Munters Reventa GmbH

Lavamatic exhaust air treatment system

for rearing layers and pullets

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FULL TEST
MUNTERS REVENTA LAVAMATIC FOR LAYERS
DLG Test Report 7521

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DLG

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.

To obtain the test mark, the “Lavamatic” exhaust air treatment system from Munters Reventa GmbH was tested for its suitability for reducing emissions of dust and ammonia from the exhaust air flow of a layer rearing facility with an aviary system. The test is based on the design of the ventilation system in accordance with DIN 18910, which stipulates a maximum air volume flow of 4.9 m^3 per animal per hour for layers with a live weight of 2 kg.

According to the current DLG test framework, at least 70 % of total dust and particulate matter (PM_{10}) and at least 70 % of ammonia must be reduced in a layer rearing system to demonstrate emission reduction. At least 70 % N reduction (N removal) must be demonstrated within a N balance and the aerosol discharge must not exceed 0.5 mg N/m^3 in the clean gas.

The test was carried out on a layer system with a Lavamatic unit, whereby only a partial flow of the barn was cleaned. The test was carried out on a Lavamatic XL for an exhaust air volume flow of 110,000 m^3/h. The system comprised four structurally and functionally identical dust filter modules. In addition to the tested system with 110,000 m^3/h, systems with 55,000 m^3/h and 27,500 m^3/h are also available.

The stated minimum requirements were satisfied and in some cases exceeded. This enabled the Lavamatic to be certified for layer rearing in accordance with the DLG test framework.

Assessment in brief

The “Lavamatic” exhaust air treatment system from Munters Reventa GmbH is a two-stage, chemically operating exhaust air washer for the reduction of dust and ammonia from layer rearing facilities with aviary systems and manure belt removal. The aviaries are equipped with perches, feeding and drinking facilities. The inspection aisles are strewn with wood shavings. The manure is removed from the barn building two to three times a week via the manure belts integrated into the aviary system.

The Lavamatic is operated according to the pressurised principle. The minimum distances are cited in Table 2. If the minimum distances are not met, a uniform flow with the specified reduction performance is no longer guaranteed. The investigations were carried out on a barn system using the pressurised principle.

The raw gas was extracted from the barn area as a partial flow via fans, with the first cleaning stage still on the suction side and the second cleaning stage on the pressure side of the fans. All fans are controlled in groups and regulate themselves according to the outside temperature. The first cleaning stage comprises dry dedusting to remove the coarse dust from the exhaust air flow. The second cleaning stage consists of a continuously operated washing drum that rotates in a water storage tank with a pH value of ≤ 3. The exhaust air flow is channelled through the drum. Due to the continuous rotation of the drum, it is always kept moist and is able to retain ammonia and dust particles.

In order to guarantee the reduction performance described in the DLG test report, a maximum conductivity of the washing water of 230 mS/cm must be maintained in addition to a pH value of ≤ 3. The filter volume load must not exceed 8,700 $m^3/(m^3*h)$, the drum speed must be at least 3 revolutions per minute (rpm), while the water in the storage tank must not sink below 30 cm and the maximum immersion depth of the drum must be 20 cm.

In the test, the “Lavamatic” exhaust air purification system achieved a minimum reduction rate for total dust of 74.3 % in winter and 80.3 % in summer. At least 72.5 % of particulate matter PM_{10} was retained in winter and at least 72.8 % in summer. Chemical reactions (the formation of ammonium sulphate) remove at least 85.1 % of ammonia in winter and at least 80.5 % in summer. In summer, 84.8 % and 83.5 % of the nitrogen could be removed from the system via the washing water and in winter 83.2 % (N removal). The aerosol discharge measurement remained unremarkable and satisfied the requirements of the DLG test framework. The results are summarised in Table 1.

As the emissions according to VDI 3894-1 for ammonia and dust in pullet rearing are safely below the specified emission factors for layer rearing (aviary system with manure belt removal) and the expected emission mass flow is lower, the tested exhaust air treatment system can also be used in a pullet rearing system.

Table 1:
Results of the Lavamatic exhaust air treatment system at a glance

Test criterion	Result	Evaluation*
Results of the emission measurements		
Total dust (gravimetric)		
Winter (3 measurements), minimum reduction rate [%] [1], [2]	74.3	■■■□□
Summer (4 measurements), minimum reduction rate [%] [1], [2]	80.3	■■■■□
Particulate matter PM_{10} (gravimetric) [3]		
Winter (3 measurements), minimum reduction rate [%] [1], [2]	72.5	■■■□□
Summer (3 measurements), minimum reduction rate [%] [1], [2]	72.8	■■■□□
Particulate matter $PM_{2.5}$ (gravimetric) [3]		
Winter (3 measurements), minimum reduction rate [%] [1], [2]	80.9	N/A
Summer (3 measurements), minimum reduction rate [%] [1], [2]	89.1	N/A

Continuation of the table on page 4

Test criterion	Result	Evaluation*
Results of the emission measurements		
Ammonia (measured continuously for at least six weeks)		
Winter, minimum reduction rate [%] [1]	85.1	■■■■□
Summer, minimum reduction rate [%] [1]	80.5	■■■■□
N removal		
Winter [%]	89.1	■■■■□
Summer 1st balance [%]	84.8	■■■■□
Summer 2nd balance [%]	83.5	■■■■□
Consumption measurements (daily mean values or annually per livestock space) [4]		
Fresh water consumption		
Winter [m^3/d] / [m^3/1,000 m^3 exhaust air] / [m^3/(TP · a)]	1.0 / 0.002 / 0.017	N/A
Summer [m^3/d] / [m^3/1,000 m^3 exhaust air] / [m^3/(TP · a)]	2.8 / 0.002 / 0.042	N/A
Annual mean [m^3/d] / [m^3/1,000 m^3 exhaust air] / [m^3/(TP · a)]	1.9 / 0.001 / 0.030	N/A
Elutriation volume [5]		
Winter [m^3/d] / [m^3/1,000 m^3 exhaust air] / [m^3/(TP · a)]	0.11 / 0.0001 / 0.0015	N/A
Summer [m^3/d] / [m^3/1,000 m^3 exhaust air] / [m^3/(TP · a)]	– / – / 0.0013	N/A
Annual mean [m^3/d] / [m^3/1,000 m^3 exhaust air] / [m^3/(TP · a)]	– / – / 0.0014	N/A
Acid consumption (based on 96 % sulphuric acid)		
Winter [kg/d] / [kg/1,000 m^3 exhaust air] / [kg/(TP · a)]	19.9 / 0.025 / 0.32	N/A
Summer [kg/d] / [kg/1,000 m^3 exhaust air] / [kg/(TP · a)]	16.7 / 0.009 / 0.27	N/A
Annual mean [kg/d] / [kg/1,000 m^3 exhaust air] / [kg/(TP · a)]	18.3 / 0.017 / 0.30	N/A
Electrical energy consumption		
Exhaust air treatment [6], [7]		
Winter [kWh/d] / [kWh/1,000 m^3 exhaust air] / [kWh/(TP · a)]	14.1 / 0.017 / 0.22	N/A
Summer [kWh/d] / [kWh/1,000 m^3 exhaust air] / [kWh/(TP · a)]	21.5 / 0.012 / 0.35	N/A
Annual mean [kWh/d] / [kWh/1,000 m^3 exhaust air] / [kWh/(TP · a)]	17.8 / 0.015 / 0.28	N/A
Fans		
Winter [kWh/d] / [kWh/1,000 m^3 exhaust air] / [kWh/(TP · a)]	41.7 / 0.050 / 0.65	N/A
Summer [kWh/d] / [kWh/1,000 m^3 exhaust air] / [kWh/(TP · a)]	267.3 / 0.138 / 3.99	N/A
Annual mean [kWh/d] / [kWh/1,000 m^3 exhaust air] / [kWh/(TP · a)]	154.4 / 0.094 / 2.32	N/A

* DLG Evaluation range:
■■■ or better = meets, exceeds or significantly exceeds the established DLG standards,
□□ = meets the legal requirements for marketability, ■ = failed, N/A = not assessed

1 The minimum reduction rate for dust is the lowest value determined during the measurement period. The minimum reduction rate for ammonia is the average reduction rate minus the standard deviation. Dust reduction is only certified with the tested dry dedusting system.
2 Due to strong fluctuating raw gas concentrations at all four fresh air chimneys, two raw gas ducts were first measured in parallel and then the other two raw gas ducts, including the corresponding clean gas measurement, were measured directly afterwards. The dust reduction over these four individual measurements was averaged as a single measured value.
3 Experience has shown that the washing process can lead to the formation of droplets in a size range of 2.5 to 10 µm, which cause an increased finding for the PM_{10} particle fraction in the cascade impactor. The $PM_{2.5}$ particle fraction is less affected by this effect. Therefore, a higher reduction rate is calculated for this particle fraction than for the PM_{10} fraction.
4 Due to partial flow treatment at the reference system, the consumption data determined can only be compared with other plants to a limited extent. The livestock space-specific data was calculated using the DIN air rate of 4.9 m^3/(TP · h) at 2 kg live weight and a maximum air volume flow of 110,000 m^3/h.
5 As the maximum conductivity of 230 mS/cm was not reached in the summer measurement, no automatic elutriation was initiated. For this reason, elutriation in summer was calculated from the acid consumption. The annual mean value is also based on this calculation.
6 The specific energy consumption of an exhaust air treatment system is highly dependent on the size of the system and decreases as the number of animals increases.
7 The difference in energy consumption between winter and summer is due to the fact that in winter the drum was only moved at 2 revolutions per minute and an electrical heating system was also operated in the measurement and control cabinet.

Manufacturer and applicant

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Product:
(2-stage) Lavamatic exhaust air treatment system for layer and pullet rearing

Description and technical details

The “Lavamatic” exhaust air treatment system is a two-stage system with a dry pre-dedusting stage and a chemical stage for purifying the exhaust air from layer barns with an aviary system and manure belt removal. This system is operated in a pressurised process, with pre-dedusting on the suction side of the fans. The feed used is standard feed.

The exhaust air is drawn from the aviaries into the first cleaning stage by a total of four fans. This consists of a filter box that is permanently installed directly in front of each fan. The filter box comprises a stainless-steel mesh grid, which is mounted on a plastic frame and is cleaned in regular sections or as required using a vibration system. In this stage, the exhaust air is cleaned of coarse dust particles.

Once the air has been conveyed horizontally through the fans, it enters the second cleaning stage. A drum washer works here, constantly rotating at three revolutions per minute. On the raw gas side, the drum is immersed in the water storage tank (washing water, process water) and wets the filling material installed in the drum with washing water. To guarantee a pH value of ≤ 3 in the washing water, 96 % sulphuric acid is added from an IBC container. The exhaust air flows through the rotating drum and then enters the vertical exhaust air duct after a 90° bend and flows upwards into the open air. There is a measuring fan in each fresh air chimney to record the air flows.

While the reduction of ammonia takes place exclusively in the second process stage (drum washer), both process stages are relevant for sufficient dust reduction. In the drum washer, coarse and fine dust particles in the process water are washed out and later removed from the system by means of elutriation and basic cleaning. Gaseous ammonia reacts with sulphuric acid washing water to form ammonium sulphate. The rising salt content leads to an increasing conductivity in the washing water. At a maximum conductivity of 230 mS/cm, a part of the water storage tank is automatically elutriated and removed from the system.

The rotation of the washing drum partially cleans the filling material. A wiper mounted at the top of the wash drum ensures that the coarser particles are removed from the drum’s exterior. Simultaneously, the wiper is used for sealing the drum. This cleaning system does not require a circulation pump to achieve the described reduction performance, as the drum moistens itself through the rotary movement.

The large specific surface area of the filling material serves to increase the contact surface between the barn exhaust air

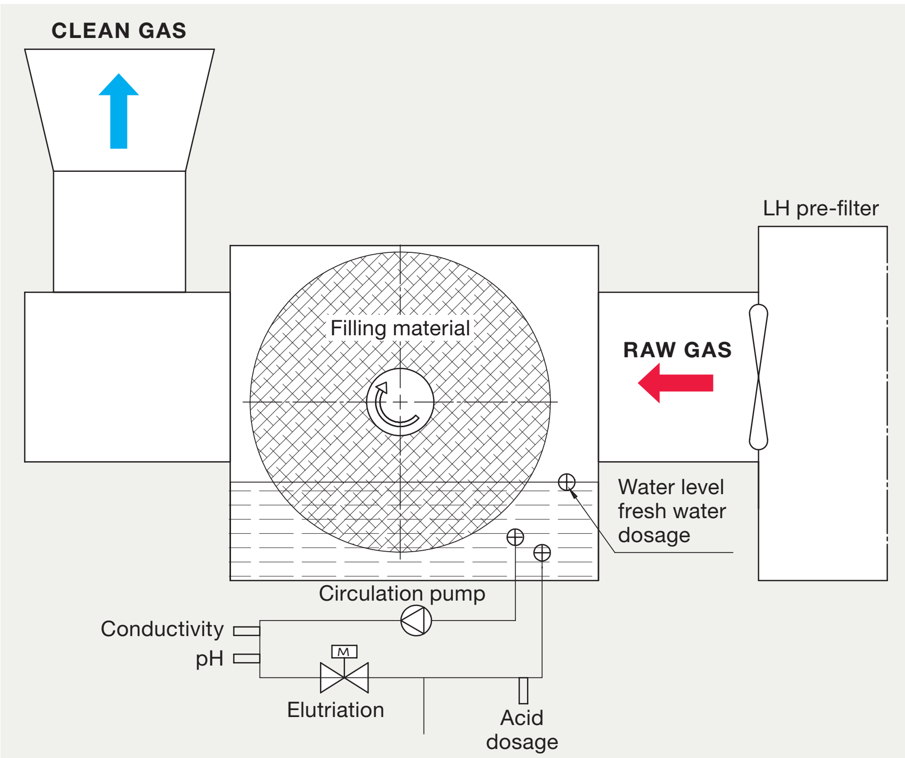

Figure 2:
Configuration of the “Lavamatic”

and washing water for effective reduction of ammonia and dust. The design of the exhaust air duct (90° bend upwards) can retain nitrogenous aerosols and thus reduce water losses.

The optimum pH value is ≤ 3 as intended. Compliance with this must be saved as a half-hourly average value in the electronic logbook (EBTB). If the maximum permitted pH value is exceeded, acid is added to the process water via an acid dosing system, causing the pH value to drop again.

Water droplets (aerosols) are to be retained in the system due to the specified structure of the Lavamatic between the fresh air and exhaust air module. A droplet separator is not provided for.

Of four fans, fans 1 and 3 (group A) were first run up to 100 %, then fans 2 and 4 (group B) were run up to the maximum speed. Both groups were controlled via the speed. The design of the exhaust air treatment system must not exceed a maximum filter volume load of 8,700 $m^3/(m^3 \cdot h)$.

To avoid excessive salt accumulation, which would lead to salt precipitation and thereby also to malfunctions, the water must be elutriated at regular intervals. Elutriation is automated depending on the salt content of the washing water, i.e. depending on the electrical conductivity. Following elutriation, the washing water is replaced with fresh water. The conductivity of the washing water is limited to 230 mS/cm.

In order to prevent an unacceptable rise in the pH value in the washing water during operation, acid is added via an acid dosing system if the maximum permitted pH value is exceeded, resulting in an immediate drop of the pH value. A sufficient quantity of acid must therefore be available for correct operation.

In addition to the filter volume load and pH or conductivity value, the process parameters of the drum operation must also be maintained for stable system operation. The rotational speed must not be less than 3 revolutions per minute and the water level in the storage tank must be kept at a minimum of 30 cm, whereby the immersion depth of the drum must be 20 cm.

As increased water evaporation also occurs during system operation, the fresh water input and elutriation volume must be recorded and stored in the electronic logbook (EBTB). The water level is checked by an electronic level sensor, which also ensures that the drum does not run dry and that fresh water is topped up to the normal level.

According to the manufacturer's instructions, the drum must be thoroughly cleaned at least every 12 weeks. In individual cases and with high feather or dust loads, cleaning may also be necessary more frequently. In this case, the operator is informed that the back pressure across the drum has reached the limit value of 250 Pa and that cleaning is required. The dry dedusting system is cleaned fully automatically either every 120 minutes or (in the case of high loads) earlier if a pressure loss of 50 Pa is exceeded via the dry dedusting system.

Figure 2 is a schematic illustration of the process. Important process engineering parameters can be found in Table 2.

Guarantee

The manufacturer provides a 2-year guarantee, which assumes correct operation of the system and does not apply to wearing parts. This is subject to installation being overseen by the manufacturer, as well as maintenance in accordance with the maintenance schedule in the operating instructions.

Table 2:
Process engineering parameters of the exhaust air treatment system from Munters Reventa

	Characteristic	Result / value
Description		Chemically operating system with dry pre-dedusting
Suitability		Purification of exhaust air from layer rearing when using standard feed by reducing dust and ammonia
Dimensioning parameters of reference system according to manufacturer's specifications (continuous operation)		
	distance livestock area / dry filter [m]	3.45
	maximum air volume flow (partial flow treatment) [m³/h]	110,000
	clean gas outlet area at the reference system [m²]	5.1
Dry filter (filter box)	number of filter boxes [units]	4
	filter width / filter height / filter depth [mm/mm/mm]	1,400 / 2,300 / 0.56
	inflow area per filter box [m²]	3.22
	maximum inflow velocity [m/s]	2.16
	maximum filter surface load [m³/(m²*h)]	8,600
	mesh size of the grid [mm]	1.80
	grid material [–]	Stainless steel (VA)
	distance dry filter / fans [m]	1.84
	distance fans / centre of drum [m]	1.90
Chem. cleaning stage	number of drum modules [units]	4
	length / outer diameter / inner diameter [m/m/m]	1.815 / 1.7 / 0.8
	free inflow area [m²] / active filter volume [m³]	15.33 / 11.8
	min. dwell time at summer air rates [s]	approx. 0.06
	maximum inflow velocity [m/s]	2.00
	immersion depth of the drum / water level [mm]	200 / 300
	maximum filter volume load [m³/(m³*h)]	8,700
	filling material type [–]	NC 20-27
	spec. surface area of the filling material [m²/m²]	125
	voids fraction [m²/m²]	> 97
	drum speed [rpm]	3
	direction of rotation [–]	raw gas side immersion in water
	distance drum / start of duct [m]	1.20
Elutriation	water tank capacity [m³]	4.12 to 4.42
	elutriation rate at the reference operation, annual average [m³/(TP · a)] [1]	0.0014
	pH value of washing water [–]	≤ 3
	maximum conductivity in the water storage tank [mS/cm]	≤ 230
Reference operation for the conducted measurements (layers in barn system on 2 levels)		
	rearing system for layers [system]	barn system (aviary), manure belt ventilation
	approved livestock spaces, total barn [number]	55,760
	usable area total barn [m²]	1,683
	ø-live weight [kg/animal]	2.0
	installed air requirement per animal [m³/(animalP · h)]	9.6
	summer air rate according to DIN 18910, total barn [m³/h]	501,840
	max. installed exhaust air volume flow, total barn at 20 Pa [m³/h]	535,296
	treated exhaust air volume flow (partial flow, Lavamatic) [m³/h]	110,000
	max. pressure loss barn plus ARA at 110,000 m³/h [Pa] [2]	300
	max. pressure loss ARA at 110,000 m³/h incl. exhaust air module [Pa] [2]	280
	number of fans, filtered (Lavamatic) [number]	4
	number of fans, unfiltered [number]	20

Parameter	Result	Evaluation*
Operating behaviour		
Technical operational safety	Apart from a few power failures, no significant faults were detected during the test periods. The fans must always be synchronously controlled.	✓
Durability	No significant wear was detected during the investigation period.	N/A
Handling		
Operating instructions	The operating instructions are detailed and clearly structured. Maintenance work to be carried out and the automatic control system are clearly described. A large number of safety instructions are provided and potential dangers are clearly described.	✓
Operation	The system runs fully automatically during normal operation. The system operator must check the system control on a daily basis. The system must be operated continuously.	✓
Maintenance	A maintenance contract between the installer/dealer and the system operator is strongly recommended. Maintenance should be carried out at least once a year. In addition to daily checks of the system control, monthly and half-yearly visual inspections and cleaning must be carried out. These checks must be documented. The maintenance work is clearly described in the operating instructions.	N/A
Cleaning of the entire system	The system must be cleaned at least every 12 weeks. If a pressure loss of 250 Pa is exceeded, the system operator is prompted to clean the system prematurely.	N/A
Replacing filling material	According to the manufacturer, it is not necessary to change the filling material with correct operation and regular performance of the necessary maintenance work.	N/A
Workload (manufacturer's specifications)		
Daily checks	approx. 15 minutes, plus occasional changing of the sieve basket (25 minutes)	N/A
Weekly checks	approx. 30 minutes	N/A
Cleaning the entire system	approx. 2 hours for 2 people	N/A
Documentation		
Technical documentation	requirements satisfied	✓
Electronic logbook	requirements satisfied	✓
Safety		
Machine and system safety	confirmed by a recognised expert for occupational safety, internal risk assessment	N/A
Fire safety	a fire protection concept must be drawn up by the operator as part of the building permit procedure for the entire barn.	N/A
Environmental safety	The washing water must be stored temporarily in a designated storage tank in accordance with the Ordinance on Installations for Handling Substances Hazardous to Water (AwSV). It is advisable to utilise the washing water as fertilizer for the plants. Proof of correct utilisation is provided by the system operator. The disposal of other system components is carried out by recognised recycling companies.	N/A
Warranty		
Manufacturer's warranty	2-year guarantee on all system parts that are not subject to normal wear and tear. Assembly overseen by manufacturer and maintenance according to maintenance schedule.	N/A

* Evaluation range: requirements fulfilled (✓) / requirements not fulfilled (✗);
N/A = not assessed

1 The elutriation was calculated from the measured nitrogen input and the acid consumption.
2 ARA is the abbreviation for exhaust air cleaning system. The filter pressure loss can vary significantly depending on the dust input. The pressure loss of the ARA essentially corresponds to the pressure loss of the drum plus the pressure loss of the pre-dedusting.

The method

The measurements were performed at a reference facility in North Rhine-Westphalia.

Due to the fact that dust reduction in this cleaning system depends primarily on the air volume flow, individual dust measurements were carried out under simulated winter conditions before or during the summer measurement for reasons of time, whereby the air volume flow was adjusted to the specifications for the period of the dust measurement.

The first summer measurement carried out could not be recognised for the most part due to a number of structural optimisations. In a decision by the DLG Technical Committee, the measurement period was set at six weeks in a subsequent summer measurement.

An explicit test of the optional odour level offered by the manufacturer was not performed at the manufacturer's request.

A layer barn with a total of around 55,000 livestock on two separate levels served as a reference system. The barn's ventilation system is designed for a total air volume flow of 535,300 m³/h, for which 20 exhaust fans were installed in the barn ceiling on the gable end. By using gratings in the floor of the upper level, both levels could be exhausted simultaneously. Of this total air flow rate, 110,000 m³/h was conveyed via the Lavamatic, while the total ventilation was correspondingly reduced.

A survey of owners of exhaust air treatment systems of the same type could not be carried out during the investigation period, because the tested system in its present form was not yet in practical use.

The exhaust air treatment system is approved for pressurised operation.

The measurements took place from October 2023 to June 2024; a single dust measurement was carried out at the beginning of October 2024.

The following parameters were used to assess the exhaust air treatment system:

Dust

Sampling was carried out in accordance with VDI Guideline 2066, Sheet 1 and DIN EN 13284-1. An isokinetic sampling system according to Paul Gothe with a flat filter head device (Ø 50 mm) was installed for this purpose.

A round glass fibre filter with a diameter of 45 mm was selected as the reduction medium.

Determination of the particulate matter (PM_{10} and $PM_{2.5}$) was carried out in accordance with VDI Guideline 2066, Sheet 10 and DIN EN ISO 23210. A Johnas II cascade impactor according to Paul Gothe with three flat filters (Ø 50 mm) was used. A round filter made of glass fibre, now with a filter diameter of 50 mm, was once again used as the reduction medium. The evaluation was carried out through gravimetric determination of the dust load.

According to the DLG test framework, the reduction rate must not fall below 70 %. This applies to total dust and particulate matter (PM_{10} fraction). The results of the PM2.5 measurement are presented for information purposes. The minimum degree of reduction is recognised as the lowest degree of reduction resulting from all measurements taken on the measurement days.

As the dust input at all four supply air stacks (raw gas) of the Lavamatic was not uniform and led to significantly fluctuating reduction rates of total dust and particulate matter, a measuring method was used after consultation with the Technical Committee, which is heavily aligned with the aforementioned procedure, whereby all four fresh air chimneys were sampled almost simultaneously and could be evaluated together with the corresponding measurements in the clean gas.

Ammonia

The ammonia measurements in the raw and clean gas range were carried out continuously over the entire test period using FTIR spectroscopy in accordance with KTBL publication 401 and DIN EN 15483, whereby the measurements were carried out using a measuring cell. To avoid condensation in the gas-carrying PTFE lines, the sample gas lines were heated along their entire length on the clean gas side.

Interferometer purging was used throughout the measurement period.

The results shown refer to measured values. If less than 0.8 ppm is measured in the clean gas of an exhaust air treatment system, this value is raised to 0.8 ppm. This is due to the measurement uncertainty of the measuring device used. Below this value, a reliable measurement cannot be quantified. Without continuous interferometer purging, the lower measuring range limit is 1.0 ppm.

The ammonia concentration at livestock level was continuously recorded on the measurement days to verify compliance with the German Animal Welfare and Livestock Farming Ordinance (TierSchNutztV) (max. 20 ppm ammonia in the animal area).

According to the assessment criteria of the DLG test framework, the minimum reduction rate for ammonia must be permanently above 70 %. The minimum reduction rate to be recognised is determined from the mean reduction rate of all results minus their standard deviation.

Aerosol discharge

Nitrogen-containing aerosols are expelled from the filling material of exhaust air treatment systems as ammonium aerosols due to the humidification of the filling material packs, and are carried along by the exhaust air flow. This means that the nitrogen originally separated is unintentionally released back into the environment.

The dust filters of the total dust measurements were analysed for ammonium sulphate $(NH_4)_2SO_4$ for aerosol determination during the investigation period in summer. The conversion to ammonium nitrogen (NH_4-N) is carried out using the molar masses of the compounds. The molar mass of ammonium sulphate is 132.1332 g/mol and the molar mass of the nitrogen it contains (2 x N) is 28.0134 g/mol. This equates to a proportion of 21.2 %. The ammonium sulphate content was therefore multiplied by a factor of 0.212 to determine the ammonium nitrogen content.

To determine the N discharge with the aerosols, a measurement was taken during the winter measurement using a flat filter in the clean gas downstream of the second droplet separator. Two sampling devices were installed, one of which was equipped with a particle filter for aerosol separation. Sampling was carried out in accordance with VDI 3496-1 (measurement of gaseous emissions).

According to the DLG test framework, the aerosol discharge must not exceed 0.50 mg nitrogen per standard cubic metre.

Nitrogen balance, N removal

The ammonia reduction of the exhaust air treatment system was verified by means of N balancing, taking into account the ammonia loads (in the raw and clean gas) and the inorganic nitrogen compounds dissolved in the washing water. The balancing period was 21 days in winter and likewise 21 days in summer. Due to a power outage, the originally planned balancing period had to be interrupted in the summer and later resumed. Two balances were therefore drawn up under summer conditions.

When balancing chemically operated washers, the process water is only analysed to determine the NH_4-N concentration, because no biological oxidation usually takes place.

To determine the actual N removal, the inorganic N mass removed is compared with the N load entering on the raw gas side.

Balancing the nitrogen flows within the system is important because:

- all relevant nitrogen compounds and their remnants can be detected
- the nitrogen content of the elutriation water is known and its manure value is quantified

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

The recovery rate of nitrogen (N balance) must be at least 80 %, but no more than 120 %, according to the test framework.

Consumption values, ambient conditions and system load

The consumption of fresh water, elutriation and electrical energy was determined by recording the corresponding meter readings (electricity meter for exhaust air treatment and separately for ventilation).

The acid consumption was determined using a weighing system (load cell or scale).

During the measurements, the ambient conditions (outside/inside temperature, outside/inside relative humidity) were recorded. On the days of the

dust and odour concentration measurements, the following parameters were also documented:

- Livestock weights (estimated) and livestock numbers
- Fresh water and electrical energy consumption (meter readings)

- Air volume flow (manufacturer's measuring fans and separate fan characteristic curve)
- Pressure loss via the system and pressure loss via the fan
- pH value and conductivity in the process water

Furthermore, the measured values recorded by the manufacturer in the electronic logbook were checked for plausibility.

Operational safety and durability

Operational safety and durability were assessed. Any faults that occurred in the overall system and in technical components were documented during the investigation period.

Operating instructions, handling and work requirements, maintenance effort

A detailed functional description of the system with a graphic representation and clear description of the regular maintenance work were checked and assessed from the user's point of view.
In the test scope for handling and working time requirements, an evaluation determines whether instruction is required from the manufacturer for commissioning and what effort is required for regularly recurring checks and work at intervals of days, weeks, months, etc. or in the event of malfunctions.

The service intervals and their duty lists are assessed for the maintenance effort.

Documentation

The following parameters must be recorded and saved in the electronic logbook as half-hourly averages or half-hourly values:

- Pressure loss across the system [Pa]
- Air flow rate [m³/h]
- Pump running time and operating time of drum operation (circulation, elutriation) [h]
- Total fresh water consumption of the system [m³], cumulative
- Elutriation volume [m³], cumulative
- Raw and clean gas temperature [°C]
- pH value [-] and electrical conductivity [mS/cm], both as half-hourly averages
- Power consumption of the exhaust air treatment system [kWh], cumulative

Furthermore, maintenance and repair times as well as calibrations of the pH value probe must be recorded. Proof of the consumption of chemical operating materials (acid, anti-foaming agent) as additives must be provided.

This data serves as proof of correct operation of the exhaust air treatment system and was checked on the reference system.

Environmental safety

The environmental safety test included an assessment of any operating materials required for system operation, such as acids and alkalis. Furthermore, the material utilisation of operational waste, such as the elutriated process water, as well as the dismantling and disposal of system components are investigated and assessed. The areas of responsibility for these aspects were also examined.

Safety aspects

To assess the system safety, compliance of the system with the currently valid regulations in the areas of fire and system safety was checked.

The test results in detail

The test was carried out on a reference system with an installed cleaning capacity of 110,000 m³/h per exhaust air treatment system (4 drum modules). Lavamatic systems that are operated with fewer modules but are otherwise identical in design can also be considered to be certified.

Based on the experience gained from previous measurements on the Lavamatic, the Technical Committee (TC) has decided in favour of a shorter measurement period in summer. Ammonia was measured continuously for a total of six consecutive weeks. Given that all the animals were removed immediately after this measurement and it was not planned that the Lavamatic remains at the test site, all the necessary dust measurements were taken during this time. Extending the measurement programme would have significantly increased the measurement effort and was also considered disproportionate. This also applies to subsequent dust measurements (total dust/fine particulate matter PM_{10}) under winter conditions, which did not lead to

Table 3:
Measurement results for emission reduction (total dust and particulate matter) at the exhaust air treatment facility of the Munters Reventa system

	Measurement under						
	Winter conditions			Summer conditions			
Date	**20/06/24**	**25/06/24**	**02/10/24**	**02/05/24**	**08/05/24**	**22/05/24**	**27/06/24**
Ambient and boundary conditions [1]							
Rel. outdoor air humidity [%rh]	59	59	90	62	72	90	92
Ambient temperature [°C]	22.6	26.2	10.4	23.0	14.8	17.3	28.2
Raw gas/clean gas humidity [%rh]	62/84	64/92	80/98	65/99	68/99	88/99	68/92
Raw gas/clean gas temperature [°C]	23.5/20.0	26.5/22.0	17.8/15.3	21.2/17.7	20.2/14.0	20.2/17.7	29.2/26.7
Quantity of livestock in the barn [units]	49,400	49,400	51,451	50,100	50,100	50,000	49,347
Average livestock weight [kg]	1.9	1.9	1.8	1.9	1.9	1.9	1.9
Air volume flow [m³/h]	31,000	31,500	32,500	83,200	91,300	78,300	106,600
Pressure loss ARA [Pa]	39	40	35	177	181	– [2]	250
Total pressure loss [Pa] [3]	56	58	– [2]	ca. 200	ca. 200	– [2]	> 250
Total dust (standardised) [4]							
Raw gas [mg/m³]	11.40	13.14	10.62	11.38	8.27	6.14	15.14
Clean gas [mg/m³]	2.41	2.76	2.73	1.47	1.33	1.21	2.71
Mean reduction rate [%]	78.9	79.0	74.3	87.1	84.0	80.3	82.1
Minimum reduction rate [%]	74,3			80,3			
Particulate matter PM_{10}/$PM_{2.5}$ (normalised) [4]							
Raw gas [mg/m³]	6.79/3.77	7.02/3.37	4.14/1.98	5.87/3.33	5.46/3.32	3.36/1.96	–
Clean gas [mg/m³]	1.86/0.58	1.92/0.64	1.14/0.00	1.23/0.24	1.22/0.20	0.92/0.21	–
Mean reduction rate PM_{10}/$PM_{2.5}$ [%]	72.6/84.6	72.6/80.9	72.5/> 99	79.0/92.8	77.6/94.2	72.8/89.1	–
Minimum reduction rate PM_{10}/$PM_{2.5}$ [%]	72.5/80.9			72.8/89.1			

1 The data was collected at the time of dust measurement.
2 The measured values were implausible or could not be collected for technical reasons.
3 The total pressure loss results from the pressure loss of the ARA (exhaust air treatment system) plus the pressure loss from the barn and, if applicable, other air resistances (e.g. duct). The pressure loss varies depending on the loading of the drum and pre-dedusting.
4 Some of the figures shown have been rounded to one decimal place. However, the reduction values were calculated using the non-rounded values.

satisfactory results due to a lack of technical optimisation work in the previous winter measurement. Dust reduction in this type of system depends mainly on the air flow. Other influences (e.g. humidity/temperature) play a subordinate role in dust reduction. For this reason, all dust measurements could be carried out during the summer measurement period. For this purpose, the air flow was briefly reduced to the winter air flow rate (approx. 30 %) during the dust measurements. In order to carry out all the necessary dust measurements at high air flows (summer conditions), two separate measurement days had to be brought forward shortly before the start of the actual summer measurement. However, all boundary parameters and all livestock-specific data were collected on each measurement date, so that this measurement planning is permissible in exceptional cases.

Dust

The reduction technology used was able to fulfil the requirements of the DLG test framework. Table 3 shows the measurement data from the winter and summer measurements.

In all, three total dust and three particulate matter measurements (PM_{10} and $PM_{2.5}$) were carried out in winter. Four total dust measurements and particulate matter measurements were performed in summer.

A minimum reduction rate of 74.3 % (winter) and 80.3 % (summer) was measured for total dust. In addition, particulate matter PM_{10} of at least 72.5 % in winter and 72.8 % in summer was separated.

Experience has shown that the washing process can lead to the formation of droplets in the size range of 2.5 to 10 µm, which cause an increased result for the PM_{10} particle fraction when measuring dust with the cascade impactor. The $PM_{2.5}$ particle fraction is less affected by this effect. Therefore, a higher reduction rate is usually calculated for this particle fraction than for the PM_{10} fraction.

Ammonia

Ammonia reduction that satisfies the requirements as a minimum can only be ensured if the process water is automatically elutriated at a maximum conductivity of 230 mS/cm and the pH value in the water is adjusted to ≤ 3.0.

The continuous monitoring of the ammonia concentration at livestock level revealed almost no abnormalities. The few times that a 20 ppm was exceeded in winter can be explained by the manure belt clearing process. In addition, the ventilation was not yet optimally adjusted during the winter measurement. This was rectified by the operator during the course of the inspection. These instances of the ppm being exceeded only ever occurred for short periods and

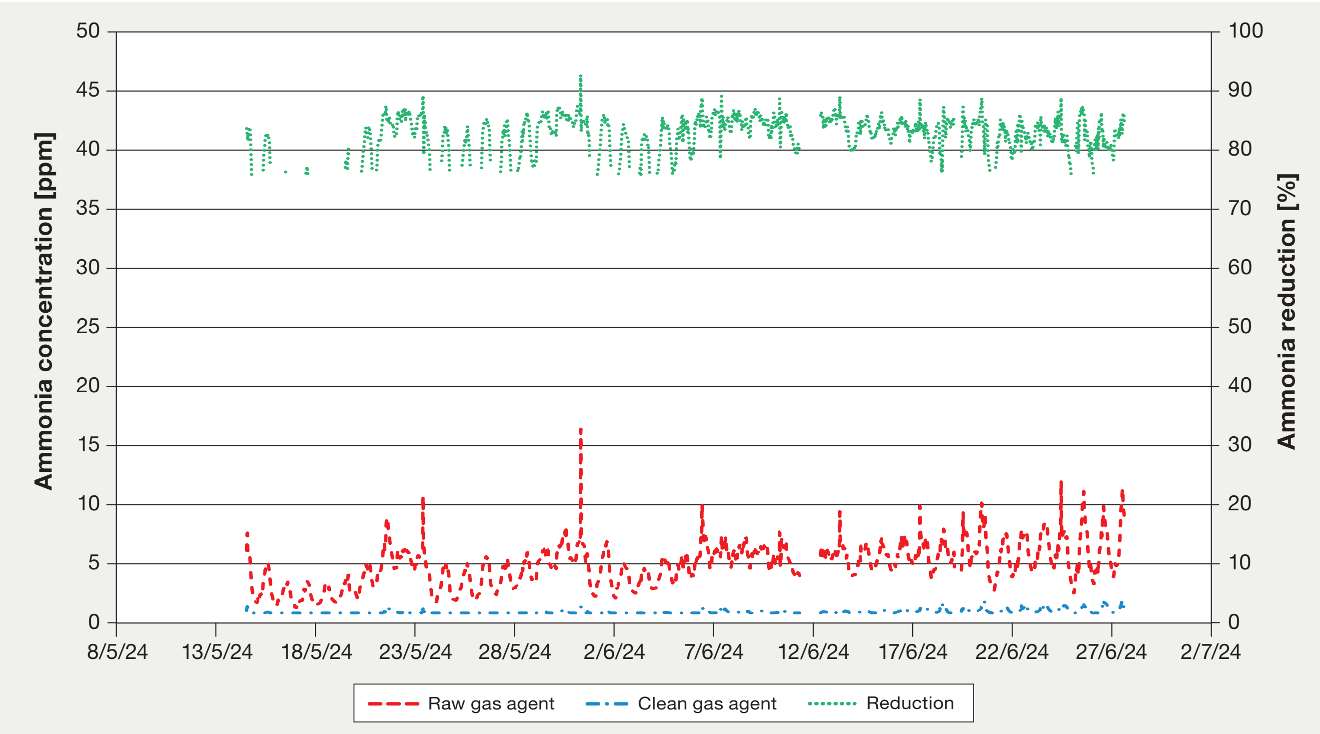

Figure 3:
Reduction rate and course of the ammonia concentration in the raw and clean gas (summer measurement)

Table 4:
Results of the aerosol discharge at the Lavamatic exhaust air treatment system

	Winter measurement			Summer measurement			
Date	15/11/23	18/12/23	20/12/23	08/05/24	22/05/24	27/06/24	27/06/24
Total air volume flow [m³/h]	38,800	49,900	53,000	75,600	77,700	106,200	107,200
Ammonium sulphate [mg/filter]	0.07	0.15	0.23	0.10	< 0.05	0.17	0.07
Aerosol content NH_4-N [mg/m³]	0.05	0.05	0.08	0.07	0.05 [1]	0.11	0.06

1 The analyses were below the detection limit.

Table 5:
Measurement results (N balance and washing water composition) of the exhaust air treatment system from Munters Reventa

		Winter measurement	Summer measurement	
Measurement period		**15/11 to 06/12/2023**	**28/05 to 10/06/2024**	**20/06 to 27/06/2024**
Gas side				
NH_3-N raw gas input	[kg]	122.61	65.66	50.16
NH_3-N clean gas discharge	[kg]	14.14	9.33	8.25
Difference	[kg]	108.5	56.3	41.9
Reduction capacity NH_3-N	[%]	88.5	85.8	83.6
Water side				
pH value [1]	[–]	2.9 to 3.5	2.9 to 3.5	
Conductivity [1]	[mS/cm]	193 to 229	117 to 199	
Water storage tank level [1]	[cm]	26 to 28	27 to 32	
N aerosol discharge	[kg]	0.86	1.4	0.9
N process water discharge	[kg]	8.55	55.66	41.86
N elutriation discharge	[kg]	100.64	0	0
N discharge in water, total	[kg]	109.19	55.66	41.86
Recovery rate N	[%]	100.6	99.0	99.9
N removal [2]	[%]	89.1	84.8	83.5

1 The data was taken from the electronic logbook.
2 The N removal was calculated without taking into account the aerosol discharge and without accounting for other gas components containing nitrogen.

only affected the winter period. There were no instances of the ppm being exceeded during the summer period.

In order to exclude increased ammonia concentrations of more than 20 ppm in the raw gas having an influence on the calculation of the reduction rate, all pairs of measured values in which more than 20 ppm was measured in the raw gas were eliminated in the winter and summer measurements. Ultimately, 2,623 pairs of values were available for evaluation as half-hourly averages in winter and 1,594 in summer.

In the winter measurement, a minimum reduction rate of 85.1 % was measured. At least 80.5 % was always achieved in summer.

Figure 3 graphically shows the ammonia concentrations based on the summer measurement. All measured values were corrected, i.e. values below 0.8 ppm were raised to 0.8 ppm (interferometer purging).

At least 70 % reduction was always achieved on all measurement days. Effective reduction of ammonia in the layer rearing process and proper operation is therefore ensured under the operating conditions described.

Aerosol discharge

The results of the aerosol measurements are summarised in Table 4. Three measurements were carried out in winter and three in summer. Measurements were taken behind the drum washer.

In winter, the measured values for aerosol discharge were below 0.1 mg NH_4-N/m³ and in summer stood at a maximum of 0.11 mg NH_4-N/m³; thus well below the limit value from the DLG test framework of 0.5 mg N/m³. This ensures good aerosol retention.

Nitrogen balance / N removal

The results of the nitrogen balance and N removal are shown in Table 5.

In the winter measurement, the nitrogen recovery rate was 101.2 %, in summer 101.0 % and 101.7 % respectively. In terms of measurement accuracy, the balance lies within a very good range.

83.2 % of nitrogen was recovered from the washing water in the winter measurement, while the summer measurement resulted in a N removal value of 84.8 % and 83.5 % respectively, which reflects stable and reliable overall operation. Due to unplanned conversion work on the exhaust air treatment system in the summer, the originally planned N balancing was split into two balancing periods.

Consumption values, ambient conditions and system load

The daily average values were recorded and stated in the test report to visualise all consumption figures. Given that only a partial flow was treated at the reference system, it is not possible to present livestock space-related data directly. For this reason, the consumption per 1,000 m³ of treated exhaust air is shown. The consumption figures were assigned to a number of livestock spaces, in order to make them even more comparable with other facilities. The maximum air rates of 110,000 m³/h and the air demand of 4.9 m³/(TP · h) were taken as a basis here. The consumption figures calculated in this way were able to withstand a plausibility check.

The consumption values stated in the test report (Table 1) for each measurement period (winter/summer) are standardised to annual consumption values (operation 365 days per year). These differ significantly in some cases (winter/summer differences). As such, only the average consumption (mean value of winter and summer consumption data) is discussed below.

The Lavamatic exhaust air treatment system is certified for a drum speed of 3 rpm. The winter measurement took place at 2 rpm, but this proved to be insufficient. Nevertheless, the values of the winter measurement can be used for evaluation with limitations.

Water consumption

The water consumption depends on the elutriation rate and evaporation. The greater the elutriation rate is and the more evaporation takes place, the more fresh water must be added to keep the process water volume in the system constant. The elutriation rate depends on the nitrogen input via the exhaust air flow and the limit value for the maximum conductivity in the process water. This was 230 mS/cm during the measurement period. During the summer measurement, no automatic elutriation took place due to insufficient conductivity. Therefore, the annual average value of 0.0014 m³/(TP · a) was calculated from the acid consumption.

The total consumption of fresh water was 1.9 m³/d, which corresponds to an annual average of 0.03 m³/(TP · a). The fresh water was added directly to the water storage tank.

Consumption of electrical energy

Energy-intensive circulation pumps are not required in this process, because in this case the exhaust air is cleaned and the filling material is moistened by immersing it in the washing liquid. The circulation pump (Figure 2) and the drum rotation cause comparatively low energy consumption. This means that the power consumption of the exhaust air treatment system is significantly lower than for systems with vertical or horizontal filter walls. The exhaust air treatment system consumed 17.8 kWh per day or 0.28 kWh/(TP · a).

In the barn area, the fans are the largest consumers. In reference operation, four pressure-stable exhaust air fans were used on the exhaust air treatment system. The fans were controlled with 0-10 V in order to adapt the speed to the exhaust air volume flow to be conveyed.

The maximum pressure losses determined on the Lavamatic were 280 Pa for the washing drum, including the exhaust air duct and pre-dedusting. Including the pressure loss via the barn system, a total pressure loss of around 300 Pa was measured.

The barn ventilation was clearly oversized in the reference system. Around 425,300 m^3/h of untreated exhaust air from the barn were released outside via ceiling fans on the gable end (at the maximum summer air rate). The Lavamatic fans deliver a total of 110,000 m^3/h, which equates to a total air volume flow of 535,300 m^3/h in the barn. In the reference barn, the additional air capacity of the Lavamatic on the ceiling fans was correspondingly reduced.

For optimum ventilation design, the fans must be designed for at least 300 Pa if the required air volume is to be conveyed.

As an annual average, a total of 154.4 kWh/d was consumed by the fans. It should be noted that significantly more energy was consumed in summer. In relation to livestock space and year, this would mean an electrical energy consumption of 2.32 kWh.

On the whole, the consumption of electrical energy corresponds to the usual values for comparable systems. The fan power consumption is slightly higher due to the pressure loss, whereas the exhaust air treatment power consumption is slightly lower.

In the reference system, the ventilation was switched in such a way that the Lavamatic fans were switched on before all other barn fans. It can therefore be assumed that layer systems in practical use with a cleaning of 100 % of the barn exhaust air have a lower energy consumption of the fans.

Other consumption values

Safe system function with the efficiency rates shown is only possible with correctly operated pH value regulation at 3.0 and elutriation at a maximum rate of 230 mS/cm. An automatic acid dosing system and a conductivity measurement system must therefore be installed and operated on the system. To reduce the pH value, sulphuric acid with a purity of 96 % was used in the reference system.

An annual average acid consumption of 18.3 kg/d was measured. In relation to livestock space and year, 0.30 kg of acid was consumed.

The manufacturer offers the addition of an anti-foaming agent in the form of a dosing device as standard. No consumption of anti-foaming agents was detected during the DLG test.

No other additives were added during the test.

Operational safety and durability

No significant faults were identified in the system engineering and equipment during the investigation period. There was also no significant damage or signs of wear to the entire exhaust air treatment system during the test.

The corrosion protection of the individual system components appears to be sufficiently durable, as far as it could be observed during the test period. The system is a complete system made almost entirely of plastic.

The shelf life could only be observed over the duration of the test (measurement period). A survey of operators of similar systems was not carried out, as the tested system was still unique in this form.

Operating instructions, handling and work requirements, maintenance effort

The operating instructions are sufficiently well described and explain the operation of the system simply and clearly. In conjunction with the documentation, the operator is informed of the work to be carried out on the system at daily, weekly and annual intervals. To make operation easier to understand, photos of the control display can be found in the operating manual.

In order to operate the system, it is necessary to receive instruction from the manufacturer and to familiarise yourself with the operating instructions.

After commissioning and a sufficient run-in phase, using the system can be regarded as simple, because the exhaust air treatment system runs fully automatically in normal operation. Only a daily check of the operating data and a weekly check of the entire exhaust air treatment system including drum operation, as well as occasional cleaning of the sieve basket are required.

In the event of error messages from the control unit, instructions for checking the relevant system components are described in the operating instructions. To simplify use and reduce the amount of labour required, we recommend concluding a maintenance contract with the dealer. Munters Reventa provides training to all listed dealers.

Cleaning the exhaust air treatment system (basic cleaning) and the pre-dedusting system is both time-controlled and automated. The time parameters are based on the manufacturer's experience and may therefore not always optimally reflect reality in individual cases. More frequent cleaning may therefore be necessary due to high levels of dust and/or feathers. If the pressure loss exceeds 250 Pa, the operator is requested to carry out a basic cleaning. At a maximum pressure loss of 50 Pa over several minutes at the pre-dedusting unit, the pre-dedusting unit is cleaned automatically. Despite this automation, regular inspection of the drum and pre-dedusting by the operator is mandatory.

Documentation

The electronic logbook enables regular recording of the data needed for safe system operation in accordance with the requirements, which must be saved as half-hourly average values (pH value and conductivity) or half-hourly values. Recording is automatic and the data must be stored for 5 years. This data can be read out by the operator, the manufacturer and also by authorities via a USB connection and converted into a standard table format. A detailed presentation of the recorded data can be found in Table 6.

Table 6:
Fulfilment of the requirements for the electronic logbook of the Lavamatic system

	completely fulfilled	not fulfilled	Remarks
Pressure loss via the exhaust air treatment system	X		is recorded and stored via Lavamatic using electronic differential pressure sockets (measuring range at least 300 Pa)
Air flow rate of exhaust air treatment system	X		is measured via measuring fans in the fresh air chimney
Drum operation	X		is recorded and stored via the motor sensor of the drum (0 to 100 %)
Fresh water consumption	X		the total fresh water consumption is recorded using a water meter
Quantity of elutriated water	X		is recorded and stored via a flow meter
Raw and clean gas temperature	X		the raw and clean gas temperatures are measured and recorded by means of a thermal sensor
Maintenance and repair times	X		are recorded and stored in the manual logbook
pH value and conductivity	X		are recorded and stored
Calibration of the pH value sensors	X		is recorded and stored in the manual logbook
Detection of additive consumption (acid, anti-foaming agent)	X		the acid consumption is recorded and stored via the strokes of the acid pump, the consumption of anti-foaming agent can be verified via delivery notes
Electrical power consumption	X		the electricity consumption of the washer is recorded and stored using a suitable electricity meter
Cleaning the dry filter unit	X		is recorded and stored with date and time

If the barn ventilation and exhaust air treatment system are installed by different manufacturers, the manufacturer of the exhaust air treatment system records the ventilation data as a characteristic line and also integrates it into the control system of the exhaust air treatment system for regulation purposes. The maximum fan power is set to 100 % in the control unit. However, there is no adjustment in a further performance range. Given that the air flow rate should be specified in absolute m³/h in accordance with the test framework and the requirements of TA Luft (chapter 5.4.7.1), a characteristic line of the entire ventilation system (barn plus exhaust air treatment) must be recorded before commissioning and entered in the electronic logbook. The characteristic line should consist of at least five different interpolation points between an air rate of 0 and 100 %.

Environmental safety

Primary ammonia reduction takes place purely chemically with the formation of ammonium sulphate. Ammonium sulphate is a substance hazardous to water and is assigned to water hazard class WGK 1 (slightly hazardous to water).

The storage space is based on the current fertiliser ordinance, which stipulates the storage period for liquid manure. The feed pipe into the elutriation tank and the storage tank itself must be suitable for the elutriation water. The administrative regulation for substances hazardous to water (ammonium sulphate) must be complied with in each country. Immediately before spreading on agricultural land, the elutriated water can be mixed with liquid manure outside the barn. Agricultural utilisation in line with system requirements, taking into account the nitrogen and sulphur content, is technically expedient.

Acid is required for safe system operation. Handling must be explained by the manufacturer in operating instructions and carried out in accordance with the EC safety data sheets for 96 % sulphuric acid and is the responsibility of the system operator. All associated safety equipment (eye wash, full body shower, protective clothing) must be provided. An acid reservoir in the form of an IBC container is recommended.

According to the manufacturer, the dismantling and disposal of other system components can be performed by registered recycling companies.

Safety aspects

Fire safety must be verified by means of a corresponding fire protection concept, which must be drawn up by the operator in conjunction with the manufacturer and attached to the building application.

The machinery and system safety of the described exhaust air washer was assessed by Klaus Ahlendorf GmbH during the initial inspection in 2024. There are no objections to the use of the system from an occupational safety perspective

Conclusion

The “Lavamatic” exhaust air treatment system from Munters Reventa GmbH is suitable for reducing the emissions of dust and ammonia (including nitrogen removal) from the exhaust air flow of littered layer rearing systems.

The two-stage process consists of upstream dry-dedusting and wet-chemical exhaust air washing. The system is operated according to the pressurised principle. To ensure that the system functions safely, the filter volume load of the washing stage must not exceed a maximum of 8,700 $m^3/(m^3 \cdot h)$. The pH value in the water storage tank must be set to ≤ 3.0 and the conductivity must not exceed 230 mS/cm. The dry-dedusting system must be operated with a maximum filter surface load of 8,600 $m^3/(m^2*h)$.

The minimum requirements of the DLG test framework for dust and ammonia reduction are satisfied and, in some cases, exceeded if the process engineering parameters described are adhered to.

The recognised minimum reduction rate for total dust is 74.3 % in winter and 80.3 % in summer. Particulate matter PM_{10} is reduced by 72.5 % in winter and 72.8 % in summer. The minimum reduction rate for ammonia is 85.1 % in winter and 80.5 % in summer. 89.1 % nitrogen is removed in winter, and 84.8 % / 83.5 % in summer respectively.

Further information

Testing agency

DLG TestService GmbH,
Gross-Umstadt location, Germany

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

Laboratory and emission measurements

LUFA North-West
Jägerstraße 23-27, 26121 Oldenburg

DLG test framework

DLG-APPROVED Full Test
"Exhaust air cleaning systems for livestock houses"
(current as of 04/2022)

Department

Farm inputs

Division head

Dr Michael Eise

Test engineer(s)

Dipl.-Ing. (FH) Tommy Pfeifer *

Technical Committee (test commission)

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

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