DLG Test Report 7263

Lubing Maschinenfabrik GmbH & Co. KG

CleaningCubes

for strawless pig housing

APPROVED 2022 DLG WWW.DLG.ORG

FULL TEST
LUBING
CLEANINGCUBES
DLG Test Report 7263

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Overview

The DLG APPROVED FULL TEST quality mark is awarded to agricultural equipment that has passed a comprehensive DLG usability test. A DLG usability test is carried out to independent and recognised test criteria and provides an objective and unbiased assessment of the product and all features considered essential by users. The test comprises individual lab tests as well as field tests in various conditions; in addition to that the product has to prove itself in on-farm applications. The test conditions and procedures are defined by an independent test commission and described in a test framework which defines the parameters for evaluation. Yet the test conditions and procedures as defined are revised on an ongoing basis so they reflect what is acknowledged as the current state of the art as well as the latest scientific findings and also agricultural insights and requirements. After a product has passed the test, a test report is produced and published and the quality mark is awarded to the product and will retain its validity for five years from the date of award.

The CleaningCubes manufactured by Lubing were submitted to the DLG test in order to obtain the quality seal for their effectiveness in reducing dust, ammonia and odour emissions from the exhaust air of strawless pig housing systems. The test is based on DIN 18910 which sets out the requirements for the design of ventilation systems in livestock buildings. According to this standard, the system must achieve ammonia, nitrogen and dust separation rates of at least 70 % for each of these elements. At the same time, odour emissions must be reduced to below 300 odour units (OU) per cubic metre of clean air and there must be no perceptible smell of untreated air in the clean air.

Assessment in brief

The CleaningCubes manufactured by Lubing are a two-stage chemical and biological exhaust air purification system (hereafter referred to as air scrubber) for removing dust, ammonia and odours from strawless pig houses with overhead exhaust systems. After entering the first acidic scrubbing stage, which is operated at pH 3.0, the exhaust air passes through a droplet separator to a biological scrubbing stage.

The chemical scrubbing stage (ChemCube) mainly removes total dust, fine dust (particulate matter) and ammonia. The droplet separator prevents larger water droplets (aerosols) from entering the downstream biological stage. Here, the Biocube reduces the concentration of odorous substances in the exhaust airflow. This biological stage can be omitted if the aim is to reduce ammonia emissions only.

In the test, the CleaningCubes achieved a minimum separation efficiency of 78.6 % in winter and 71.4 % in summer for PM_{10} fine dust. For total dust, the rate was 91.3 % and more in winter and 85.0 % and more in summer. The minimum separation efficiency for ammonia was 77.3 % in winter and 80.7 % in summer. The nitrogen removal figures were 87.3 % in winter and 84.6 % in summer. The higher nitrogen removal rate compared with ammonia is due to the different measurement periods and the fact that the clean air values were corrected (rounded up to 1 ppm).

The results are summarised in Table 1.

Table 1:
Overview of results for the CleaningCubes air scrubber

TEST CRITERION	RESULT	Evaluation*
Results of emission measurements		
Total dust (gravimetric)		
Winter (2 measurements), minimum separation efficiency [%] [1], [2]	91.3	■■■■■
Summer (3 measurements), minimum separation efficiency [%] [1], [2]	85.0	■■■■
Fine dust PM_{10} (gravimetric) [3]		
Winter (2 measurements), minimum separation efficiency [%] [1], [2]	78.6	■■■
Summer (3 measurements), minimum separation efficiency [%] [1], [2]	71.4	■■■
Fine dust $PM_{2.5}$ (gravimetric) [3]		
Winter (2 measurements), minimum separation efficiency [%] [1], [2]	75.0	not evaluated
Summer (3 measurements), minimum separation efficiency [%] [1], [2]	75.0	not evaluated
Ammonia (measured continuously for a minimum of four weeks) [4]		
Winter, minimum separation efficiency [%] [1]	77.3	■■■
Summer, minimum separation efficiency [%] [1]	80.7	■■■■
Nitrogen removal [4]		
Winter [%]	87.3	■■■■
Summer [%]	84.6	■■■■
Odour [4]		
Winter (8 measurements)	< 300 OU/m³ and no perceptible untreated gas	✓ **
Summer (8 measurements)	< 300 OU/m³ and no perceptible untreated gas	✓ **
Consumption measurements (mean values per day or per animal place [AP] and year) [5], [6]		
Total fresh water consumption		
Winter [m³/d] / [m³/(AP · a)]	0.67 / 0.33	not evaluated
Summer [m³/d] / [m³/(AP · a)]	1.96 / 0.97	not evaluated
Av. annual rate [m³/d] / [m³/(AP · a)]	1.32 / 0.65	not evaluated
Volumen of sludge water, ChemCube (conductivity-controlled) [7]		
Winter [m³/d] / [m³/(AP · a)]	0.10 / 0.049	not evaluated
Summer [m³/d] / [m³/(AP · a)]	0.11 / 0.056	not evaluated
Av. annual rate [m³/d] / [m³/(AP · a)]	0.11 / 0.053	not evaluated
Acid consumption (based on 96 % sulphuric acid)		
Winter [kg/d] / [kg/(AP · a)]	18.0 / 8.9	not evaluated
Summer [kg/d] / [kg/(AP · a)]	20.7 / 10.2	not evaluated
Av. annual rate [kg/d] / [kg/(AP · a)]	19.4 / 9.6	not evaluated
Electrical energy consumption		
Exhaust air scrubber [8]		
Winter [kWh/d] / [kWh/(AP · a)	– – / – –	not evaluated
Summer [kWh/d] / [kWh/(AP · a)]	38.3 / 19.0	not evaluated
Av. annual rate [kWh/d] / [kWh/(AP · a)]	– – / – –	not evaluated
Fans		
Winter [kWh/d] / [kWh/(AP · a)]	26.5 / 12.9	not evaluated
Summer [kWh/d] / [kWh/(AP · a)]	82.3 / 40.7	not evaluated
Av. annual rate [kWh/d] / [kWh/(AP · a)]	54.2 / 26.8	not evaluated

* The DLG test framework provides the following options in its evaluation schemes:
■■■ or better = meets, exceeds or clearly exceeds the specified DLG standard, ■■ = meets the legal requirements for marketability, ■ = failed

** Evaluation range: Meets the requirement (✓)/ Does not meet the requirement (✗)

[1] The minimum separation efficiency for dust is the lowest value recorded during the measurement period. The minimum separation efficiency for ammonia is the recorded separation rate minus the standard deviation.

[2] Due to limited technical options, it was only possible to measure total dust and fine dust downstream of the biofilter. Therefore, approval for dust applies only to systems that include both scrubbing stages.

[3] Experience shows that the scrubbing process can lead to the formation of droplets with sizes ranging from 2.5 to 10 µm, which can result in increased levels of the particulate fraction PM_{10} in the cascade impactor. The particulate fraction $PM_{2.5}$ is less susceptible to this effect. As a result, a higher separation efficiency is calculated for this particulate fraction than for the PM_{10} fraction.

[4] Measurements were taken on Test Farm 1 for eight weeks in both winter and summer. Because of the need to remeasure odour concentrations, ammonia was also measured on Test Farm 2 for four weeks in summer. Consequently, the winter ammonia and nitrogen removal rates relate to Test Farm 1 and the summer rates to Test Farm 2.

[5] All annual consumption data refer to an operating time of 365 days a year to enable comparison with other systems. In practice, consumption may be lower due to servicing and downtimes.

[6] In order to compare the consumption values more easily, only the values for the winter and summer measurements from Test Farm 1 (two modules) were included. Consumption data from Test Farm 2, which has one module, are presented in the chapter entitled ‚Test results in detail'.

[7] The scrubbing liquid was always desludged at a conductivity of max. 220 mS/cm

[8] No representative measured values could be recorded during the winter measurement period since the power consumption readings also included consumption by the emissions measurement equipment. However, it can be reasonably assumed that the annual consumption is roughly the same as the summer measurement.

The product

Manufacturer and applicant

LUBING Maschinenfabrik GmbH & Co. KG
Lubingstraße 6, 49406 Barnstorf
Germany

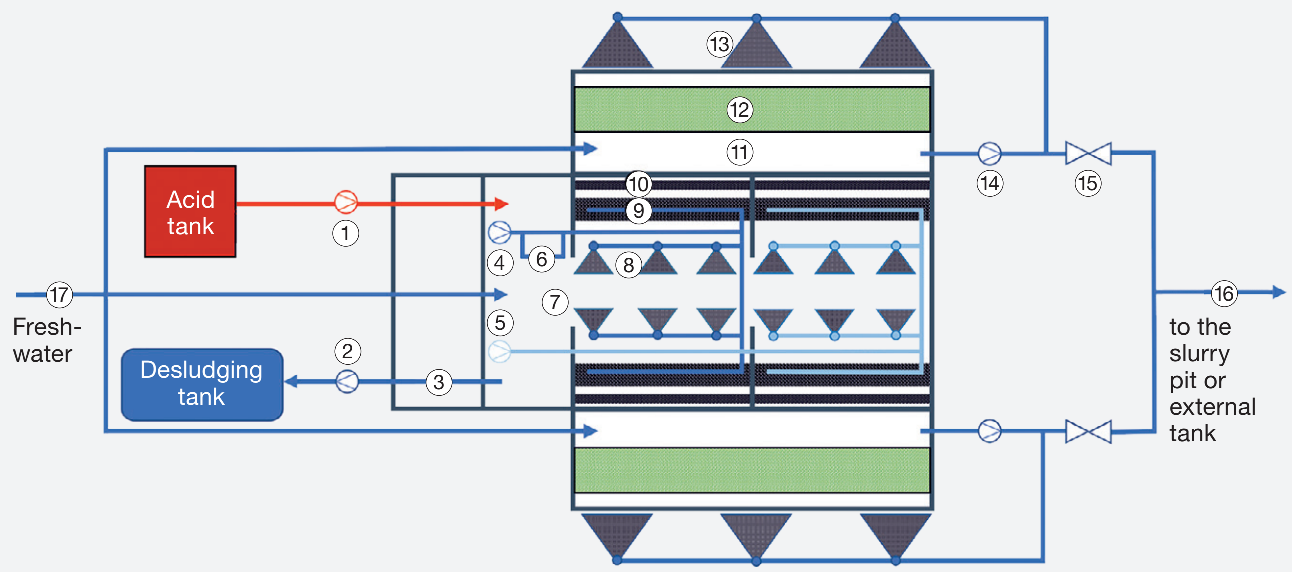
Contact:
Tel +49 (0)5442 9879-0, Fax +49 (0)5442 9879-33
www.Lubing.de, info@Lubing.de

Product:
CleaningCubes air scrubber

Description and technical data

The CleaningCubes air scrubber is a two-stage system consisting of a chemical stage and a downstream biological stage for cleaning the exhaust air from strawless pig houses. Unlike other systems, on entering the cube, the exhaust air stream is split into two equal-sized sub streams which are cleaned in two identical scrubber units. The system is suitable for overhead exhaust air extraction and works on the pressure principle, i.e. the exhaust air is forced through the system.

The exhaust air is piped from the exhaust air duct vertically down into the cleaning cube via a duct system. One cube is connected to each of the housing's exhaust air fans. On entering the cube, the exhaust air is split into two sub streams which are diverted to one of the CleaningCube's two scrubbing units. Each sub stream



1 – dosing pump
2 – desludging pump
3 – water gauge for sludge water from chem. stage
4 – CleaningCube 1 circulation pump
5 – CleaningCube 2 circulation pump
6 – pH and conductivity sampling point
7 – receiving tank of the chemical stage
8 – sprinkler nozzles
9 – sprinkler pipe and filter wall
10 – droplet separator
11 – receiving tank for biological stage
12 – root wood biofilter
13 – sprinkler nozzles for biofilter
14 – pump to biological stage
15 – desludging valve for biological stage
16 – water gauge for sludge water from biological stage
17 – fresh water gauge

Fig. 2:
Function of CleaningCubes (schematic diagram, viewed from above)

then passes through the first filter wall (plastic honeycomb filter) which is continuously sprayed with acidified water to keep the filter moist. Sulphuric acid is added to the continuously circulating wash water to maintain a pH of 3.0. Before entering the first filter wall, the exhaust air passes through a sprinkler system fitted with 28 hollow-cone spray tips, where it is wetted with acidified water. The first scrubber wall mainly removes dust and ammonia. Ammonia accumulates in solution in the wash water until it is removed from the system by desludging. Downstream of the chemical cleaning stage, the exhaust air is forced though a droplet separator which removes the water droplets. Then it passes through to the second cleaning stage. This consists of a 0.65 m thick filter wall packed with root wood which is kept permanently moist by circulating water. After the biological stage, the cleaned exhaust air exits the scrubber and disperses into the atmosphere.

Several modules can be installed next to one another to extend the CleaningCubes air scrubber. All the Cubes are operated synchronously with the same volume of exhaust air. A dividing wall separates the chemical cleaning stages from adjacent modules to prevent mixing the exhaust air streams. There is no dividing wall separating the droplet separators and the bio-stage of adjacent modules, so sub streams from adjoining modules can spread to the bio-stages of other modules.

However, the process circuits of the chemical and biological stages are always structurally separated to prevent the mixing of water.

The wash water must be desludged at regular intervals to prevent an accumulation of salts. Desludging takes place automatically and relative to the current salt content of the wash water, which is determined by its electrical conductivity. The sludge water is replaced with fresh water at regular intervals. The chemical and biological cleaning stages have separate desludging systems. Desludging takes place when the conductivity of the wash water from the chemical stage reaches maximum 220 mS/cm.

To prevent a rise of the pH level of the water in the chemical cleaning stage during operation, acid is added by an acid metering pump to reduce the pH level when the maximum threshold is exceeded. As a constant supply of acid is required for correct operation a sufficient quantity of acid must be held in stock. It is not necessary to control the pH level of the biological cleaning stage.

Since scrubbing increases the evaporation of water, the fresh water and sludge water volumes are recorded in the electronic logbook. The water level is monitored by a float switch which transmits an alarm signal to the SPS. An additional float switch protects the recirculation pumps from running dry.

The downstream biological cleaning stage consists of shredded root wood with a layer thickness of 0.65 m, which is initially packed to a height of 2.95 m. Every hour a sprinkler system sprays water onto this root wood for 1 minute. The water is then recirculated.

The chemical stage of the air scrubber is designed for a maximum filter surface load of 3,210 $m^3/(m^2 \cdot h)$.

To achieve the separation efficiencies described in Table 1, the air scrubber must be operated continuously.

Figure 2 shows a diagram of the process.

Warranty

The manufacturer provides a two-year warranty which is valid only if the system is operated as intended. Consumables are excluded from this warranty.

The installation and maintenance must be carried out by an accredited installer.

Table 2:
Overview of process parameters for the CleaningCubes air scrubber

Feature	Result / Value	
Description	Chemical and biological system with continuous irrigation	
Suitability	Purification of exhaust air from strawless pig housing with overhead ventilation by reducing dust, ammonia and odour emissions	
Dimensioning parameters of reference system as per manufacturer's specifications for one module		
ChemCube		
Number of filters per module		2
Filter length / filter height / filter depth	[m/m/m]	2.10 / 1.79 / 0.2
Number of hollow-cone spray tips		28
Inflow area / filter volumes	[m²] / [m³]	7.52 / 1.50
Minimum dwell time at summer airflow rates	[secs]	0.22
Maximum inflow rate	[m/s]	0.89
Maximum filter surface load	[m³/(m² · h)]	3,210
Maximum filter volume load	[m³/(m³ · h)]	16,049
Sprinkling density	[m³/(m² · h)]	1.57
maximum airflow rate per module	[m³/h]	2x 12,500
Distance filter wall – droplet separator	[m]	0.075
Droplet separator		
Number of droplet separators per module		2
Filter length / filter height / filter depth	[m/m/m]	2.10 / 1.79 / 0.125
Inflow area / filter volumes	[m²] / [m³]	7.52 / 0.94
Minimum dwell time at summer airflow rates	[secs]	0.14
Maximum inflow rate	[m/s]	0.89
Maximum filter surface load	[m³/(m² · h)]	3,210
Maximum filter volume load	[m³/(m³ · h)]	25,680
Distance droplet separator – biofilter	[m]	0.75
BioCube		
Number of filters per module		2
Filter length / filter height / filter depth	[m/m/m]	1.89 / 2.63 / 0.65
Inflow area / filter volumes	[m²] / [m³]	9.92 / 6.45
Minimum dwell time at summer airflow rates	[secs]	0.96
Maximum inflow rate	[m/s]	0.68
Maximum filter surface load	[m³/(m² · h)]	2,432
Maximum filter volume load	[m³/(m³ · h)]	3,741
Sprinkling density	[m³/(m² · h)]	0.0036
ChemCube desludging		
Water tank capacity	[m³] [1]	1.0
Average annual desludging rate for reference farm	[m³/(AP · a)] [2]	0.053
pH value of circulating water	[–]	3.0
Maximum conductivity of circulating water	[mS/cm]	220
BioCube desludging		
Water tank capacity	[m³] [1]	2 x 0.120
Average annual desludging rate on the reference farm	[m³/(AP · a)]	0.005
Maximum conductivity of circulating water	[mS/cm]	5
Reference farm for performed measurements (fattening pigs, strawless all-in/all-out system, 1 module)		
Number of animals	[heads]	360
Initial weight	[kg]	31.5
Final weight	[kg]	124
Maximum summer airflow rates as per DIN 18910	[m³/h] [3]	36,000
max. inst. exhaust airflow rate of scrubber at 50 Pa	[m³/h] [3]	38,100
Maximum pressure loss in the chemical stage at 22,500 m³/h	[Pa]	10
Maximum pressure loss in the biological stage at 22,500 m³/h	[Pa] [4]	46
Maximum pressure loss, pig house + scrubber at 22,500 m³/h	[Pa]	94
Number of fans	[units]	1
Service life of biofilter material	[years]	5

Feature		Evaluation
Operating behaviour		
Technical operational reliability	No significant faults were detected during the test periods. The fans must be activated synchronously.	✓
Durability	No significant signs of wear were detected during the assessment period.	not evaluated
Handling		
Operator manual	The operating instructions are clear and detailed. The automatic control system and maintenance required are clearly explained.	✓
Operation	The system is fully automatic under normal operating conditions. The operator must inspect the system controller on a daily basis. The system must be operated continuously.	✓
Maintenance	The manufacturer strongly recommends a maintenance agreement between the installer and the operator. Maintenance should be carried out at least once a year. This essentially involves calibrating the instruments used and checking the spray pattern of the filter packing elements. In addition to the daily inspection of the controller, the system must be visually inspected and cleaned weekly and monthly. These inspections must be logged.	not evaluated
Cleaning the entire system	The system must be cleaned after each finishing cycle (all-in/all-out) or every four months (continuous finishing). The system is fitted with a fault alarm function which informs the operator when the filter packing needs cleaning. This occurs when a pressure loss of more than 50 Pa is recorded across the filter packing.	not evaluated
Changing the filter material	According to the manufacturer, it is not necessary to change the packing under normal operating conditions, provided that the necessary maintenance work is routinely carried out.	not evaluated
Working time requirement (manufacturer's specifications)		
Daily inspections	approx. 10 minutes	not evaluated
Weekly inspections	approx. 30 minutes	not evaluated
Cleaning the entire system	approx. 6 working hours required every 4 months	not evaluated
Documentation		
Technical documentation	Requirements met	✓
Electronic logbook	Requirements met	✓
Safety		
Machine and plant safety	Certified by an accredited occupational safety specialist	not evaluated
Fire safety	The operator is to draw up a fire safety plan for the entire housing system as part of the building approval process.	not evaluated
Environmental safety	The wastewater (sludge water) must be temporary stored in a designated storage tank in accordance with the German ordinance governing facilities that handle substances hazardous to water (AwSV). It is advisable to recover the sludge water for use as organic fertiliser in accordance with regulations. The plant operator is responsible for verifying the correct application. Other elements of the facility are disposed of by accredited recycling companies.	not evaluated
Warranty		
Manufacturer's warranty	Two-year warranty on all plant elements, excluding those that are subject to normal wear	not evaluated

* Evaluation range: Meets the requirement (✓)/ Does not meet the requirement (✗)

[1] Each additional module requires 800 litres per chemical stage and 240 litres per biological stage.
[2] Due to technical difficulties, it was not possible to record any plausible sludge volumes. As a result, the sludge value was calculated based on acid consumed.
[3] The maximum rate of airflowing through the scrubber was 25,000 m³/h. In order to clean the air volume that is required for pig houses by DIN 18910, an additional emergency fan was installed in the reference system. This exhaust air was released without prior treatment to outdoors.
[4] The filter pressure loss may vary significantly depending on the service hours of the filter material and the dust load.

The method

The measurements were performed on a reference system on a farm in Barnstorf. The tests included one summer and one winter measurement period.
As the tested system was a prototype, it was not possible to survey owners of the same type of exhaust air purification system during the testing period.

Due to the specific nature of the pig housing, the summer measurement had to be continued on another farm (Test Farm 2) On this second farm ammonia was measured continuously for four weeks under summer conditions, whereas dust, odour and aerosol emissions were measured at selected intervals.

There were 1440 finishing pigs (of which only 740 were housed in buildings that were equipped with the air scrubber) on the first farm and 360 on the second. In both cases the pigs were housed in strawless all-in/all-out systems with overhead ventilation. The exhaust air was extracted from the central overhead duct by fans and fed to the air scrubber via a duct system. Each cleaning module is supplied by one dedicated duct and fan. The maximum extraction rate per module is 25,000 m^3/h. This means that it is possible to treat either some or all the air in the pig house, provided that sufficient modules are installed.

The air scrubber is approved for operating under pressure.

The measurements were carried out from February to April 2020 (winter measurement) and from August to October 2020 (summer measurement). The repeat measurement was carried out under summer conditions from June to July 2021.

The following parameters were used to assess the air scrubber:

Dust

Sampling was carried out in accordance with VDI Standard 2066, Part 1 and to DIN EN 13284-1. For this purpose, an isokinetic sampling system (Paul Gothe design) with a plane filter device (diameter 50 mm) was installed. A round glass-fibre filter with a diameter of 45 mm was chosen as the separation medium.

The amount of fine dust (PM_{10} and $PM_{2.5}$) was determined in accordance with VDI Standard 2066, Part 10 and to DIN EN ISO 23210. A Johnas II cascade impactor (Paul Gothe design) with three plane filters (diameter 50 mm) was used. The chosen separation medium in this case was another round glass-fibre filter, but this time with a filter diameter of 50 mm. The analysis was performed by gravimetric measurement of the dust load.

The DLG test framework stipulates that the separation efficiency must not fall below 70 %. This applies to total dust and the PM_{10} fine dust fraction. The results for the $PM_{2.5}$ measurement are provided for information purposes. The recognised minimum separation efficiency is the lowest level recorded from all measurements taken on the days of recording.

Ammonia

Ammonia concentrations in the untreated and treated air sections were measured continuously throughout the entire test period using FTIR spectroscopy based on KTBL document 401 and DIN EN 15483. The measurements were performed in a measurement cell. To prevent condensation in the sampling PTFE air lines these were heated along their entire length on the clean air-side.

The results presented relate to measured values. If less than 1.0 ppm of ammonia is measured in the exhaust air of the scrubber, the value is rounded up to 1.0 ppm to reflect the measurement uncertainty of the instrumentation used. It is not possible to obtain a reliable, quantifiable measurement below this value.

To verify compliance with the German Animal Welfare Act (TierSchNutztV) (max. 20 ppm ammonia in the animal area), ammonia (NH_3) levels at animal height in a selected part of the housing were continuously monitored on both farms throughout the entire test period.

According to the criteria in the DLG test framework, the ammonia separation level must be permanently higher than 70 %. The acceptable level is obtained by averaging all measurements and deducting the standard deviation figure from this average value.

Measurements of ammonia separation levels always refer to the first cleaning stage. Thus the sampling point is always located downstream of the droplet separator.

Aerosol emissions

Sprinkling the filter wall of the scrubber causes aerosols containing nitrogen to be stripped out of the filter material in the form of ammonium aerosols and entrained in the exhaust airflow. In this way, nitrogen (N) that is initially separated is unintentionally returned into the ambient air.

The level of nitrogen entrained in the aerosols was measured during the winter and summer periods using a plane filter that was installed in the clean airflow downstream of the droplet separator. To this end, two sampling points were installed, one of which was fitted with an upstream particulate filter that removed the aerosols. Sampling was carried out in accordance with VDI 3496-1 (gaseous emission measurement). The DLG test framework stipulates that aerosol emissions must not exceed 0.50 mg of nitrogen per standard cubic metre.

Nitrogen balance and nitrogen removal

The rate of ammonia separation in the air scrubber was verified by means of an N balance, taking into account the ammonia loads (in the untreated and clean air) and the inorganic nitrogen compounds dissolved in the wash water. The balancing measurements were taken during 15 days in winter and 28 days in summer.

When performing balancing measurements on chemical scrubbers, only the ammonium (NH_4-N) concentration in the process water is tested since biological oxidation does not generally take place.

The method to determine the amount of actually removed N is to ascertain the ratio of inorganic N mass removed from the system and of N load entering the system on the raw gas side.

Balancing the nitrogen flows within the system is important because

- all relevant nitrogen compounds and their whereabouts are accounted for
- the nitrogen content of the sludge water is known and its fertiliser value is quantified.

According to the DLG test framework, N removal within the nitrogen balance must be at least 70 % during both the summer and winter measurement period.

The test framework stipulates a nitrogen recovery rate (N balance) of at least 80 %, but no more than 120 %.

Odour

Odour concentrations were determined by dynamic olfactometry (dilution to the threshold) based on DIN EN 13725 using the yes/no detection method. The untreated and clean air sides were sampled using a vacuum sampler (CSD-30). A T08 olfactometer manufactured by Ecoma GmbH was used to analyse the odour samples. The test subjects were screened on each test date using the standard odorant (n-Butanol). Eight odour samples were taken during each measurement period to verify odour removal. The DLG test framework stipulates that odour concentrations in the clean air must not exceed 300 OU/m³ in each measurement. In addition, the typical smell of untreated air (pigs) must not be detectable in the sample.

Consumption values, ambient conditions and system load

Consumption of fresh water, sludge and electrical energy was determined by recording the relevant meter readings (separate meter for exhaust air scrubber and ventilation system). Acid and defoamer consumption rates were determined using a weighing system (force transducer/load cell or scales).

The ambient conditions (temperature and relative indoor/outdoor humidity) were recorded during the measurements. On the days when dust and odour concentrations were measured, the following parameters were also recorded:

- animal weights (estimated) and animal numbers
- fresh water and electrical energy consumption (meter readings)
- absolute airflow volume (calibrated measuring fans and separate fan curve)
- pressure loss across the system and pressure loss across the fan
- pH value and conductivity of the process water

In addition, the measured values recorded by the manufacturer in the electronic logbook were verified for plausibility.

Operational reliability and durability

Operational reliability and durability were also assessed. Any malfunctions affecting the overall system or technical components during the test period were documented.

Operating instructions, handling and operation, workload and maintenance requirements

The test assesses the operating instructions from a user's perspective to determine whether the description of how the system works, the illustrations provided and the descriptions of the routine maintenance work required are sufficiently clear and detailed. The test module covering handling and operation as well as the workload involved assesses whether it is necessary for the manufacturer to provide instruction during commissioning and the requirements on routine inspections and daily, weekly and monthly etc. services and on how to deal with malfunctions.

In terms of service and maintenance, the service intervals and the service checklists are assessed.

Documentation

The following parameters must be recorded and saved in the electronic logbook as half-hourly intervals as a minimum:

- pressure loss across the system [Pa]
- airflow rate [m^3/h]
- pump runtime (circulation and desludging) [h]
- sprinkling rate [m^3/h]
- total fresh water consumption by the system [m^3], cumulative
- sludge accumulated [m^3]
- untreated air and clean air temperatures [°C]
- pH value [–] and electrical conductivity of the process water in the chemical scrubbing stage [mS/cm] as half-hourly mean values
- electricity consumption [kWh], cumulative

In addition, the spray pattern inspections, Service and repair times, and pH and conductivity sensor calibrations must be recorded. The same applies to the use of chemical additives (acid, defoamer) and the quantities at which they are used.

These data are required to verify that the air scrubber is operating as intended and were verified on the reference system.

Environmental safety

The test module on environmental safety included an assessment of all inputs required to operate the system (e.g. acids and alkalis), to recover operational waste (e.g. waste process water containing sludge), and of the dismantling and disposal of individual elements of the plant. The assessment also examined who would be in charge of the individual requirements.

Safety aspects

To assess the safety of the system, checks were carried out to verify compliance with the current fire and plant safety requirements

Detailed account of the test results

Dust

Based on the system's construction and dimensioning, it was assumed that separation efficiencies of over 70 % can be achieved permanently, and this was indeed confirmed by the measurements. All measurements consistently showed a separation rate of over 70 % for both total and fine dust. During the winter period, two total dust and two fine dust measurements were conducted on one of the two available scrubber modules on Test Farm 1. Two total dust and two fine dust measurements were also conducted during the summer measurement period. In addition, one total dust and one fine dust measurement was conducted at Test Farm 2 during the subsequent repeat measurement under summer conditions. Since, for technical reasons, only the first dust measurement in winter and the two final measurements in summer were carried out downstream of the chemical stage whereas all other dust measurements were taken downstream of the biological stage, the approval for dust removal applies only to systems that include the optional biological stage.

A minimum separation rate of 91.3 % in winter and 85.0 % in summer was recorded for total dust. The separation rate for fine dust (PM_{10}) was no less than 78.6 % in winter and 71.4 % in summer. The results are shown in Table 3.

Experience shows that the scrubbing process can lead to the formation of droplets with sizes ranging from 2.5 to 10 µm, which can result in increased levels of the particulate fraction PM_{10} in the cascade impactor during dust measurements. The particulate fraction $PM_{2.5}$ is less susceptible to this effect. As a result, a higher separation rate is calculated for this particulate fraction than for the PM_{10} fraction.

Table 3:
Measurements for emissions reduction (total and fine dust) on the CleaningCubes

		Winter measurement		Summer measurement				
Date		**16/04/20**	**29/04/20**	**03/08/20**	**04/08/20**	**06/10/20**	**17/06/21**	**18/06/21**
Finishing stage		Day 55	Day 68	Day 27	Day 28	Day 91	Day 70	Day 71
Tested module		1	1	2	2	2	1	1
Ambient and boundary conditions [1]								
rel. humidity outside	[% RH]	62	83	73	69	89	48	69
Ambient air temperature	[°C]	1	8	23	22	16	33	31
Untreated air/clean air humidity	[% RH]	74/97	75/94	63/95	74/95	70/97	48/89	78/93
Untreated air/clean air temperature	[°C]	21.7/19.6	22.2/21.1	24.3/20.8	23.1/20.8	20.8/16.0	32.8/25.4	26.6/23.8
Animal head count in the shed [2]	[heads]	734	734	745	745	700	355	355
Average animal weight	[kg]	60	63	32	32	85	93.5	93.5
Airflow volume [3]	[m³/h]	12,320	11,990	14,060	11,260	14,680	22,340	22,030
Pressure loss, scrubber	[Pa]	24	22	28	19	32	– – [4]	– – [4]
Pressure loss, shed + scrubber	[Pa]	42	41	52	39	53	– – [4]	– – [4]
Total dust (normalised)								
Untreated air	[mg/m³]	2.3	1.7		2.0	1.9	0.40	
Clean air	[mg/m³]	0.2	0.1		0.1	0.2	0.06	
Mean separation efficiency	[%]	91.3	94.1		94.1	88.8	85.0	
Minimum separation efficiency	[%]	91.3				85.0		
Fine dust $PM_{10}/PM_{2.5}$ (standardised)								
Untreated air	[mg/m³]	1.9/1.1	1.4/0.8	2.4/0.8		1.4/0.7		0.21/0.12
Clean air	[mg/m³]	0.4/0.2	0.3/0.2	0.3/0.1		0.4/0.1		0.06/0.03
Mean separation efficiency $PM_{10}/PM_{2.5}$	[%]	78.9/81.8	78.6/75.0	87.5/87.5		71.4/85.7		71.4/75.0
Minimum separation efficiency $PM_{10}/PM_{2.5}$	[%]	78.6/75.0				71.4/75.0		

[1] The data were recorded at the time that the dust measurements were taken.
[2] Only around half of the 1440 permitted animal places on the first test farm were in the sections that were ventilated by the air scrubber.
[3] Refers to the airflow volume in the tested module.
[4] No plausible values could be obtained at the time that the dust measurements were taken due to an accumulation of water in the measuring tube.

Ammonia

The chemical scrubbing stage (stage 1) can achieve a separation rate for ammonia that at least meets requirements only in that case that the wash water is automatically desludged whenever conductivity reaches the maximum value of 220 mS/cm and that water pH is set to 3.0.

Due to measurement problems in the winter, only 3795 paired values were available overall. These relate to two modules tested. During the subsequent summer measurements, 1411 paired half-hourly mean values were available for assessment. These paired values relate to two sides of the tested module.

Ammonia concentrations in the animal area were continuously monitored to verify compliance with the requirements of the German Animal Welfare Act (TierSchNutztV). The mean concentration recorded at animal height in winter was 8.2 ppm NH_3. The threshold of 20 ppm was briefly exceeded for a few minutes on a small number of days. Temporarily, the maximum level was 22.4 ppm. During the subsequent summer measurements, the mean value at animal height was 7.3 ppm. The recordings ranged from 4 to 20 ppm. Thus the animal welfare requirements for ammonia were adhered to at all times.

During the winter measurement a minimum separation efficiency of 79.6 % (module 1) and 75.0 % (module 2) was achieved. The mean winter value is 77.3 %. The minimum separation efficiency in summer was 80.7 %.

Figure 3 shows the ammonia concentrations during the summer measurement period. The separation curve was plotted using corrected data, i.e. values below 1.0 ppm were rounded up to 1.0 ppm. Since the ammonia concentration in the clean air frequently lay below 1.0 ppm, these data were rounded up to 1.0 ppm in almost all cases, as is reflected in Figure 3. As a result of this correction, the ammonia separation rate is lower than the N removal.

Thus under the operating conditions described and when operated as intended, the scrubber effectively removes ammonia in strawless pig housing systems.

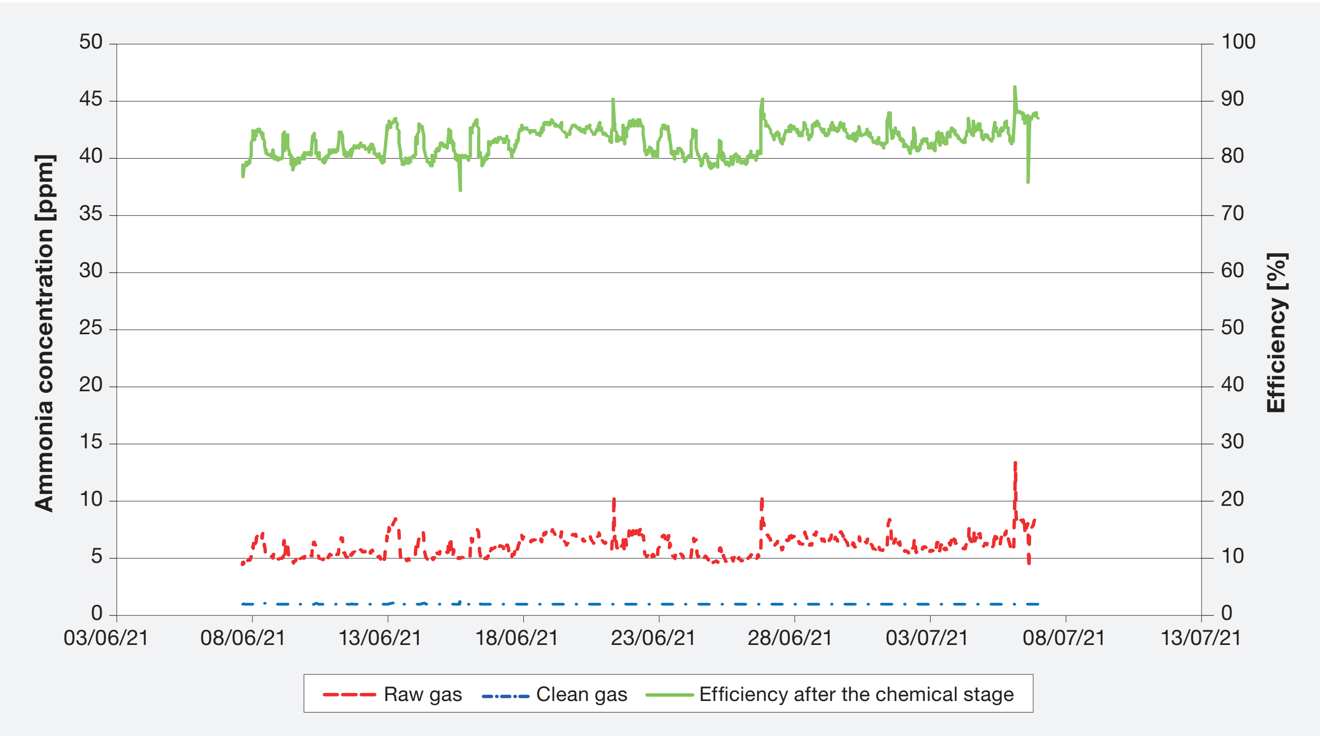


Fig. 3:
Separation efficiency and ammonia concentration curves for the raw and clean gas (summer measurements)

Odour

The results of the odour samples taken in accordance with the DLG test framework are shown in Tables 4a (winter) and 4b (summer). During the winter measurement period, ten samples were collected in total, of which seven were deemed suitable for assessment. One sample was taken when the system was not operating as intended (25/02/2020), while significantly increased untreated air values were recorded on two days as a result of unscheduled slurry spreading by the farmer (16/03/2020, 30/03/2020).

Overall, the criteria of the DLG test framework were met (300 OU/m³ and no perceptible odour of untreated gas). The group of testers as a whole, or a majority of the testers, detected no odour of untreated air in the clean air in any of the samples.

Table 4a:
Results of emissions measurements (odour) on the CleaningCubes air scrubber

Winter measurement										
Date		**25/02/20**	**02/03/20**	**10/03/20**	**23/03/20**	**03/04/20**	**06/04/20**	**15/04/20**	**22/04/20**
Finishing stage		Day 4	Day 10	Day 18	Day 31	Day 42	Day 45	Day 54	Day 61
Comments		System not operating as intended	– –	– –	– –	– –	– –	– –	– –
Conditions [1]									
rel. humidity outside	[% RH]	76	92	92	50	70	55	62	44
Ambient air temperature	[°C]	6.0	5.0	6.0	-1.0	6.0	8.0	4.0	7.0
Untreated air/clean air humidity	[% RH]	70/99	71/99	67/99	56/99	65/99	66/99	68/99	66/99
Untreated air/clean air temperature	[°C]	24.3/18.1	23.5/20.5	23.5/19.6	22.6/17.9	22.6/19.4	22.2/19.2	20.4/18.0	20.2/17.9
Number of animals in shed	[heads]	740	744	743	742	737	735	734	734
Average animal weight	[kg]	28	30	34	40	50	51	60	63
Airflow volume, module 1	[m³/h]	330	4,260	6,100	6,480	7,190	7,240	7,850	9,480
Airflow volume, module 2	[m³/h]	900	4,420	5,590	5,850	6,590	6,680	6,310	8,390
Filter surface load, module 1	[m³/(m² · h)]	33	429	615	653	725	730	791	955
Filter surface load, module 2	[m³/(m² · h)]	91	445	563	590	664	673	636	846
Odour [2]									
Untreated air, module 1	[OU/m³]	3,300	3,300	2,500	3,300	2,200	2,600	3,900	3,300
Untreated air, module 2	[OU/m³]	2,300	2,300	2,500	2,900	1,100	1,500	2,500	2,200
Clean air, module 1	[OU/m³]	118	212	220	290	188	187	179	275
Clean air, module 2	[OU/m³]	51	224	190	275	130	145	140	270
Untreated air odour mass flow, module 1	[Mio OU/h]	1.1	14.1	15.3	21.4	15.8	18.8	30.6	31.3
Untreated air odour mass flow, module 2	[Mio OU/h]	2.1	10.2	14.0	17.0	7.2	10.0	15.8	18.5
Clean air odour mass flow, module 1	[Mio OU/h]	0.0	0.9	1.3	1.9	1.3	1.4	1.4	2.6
Clean air odour mass flow, module 2	[Mio OU/h]	0.0	1.0	1.1	1.6	0.9	1.0	0.9	2.3
Spec. odour mass flow untreated air, module 1	[OU/(GV · s)]	7	87	84	100	60	70	97	94
Spec. odour mass flow untreated air, module 2	[OU/(GV · s)]	14	63	77	79	27	37	50	55
Spec. odour mass flow clean air, module 1	[OU/(GV · s)]	0	6	7	9	5	5	4	8
Spec. odour mass flow clean air, module 2	[OU/(GV · s)]	0	6	6	8	3	4	3	7
Odour of untreated air perceptible in clean air?		No	No	No	No	No	No	No	No

[1] Data collected at the time of the odour measurements (exemplary on module 1 and on one module side)
[2] Geometric mean from two individual measurements on two modules

Table 4b:
Results of emissions measurements (odour) on the CleaningCubes air scrubber

Summer measurement									
Date		**11/06/21**	**11/06/21**	**17/06/21**	**17/06/21**	**21/06/21**	**21/06/21**	**01/07/21**	**01/07/21**
Finishing stage		Day 64	Day 64	Day 70	Day 70	Day 74	Day 74	Day 84	Day 84
Comments		– –	– –	– –	– –	– –	– –	– –	– –
Conditions [1]									
rel. humidity outside	[% RH]	– –	67	– –	48	– –	92	– –	84
Ambient air temperature	[°C]	13.0	26.0	18.0	33.0	14.0	16.0	13.0	19.0
Untreated air/clean air humidity	[% RH]	76 / 98	69 / 98	74 / 95	63 / 95	78 / 97	80 / 97	79 / 94	81 / 94
Untreated air/clean air temperature	[°C]	21.4 / 19.6	25.6 / 22.0	24.9 / 22.3	26.9 / 21.8	19.6 / 18.0	19.3 / 18.2	18.9 / 17.7	20.7 / 19.7
Number of animals in shed	[heads]	356	356	355	355	355	355	354	354
Average animal weight	[kg]	89	89	94	94	96	96	113	113
Airflow volume, module 1	[m³/h]	20,030	22,600	22,010	19,410	18,310	19,130	21,890	8,400
Airflow volume, module 2	[m³/h]	– –	– –	– –	– –	– –	– –	– –	– –
Filter surface load, module 1	[m³/(m² · h)]	2,019	2,278	2,218	1,956	1,845	1,928	2,206	847
Filter surface load, module 2	[m³/(m² · h)]	– –	– –	– –	– –	– –	– –	– –	– –
Odour [2]									
Untreated air, module 1	[OU/m³]	1600	2000	1900	1200	870	1200	1200	1200
Untreated air, module 2	[OU/m³]	– –	– –	– –	– –	– –	– –	– –	– –
Clean air, module 1	[OU/m³]	214	238	186	206	112	78	166	120
Clean air, module 2	[OU/m³]	– –	– –	– –	– –	– –	– –	– –	– –
Untreated air odour mass flow, module 1	[Mio OU/h]	32.0	45.2	41.8	23.3	15.9	23.0	26.3	10.1
Untreated air odour mass flow, module 2	[Mio OU/h]	– –	– –	– –	– –	– –	– –	– –	– –
Clean air odour mass flow, module 1	[Mio OU/h]	0.4	0.5	0.4	0.4	0.2	0.2	0.4	0.1
Clean air odour mass flow, module 2	[Mio OU/h]	– –	– –	– –	– –	– –	– –	– –	– –
Spec. odour mass flow untreated air, module 1	[OU/(GV · s)]	140	198	174	97	65	94	91	35
Spec. odour mass flow untreated air, module 2	[OU/(GV · s)]	– –	– –	– –	– –	– –	– –	– –	– –
Spec. odour mass flow clean air, module 1	[OU/(GV · s)]	19	24	17	17	8	6	13	3
Spec. odour mass flow clean air, module 2	[OU/(GV · s)]	– –	– –	– –	– –	– –	– –	– –	– –
Odour of untreated air perceptible in clean air?		No	No	No	No	No	No	No	No

[1] Data collected at the time of the odour measurements (exemplary on module 1 and on one module side)
[2] Geometric mean from two individual measurements on two modules

Aerosol emissions

The results of the aerosol measurements are summarised in Table 5. Each parameter was measured once under winter conditions and twice under summer conditions.

Aerosol emissions in winter were 0.21 mg NH_4-N/m³. In summer 0.24 mg NH_4-N/m³ was recorded on the first farm and 0.05 mg NH_4-N/m³ on the second. Thus the requirements of the DLG test framework were complied with at all times.

Table 5:
Results of aerosol emissions from the CleaningCubes air scrubber

		Winter measurement	Summer measurement	
Date		**29/04/20**	**04/08/20**	**06/07/21**
Sampling point		Module 2	Module 2	Module 1
Airflow volume per module	[m³/h]	11,350	10,120	20,920
Ammonia with aerosols	[mg/m³]	0.98	3.51	0.77
Ammonia without aerosols	[mg/m³]	0.72	3.22	0.71
NH_3 aerosol emissions	[mg/m³]	0.26	0.29	0.06
NH_4-N aerosol fraction	[mg/m³]	0.21	0.24	0.05

Nitrogen balance and nitrogen removal

The results of the nitrogen balance and resultant nitrogen removal are shown in Table 6.

A nitrogen recovery rate of 107.8 % was recorded during the winter measurement period and 93.1 % during the summer. Within the context of measurement accuracy, this is a very good result for both balances. Recovery rates above 100 % are possible and attributed to measurement uncertainties and incomplete system cleaning.

During the winter measurement, 87.3 % of nitrogen in the wash water was recovered. The equivalent figure for summer was 84.6 %. Both values are plausible and indicate stable and reliable operation of the system. Due to the corrected ammonia concentrations in the clean air (< 1 ppm), ammonia separation was lower than nitrogen removal.

Table 6:
Nitrogen balance results for the CleaningCubes air scrubber

		Winter measurement	Summer measurement
Measurement period		**25/03/ to 09/04/2020**	**07/06/ to 05/07/2021**
Test farm	[–]	1	2
Number of animals	[heads]	740	360
NH_3-N untreated air input	[kg]	15.453	52.273
NH_3-N clean air output	[kg]	3.161	4.458
Difference	[kg]	12.3	47.8
NH_3-N separation rate	[%]	79.5	91.5
pH value [1]	[–]	3.0	3.0
Conductivity [1]	[mS/cm]	113…221	113…226
N aerosol output	[kg]	– –	– –
N circulation water output	[kg]	10.911	23.077
N sludge output	[kg]	2.586	21.154
Total N output	[kg]	13.497	44.231
N recovery rate	[%]	107.8	93.1
N removal [2]	[%]	87.3	84.6

[1] The data were taken from the electronic logbook.
[2] N removal was calculated without taking aerosol emissions into account

Consumption rates, ambient conditions and system load

The consumption values per measurement period (winter/summer) listed in the test report (Table 1) were scaled to annual consumption rates (365 days) in order to compare these results with data from other makers. Since these rates vary significantly in some cases (winter/summer differences, two-module operation), annual consumption figures were calculated from the summer and winter measurements on Test Farm 1 (two modules) only. The consumption figures from the summer measurements on Test Farm 2 (one module) are additionally included in this chapter. In total, 1440 fattening pigs were housed on Test Farm 1, although only around half of these (740 animals) were housed in areas that were ventilated by the system. For this reason, consumption rates per animal place and year (AP · a) refer to 740 animals (Test Farm 1) and 360 animals (Test Farm 2).

Water consumption

Water consumption is calculated from the desludging and evaporation rates. The higher the rate of desludging and evaporation, the more fresh water must be added to maintain a constant volume of process water in the system. The desludging rate is determined by the levels of nitrogen that are carried in by the exhaust airflow on the one hand and the maximum conductivity limit for the process water on the other. During the measurement period, this was 220 mS/cm. For technical reasons it was not possible to measure the sludge volumes using the instrumentation, so these rates were calculated based on the acid consumption figures. The values are plausible and present a coherent picture. On Test Farm 1 a desludging rate of 0.049 m^3/(AP · a) was recorded in winter and 0.056 m^3/(AP · a) in summer. Similar values were obtained on Test Farm 2.

Freshwater was added to both the chemical and biological stage of the CleaningCubes air scrubber as required. The mean total fresh water consumption calculated for two modules was 1.32 m^3/d and 0.65 m^3/(AP · a). The figure obtained under summer conditions for Test Farm 2 was 1.56 m^3/d or 1.61 m^3/(AP · a).

On completion of the DLG assessment on Test Farm 2, the manufacturer installed a splash guard at the fresh water inlet on the biological stage, which was not included in these tests. However, it can be assumed that this improvement could lead to a slight reduction in fresh water consumption

Electrical energy consumption

The continuously operating circulation pump is the largest electrical consumer in a CleaningCubes air scrubber module. In the pig house, the fans are the largest consumers. On Test Farm 2, one fan was used for one scrubber module. The fan was controlled by a frequency converter to adjust the exhaust airflow as required.

The maximum pressure losses recorded across the scrubber system were 55 Pa for the chemical and biological stages combined and 46 PA for the biological stage alone. A maximum pressure loss of 94 Pa was recorded for the shed and scrubber system combined. This means that fans must be designed for a pressure loss of at least 100 Pa to operate the shed ventilation and the air scrubber.

Apart from the flow rate, the pressure loss of the exhaust air cleaning system largely depends on the growth and deposits on and inside the packing wall. Therefore, in individual cases, the pressure loss of the exhaust air cleaning system might even be higher than specified here. The manufacturer specifies a guide value of up to 30 Pa for the chemical stage.

On Test Farm 1, 54.2 kWh/d and 26.8 kWh/(AP · a) were measured on two modules. The fan consumption figures recorded during the subsequent summer measurement period on Test Farm 2 were 100.1 kWh/d and 102.9 kWh/(AP · a).

While the electricity consumption for the scrubber on Test Farm 2 seems plausible, it is clearly too high for the fans. These high consumption figures can be attributed to the fact that an additional emergency fan that was in very frequent use during the summer measurement period was connected to the electricity meter. Furthermore, the fan installed on Test Farm 2 was significantly more powerful than the one on the first farm.

In summer, electricity consumption for the two-module scrubber on Test Farm 1 was calculated to be 38.3 kWh/d or 19.0 kWh/(AP · a). No representative measurement data could be obtained in winter because all the instrumentation for measuring emissions was connected to the electricity meter. However, it can be assumed that the average annual consumption is more or less at this level. Electricity consumption for the one-module system on Test Farm 2 was 29.0 kWh/(AP · a). The higher consumption could be due to a more powerful pump which had recently been installed on Test Farm 2. The power consumption depends to a large extent on the size of the system and can therefore vary greatly from farm to farm.

Other consumption values

Reliable operation with the stated efficiencies can be achieved in the chemical stage only if the pH control system maintains a pH of 3.0 and desludging is triggered at a maximum conductivity of 220 mS/cm. To ensure this, automatic acid dosing and conductivity metering equipment must be correctly installed and operated in all cleaning stages of the scrubber. Sulphuric acid with a purity of 96 % was used to reduce the pH level.

An average annual acid consumption of 19.4 kg/d and 9.6 kg/(AP · a) was recorded for the two-module system on Test Farm 1. During the subsequent summer measurement period, acid consumption of 6.8 kg/d and 7.0 kg/(AP · a) was recorded on Test Farm 2, which correlates well with the theoretical values.

There is provision for the use of defoamers to ensure that the system operates as intended. However, during the measurement periods virtually no defoamer was used. On Test Farm 2, defoamer consumption was calculated to be 0.4 ml/(AP · a) in winter and 1.1 ml/(AP · a) in summer. No consumption was recorded during the summer measurement period on Test Farm 2. In practice, however, a defoamer may be required at any time.

Operational reliability and durability

During the test period, no notable malfunctions were found in the system, nor did any significant damage or signs of wear occur anywhere in the air scrubber.

As far as could be observed during the test period, the individual components of the system appeared to be sufficiently protected from corrosion. The complete system is manufactured almost entirely from plastic.

Operating instructions, operation, working time requirements and maintenance requirements

The operating instructions are sufficiently precise and explain the system‘s mode of operation in general terms. In conjunction with the documentation, they explain what work the operator must carry out on the system on a daily, weekly and annual basis. The manual contains photos of the system components to make it easier to understand how it operates.

To operate the system, it is necessary to receive instructions from the installer and to familiarise oneself with the operating instructions.

However, after successful start-up and a sufficient running in phase, the system can be regarded as easy to operate since the air scrubber runs fully automatically in normal operation. All that is required is a daily check of the operational data and a weekly inspection of the entire system, including the nozzles. In the event of error messages from the control system, the operating instructions explain how to check the relevant system components. To simplify operation and reduce the workload, it is advisable to have a maintenance agreement with the manufacturer.

The nozzle spray pattern must be inspected weekly and if it is found to be uneven, the nozzles must be cleaned or replaced. This action must be recorded in the manual logbook.

Documentation

The electronic logbook permits the recording of all data required for the safe operation of the system as half-hourly mean values or half-hourly values in compliance with requirements. The data are recorded automatically and must be stored for 5 years. These data can be read by the farmer as well as by authorities via an online cloud platform and imported into a common spreadsheet program. The recorded data is described in detail in Table 7.

If the housing ventilation system and the air scrubber installed are sourced from different manufacturers, the manufacturer of the air scrubber records the ventilation data as a characteristic curve and incorporates these data into the scrubber‘s control system for control purposes. The maximum fan capacity is set at 100 % in the controller. However, it is not possible to adjust it to a broader capacity range. Since the test framework requires the airflow rate to be indicated in absolute terms in m³/h, a characteristic curve of the entire ventilation system (stall plus scrubber) must be plotted prior to commissioning and entered in the electronic logbook. The characteristic curve should consist of at least five different supporting points between an airflow rate of 0 and 100 %.

Table 7:
Fulfilling the requirements of the electronic logbook for the CleaningCubes air scrubber

	Met in full	Not met	Comments
Pressure loss across the air scrubber	X		Recorded on the filter wall plus the droplet separator by an electronic differential pressure gauge and stored
Exhaust airflow scrubber	X		Recorded by means of measuring fans or fan characteristic curve and stored
Pump runtime	X		Based on the electricity consumption
Sprinkling interval and quantity (chemical stage)	X		The power consumption is recorded and converted to the flow rate by means of a characteristic curve
Fresh water consumption	X		Total fresh water consumption is recorded using a water meter
Sludge water volume	X		Recorded separately for the chemical and biological stage using two water meters and stored
Untreated air and clean air temperature	X		The untreated and clean air temperatures are recorded with a thermocouple. The external temperature and water temperature are also recorded.
Spray pattern check	X		Verifiable from manual logbook
Maintenance and repair times	X		Recorded and stored in the manual logbook
pH value and conductivity of the process water	X		Recorded and stored
pH value sensor calibration	X		Recorded and stored in the manual logbook
Verification of additive consumption (acids, defoamer)	X		Acid consumption is recorded via the pulse output of the pump and stored. Defoamer consumption is verified from purchasing records.
Electrical power consumption, scrubber	X		Recorded using suitable electricity meters and stored

Environmental safety

The process water from the chemical scrubbing stage mainly contains ammonium sulphate ($(NH_4)2SO_4$). Microbiological processes leading to the formation of nitrite and nitrate do not generally take place.

Ammonium sulphate is hazardous to water and is classified in water hazard class (WGK) 1 (slightly hazardous to water).

The storage period is based on the specifications of the German Fertiliser Ordinance on the storage of liquid manure. The feed pipe to the desludging tank and the buffer tank itself must be suitable for handling and storing sludge water and must comply with national administrative provisions governing substances hazardous to water (ammonium sulphate). The sludge water can be mixed with liquid manure outside of the building immediately before spreading on farmland. From the farmer's point of view, it makes sense to take account of the nitrogen and sulphur content of the sludge water and ensure that, as a fertiliser, it meets the needs of the crop.

According to the manufacturer, the removal and disposal of other system components can be undertaken by accredited recycling companies.

Acid is required to operate the system. The manufacturer should explain in the operating instructions how to safely handle this chemical in accordance with EU safety data sheets for 96 % sulphuric acid. The plant operator is responsible for the safe handling of the acid. All relevant safety equipment (eyewash, body shower, protective clothing) must be provided. An acid tank in the form of an IBC container is advisable.

Containing, valuable nitrogen, the sludge water from the biological stage can be used as slurry and organic fertiliser. This sludge water can be stored with the liquid manure without any problem.

Safety aspects

Fire safety is to be verified by means of an appropriate fire safety plan which the operator compiles in conjunction with the manufacturer and appends to the planning application.

The machinery and plant safety of the Lubing air scrubber described here has been assessed by an accredited expert. There are no concerns about using the system from an occupational safety perspective.

Summary

The CleaningCubes air scrubber manufactured by Lubing Maschinenfabrik GmbH & Co. KG is suitable for reducing dust, ammonia (including nitrogen removal) and odour emissions from the exhaust air of strawless pig housing systems.

The system works on the pressure principle.
To ensure safe operation of the system, the filter surface load should not exceed maximum 3,210 m³/(m²·h). The pH value of the wash water in the chemical stage must be set to 3.0 and conductivity should not exceed maximum 220 mS/cm.

Provided that the described process parameters are adhered to, the minimum requirements of the DLG test framework for dust, ammonia and odour reduction are met, and in some cases exceeded.
The recognised minimum separation efficiencies for total dust was 91.3 % in winter and 85.0 % in summer. For PM_{10} fine dust the rate fell to 78.6 % in winter and 71.4 % in summer. The minimum separation efficiency for ammonia was 77.3 % in winter and 80.7 % in summer. Nitrogen removal rates were 87.3 % (winter) and 84.6 % (summer). Odour was reduced to at least 300 OU/m³ in all cases. On no occasion was the smell of untreated air detected in the clean air.

In multi-module operation, all modules must be controlled synchronously.

Further information

Testing agency

DLG TestService GmbH,
Gross-Umstadt test site, Germany

The tests are conducted on behalf of DLG e.V.

Laboratory and emissions measurements

SGS Institut Fresenius GmbH,
Im Paesch 1a, 54340 Longuich

BUB Braunschweiger Umwelt-Biotechnologie GmbH,
Hamburger Straße 273 a, 38114 Braunschweig

Machine and plant safety

Expert Klaus Ahlendorf GmbH,
Von-Loe-Straße 40 a, 47906 Kempen

DLG test framework

DLG Full Test:
Exhaust air cleaning systems for livestock houses
(issue date 03/2016)

Department

Agriculture

Project Manager

Dr. Ulrich Rubenschuh

Test engineer(s)

Dipl.-Ing. (FH) Tommy Pfeifer*

Test commission

Friedrich Arends, Chamber of Agriculture of Lower Saxony
Christian Dohrmann, farmer
Doris Düsing, LK Cloppenburg
Bernhard Feller, Chamber of Agriculture North Rhine-Westphalia
Ewald Grimm, KTBL Darmstadt
Dr Jochen Hahne, TI Braunschweig
Andreas Schlichting, TÜV Nord Hamburg
Thomas Üffing, farmer

* Author

DLG – the open network and professional voice

Founded in 1885 by the German engineer Max Eyth, DLG (Deutsche Landwirtschafts-Gesellschaft – German Agricultural Society) is an expert organisation in the fields of agriculture, agribusiness and the food sector. Its mission is to promote progress through the transfer of knowledge, quality standards and technology. As such, DLG is an open network and acts as the professional voice of the agricultural, agribusiness and food sectors.

As one of the leading organisations in the agricultural and food market, DLG organises international trade fairs and events in the specialist areas of crop production, animal husbandry, machinery and equipment for farming and forestry work as well as energy supply and food technology. DLG's quality tests for food, agricultural equipment and farm inputs are highly acclaimed around the world.

For more than 130 years, our mission has also been to promote dialogue between academia, farmers and the general public across disciplines and national borders. As an open and independent organisation, our network of experts collaborate with farmers, academics, consultants, policymakers and specialists in administration in the development of future-proof solutions for the challenges facing the agriculture and the food industry.

Leaders in the testing of agricultural equipment and input products

The DLG Test Center Technology and Farm Inputs and its test methods, test profiles and quality seals hold a leading position in testing and certifying equipment and inputs for the agricultural industry. Our test methods and test profiles are developed by an independent and impartial commission to simulate in-field applications of the products. All tests are carried out using state-of-the-art measuring and test methods applying also international standards.

Internal test code DLG: 2019-00082 and 2104-0065

DLG TestService GmbH
Groß-Umstadt location
Max-Eyth-Weg 1 • 64823 Groß-Umstadt • Germany
Phone: +49 69 24788-600 • Fax: +49 69 24788-690
Tech@DLG.org • www.DLG.org

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