distinguish about 10,000 different odour compounds. More than 200 odour compounds have been identified in manure. Although odour is in gas phase, some compounds may be associated with dust and can later evaporate.

All types of animal house hold may lead to odour problems, but pig production appears to be the most important cause of odour leading to annoyance problems (Eder W. et. al. 2006) – at least quantitavely. Another important concern is the potential health problems related to allergens and other harmful compounds emitted from farm animals. In this context especially allergens from horses have been in focus in a strong debate that has taken place in Sweden.

The origins of the bioaerosols are the animals themselves: their feed, stools and urine with some allergens from skin and hair. Additional components stem from insects and microorganisms thriving on the organic material in animal buildings. Disinfectants and other agents applied to the environment are also present, and may add to the adverse health effects of workers (Preller L. et al. 1995). Bacteria thrive in this environment and give origin to high concentrations of bacteria, endotoxins, and other bacterial components in the air. The fungal load in animal houses with concrete floors without litter is likely to originate primarily from outside air. For livestock raised on litter or animals fed on hay fungi probably originate to a great extent indoors. This is important, since fungal spores appear to be closer associated with the asthma prevalence in livestock farmers than endotoxins and more protective in individuals disposed for allergic diseases and more harmful in individuals not disposed for allergic diseases (Eduard W. et al. 2004).

Bioaerosols containing this type of components have repeatedly been found to induce lung function changes, upper airway and mucosal inflammation, symptoms and sys-

[1] National Environmental Research Institute (NERI) Department for Atmospheric Environment (ATMI) Aarhus, Denmark

[2] Aarhus University, Department for Environment and Occupational Health, Aarhus, Denmark

[3] Finnish Meteorological Institute, Air Quality Research, Helsinki, Finland

temic inflammatory reactions in adults exposed to them.

Airborne concentrations of live bacteria are also very high (Duchaine C. et al. 2000, Donham K. J. et al. 1986, Attwood P. et al. 1987). Gram-positive bacteria dominate this population as they easily represent 90-95% of the total bacteria. Experimentally, endotoxins are capable of inducing many of the symptoms associated with livestock exposure, including fever reactions as seen in organic dust toxic syndrome and farmer's lung and worsening of asthma with cough and breathlessness. Thus, it is not surprising, that endotoxins have drawn so much attraction. Several epidemiologic investigations have found that respirable endotoxin in farming environments were closer associated with adverse effects on the airways and immune system than were airborne dust levels (Wing S. et al. 2002).

National status of odour

In Denmark an increasing pig production has increased the odour problems over the last decade. Table 1 shows the number of private residences in Denmark that are placed in the vicinity of livestock farms over a certain size. This selection is based on the number of Animal Units per livestock farm. One Animal Unit is defined as the animals leading to an emission of 100 kg N/year. This is equal to 0.85 milking cow in stable, annual production of 36 slaughter pigs (equal to 9 in stable), or 2900 annually produced slaughter chickens. Larger livestock farms typically cover an area with a diameter of 100 m (radius 50 m), and the distances given in Table 1 should therefore be reduced by approximately 50 m. Thus about 6700 residences are placed within 300 m from a livestock farm with more than 249 Animal Units. It should here be noted that the figures in the table refer to number of houses in Denmark with a potential odour problem related to livestock farming.

Table 1:
Number of private residences in the vicinity of livestock farms in Denmark based on registry data per 31/12/2002 (Source: Steen Gyldenkærne Policy Analysis, NERI 2005)

	Size and number of livestock farms	
	>125 DE	>249 DE
	6238	963
Radius (meters)	Number of private houses	
100	8708	1258
150	13939	1953
250	28190	3983
350	46548	6699
500	84312	12561
1000	298966	53630

Odour problems are mainly related to manure and the emissions may have three different sources: from stables, manure storages and from out bringing to the fields. The odour from storages may be reduced significantly e.g. by covering of manure storage tanks. Out bringing takes place over relatively short periods of time, whereas stables have to be ventilated continuously. Stables may therefore emit odour during the entire year and research in this field has to a large part been devoted to regulation of ventilation and control of air flows inside the stables.

In Denmark the agriculture is in general more intense than in the other Nordic countries. The public concern about especially about odour and ammonia has also been high for several years putting a pressure on the political system for regulation of this area through legislation. A Danish Guideline for handling odour from livestock farming has been in preparation for a longer period of time. Currently this Guideline is awaiting the restructuring of Danish counties and municipalities which took place by 1. January 2007.

In Sweden there has recently been an increasing concern not only to odour problems but also concerning the release of allergens from livestock farming and how these releases of allergens affect the health of the population in the nearby surroundings of the farms. In Germany the "NILS" study has shown, that there is a detrimental effect on the lung function of living in the vicinity of many animal farms. The researchers showed, that for people exposed to > 20EU LPS m^{-3} there was a tendency to asthmatic patterns in lung function measures. Allergens from horses may to a higher extend than allergens from other farm animals be spread further away from the farm houses.

Finland has no formalised guidelines for odour. Applied principles are formed with certain limit values or with set back distances. Odour management obligations for odour emitting plants are set in regional EPA environmental permits. Often the emission limits are set and followed up locally resulting in limited predictability for farmers. For life stock operation, set back distances are usually applied.

Livestock farming has caused odour complaints in Finland, the impact of these activities is usually limited to less than 0.5 km, although large pig farms can cause significant annoyance depending on the volume and animal unit.

Due to environmental measures, the odour load and annoyance has generally diminished from industries, agricultural odour being an exception. The reason for this is that the production units in Finnish livestock production are significantly increasing as well as in the other Nordic countries. Large animal houses are built closer to dwelling houses and as a consequence, odour annoyance becomes significant (Beaman A. L. 1988).

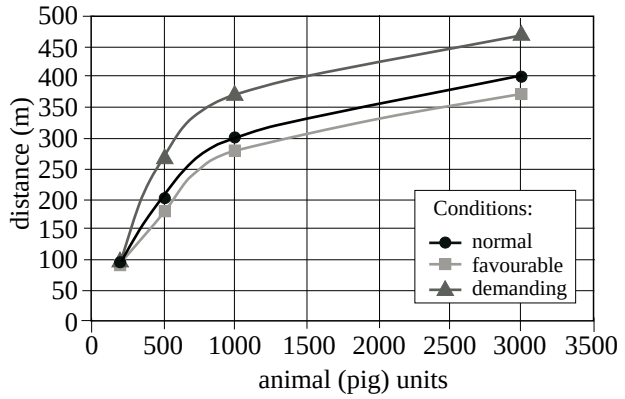
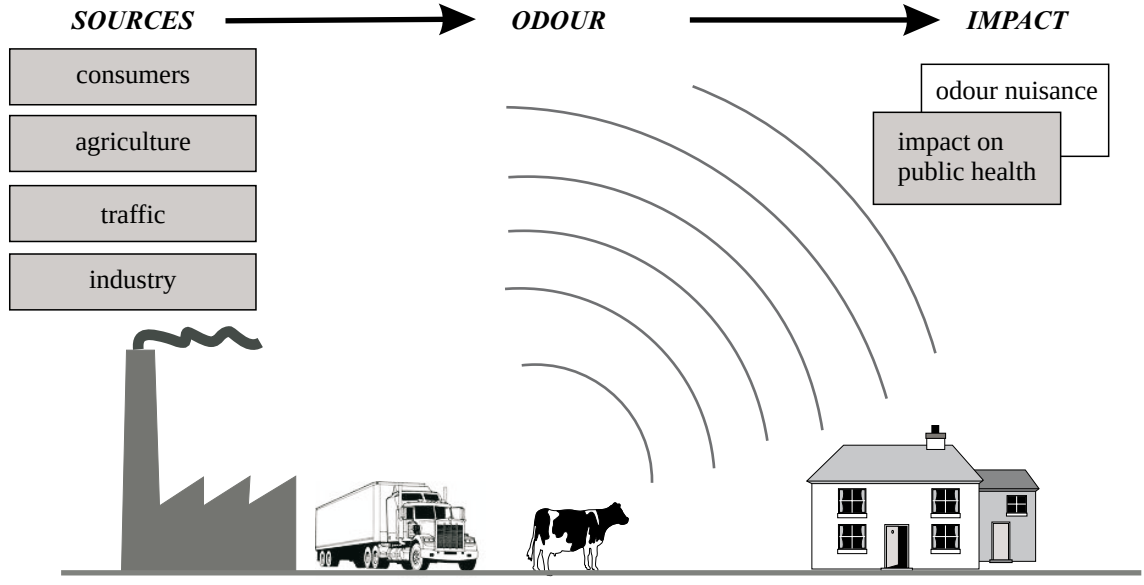


Figure 1:
Minimum distance between livestock units and sensible areas

In the nearest surrounding area of the production unit the odour occurrence levels are above 12 % of favourable condition calculated in yearly hours. The odour occurrence levels are decreasing as the distance from emission sources is increasing.



Source: RIVM

RIVM/ED/Oct02/0949

Figure 2:
Sources of odour

Distinction between odour nuisance and severe odour nuisance

The Dutch government uses two definitions for the environmental problem of odour nuisance: odour nuisance and severe odour nuisance. The concept of odour nuisance is based on the terminology used by Statistics Netherlands in its "Ongoing Survey of Living Conditions" (OSLC). The term 'severe odour nuisance' comes from the periodical nuisance survey conducted by the Dutch research institute TNO (also known as the 'questionnaire survey').

Odour nuisance (in the Statistics Netherlands definition) is defined as experiencing frequent or occasional nuisance from stench, in line with the questions asked in the OSLC. Sources of odour included in the survey are road traffic, industry or business, agriculture and open fires/multi-burners illustrated in figure 2.

Severe odour nuisance (in the definition given by TNO) is based on the question from the periodical nuisance survey of TNO about the extent to which people see a specific source in the living environment as a nuisance on a scale from of 1 (not a nuisance at all) to 10 (extreme nuisance). People giving answers in the 8 to 10 range are classified as experiencing 'severe nuisance' (Rantakrans E. et al. 1995).

It is not easy to compare the concepts because of the different ways the questions are formulated and the different definitions of the sources.

Allergens and health

It is a well known fact that exposure to the environment in swine confinement buildings is a cause of respiratory impairment and loss of lung function in farmers (Omland O. 2002, Omland O. et al. 2000, Preller L. et al. 1995b), Thorne, (Cormier Y. et al. 1991). Acute exposure to high amounts of dust from swine confinement buildings has

been shown to induce a neutrophilic pneumonitis.

Furthermore acute exposure of subjects has been shown to induce substantial more inflammation in subjects naïve to farming compared to farmers. Cattle and poultry are also known to cause both short and long term respiratory impairment among exposed workers. In addition there are reports on adverse effects on the respiratory system from exposures to other livestock such as sheep and horses. The common belief that odour is worse from swine than from cattle farms is supported by the greater emission rates from such buildings in Europe (Takai H. et al. 1998).

The airway diseases that can be caused by livestock exposures include development of allergic and non-allergic rhinitis, other upper airway and mucous membrane irritation symptoms, allergic and non-allergic asthma, aggravation of existing asthma, chronic obstructive pulmonary disease, hypersensitivity pneumonitis, and airway infections. Allergic alveolitis may be caused by exposure to mouldy hay and thus be related to although not directly caused by exposure to cattle and cows.

Odour alone has been shown to negatively affect immune function in neighbouring residential mediated via stress (Avery R. C. et al. 2004) but the isolated effect of odour has not been studied in livestock exposed workers. Allergens appear to play a limited role in industrialized farming environments such as in modern swine farming with low prevalences of allergic sensitization and allergic diseases. It cannot be ruled out that this is partly because of self selection out of the trade by individuals with atopic disposition. Most investigators agree that no single component or factor is responsible for the adverse health effects that occur after exposure to the animal farming environment. Rather the mixture of gases, dust particles, allergens, microbes and substances of microbial origin together induce the neutrophilic inflammation in the airways and the systemic changes in immune function.

Many different allergens of animal and plant origin are abundant in farming. In cattle breeders it has been shown that even several years after the last animal contact, there are significantly more allergens in the farmers houses, compared to other houses (Schulze A. 2006). For people having horses, it has also been observed, that their families are exposed to high amounts of horse allergen. This means that the allergens are stable over time, and can be transported from the stables to housing quarters of the farmers or horseback riders themselves. There is only very scarce information on the allergen concentrations in the area surrounding a horse stable or a cow-shed.

Exposure to high levels of endotoxin is particularly well documented in many types of farming, but other substances of microbiologic origin such as peptidoglycans and β-glucans are present in high concentrations. Airborne concentrations of live bacteria are also very high (Duchaine C. et al. 2000), Donham K. J. et al. 1986, Attwood P. et al. 1987a). Gram-positive bacteria dominate this population as they easily represent 90-95% of the total (dead as well as live) bacteria.

The origins of the bioaerosols are the animals themselves: their feed, stools and urine with some allergens from skin and hair. Additional components stem from insects and microorganisms thriving on the organic material in animal buildings. Disinfectants and other agents applied to the environment are also present, and may add to the adverse health effects of workers (Preller L. et al. 1995a). Bacteria thrive in this environment and give origin to high concentrations of bacteria, endotoxins, and other bacterial components in the air. The fungal load in animal houses with concrete floors without litter is likely to originate primarily from outside air (at least this is true for pigs on slatter). For livestock raised on litter (e.g. swine or cattle on chopped straw or on shavings) or animals fed on hay (such as horses) fungi probably originate to a great extent indoors. This is important, since fungal spores appear to be closer associated with the asthma prevalence in livestock farmers than endotoxins (more protective in atopics and more harmfull in non-atopics) (Eduard W. et al. 2004c). Gases evaporate from the manure pits underneath or in close adjunction to the swine buildings.

Bioaerosols containing this type of components have repeatedly been found to induce lung function changes, upper airway and mucosal inflammation, symptoms and systemic inflammatory reactions in adults exposed to them.

The effects on children's health are subject to some debate. On the one side there is evidence that the farming environment is protective against the development of allergies and some allergic disease and more so with animal exposure. On the other side, there is impelling evidence, that high concentrations of modern livestock operations in close vicinity of children's homes is associated with negative health effects and increased risk of lung disease including asthma-like symptoms. Children's exposure is likely to differ from that of adults with less exposure from inside concentrated animal buildings and more exposure to diesel exhaust and feed, grain and other dusts outside these buildings as well as odours. Livestock exposures even appear to be strongly protective against atopy in the prenatal period (Ege M. J. et al. 2006). Whether livestock exposures are protective or harmful depends on the genetic background of the exposed person and this is true both in childhood (Eder W. et al. 2006) and adulthood (Eduard W. et al. 2004a).

Differences in technology and climate is, however, likely to cause differences in qualities and quantities of exposures in residential areas. Importantly, it has been shown that whereas bioaerosol components such as gases and bacteria can be traced at long distances from CAFO's, they are di-

luted to minute amounts within very short distances of the ventilatory outlets. However, higher background levels of e.g. endotoxin can be found in rural areas with intensive livestock production than in urban areas (Schulze A. et al. 2006). With the current knowledge of mechanisms there is no reason to think that such low levels could have adverse health effects other than those caused by odour.

Quality of life, as indicated by the number of times residents could not open their windows or go outside even in nice weather, was found to be similar in residents in the vicinity of a cattle operation or far away from livestock but greatly reduced among residents near a hog operation (Wing S. et al. 2000). More wheezing has been observed among pupils at schools in the vicinity of confined swine feeding operations (Mirabelli M. C. et al. 2006).

Regulation and abatement

Since the end of the 1990's there was a strong need felt by the environmental authorities to improve the scientific basis of the odour regulations especially in the agricultural sector to increase their acceptance and effectiveness. (Cormier Y. 2004). This was further elaborated in a couple of larger research projects (Wing S. et al. 2002).

The concern of the public is growing in the Nordic countries. It would be beneficial in the Nordic countries to exchange knowledge about strategies behind environmental management and regulation of odour and allergens from livestock farming. A common Nordic strategy could be use a basis for recommendations to a new EU legislation in this field.

Emission factor data for pig and broiler production has been established for odour impact assessments. The emission data for pig production were slightly higher than results obtained in other countries, although in the same order of magnitude. Emission rates are influenced by a range of local factors including feed, manure management, building design and ventilation rate. Certain lack of unanimity in published odour emission data speaks up for the importance of using data obtained in representative national conditions. Finnish agricultural circumstances differ noticeable from those in Central Europe or North America concerning both climate and production methods.

Odour annoyance study has showed that people's reactions to pig and poultry odour are very different. Thus no clear indication for need for set back distances for mid-size the poultry production plants could be identified in the investigated plants. On the other hand, there seems to be a need for significant set back distances for large swine production units if no odour reducing measures implemented.

Dust emitted by housing units contributes to odour transport and plumes may have potential for transmitting diseases to other housing units or neighbouring people. Odour is combined with higher concentrations of endotoxins in the surroundings of a farm. This subject is currently being investigated with regard to potential effects on health of farmer families and neighbouring residential. At the same time, a Finnish study has indicated that newborns' exposure to microbes related to livestock farming diminishes the risk for the child to develop allergies (Omland O. et al. 2002).

Summary

Odour is one of the most remarkable environmental hazards caused by livestock farming. Odour is annoying people living in the neighborhood of farming units and odour inconveniencies may cause complaining in the vicinity of production units.

A major part of the on-going projects on air emissions from agricultural sources relates to monitoring and diminishing greenhouse gases. There is, however a need to revise the current general set of guidelines for livestock production and base them on the actual odour impact. Very little data is available e.g. on odour emissions from cow sheds and fur production.

A major odour source is the application of slurry in the fields. These intermittent fugitive odour sources are difficult to regulate and control. Investigation in the odour emission and annoyance arising from spreading slurry in the field would function as a base for further guidelines.

Exposure to high levels of endotoxin is particularly well documented in many types of farming, but other substances of microbiologic origin such as peptidoglycans and β-glucans are present in high concentrations.

Reduction of life quality in cities downstream from livestock farming some studies have been conducted to investigate possible negative effects of exposure from these facilities.

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