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SYSTEMS FOR ELIMINATING PATHOGENS FROM EXHAUST AIR OF ANIMAL HOUSES

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ABSTRACT

Recent outbreaks of highly infectious viral diseases like swine fever and avian influenza in The Netherlands have shown that despite extensive bio-security measures aiming at minimizing physical contacts between farms, disease spread could not be halted. Dust in exhaust air from swine and chicken houses may provide a favorable environment in which these viruses and other pathogenic microorganisms can survive and be transported over long distances to other farms. In a field study and in an experimental pilot-scale system, the effects of air scrubbers (bio-scrubber and acid scrubber) were tested. The field test showed higher bacterial counts in the outlet air than in the inlet air of the bio-scrubber (increase from 6.1 x 10^4 to 24.4 x 10^4 cfu/m^3). An acid scrubber with sulfuric acid reduced bacteria emissions from 27 x 10^4 to 8.4 x 10^4 cfu/m^3. In the pilot-scale cleaning system, different disinfectants were tested, including hydrogen peroxide, ozone, and peracetic acid. Peracetic acid gave by far the best results. It reduced bacteria and virus emissions to below detectable levels and reduced ammonia emissions by 96%. We conclude that an acid scrubber with sulfuric acid is very useful to reduce ammonia and dust emissions to the atmosphere; however, it cannot prevent the emission of pathogens. Peracetic acid reduces all these emissions, but is too costly to be used continuously. Therefore, an interesting option to prevent disease spread is to replace or supplement sulfuric acid in existing scrubbers with peracetic acid in times of high risk of disease outbreak.

KEYWORDS. Livestock production, air cleaning, peracetic acid, infectious diseases, disinfectants, environmental emissions

INTRODUCTION

Recent outbreaks of highly infectious viral diseases like swine fever and avian influenza have shown that despite extensive bio-security measures aiming at minimizing disease spread between farms, invasion of infectious agent could not be halted. Dust in exhaust air from animal houses may provide a favorable environment in which pathogens can survive and be transported to other farms. In this way, in an intensive animal production area, infectious diseases could easily be dispersed from farm to farm and infect a lot of animals in a short period of time.

In animal-dense areas, the emissions of environmental pollutants are also recognized as a serious problem. In The Netherlands, goals have been formulated to reduce emissions of ammonia, odor, greenhouse gases, and dust (Anonymous, 2001). By 2030, ammonia and dust emissions should be reduced by approximately 80 and 90%, respectively, and the long-term reduction goal for methane is 70%, with regard to 1990 emission levels. Odor emissions must be reduced to the extent that people living near the facility do not have severe problems with odor.

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In this study, full-scale operating air scrubbers and a laboratory scrubber set-up were examined to determine their abilities to reduce pathogens and environmental pollutants. The objective of this project is to develop an air cleaning system for animal houses, especially for pigs and poultry, that not only reduces emissions of environmental pollutants, but that effectively eliminates pathogen emissions as well.

MATERIALS AND METHODS

Field measurements

Two commercially available air-cleaning systems were tested under field conditions in pig houses: 1) a biological air treatment system ('bio-scrubber'), and 2) a chemical air treatment system ('acid scrubber').

The working mechanism of the bio-scrubber is based on the degradation or conversion of environmental pollutants by microorganisms. Ammonia is converted to nitrite and nitrate; odorous compounds are mainly degraded to water, carbon dioxide, and sulfate (Melse and Willers, 2004). This results in a strong reduction of the emissions of ammonia and odor. The bio-scrubber had a basal area of 1.5 x 2.0 m and a height of 4.5 m. Within this unit, there was a plastic packing material with a relatively open structure, with a height of 1.1 m and a volume of 3.3 m^3. The scrubber was designed for an airflow of 20 000 m^3/h. The air from the pig house was drawn through the filter packing in an upward direction. Water from sprinklers trickled downwards through the packing (counter-current principle) and was collected in a basin (basin volume 9 m^3). The bacterial mass, which is partly attached to the packing surface and partly suspended in the trickling water, is responsible for conversion of ammonia to nitrite and nitrate (nitrification). In a second basin (basin volume 25 m^3), the nitrate is converted to nitrogen gas (denitrification). Both basins contained submerged packing material, equal to the packing in the scrubber itself. Finally, the water entered a sedimentation tank (tank volume 20 m^3). From this tank the water was partly recirculated and partly replaced with fresh water.

An acid scrubber scrubs alkaline compounds, such as ammonia, from the exhaust air of the animal house using an acid solution. In The Netherlands, only sulfuric acid is allowed for this purpose. Measurement of the pH of the recirculation water determined the quantity of acid supplied. Measuring the electrical conductivity of the recirculation water determine the quantity of displacement water supplied. Electrical conductivity is a measure of the amount of dissolved salts, in this case ammonium sulfate. The acid scrubber was designed for an airflow of 30 000 m^3/h. The scrubber consisted of a stack of vertically positioned fiber cloths that were wetted by spraying a sulfuric acid solution on top of the cloths; the air flowed in a horizontal direction, parallel to the cloth surface through the stack (cross-current principle). The stack had a volume of 2.9 m^3 (3.0 x 1.0 x 0.95 m). When the air moves along the fiber cloth, ammonia in the air is bound by sulfuric acid in the scrubbing liquid to form ammonia sulfate. The scrubbing liquid was collected in a basin of 600 L volume. From this basin, the liquid was partly recirculated and partly replaced.

The bio-scrubber was studied at a farm with growing-finishing pigs, while the acid scrubber was studied at a farm with sows. The following was determined in both systems during one day at approximately 9:30, 12:30 and 16:00 h:

- Total bacterial counts of ingoing and outgoing air of the scrubber. Air was sampled during a 5-minute period; with airflow of 3000 L/h. Bacterial counts were done in the lab according to standard procedures (ISO 6887, 1983).
- Ventilation rate across the scrubber (only measured at 12:30 and 16:00. Measuring the air speed at 3 representative places and multiplying it by the cross-sectional area of the air duct determined ventilation rate.
- Ammonia concentration of ingoing and outgoing air of the scrubber with gas detection tubes.

- Temperature and relative humidity of ingoing and outgoing air of the scrubber by a combined temperature / humidity sensor.

Measurements in experimental setting

A small-scale model of a commercially available air scrubber (30 L volume) was built and its ability to reduce the emission of environmental pollutants as well as microorganisms (*Enterococcus faecalis* and *Gumboro* virus) was tested, both with and without adding disinfectants to the water in the system. The disinfectants studied were: hydrogen peroxide (0.6%), ozone (0.015 %) and peracetic acid (solution of 0.13% peracetic acid, in equilibrium with 0.6% peroxide). Their effects on the outlet concentrations of pathogens, odor, dust, and ammonia were compared with a control treatment in which the air was scrubbed with water alone. The airflow rate through the scrubber was 60 m^3/h. Ventilation air was drawn off from 4 isolators (small isolated cabins) containing 7 roosters each. At 3 different days within a period of 6 days the concentrations of ammonia, odor, methane, nitrogen oxides and inhalable dust were measured in the inlet and outlet air of the scrubber. Pathogen reduction was measured by aerosolization of approximately $10^{10.2}$ cfu (colony forming units) *E. faecalis* per m^3 of isolator air, followed by measurement of the inlet and outlet air concentration of this bacterium at 3, 10, 20, and 30 min after starting the aerosol production. The same measurements were done after the aerosolization of $10^{8.08}$ ID_{50} (Cell Culture Infective Dose 50%) *Gumboro* virus when peracetic acid was used as the disinfectant. To determine differences in the effects of the disinfectants, the results were statistically analyzed by the ANOVA procedure of Genstat (Genstat Committee, 2003).

RESULTS

Field measurements

The ventilation rate through the bio-scrubber was on average 16 500 m3/h. Temperature and relative humidity before and after the filter were 18.9 ^{o}C and 68.7%, and 14.8 ^{o}C and 98.4%, respectively. The ventilation rate through the acid scrubber was on average 12 200 m3/h. Temperature and relative humidity before and after the scrubber were 21.9 ^{o}C and 72.3%, and 17.9 ^{o}C and 94.2%, respectively. The bio-scrubber and acid scrubber reduced the ammonia emission by 66% (s.e.m. 8%) and 90% (s.e.m. 1%), respectively.

For the bio-scrubber, the field test showed higher bacterial counts in the outlet air than in the inlet air (increase from 6.1 x 10^4 to 24.4 x 10^4 cfu). The acid scrubber reduced bacteria emission from 27 x 10^4 to 8.4 x 10^4 cfu.

Measurements in experimental setting

The results in Table 1 show that there were no significant differences in the reduction of the emission of any of the components between water, hydrogen peroxide, and ozone. However, peracetic acid reduced the concentrations of *E. faecalis* to below the detectable level of $10^{3.9}$ cfu/m^3 air, and ammonia by 96%. The effects of peracetic acid on odor and dust were not significantly different from water. The peracetic acid treatment also showed a reduction for *Gumboro* virus emissions to below the detectable level of $10^{3.6}$ ID_{50}/m^3 air.

Table 1. Reduction of emission of bacteria and environmental pollutants when using various disinfectants in the experimental air scrubber compared to using water only (in %).

Disinfectant	*E. faecalis*[1] n=4	Ammonia[1] n=3	Odor[1] n=3	Dust[1] n=3
Control with water	33[a]	25[a]	55[a]	88[a]
Hydrogen peroxide	34[a]	64[ab]	7[a]	-
Ozone	41[a]	42[a]	-4[a]	48[a]
Peracetic acid	100[b]	96[b]	-15[a]	78[a]
s.e.m.[2]	8	12	21	19

[1] Means within a column lacking a common superscript letter differ (P<0.05)
[2] Standard error of mean

DISCUSSION

The bio-scrubber in this study showed no reduction in bacterial count, but instead an increase with a factor 4. It could not be determined from this study whether the bacteria in the outgoing air were of the same species as in the ingoing air. So the question remains whether pathogens are outnumbered by the 'good ones' or that the pathogens can multiply themselves in the bio-scrubber. Results are in agreement with findings of (Seedorf and Hartung (1999). They found an increase of endotoxin and mesophilic fungi in the air going through a bio-scrubber by a factor of 3.8 and 2.7, respectively. They found that the recirculating washing water was highly contaminated with different air contaminants. Also in our study we found clearly higher bacteria numbers in the discharge water of the scrubber than in the ingoing water (a factor 5 higher).

The bacteria reducing effect of the acid scrubber was on average 70%. From a veterinary point of view, this is only a marginal reduction, because high numbers of bacteria were still emitted. In the washing water of the acid scrubber, the bacterial count was reduced by 99.8% when it went through the scrubber. But still this water is not sterile, with a bacterial count of more than 300 000 aerobic bacteria per liter. For the full-scale bio- and acid scrubber, the emission of viruses was not determined.

In the pilot scale scrubber system, peracetic acid proved to be very effective in killing pathogens in the exhaust air. Peracetic acid proved to be effective in reducing ammonia emission, as well. Using peracetic acid did not reduce odor. Analyses of the odorous compounds within the inlet and outlet air of the scrubber with GC-MS showed that most odorous compounds were reduced to a great extent. However, the acetic acid concentration in the outgoing air increased by a factor of 4. So, it seems that peracetic acid breaks down a lot of odorous compounds, but also generates odor, as well. Acetic acid might be cleaned from the air rather easily by a second scrubbing step with (alkaline) water.

In Table 2, an estimate is made of the total costs of the most promising systems to eliminate pathogens from the air. The system with peracetic acid is not yet optimized and the costs of peracetic acid probably would be reduced substantially if it were produced in bulk amount. Therefore in the table we assume that the costs of peracetic acid use will be reduced by a factor 10 when optimized and operated at full-scale.

Table 2. Total costs of promising systems to reduce pathogen emissions from the exhaust air (in € per fattener's place per year (excl. tax).

Treatment	Continuously working	Only working in calamity periods (4 weeks per 5 years)
Peracetic acid[1]	48	13.1
UV_C	32[2]	2.3
Absolute filtration	23	17.6

[1] It is assumed that by optimization of the system and the reduction of the costs per kg of peracetic acid by bulk production, the costs of peracetic use are only 10% of current costs.
[2] Excluding prior dust removal.

From Table 2 it can be seen that for a continuous working system absolute filtration is the most cost effective, followed by UV_C radiation, and finally the peracetic acid system. When the system is only used in calamity periods, UV_C radiation is the most cost effective, followed by the peracetic acid system and absolute filtration. The disadvantage of absolute filtration and UV_C radiation, as compared to the peracetic acid system, is that it has little or no effect on the emissions of ammonia, odor, and dust. Furthermore, it should be emphasized that prior to a UV_C radiation treatment, the air should be cleaned of dust. This costs an additional €13, - (excl. tax) per fattener's place per year. When using the peracetic acid system during calamity periods only, during the rest of the year an ammonia emission reduction of 90% could be achieved for an additional €2.20 per fattener's place per year (excl. tax), if the scrubber is used as an acid scrubber with sulfuric acid.

So, for the time being, with respect to costs, we would recommend that peracetic acid be used only during periods of an outbreak or threat of an outbreak of highly infectious diseases. During these periods, livestock farms with an acid scrubber could replace sulfuric acid by peracetic acid. In this way, the dispersion of infectious diseases from farm to farm would be reduced. A precondition is that the majority of farms in that area have installed an acid scrubber and that immediately is reacted to a disease outbreak.

This study was a first orientation to examine the effect of air scrubbers on the emission of microorganisms. Different questions still need to be answered before peracetic acid could be used on the farm, e.g. how should peracetic acid be stored on the farm, how can it be dosed to the scrubbing liquid, what is the optimum concentration. It should be investigated, furthermore, whether the present, commercially available scrubbers can be optimized for elimination of pathogens, as well. It should also be investigated whether bio-scrubbers contribute to even higher emissions of pathogens than in the normal situation without air treatment. More basic knowledge is necessary on the survival time of pathogens in exhaust air, whether they are airborne or carried by dust. This knowledge is important for optimal design of the scrubbers.

CONCLUSIONS

- The commercially available air scrubbers (bio-scrubber and acid scrubber) are suitable to reduce ammonia (and odor) emission from exhaust air of animal houses, but give insufficient reductions in emissions of microorganisms to be sure that spreading of infectious diseases is prevented.
- The use of 0.6% peroxide or 0.015% ozone in an air scrubber is insufficient to prevent the spreading of pathogens to the environment.
- The use of peracetic acid (solution of 0.13% peracetic acid, in equilibrium with 0.6% peroxide) in air scrubbing systems was effective at reducing pathogen emissions (bacteria and viruses) to the environment to below detectable levels. As an acid scrubber, it reduces the emission of ammonia for almost 100%, as well.
- Sulfuric acid, which is commonly used in acid scrubbers, could be replaced or supplemented with peracetic acid during periods of an outbreak or threat of an outbreak of highly infectious diseases. In this way the dispersion of infectious diseases from farm to farm is prevented. For continuous use, peracetic acid is too expensive at this moment.

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REFERENCES

1. Aarnink, A.J.A., Landman, W.J.M., Huynh, T.T.T., Melse, R.W., de Gijsel, P., Fabri, T., 2004. Cleaning exhaust air from pathogens and environmental pollutants in animal houses. Engineering the Future, AgEng conference, Leuven, Belgium, session 22.
2. Anonymous, 2001. Een wereld en een wil; werken aan duurzaamheid; Nationaal Milieubeleidsplan 4. [A world and a will; working for sustainability; National Environmental Policy Plan 4.] Report submitted to the Lower House, 220 pp.
3. Genstat Committee, 2003. Genstat 7th Edition. VSN International Ltd, Hemel Hempstead, UK.
4. ISO 6887 (1983). Microbiology - General guidance for the preparation of dilutions for microbiological examination. International Standard Organization, 1st Edn, Geneva.
5. Melse, R. W., Willers, H. C. (2004). Toepassing van luchtbehandelingstechnieken binnen de intensieve veehouderij. Fase 1: Techniek en kosten. [Use of air cleaning systems in intensive

livestock production. Phase 1: Techniques and costs.] Agrotechnology and Food Innovations, Wageningen UR. Report 029.

6. Roelofs, P., 1999. Desinfectie binnenkomende lucht met UV-straling. [Disinfection of incoming air by UV-radiation.] Periodiek Varkenshouderij, Proefstation voor de Varkenshouderij, Rosmalen.

7. Seedorf, J., Hartung, J., 1999. Reduction efficiencies of a biofilter and a bioscrubber for bioaerosols from two different piggeries. Berliner und Munchener Tierarztliche Wochenschrift 112, 444-447.