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State-of-the-art of Waste Air Purification Systems for Application in Animal Husbandry Facilities

Waste air purification systems are not state-of-the-art of low-emission animal husbandry. They are applied in order to prevent harmful environmental effects, if set-back distances from residential areas or from forests are not kept and all other possible measures to reduce emissions have been taken. Systems available differ with respect to the purification principle, the range of use, the cleaning objective (odour, ammonia, dust), the cleaning efficiency and the costs.

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Literature

Literature references can be called up under LT 05123 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

The cleaning of the waste air of animal housings is costly. For example, additional expenses for the construction of the installations amount up to € 60 per pig place in pig fattening.

For this reason waste air purification systems are only applied in the case a building project would otherwise not be permitted. In some regions of Lower Saxony, where livestock density and immission loads are high, the enlargement of livestock farms is only admissible if air purification systems will be applied. Very often, the only alternative to the application of air purification systems is to construct the facility at another site. But costs for the development of the site may often exceed costs for the air treatment at an existing site. In addition, in many regions promising sites allowing the further development of the production are rarely available.

Therefore, in regions with intensive livestock production and where the farms have grown strongly the application of air purification systems is the only mean to develop the farms and to increase production.

Available air purification systems and fields of application

The most important waste air purification systems offered on the market are summarised in *table 1*.

The type of system applied depends mainly on the kind of emission, which should be reduced, on the field of application and the cleaning effectiveness required. In any case it should be examined if all possibilities to reduce emissions by housing-internal measures such as the optimisation of the house climate control have been taken.

In principle all systems with forced-ventilated housings can be applied, since the waste air has to be collected in order to guide it through the purification system. Naturally ventilated housing systems can not be equipped with waste air filters. Therefore the main field of application is the housing of pigs and poultry. In cattle-farming the purification systems do not play an important role, since naturally ventilated loose housing is dominating and the emission load and the annoying potential of the waste air is low, compared to pig and poultry housings.

Additionally it has to be remarked that all systems can be applied in pig production, but only two of them are suitable for poultry housing. Those work well, although the load of dust and feathers is high. Only the three-stage combination-system can be applied with all housing systems independently of the manure removal regime (solid or liquid manure system; see *table 1*).

Removal efficiencies

With respect to odour, bio-scrubbers (trickling-bed filters), biofilters and so-called combination systems attain the highest cleaning efficiency of all systems (*table 1*). For proper function biofilters must always be humidified sufficiently (inlet air > 95% relative humidity, humidity of the filter bed material > 40%). Chemical scrubbers are not

Table 1: Available waste air purification systems [1]

	Chemical scrubber	Tickling-bed filter (bio-scrubbers)	Biofilter	Combination system (3-stage)
Odour	-	+ +	+ +	+ +
Ammonia	+ +	+	-	+ +
Dust	+	+	+	+ +
Field of application (housing system)	Pigs (liquid manure), fattening poultry (floor housing)	Pigs (liquid manure)	Pigs (liquid manure)	Pigs, poultry (solid and liquid manure)

Cleaning efficiency (proper design and operation provided): - unsuitable, + at least 70%, + + at least 90% (odour: indoor smell not perceptible in the clean air and clean air concentration < 300 OU/m^3 respectively)

	Chemical scrubber	Tickling-bed filter (bio-scrubbers)	Biofilter	Combination system (3-stage)
air passage construction	central tower or compact	central tower or compact	central/decentral Single-level filter	central filter building
Area load*) [$m^3/(m^2$ h)]	5000 - 7500	1450 - 7000	250 - 350	1000 - 1690
Volume load*) [$m^3/(m^3$ h)]	25000	1450 - 5800	275 - 1000	-
Flow velocity*) [m/s]	3	0.4 - 2	< 0,1	< 1 - 1.5
Time of direct contact*) [s]	2	1 - 3	3.6 - 12	0.8 - 0.9 (only filter-walls)
Pressure drop*) [Pa]	< 40	< 60 - 70	< 20 - 100	< 60 - 100
acidification / pH-control	yes	- / yes	-	yes
Pumps (connection power 1,000 fattening pig places) [kW]	3	1,2 - 4	0 (primary pressure house service connection) - 1.5	2 - 3

*) related to the maximal air flow rate

Table 2: Selected design-parameters

recommended to reduce odour because they reach only low cleaning efficiencies, compared to the other systems. In addition, due to the application of acid, the type of odour may change [2].

The adjustment of the pH (< 5) by adding acid to the scrubbing suspension is a prerequisite to remove ammonia permanently with a high efficiency. For this aim chemical washers and the second stage of the combination systems are specially designed. In principle biofilters are not suitable for the ammonia removal. Depending on the moisture content of the filter bed (humid, dry) ammonia is either accumulated in the filter material and the leachate, passed through or released. Ammonia that has been accumulated is partly nitrificated and nitrate and nitrite are formed. Both inhibit the biological odour degradation. Other parts ammonia is released as nitrogen oxide and nitrous oxide. In addition, the pH-level of the filter bed and the leachate is lowered [2, 3].

All systems remove dust. The larger the column packing and the more treatment stages are combined in series (e.g. three-stage combination-system) respectively, the better is the removal of dust. But if biofilters dry out they can act as a source of particles [2]. In order to avoid emission of droplets of the washing suspension, washers must always be designed with a droplet eliminator at the outlet.

Along with the dust its biological components are removed. However germs and endotoxins may be accumulated in the clean-air so that raw gas concentrations are lower than the clean gas concentrations. This may be observed especially in the case of biological systems that depend on micro-organisms for proper function. In addition the composition of species in the air may change, while passing the purification system, i.e. the clean air may contain micro-organisms that can not be found in the raw air [4, 5].

Often a lower cleaning efficiency is required in practice than a manufacturer guarantees. In those cases it is more profitable to treat only a part of the exhaust air with a high efficiency than to treat the total air with low efficiency, because of lower investment and operating costs.

A permanently high cleaning efficiency implies that the installation is accurately designed and orderly operated. Selected parameters for the design of the systems are condensed in *table 2*.

This implies the periodical monitoring and maintenance of the systems. In this regard the farmer as the operator of the unit is in charge. In order to facilitate this task and to document the proper function at any time the consumption of electricity, water and chemicals should be recorded.

The automatic control and recording of the essential parameters with a computer is helpful. Finally the manufacturer should provide a manual and a revision and maintenance scheme as well as training for operation. In addition the manufacturer should control the start-up of the facility in order to ensure its orderly function.

Costs

In *table 3* the costs of the different systems according to manufacturers' information are compiled. Partly the cost data greatly diverge from each other whichever technical standard (design of the system and cleaning efficiency, degree of automation) and bases of calculation are assumed (e.g. consumption and prices of electricity and water, depreciation period of components) and to what extent the personal contribution of the farmer is included in the calculation. Normally the additional costs for the storage and application of effluents that are fed into the slurry are not included.

The costs for installations with a high cleaning efficiency are at the upper margin of the costs.The additional labour for monitoring and maintenance amounts from 20 to 50 hours per year (1,000 fattening pig places). Additional costs may arise, if the treatment system is retrofitted and the ventilation system has to be reconstructed and more effective ventilators have to be installed.

In the case of pig fattening the additional costs per pig produced amount at least to € 4.

Waste air purification systems - state-of-the-art?

The state-of-the-art of low emission-housing techniques is specified in the German TA Luft (Technical Instructions on Air Pollution Control) and the European Best Available Techniques Reference Documents (BREF) „Intensive Rearing of Poultry and Pigs“ [8]. Waste air purification systems do not belong to the state-of-the-art of low emission-housing techniques due to the high cost associated with their application. The average successful pig producer suffers losses when operating the systems.

In contrast, the guidelines of the German Association of Engineers (VDI) VDI 3477 „Biological Waste Gas Purification - Biofilters“ and VDI 3478 „Biological Waste Gas Purification - Bio-Scrubbers and Tickle Bed Reactors“ describe the general state-of-the art of purification systems. In the future for the application in livestock farming these global requirements are specified by a test procedure to be conducted by the German Agricultural Society (DLG). This test replaces the suitability test, which was carried out by the county of Cloppenburg for its scope. In future KTBL will provide planning data for a better assessment of the main systems regarding costs.

Table 3: Investment and operating costs with the example pig fattening (incl. VAT)

	Chemical scrubber	Tickling-bed filter (bio-scrubbers)	Biofilter	Combination system (3-stage)
Investment costs [ ] per fattening pig place	39 - 58	52 - 70	23 - 35	45 - 70
Operating costs [ ] per pig delivered	1.75 - 2.55	0.60 - 1.75	1.15 -1.75	1.15 - 2.05
Total costs [ ] per pig delivered	3.20 - 4.70	2.50 - 4.35	2.00 - 3.05	2.80 - 4.65

Calculation basis: 1,000 fattening pigs, 2.7 turnover/a, 10 years depreciation period for investment; without additional costs for ventilators, air ducts, effluents storage and application