CLEANING EXHAUST AIR BY BIOLOGICAL WASTE GAS PURIFICATION SYSTEMS IN LIVESTOCK BUILDINGS – STATE OF ART AND SHORTCOMINGS

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Introduction

Modern farm animal production is increasingly being regarded as a source of gaseous, odorous and particulate emissions which are environmentally harmful and can cause nuisance. Therefore, livestock operations are under pressure to fulfil minimum legal requirements and reduce the pollution of the atmosphere (e.g. ammonia, PM_{10}). However, ambient air quality demands can often only be achieved when biological waste air purification systems (BWAPS) are used.

The present article gives a short overview of the most common BWAPS applied in agriculture, their composition, functionality and efficiency, and will also highlight some potential shortcomings, which might affect the biosafety of such devices.

Applied systems and their efficiencies

BWAPS belong to the most important techniques to remove environmentally harmful agents such as odour, some gases and dust from the exhaust air of mechanical ventilated livestock buildings. The air is actively transported by fans through the BWAPS. Therefore, it cannot be applied in naturally ventilated farm buildings.

Microorganisms which are settled and sessile in the system play the most important role in all BWAPS. They are responsible for the reduction of gas components and odours by their oxidative metabolic capacities. This is different from chemoscrubbers which are using acid solutions to reduce (mainly) ammonia emissions. Parameters such as temperature, humidity of the air, structure of biofilter material, pH values, oxygen supply, contaminant loads, residence time, air flow velocities and directions determine the biological processes within and therefore the proper functionality of BWAPS.

Overall, four different biological techniques can be principally distinguished (Grimm 2005, Hahne et al. 2002), which are briefly characterised below.

Biofilter. Biofilters contain organic material (e.g. wood shavings) carrying sessile microorganisms, which utilize components of both the carrier material and the nutrients in the waste air. This two-way utilization of nutrients is advantageous, because fluctuations in the concentration of nutritive components in the waste air are compensated by the other nutrient source. The number of active microorganisms and their metabolic degradation capabilities are consequently not diminished and the effectiveness of the system does not decline. In all BWAPS water plays a crucial role for microbial activity, transport of nutrients and removal of toxic by-products. Therefore, permanent water irrigation of the filter material and humidification of the waste gas in pre-scrubber units are carried out. Specific problems are caused by the high amounts of airborne dust in livestock buildings. It is essential to remove this dust before the waste air is passed through the biofilter to avoid clogging of the biofilter material.

Biotrickling reactor. In a trickle bed reactor the contaminants from the waste air are passing an inert packing material, which is permanently sprinkled by water from above. The large surface of the packing material is fully covered by a biofilm of microorganisms, which remove and metabolize the components/nutrients from the air. A disadvantage is that the inert material does not contain nutrients. Therefore, the material has to be frequently flushed with soluble nutrients to support a stable biofilm. Furthermore, pH adjustment is also necessary to guarantee sufficient purification efficiency.

Bioscrubber. A bioscrubber consists of an absorber unit where the interaction between waste air and activated sludge takes place and a fermentation tank where the sludge is aerated and conditioned (water, pH etc.). A cycle pump is continuously transferring the sludge between absorber and fermentation tank. Excess sludge and water leave the fermentation tank by an overflow and run into a slurry pit, for instance. By the very close contact of sludge and waste gas, bioscrubbers are well suited for purification of heavy polluted air and the efficiency to remove water soluble components is relatively high.

Combined systems. Numerous combinations of the BWAPS described above exist in practice. Very often combined systems can reduce airborne pollutants much more efficient than single step purification systems can do. Typical cascade-like air treatment systems are constructed by the combination of a water rinsed filter wall (dust removal), an acid-in-water rinsed filter wall (ammonia removal) and a biofilter module with organic material as described above (odour removal).

The reduction efficiency can vary greatly and is dependent on the type of BWAPS and the pollutant, which has to be removed from the exhaust air (Table 1).

Table 1. Common BWAPS , their reduction efficiencies and typical areas of application (Grimm 2005, modified).

	Chemoscrubber	Biotrickling and	Biofilter	Combined Systems

	Bioscrubber			(3-step)
Odour	-	++	++	++
Ammonia	++	+	-	++
Dust	+	+	+	++
Area of application	Pigs (liquid manure) Fattening poultry (floor systems)	Pigs (liquid manure)	Pigs (liquid manure)	Pigs and poultry (liquid or solid manure)

Reduction efficiency: - unsuitable, + at least 70 %, ++ at least 90 % (odour: no livestock odour detectable by nose or clean air < 300 odorous units per m³)

Shortcomings

The complex physical, chemical and biological processes in the BWAPS require frequent monitoring of all relevant process factors to prevent inappropriate operation which does not protect the environment and is economically questionable. For example, too low oxygen supply within BWAPS can lead to unbalanced nitrification and denitrification reactions and the release of the strong greenhouse gas; nitrous oxide. Highly compressed biofilter material promotes filter break-throughs of untreated waste gas or it could enhance anaerobic processes within BWAPS. Such situation can lead to an increase in emitted odour, which might be even worse than the original odour in the waste gas. In contrast to these relatively well documented limitations of BWAPS, little is known about the risk of uncontrolled emissions of system-related microorganisms from such operations.

The microbial ecosystem in BWAPS is influenced by three main components, namely livestock air, immobilized biofilms and recirculated process water, which connect the two former components. Therefore a considerable biodiversity exists due to the permanent intake of microbes via the waste air and due to the reproductive capacities of deposited (process water) and biofilm-related microorganisms (Tab. 2). Apart from the large amounts of microorganisms per ml, health-related microbes such as *Escherichia coli* (smear infection, endotoxin release), *Acinetobacter* ssp. (facultative respiratory infection, endotoxin release, high tenacity) or *Aspergillus* ssp. (allergenicity) were found. Additionally, pro-inflammatory endotoxins are also significantly concentrated in the process water. In a previous study very high relative enrichment for endotoxins was seen (11,300 %) in the air within the BWAPS compared to the waste air of the animal house (Seedorf and Hartung 2002). Such a microbiological mixture (enriched in the process water) is then sprayed and aerosolized within the BWAPS for humidifying purposes. It highlights the question of biosecurity both for the operator (farmer) and the environment (residents).

Table 2. Results of microbial spot investigations of process water from a BWAPS installed at a duck fattening farm (Seedorf 2004).

Sum parameter	Day 1	Day 2	Genus/species	Day 1	Day 2
in colony forming units (CFU) per ml:			In CFU/ml (approximately):		
Total bacteria	205,000	3,270,000	*Bacillus* ssp.	10^5	-
Staphylococci	53,700	517,000	Pseudomonas stutzeri	-	10^5
Enterobacteriaceae	5,170	393,930	*Proteus* ssp.	10^5	10^6
Fungi 25 °C	17	113	*Acinetobacter* ssp.	-	10^6
Fungi 40 °C	13	10	*Escherichia coli*	10^5	-
in Endotoxin Units (EU) per ml:			Coliforme bacteria	-	10^6
Endotoxins	4,655	3,522	Coagulase (-) Staphylococci	10^5	10^6
			Enterococci	-	10^6
			Alpha-hemolytic Streptococci	10^5	10^6
			Weeksella virosa	-	10^6
			Alcaligenes ssp.	-	10^6
			Aspergillus ssp.	-	10^2
			Other moulds	-	10^2
			Yeasts	-	10^2

Conclusions

- Well operated common BWAPS are able to reduce odour, ammonia and dust up to 70 %.
- A cascade-like combination of different component-specific reduction techniques can even reach 90 % reduction efficiencies for livestock-related airborne pollutants.
- The high number and large variety of microorganisms and their compounds in water and in the air of BWAPS may cause health hazards for staff and the environment.
- It is presently unknown whether observed enrichments in the clean gas are caused by primary (livestock air) or secondary (BWAPS-related) emissions; new technical improvements may necessary to avoid such emissions.
- There is a need for regular control measurements, sufficient and frequent maintenance schemes and a better training of farmers how to operate the systems to guarantee long-term operation of BWAPS and to reduce hygienic and environmental risks.

References

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