DLG Test Report 6260

Inno+ B.V.

Inno+ Pollo-M 1-stage chemical air cleaner with droplet separator

for broilers

SIGNUM TEST
05/15 passed

DLG e.V.
Test Center Technology and Farm Inputs

www.DLG-Test.de

Overview

The SignumTest 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 recognized test criteria. The DLG SignumTest provides a neutral assessment of the essential features of the product, from performance capability and animal welfare, to stability, occupational and functional safety. These tests are performed in the lab and under a range of operating conditions and rate how the test candidate performs during practical testing on the farm.

The specific test conditions and procedures are defined by an independent test commission and described in a test framework which also defines the parameters for evaluation. The test conditions and procedures as defined are revised on an ongoing basis so they reflect what is acknowledged by the current state of the art as well as the latest scientific findings and agricultural insights and requirements. The tests are performed in accordance with procedures that allow an objective assessment based on reproducible results. After a product has passed the test, a test report is produced and published and the quality mark is awarded to the product.

This DLG SignumTest tested the 1-stage chemical air cleaner with droplet separation from Inno+ B.V. as regards its suitability for reducing dust and ammonia emissions from the exhaust air flow of broiler buildings with bedding. For a ventilation system to be tested, it must meet the requirements set down by the German regulation on the protection of animals and the keeping of production animals (TierSchNutztV) which stipulates an exhaust air flow volume of 4.5 m³/(kg live weight · h). The system must comply with the emission reduction rates laid down in the DLG SignumTest framework. According to this, total dust, fine dust (PM_{10}, $PM_{2,5}$) and ammonia rates must be reduced to at least 70%. At the same time, the exhaust air odour level in the clean air must not exceed 300 OU/m³ exhaust air, so that a typical exhaust air odour (poultry) is no longer perceptible. The tested exhaust air cleaning system reliably met and surpassed the requirements for reducing ammonia, total dust and fine dust. An assessment of odour separation did not form part of the test and was not certified.

Assessment – Brief Summary

The exhaust air cleaning system from Inno+ is a single-stage chemical air cleaner that separates dust and ammonia from broiler houses. The exhaust air cleaning system operates according to the suction principle. After the exhaust air is humidified on its way to the coarse dust separator, it enters the packing where ammonia and dust are separated.

The packing is installed horizontally in the exhaust air tower. A droplet separator above the filter package prevents any emission of aerosol. The circulation water for sprinkling the packing is acidified with sulphuric acid until its pH value is ≤ 3.3. In the test, the exhaust air cleaning system achieved an average ammonia separation rate of around 91 %.

The level of total dust separation was 87 %, PM_{10} fine dust separation was 77 % and $PM_{2.5}$ fine dust separation was 93.7 %. Ammonia and dust formed the main parameters that were certified by this test.

Further results and the determined consumption data are summarised in Table 1.

Table 1:
Overview of Pollo-M single-stage exhaust air cleaning system results

Test criterion	Result		Assessment*
Emission measurements			
Total dust (gravimetric, ten measurement dates)			
– Summer (4 measurements): mean separation rate	[%]	89.3	+
– Winter (6 measurements): mean separation rate	[%]	85.5	+
Fine dust (gravimetric, five measurement dates) [1]			
– Summer (2 measurements)			
Mean separation rate PM_{10}	[%]	72.5	○
Mean separation rate $PM_{2.5}$	[%]	90.3	+ +
– Winter (3 measurements)			
Mean separation rate PM_{10}	[%]	81.5	+
Mean separation rate $PM_{2.5}$	[%]	97.0	+ +

Ammonia (measured continuously, half-hourly means) [2]					
– Summer (2 measurement periods), mean separation rate	[%]	89.9			+
– Winter (2 measurement periods), mean separation rate	[%]	91.6			+ +
N balancing, N removal [3]					
– Summer (2 cycles)					
N balance recovery rate	[%]	91			+ +
N removal	[%]	88			+
– Winter (2 cycles)					
N balance recovery rate	[%]	103			+ +
N removal	[%]	91			+ +
Aerosol emission (sulphate)					
– Summer (4 measurements), inorganic aerosol, mean	[mg/m³]	0.04			+
– Winter (4 measurements), inorganic aerosol, mean	[mg/m³]	0.05			+
Consumption measurements (averages per day or animal place (AP) and year)					
Fresh water consumption					
– Summer (2 cycles)	[m³/d]	4.05	[m³/(AP · a)]	0.04 [4]	n/a
			[m³/(AP · a)]	0.04 [5]	n/a
– Winter (2 cycles)	[m³/d]	2.16	[m³/(AP · a)]	0.02 [4]	n/a
			[m³/(AP · a)]	0.02 [5]	n/a
Desludging					
– Summer (2 cycles)	[m³/DG]	5.0	[l/(AP · a)]	0.95	n/a
– Winter (2 cycles)	[m³/DG]	5.0	[l/(AP · a)]	0.95	n/a
Acid consumption (with reference to 96 % sulphuric acid)					
– Summer	[kg/d]	15.7	[l/d]	8.4	n/a
	[kg/(AP · a)]	0.17	[l/(AP · a)]	0.09 [4]	n/a
	[kg/(AP · a)]	0.10	[l/(AP · a)]	0.06 [5]	n/a
– Winter	[kg/d]	12.6	[l/d]	6.7	n/a
	[kg/(AP · a)]	0.14	[l/(AP · a)]	0.07 [4]	n/a
	[kg/(AP · a)]	0.08	[l/(AP · a)]	0.04 [5]	n/a
Defoamer consumption					
– Summer	[kg/cycle]	1.8			n/a
– Winter	[kg/cycle]	1.8			n/a
Electrical energy consumption					
Exhaust air cleaning circulation pumps					
– Summer	[kWh/d]	114.4	[kWh/(AP · a)]	1.22 [4]	n/a
			[kWh/(AP · a)]	0.76 [5]	n/a
– Winter	[kWh/d]	111.2	[kWh/(AP · a)]	1.19 [4]	n/a
			[kWh/(AP · a)]	0.77 [5]	n/a
Building fans					
– Summer	[kWh/d]	69.3	[kWh/(AP · a)]	0.73 [4]	n/a
			[kWh/(AP · a)]	0.55 [5]	n/a
– Winter	[kWh/d]	36.9	[kWh/(AP · a)]	0.39 [4]	n/a
			[kWh/(AP · a)]	0.29 [5]	n/a

* Evaluation range: + + / + / ○ / – / – – (○ = standard, n/a = not applicable/evaluated)

1) Experience has shown that the cleaning process can lead to the formation of droplets that range between 2.5 and 10 µm in size. These lead to an increase of PM_{10} particles in the cascade impactor. The $PM_{2.5}$ particle fraction is not affected as extensively by this effect. A higher separation rate is therefore calculated for this particle fraction than for the PM_{10} fraction.

2) Taking into account all separation values as of the 7th day of growing (start of the cleaner), whereby the exhaust air concentrations were over 3 ppm (separation rate averaged from all half-hourly means).

3) The N balance recovery rate has a tolerance range of ± 15 % which is due to water analysis measuring uncertainties and due to N loads being calculated in gaseous form. Further troubleshooting is required at a recovery rate of > 115 % or < 85 %.

4) Average values per day or per animal place and year, normalised to 365 days and taking animal differencees into account.

5) Average values per animal place and year, normalised to 7.5 cycles per year with an exhaust air cleaning system operating time of 35 days (39,900 broilers).

The Product

Manufacturer and applicant

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Inno+ Pollo-M, exhaust air cleaning system

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Description and specifications

The Pollo-M exhaust air cleaning system from Inno+ is a single-stage chemical system that operates according to the suction principle for cleaning the exhaust air from broiler houses with bedding. The system enables the removal of dust and ammonia emissions from broiler houses (stocking density of up to 39 kg/m²).

Figure 2 shows the cleaner's operating principle in schematic form.

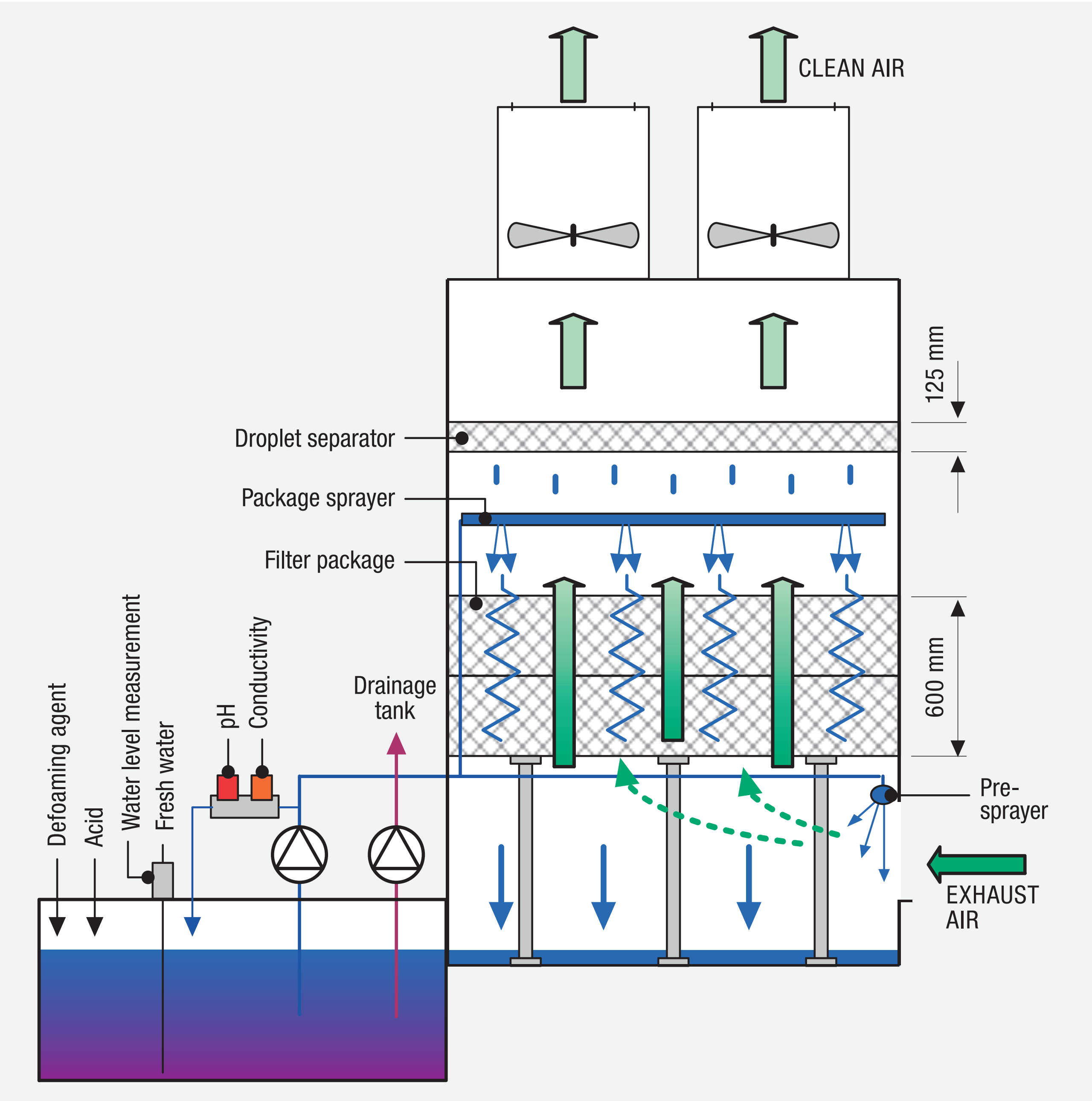

Figure 2:
Schematic diagram of the Inno+ Pollo-M exhaust air cleaning system

The most important process parameters are summarised in Table 2.

The wet cleaning stage uses the trickle bed principal with the process water pH value set to ≤ 3.3.

The exhaust air from the building is suctioned off over the complete width of the cleaner. In the process, coarse dust (feathers, feed and bedding dust) is removed from the air by a prespray system that are mounted across the entire width and beneath the actual filter package. These conical flat spray nozzles are arranged in such a way that the building's exhaust air flows through the spray mist. The exhaust air is then routed to a filter package mounted on a stainless steel construction where it is continuously sprinkled from above with process water that is applied in a reverse flow from a water reservoir. The packing's large, specific surface serves to enlarge the contact surface between the building's exhaust air and the process water in order to separate off ammonia and dust. A droplet separator is positioned above the packing (filter package); the exhaust air fans are located downstream of this. The droplet separator is used to separate aerosols containing nitrogen, which must not enter the environment. One or two of the fans used are frequency-controlled to remove the basic air flow rates after stabling the animals. The other fans switched on or off depending on the actual ventilation requirements.

For reasons of hygiene, the water reservoir is completely drained after each growing cycle. Acid is added to the process water by a dosing system that uses upstream conductivity measuring techno-logy.

The cycle water is circulated until the animals are removed from the building. Conductivity values of up to 140 mS/cm were measured during the certification test. In order to prevent salination in the packing and ensure an average ammonia elimination capacity of 90 %, conductivity must not exceed a maximum of 140 mS/cm to receive the certification. If this value is reached during the growing cycle, a quantity of water must be automatically removed from the water reservoir by the desludging pump in order to reduce the process water's conductivity. The desludging pump's operating time controls the desludging rate. At least 50 % of the water in the reservoir are usually removed and topped up again with fresh water. As a result, the 140 mS/cm threshold drops due to the effect of dilution. As cleaner operation increases the water evaporation levels, both the desludging and the fresh water consumption values must be entered in the electronic operating log (EOL).

The water level is checked using an electronic filling level sensor, which also protects the circulation pump against running dry.

For the exhaust air cleaning system to achieve the separation capacities described in Table 1 it is necessary to operate the system continuously and as specified from the 7th day of growing. It must be ensured that the cleaning system delivers 70 % of the installed maximum summer air flow rate (exhaust air cleaning system design flow rate) that is required according to the German Order on the Protection of Animals and the Keeping of Production Animals TierSchNutztV (4.5 m³/kg · (live weight · h)). When flow rates exceed 70 % of the design air flow rate (finishing conditions in the summer), it is possible to remove some of the air flow with the help of emergency fans. The operating time of the emergency fans must be documented in the electronic operating log.

Warranty

The manufacturer offers a two-year warranty, provided the system is operated properly. Installation and maintenance must be performed by a recognised installation company.

Table 2:
Inno+ Pollo-M exhaust air cleaning system process parameters

Characteristic	Result	
Description		
Single-stage chemical cleaner with droplet separator		
Suitability		
Cleaning exhaust air from broiler houses with bedding to reduce dust and ammonia		
Dimensioning parameters, packing dimension data, reference system		
Packing		
– Length / Width / Depth	[m] / [m] / [m]	14,4 / 6,6 / 0,6
– Surface/volume	[m²] / [m³]	95,04 / 57,02
– Maximum filter surface load	[m³/(m² · h)]	2.741
– Maximum filter volume load	[m³/(m³ · h)]	4.569
– Air speed at max. summer air flow rate	[m/sec]	0,76
– Contact time at maximum summer air flow rate	[sec]	0,79

Continuation of Table 2, page 5

Characteristic		Result
Dimensioning parameters, packing dimension data, reference system		
Droplet separator		
– Length / Width / Depth	[m] / [m] / [m]	14,4 / 4,2 / 0,125
– Surface/volume	[m²]/[m³]	60,48 / 7,56
– Maximum surface load	[m³/(m² · h)]	4.307
– Maximum volume load	[m³/(m³ · h)]	34.458
– Air speed at max. summer air flow rate	[m/sec]	1,20
– Contact time at maximum summer air flow rate	[sec]	0,10
– Sprinkling volume	[m³/h]	13,50
– Sprinkling intensity	[m³/(h · linear m])]	0,94
– Number of nozzles	[Quantity/linear m]	0,8
Packing sprinkling (continuous)		
– Sprinkling volume	[m³/h]	82,50
– Sprinkling density	[m³/(m² · h)]	0,87
– Number of nozzles	[Quantity/m²]	0,25
Desludging		
– Cleaning water reservoir capacity	[m³]	5,00
– Desludging rate per growing cycle	[m³/cycle]	5,00
– Average desludging rate	[m³/d]	0,119
– Average desludging rate	[m³/(TP · a)]	0,001
– pH value of the circuit water	[1]	≤ 3,30
– Maximum conductivity in the circuit water	[mS/cm]	≤ 140
Reference farm for completed measurements		
– Building floor space	[m²]	1.800
– Maximum stocking density in the building	[kg/m²]	39,00
– Maximum summer air flow rate as per TierSchNutztV [1)]	[m³/h]	315.900
– Maximum installed exhaust air flow rate over the exhaust air cleaning system [2)]	[m³/h]	315.900
– Maximum installed air rate in the building at 40 Pa pressure difference	[m³/h]	347.490
– Number of fans	[Quantity]	8
– Animal places	[Quantity]	39.900
– Maximum live weight (thinning/finishing weight)	[kg/animal]	1,90 / 2,71
– Maximum packing pressure difference (summer)	[Pa]	31
– Maximum droplet separator pressure difference (summer)	[Pa]	10
– Total pressure difference, building and exhaust air cleaning (summer) [3)]	[Pa]	60

1) TierSchNutztV: German Order on the Protection of Animals and Keeping of Protection Animals. Values may vary in other countries.

2) Due to cost and dimensioning reasons, only 70 % of the maximum summer air flow rate (according to TierSchNutztV) have to be discharged via the exhaust air cleaning system (221,130 m³/h).

3) Additional pressure difference due to air escaping through the exhaust air flues was not taken into account and must be factored in at 40 Pa for generating the maximum summer air flow rate.

The Method

The measurements were performed on a reference system in Recke, Germany. The test comprised two summer and two winter measurements. As the tested system was a prototype, it was not possible to conduct a survey amongst owners of air cleaning systems of the same type.

Around 39,900 broilers were housed in the reference building in which the measurements were carried out. Here, straw pellets were used as bedding. The fresh air flowed into the building through inlet valves on both longitudinal sides of the building and was extracted from the animal area by exhaust fans. According to TierSchNutztV (German Order on the Protection of Animals and Keeping of Protection Animals), the ventilation system was designed to a capacity of 4.5 m³/h per kg live animal weight. With a floor space of 1,800 m² and a maximum final growing weight of 39 kg/m² building floor space, at least 315,900 m³/h of the maximum summer air flow rate must be discharged from the building. With 8 fans and an effective maximum summer flow rate of 347,490 m³/h at a calculated pressure difference of 40 Pa, the building was ventilated according to the vacuum principle.

The exhaust air cleaning system was only put into operation from the 7th day of growing, as only very low air flow rates and emissions are to be anticipated during the initial days of growing. After the system was started up, the building's exhaust air was then inducted across the entire width of the cleaner, humidified by a the prespray system, which consists of a bar with nozzles and routed through the filter package. Humidification took place in a cross-flow pattern whereas sprinkling the packing was carried out in reverse flow from above. The process water's pH must be reduced to a value of ≤ 3.3. During the summer and winter measurements, ClO_2 dosing technology was used to reduce odorants; however, this was not subject of the certification test. This dosing technology does not have be used to separate dust or ammonia. A droplet separator must be installed downstream of the cleaner assembly to separate nitrogenous aerosols. The exhaust air cleaning system was operated in suction mode (exhaust air fans downstream of the cleaner), and was only certified as such.

The measurements took place from January to April 2014 (winter measurements) and from June to September 2014 (summer measurements).

The water reservoir (capacity around 5 m³) was completely drained and cleaned after each growing period, thus meeting all hygiene and emission requirements. A circulation pump and a desludging pump were used in the water reservoir. The circulation pump fills the prespraying system's humidification line and the packing's actual sprinkling facility. During the growing cycle, the desludging pump can be used to desludge a defined volume of process water (usually 50 % of the total water stored) if the certified maximum conductivity value of 140 mS/cm is exceeded. Fresh water is automatically fed into the reservoir to restore the proper water level. An electronic filling level sensor continuously checks the water levels. The desludging volume and fresh water consumption are stored in the electronic operating log.

The ambient conditions (exterior/interior temperature, relative exterior/interior humidity) were recorded during the measurements; the following parameters were additionally documented on the dates on which dust and odour levels were measured

- Animal weights (available animal scale) and animal numbers (building log)
- Fresh water and electrical energy consumption (meter readings)
- Absolute air flow volume (ventilation control system and DLG measurement fans)
- Pressure difference over the exhaust air cleaning system as well as pressure difference over the fan

The measured values recorded in the electronic operating log by the manufacturer were also checked for plausibility.

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

Dust

Total dust was sampled according to VDI Standard 2066, Part 1 and DIN EN 13284-1. To do this, an isokinetic sampling system with a planar filter device (Paul Gothe design) was installed (diameter 50 mm). A round glass fibre filter with a diameter of 45 mm was selected as the separation medium. Fine dust (PM_{10} and $PM_{2.5}$) was determined according to VDI Standard 2066, Part $_{10}$ and DIN EN ISO 23210. A Johnas II cascade impactor (Paul Gothe design) with three planar filters (diameter 50 mm) was used. The separation medium was again a round glass fibre filter but this time with a filter diameter of 50 mm.

As the high organic and biological dust contents require the samples to be dried gently, sampling was performed in deviation from DIN EN 13284-1. The evaluation was carried out by determining the dust load gravimetrically.

According to the current DLG test framework, the separation value must not be less than 70 %. This applies to both total dust and the PM_{10} and $PM_{2.5}$ fine dust fractions.

Ammonia

The ammonia measurements in the exhaust and clean air sections of the system were carried out continuously throughout the test period using FTIR spectroscopy based on KTBL document 401 and DIN EN 15483, whereby the measurements were performed using a measuring cell. In parallel to these measurements, air samples were taken in washing bottles on two days per cycle in the summer and winter. These were evaluated according to VDI 3496, Part 1. The aerosol impingement measurement method is used to verify the readings obtained in the continuous measurement procedure. To prevent condensation in the PTFE air lines, the measured air lines were heated along their entire lengths. The ammonia concentration levels in the animal area were measured at animal height during regular inspections. According to the current DLG test framework, NH_3 separation must not fall below a value of 70 %, i.e. it must be permanently higher than 70 %.

Aerosol emission

By moistening the filter package, the nitrogenous aerosols are driven out of the reservoirs of exhaust air cleaning systems. These NH_3 aerosols are carried along by the exhaust air flow. In this way, the nitrogen that is originally separated from the air is unintentionally returned to the environment.

To determine the amount of aerosol emission of the tested system, the exhaust air was routed over washing bottles containing 100 ml absorption solution (0.01 n sulphuric acid). In order to determine the levels of aerosol, the samples were taken using filtration and no filtration in parallel, and then the difference was determined. The analysis was carried out according to the indophenol method. The concentration of ammonia in the sample solutions was determined photometrically. There are no limit values specified as yet by the DLG test framework.

N balance, N removal

The rate of the cleaning system's nitrogen separation was verified by means of N balancing, taking account of the ammonia loads (in the exhaust air and clean air), the aerosol emissions and the inorganic nitrogen compounds that are dissolved in the cleaning water. These measurements were taken over a period of two weeks during the two summer and winter measurements. In both summer measurements the cleaning waste water was additionally analysed for inorganic nitrogen compounds. The method to determine the amount of N actually removed is to ascertain the ratio of inorganic N mass removed from the system and the N load entering the system on the exhaust air side.

In the Pollo-M chemical cleaning system from Inno+, the formation of nitrite and nitrate in the process water can be disregarded. The concentrations of further gaseous nitrogen compounds lay below the detection limit and were therefore disregarded.

This means that the nitrogen separated from the exhaust air ammonia was detected in the form of ammonium in the cleaning water; also, residual ammonia was detected in the clean air.

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 desludging water is known and its fertilisation value is quantified.

As per the DLG test framework, the nitrogen recovery rate and N removal rate within the nitrogen balance must each be ≥ 70 % during summer and winter measurement.

Consumption values, ambient conditions and system load

The consumption of fresh water and electrical energy was determined by recording the meter readings (separate electricity meters for the air cleaner and the ventilation system). Acid consumption and defoamer consumption during the test phase were determined using a weighing system (force transducer or load cell). The temperatures outside and inside of the building were recorded during the measurements to document the ambient conditions.

The number of animals and animal weights were documented as additional parameters on the days the dust measurements were taken. The pH value and conductivity in the process water were also determined, compared with the values recorded in the system's electronic operating log and checked for plausibility.

Operating reliability and durability

Operating reliability and durability were assessed and documented. Any malfunctions suffered by the system as a whole and by its components during the test period were documented. In addition, the occurrence of damage caused by corrosion and the durability during continuous operation were evaluated.

Operating instructions, handling, working time and maintenance requirements

The operating instructions were assessed from the user's perspective. The instructions focus on a description of the system functions, with great attention to detail including illustrations, and on the clear presentation of regular maintenance work.

The handling and working time requirements section of this test assesses whether it is necessary for the manufacturer to provide instruction during commissioning and on the requirements for regularly recurring inspections and work on a daily, weekly or monthly, etc. basis or in the event that any malfunctions occur.

The servicing intervals and their specification lists are assessed in terms of the maintenance requirements.

Documentation

The following parameters must generally be recorded in the electronic operating log:

- Pressure difference in the system
- Air flow rate in m^3/h
- Pump operating time (circulation)

– Sprinkling intervals and quantity
– Total fresh water consumption by the system
– Amount of the desludging rate
– Exhaust and clean air temperature
– pH value and electrical conductivity
– Exhaust air cleaning system electricity consumption
– Emergency fan operating time

Spray pattern checks, maintenance and repair times as well as pH value sensor calibrations must also be recorded. Evidence of acid consumption must be provided.

These data are used to verify proper operation of the exhaust air cleaning system. Inno+ provided the data on the Pollo-M exhaust air cleaning system and they were verified accordingly.

Environmental safety

The environmental safety section of this test included an assessment of any inputs that are necessary to operate the system (e.g. acid and defoamer), the recycling of any waste material (e.g. the desludged water), and the removal and disposal of system components. Who is in charge of the individual aspects was also examined.

Safety aspects

In order to assess the system's safety, its conformity with the currently applicable fire and occupational safety regulations was checked by the DPLF.

The Test Results in Detail

Dust

Six total dust and three fine dust measurements (PM_{10} / $PM_{2.5}$) were conducted during the two winter measurements. Four total dust and two fine dust measurements were conducted during the two summer measurements.

Table 3 (see page 10) shows that an average of 85.6 % (1st growing cycle) and 85.3 % (2nd growing cycle) total dust were separated off in the two winter cycles. An average of 91.1 % (1st growing cycle) and 87.5 % (2nd growing cycle) total dust were separated in the two summer cycles. The mean PM_{10} fine dust separation rate was 81.5 % in the winter and 72.5 % in the summer. $PM_{2.5}$ fine dust fraction separation was 97.0 % in the winter and 90.3 % in the summer.

This good separation rate measured both in the summer and winter is attributable to the fact that the exhaust air coming in from the building is sprayed by upstream nozzles to the cross-flow method on the one hand , prespray system, and that the filter package is moistened intensively to the reverse flow method on the other. At around 0.8 seconds, the exhaust air's contact time in the filter package is high at maximum load. As a result the exhaust air has sufficient time to come into contact with the moistened, specific surface of the filter package (125 m²/m³) so that the dust is separated off.

The number of nozzles at the prespray system used for pre-moistening depends on the length of the cleaner tower. The nozzles must be mounted so that the spray angles completely overlap. A moistening intensity of > 0.9 m³/(linear m · h) must be adhered to. The filter packages sprinkling density is ≥ 0.87 m³/(m² · h).

Experience has shown that the cleaning process can lead to the formation of droplets that range between 2.5 and 10 µm in size. These lead to an increase of PM_{10} particles in the impactor. The $PM_{2.5}$ particle fraction is not affected as extensively by this effect. A higher separation rate is therefore calculated for this particle fraction than for the PM_{10} dust fraction.

The boundary parameters shown in Table 3 were each recorded at 12 noon, local time.

The air flow volume and pressure difference data are mean values that were calculated from the measured minute values of the DLG recordings during the measurement period.

Ammonia

Ammonia concentrations of between 0 and a maximum of 25 ppm were measured in the exhaust air section of the system during the first winter cycle.
25 ppm is too high and was measured over a few hours during the final days of growing. The reason was one ventilation system that was not functioning properly. After adjusting the ventilation control system, the concentration permanently fell to < 20 ppm. After the ventilation was optimised, ammonia concentrations ranged between 0 and 18 ppm (final growing phase) in the second winter cycle. Due to the higher air flow rates in the summer measurements, the NH_3 exhaust air concentration ranged between 0 and 10 ppm. No higher concentrations were measured.

NH_3 separation rate is only evaluated when the concentration reaches ≥ 3 ppm. This is because the measuring uncertainty does not allow the testers to make a sound assessment when measurements are below this value.

1,259 and 854 value pairs were available in the winter (mean half-hourly values), and 858 and 958 in the summer. To guarantee a reliable separation rate after a growing cycle is completed (even in high

Table 3:
Inno+ Pollo-M exhaust air cleaning system emission reduction (dust) measurement results

Winter measurements		Growing cycle 1				Growing cycle 2	
Date		**05.02.2014**	**10.02.2014**	**17.02.2014**	**24.02.2014**	**31.03.2014**	**07.04.2014**
Growing day		**21**	**26**	**33**	**40**	**26**	**33**
Ambient and boundary conditions							
Rel. humidity	[% r.h.]	62	89	78	66	65	55
Ambient air temperature	[°C]	7.8	3.3	8.5	7.9	15.8	20.8
Exhaust air/clean air humidity	[% r.h.]	69/97	74/99	78/99	67/99	71/99	63/97
Exhaust air/clean air temperature	[°C]	23.9/20.3	22.1/16.0	20.5/16.2	20.5/16.2	23.7/19.9	22.4/19.0
Number of animals		38,871	38,803	38,707	25,925	39,053	38,943
Average animal weight	[kg]	0.791	1.187	1.639	2.166	1.018	1.497
Total air flow volume	[m³/h]	32,700	47,500	74,800	76,700	60,700	210,300
Cleaner pressure difference	[Pa]	7.9	7.1	6.9	10.4	10.8	34.6
Building and cleaner pressure difference	[Pa]	28.5	28.9	32.4	33.1	41.0	83.7
Total dust (normalised)							
Exhaust air concentration	[mg/m³]	6.5	8.7	6.8	8.4	7.0	5.1
Clean air concentration	[mg/m³]	0.9	1.6	0.9	1.1	1.0	0.8
Separation rate	[%]	86.1	82.2	87.1	87.0	85.6	85.0
Fine dust (normalised)							
Exhaust air $PM_{10}/PM_{2.5}$	[mg/m³]	––	1.8 / 0.5	––	2.86/1.31	2.18/0.93	––
Clean air $PM_{10}/PM_{2.5}$	[mg/m³]	––	0.33/0.02	––	0.53/0.01	0.41/0.04	––
Separation rate $PM_{10}/PM_{2.5}$	[%]	––	82.0/96.2	––	81.5/99.2	81.2/95.7	––

Summer measurements		Growing cycle 1		Growing cycle 2	
Date		**30.06.2014**	**21.07.2014**	**18.08.2014**	**25.08.2014**
Growing day		**19**	**40**	**19**	**26**
Ambient and boundary conditions					
Rel. humidity	[% r.h.]	63	92	64	56
Ambient air temperature	[°C]	16.5	21.1	17	18.4
Exhaust air/clean air humidity	[% r.h.]	60/96	85/97	66/95	66/94
Exhaust air/clean air temperature	[°C]	27.5/23.3	23.3/21.1	27.1/23.7	23.6/19.1
Number of animals in building		38,781	24,299	39,297	39,209
Average animal weight	[kg]	0.713	2.089	0.733	1.121
Total air flow volume	[m³/h]	46,000	209,700	42,400	67,300
Cleaner pressure difference	[Pa]	8.8	24.6	7.1	9.3
Building and cleaner pressure difference	[Pa]	26.6	66.9	32.5	25.6
Total dust (normalised)					
Exhaust air concentration	[mg/m³]	3.7	1.7	4.7	6.2
Clean air concentration	[mg/m³]	0.5	0.1	0.5	0.9
Separation rate	[%]	86.2	95.9	89.8	85.2
Fine dust (normalised)					
Exhaust air $PM_{10}/PM_{2.5}$	[mg/m³]	––	0.54/0.13	––	2.07/0.75
Clean air $PM_{10}/PM_{2.5}$	[mg/m³]	––	0.14/0.02	––	0.60/0.03
Separation rate $PM_{10}/PM_{2.5}$	[%]	––	74.1/84.6	––	71.0/96.0

ammonia loads), the manure removal time in the second summer cycle was also analysed after the measurement period.

In some cases, up to > 28 ppm ammonia were entrained into the cleaner and were scrubbed with an rate of up to 95 %. An overview of separation performance during demucking is shown in Table 4.

Figure 3 shows the ammonia concentrations and the separation rates as examples from the first winter measurement. Once the exhaust air cleaning system was started up (7th day of growing) on 22/01/2014, concentrations of ≥ 3.0 ppm NH_3 were constantly measured from 31/01/2014 onwards; these were taken into consideration in the figure. Figure 4 is an excerpt from the Inno+ Pollo-M exhaust air cleaning system's electronic operating log, and shows the pH value progression and the increase in conductivity in the exhaust air cleaning system's process water for the same measurement period.

Figure 3 shows that, with a very few exceptions, separation is always well over 70 %. The extreme drops down to as little as < 60 % (minimum 2.8 %) are explained by Figure 4 and were down to the fact that the acid tank was depleted several times and replenished too late during the measurement period. During these short periods of a few hours, the pH value increased to well over > 6.0. The 70 % separation rate can then no longer be achieved by Pollo-M. When the acid dosing system failed for a longer time (02/02/14 and 09/02/2014), process water conductivity no longer increased either. After topping up the acid tank and lowering the pH value to < 3.3, separation levels of significantly over > 70 % were immediately achieved again. Table 5 summarises the measurement results on ammonia reduction on selected days (average daily values) as well as the corresponding process data. The days selected were the last growing day of each winter cycle. As only ammonia concentrations of ≥ 3.0 ppm were taken into account, growing day 29 was selected in summer cycle 1 and growing day 33 in summer cycle 2. The requirements of 20 ppm ammonia at animal level, as set down by the

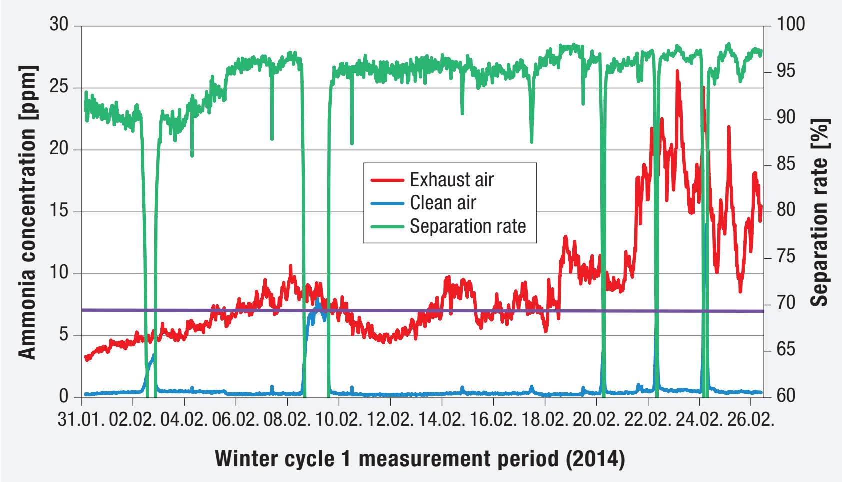

Figure 3:
Separation rate and ammonia concentration curves for the exhaust and clean air during winter measurement 1 (16.01.2014 to 26.02.2014)

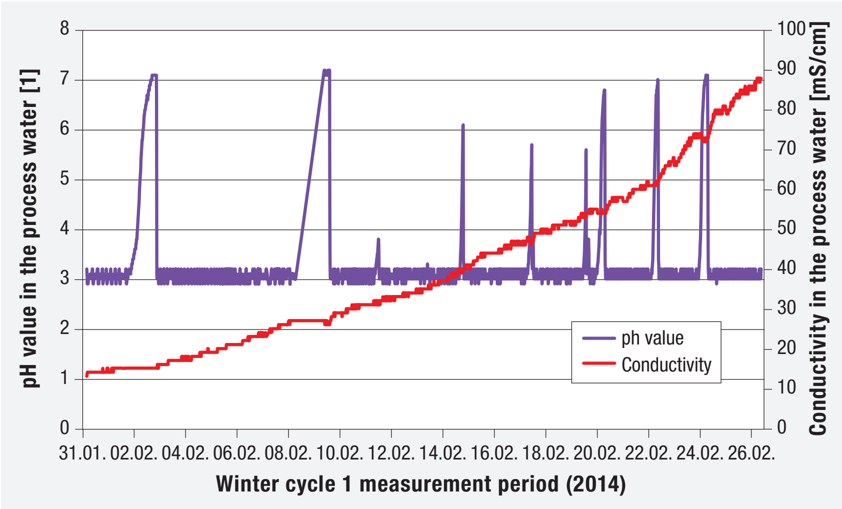

Figure 4:
Progression of the pH values and conductivities in the process water of the Inno+ Pollo-M exhaust air cleaning system during winter measurement 1 (16.01.2014 to 26.02.2014; original data from the EOL)

Table 4:
Ammonia loads during the Inno+ Pollo-M exhaust air cleaner manure removal times

	Exhaust air flow rate	NH_3 concentration			NH_3 mass flow		
		Exhaust air	Clean air	Rate	Exhaust air	Clean air	Rate
	[m³/h]	[ppm]	[ppm]	[%]	[kg/h]	[kg/h]	[kg/h]
Min.	242,000	5.8	0.2	96.6	0.997	0.034	0.962
Max.	201,000	28.6	0.9	96.9	4.082	0.128	3.953
Mean	224,000	15.2	0.7	95.4	2.417	0.111	2.306

German regulation on the keeping of production animals, were met at all times with the exception of the first winter cycle. As the fault lay in a malfunctioning ventilation control system which occurred for only a few hours, the cycle was recognised for certification.

Hence, when operating properly the system separates ammonia effectively from bedded chicken floors under the described conditions. An acid tank in the form of an IBC container (capacity of 1,500 to 1,800 kg) is recommended.

Aerosol emission

The aerosol impingement measurement method was used to determine nitrogen emissions in aerosol form downstream of the droplet separator. At the same time, filtered and unfiltered impingement measurements were performed in the clean air. The difference between these measurements is the level of aerosol emission. Analysis was carried out using the indophenol method. The measurements took place on two dates in both the summer and winter cycles during the second half of the growing cycle. The results are summarised in Table 6. Aerosol emission levels are low, amounting to only 0.08 ppm (winter measurement) and 0.06 ppm (summer measurement) ammonia in the clean air and escaping in aerosol form. The measurements were conducted at average exhaust air flow rates of 103,500 m³/h in the winter and 123,000 m³/h in the summer.

N balance and N removal

The single-stage chemical exhaust air cleaning system‘s nitrogen separation was verified over a period of two weeks during both summer and winter cycles. The method applied was verified by means of N balancing which takes into account the ammonia loads (in the exhaust air and clean air), the inorganic N content in the cleaning waste water and the inorganic nitrogen dissolved in the process water.

The level of N removal is determined by relating the removed inorganic N mass (enriched in the process and cleaning waste water) to the N mass that enters the system on the exhaust air side. This means that the nitrogen that is separated from the exhaust air ammonia was detected in the form of ammonium in the cleaning water. The same applies to residual ammonia emissions in the clean air.

The formation of nitrite and nitrate in the process water and the emission of nitrous gases in the clean air do not have to be analysed, as this exhaust air cleaning system operates on a chemical basis.

As per the DLG test framework, the nitrogen recovery rate within the nitrogen balance must be ≥ 70 % during the test period (winter and summer measurements). Table 7 summarises the separation capacity (exhaust air and clean air emissions), N balance and N removal results that were determined during a 14-day measurement period. The measuring uncertainty involved in determining the process water volume may cause the balance‘s N recovery rate (N emission in the clean air is also taken into account) to exceed 100 %. Actual N removal is therefore also included in the analysis method. This is an average

Table 5:
Results on ammonia emission reduction and process data during the summer and winter cycles (selected mean daily values)

Measurement period		Winter		Summer	
Date		25.02.2014	13.04.2014	10.07.2014	01.09.2014
Ventilation rate	[m³/h]	75,251	71,423	155,767	88,124
Flow velocity	[m/s]	0.22	0.21	0.46	0.26
Packing volume load	[m³/(m³ · h)]	1,320	1,253	2,732	1,545
Sprinkling intensity (pre-spraying)	[m³/(h · linear m)]	0.99	0.91	0.94	0.88
Sprinkling density (packing)	[m³/(m² · h)]	0.82	0.76	0.82	0.81
Ammonia in exhaust air	[ppm]	13.51	8.12	5.93	5.43
Ammonia in clean air	[ppm]	0.46	0.83	0.88	0.27
Ammonia separation rate	[%]	96.6	89.8	85.2	95.0

Table 6:
Aerosol emission from the Pollo-M exhaust air cleaning system

		Winter measurements				Summer measurements			
Date		Cycle 1		Cycle 2		Cycle 1		Cycle 2	
Unfiltered NH_3 C_{Norm}	[mg/m³]	1.64	0.76	0.44	0.57	0.45	0.31	0.12	0.23
Filtered NH_3 C_{Norm}	[mg/m³]	1.58	0.71	0.37	0.51	0.44	0.23	0.10	0.17
NH_3 C_{Norm} difference	[mg/m³]	0.06	0.05	0.06	0.05	0.01	0.08	0.02	0.07
Average NH_3 C_{Norm}	[mg/m³]	0.05		0.06		0.04		0.04	
NH_3-N C_{Norm} aerosol emission	[mg/m³]	0.04		0.05		0.03		0.03	
Total NH_3-N C_{Norm} average	[mg/m³]	0.05				0.03			

of 90.7 % and 88.3 % in the two winter cycles and summer cycles respectively. The minimum requirements of the DLG test framework (N removal ≥ 70 %) are therefore reliably met.

Consumption values, ambient conditions and system load

The consumption values listed in the test report (see Table 1) are normalised to annual consumption values (365 days) in order to compare these results with the data of other manufacturers. The consumption rates were also converted to the actual consumption rates that occur after starting up the system (7th day of growing) and 7.5 growing cycles per year. The consumption rates listed below always refer to 7.5 growing cycles per year with a system operating time as of the 7th day of growing and a building with 39,900 broiler places.

Water consumption

Fresh water must be fed into the system to compensate water differencees caused by desludging and evaporation. After each growing cycle, the water reservoir was desludged and refilled after cleaning. The volume of water that evaporates with the exhaust air was compensated with fresh water. This fresh water compensation must be stored in the electronic operating log (EOL).

Fresh water consumption measured in the winter was an average of 2.75 m^3/d, which translates into an annual consumption of 0.02 m^3/(AP · a) whereas 5.61 m^3/d or 0.04 m^3/(AP · a) were measured in the summer.

On the whole, 5 m^3 stored water were exchanged after each growing cycle throughout the entire measurement period (winter and summer measurement). With 7.5 growing cycles per year, this would equate to a desludging rate of 0.94 l/(AP · a). The maximum conductivity in the process water is permitted to increase up to 140 mS/cm. Desludging is carried out in an automated process. The conductivity in the process water and the desludging volume must be stored in the EOL. The measured data are shown in Table 1.

Total water consumption is determined by adding up the fresh water that is consumed to operate the system (evaporation and desludging) and the cleaning water. Depending on the level of system contamination, the consumption volume is 2 to 3 m^3 per cleaning cycle (according to the manufacturer). With 7.5 cycles per year, this amounts to around 0.47 l/(AP · a).

Electrical energy consumption

The continuously operated circulation pump is the exhaust air cleaning system's biggest electrical consumer. The biggest consumers inside the building are the fans, because these have to be more powerful than fans in ventilation systems that do not clean the exhaust air. In air cleaning systems, however, they have to compensate for the extra pressure difference inside the system. As the measurement equipment used (heating lines, etc.) was not connected to the cleaner's electricity meter, it is not necessary to deduct its electricity consumption from the measured consumption. The consumption data are summarised in Table 1.

The circulation pumps' electricity consumptions only differ marginally in the summer and winter measurements. An additional 2.45 kWh/d were consumed in the winter. The average annual electricity consumption of the circulation pumps is a calculated 116 kWh/d; this amounts to around 0.77 kWh/(AP · a).

The electricity consumed by the ventilation system differs extensively in the summer and winter cycles. This is attributed to the fact that higher volumes of air have to be removed in the summer than in the winter. The consumption determined in both winter cycles was 37 kWh/d, which translates into an electricity quantity of 0.30 kWh/(AP · a). In the summer, the readings were 69 kWh/d, i.e. 0.54 kWh/(AP · a). The exhaust air cleaning system's electricity consumptions are stored in the EOL.

Table 7:
Separation capacity, N balance and N removal results measured on the Pollo-M exhaust air cleaning system over a 14-day measuringt period during the winter and summer measurements

		Winter measurement		Summer measurement	
Cycles		**Cycle 1**	**Cycle 2**	**Cycle 2**	**Cycle 2**
NH_3-N exhaust air input	[kg]	68.4	59.5	122.4	52.6
NH_3-N clean air emission	[kg]	5.8	7.5	24.3	4.6
Difference	[kg]	62.6	52.0	98.1	48.0
Separation capacity	[%]	91.5	87.5	80.1	91.3
pH value	[1]	2.9 to 3.6	2.9 to 3.3	2.9 to 4.2	3.0 to 4.0
Conductivity	[mS/cm]	19 to 93	35 to 67	45 to 146	30 to 74
$N_{inorg.}$ circuit water	[kg]	62.2	53.7	94.3	39.9
$N_{inorg.}$ cleaning water	[kg]	0.0	0.0	9.7	8.3
N balance recovery rate	[%]	99.4	102.8	96.9	84.6
N removal	[%]	91.0	90.3	85.0	91.6

Other consumption values

To ensure reliable operation, the system was equipped with automatic acid dosing and conductivity recording functions. The acid dosing function was used to control the pH value in the process water. The pH value in the water circuit that supplies the filter package spraying nozzles and the packing sprinklers must be set to ≤ 3.3. The determined consumption data are summarised in Table 1. The values refer to sulphuric acid with a purity of 96 %. During the measurement, 96 % sulphuric acid was added to the reference system. The summer and winter consumption data barely differ. An average annual consumption of 14 kg/d or 0.09 kg/(AP · a) must be anticipated. This can increase if the ammonia emission loads are higher. Reliable system function with the described efficiencies is only possible with proper pH regulation (pH ≤ 3.3).

A defoamer was used to prevent foam formation in the water circuit system. Its consumption was an average of 1.8 kg per cycle in the summer and winter.

Operating reliability and durability

No notable malfunctions were determined in the system during the test period, nor did any significant damage or signs of wear occur on the exhaust air cleaning system as a whole during the test.

As far as could be observed during the test period, the individual components of the system appeared to be sufficiently protected from corrosion. Almost the entire system was manufactured from plastic (polypropylene).

Operating instructions, handling, working time and maintenance requirements

The operating instructions are sufficiently precise and explain the system's mode of operation in general terms. They also explain what kind of work must be carried out on the system on a daily, weekly and annual basis.

To operate the system, it is necessary to receive instruction from the manufacturer and to familiarise oneself with the manual.

After starting up the system and running it for an adequate period of time, the system can be regarded as user friendly, because the exhaust air cleaning system runs fully automatically in normal operation. It is only necessary to check the control system and the operating data each day and to inspect the exhaust air cleaning system, including the nozzles, on a weekly basis. Error messages are explained in the instructions along with instructions on checking the respective system components in each instance. The completion of a maintenance contract with the manufacturer is recommended to simplify handling and reduce the time spent on service and maintenance.

On completion of a maintenance contract, the maintenance work set out in the maintenance schedule is performed twice a year. Any defects that are discovered and any parts replaced are documented in a maintenance log. In the regular maintenance checks, a record is made of the ammonia concentrations in the exhaust air and clean air, the air velocity through the filter walls and the volume of purging water. In addition, the pH value and conductivity meter is calibrated. The state of the packing and the pump's electricity consumption are checked, and the electronic operating log is checked as regards plausibility.

After each cycle, the exhaust air cleaning system is cleaned, and the water reservoir is drained and filled with fresh water. Each time after the filter package has been cleaned, it is necessary to determine the pressure difference inside the packing by measuring the pressure difference whilst applying a flow rate that is 100% of the design flow rate. If the pressure difference exceeds a target value of ≥ 50 Pa, the filter package must be cleaned again. Then the procedure is repeated, again applying the 100% design flow rate, to determine the pressure difference. If this is below the maximum target value of 50 Pa, the system operator can start the system up again. If the target value of 50 Pa is exceeded, the removal and intensive cleaning of the individual filter elements by a specialist company are recommended.

The pH value sensors must be calibrated by the operator prior to the start of the new growing cycle. This calibration must be stored in the electronic operating log along with the date and time.

Documentation

The electronic operating log records all data required for safe system operation on a half-hourly basis. The system manufacturer records these data and stores them for 5 years. These data can be read out remotely by the farmer or the manufacturer and transferred to a conventional spreadsheet program. Official bodies can download the stored data using a USB connection. The data to be recorded are summarised in detail in Table 8.

Environmental safety

The desludged process water from the water reservoir (pH value 3.3) must be buffered in a separate desludging tank. The storage period depends on the current fertiliser regulations, which specify the storage period of liquid manure. The feed line into the desludging tank and the storage tank itself must be suitable for handling desludging water and must comply with the specific administrative regulations on substances hazardous to waters (ammonium sulphate, ASL) in the individual federal states. Immediately prior to spreading on farmland, the desludging water can be mixed with liquid manure outside of the building and applied according to good agricultural practice.

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

Sulphuric acid is required to operate the system. Its handling is explained by the manufacturer in specific operating instructions and is the responsibility of the operator. All necessary safety facilities must be installed as specified by the licensing authorities.

Safety aspects

The occupational safety of the described Pollo-M exhaust air cleaner from Inno+ B.V. has been appraised by the German Centre for the Testing and Certification of Agricultural and Forestry Technology (DPLF). From an occupational safety perspective, there are no concerns about operating the Pollo-M exhaust air cleaning system.

Table 8:
Requirements met by the Pollo-M exhaust air cleaner operating log

	Met in full	Met in part	Not met	Remarks
Pressure difference in the exhaust air cleaning system	X			Electronic differential pressure cells downstream of the droplet separator and upstream of the exhaust air fans (recorded in Pa)
Exhaust air flow volume	X			Two controlled fans with measurement fans. The fans are engaged after calculating the fan characteristic curve and pressure differencees (exhaust air flow volumes recorded and stored in m³/h)
Emergency fan operating time	X			The operating times of the emergency fans are stored in hours
Pump operating time	X			Based on the recorded electricity consumption rates of the pump and one flow rate measurement (MID)
Sprinkling intervals and sprinkling volume	X			Measuring the flow rate in the main pressure line to the filter package sprinkler and exhaust air spray valves (recorded in m³/h)
Cleaner fresh water consumption	X			Recorded in m³ using a water meter with pulse generator
Desludged water volume	X			Recorded using flow measurement (MID) and stored in m³
Exhaust air and clean air	X			Both temperatures are recorded; the water temperature (process water) is also registered
Spray pattern check	X			Indirectly verifiable by measuring the flow and a manually maintained operating log
Maintenance and repair times	X			Stored in the electronic operating log
pH value and conductivity measurement in the process water	X			Recorded in a bypass of the main pressure line to the packing sprinkler and stored electronically
pH value sensor calibration	X			Stored in the electronic operating log
Verification of acid consumption		X		Carried out using purchase invoices stored in the manual operating log
Electricity consumption	X			Recorded using suitable electricity meters and stored in kWh

Summary

The Pollo-M exhaust air cleaning system from Inno+ B.V. is suitable for reducing dust and ammonia emissions from the exhaust air of intensive chicken growing facilities with floor bedding provided the ventilation system is designed according to TierSchNutztV (German Order on the Protection of Animals and the Keeping of Production Animals) and provided it adheres to the process parameters described for the separation of ammonia (separation rate ≥ 70 %) and dust (separation rate ≥ 70 %). The averaged results of all measurements are 91 % for ammonia separation, 87 % for dust separation (total dust), 77 % (PM_{10}) and 94 % ($PM_{2.5}$).

More information

Please go to www.dlg.org/gebaeude.html#Abluft to download more reports on exhaust air cleaning systems. The DLG Technical Committee for Animal Husbandry has published a paper on „Husbandry of broilers“. This is available free of charge in PDF format at www.dlg.org.merkblaetter.html.
A short version of the DLG test framework can be downloaded at www.dlg.org/3409.html.

DLG test scope

SignumTest „Abluftreinigungssysteme für Tierhaltungsanlagen“ (Stand 10/2010)

Testing board

Test accompanied by
Dr. Jochen Hahne, TI Braunschweig; Friedrich Arends, LWK Niedersachsen; Andreas Schlichting, TÜV Nord Hamburg

In an advisory capacity
Gerd Franke, LLH Kassel
Ewald Grimm, KTBL Darmstadt
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Test performed by

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