REDUCTION EFFICIENCY OF A CONTAINER-BASED BIOFILTER FOR BIOAEROSOLS FROM A BROILER HOUSE

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SUMMARY
Biofiltration is known as a method to abate odour pollution from agricultural and industrial sources. In recent years there is an increasing interest in reducing or removing further pollutants such as dust particles and micro-organisms (bioaerosols) from the exhaust air of farm animal buildings. An orientating study was performed to investigate the efficiency of a combined scrubber/biofilter unit to remove bioaerosols from the exhaust air of a broiler house with about 20,000 birds. Samples were taken in the animal house air, from the air stream inside the biofilter after the second scrubber and from the cleaned air above the biofilter bed. Minimum reduction efficiencies were calculated for airborne dust particles, total bacteria and fungi at 83, 90 and 73%, respectively. Similar reduction efficiencies were grossly seen for endotoxins too, but many of the results showed considerable variations, which probably were due to cumulative and enrichment effects in the aerosolised scrubber water of the biofilter. The results show that the investigated biofilter system is able to reduce the amount of airborne particulates in the exhaust air of the broiler barn significantly. Future work is needed to specify kind and number of those micro-organisms which are released into the environment by passing the biofilter. This is necessary from the point of view of occupational and environmental hygiene.

Keywords: biofilter, bioaerosols, reduction efficiency, broiler

INTRODUCTION
The air in livestock buildings contains gases, odours, dust particles and micro-organisms which are emitted by the ventilation system into the environment. It is known that odour emissions can be a severe nuisance for near-by living residents. Therefore administrative procedures are in place when new farms are licensed either to establish sufficiently large distances between residential areas and the emitting farms or to enforce abatement techniques to minimise odour emissions. One of the appropriate methods which is already approved in practice for odour reduction is the biofilter technique. The polluted exhaust air from the animal house is forced to pass a filter bed which usually consists of brushwood, bark, compost material or similar organic stuff. The break down of the odorous compounds is performed by micro-organisms which are naturally present colonising massively the surfaces of the filter bed materials. The activity of this mixture of bacteria can be supported when the scrubber water is inoculated with a specimen of fresh sewage sludge. The efficiency of biofilters mainly depends on the activity of the micro-organisms, the nature and concentration of the pollutants which should be reduced and the operational status and maintenance of the bedding material. Odour reductions in ventilation air from livestock buildings between 41% (Siemers and van den Weghe 1997) and 99% (Holste and Mannebeck 1997) are reported.

Little is known on the role of the emitted particles in the surrounding of the farms. There is increasing concern in recent years that emitted airborne dust, dust borne components and micro-organisms may play a role in respiratory affections in people living in the vicinity of animal enterprises. Measures to reduce particulate emissions from animal houses are not yet well investigated. Orientating tests with biofilters showed that the dust mass in the exhaust air of piggeries can be reduced by up to 85% (Siemers and van den Weghe 1997). Martens et al. (2001) found a reduction potential for bacteria in half technical scale biofilter units between 70 and 95%, while much less reductions of only 11% were observed in a commercially operated biofilter at a pig house (Seedorf and Hartung 1999). These inconclusive results are probably due to the different constructions of the biofilters that can vary between simple filter beds and filter/scrubber combinations. Another reason may be the use of different sampling techniques (time, place, duration, medium etc.) and analysis procedures for the
various compounds. The development of standardised techniques and procedures would be advantageous in future.

This paper reports on the reduction efficiencies of a newly designed container based biofilter with two scrubber steps and a biofilter bed for airborne particulates such as dust, bacteria and fungi using a standard glass impinger for sampling both micro-organisms and particles.

**MATERIALS AND METHODS**

**Broiler house and biofilter**

The investigations were carried out in a conventional broiler house with straw as litter material. The number of animals varied between 22,000 at the beginning and 16,000 at the end of the measuring campaign after 44 days. At days 30 to 33 about 6000 bigger birds were caught and brought to slaughter. The forced ventilated building was equipped with fans on the rear side and auxiliary fans in the ceiling providing additional ventilation capacity for hot summer conditions. The main air stream was moved by the rear fans and passed horizontally through an attached biofilter container. The biofilter unit itself contains three compartments to reduce odour, gases and dust. The first two stages of the system are scrubbers to wash out water soluble and solid components, i.e. ammonia and dust, from the polluted livestock air (pre-attached scrubber unit). The washing water is recirculated, spilled and evaporated water is replaced by fresh water automatically. The third cleaning stage is the virtual biofilter where the particles not yet eliminated by the scrubber should be retained in the filter bed. The bed consisted of a frame of stainless steel bars filled with bark and coarse wood chips. The area of the filter was 16 m².

**Sampling Procedure**

Dust particles, bacteria, fungi and endotoxins were sampled at three positions. One sampling position was within the broiler house, one behind the second scrubber unit and the third above the biofilter bed, shielded by a plastic barrel to avoid atmospheric influences. The barrel was equipped with a chimney-like integrated funnel for the air outlet causing a slight over-pressure within the barrel to prevent uncontrolled influx of atmospheric air at the point of contact between the barrel edge and the rough structured surface material of the biofilter bed. Samplings were carried out at six days between June and October. At each sampling day 3 samplings with three replicates were taken, 54 samples in total. The samples were taken with All Glass Impinger 30 (AGI-30) systems. The air was sucked through the impingers for 20 minutes with a flow rate of 10.5 l min⁻¹. Each impinger was filled with 50 ml sterile isotonic NaCl solution. The sampling height was 1.5 m above ground. Figure 1 shows a rough scheme of the biofilter/scrubber system and the position of the sampling points.

**Analysis**

The saline impinger solutions were investigated for mesophilic total bacteria, mesophilic fungi, endotoxins and suspended particles. The bacteria were grown on blood agar (incubation temperature 36 °C) and the fungi on DG 18 agar (incubation temperature 25 °C), respectively. The readings are given in colony forming units (CFU) per m³ of air. Endotoxins were determined with the Limulus-Amoeocyte-Lysat (LAL) Test and quantified photometrically by the chromogenic-kinetic method. The results are given in endotoxin units (EU) per m³, where 8 EU are approximately proportional to 1 ng. The number of suspended particles in the Impinger solution was counted with an optical particle counter (Abakus, Klotz, Unterhaugstett, Germany) which is able to detect particle sizes in the range between 0.7 µm and 120 µm. The results are expressed as number of particles (n) per m³ air.

**Data processing**

Assuming that the volume flow of the waste gas is not negatively influenced by the design of the filter system or the sampling technique the reduction efficiency \( \eta_B \) (%) can be calculated from the corresponding concentrations at the three sampling points for the different pollutants as follows:

\[ \eta_B = \frac{C_{B, \text{crude}} - C_{B, \text{clean}}}{C_{B, \text{crude}}} \times 100 \]
where C is the bioaerosol concentration (particle, bacteria, fungi, endotoxins) in the crude gas and in clean gas I and II. The difference $\eta_B$ between crude and clean gas II is the total reduction efficiency. Negative $\eta_B$ are indicating an increase of airborne components in the clean gas.

RESULTS
The indoor concentrations of particles (P), total bacteria (B), mesophilic fungi (F) and endotoxins (etox) ranged between 2.26 x 10^6 to 11.9 x 10^6 n m^-3, 1.04 x 10^6 to 14.9 x 10^6 CFU m^-3, 2.15 x 10^3 to 104.5 x 10^3 CFU m^-3 and 10.3 to 216.6 EU m^-3, respectively. In Table 1 the calculated reduction efficiencies between the crude gas and the air behind the second scrubber (difference between sampling point 1 and 2) and between the crude gas and the clean gas (1-3) are shown. The concentrations in the clean gas were distinctly lower in most cases. The average reduction efficiencies for particles were between 83.1 and 97.2%. Usually the filter (step 3) clearly increased the reduction efficiency. Only at day one the reduction efficiency dropped slightly by approximately 2 % between sampling point 2 and 3. The lowest reduction efficiency for total bacteria (B) was 89.9 the highest 99.1% (day 2). The reduction efficiencies for mesophilic fungi (F) were between 73.1% and 97.9%, with one exception. At day six more airborne fungi were found in the scrubber unit (sampling point 2) than in the air of the broiler house ($\eta_B$: -88.7%). The reduction efficiency of the container based biofilter for endotoxins (Etox) differs considerably. The best $\eta_B$ was calculated with 92.9%, but on day 6, an increase of nearly 180% of endotoxins in the clean gas II was observed. At days 3, 5 and 6 higher Etox concentrations are observed in the cleaned gas behind second scrubber than in the animal house. The highest enrichment was seen at day 5 with 11300%.

Table 1. Reduction efficiencies $\eta_B$ (%) of the biofilter compartments 1, 2 and 3 for selected bioaerosol components (for 1, 2 and 3 see Figure 1)

<table>
<thead>
<tr>
<th>Day:</th>
<th>P</th>
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<th>Etox</th>
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<tr>
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<tr>
<td>Etox</td>
<td>11</td>
<td>8</td>
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n.c. not calculated due to missing values; underlined values indicate enrichments in the clean gas in opposite to the crude gas.

Figure 1. Scheme of the container based biofilter and the position of the AGI-30 samplers. 1: crude gas, 2: clean gas I, 3: clean gas II. Bold arrows are indicating the main air flow through the biofilter. The first scrubber unit is not drawn.
DISCUSSION

Biofiltration is one technical option to remove volatile and particulate pollutants from waste gases in gases like ammonia in the exhaust ventilation air of livestock buildings. In recent years since concerns are rising in the residential areas around livestock enterprises about possible health effects caused by emitted particles and micro-organisms interest grows to use biofilters in or at animal houses as an abatement technique for these bioaerosols. First investigations revealed inconclusive results. Some filters worked with high others with low cleaning efficiencies. The presented study demonstrates considerable differences in reduction efficiency between sampling days in the same plant. A critical point is the organic biofilter material, which is poorly defined. The structure and type of bedding can vary between batches in the same plant and between different plants. It can also deteriorate with time which may change its retention capacities for various compounds. Bedding material usually contains more than $10^7$ germs per gram that colonise the surfaces of the material. The permanent air flow through the biofilter can mobilise some of these attached micro-organisms as demonstrated for fungi by Rabe and Becker (2000). In extreme situations emission quantities may be higher than without a biofilter. From investigations on biofilter surfaces in composting plants it is known that the clean gas can contain two times higher concentrations of fungi than were found in the crude gas before the filter (Seedorf 2000).

In this study slight enrichment processes were observed for particles at sampling day one between sampling point 2 and sampling point 3 when the total reduction efficiency decreased by 2 %. The additional particles are probably released from the wooden biofilter bed. An enrichment of compounds can occur in the scrubber unit. The washing water retains water-soluble substances and dust particles, and is re-circulated, accumulating large amounts of compounds. If the accumulation capacity of the liquid is exceeded compounds can break through and carry on to the biofilter. This may have happened with the endotoxins at sampling days 3 and 5. If the compounds and microorganisms are not kept back by the biofilter they appear in the ‘clean’ gas (sampling day 6). The example of sampling day 5 shows that good adsorption properties of the filter bed may compensate overloading of the scrubber step for some time. The same mechanism seemed to work for fungi at day six.

The results of this investigation show that a repeated and regular monitoring of biofilter systems is necessary to recognise mis-functions and leaks. Because of the complexity of factors which can influence the total reduction efficiency, a deeper understanding of the different technical and biological steps in the cleaning process are desirable. The presented method is relatively simple to perform and covers the most important pollutants that may cause harm in the residential surrounding of farms. For new biofilter/scrubber systems it seems useful to introduce a monitoring procedure that covers typical and extreme operational situations as well as various weather and climatic conditions.

Furthermore it is desirable to define specific bacteria and fungi which are related to public health hazards and which may serve as marker substances. However, the investigations should not only focus on micro-organisms which pass a biofilter, occupational health aspects should also be regarded because the biofilter operations need maintenance and service periods where people are working directly in and with the system and are exposed.

REFERENCES


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