DLG Test Report 6344

Inno+ B.V.

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

for keeping laying hens

SIGNUM TEST
03/16 passed

Test Center
Technology and Farm Inputs

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Overview

The SignumTest quality mark is awarded to agricultural equipment that has passed a comprehensive DLG usability test. Carried out to independent and recognised 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 both 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 single-stage chemical air cleaner with droplet separator from Inno+ B.V. as regards its suitability for reducing dust and ammonia emissions from the exhaust air flow of a laying hen house. The test is based on the requirements set down by DIN 18910 standards. The system must comply with the DLG SignumTest framework on exhaust air cleaning systems. According to this, the system must be able to reduce total dust, fine dust (PM_{10}, $PM_{2.5}$) and ammonia emissions from laying hen houses to at least 70 %. At the same time, the exhaust air odour level in the clean air must not exceed 300 OU/m³, so that a typical exhaust air odour (poultry) must no longer be perceptible. The test must show a 70 % eduction of N (N removal) in the N balance. This applies to the two test periods (summer, winter). Except for reducing odorants, the tested system met and partly surpassed the minimum requirements laid down in the DLG test framework.

Assessment – Brief Summary

The exhaust air cleaning system from Inno+ is a single-stage chemical air cleaner that separates dust and ammonia from laying hen houses (aviary system) with a bedding of wood shaving in the scratching patches (patrol paths). 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 filter package where ammonia and dust are separated. The filter package is installed horizontally in the exhaust air tower. A droplet separator is installed above the filter package to prevent the emission of aerosol. The process water (circulation water) that sprinkles the filter package is acidified with sulphuric acid until its pH value is ≤ 3.3.

In the winter measurements, the exhaust air cleaning system achieved a minimum ammonia separation rate of 86 % in the winter with a proven N removal of 85 %. During the summer the minimum ammonia separation was 75 % but N removal was 83 %. This is unusual, since N removal rates cannot be higher than the minimum ammonia separation rates.

It may be attributed to the fact that the assumption on actual N removal was too high as the level of N removal within the N balance is determined by taking into account aireous N input and removal rates, by nitrogen accumulating in the process water and by the percentage of N presence in the water that is used for cleaning the filter package. In this context, it is mainly down to the ammonia sulphate deposits that collect inside the filter package during the balancing period and that cannot be measured accurately (see pages 14 and 15).

The minimum level of separation for total dust is 77 %, for PM_{10} it is 76 % and for $PM_{2.5}$ it is 91 %. Ammonia and dust formed the main parameters that were certified by this test. To ensure the reliability of separation rate for these parameters, a maximum filter surface area load of 2,000 m ³/(m² · h) is recognised.

Further results and the consumption measurements are summarised in Table 1.

Table 1:
Overview of Pollo-L single-stage exhaust air cleaner results

Test criterion	Result				Assessment*
Emission measurements					
Total dust (gravimetric, ten measurement dates)[1)]					
(8) Winter measurements					
Minimum separation	[%]	81.3			+
(8) Summer measurements					
Minimum separation	[%]	77.3			
Fine dust (gravimetric, five measurement dates) [1)]					
Winter measurements (2)					
Minimum separation PM_{10}	[%]	75.9			
Minimum separation $PM_{2.5}$[2)]	[%]	91.0			+ +
Summer measurements (2)					
Minimum separation PM_{10}	[%]	82.0			+
Minimum separation $PM_{2.5}$[2)]	[%]	95.3			+ +
Ammonia (measured continuously, half-hourly means) [3)]					
Winter (2,726 valid measurements)					
Minimum separation	[%]	85.5			+
Summer (877 valid measurements)					
Minimum separation	[%]	74.9			
N balance, N removal					
Winter (14-day balancing period)					
N removal	[%]	85			+
Summer (21-day balancing period)					
N removal [4)]	[%]	83			+
Aerosol emission					
Winter (4 measurements), inorganic aerosol (NH3-N C_{Norm}), mean					
inorganic aerosol (NH3-N C_{Norm}), mean	[mg/m³]	0.59			n/a
inorganic aerosol (NH3-N C_{Norm}) mass flow	[g/h]	15.2			n/a
Summer (4 measurements), inorganic aerosol (NH3-N C_{Norm}), mean					
inorganic aerosol (NH3-N C_{Norm}), mean	[mg/m³]	0.08			n/a
inorganic aerosol (NH3-N C_{Norm}) mass flow	[g/h]	5.85			n/a
Consumption measurements (averages per day or animal place and year) [5)]					
Fresh water consumption					
Winter (57 measuring days)	[m³/d]	1.90	[m³/(AP · a)]	0.03	n/a
Summer (56 measuring days)	[m³/d]	4.70	[m³/(AP · a)]	0.07	n/a
Average annual value	[m³/d]	3.30	[m³/(AP · a)]	0.05	n/a
Desludging					
Winter (57 measuring days)	[m³/d]	0.044	[m³/(AP · a)]	0.001	n/a
Summer (56 measuring days)	[m³/d]	0.219	[m³/(AP · a)]	0.003	n/a
Average annual value	[m³/d]	0.132	[m³/(AP · a)]	0.002	n/a
Acid consumption (based on 96 % sulphuric acid)					
Winter (57 measuring days)	[kg/d]	34.9	[l/d]	18.5	n/a
	[kg/(AP · a)]	0.53	[l/(AP · a)]	0.28	n/a
Summer (56 measuring days)	[kg/d]	33.5	[l/d]	17.8	n/a
	[kg/(AP · a)]	0.51	[l/(AP · a)]	0.27	n/a
Average annual value	[kg/d]	34.2	[l/d]	18.2	n/a
	[kg/(AP · a)]	0.52	[l/(AP · a)]	0.28	n/a
Defoamer consumption [6)]					
Average annual value	[kg/a]	20			n/a

Electrical energy consumption					
Exhaust air cleaning circulation pumps					
Winter (57 measuring days)	[kWh/d]	69.9	[kWh/(AP · a)]	1.06	n/a
Summer (56 measuring days)	[kWh/d]	72.0	[kWh/(AP · a)]	1.10	n/a
Average annual value	[kWh/d]	71.0	[kWh/(AP · a)]	1.08	n/a
Building fans					
Winter (57 measuring days)	[kWh/d]	39.1	[kWh/(AP · a)]	0.59	n/a
Summer (56 measuring days)	[kWh/d]	79.2	[kWh/(AP · a)]	1.20	n/a
Average annual value	[kWh/d]	59.2	[kWh/(AP · a)]	0.90	n/a

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

1) The DLG test framework on measuring the dust separation rate of exhaust air cleaning systems recognises that minimum separation rate which is obtained from the smallest separation level from all dust measurements (total and fine dust).
2) 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 impacted as extensively by this effect, so that the calculated separation rate for this particle fraction is higher than for the PM_{10} fraction.
3) To determine the ammonia reduction rate, the current DLG test framework on air cleaning systems recognises the minimum separation rate as a result from averaging all separation measurements and deducting the standard deviation figure from this.
4) The ammonia sulphate deposits that collect inside the filter package during the balancing period may lead to excessive results on N removal. It is not really feasible to determine the exact levels of ammonia sulphate deposits inside the filter package during the balancing period. As it is not possible to quantify the deposits formed during the previous operating cycles the quantities of inorganic N detected in the cleaning water may lead to false readings. In analogy, the results of N removal will be overvaluated.
5) Consumption measurements during the summer and winter, normalised to 365 days and related to the approved number of animal places inside the building (24,000 layers). The mean annual value is obtained by averaging the summer and winter measurements.
6) The used defoamer is a Fatty Alcohol Ethoxylate.

The Product

Manufacturer and applicant

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air cleaning system

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Description and specifications

The Pollo-L 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 bedded layer buildings. The layers were held in an aviary with a patrol path (scratching patch) bedded with wood shavings (approx. 1 kg/m²) where the manure was removed by belts once a week. Dust and ammonia emissions are removed from the layer aviary. Figure 2 shows the cleaner's operating principle in a schematic form. The most important process parameters are summarised in Table 2. The pH value of the process water that circulates inside the cleaner must be set to pH ≤ 3.3, and this has to be maintained throughout operation.

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 system of spray valves 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 waste air flows through the spray mist.
The humidification must be rated to a level that ensures that the waste air flowing into the cleaner at a rate of ≥ 0.85 m³/h per linear meter is humidified by the process water from the reservoir.

The exhaust air is then routed to a filter package that is mounted on a stainless steel construction and where the air is continuously sprinkled from above with process water applied in a reverse flow. The sprinkling density for the filter package must be set to ≥ 0.90 m³/(m² · h). The filter package's large, specific surface serves to enlarge the contact surface between the building's exhaust air and the process water in order to improve the separation of ammonia and dust. A droplet separator is positioned above the filter package; the exhaust air fans are located downstream of this. It is absolutely necessary that the fans are corrosion-proof. The exhaust fans and the droplet separator must be spaced at a minimum of 1.5 m. This is necessary to ensure a uniform air flow through the droplet separator.

The droplet separator is used to separate aerosols containing nitrogen, which must not enter the environment. One of the fans used was frequency-controlled to remove the basic exhaust air flow rates. The other fans were not controlled and operated at a 100 % exhaust air flow relative to the temperatures inside the building. The DLG test framework recognises only a system with simultaneous fan control which operates all fans to the same flow rate at any one time. This is due to the low exhaust air concentrations and the great variations in ammonia separation levels that are produced by such a step by step ventilation control system To achieve the exhaust rate that is stipulated by DIN 18910, it is necessary that the fan speeds are controlled infinitely variably by a frequency converter.

The process water circulates continuously in the system. Conductivity values of up to 180 mS/cm were measured during the certification test. The maximum conductivity recognised is 150 mS/cm to prevent salination in the filter package.

If this value is reached, the desludging pump has to remove automatically a certain quantity of water from the water reservoir to reduce the conductivity level of the process water. The amount of desludged process water is measured by a flow meter and logged to the electronic operating log (EOL). Normally, at least 50 % of the water in the reservoir (5.5 m^3) is used for the processes and topped up again with fresh water. Desludging reduces the conductivity level which must not exceed 150 mS/cm. The pH-value of the desludged process water is pH ≤ 3.3. 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 5.5 m^3 water reservoir is emptied and cleaned only at the end of a laying period. To prevent salination or clogging of the filter package, the Pollo-L exhaust air cleaning system from Inno+ must have an alarm system that reminds the operator of cleaning the filter package. To properly check on the actual contamination of the filter package, a pressure difference curve is established while the exhaust air cleaner is being operated before the system is actually taken into operation (sprinkling the filter package with clean process water).

The differences recorded at exhaust air flow rates of 10 %, 25 %, 45 %, 80 % and 100 % are augmented by a 10 Pa tolerance value and form the pressure difference reference curve that must not be exceeded. If this line is exceeded for half an hour while the system is operating, an alarm will sound to remind the operator of cleaning the filter package. Only after the pressure differences have dropped below the reference curve is it possible to reset the alarm.

To ensure the process water pH level is ≤ 3.3 the cleaner has an acid dosing system that uses upstream conductivity measuring technology. 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 levels described in Table 1 it is necessary to operate the system continuously. It must be ensured that the cleaner maintains the maximum summer air flow rate as determined in accordance with DIN 18910. Flow rates that exceed this design rate can be exhausted by emergency fans in a separate air flow. The operating time of the emergency fans must be documented in the electronic operating log.

Warranty

The manufacturer offers a two-year warranty under the provision that the system is operated properly. Installation and maintenance must be performed by a authorised installation company.

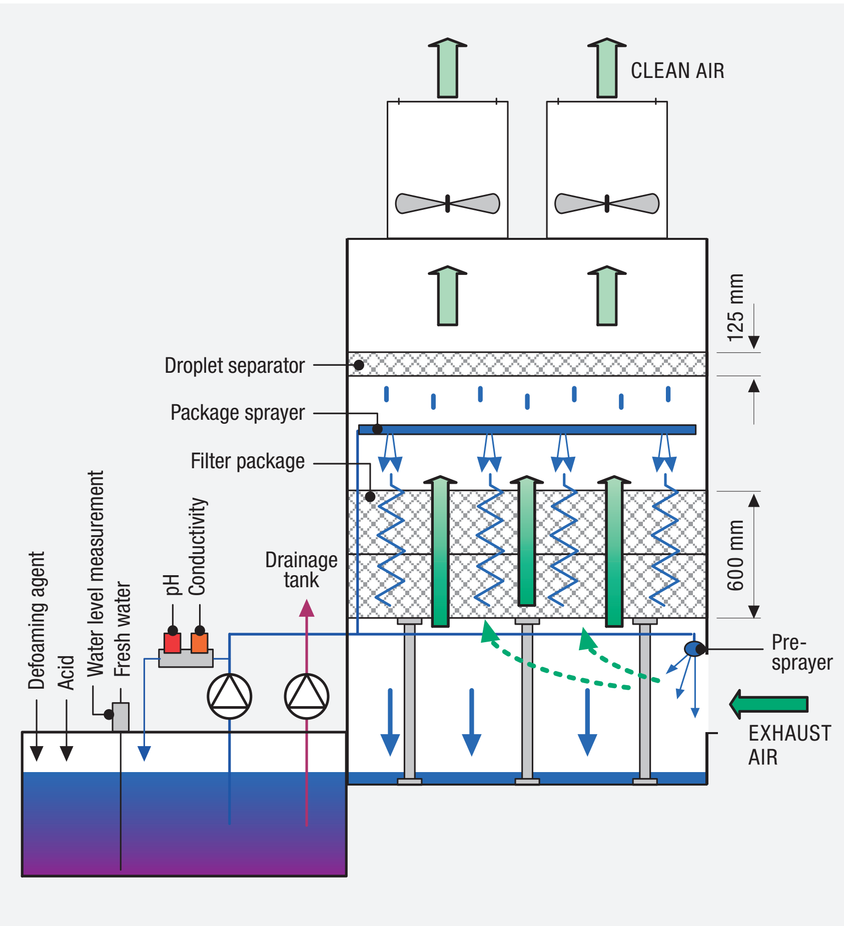

Figure 2:
Schematic diagram of the Inno+ Pollo-L exhaust air cleaning system

Table 2:
Inno+ Pollo-L exhaust air cleaner process parameters

Characteristic	Result / value	
Description		
Single-stage exhaust air cleaner with droplet separator		
Suitability		
Cleans the exhaust air from laying hen aviaries with bedding in the patrol path and weekly removals of the manure by belts to reduce dust and ammonia.		
Dimensioning parameters, filter package and droplet separator dimensions (reference system)		
Filter package		
Length / width / depth	[m] / [m] / [m]	14.4 / 3.6 / 0.6
Face area / volume	[m²] / [m³]	51.84 / 31.10
Maximum filter surface area load	[m³/(m² · h)]	2,000
Maximum filter volume load	[m³/(m³ · h)]	3,333
Air speed at max. summer air flow rate	[m/s]	0.56
Contact time at maximum summer air flow rate	[s]	1.08
Droplet separator		
Length / width / depth	[m] / [m] / [m]	14.4 / 2.4 / 0.125
Face area / volume	[m²]/[m³]	34.56 / 4.32
Maximum surface area load	[m³/(m² · h)]	3,000
Maximum volume load	[m³/(m³ · h)]	24,000
Air speed at max. summer air flow rate	[m/s]	0.83
Contact time at maximum summer air flow rate	[s]	0.15
Minimum distance between the elements		
Concrete floor – filter package	[m]	2.0
Filter package – droplet separator	[m]	1.0
Droplet separator – fans	[m]	1.5
Sprinkling density (continuous)		
Filter package		
Sprinkling rate (summer / winter)	[m³/h]	47.2 / 40.6
Sprinkling density (summer / winter)	[m³/(m² · h)]	0.91 / 0.78
Number of nozzles	[Quantity/m²]	0.25
Prespraying (continuous)		
Sprinkling rate (summer / winter)	[m³/h]	12.1 / 15.1
Sprinkling intensity (summer / winter)	[m³/(h · linear m)]	0.84 / 1.05
Number of nozzles	[Quantity/linear m]	0.8
Desludging		
Cleaning water reservoir capacity	[m³]	5.50
Desludging rate per year	[m³/a]	48.18
Average desludging rate	[m³/d]	0.132
	[m³/(AP · a)]	0.002
pH value of the circulation water	[-]	≤ 3.30
Maximum conductivity in the circulation water	[mS/cm]	≤ 150
Reference farm where measurements were taken (24,000 layers held in an aviary system)		
Laying hen house (type of housing)	[System]	Aviary
Maximum stocking density in the building	[Quantity]	24,000
Maximum live weight (before removal from the house)	[kg/animal]	1.70
Maximum summer air flow rate to DIN 18910	[m³/animal]	3.90
Maximum cleaner exhaust air flow rate to DIN 18910	[m³/h]	93,600
Maximum installed cleaner exhaust air flow rate at 50 Pa pressure difference	[m³/h]	160,000
Number of fans	[Quantity]	4
Maximum exhaust air flow measured (summer)	[m³/h]	122,400
Maximum pressure difference in the filter package (summer)	[Pa]	36
Maximum pressure difference in the droplet separator (summer)	[Pa]	9
Total pressure difference in the building and the cleaner (summer) [1)]	[Pa]	106

Characteristic	Result / value	Assessment*
System performance		
Operating reliability	To ensure the necessary separation rates are achieved, it is necessary that all fans are controlled infinitely variably by a frequency converter. The exhaust air cleaner must have an alarm system that indicates the level of filter contamination and that reminds the operator of cleaning.	
Durability	No significant signs of wear were found during the test period. The exhaust fans used must prove to be corrosion-proof.	+
Pressure difference curve (alarm)	To properly check on the actual level of contamination in the filter package, a pressure difference curve is established while the exhaust air cleaner is being operated (sprinkling the filter package with clean process water) before it is actually taken into operation. The pressure differences recorded at exhaust air flow rates of 10 %, 25 %, 45 %, 80 % and 100 % are augmented by a 10 Pa tolerance value. This pressure difference curve is stored in the SPS memory based programmable control system and must not be exceeded during operation.	
Handling		
Operating instructions	The manual gives a detailed and clear account of the automatic control system and the necessary maintenance work with photos for good visualisation.	+
Operating the system	The system is designed to operate automatically. Operators must perform daily checks of the exhaust air cleaner via the control system. The system must be operated continuously.	
Maintenance	The manufacturer recommends concluding a maintenance contract with the manufacturer. Maintenance must be performed once a year and comprises calibrating the measurement equipment and checking the spray pattern on the filter package. As an option, the manufacturer offers remote monitoring of the system and of the electronic operating log (EOL).	
Cleaning the entire system	The exhaust air cleaner has an alarm system that indicates to the operator when the filter package needs cleaning. This becomes necessary when over a period of 30 minutes the pressure difference exceeds the maximum pressure difference curve that was established by the manufacturer before the exhaust air cleaner was taken into operation. After each cleaning of the filter package, the entire water in the 5.5 m^3 reservoir must be replaced. During an egg production period the cleaning is carried out with the process water in the reservoir. At the end of a production cycle, the water reservoir and the nozzles are cleaned with process and fresh water from a pressure cleaner.	
Replacing the filter package	Provided the exhaust air cleaner is operated properly and all cleaning is performed as required, according to the manufacturer the filter package does not need replacing.	n/a
Time spent on monitoring, service and maintenance		
Daily checks	approx. 2 minutes (remotely)	+
	approx. 5 minutes (not remotely)	
Weekly checks	approx. 30 minutes (meters and spray pattern on the filter package)	
Cleaning the nozzles	approx. 1 hour (pre-moistening and sprinkling the filter package)	
Cleaning the filter packages	approx. 3 hours (after an alarm)	
Cleaning the entire system	approx. 5 hours (at the end of a production cycle)	
Documentation		
Technical documents	Meets requirements	+
Electronic operating log	Meets requirements	+
Safety		
Work safety	Audited and certified by the German Test and Certifying Center for Agricultural and Forestry Machinery (DPLF)	n/a
Fire safety	Not required	n/a
Environmental safety	The cleaning water must be buffered in a separate tank that is approved for this purpose. The cleaning water can be used for watering plants. The operator has to document the proper usage of the water. The removal and disposal of other system components is undertaken by recognised recycling companies.	
Warranty		
Manufacturer's warranty	2-year warranty on removable parts; 5-year warranty on buildings. This does not apply to regular wear parts (e.g. pH electrode) and consumables.	n/a

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

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

The measurements were performed on a reference system in Recke, Germany. The measurements took place over a period of eight weeks during the winter (winter measurements from February to April 2015) and the summer (summer measurements from July to September 2015). The tested system was a prototype.

Around 24,000 hens were housed in the reference building in aviaries with a belt system for removing the manure. The manure was removed on a weekly basis to reduce the ammonia concentration inside the building. The scratching patches (patrol paths) were bedded with wood shavings (approx.1.0 kg/m²). The fresh air flowed into the building through inlet valves on both longitudinal sides of the building and the exhaust air was extracted from the building by four corrosion-proof exhaust fans that inducted the air into the exhaust air cleaner. The installed fans produced a maximum air flow rate of 160,000 m³/h at a calculated pressure difference of 50 Pa.

In compliance with DIN 18910, the ventilation system was designed for ventilating 3.90 m³/(animal · h) with ΔT equal to 3K. With 24,000 layers of an average live weight of 1.8kg in the building, the system can exhaust about 6.7 m³/(animal· h) from the barn. During the testing period, the maximum exhaust air flow rate was 122,400 m³/h. Given a 51.84 m² filter surface area, this volume translates into a maximum permitted air load of 2,360 m³/(m² · h) on the filter surface. However, the recognised maximum air load on the filter surface is only 2,000 m³/(m² · h) to ensure an ammonia separation rate of 70 % as a minimum.

Unlike the exhaust air cleaner used in chicken fattening, the cleaner for layer buildings must be taken into operation immediately after the hens have moved in. After the system is started up, the waste air from the building is then inducted across the entire width of the cleaner, humidified by a nozzle bar and routed through the filter package. Humidification took place in a cross-flow pattern and the sprinkling of the filter package was carried out in reverse flow from above. The process water's pH value must be reduced to a value of ≤ 3.3. A droplet separator must be installed above the filter package 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.

To ensure an ammonia separation rate of ≥ 70 % is maintained throughout operation, it is necessary that the fan speeds are controlled infinitely variably by a frequency converter. The load on the filter surface area must not exceed 2,000 m³/(m² · h). Group control for the fans where only one exhaust fan is controlled (step by step system) is not recognised. The exhaust fans used must prove to be resistant to corrosion.

The water reservoir (around 5.5 m³ capacity) was completely drained and cleaned after the winter measuring period. When the pressure difference in the filter package and the droplet separator is permanently ≥ 40 Pa for a time period of at least two hours, the system indicates to the operator to clean to the filter package.

The main water line to the nozzle bar that moistens the actual filter package between the filter package and the droplet separator has extra hose connections (DN 50) for intensive filter package rinsing with circulation water. Rinsing can take place several times during a laying period and is controlled by the pressure inside the filter package and the droplet separator. This must not drop below 40 Pa and is recorded in the EOL. The flanges and hoses required for rinsing the filter package must be stored in the utility room.

A circulation pump and a desludging pump were used in the water reservoir. The circulation pump fills the line to the prespraying nozzles and the actual filter package sprinkler (between filter package and droplet separator). The pump must be rated to a capacity that ensures a humidification intensity of 0.85 m³/(linear m · h) for the prespraying system and a sprinkling density of 0.90 m³/(m² · h) for the actual filter package.

If the maximum conductivity value of 150 mS/cm is exceeded during the egg laying period, the desludging pump feeds about 50 % of the total water in the reservoir from the process water circulation into a buffer tank that is specifically approved for this purpose. 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 figures on desludging volume and fresh water consumption are stored in the electronic operating log.

During the measurements the temperature and relative humidity were also recorded. The following extra parameters were recorded on the days the dust measurements were taken:

- Number of animals (barn log)
- Fresh water and electrical energy consumption (meter readings)
- Absolute air flow (ventilation control system and DLG measurement fans)
- Pressure difference in the exhaust air cleaning system and the pressure difference in the fan
- Process water pH and conductivity levels

In addition, the manufacturer records in the electronic operating log were also checked for plausibility (see Table 8). 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 fibreglass filter with a diameter of 45 mm was selected as the separation medium. Fine dust levels (PM_{10} and $PM_{2.5}$) were determined according to VDI Standard 2066, Part 10 and to DIN EN ISO 23210. A Johnas II cascade impactor (Paul Gothe design) with three planar filters (50 mm diameter) was used. The separation medium was again a round fibreglass filter but this time with a filter diameter of 50 mm.

As the high levels of organic and biological dust 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 all total dust and fine dust measurements (PM_{10} and $PM_{2.5}$ fractions). The recognised minimum level of separation is the lowest level from all recordings during the measurement days.

Ammonia

The ammonia measurements in the exhaust air 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 with a measuring cell. In parallel to these measurements, air samples were taken in washing bottles on two days during the summer and winter cycle. These were evaluated according to VDI 3496, Part 1.

To prevent condensation in the PTFE air lines, the measured air lines were heated along their entire lengths. The ammonia levels in the animal area were measured at animal height during regular inspections.

According to the current DLG test framework, NH3 separation must not fall below 70 %, i.e. the level must be permanently higher than 70 %. The acceptable minimum level of separation is determined by averaging all measurements and deducting the standard deviation figure from this average value.

Aerosol emission

By moistening the filter package material, the nitrogenous aerosols are driven out of exhaust air cleaner reservoirs as NH_3 aerosols and 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 from the tested system, the exhaust air was routed at a rate of 2 m^3/h and for 30 minutes over washing bottles containing 100 ml of an absorbent solution (0.05 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.

The DLG test framework stipulates that the emission rate of aerosol must not exceed 0.50 mg of nitrogen per standard cubic metre.

N balance, N removal

The rate of nitrogen separation in the system was verified by means of two N balances, taking into account the ammonia loads (in the exhaust air and clean air), the aerosol emissions and the inorganic nitrogen compounds dissolved in the cleaning water. These measurements were taken during the summer and winter measurements. During both N balancing periods (winter and summer), 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. The balancing must be carried out during 14 days at least.

In the Pollo-L exhaust cleaning system from Inno+, the formation of nitrite and nitrate in the process water can be disregarded. The concentrations of further aireous 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 N removal rate within the nitrogen balance must be ≥ 70 % both for the summer and winter period.

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.

Operating reliability and durability

Operating reliability and durability were assessed and documented. Any malfunctions to the system as a whole or 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 test assesses whether the descriptions and illustrations of the system and of regular maintenance work are clear and meet user needs.

The tests on handling and working time requirements assess whether it is necessary for the manufacturer to provide instruction during commissioning, on regularly inspections and daily, weekly or monthly, service and maintenance work and in the event of malfunctions.

Documentation

In general, the following parameters must be recorded as mean half-hourly values in the electronic operating log:

- Pressure difference in the filter package and the droplet separator (Pa)
- Air flow rate in m^3/h
- Pump operating time (h)
- Volume flow of cleaning water (m^3/h)
- Total fresh water consumption by the system (m^3)
- Amount of the desludging rate (m^3)
- Exhaust air and clean air temperatures (°C)
- pH and electrical conductivity levels (mS/cm)
- System consumption of electricity (kWh)
- Emergency fan operating time (h)

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

These data are used to verify that the exhaust air cleaning system is operated properly. They were verified on the Pollo-L exhaust air cleaning system from Inno+.

Environmental safety

The environmental safety tests included an assessment of all inputs that are necessary to operate the system (e.g. acid). Also, recycling of the desludged water and disposal of system components were assessed. It was also examined who is in charge of the individual aspects.

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.

Dust

During each of the two measurement periods (winter, summer), the testers carried out eight total dust and eight fine dust measurements (PM_{10}/$PM_{2.5}$). The minimum separation rate recognised for this dust fraction equals the smallest separation rate that was determined in each measurement period (winter, summer). Table 3 summarises all dust measurement results.

The total dust separation rate was 81.3 % in the winter (10.02.2015) and 77.3 % in the summer (22.07.2015). The recognised minimum separation level for fine dust (PM_{10}) was 75.9 % in the winter (24.03.2015) and 82.0 % in the summer (29.07.2015). The minimum separation rate for the $PM_{2.5}$ fine dust fraction separation was 91.0 % in the winter (24.03.2015) and 95.3 % in the summer (29.07.2015).

Both separation rates (winter and summer) are considered as good and are attributable to the fact that the exhaust air coming into the system from the building is sprayed by upstream nozzles to the cross-flow method on the one hand and that the filter package material is moistened intensively to the reverse flow method on the other. In addition, the exhaust air's residence time inside the actual filter package at maximum load is long. As a result the waste air has sufficient time to come into contact with the moistened and specific surface of the filter package (125 m²/m³) so that the dust is separated.

The number of nozzles 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 > 0.85 m³/(linear m · h) must be adhered to. The filter's sprinkling density is ≥ 0.90 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 impacted 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 recorded during the specific measuring period on the days when regular measurements were carried out. The air flow volume and pressure difference data are mean values that were calculated from the measurements taken every minute and noted in the DLG recordings.

Ammonia

The rate of NH_3 separation is assessed only at a exhaust air concentration ≥ 3.0 ppm. This is attributed to the fact that it takes a exhaust air concentration of < 1.0 ppm for a required minimum separation of 70 %. However, the measuring uncertainty inherent to the measuring equipment does not allow the testers to make a perfect assessment of ammonia levels of ≤ 1.0 ppm. The number of paired readings that were available for evaluating the ammonia separation rate during the winter measurements was 2,726 (mean values every 30 minutes) whereas the number of pairs (30-minute averages) obtained from the summer measurements was as low as 877.

Figure 3 shows the ammonia concentrations and the separation rates as examples from the first winter 2015 measurement. After starting the exhaust air cleaner, the

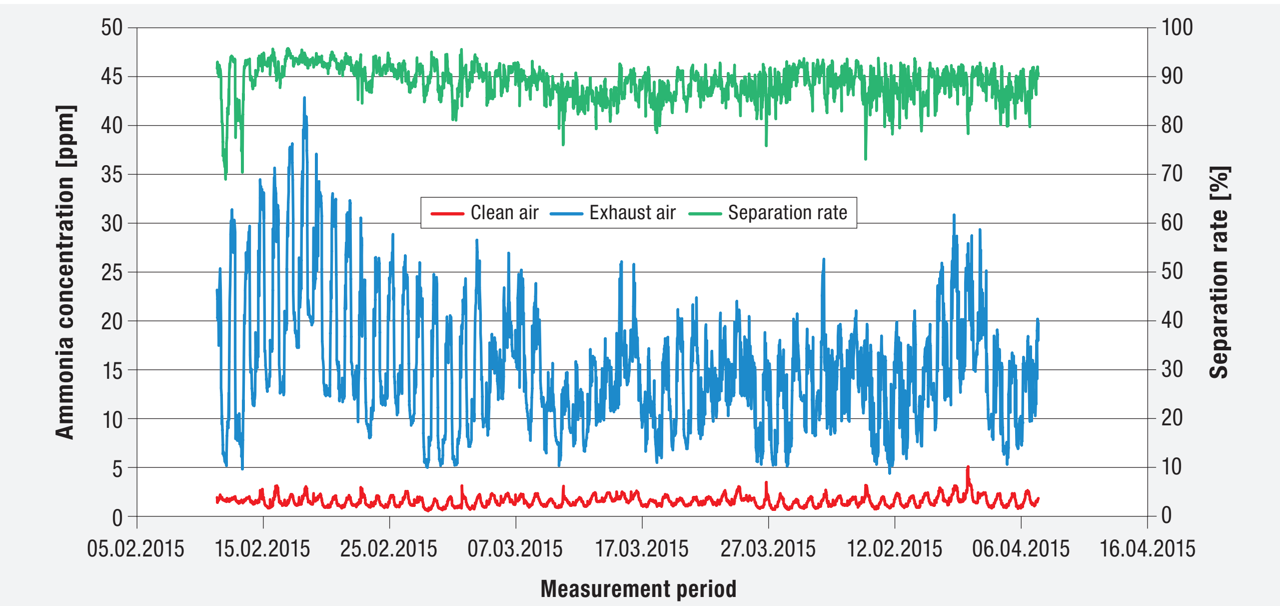

Figure 3:
Separation rate and ammonia concentration curves for the exhaust air and clean air during the winter measurement (10.02.2015 to 08.04.2015)

Table 3:
Inno+ Pollo-L exhaust air cleaner emission reduction (dust) measurements

		Winter measurement							
Date		**10.02.15**	**17.02.15**	**24.02.15**	**03.03.15**	**10.03.15**	**17.03.15**	**24.03.15**	**07.04.15**
Ambient and boundary conditions									
Rel. humidity	[%]	89	86	74	75	72	63	52	78
Ambient air temperature	[°C]	9.0	3.2	6.6	6.0	14.5	10.6	10.6	9.9
Exhaust/clean air humidity	[%]	73/99	80/100	71/99	66/96	74/99	64/95	69/95	73/96
Exhaust/clean air temperature	[°C]	15.4/14.6	16.7/15.4	16.9/12.8	15.2/12.8	17.0/14.4	16.1/14.5	14.8/13.7	16.1/13.1
Layers	[Quantity]	22,623	22,569	22,531	22,503	22,464	22,428	22,390	22,302
Average animal weight	[kg]	1.65	1.65	1.65	1.66	1.66	1.66	1.66	1.66
Total air flow volume	[m³]	43,360	31,030	28,360	44,290	46,160	64,040	36,670	61,510
Cleaner pressure difference	[Pa]	4	2	4	8	12	20	6	22
Building/cleaner pressure difference	[Pa]	15	8	7	22	30	52	16	54
Total dust (normalised)									
Exhaust air	[mg/m³]	5.29	8.78	23.23	4.85	7.64	8.70	6.54	5.32
Clean air	[mg/m³]	0.99	1.06	1.69	0.88	1.04	0.95	0.85	0.74
Separation rate	[%]	81.3	87.9	92.7	81.9	86.4	89.1	87.0	86.1
Fine dust PM_{10}/$PM_{2.5}$ (normalised)									
Exhaust air	[mg/m³]					2.92/1.14		3.70/1.78	
Clean air	[mg/m³]					0.59/0.06		0.89/0.16	
Separation rate	[%]					79.8/94.7		75.9/91.0	

		Summer measurement							
Date		**22.07.15**	**29.07.15**	**05.08.15**	**12.08.15**	**17.08.15**	**26.08.15**	**03.09.15**	**10.09.15**
Ambient and boundary conditions									
Rel. humidity	[%]	69	80	64	80	96	80	79	63
Ambient air temperature	[°C]	22.3	12.5	20.5	19.7	18.4	20.6	15.9	19.0
Exhaust/clean air humidity	[%]	69/96	73/98	74/99	73/98	87/100	77/100	74/97	73/100
Exhaust/clean air temperature	[°C]	23.8/20.3	21.3/19.7	21.6/21.3	23.7/23.0	23.5/21.5	23.3/20.8	19.0/16.5	19.1/18.2
Layers	[Quantity]	23,901	23,881	23,860	23,841	23,818	23,796	23,743	23,711
Average animal weight	[kg]	1.43	1.43	1.45	1.46	1.47	1.50	1.52	1.53
Total air flow volume	[m³]	81,550	53,940	78,680	48,810	98,220	97,350	95,670	76,950
Cleaner pressure difference	[Pa]	29	15	22	31	32	34	38	16
Building/cleaner pressure difference	[Pa]	83	41	80	90	93	98	106	54
Total dust (normalised)									
exhaust air	[mg/m³]	8.83	19.34	14.67	8.36	14.72	14.79	8.97	14.69
Clean air	[mg/m³]	2.00	2.98	2.29	1.60	1.04	1.79	0.99	2.17
Separation rate	[%]	77.3	84.6	84.4	80.9	92.9	87.9	89.0	85.2
Fine dust PM_{10}/$PM_{2.5}$ (normalised)									
exhaust air	[mg/m³]		7.55/3.65			7.10/3.09			
Clean air	[mg/m³]		1.29/0.17			1.28/0.13			
Separation rate	[%]		82.9/95.3			82.0/95.8			

levels of ammonia in the system's exhaust air section ranged from 5.0 ppm to 42.9 ppm during the winter measurements. These levels were clearly too high and were measured during 8 to 14 hours on only a few days early in the measuring period. During this time, the air control system was not set up as required for the generation of the minimum exhaust flow rates that are stipulated by DIN 18910. After it was set up according to DIN 18910, the ammonia levels in the exhaust air dropped below 20 ppm. The ammonia levels in the clean air ranged between 1.0 ppm and 5.1 ppm during the measurement period. Figure 3 shows that separation rate is always well over the required 70 % level. The calculated minimum ammonia separation is 85.5 %.

In the summer cycle, and unlike the winter cycle, the minimum ammonia separation rate was determined on the basis of only 877 paired values. The reasons are explained below. Table 4 shows the factors that influenced the evaluation of the minimum ammonia separation rate.

Measuring uncertainty

The flow rates that the cleaning system exhausts from the building in summer are clearly higher than in winter. As a result, the concentrations of ammonia are clearly lower. A exhaust air concentration of ≥ 3.3 ppm requires a clean air concentration of 1.0 ppm to meet the minimum separation of 70 % as required by the DLG test framework. Yet a significantly higher measuring uncertainty (approx. 20 %) needs to be taken into account for the concentration range of 1.0 ppm. Consequently, at this level exhaust air concentration (22.5 % of all paired values) is not taken into account for determining minimum separation.

Ventilation control

Ammonia levels inside the exhaust pipes from the controlled fan and the first auxiliary fan were measured in two positions. This was necessary because the control system relied on one controlled exhaust air fan and two supporting fans which were engaged to deliver 100 % of exhaust air volumes whenever this was required. When one of the fans was not working, the ammonia concentration increased significantly at the appropriate measuring point resulting in a lower separation rate. 98 paired values that were found to be distorting the actual rate were determined with the help of the recorded exhaust air flows (minute values). These pairs were not taken into account in the assessment of the ammonia separation rate. Therefore, to avoid this negative influence, it is mandatory to operate the Pollo-L exhaust air cleaning system from Inno+ with infinitely controlled fan systems only.

pH values

On 12/09/2015, the measurements showed clear drops in separation rate and even negative rate readings. On that date the acid reservoir was depleted. The incident was not taken into consideration for evaluation, because the malfunction had been indexed by the electronic operating log (EOL) which recorded the rapid increase in pH value to pH >7.0 in the process water.

Increased pH values were also observed on 04/09/2015, when the EOL recorded higher pH values before desludging, which should take place at a pH value of pH = 6.0. Increasing the pH value and reducing it to the required pH ≤ 3.3 after desludging took about four to six hours at the reference farm. With the separation rate dropping below 70 % during this time, this type of desludging process (shutting off the acid dosage system, thus increasing the pH value, desludging at a pH value of > 6.0) cannot receive approval. Desludging must be carried out with the pH value at pH ≤ 3.3. On the whole, 18 paired values were not taken into account.

Service and maintenance

During the summer measurements, parts of the exhaust air cleaning system had to be shut off for servicing (nozzle checks, cleaning). These activities took 27 hours and were logged to the EOL and to internal Inno+ service protocols.

Table 4:
Factors influencing the minimum ammonia separation rate measurements on the Inno+ Pollo-L exhaust air cleaning system (summer measurements taken 15.07.2015 to 17.09.2015).

			Ammonia separation rate		
	Measurements [Number]	**Percentage [%]**	**Average depth [%]**	**Standard deviation [%]**	**Minimum separation rate [%]**
Measurement period	**1,344**	**100.0**	**72.5**	**13.3**	**59.2**
Influencing factors					
Measuring uncertainty	302	22.5	56.9	12.5	44.4
Ventilation control	98	7.3	70.2	12.7	57.5
pH values	18	1.3	40.8	26.2	14.6
Maintenance work	27	2.0	57.7	12.8	44.9
Filter surface area load	22	1.6	66.2	3.2	63.0
Total measurements, summer 2015	**877**	**65.3**	**79.4**	**4.5**	**74.9**

The reduced ammonia separation rate during this time was not taken into account for the evaluation.

Filter surface area load

The minimum ammonia separation rate of 70 % was not met when exhaust air concentrations were very low (< 5 ppm) and the load on the filters exceeded 2,200 $m^3/(m^2 \cdot h)$. This was found to be the case during about 22 hours (1.6 % of all paired values). Consequently, for safety reasons the accepted load on the filters must not exceed 2,000 $m^3/(m^2 \cdot h)$.

After correcting the measurements during the entire measurement period by taking the described factors into account that impacted the readings, 877 paired values were used to determine the minimum separation rate.
The minimum ammonia separation recognised is 74.9 %.

Operated properly, the Pollo-L exhaust air cleaning system can ensure a minimum ammonia separation of 80.2 % as an average annual value.

An acid tank in the form of an IBC container (capacity of 1,500-1,800 kg) is required.

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 to the indophenol method.

The measurements took place on two dates in both the summer and winter cycles. The results are summarised in Table 5. Aerosol emission levels are very low in summer, amounting to only 0.07 mg/m^3.

The DLG test framework stipulates a maximum of 0.5 mg nitrogen in the form of aerosol emission per standard cubic metre. On average this limit was exceeded by 0.09 mg/m^3 during the winter period measurements. This excess rate is accepted since the limit had not yet been defined by the DLG test commission at the time when the manufacturer applied for the test.

However, it is recommended to reduce the surface area of the droplet separator to increase the exhaust flow rate through the system, particularly when waste air volumes are low. Increasing the load on the filter surface area of the droplet separator will improve aerosol separation when waste air volumes are low. It is possible to reduce the face area. This is shown by evaluating the DLG measurements on the maximum pressure difference in the droplet separator (9 Pa) as determined in the summer.

N balance and N removal

The actual level of nitrogen separation by the single-stage chemical exhaust air cleaning system Pollo-L was verified during the summer and winter. The method applied was N balancing which takes into account the ammonia loads (in the exhaust air and clean air), the presence of inorganic N in the cleaning waste water and the amount of inorganic nitrogen dissolved in the process water.

The DLG test framework stipulates that the rate of nitrogen removal within the nitrogen balance is ≥ 70 % during the test period.

Table 6 illustrates mean NH_3 separation (exhaust air and clean air emissions) and N removal as determined during the N balancing periods.

In the winter, N removal was determined at 84.8 %. For this time period, the average NH_3-N removal rate was calculated to be 91.9 %. In summer the removal rate for NH_3-N was only 78 %, N removal was found to be 83 %. This may seem implausible, since N removal cannot be higher than the average NH_3-N removal.

N removal that is too low (< 70 %) or too high relative to the average NH_3-N separation rate may be an indicator of inadequate desludging measurements or water leakage from the reservoir. But it is also conceivable that other processes

Table 5:
Aerosol emission from the Pollo-L exhaust air cleaning system

		Winter measurement				Summer measurement			
Date		**17.02.2015**		**03.03.2015**		**22.07.2015**		**05.08.2015**	
NH_3 unfiltered C_{Norm}	[mg/m^3]	1.45	1.39	0.93	2.01	1.31	0.94	0.87	0.87
NH_3 filtered C_{Norm}	[mg/m^3]	0.48	0.77	0.84	0.83	1.10	0.89	0.82	0.83
Difference NH_3 C_{Norm}	[mg/m^3]	0.97	0.62	0.09	1.18	0.21	0.05	0.05	0.04
Exhaust air flow volume	[m^3/h]	20,900		31,700		81,800		79,300	
Difference ø NH_3 C_{Norm}	[mg/m^3]	0.80		0.64		0.13		0.05	
Aerosol emission NH_3-N C_{Norm}	[mg/m^3]	0.65		0.52		0.11		0.04	
Mean value of NH_3-N C_{Norm}	[mg/m^3]	0.59		0.07		0.07			
Mass flow ø NH_3-N	[g/h]	15.13		5.85		5.85			

lead to build-up and fallout of nitrogen compounds in the cleaning system.

In this particular case, determining the ligated nitrogen especially in the cleaning water involved high measuring uncertainties. It was not possible to determine the exact levels of ammonia sulphate deposits inside the filter package during the balancing period. As it was not possible to quantify the deposits formed during the previous operating cycles the quantities of inorganic N detected in the cleaning water led to false readings. In analogy, the results of N removal increased.

In addition, it was difficult to determine the exact volume of process water at the time of sampling. The water reservoir of the Pollo-L exhaust air cleaning system holds only small volumes of process water (approx. 1.8 m³). A much greater volume of the process water (approx. 3.7 m³) is circulated by the pumps in the system. This can lead to an over- or undervaluation of the amount of inorganic nitrogen absorbed by the process water and as a result affect the evaluation on N removal.

The measuring uncertainties described herein account for the lower NH_3-N removal (78 %) measurements as compared with N removal rates (83 %) during the summer measurements. Yet, the minimum test requirement of a 70 % N removal is met and recognised.

Table 7 shows how the ammonia N concentration builds up in the process water, as analysed in the winter and summer measurements. The formation of nitrite and nitrate in the process water and the emission of nitrous aires in the clean air do not have to be analysed, as this exhaust air cleaning system operates on a chemical basis.

Table 6:
Separation rate and N removal results measured on the Pollo-L exhaust air cleaning system during the winter and summer measurements

		Winter measurement	Summer measurement 1)
Measurement period		**17.02.15-03.03.15**	**05.08.15-17.08.15 26.08.15-03.09.15**
NH_3-N exhaust air input	[kg]	101.0	70.0
NH_3-N clean air emission	[kg]	9.1	15.4
Difference	[kg]	91.9	54.6
NH_3-N separation rate	[%]	91.0	78.0
$N_{inorg.}$process water	[kg]	38.1	47.8
$N_{inorg.}$cleaning water	[kg]	47.5	10.3
$N_{inorganic}$ sludge	[kg]	0.0	0.0
NH_3-N clean air emission	[kg]	9.1	15.4
Clean air$_{\text{further aireous N compounds}}$	[kg]	0.0	0.0
N emission as per water analysis	[kg]	85.6	58.1
Total emission	[kg]	94.7	73.5
pH value	[-]	2.7 / 3.6	2.9 / 3.3
Conductivity	[mS/cm]	86-123	44-196 2)
Total input	[kg]	101.0	70.0
N emission as per water analysis	[kg]	85.6	58.1
N removal	[%]	84.8	83.0

1) Due to measurement failures and vague desludging results N balancing was split into two time periods to minimise errors.
2) A maximum conductivity of 150 mS/cm is recognised to ensure reliable operation of the Pollo-L exhaust air cleaning system.

Table 7:
Ammonia N concentration in the process water of the Pollo-L exhaust air cleaner in the winter and summer measurements

Winter measurement		Summer measurement	
Sampling taking place Day	**Ammonia N [g/l]**	**Sampling taking place Day**	**Ammonia N [g/l]**
10.02.15	11.5	15.07.15	10.6
17.02.15	14.4	22.07.15	17.3
24.02.15	17.3	29.07.15	24.2
03.03.15	22.4	05.08.15	25.2
10.03.15	23.9	12.08.15	32.4
17.03.15	24.1	17.08.15 1)	34.7
24.03.15	31.4	26.08.15	18.4
27.03.15 1)	33.3	03.09.15 1)	29.0
31.03.15	24.5	10.09.15	20.6

1) After 27/3, 17/3 and 03/09/2015, automatic desludging was activated because of high conductivity and 50 % of the water content in the reservoir was transferred to the storage tank.

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. All conversions to consumption per animal place and year are based on an approved animal population of 24,000 for this building.

The consumption levels indicated are considered as guidance levels that may vary depending on location , form of keeping, management system and individual ammonia and dust emission volumes.

Water consumption

Fresh water must be fed into the system to compensate water differences caused by desludging and evaporation. The use of fresh water and water for desludging must be entered to the electronic operating log (EOL) so that it becomes possible to differentiate between the desludging rate and the actual water evaporation rate. The maximum conductivity in the process water, which accounts for the desludging rate, is permitted to increase to up to 150 mS/cm and is entered to the EOL.

During the entire measuring period (winter and summer measurement) an average of 0.132 m^3/d of material was desludged from the process water. This translates into an annual desludging rate of 48.2 m^3/a or 0.002 m^3/(AP · a).

After deducting the desludging rate from the total consumption of fresh water, it is possible to compute the annual evaporation rate. This is 3.17 m^3/d and equals an annual consumption of 0.048 m^3/(AP · a).

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. Being high in nitrogen, the cleaning water must be buffered in the storage tank.

Any cleaning that needs to be done in the filter package is done with process water. It will not affect the fresh water consumption. Fresh water is used for cleaning the entire system after the egg production period is finished. Depending on the level of system contamination, the consumption rate is 8 to 10 m^3 per cleaning cycle (according to the manufacturer) and translates into a maximum consumption of 0.42 l/(AP · a).

Electrical energy consumption

The continuously operated circulation pump is the biggest electrical consumer in the exhaust air cleaning system. 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. The average annual electricity consumption of the circulation pumps is a calculated 71 kWh/d; this amounts to around 1.08 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 in the summer higher volumes of air have to be removed than in the winter. The measurements showed that electricity consumption was 39.1 kWh/d during the winter period and 79.2 kWh/d during the summer period. These readings equate an average consumption of 0.90 kWh/(AP · a).

Other consumption values

To ensure reliable operation, the system was equipped with automatic acid dosage system 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 circulation that supplies the exhaust air spraying nozzles and the filter package 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 34.2 kg/d or 0.52 kg/(AP · a) must be anticipated. This may be less if the ammonia emission loads are lower. Reliable system function with the described efficiencies is only possible with proper pH regulation (pH ≤ 3.3).

A defoamer (Fatty Alcohol Ethoxylate = surfactant) was used to prevent foam formation in the water circulation system. The amount of defoamer used is calculated at about 18 kg to 20 kg per year.

Operating reliability and durability

No notable malfunctions were found in the system during the test period, nor did any significant damage or signs of wear occur anywhere on the exhaust air cleaning. The spraying patterns applied by the prespraying system and by the filter package sprinkler were inspected once a week. The nozzles were cleaned every two or three weeks during the testing period.

As far as could be observed during the test period, the individual components of the system appeared to be sufficiently protected from corrosion.

The Pollo-L exhaust air cleaning system from Inno+ has an alarm system that reminds the operator of cleaning the filter package. This becomes necessary when over a period of 30 minutes the pressure difference exceeds the maximum pressure difference curve that was established by the manufacturer before the cleaner was taken into operation. Cleaning prevents excessive salination and sludge build-up in the filter package. This is a malfunction that may occur during an egg production period and must be removed immediately.

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. This takes 30 minutes and must be done once a week. If the nozzles require cleaning, the working time extends to one hour.

Also, the operator has to calibrate the pH electrodes every four to six weeks and document this in the service and maintenance log. This takes 15 minutes.

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. During the regular maintenance checks, records are made of the ammonia concentrations in the exhaust air and clean air, the air velocity through the filter package and the rinsing water volume. In addition, the pH value and conductivity meter is calibrated. Furthermore, the condition of the filter package and the pump's electricity consumption are verified and the electronic operating log is checked for plausibility.

An independent inspection of the system can be assigned by the authority and is performed by a measuring agency as lined out in § 26 BImSchG. This inspection comprises regular function checks of the air cleaning system and a graphic illustration of the pH value and the cleaning water conductivity curve. Some districts in Germany require such a mandatory inspection for every system. More information can be downloaded from the Cloppenburg district website.

The main water line to the nozzle bar that moistens the filter package has extra hose connections (DN 50) for fast and intensive filter package rinsing with process water following a system warning due to excessive pressure difference. The large amounts of water that will then rinse specific sections of the filter package dissolve the salt and dirt deposits and flush them into the water reservoir. The flanges and hoses required for rinsing the filter package are stored in the utility room.

After such a cleaning, the water reservoir is drained and refilled with fresh water. The process takes about 2 to 3 hours, depending on the size of the system.

At the end of a egg laying period, it is possible to carry out the cleaning by using process water for a preliminary cleaning.

For reasons of hygiene, this must be followed by a second cleaning with fresh water. This takes 4 to 5 hours depending on the size of the system.

The pH and conductivity sensors must be recalibrated by the operator before the next egg production period begins. Date and time of this calibration test must be documented in the electronic operating log.

Documentation

The electronic operating log records all data essential for the safe operation of the system by taking an average value every 30 minutes. The system manufacturer stores these data for 5 years. They can be read out remotely by the farmer or the manufacturer and imported into a common spreadsheet program. Authorities can download the data to a USB drive. The recorded data 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 buffer time depends on the current fertiliser regulations which specify the liquid manure buffer periods. The feed line to the desludging tank and the buffer tank itself must be suitably specified for the storage of desludging water and must comply with the specific state regulations on substances hazardous to waters (ammonium sulphate). Immediately prior to spreading the desludging water on farmland, it 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. Safe handling of the acid is explained by the manufacturer in specific instructions and is in the responsibility of the operator. All necessary safety facilities must be installed as specified by the licensing authorities. An acid tank in the form of an IBC container (capacity of 1,500-1,800 kg) is required.

Safety aspects

The occupational safety of the described Pollo-L 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 on operating the Pollo-L exhaust air cleaning system.

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

	Met in full	Met in part	Not met	Comments
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	X			Use of frequency controlled exhaust air fans Exhaust air flow can be recorded and stored as m³/h rates by computing the fan output curve or by using measuring fans
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 quantities	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 temperature	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 updated 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 filter package 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 single-stage chemical exhaust air cleaner Pollo-L from Inno+ B.V. is suitable for reducing dust and ammonia emissions from waste air exhausted from layer houses (aviary system).

To ensure a reliable separation of dust and ammonia, the maximum load to which the filter surface area is certified is 2,000 $m^3/(m^2 \cdot h)$.

The pH value range for the process water is pH ≤ 3.3. The maximum conductivity for desludging is 150 mS/cm.

The process parameters described herein meet or partly surpass the minimum requirements laid down in the DLG test framework.

In the winter test, the exhaust air cleaning system achieved a minimum ammonia separation rate of 86 % with a proven N removal of 85 %. In the summer, minimum ammonia separation was 75 % and N removal 83 %., see pages 14, 15.

The recognised minimum separation is 77 % for total dust, 76 % for fine dust PM_{10} and 91 % for $PM_{2.5}$.

Further 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

"Exhaust air cleaning systems for livestock farming installations" (Issue date 03/2016)

Testing board

Test accompanied by

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In addition to being the executing body of well-known tests for agricultural engineering, farm inputs and foods, the DLG is also an open forum for the exchange of knowledge and opinions in the agricultural and food industry.

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