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ENVIRONMENTAL IMPACT OF AIRBORNE POLLUTANTS FROM LIVESTOCK OPERATIONS

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Abstract

Modern farm animal production is increasingly regarded as a source of gaseous and odorous emissions which can be both a nuisance and environmentally harmful. One of the most dominant aerial compounds is ammonia (NH_3), which can cause severe ecological effects. Plants and forests near intensive animal husbandry systems can show toxic effects like necrosis of leaves, for example. Apart from these direct impacts, acidification and eutrophication of the soil and of aquatic habitats are further important ecological problems caused by NH_3. Additionally, ammonia as precursor has also the potential to form secondary aerosols. In a global context greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) are also emitted in significant amounts from livestock buildings. Cattles and housing systems with deep litter and straw in particular contribute to the overall quantities of greenhouse gases, which are responsible for climate changes. In the case of odour all livestock types has to be taken into account due to the annoying smell.

Except gases and odour primary aerosols have also to be considered. The so called bioaerosols are emitted in considerable quantities into the environment by the ventilation system. Bioaerosols in livestock buildings consist of a complex mixture of organic material (i.e. proteins), biological active components (i.e. endotoxins) and microorganisms (i.e. bacteria). Even gases such as ammonia can be adsorbed to the surface of bioaerosol particles. Typically, bioaerosols are characterised by a range of biological properties which can include infectivity, allergenicity, toxicity and pharmacological or similar effects. Therefore it is discussed whether bioaerosols may not only cause complaints in exposed farmers but also in residents in the vicinity of livestock production facilities.

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Introduction

European wide airborne emissions from industry and traffic are able to change considerably the quality of the atmosphere. To avoid, prevent or reduce harmful effects on human health and the environment as a whole, national and international committees are searching for basic principles based on common strategies to define and establish objectives for ambient air quality (COUNCIL DIRECTIVE 96/62/EC).

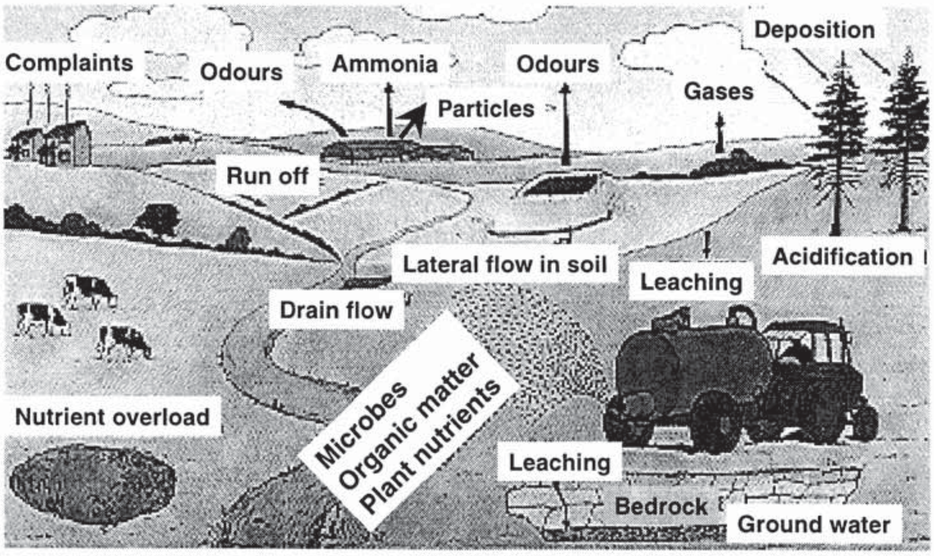
At present, the environmental effects of released ammonia from livestock production facilities has stimulated public interest with the main focus on animal husbandry systems as significant emitters. Hence, in recent years modern farm animal production is increasingly being regarded as a source of gaseous, odorous and particulate emissions which are all environmentally harmful and a nuisance (Fig. 1). Therefore, livestock operations are under increasing pressure to fulfil minimum requirements, and avoid the pollution of the atmosphere. The need of such minimization efforts is underlined by the so called European Directive on Integrated Pollution Prevention and Control (IPPC, COUNCIL DIRECTIVE 96/61/EC), which regards environmental protection as the highest priority. This target has to be reached by the best available techniques guaranteeing the lowest emissions possible. Additionally, emissions have to be controlled according to the EC directive. For this reason, an European pollutant emission register (EPER) must be implemented, based on Article 15(3) of Council Directive 96/61/EC. Within the EPER animal production facilities which house more than 40,000 poultry, 2,000 pigs (> 30 kg body weight) and 750 sows are currently listed. From these production units ammonia, methane, nitrous oxide and particulate matter smaller than 10 μm has to be monitored and recorded.

Due to the recent developments in the field of environmental protection and its relation to agricultural operations the aim of this report is to characterize the most important livestock-related airborne pollutants by individual fact sheets and going then in details concerning emission potencies and environmental impacts. Finally abatement techniques are also briefly mentioned, but mainly focused on biological waste air purification systems, which become increasingly important for livestock buildings as an 'end-of-pipe' technology.

Ammonia

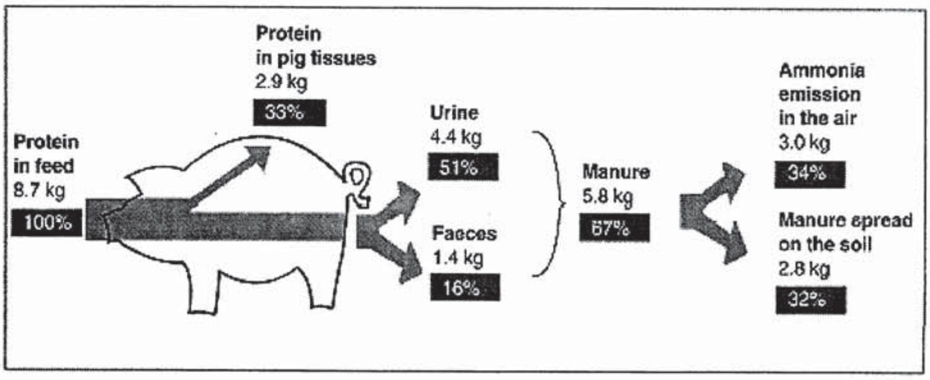
Fact sheet. Microbial degradation of urea in urine and uric acid in faeces are the main sources of ammonia (NH_3) in conjunction with mammals and poultry kept in livestock operations. For the degradation process (hydrolysis), the key enzymes are urease and uricase, and water as the chemical reacting partner is also essential. The named enzymes are original components in many microorganisms hosted in the intestine of animals like the gram-negative bacteria for instance *Proteus* spp. or *Yersinia* spp., which are urease positive. Excretion of faecal substrates and metabolizing microbes then facilitate an effective ammonia generation mechanism.

Fig. 1. - ENVIRONMENTAL ASPECTS RELATED TO INTENSIVE LIVESTOCK FARMING (BREF-ILF 2003).



The nitrogen (N) intake via proteins in feed is the basis for the ammonia production in the manure. Feeding more protein than is needed for optimum production results in increased urea concentrations in the urine. Additionally, proteins in faeces contribute to ammonia volatilisation, as well. Here residues of non-digested nutrients are responsible for the ammonia generation. In contrast to the amount of manure spread on the soil a significant proportion is released in the air supported by the lower physical density of ammonia in comparison to the air (Fig.2).

Fig. 2. - CONSUMPTION, UTILISATION AND LOSSES OF PROTEIN IN THE PRODUCTION OF A PIG OF 108 KG (BREF-ILF 2003)



The quantitative relationship between faeces and urine in manure is an influencing factor to what extent ammonia is released from manure. The greater the percentage of faeces, than lower is the amount of ammonia emitted (Tab. 1).

Table 1. - VOLATILIZATION OF AMMONIA FROM STORED BOVINE FAECES AND URINE (ADAPTED FROM KELLEMS ET AL. 1979)

Composition of the manure in %			NH_3 release
Faeces	Urine	Water	µg h^{-1}
100	-	-	3.15
-	100	-	426.0
50	50	-	120.0
75	25	-	16.0
75	-	25	3.4
50	-	50	6.6
25	-	75	9.7
5	-	95	2.2

The dynamics of ammonia release quantities is strongly linked with fluctuations of temperatures, acid/base conditions and the availability of oxygen in the manure. Increasing temperatures and pH values accelerate ammonia generation and release. In case of sufficient amounts of oxygen the microbial oxidation of ammonia nitrogen to nitrate nitrogen (nitrification) is principally possible, but that is however improbable, because aerobic conditions rarely exist in conventional manure management systems (see also nitrous oxide).

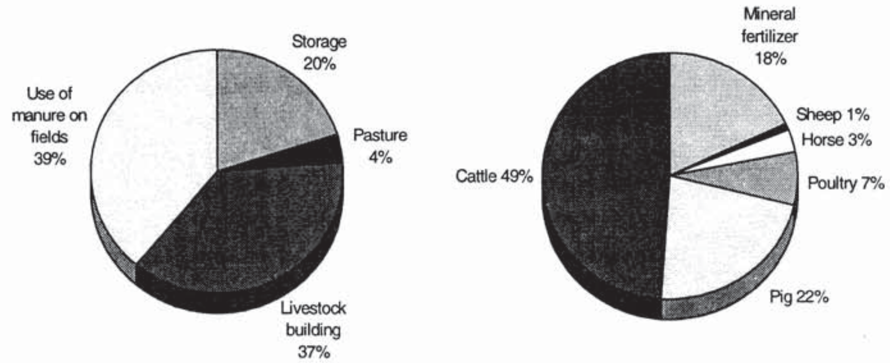
Furthermore, a significant biological factor is related to the availability of water for the degrading microorganisms. Loss of sufficient amounts of water due to metabolic activities results in the generation of less ammonia; a principle which is well established for aerated conveyor belt systems in poultry houses (Hartung 1991). A rapid drying of the manure down to approximately 80 % dry matter can be normally fulfilled to decrease ammonia production significantly. It is quite obvious that the availability of water for microorganisms interferes with the stochiometric chemical reaction requirements as mentioned above. Apart from temperature, acidity, oxygen and water the air movement at the boundary layer to the manure surface also determines the ammonia emissions. Because ammonia transition from the manure surface into the ambient air is accelerated by increased air movement, this has to be integrated into the models used for calculating ammonia releases (NI 1999). At the barn level, other factors which affect the release of ammonia include:

- animal density and size of the animals
- the moisture content and carbon/nitrogen ratio of the manure
- the size of surfaces where manure is exposed
- the overall hygienic conditions
- the storage time of manure inside the buildings
- the technique of manure handling
- the ventilation rate

Emission potency. The definition of suitable emission factors is a key task in fulfilling the demands of environmental protection, because emission status reports and scenarios on how emissions are developed need such emission factors. This is especially true for ammonia, because approximately 95 % of the total atmospheric ammonia emissions originate from agriculture. Releases from livestock buildings and the use of manure on fields are the most important activities, with cattle contributing the most to the ammonia emissions as a species (Fig. 3).

Focusing on species ammonia emissions from cattle varied between 315 and 1,798 mg h^{-1} LU^{-1} (LU = Livestock unit = 500 kg body weight), while ammonia releases from pigs ranged between 649 and 3,751 mg h^{-1} LU^{-1}. The highest emission loads are generally caused by poultry houses, namely 602 to 10,892 mg h^{-1} LU^{-1} (Groot Koerkamp et al. 1998).

Fig. 3. - THE RELATIVE DISTRIBUTION OF AMMONIA CONTRI-BUTING SOURCES. SPATIAL AND SPECIES RELATED (ADAPTED FROM AID 2003)



A more specific viewpoint is necessary in order to also integrate different husbandry types into a database of emission factors. This requirement is important to assess the environmental impact of new livestock buildings. Therefore authorities need such detailed emission factors to licence agricultural production units, for instance. Within the regulation Ta Luft (2002), as a part of the German legislation for environmental protection, the current official emission values are defined, although several alternative publications are also dealing with emission rates from livestock operations. But to give an impression of 'fine tuned' ammonia emission factors such species- and husbandry-related emission values are shown in Table 2.

Environmental impact. Once released into the ambient air ammonia has a relatively short life in the atmosphere ranging from few hours to several days depending on the atmospheric conditions. A farm will dominate the outdoor NH_3 concentration up to 0.5 – 1.0 km distance, while the deposition will rapidly occur within 4 – 5 km from the source (Krupa 2003). Other studies stated that about 16 % of the emissions is deposited 500 m from the source, 34 % within 10 km, 56 % within 100 km and 87 % is deposited within 1,000 km (Asman and Van Jaarsveld 1992, Asman et al. 1999). Dry and wet deposition is the initial input into terrestrial and aquatic ecosystems. Excess amounts of NH_3 can exhaust the capacities of detoxification in plants. The following cumulations of nitrogen can supersaturate sensible biospheres due to imbalances between offered and consumed nitrogen. The overall effects can be divided into direct and indirect environmental damages.

Coming to direct impacts, human health is not really threatened by current ammonia concentrations in the ambient air. Relevant health effects like mucosal irritations on eyes and airways is expected above 14 mg m^{-3}, which is equivalent to 20 ppm NH_3, the occupational threshold limit value (DFG 2003). Half-yearly measurements near a large cattle production facilities (15,000 animals) and a laying hen livestock unit (207,000 animals) have shown average concentration of 19 $\mu g\ m^{-3}$ and 3.3 $\mu g\ m^{-3}$ in 350 m and 100 m distance, respectively. Dependent on the wind conditions maximum hourly means were detected up to 141 $\mu g\ m^{-3}$ and 30 $\mu g\ m^{-3}$, respectively (FEDERAL AGENCY FOR ENVIRONMENT, NATURE AND GEOLOGY MECKLENBURG-VORPOMMERN 2003). Whereas in contrast, another study presented low ammonia concentrations at an agricultural site, where a mean value of 5.55 $\mu g\ m^{-3}$ was measured during an one year survey (Robargea et al. 2002).

Table 2. - LIVESTOCK TYPES AND ITS RELATED EMISSION FACTORS OF AMMONIA (ADAPTED FROM TA LUFT 2002)

Livestock type	NH_3 emission factor kg per animal place and year
Fattening pigs	
- forced ventilated, slatted floor	3.64
- forced ventilated, deep litter	4.86
- natural ventilated with kennel housing system (solid or liquid manure)	2.43
- natural ventilated with deep litter or compost bedding	4.86
Piglet Production (Sows)	
- all husbandry systems (sows incl. piglets up to 25 kg)	7.29
Laying hens	
- cages with aerated conveyor belt	0.0389
- aviary with aerated conveyor belt	0.0911
- floor system/outdoor (manure removal once per production cycle)	0.3157
Other poultry	
- Broiler on floor	0.0486
- Ducks	0.1457
- Turkeys	0.7286
Dairy cows	
- tied stalls, solid or liquid manure	4.86
- cubicles, solid or liquid manure	14.57
- loose house, deep litter	14.57
- loose house, sloping floor straw yard system	15.79
Beef	
- tied stalls, solid or liquid manure	2.43
- loose house, liquid manure	3.04
- loose house, sloping floor straw yard system	3.64

More important, are damages which occur in plants. Direct foliar injuries and necroses are observable in particular. Further adverse effects are related to alterations in growth, nutrient content of tissues, frost tolerance, responses to insect pests and disease causing pathogenic microorganisms like fungi (Krupa 2003). However, these obervations are also related to indirect effects due to changes of the chemical conditions in the soil (see below). Especially forest plants like winter lime tree (*Tilia cordata* Mill.), common alder (*Alnus glutinosa*) and beech (*Carpinus betulus*) are threatened under such conditions. To protect such sensitive plants critical levels were recommended to avoid direct alterations. Currently 8 µg NH_3 per m^{-3} on a yearly average basis was defined to guarantee protection for 95 % of all plant species with a confidence limit of 95 % (Schütze et al. 2002).

Indirect effects are related to acidification and eutrophication in soil and surface water. The causal chain of the development of acidified soils are quite complex and linked to confounding mechanisms, whereby several hypotheses exist. A common explanation for the acidification processes is related to two pathways. Ammonia is deposited primarily as ammonium ion (NH_4^+). To utilise the nitrogen, ammonium ions are absorbed by the roots of plants. This uptake process causes the release of free hydrogen ions (H^+). Additional, NH_4^+ can be nitrified in the soil by aerobic microorganisms according to the chemical equation:

$$NH_4^+ + 2O_2 + H_2O \rightarrow NO_3^- + 2H_2O + 2H^+ \text{ (Nitrification)} \qquad (1)$$

The generated protons are normally neutralized by different hierarchical ordered buffer systems but the functionality of such a soil pH regulating system is highly dependent on the available buffer capacities. Therefore continuous acid entries into the soil lead to a gradual consumption of these capacities which may be then exhausted and the pH value decreases. As consequence direct damages of the roots are possible or the changed pH conditions in the soil may cause at the very least imbalances of nutrient uptakes whereby growth disturbances are the result. Toxic impacts on the plants are related to enhanced aluminium releases from the soil due to the acidity (Schütze et al. 2002). The different susceptibility of plants to all these stress factors will selectively reduce the vitality of plants and therefore provoke a considerable change of biodiversity.

Increased nitrogen intakes are not only responsible for acidification. A further ecological threat is eutrophication, which cause a shift from oligotrophic plant species to more nitrophilic species. Therefore, the so called critical loads for nitrogen intakes were introduced, to define limits where significant ecological changes occur. For example, forests with coniferous trees, acid soil undergoing low nitrification and alpine neglected grasslands have a critical load of 10 to 15 kg N ha^{-1} a^{-1}. Exceeded critical loads cause imbalances of nutrients and decreased biodiversity (Schütze et al. 2002).

Another sensitive ecological system are natural surface water reservoirs like lakes. Transmission of ammonia via the atmosphere or the leaching of nitrogen containing components (NH_4^+, NO_2^-, NO_3^-) from the soil can cumulate nitrogen in surface waters. In Germany about 60 % of all nitrogen intakes into surface water are caused by agriculture. This corresponds to 465,000 tons N per year. The excessive offer of nitrogen together with phosphorus can initiate the geometric increase of plankton, which is observable as algal blooms. Due to the intensive turnover rate of the plankton the aerobic degradation of the growing biomass reduces the oxygen content in the water significantly. Lacking oxygen concentrations and an increasing shift to anaerobic metabolizing activities with generated toxic components (i.e. hydrogen sulphide) cause the death of the water fauna (fishes) and destroy the ecosystem. Artificial forced aeration as 'first aid measure' may help to convert the processes to aerobic activities again and may allow a revival of the water ecosystems. To prevent leaching processes and excessive run-offs of N-containing effluents counter measures are mainly targeted to an adequate waste management scheme set up in accordance with national regulations.

Greenhouse gases

Fact sheet. Methane (CH_4) and nitrous oxide (N_2O) are components of the so called greenhouse gases. Methane is a colourless, odourless, non toxic gas and lighter than air while N_2O is also colourless but it smells and tastes sweet in higher concentrations. Nitrous oxide is 1.5-fold heavier than air, similar to carbon dioxide, and is used as a well known anaesthetic in surgeries.

In the case of methane, enteric fermentation is the main activity responsible for methane generation in the digestive tract of animals. It can be postulated that the higher the feed intake is, the higher the methane releases can be expected. Ruminants with a polygastric system cause the highest emission potencies. Within their digestive system anaerobe degradation processes facilitate the methanogenesis. The produced methane is finally released into the air by the physiological occurring eructation through the oesophagus. Monogastric animals (pigs) produce clearly lower amounts of CH_4, because methanogenesis can be nearly neglected. Traces of methane are released into the atmosphere by flatulence (Hartung and Monteny 2000).

In contrast to methane the generation of N_2O is not directly related to the internal metabolism of animals. The presence of nitrous oxide is more the consequence of reactions due to primary nitrogen compounds, which underlay the processes of nitrification (see equation 1) and denitrification (equation 2). If the oxygen supply is suboptimal, a complete nitrification according to equation 1 does not occur and considerable amount of N_2O is not only caused by denitrification but then released during the nitrification process, too.

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2 \text{ (Denitrification)} \qquad (2)$$

Typical locations of N_2O generations are the bedding and manure systems of livestock operations. Liquid manure is not causing significant amounts of nitrous oxide, because of the lack of utilizing oxygen, which is necessary for nitrification. More oxygen is available in deep litter systems and therefore the nitrous oxide formation processes are enhanced there and considerable amounts are finally released (Hartung and Monteny 2000).

Emission potency. During 1999 methane was emitted from German livestock operations in quantities of 1,468 kilotons (kt), while nitrous oxide was released in amounts of 83 kt (Benndorf 2002). Concerning emission factors a comprehensive overview of reviewed literature can be found by Hartung and Monteny (2000). Nevertheless, a small selection of emission factors for greenhouse gases is shown in Table 3 at least.

Table 3. - SELECTED EMISSION FACTORS FOR CH_4 AND N_2O (AP=ANIMAL PLACE)

Livestock type	CH_4	N_2O	Reference
Cattle, i.e.	$g\ d^{-1}\ LU^{-1}$	$g\ d^{-1}\ LU^{-1}$	
Dairy cows, cubicle	320	0.8	Sneath et al. (1997)
Pigs, i.e.	$kg\ y^{-1}\ AP^{-1}$	$kg\ y^{-1}\ AP^{-1}$	
Fattening pigs, fully slatted floor	2.8-4.5	0.15	Hahne et al. (1999)
Poultry, i.e.	$kg\ y^{-1}\ AP^{-1}$	$kg\ y^{-1}\ AP^{-1}$	
Laying hens, floor system with straw	0.076	0.017	Mennicken (1998)

Environmental impact. The greenhouse gases contribute to global warming and N_2O also affects the ozone layer. The global change is indicated by a mean increase of the temperature between 0.4 to 0.8 °C during the last 100 years and it is expected that the temperatures from today to 2100 will differ between 1.4

and 5.8 °C (IPCC 2001). The possible effects are well known as thermal expansion of the oceans, melting of glaciers and a following increase of the sea level between 10 and 90 cm, for instance.

The predicted drastic effects are not exclusively caused only by methane and nitrous oxide, because carbon dioxide is the most severe climate changing agents due to the huge amounts released from anthropogenic sources (i.e. combustion). Carbon dioxide contributes about 60% of the global warming, while methane accounts for about 20% of the enhanced warming, and nitrous oxide and halocarbons together account for another 20% (Blair 2002). But nevertheless, methane and nitrous oxide play an important role in the atmosphere due to their chemical longevity. Methane and nitrous oxide have a lifetime range from 8.4-12 years and from 114-120 years, respectively.

The effects from global warming will also have consequences for agriculture itself. It is related to plant production as well as to livestock production. The threat of such global changes for agriculture is shown in Table 4.

Table 4. - EXAMPLES OF IMPACTS ON AGRICULTURE DUE TO CLIMATIC CHANGES (ADAPTED FROM IPCC 2001)

Expected climate change in the 21th century	Possible impacts on agriculture
• Increase of the mean air temperature	Higher evaporation, heat stress, lengthen of the vegetation period, new pests and diseases for plant and animals
• Higher maximum temperatures, heat periods	Increasing heat stress for animals in livestock production
• Higher minimum temperatures, less frost days	Decreasing frost damages, improved distribution conditions for diseases and pests
• Increasing dryness in summer	Decreasing harvest yields, increasing fire risks
• Higher sea level	Lost of area, salting of ground water
• More frequently occurring heavy rain falls	Erosion, soil leaching and flooding of fields

Odour

Fact sheet. Odour is the property of a chemical substance or substance mixtures, dependent on the concentration, to activate the sense of smell and thus being able to start an odour sensation. The way the human response to an odour is evaluated depends on the particular sensory property that is being measured, including the intensity, detectability, character, and hedonic tone of the odour. The combined effect of these properties is related to the annoyance that may be caused by the odour. Due the complexity of odour the most used analytical method is the olfactometry by using human sensory panels. The odour concentration is determined as the number of dilutions to bring the odour to the level that can be detected by 50% of a population. The concentration is then expressed as Odour Unit (OU).

Sources of odour within livestock buildings are quite various. Releases from primary sources (feed, manure) or secondary caused odour (degradation of organic material) are able to change odorous impressions considerably. Odorous compounds in livestock air can be molecularly dispersed (volatile organic compounds, VOC) or adsorbed on to particles of dust. Over time more than 300 different odour-related chemical structures have been chemically detected (Hartung 1986, Schiffman et al. 2001). These compounds are markedly different concerning the individual odour reception threshold. For ammonia about 1.0 x 10^{11} molecules per cm³ air is needed to provoke a smell feeling, whereas the number of skatole molecules, i.e. agents which typically smells of faeces, can be decreased down to 7.3 x 10^4 cm^{-3} to cause an olfactory signal in the nose (Krause 1998).

Emission potency. It is generally possible to determine odour units in the released air from livestock buildings. For example, the average odour concentrations from swine barn exhaust ranged from 131 to 1842 OU m^{-3} and odour emission rates from 12 to 39 OU s^{-1} per m^2 of floor area (Zhou and Zhang 2003). But for practical applications due to licensing of livestock operations empirical determined minimum distance requirements are used. For that purpose different husbandry systems, manure and feeding techniques are evaluated in terms of their potency to cause annoying smell. The better an odour avoiding system is the smaller is the necessary distance between livestock building and the nearest resident. This evaluation principle is realized in the German VDI guidelines 3471 (1986) and 3472 (1986), for instance.

Environmental impact. Odour is a nuisance and annoyance, which is directly related to residents living in the vinicity of livestock production units. Due to the frequency, the intensity and hedonic tone of odour, human's individually felt well-being can be severely affected.

There are four main discussed ways that odours could potentially affect human health. First, the VOC themselves could produce toxicological effects. Second, odorant compounds could cause sensory irritation in the eye, nose, and throat. Third, the VOC could stimulate sensory nerves to cause neurochemical changes that potentially influence health. Fourth, health effects from agricultural odours could be due to cognitive and emotional factors such as stored mental experience with similar odours or attitudes toward unpleasant odours. Complaints of health effects from odours associated with livestock operations probably derive from a combination of physiological and psychogenic sources (Schiffman 1998).

Particulate matter

Fact sheet. Apart from gases and odour, airborne particles (dust) within livestock buildings belong to the most important agents, which are not only annoying but being also biological effective on animals and human. Different sources like feed, bedding material or manure contribute to the overall dust generation. In opposite to many industrial-related dust qualities, airborne particles from animal houses are of organic character, indicated by a relative protein content of 23 % and more. Furthermore, several other agents could be determined in dust masses like endotoxins, glucans or mycotoxins, which additionally indicate the co-existence between dust particles and adsorbed microorganisms. Therefore a common expression for dust is the terminus 'bioaerosol', taking into account the abiotic and biotic complexity of such organic dust. Such bioaerosols can be physically distinguished by their particle size distribution. Normally, the particle size range is between 0.5 and 100 µm.

Emission potency. Similar to the detection of gas releases, dust emission rates can be determined by the knowledge of airborne concentrations and corresponding ventilation rates. Related to the distribution of dust in the surrounding of animal enterprise a simple calculation can be made. Assuming a mean concentration of 2 mg m^{-3} in the exhaust air of a piggery house with 1,000 fattening pigs and a mean ventilation rate of 200 m^3 h^{-1} LU^{-1} throughout the year the total emission per year will be about 500 kg (Hartung 1998). A more flexible calculation of emitted dust loads is obtainable by the use of emission rates. Table 5 gives an example of measured dust emission rates of inhalable and respirable dust (particle sizes ≤ 5 µm).

Table 5. - MEAN EMISSION RATES OF INHALABLE (ID) AND RESPIRABLE DUST (RD) FROM CATTLE, PIG AND POULTRY BUILDINGS (TAKAI ET AL. 1998)

	Cattle		Pig		Poultry	
	ID	RD	ID	RD	ID	RD
mg $Animal^{-1}$ h^{-1}	110	19	111	14	12	2
mg LU^{-1} h^{-1}	145	24	762	85	3165	504

According to public health demands international measurement standards have to guarantee the determination of so called PM_{10}, a dust fraction of particles not bigger than 10 µm. Unfortunately, until now there are no comprehensive surveys, which focused particularly on PM_{10} emissions from livestock operations. Instead of PM_{10} measurements it was tried to introduce conversion factors by means of results from some few experiments, which determined the relationship between total dust and PM_{10}, for instance. But the precision of applied conversion factors may be critical, because of the broad range of used measurement instruments with different physical sampling characteristics. This circumstance may led to false PM_{10} emission factors.

Environmental impact. Primary particulate emissions from livestock buildings are supposed to play a role in respiratory and allergic affections in people living in the vicinity of animal enterprises. These hypotheses are supported by our comprehensive knowledge from occupational investigations, which demonstrated the potency of livestock dust to cause respiratory disorders, over-sensitivity reactions, toxic and inflammatory effects among exposed farm workers. Even though it is not exactly known how far emitted dust particles are able to travel via the atmosphere. Thu et al. (1997) have found some epidemiological hints that residents living near a large-scale swine operation have shown more respiratory symptoms than a control group. But a direct causality between emitted dust amounts from a specific livestock operation and triggered human-related biological effects remains unclear. More evidences of long-term transmissions of particles are available concerning the transmission of infectious diseases among livestock production facilities (i.e. foot-and-mouth disease). A new aspect is related to the potential emission of dustborne chemotherapeutics (i.e. antibiotics), which are distributed in the environment. A comprehensive overview about airborne dust and microorganisms in livestock operations can be found by Seedorf and Hartung (2002).

Global public health effects of particulate matter are linked to PM_{10}. It is assessed that an increase of 10 µg PM_{10} per m^3 air will increase the relative mortality by 2 % of exposed humans (WHO 1999). Smaller particles than PM_{10} are often secondarily formed by the reaction of precursors like ammonia and pollutants from other sources like sulphuric acid, nitric acid and hydrochloric acid. These particles are related to $PM_{2.5}$ and finer fractions. Overall these PM are stressing the respiratory and circulatory system of human and therefore being of public concern.

Atmospheric particles also impairs air quality by reducing visibility. Furthermore particles are effective in scattering of radiation and in contributing to climate change. Such impaired visibility and reduced solar radiation may also cause ecological impacts like the restriction of photosynthetic capabilities of plants (Grantz et al. 2003). This mechanism may not only have consequences for plants in nature it may be also harmful for plant production in agriculture due to decreasing biomass yields over time.

Abatement techniques

There a many options to reduce airborne pollutants in and from livestock buildings. These options are related to adequate animal nutrition (i.e. N-balanced feed), housing and management (i.e. liquid vs. solid manure) or auxiliary measures like oil-sprinkling to reduce dust within animal houses. Especially in regions with high animal densities biological waste air purification systems become more important, because from an environmental point of view such devices are often the last option to licence new livestock buildings. Typically it can be distinguished between biofilters, bioscrubbers, biotrickling filters and wet scrubbers using chemical additives (Hahne et al. 2002). The main targets of waste gas purification in agriculture are the elimination of odour, ammonia, dust and microorganisms and trace gases. Unfortunately, none of the mentioned systems is normally able to guarantee equally an efficient elimination of all hazardous components, if minimum reduction efficiencies of 70 % and more are required for each pollutant. Higher reduction efficiencies together with clear co-eliminations of different relevant pollutants can be expected by the combination of elimination processes. Such devices are composed of wet scrubber with pure water (deposition of dust), a wet scrubber unit with acidified water (fixing ammonia as ammonium in water) and a biofilter (reducing livestock-related odour). These modular composition of a waste gas purification system is able to increase the cleaning efficiency up to 90 %. But due to the complex physical, chemical and biological processes within the purification systems, control measurements, frequent maintenance and trained farmers are necessary to guarantee long-term efficiencies of these systems otherwise the potential advantage for the environment is negligible or turns around even in the opposite.

Conclusions

- There are loads of emittable gases and particulate matter in the air of livestock operations.
- The ecological risk is mainly related to ammonia and greenhouse gas emissions, which have regional and global impacts.
- The environmental threat is related to soil and surface water acidification and eutrophication as well as to global warming.
- Event though livestock production facilities are causing environmental problems, agriculture can be threatened by itself, because global warming will propably cause ineffective plant production and will increase the stress in animals due to the changed climate.
- More knowledge is necessary to assess the risk of livestock-related emissions of airborne particulates and their integrated biological and chemical compounds.
- Despite of several available reduction techniques for airborne pollutants, biological waste gas purification systems offer an alternative measure to reduce significantly odour, ammonia and dust if such systems are working properly.

LITERATURE

1. AID (2003): Ammoniak-Emissionen in der Landwirtschaft mindern. Gute fachliche Praxis. Heft-Nr. 1454, aid Infodienst e.V., Bonn, Germany, 74 p.
2. Asman, W. A. H., Van Jaarsveld, J. A. (1992): A variable-resolution transport model applied to NH_x for Europe. Atmos. Environ., 26A, 445-464.
3. Asman, W. A. H., Andersen, J., Løftstrøm, P., Hutchings, N. J., Sommer, S. (1999): Tools to control ammonia and odour from danish agriculture. In: Regulation of Animal Production in Europe, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL, ed.), Darmstadt, Germany, Arbeitspapier 270, 243-248.
4. Benndorf, R. (2002): Klimarelevante Wirkungen von Lachgąs und Methan. In: Emissionen der Tierhaltung, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL, ed.), Darmstadt, Germany, KTBL-Schrift 406, 24-29.
5. Blair, D. (2002): How Do We Know Climate Change is Real? Climate Change Connection Chair, Geography Department, University of Winnipeg, Canada.
6. Bref-IIc (2003): Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs, European Commission, 383 p.
7. COUNCIL DIRECTIVE 96/61/EC concerning integrated pollution prevention and control (IPPC).
8. COUNCIL DIRECTIVE 96/62/EC of 27 September 1996 on ambient air quality assessment and management.

9. DFG (2003): MAK- und BAT-Werte-Liste 2003. Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe, Deutsche Forschungsgemeinschaft, Mitteilung 39.
10. FEDERAL AGENCY FOR ENVIRONMENT, NATURE AND GEOLOGY MECKLENBURG-VORPOMMERN (2003): Report of ammonia measurements in the vicinity of livestock buildings, 8pp.
11. Grantz, D. A., Garner, J. H., Johnson, D. W. (2003): Ecological effects of particulate matter. Environ. Intern., 29, 213-39.
12. Groot Koerkamp, P. W. G., Uenk, G. H., Metz, J. H. M., Phillips, V. R., Holden, M. R., Sneath, R. W., Short, J. L., White, R. P., Hartung, J., Seedorf, J., Schröder, M., Linkert, K. H., Pedersen, S., Takai, H., Johnsen, J. O., Wathes, C. M. (1998): Concentrations and emissions of ammonia in livestock buildings in Northern Europe. J. agric. Engng Res., 70, 79-95.
13. Hahne, J., Asendorf, W., Vorlop, K.-D. (2002): Abluftreinigung – Möglichkeiten und Grenzen. In: Emissionen der Tierhaltung, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL, ed.), Darmstadt, Germany, KTBL-Schrift 406, 106-122.
14. Hahne, J., Hesse, D., Vorlop, K.D. (1999): Spurengasemission aus der Mastschweinehaltung. Landtechnik, 54, 180-181.
15. Hartung, J. (1986): Dust in livestock buildings as a carrier of odours. In: V.C. Nielsen, J.H. Voorburg , P. L'Hermite (Hrsg.): Odour Prevention and Control of Organic Sludge and Livestock Farming. Elsevier Appl. Sci. Publisher, London, New York, 321-332.
16. Hartung, J. (1991): Influence of housing and livestock on ammonia release from buildings. In: Odour and ammonia emissions from livestock farming; Nielsen, V.C., Voorburg, J.H., L'Hermite, P. (eds.), Elsevier Applied Science, London and New York, 22-30.
17. Hartung, J. (1998): Art und Umfang der von Nutztierställen ausgehenden Luftverunreinigungen. Dtsch. tierärztl. Wschr., 105, 213-216.
18. Hartung, E., Büscher, W., Lais, S. (1996): Ammoniakemissionen aus Schweineställen senken. Landtechnik, 51, 160-161.
19. Hartung, E., Monteny, G.-J. (2000): Methane (CH_4) and nitrous Oxide (N_2O) emissions from animal husbandry. Agrartechn. Forsch., 6, E62-E69.
20. IPCC (2001): Third assessment report. Working group I; Worling group II, Cambridge University Press, 944 p. and 1000p., respectively.
21. Kellems, R.O., Miner, J.R., Church, D.C. (1979): Effect of ration, waste composition and length of storage on the volatilization of ammonia, hydrogen sulfide and odors from cattle waste. J. Anim. Sci., 48, 436-445.
22. Krause, K.-H. (1998): Methodologie zur praxisgerechten Beschreibung und Quantifizierung von Ausbreitungsvorgängen von Gerüchen. In: Freisetzung, Eintrag und Bewertung von Gerüchen in der Landwirtschaft, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL, ed.), Darmstadt, Germany, Arbeitspapier 253, 27-48.
23. Krupa, S. V. (2003): Effects of atmospheric ammonia (NH3) on terrestrial vegetation: a review. Environ. Poll., 124, 179-221.
24. Mennecken, L. (1998): Biobett für Legehennen – ein Beitrag zum Umweltschutz ? DGS, 13, 12-20.
25. Ni, J. (1999): Mechanistic Models of Ammonia Release from Liquid Manure: a Review. J. Agric. Engng Res., 72, 1-17.
26. Robargea, W. P., Walker, J. T., McCulloch, R. B., Murray, G. (2002): Atmospheric concentrations of ammonia at an agricultural site in the southeast United States. Atmos. Environ., 36, 1661-1674.

27. Schiffman, S. S. (1998): Livestock odors: implications for human health and well-being. J. Anim. Sci., 76, 1343-1355.

28. Schiffman, S. S., Benett, J. L., Raymer, J. H. (2001): Quantification of odors and odorants from swine operations in North Carolina. Agri. Forest Meteorol., 108, 213-240.

29. Schütze, G., Gregor, H.-D., Spranger, T., Nagel, H.-D. (2002): Ökologische Wirkungen von Ammoniak. In: Emissionen der Tierhaltung, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL, ed.), Darmstadt, Germany, KTBL-Schrift 406, 9-23.

30. Seedorf, J., Hartung, J. (2002): Stäube und Mikroorganismen in der Tierhaltung. Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL, ed.), KTBL-Schrift 393, Landwirtschaftsverlag Münster, 166 p.

31. Sneath, R. W., Phillips, V. P., Demmers, T. G. M., Burgess, L. R., Short, J. L., Welch, S. K. (1997): Long term measurements of greenhouse gases from UK livestock buildings. Livestock Environment V, Proc. 5th Intern. Symp., Bloomington, Minnesota, USA, 146-153.

32. Takai, T., Pedersen, S., Johnsen, J. O., Phillips, V. R., Holden, M. R., Sneath, R. W., Short, J. L., White, R. P., Hartung, J., Seedorf, J., Schröder, M., Linkert, K. H., Metz, J. H. M., Koerkamp, P. W. G., Uenk, G. H., Wathes, C. M. (1998): Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. J. agric. Engng Res., 70, 59-77.

33. Ta Luft (2002): Technische Anleitung zur Reinhaltung der Luft. Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz, vom 24. Juli 2002, GMBl. Nr. 25 - 29 vom 30.7. 2002 S. 511.

34. Thu, K., Donham, K. J., Ziegenhorn, R., Reynolds, S., Thorne, P. S., Subramanian, P., Whitten, P., Stookesberry, J. (1997):A control study of the physical and mental health of residents living near a large-scale swine operation. J. Agric. Safety Health, 3, 13-26.

35. VDI 3471 (1986): Emissionsminderung. Tierhaltung-Schweine. Verein Deutscher Ingenieure, Ausgabe Juni 1986, Beuth Verlag, Berlin.

36. VDI 3472 (1986): Emissionsminderung. Tierhaltung-Hühner. Verein Deutscher Ingenieure, Ausgabe Juni 1986, Beuth Verlag, Berlin.

37. WHO (1999): Health risk of particulate matter from long-range transboundary air pollution. Preliminary Assessment. Task Force on Health Aspects of Long Range Transboundary Air Pollution, World Health Organization, Regional Office for Europe, European Centre for Environment and Health, Bilthoven Division, 56 p.

38. Zhou, X., Zhang, Q. (2003): Measurements of odour and hydrogen sulfide emissions from swine barns. Can. Biosys. Eng., 45, 6.13-6.18.

UTJECAJ ZRAČNIH ONEČIŠĆIVAČA IZ STOČARSTVA NA OKOLIŠ

Sažetak

Moderna farmska proizvodnja sve je jači izvor emisija plinova i neugodnih mirisa koji mogu predstavljati kako neugodu tako i biti štetne po okoliš. Najčešći takav sastojak u zraku je amonijak (NH_3), koji može ozbiljno narušiti okoliš. Biljke i šume u blizini intezivne stočarske poizvodnje, koji može ozbiljno narušiti okoliš. Štetni utjecaji mogu se ispoljiti na biljkma i šumama u blizini intezivne stočarske proizvodnje, primjerice nekroza lišća. Osim ovih direktnih utjecaja amonijaka, daljnji ekološki problem predstavljaju zakiseljenje i eutrofikacija tla i voda. Dodatno, amonijak kao prekursor također može stvarati sekundarne aerosole. Gledajući globalno, staklenički plinovi kao

što su metan (CH_4) i dušikov oksid (N_2O) također se iz nastambi za životinje emitiraju u značajnim količinama. Goveda i držanje na dubokoj stelji posebice doprinose stvaranju stakleničkih plinova koji su odgovorni za klimatske promjene. Što se tiče neugodnih mirisa sve vrste stočarstva moraju se uzeti u obzir zbog "dosadnog" mirisa.

Osim plinova i neugodnih mirisa, primarni aerosoli trebaju biti uzeti u obzir. Takozvani biaerosoli emitiraju seu značajnim količinama u okoliš ventilacijskim sistemom. Biaerosoli u nastambama za životinje sastoje se od organskog metarijala (proteini), biološki aktivnih sastojaka (endotoksini) i mikroorganizama (bakterije). Čak i plinovi kao što je amonijak mogu biti adsorbirani na površinu čestica bioaerosola. Bioaerosoli se mogu razvrstati po svojim biološkim svojstvima koja uključuju infektivnost, alergenost, toksičnost te farmakološke i slične efekte. Stoga se raspravlja o tome da bioaerosoli ne mogu samo uzrokovati probleme u izloženih farmera već i u svih onih u bližoj okolici takvih stočarskih nastambi.

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