VERA

VERIFICATION OF ENVIRONMENTAL TECHNOLOGIES
FOR AGRICULTURAL PRODUCTION

Test Protocol

for

Air Cleaning Technologies

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Test Protocol for Air Cleaning Technologies

Content

Foreword

To meet the environmental challenges within the livestock production new technologies are developed within the EU member states and elsewhere. They are developed for different parts of the livestock production chain and enhance the eco-efficiency by reducing material inputs, emission of pollutants, energy consumption, recover valuable by-products and minimize waste disposal problems. These technologies are here and elsewhere referred to as environmental technologies.

However, central stakeholders, such as farmers and authorities only have limited information on their performance which hampers the diffusion of these environmental technologies in the livestock production. Therefore, the Dutch Ministry of Housing, Spatial Planning and the Environment, the German Federal Ministry of Food, Agriculture and Consumer Protection, the German Federal Environment Agency and the Danish Ministry of Environment decided in cooperation with experts from Wageningen University & Research Centre in the Netherlands, the German Association for Technology and Structures in Agriculture (KTBL), the German Federal Research Institute for Rural Areas, Forestry and Fisheries, the German Agricultural Society DLG, University of Hohenheim and Kiel University in Germany, University of Aarhus in Denmark, the Danish Institute for Agro Technology and Food Innovation (AgroTech) and the Danish Pig Production to develop common test-protocols for test and verification of a number of these environmental technologies for livestock production The work on the different test-protocols was initiated in October 2008. The work on this test protocol for air cleaning technologies was finalised in September 2010.

These standardized test-protocols are designed to test and verify the environmental performance and operational stability of different environmental technologies for livestock production. Basically, the test-protocols can therefore be used to provide reliable and comparable information on the performance of new technologies to farmers, authorities and other stakeholder and thereby prepare the ground for that these technologies to a higher extent are used in meeting the environmental challenges of the livestock production within the EU.

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1. Introduction

The sustainability of livestock production can be improved by stimulating the use of newly developed technology and equipment designed for better ecological, i.e. eco-efficient performance. The eco-efficiency of the production is enhanced by reducing material inputs, emission of pollutants, energy consumption, recover valuable by-products and minimize waste disposal problems. These environmental technologies have been developed or are in development that can be implemented in different parts of the livestock production chain, like techniques to be applied in animal houses or techniques to storage, manure processing or application.

In order to facilitate the diffusion of environmental technologies for agricultural production it is central that these technologies' environmental performance and operational stability is thoroughly tested, making use of test protocols that incorporate the most recent knowledge on measurement methods.

Therefore, in a joint initiative of parties from Denmark, the Netherlands and Germany test protocols have been developed to test and verify different types of environmental technologies for agricultural production. This paper defines the test protocol for air cleaning systems applied in livestock production.

The objective of this protocol is to specify the test procedure for the eco-efficiency of air cleaning systems in animal housings, including definitions, requirements and conditions for parties involved in the test, measurement and sampling methods, processing and interpretation of measurement results, and reporting.

In this protocol an air cleaning system is defined as a unit connected to the mechanical ventilation system of a livestock housing unit in which the outlet air is treated to reduce the emission of one or more pollutants.

During the last 1-2 decades air cleaning systems have been developed for application in livestock production in North European regions with high animal densities. Initially, air cleaning was especially applied in incidental cases as a mean to abate odour nuisance of livestock operations that increased their production scale near residential areas.

Technological developments were mainly based on adapting biofiltration techniques with organic package materials. In a later phase new policies and regulations to control the ammonia deposition for the protection of sensitive ecosystems stimulated the development of air cleaning systems designed for ammonia removal. A variety of chemical and biological air cleaning systems have been developed for this purpose.

More recently, multi-pollutant air cleaners for the combined removal of ammonia, odour and fine dust, defined as PM10 and PM2.5 were introduced. These scrubbers combine physical, chemical and biological removal principles. Removal of fine dust has become an issue in regions with high background concentration of PM10/2.5 in ambient air. Here, newly (2008) set EU limit values for both PM10 and PM2.5 concentrations in ambient air to protect public health can be exceeded by industrial and agricultural activities. The capacity to remove PM10 and PM2.5 has made air cleaning systems more interesting for application in poultry facilities that exceed fine dust threshold levels in the environment.

Currently about ten European manufacturers are supplying air cleaning systems to livestock producers in Northern Europe. Up to now they have to deal with various admission and assessment procedures in the different nations. Overcoming this fragmentation by an international test protocol and verification scheme will benefit to all stakeholders in assessment procedures, saving time and costs in implementing eco-efficient technologies.

It is important that the scope and performance statements of the international verification system are defined such that its information can be optimally used by different stakeholders in the member states. This implies that the test protocol should provide a broad array of reliable information that can be analyzed and summarized during the verification in such a way that it can be directly or indirectly used by the different national users as widely as possible.

However, for reasons of costs and time, test protocols have restrictions in the number of parameters to be evaluated and applied methods. The starting point in the design of the present test protocol therefore was to create an optimal balance between reliable information that meets the demands of the different users, and costs in terms of time and budgets to carry out the test procedure.

This protocol describes the requirements for testing air cleaning technologies during a defined testing period. The test period and the number of sampling days are determined by the requirements for a statistically adequate evaluation of the removal performance. During the testing period the operational stability and deviations from normal operational functioning shall be observed and registered, and the observations reported in the test and verification report. Specific test parameters for the assessment of long term operational reliability and durability will, however, not be included in this protocol.

Nevertheless it is recommended that durability and maintenance cost of the air cleaners are evaluated 3-5 years after market introduction, although the present test protocol does not include specifications on such an evaluation.

2. Scope

This protocol specifies the information that is needed as basis for an environmental verification of air cleaners for livestock housing systems.

The specified information includes

- a comprehensive description of the air cleaning system: working principle, system description, essential operation parameters, applicable animal housing systems, user manual;
- the technical performance of the air cleaner based on data that are collected during the test period. The protocol specifies requirements for test parameters, measurement methods, sampling strategy, data collection and handling, calculation methods, reporting;
- evaluation parameters to assess the eco-efficiency of the tested air cleaner;
- an evaluation of operating stability of the air cleaning system.

3. Terms and definitions

Air cleaner
Also called air purifying or air treatment systems. End-of-pipe installation for cleaning the exhaust air of forced-ventilated animal housing systems from specified contaminants such as odour, ammonia and dust. Air cleaners operate on different removal principles (physical, biological and/or chemical). Currently bio filters, bio trickling filters, acid scrubbers and multi-stage air cleaning systems are applied for the removal of pollutants from the exhaust air of animal housings. They differ in applicability and removal performance (see Table 1).

Table 1. *Applicability and removal performance of different exhaust air cleaning systems for forced-ventilated animal housing facilities according to present knowledge (from KTBL (2008))*

Type of air Cleaner	Applicability		Assessment of the removal performance		
	Animal category	Manure removal system	Odour	Ammonia	Dust
Bio filter	Pigs, cattle	liquid manure system (no bedding)	++	n.s.	+
Bio trickling filter	Pigs, cattle	liquid manure system (no bedding)	+	+	+
Acid scrubber	Pigs, cattle, dry dung store	liquid manure system (no bedding)	n.s.	++	+
MULTI-STAGE AIR CLEANING SYSTEMS					
Two stages					
Water scrubber + acid scrubber	All kinds of animals	Liquid and solid manure system	0/+	++	++
Water scrubber + bio filter	All kinds of animals	Liquid and solid manure system	++	0/+	++
Acid scrubber + bio filter	All kinds of animals	Liquid and solid manure system	++	++	++
Acid scrubber + bio trickling filter	All kinds of animals	Liquid and solid manure system	+	++	++
Three stages					
Water scrubber + water scrubber + bio filter	All kinds of animals	Liquid and solid manure system	++	+	+++
Water scrubber + acid scrubber + bio filter	All kinds of animals	Liquid and solid manure system	+++	+++	+++
n.s.= not suitable; 0 = conditionally suitable; + = suitable ++ = good; +++ = very good					

Acid scrubber
Also called chemical scrubber. A trickling filter in which the pH of the washing liquid is kept at low levels (pH < 5) by addition of acid (usually sulphuric acid) in order to remove ammonia from the contaminated air. The ammonium ions produced by the chemical reaction between NH_3 and the acid is removed from the system with the discharge water. Due to the low pH-value microbial degradation does not take place. So, odour reduction is relatively insignificant and subject to considerable fluctuations.

Air flow
The volume flow of exhaust air in m^3 $hour^{-1}$ can be given for the entire housing unit or per animal (place). If the system is based on partial air cleaning, the air flow can be spilt into two – the primary air flow through the air cleaner and the secondary, untreated air flow which is blown directly out to the surroundings.

When the external dimensions of a filter are evaluated or when air filter is subsequently up/downscaled on another farm, the air flow per area of front filter in m^3 h^{-1} m^{-2} is a basic parameter.

The air flow can also be given per filter volume in m^3 h^{-1} m^{-3}, which is the reciprocal value of the retention time.

Air purifier
See air cleaner.

Ammonia (NH_3)
A gas derived from e.g. urea (uric acid) excreted by livestock (poultry) and implicated in acidification and nitrogen enrichment of sensitive ecosystems.

Animal housing system
A housing system is defined by the way a certain animal category is stocked (floor and pen design), the system for the management and internal storing of manures produced, the ventilation system to control indoor climate and the type and regime to feed and water the animals.

Animal category
Different types of animals according to their species (pigs, cattle, chicken, ducks and turkeys etc.), sex, age and scope of production (breeding, rearing, growing and finishing for meat, milk or egg production).

Bio filter
Installation in which the exhaust air is led through a filter bed usually consisting of organic material, such as root wood or wood chips. The filter material has to be kept moisture so that gaseous contaminants are absorbed by the moisture film of the bio filter material and generally oxidized or degraded by microorganisms living on the filter material. In order to compensate for evaporation losses and to guarantee proper function the exhaust air has either to be prehumidified e.g. by a washer and/or the filter be has be moistened by controlled intermittent irrigation.

Bio filters are mainly used to eliminate odours in housings with no bedding material. They can also be used for dust separation if coarsely structured filter material, which does not tend to clog, is used at least on the crude gas side. Bio filters as a sole process stage are not suitable for ammonia separation.

Bio trickling filter
Trickling filter for the removal of dust, ammonia, and odour by means of absorption of the contaminants in the liquid phase and degradation by microorganisms settling on the filter elements as a bio film. Ammonia is degraded by a bacterial conversion to nitrite and nitrate; this process is called nitrification. The accumulated nitrate and especially nitrite which may be toxic to the microorganisms has to be removed with the discharged water.

Chemical scrubber
Trickling filter that removes pollutants by means of absorption of the contaminants in a liquid phase with specific chemical properties. In case of using pH for facilitation of pollution removal, the pH value could be obtained by addition of an acid, e.g. Sulphuric Acid (see acid scrubber), or by addition of a base.

Denitrification unit
Biological denitrification units are used for removing oxidised nitrogen species originating from NH_3 in the polluted air. Denitrification is a biological process in which bacteria use one or more of the oxidised Nitrogen species, Nitrate (NO_3^-), Nitrite (NO_2^-), Nitric Oxide (NO) and Nitrous Oxide (N_2O) for respiration under anoxic conditions, while degrading organic material. The ultimate end product of denitrification is atmospheric Nitrogen, N_2 which is harmless in the environment, and N_2O which must be minimised through the controlled denitrification process.

Prior to denitrification NH_3 has to be oxidised within the air cleaner, or in a separate unit external to the air cleaner. The growing of nitrifiers strictly depends on temperature. Therefore it is recommendable to avoid energy losses as far as possible. Good operation results will be achieved at temperatures above 15°C, otherwise growing of the nitrifying bacteria and nitrification rates are very low.

Downtime
The period of time when the system tested is not operating as a result of malfunctions.

Dust
See Particulate matter.

Filter area
The front area of the filter where the air flows in is based on the external dimensions of the filter (m^2).

The specific filter area is the area of the filter material per volume of filter element (m^2 filter m^3 filter element).

Multi-stage cleaning system
Multi-stage exhaust air cleaning systems usually consisting of two or three stages combine different cleaning principles and their advantages (see Table 1), e.g. an improved ammonia separation by an acid scrubber with an optimal odour degradation in a bio filter.

Odour
Pleasant or unpleasant smell caused by different odorants with very different chemical, physical, and biological properties.

The odour concentration is given in European Odour Units per cubic meter air (OU_E/m^3) and the concentration is measured by olfactometric in accordance with the European CEN-standard (EN 13725).

Particulate Matter (PM)
Also called dust. Airborne, finely divided solid or liquid particles with aerodynamic diameters generally less than 500 micrometers. PM10: particles with aerodynamic diameters less than 10 micrometers; PM2.5: particles with aerodynamic diameters less than 2.5 micrometers.

Physical air cleaners
Experimental installations where odorants are intended to be oxidized with the aid of UV-radiation, ozone or a plasma reaction technology. Since the effectiveness of these techniques and others which are currently being developed has not yet been proven in practice to reduce emission of dust ammonia and odour at reasonable costs, they are not described in detail here.

Pressure drop
Pressure drop (Pa) across the air cleaner or across the entire system (animal housing and air cleaner) could be presented as a curve or table for different airflow rates (m^3/hour).

The ventilation fans must be sufficiently pressure-stable so that they are able to overcome the flow resistance of the animal housing and the exhaust air cleaning system at all times in order to supply the animals with the required air rates in particular under summer conditions.

Retention time
The retention time is the period or time length wherein the air penetrates the filter of the air cleaner (sec.).

Trickling filter
Also called trickle bed reactor or more commonly air scrubber or air washer.

Installation in which the polluted air is passed either horizontally (cross-current) or upwards (counter-current) over filter elements that are continuously or intermittently sprinkled with a washing liquid. Due to an intensive contact between air and washing liquid the components contained in the contaminated air change from the gas to the liquid phase.

Currently, water and diluted acids are used as washing media. The decisive factor for the proper operation of these installations is that the separated substances contained in the exhaust air as well as the reaction products are removed from the system by de-sludging, i.e. the draining of polluted wastewater. So, usually a fraction of the washing liquid is continuously recirculated; another fraction is discharged and replaced by fresh water and/or diluted acid.

The reactor (filter) elements are usually made of an inert or inorganic packing material that has a large porosity, or void volume, and a large specific area in order to improve mass transfer. For the prevention of aerosol emission to the environment, drip separators are needed in any case.

Three types of trickling filters are common: acid scrubbers, bio trickling filters, and water scrubbers (see those).

Uptime of the system
The period of time when the system tested is functioning.

Water scrubber
Trickling filter that uses water as an absorbent.

4. System description

The applicant/manufacturer is responsible for providing a precise and full system description before the test starts. The system description shall include all relevant and essential information that is needed

- to organize and design the test,
- to enable the farmer to operate, to maintain and to monitor the system properly,
- to on-line monitor the system including key parameters needed for the determination of the uptime/downtime of the system, and
- to allow the verification authorities to check the system afterwards.

In particular, the description of the air cleaning system shall include

- the range of application with respect to animal category and housing system;
- the system's function in detail and the expected performance of the system with respect to the pollutants (odour, ammonia, dust) to be treated;
- illustrations and/or diagrams of the system (top and sectional views, details if necessary);
- the dimensioning of the system;
- a list of the (technical) components including type (e.g. material and characteristics), technical and functional description, and arrangement;
- a list of the essential design and operational parameters (ranges) that are specific for the air cleaning system to be tested and that are decisive for proper function (see Annex A). Special focus shall be laid on these parameters and their ranges as they are needed for up- and downscaling of a system and for the evaluation to which extent the system can be changed before a new test is needed; changes within the given ranges are not crucial;
- a list of key parameters to be electronically or manually logged during operation of the system as part of system surveillance; this list shall include those parameters listed in Annex B and a description on how they are controlled;
- a compilation of the input materials needed and liquids and wastes produced (including amount and relevant chemical composition).

In addition, the description shall include detailed instructions for operation, service and maintenance and surveillance (see chapter 6).

Finally, the applicant/manufacturer shall provide (by start-up companies if available) information on

- reference units (animal category, type of housing system, animal weights, ventilation rates, and flow resistance in particular),
- which parameters are essential for the calculation of the uptime/downtime of the system (the test institute is, however, responsible for a professional evaluation of whether this information is reliable and sufficient),
- the predicted durability of the system and its components, and
- warranty provisions.

5. Requirements

This chapter describes the requirements related to the test of air cleaning technologies. The requirements described apply to the organization of the test activities, test facilities and test organization, as well as requirements for the framework and contents of the test plan.

In addition the chapter describes the measurement parameters to be included in the test and a specification of the methods to be used. Finally the chapter includes requirements to ensure representative feeding and management conditions on the test facility, and requirements related to the impact of the technology on occupational health and safety as well as animal welfare.

5.1 Pre-testing or a full test of a technology

The test protocol can be used during the phases of developing a new technology (pre-testing) as well as for testing of a final technology (ready for sale) with the aim of verification or certification.

It is strongly recommended to make pre-testing of a new technology before a final test is initiated, and to start a full test of a new technology only when it has shown to be stable and well functioning.

During pre-testing of a technology parts of the test protocol can be used in order to clarify and optimise the performance and stability of a new technology. During such pre-testing of a technology a manufacturer can visit the test facility whenever he wants.

However, during a full test of a technology with the aim of verification or certification all the below mentioned requirements have to be fulfilled.

This means too that the results of a pre-testing can only be used as part of a full test if all the below mentioned specific requirements in 5.2 – 5.4 are fulfilled including quality requirements and requirements/restrictions on farm visit and modifications of the technology.

5.2 Requirements for the organization of the test activities

The test of a new air cleaning technology involves various actors:

1. The applicant which intent to have a technology tested.
2. The test organization which will conduct the required tests of the technology.
3. The farmer(s) which own the facilities where the tests are conducted.

Test plan
It is required that the applicant or test organization writes (in local language) the test plan based on the template in Annex F, and that all questions of the template have to be answered. To reduce the risk that the test results in the end are rejected because they have not been produced in accordance with the test protocols it is advised to confer relevant verification authorities in case of uncertainties about how to prepare the test plan.

The applicant or the test organization can decide whether the test plan shall be handled with confidence.

Prior to start a full-scale test on an air cleaning system an evaluation of the potential risks on normal and potential unintentional use of the product shall be performed in relation to:

1. Animal welfare.
2. Occupational health and safety.
3. External environment.

Full system description of the technology tested
Prior to the test activities starts a full system description of the technology to be tested shall be available, cf. chapter 4. The description shall include detailed instructions for operation, service and maintenance and surveillance.

During the test period
During operation of the system, the applicant/manufacturer of the air cleaner is responsible for electronic logging of a number of key parameters to ensure the operation of the system, cf. Annex B. This logging shall include those parameters essential for the calculation of the uptime/downtime of the system, cf. chapter 4.

The test organisation shall verify that the selected parameters for surveillance of the operation of the system are relevant, essential and adequate.

During the test period the applicant/manufacturer of the air cleaner is not allowed to visit the farm unless they are contacted by the test organisation or the farm owner due to problems with the air cleaner. In this case the applicant/manufacturer can visit the farm but only in company with the farmer and the test organisation.

Any operational problem identified shall be dated and described in the test log-book by the farmer or the test organization. In addition it shall be dated when and how the problem is solved and signed by the farmer, the applicant/manufacturer and the test organisation when repairs have been finalised.

During the test period no changes of the technology are allowed that may have a crucial impact on the cleaning process.

If the applicant/manufacturer has conducted tests on earlier models of the air cleaner, all the test reports must be enclosed including a description of the differences between the models.

The test organisation is responsible for coordinating and implementing the test plan and for drawing up all the necessary data record tables. Furthermore, the test organisation is responsible for the calculation of the uptime/downtime of the system tested.

In addition the test organisation must insure that the log-book is kept in the right place in the housing unit e.g. next to the air cleaner.

The farmer is responsible for recording the production conditions in accordance with the test plan. The farmer must also record the time spent on operational problems and maintenance of the air cleaning system.

5.3 Requirements for the test facility and the test organization

This chapter describes the overall requirements for the lay-out of farms that are used as test facilities. The requirements for management conditions with an emphasis on feeding characteristics are described as conditional measurement parameters in chapter 5.4. To ensure adequate quality of all activities related to the test measurements and reporting, general requirements for the test organization are specified as well in this chapter.

The test facilities used for the test of the air cleaning system must represent farm characteristics that can be considered representative for standard practices in the country in question. The following items have to be considered:

1. Size of the livestock units involved in the test.
2. Stock density.
3. Pen design.
4. Feeding system.
5. Applicability to other housing systems and animal categories (cf. annex I).
6. Manure removal system.
7. Ventilation system: lay-out and dimensioning in relation to number of animals.
8. Management strategy.

The air cleaning system shall be tested under farm conditions that are representative for the standard practices of the animal categories for which the system is intended for use. This implies that requirements are defined to ensure that both the lay-out of the test facility and the management conditions during the test period are representative for the applied categories.

The following requirements are specified for the test organization and involved laboratories:

1. Sampling and measuring of all test parameters listed in Table 3 shall be performed by laboratories accredited acccording to ISO/IEC 17025 *General requirements for the competence of testing and calibration laboratories*. In addition, it is recommended that the test organization fulfils the general requirements of ISO 9001 *Quality management.*
2. For specific measurement parameters, as defined in chapter 5.5, laboratories have to fulfil the specific requirements of the indicated quality standards (see annex C). If internationally standardized methods are not available, nationally standardized methods have to be applied; cf. Annex C.
3. The test organization and involved laboratories must demonstrate relevant and adequate experience and expertise to the IVC – the International VERA Committee. The relevant experience should include measurement experience in livestock production in general and more specific experience in measuring emissions from animal categories that are involved in the test. The involved technicians and researchers should have a thorough understanding of livestock production systems and its management. The test organization must demonstrate its ability to combine measurement experience and livestock production expertise into data collection, handling, analysis, interpretation and reporting that meet the standards of sound research.
4. The test organization has to show their independency from involved actors and the results of the test evaluation.

5.4 Test design and sampling strategy

Basically, the international VERA-test is performed on two farm sites (see Table 2).

The test facilities of both installations shall be representative for farms in the participating states including unit size, feeding regimes and ventilation rates, cf. chapter 5.3.

It is recommended, if possible to perform the two tests on farms located in two different participating countries. In addition it is recommended to perform the tests on the two farm

sites consecutively in order not to waste money if there are fundamental operational problems.

Table 2 describes the main requirements for the sampling strategy.

In addition to the specific sampling and measurement parameters specified below with the aim of producing information on the technical performance of the air cleaner the test design shall include a monitoring of the system and a continuous logging of key parameters over a period of one year (around the test period) as basis for an evaluation of the operation stability of the system, cf. chapter 5.2 and annexes A and B.

The operation stability shall minimum be verified by a one year monitoring by either

a) two monthly visits with overall check up and checking of 'logbook', discharge water, and NH_3 measurement with drains,

or

b) by electronic monitoring of secondary parameters (same requirements as during measurement periods)

Table 2. *Sampling strategy during test of air cleaning systems*

Sampling/ parameters	**Requirement**	
	Test location A	**Test location B**
Sampling period [1]	≥ 8 weeks summer conditions (continuously) ≥ 8 weeks winter conditions (continuously).	Identical to location A.
Sampling points	Simultaneously sampling of inlet and outlet air.	Identical to location A.
Measurement parameters		
Odour, concentration	Weekly, 2 samples per day, sampling period minimum 30 minutes (one sample per day is enough if the sampling time is 120 minutes).	Identical to location A but sampling on 4 days during the 8 weeks winter period and 6 days during the 8 weeks summer period. Sampling days equally spread over the 8 weeks period with at least one sampling during the first week and one sampling during the last week.
Odour, characteristics	Samples have to be analyzed in terms of kind of odour (pig smell, earthy etc.)[2]	No odour characterization.
Dust	Total dust: One 24 hour sample in each of the 8 weeks periods. Measurements of PM10 and PM2.5 are optional[3]	No dust measurements.

[1] Summer conditions: ventilation rate > 80% of maximum ventilation rate. Winter conditions: daily average of ventilation rate shall be low and below 30% of maximum ventilation rate. A minimum of two month interval in between the summer and winter measurements is required.
[2] To define the specific odour of pig or poultry a team of test persons skilled according to EN 13725 is appointed. The team has to be trained to process-typical odours resulting in qualified yes/no statement about the process-typical odour during the olfactometry measurement.

Ammonia	24 hours continuous sampling once a week during each of the two 8 week periods. A 2 week continuous NH_3 sampling shall be carried out within the two 8 week periods[4].	Identical to location A but measurements on only 4 days during the 8 weeks winter period and 6 days during the 8 weeks summer period. Measurement days equally spread over the 8 weeks period with at least one sampling during the first week and one sampling during the last week.
Nitrogen balance - confirmation of stable operation - essential nitrogen balance	Water analyses once a week with pH electric conductivity, NH_4-N, NO_2-N and NO_3-N (within 8 week periods). Period of at least two weeks within 8 week periods with online gas (NH_3, NO_X, N_2O) and volumetric flow measurements (gas and liquid) and water analyses, see Annex D.	No measurements
Operation parameters	During measurements of odour and ammonia: • Air volume flow (continuously). • Temperature. • Relative humidity (before & after the air cleaner). • pH of discharged water.	Identical to location A.
Discharged liquid from the air cleaner	During the 2 week continuous NH_3 measurements the drained discharge water shall be stored in a tank. Liquid samples from the first day, a day in the middle and the last day of the 2 week period shall be taken from the air cleaner and the storage. The samples must be stored in a cooled box immediately after sampling. and analysed for • Amount • pH • Conductivity • NH_4^+ • NO_2^-/NO_3^-	Samples of the recirculation liquid of the air cleaner shall be taken on all days with odour and ammonia measurements. Samples shall be analysed for • Amount • pH • Conductivity • NH_4^+ • NO_2^-/NO_3^-

5.5 Measurement parameters

Two lists of measurement parameters are shown in the two tables below: a list of primary measurement parameters and a list of conditional measurement parameters.

Table 3 shows the primary measurement parameters consisting of the primary environmental pollutants emitted from the mechanical ventilation system of a livestock housing unit and which are the primary targets of the air cleaning system.

As seen in Table 3 the primary measurement parameters are ammonia, odour and dust.

If it is known that the type of air cleaner tested does not reduce a specific parameter or have only marginal effect on it (e.g. the odour concentration in air cleaners using sulphuric acid), or

[3] Measurements of PM10 and PM2.5 are optional due to methodological reasons. More research and experiences are needed before a mandatory requirement will be defined.
[4] The continuous NH_3 measurements to be used for establishing an N-balance.

the manufacturer/applicant for other reasons do not want to perform measurement on a specific parameter, the manufacturer/applicant can decide to specify the cleaning efficiency as zero without making measurements.

Table 3. *Primary measurement parameters*[5]

Parameter/ Unit	**Sample conditions** (where, how and how often)	**Measuring method*** (reference to the method)
Odour [OU/m³]	• Minimum number and distribution of sampling days (cf. chapter 5.4.). • Sampling between 9 am and 4 pm. • Sampling location: Cross section of air outlets, preferably mixed sample • Sampling time: Minimum 30 minutes. • Sampling equipment: Nalophan, 30 litres bags (minimum size).	Standards for measurements exist, see Annex C.
Ammonia [mg/m³]	• Minimum number and distribution of sampling days (cf. chapter 5.4.). Continuous measuring methods.	Photo-acoustic monitor (NDIR), FTIR spectrometer, NOx-chemoluminescence monitor, impinger system.
Dust - PM10 - PM2.5 - Total [mg/m³]	• Minimum number and distribution of sampling days (cf. chapter 5.4.). • Sampling between 9 am and 4 pm. • Sampling time: 30/120 minutes. • Sampling location: Cross section of air outlets (raw air and air outlet (cleaned air)).	Standards for measurements exist[6], see Annex C.

* Other methods can only be used if in compliance with CEN standards or national standards according to Annex C or the state of the art is demonstrated according to the requirements of ISO/IEC 17025.

Table 4 shows the conditional measurement parameters, which include parameters that may influence the emission level of the primary environmental pollutants, e.g. by affecting the performance of the air cleaning system. In addition the table includes other – secondary - environmental pollutants.

Some of the conditional parameters are mandatory while others are optional. In the table the mandatory and optional measurement parameter are marked with “M” or “O”, respectively.

[5] Laboratory practice will be worked out in guidelines (reference documents, to be prepared).
[6] A new, validated standard for measuring the emission of dust from livestock houses is needed.

Table 4. *Conditional measurement parameters*

Parameter/Unit M: Mandatory O: Optional	**Sample conditions** (where, how and how often)	**Measuring method** (reference to the method)
Ventilation rate (M) [m³/h]	Ventilation rate through the air cleaner. Continuous measurements. In housing units with partially air cleaning the ventilation rate must also be measured for the whole housing unit	Fan wheel anemometer covering the whole outlet installed upstream the van. Requirements of fluid mechanics must be respected. Other methods may be used.
Number and weight of animals in the housing unit (M) [kg]	Date, number and weight of animals when they are inserted and taken out of the housing unit.	Weighing, “housing diary”.
CO_2 (O) [mg/m³]	cf. Table 3 “Ammonia” and “General recommendations” above	
CH_4 (O) [mg/m³]	cf. Table 3 “Ammonia” and “General recommendations” above, or combined with odour sampling	
H_2S (O) [mg/m³]	Combine with odour sampling	Electrical resistance of thin gold film
N_2O (M for biological systems only) [mg/m³]	Combine with odour sampling	GC-ECD FTIR continuously if an N balance is needed.
Temperature (M) [°C]	• Continuous measurements. • Sampling location: Air inlet and air outlet.	Thermo couples. Adequate measuring range, sensitivity, detection limit. Consider undesired effects on measuring device through e.g. contaminations, wind or direct sunshine.
Humidity (M) Relative humidity [%]	• Continuous measurements. • Sampling location: Air inlet and air outlet.	Capacity sensor. Adequate measuring range, sensitivity, detection limit. Consider undesired effects on measuring device through e.g. contaminations, wind, water or direct sunshine, frost.
Pressure loss (M) [Pa]	Across the air cleaner alone and across the entire ventilation system including the air cleaner. Continuous measurements.	Manemometer, electronic micro manemometer (difference pressure across membrane).
Noise (O)	Outdoor 1-2 m from ventilation outlet.	Noise level meter ISO 3746
Consumption of electricity (M) [Kwh]	Continuous measurement of 1) electricity consumption by ventilation in general, and 2) by the pumps in the air cleaning system	Both measurements every second week.
Consumption of water (M) [l] [m³] Related to time	Continuous measurement	

Consumption of chemicals (e.g. acid) (M) [mg or kg] mass [l or m³] volume		
Discharged liquid from the air cleaner - Amount (M) - pH (M) - Conductivity (M) - NH_4^+ (M) - NO_2^-/NO_3^- (M) - Chemicals (those added to the air cleaner) (M)	See Table 2. Immediately after sampling the samples must be stored in a cooled box.	Radiometer, GLM
Registration of the dates of emptying the pits or manure channels (M)		
Cleaning of animal house and dunging behaviour (M)	Description of cleaning procedure. Registration of dunging behaviour in each pen on days with odour sampling	
Feeding parameters (M)	During the testing period the dietary protein contents should be within specific ranges for different pig categories and poultry. See Annex H.	
Operational function and stability (M)	Continuous measurements of key parameters for functioning, see Annex B	

5.6 Occupational health and safety requirements

In general, air treatment systems - as all industrial machinery and equipment – must comply with the Machinery Directive (Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)). They must be designed and constructed in such a way that they can be used, adjusted and maintained throughout all phases of their life without putting persons at risk.

In detail the installations must satisfy the essential safety requirements contained in Annex I of the Directive, a correct conformity assessment must be carried out and a “Declaration of Conformity” must be given.

It is the responsibility of the manufacturer/applicant, importer or end supplier of the equipment to ensure that equipment supplied is in conformity with the Directive. In addition, Council Directive 89/655/EEC of 30 November 1989 concerns the minimum safety and health requirements for the use of work equipment by workers at work (amended 2007/30/EC) and places obligations on businesses and employers to take into account potential dangers to operators and other persons using or affected by machines and equipment.

In general terms, the directive requires that all equipment provided for use at work is:

Suitable for the intended use; safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case; used only by people who have received adequate information, instruction and training; and accompanied by suitable safety measures, e.g. protective devices, markings, warnings.

In addition, ISO 12100-2:2003 *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles* define technical principles to help designers in achieving safety in the design of machinery.

The obligations mentioned above must generally be applied and especially with respect to the chemical washers and the chemical stages of multiple-stage installations operated with inorganic acids, such as sulphuric acid, although the acid is strongly diluted in the washing stages.

The safety instructions must be documented in a safety data sheet and must be observed carefully.

In addition to design and construction of all installations in such a way that they can be used, adjusted and maintained throughout all phases of their life without putting persons at risk, good ventilation and appropriate protective equipment, such as acid-resistant protective clothing, eye protection, etc. are required. Moreover, one must make sure that protective installations, such as eye wash and shower units, are available and work properly.

Additionally, chemical washers and the chemical stages of multiple-stage installations should first be rinsed thoroughly with water after they have been shut down. In these installations, acid and salt residues deposit on the highly porous lamellas as well as other filter walls. These residues must be removed.

5.7 Animal health and welfare

The air cleaner is connected directly to the ventilation system in the housing unit. Therefore, the air cleaner will have a direct impact on the climate in the housing unit and on the health and welfare of the animals.

Generally the housing system, the climate in the housing unit and the welfare of the animals should be in compliance with the national regulations. Problems may, however, arise in housing units with air cleaning systems, if they are not properly designed and operated.

For example, the air cleaner could result in:

- different air qualities in the individual pens;
- fluctuations in the ventilation flow and temperature level;
- problems with the air inlet in housing units with diffuse air intake through the ceiling;
- emergency ventilation in the housing unit in connection with power failures
- tail biting;
- increased respiratory problems among the animals;
- reduced thermal comfort;
- reduced productivity and, in extreme cases, death among the animals.

The above points are further elaborated in Annex G, and all the descriptions are based on practical cases in which air cleaners have been connected to the ventilation system.

Since the air cleaning system can affect the welfare of the animals and, in extreme cases, can result in death among the animals, the companies that install the systems should be able to demonstrate that they are experts in ventilation and climate control in animal housing units. The systems shall be designed, operated, and controlled in such a way, that that animal health and welfare are not negatively affected. Furthermore, the test organisations must also be able to assess the entire air cleaning system and not just the individual air cleaner.

It is recommended that the test organisation and the manufacturer/the company that installs the air cleaning system are able to demonstrate theoretical and practical knowledge of:

- thermal comfort for animals;
- climate control in animal housing units;
- design of the ventilation duct system;
- electronic control of the ventilation system in the entire housing unit;
- regulatory demands and safety recommendation relating to the alarm system;
- project management;
- spoken and written advice for the farmer and his employees.

6. User manual

In general, the user manual shall be written in a local language and in consideration of EN 62079:2003 *Preparation of instructions - Structuring, content and presentation* that provides general principles and detailed requirements for the design and formulation of all types of instructions.

The manual shall include the information provided with the system description according to chapter 4. In particular, it should bear instructions for

- the operation of the system;
- the prevention of and dealing with incidents (environmental safety);
- operational health and safety measures (see chapter 5.5);
- service and maintenance:
- surveillance of the installation.

Corresponding requirements for the different cleaning systems are described in detail in KTBL (2008). Some examples are given in Annex I.

7. Test reporting and evaluation

The test report shall be written in English and in the local language.

Generally, the test results shall be reported on the basis of EN 15259 *Air quality - Measurement of stationary source emissions - Requirements for measurement sections and sites and for the measurement objective, plan and report*.

The report shall include chapters on the below mentioned subheadings. The following text gives a description of the contents which must be included in the chapters.

Foreword
The foreword should include a description of the three parties that have been involved in the test - the applicant, the test organisation and the farmers.

The period in which the test has been performed must also be mentioned with specific dates.

The foreword must end with the date and signatures of the person(s) who have been responsible for the test. The signature must be accompanied by the name and address of the test organisation.

Introduction
The introduction may include a general description of, for example, the odour, and ammonia and dust problems in the agricultural sector and the need for new technology.

In addition, the introduction shall include a description of the manufacturer/applicant involved in the test and give a general description of their air cleaner. If the applicant/ manufacturer has performed previous tests, these shall be specified, and references shall be provided.

Materials and Methods
The materials and methods section shall include a description of:

- the farms involved in the test;
- the air cleaning system:
- the measurement method including measurement uncertainty.

The housing unit in which the test is performed shall be described. The description shall include the

- animal category;
- the number of sections that are connected to the air cleaning system;
- the dimensions of the sections and pens;
- the number of pens per section;
- the number of animals per section.

In addition, the type of floor, dunging system, feed system and ventilation system shall be described. Photos taken inside the sections and photos of the housing unit shall be included in the test report.

The description of the housing unit shall be followed by a description of the air cleaner, dimensioning criteria and the control principle, and a description of how the air cleaner is connected to the ventilation system. More specific details can be included in an appendix. The test report must also include photos and any drawings of the air cleaning system.

The description of the air cleaner shall be followed by a description of the test design, the dimensioning of the test and the measurement methods, including a specification of the measurement instruments used, the measurement points, and the measurement frequency and calibration procedures.

Furthermore the test report shall include a description of the statistical data processing method, including used models and the statistical software package.

Results
The description of the results starts with a specification of the measured primary parameters (odour, ammonia and dust concentrations, cf. Table 3) which are the primary targets of the test. The individual raw data shall be shown first in graphs and subsequently the processed data shall be given in tables with median, average and 95 percentile.

After the presentation of the raw data a discussion of the results shall be given.

The average and standard deviation of the conditional measurement parameters (cf. Table 4) shall be shown in tables and commented on in the text.

A mass balance for nitrogen shall be shown if necessary, cf. Annex D.

The average and standard deviation of the supplementary measurement parameters shall be shown in tables and commented on in the text.

An evaluation of the operating stability of the system shall be given. This evaluation shall be based on observations made during the entire testing period and shall include all recorded data describing the stability of the air cleaning system.

The uptime of the technology during the test period shall be calculated as well as the efficiency of the technology corrected by the uptime factor.[7]

Furthermore, the test report shall include an evaluation of the potential risks which may be related to the use of the system including potential impact on

- the health and welfare of the animals;
- the occupational health and safety;
- the total (external) environment.

These evaluations shall include situations with normal operation of the air cleaning system and any unforeseen use and problem.

The test report shall include advice to the authorities on how to inspect the system, cf. Annex B Monitoring and documentation of operation.

Finally the test report shall include an evaluation of how the results can be applied to other types of animal housing units or other animal categories cf. Annex I.

Conclusion
The conclusion describes and discusses the test results and validates the air cleaner in general. The conclusion chapter shall include only such aspect that can be justified in the results chapter in the test report.

[7] If, for example, the cleaning efficiency of a technology is 90% and the uptime is 80% the corrected efficiency of the technology is 72%.

References
Relevant references to be specified.

Annexes
Annexes can be added if relevant.

8. Bibliography

EN 481:1994 *Workplace atmospheres - Size fraction definitions for measurement of airborne particles.*

EN 12341:1999 *Air quality - Determination of the PM 10 fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods.*

EN 14907:2005 *Ambient air quality - Reference gravimetric measurement method for the determination of the PM2,5 mass fraction of suspended particulate matter.*

EN 13284-2:2004 *Stationary source emissions - Determination of low range mass concentration of dust - Part 2: Automated measuring systems.*

KTBL (2008) *Exhaust Air Treatment Systems for Animal Housing Facilities*. KTBL Publication 464, Darmstadt.

For other measuring standards, see Annex C.

Annexes

Annex A (mandatory) Decisive design and operational parameters

The description of the air cleaning system to be tested shall include a list of the essential design and operational parameters (ranges) that are specific for the system and that are decisive for proper function.

The description shall include the parameters listed below. The relevant parameters depend on the cleaning principle; largest differences occur between bio filters and other systems.

Examples for the design and ranges of operational parameters of different air cleaning systems that have been tested in Germany are published in KTBL (2008).

Parameter (total system or cleaning stage)	**Unit**	**Specification**
Filter surface load	m³/(m² h)	
Filter volume load	m³/(m³ h)	
Thickness of the contact bed packing	m	
Specific contact bed surface	m²/m³	
Dwell time[1)]	s	
Pressure loss[1)]	Pa	
Sprinkling density	m³/(m² h)	
Fresh water requirements[1)]	l/1 000 m³ exhaust air	
Sulphuric acid requirements (96 %)	kg/kg NH_3-input	
pH-value of the washing water	–	
De-sludging / elutriation rate	m³/kg NH_3-input	
Only bio filters:		
Evaporation losses		
- Summer conditions, full load	l/(m² h)	
- Winter conditions	l/(m² h)	
Recommended sprinkling intervals		
- Summer conditions	h	
- Winter conditions	h	
Service life of filter materials (rough values)		
- Coarse root wood	years	
- Chips, bark mulch	years	
Removal of salts and reaction products by means of		
- De-sludging	–	recommended for filter materials with long service life
- Filter material change	–	recommended for filter materials with short service life

1) In the case of multi-stage systems for the total installation

KTBL (2008) *Exhaust Air Treatment Systems for Animal Housing Facilities*. KTBL Publication 464, Darmstadt.

Annex B (mandatory) Monitoring and documentation of operation

In principle, all exhaust air cleaning systems should be equipped with an electronic operations logbook which records data relevant for operation. Mainly it serves to document the proper operation of the exhaust air cleaning system.

The most important parameters to be recorded in this logbook are listed in the following table for the different cleaning techniques (KTBL (2008).

Parameter	Bio filter	Bio trickling filter	Acid scrubber and multi-stage systems
Pressure loss in the exhaust air cleaning system	X	X	X
Air flow rate [m^3/h]	X	X	X
Pump running times (separate for the circulation pumps and the elutriation pump)		X	X
Sprinkling intervals	X	X	X
Total water consumption of the exhaust air cleaning system	X	X	X
Proof of acid consumption (with receipts, only if acid is used)		M	M
Elutriated water quantity and its discharge, conductivity		X	M
Keeping of the pH-value		X	X
Water pressure (for house water supply)	X	X	X
Crude gas temperature	X	X	X
Clean gas temperature		X	X
Calibration of the pH sensor		M	M
System control – sprinkling pattern	M	M	M
Maintenance and repair times (including the kind of work)	M	M	M
Change of the filter material	M		

X = electronic recording, M = manual recording (computer or list).

Operational data such as pressure loss and air rate, the running times of the pumps and the sprinkling intervals, as well as data regarding the consumption of freshwater and acid (if applicable) as well as the quantity of wastewater are generally relevant.

In addition, significant parameters, such as the pH-value in bio trickling filters, chemical scrubbers, and multi-stage cleaning systems as well as water pressure in house water supply as well as crude and clean gas temperatures must be documented. Moreover, the calibration of the pH-sensor, the control of the sprinkling pattern, as well as maintenance and repair times should be recorded. Operational values, such as pressure loss, pH-value, temperatures

etc. must be archived in hourly intervals.

The air rate can be determined with the aid of measuring fans or the operating points of the ventilation system, for example. This requires the precise determination of the operating points of the ventilation system (at least 3, better 5) which correspond to the different rotational speeds of the ventilation fans in the animal house. In addition, the actual volume flows must be established in advance. The operating points are the intersecting points of the characteristic curve of the fans and the so-called system characteristics, which are the sum of resistance in the system.

In bio trickling filters, the elutriated water quantity is either measured automatically, or it can be controlled based on conductivity, which may not exceed 15 mS/cm in the washing water.

In individual cases, it may be necessary to document others or additional parameters besides those listed in the table above.

This in particular also applies to exhaust air cleaning techniques which cannot be classified as a variant of one of the described techniques. Methods such as oxidizing exhaust air cleaning, which clean the air with the aid of additives, would fall under this category. In this case, the additive quantities consumed would have to be recorded in a suitable form.

The data of the electronic operations logbook help farmers to run their installations efficiently and in a cost-effective manner. If pressure losses grow due to improper operation, for example, while the air volume flow remains constant, this leads to significant additional energy costs, which could be avoided. Significantly higher acid consumption values also show that the exhaust air cleaning system is operated improperly and, hence, causes unnecessary expenses. If maintenance contracts are concluded, these costs decrease if any of the potential faults are detected because the information needed for the elimination of the malfunctions is available immediately.

In addition, the electronic operations logbook allows the farmer to prove the proper operation of the installation at any time if neighbours complain or if such proof is required by the supervising authority. This improves legal security significantly.

KTBL (2008) *Exhaust Air Treatment Systems for Animal Housing Facilities*. KTBL Publication 464, Darmstadt.

Annex C (mandatory) List of standards for testing of air cleaning systems

General

Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast

EN ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories.

EN 15259:2007 Air quality - Measurement of stationary source emissions - Requirements for measurement sections and sites and for the measurement objective, plan and report.

EN 12599:2000 Ventilation for buildings - Test procedures and measuring methods for handing over installed ventilation and air conditioning systems

EN ISO 12100-2:2005 Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles

***EN 62079*:2003** Preparation of instructions - Structuring, content and presentation.

ISO 3600:1996 Tractors and machinery for agriculture and forestry - Operator's manuals and technical publications – Presentation.

KTBL (2001) Messmethoden für Ammoniakemissionen. KTBL-Schrift 401, Darmstadt.

IMAG (2002) Meetmethoden gasvormige emissies uit de veehouderij (Measurement methods for gaseous emissions from livestock production), IMAG-rapport 2002-12, Wageningen.

Measurement of particles

EN 13284-1:2001 Stationary source emissions - Determination of low range mass concentration of dust - Part 1: Manual gravimetric method.

VDI 2066 Blatt 1, Ausgabe: 1975-10 Messen von Partikeln; Staubmessungen in strömenden Gasen; Gravimetrische Bestimmung der Staubbeladung; Übersicht

VDI 2066 Blatt 2, Ausgabe: 1993-08 Messen von Partikeln; Manuelle Staubmessung in strömenden Gasen; Gravimetrische Bestimmung der Staubbeladung; Filterkopfgeräte (4 m³/h, 12 m³/h)

VDI 2066 Blatt 3, Ausgabe: 1994-01 Messen von Partikeln; Manuelle Staubmessung in strömenden Gasen; Gravimetrische Bestimmung der Staubbeladung; Filterkopfgerät (40 m³/)

VDI 2066 Blatt 4, Ausgabe: 1989-01 Messen von Partikeln; Staubmessung in strömenden Gasen; Staubbeladung durch kontinuierliches Messen der optischen Transmission

VDI 2066 Blatt 5, Ausgabe: 1994-11 Messen von Partikeln; Staubmessung in strömenden Gasen; Fraktionierende Staubmessung nach dem Impaktionsverfahren - Kaskadenimpaktor

VDI 2066 Blatt 6, Ausgabe: 1989-01 Messen von Partikeln; Staubmessung in strömenden Gasen; Bestimmung der Staubbeladung durch kontinuierliches Messen des Streulichtes mit dem Photometer KTN

VDI 2066 Blatt 7, Ausgabe: 1993-08 Messen von Partikeln; Manuelle Staubmessung in strömenden Gasen; Bestimmung geringer Staubgehalte; Planfilterkopfgeräte

VDI 2066 Blatt 10, Ausgabe: 2004-10 Messen von Partikeln - Staubmessung in strömenden Gasen - Messung der Emissionen von PM<(Index)10> und PM<(Index)2,5> an geführten Quellen nach dem Impaktionsverfahren

Measurement of odour

EN 13725:2003 Air quality - Determination of odour concentration by dynamic olfactometry

VDI 3940, Ausgabe: 1993-10 Bestimmung der Geruchsstoffimmission durch Begehungen

Measurement of Ammonia

KTBL (2001) Messmethoden für Ammoniakemissionen. KTBL-Schrift 401, Darmstadt.

IMAG (2002) Meetmethoden gasvormige emissies uit de veehouderij (Measurement methods for gaseous emissions from livestock production), IMAG-rapport 2002-12, Wageningen.

Analysis of effluent water

Ammonium Nitrogen:

EN ISO 11732: 2005 Water quality - Determination of ammonium nitrogen - Method by flow analysis (CFA and FIA) and spectrometric detection

EN ISO 14911: 2000 Water quality - Determination of dissolved Li+, Na+, NH4+, K+, Mn2+, Ca2+, Mg2+, Sr2+ and Ba2+ using ion chromatography - Method for water and waste water

DIN 38406-E5: 1983-10 Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung; Kationen (Gruppe E); Bestimmung des Ammonium-Stickstoffs (E 5) (German standard methods for the examination of water, waste water and sludge; cations (group E); determination of ammonia-nitrogen (E 5))

Nitrite Nitrogen:

EN 26777: 2003 Water quality - Determination of nitrite - Molecular absorption spectrometric method

EN ISO 10304-1: 2009 Water quality - Determination of dissolved anions by liquid chromatography of ions - Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulphate

EN ISO 13395: 1996 Water quality - Determination of nitrite nitrogen and nitrate nitrogen and the sum of both by flow analysis (CFA and FIA) and spectrometric detection

Nitrate Nitrogen:

EN ISO 10304-1: 2009 Water quality - Determination of dissolved anions by liquid chromatography of ions - Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulphate

EN ISO 13395: 1996 Water quality - Determination of nitrite nitrogen and nitrate nitrogen and the sum of both by flow analysis (CFA and FIA) and spectrometric detection

DIN 38405-09-2/9-3: 1979-05 Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung; Anionen (Gruppe D); Bestimmung des Nitrat-Ions (D 9) (German

standard methods for examination of water, waste water and sludge; anions (group D), determination of nitrate ion (D9))

DIN 38405-029: 1994-11 Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung - Anionen (Gruppe D) - Teil 29: Photometrische Bestimmung von Nitrat mit Sulfosalizylsäure (D 29); ISO 7890-3:1988, modifiziert (German standard methods for the examination of water, waste water and sludge - Anions (group D) - Part 29: Spectrometric determination of nitrate with sulfosalicylic acid (D 29); ISO 7890-3:1988, modified)

Gas analysis

Methods:

VDI Richtlinie 3496 Blatt 1 (1982-04) Messen gasförmiger Emissionen; Bestimmung der durch Absorption in Schwefelsäure erfaßbaren basischen Stickstoffverbindungen (Gaseous emission measurement; determination of basic nitrogen compounds seizable by absorption in sulphuric acid.

Annex D (mandatory) Nitrogen balance

Air cleaning technologies used in animal husbandry shouldn't contribute to secondary trace gases which may create stronger environmental impacts than the raw gas compounds itself. An unintentional transformation of ammonia into NO_x and N_2O is one example for those processes.

With a nitrogen balance of air cleaning technologies the following goals should be achieved:

- Documentation of all relevant processes within the air cleaning system.
- Documentation of possible secondary trace gases with a very high greenhouse potential (N_2O) or caustic character (NO, NO_2).
- Securing a long operating air cleaning technology by nitrogen mass equation.

For a nitrogen balance of an air purification system all possible mass flows as indicated in Figure 1 have to be considered in principle.

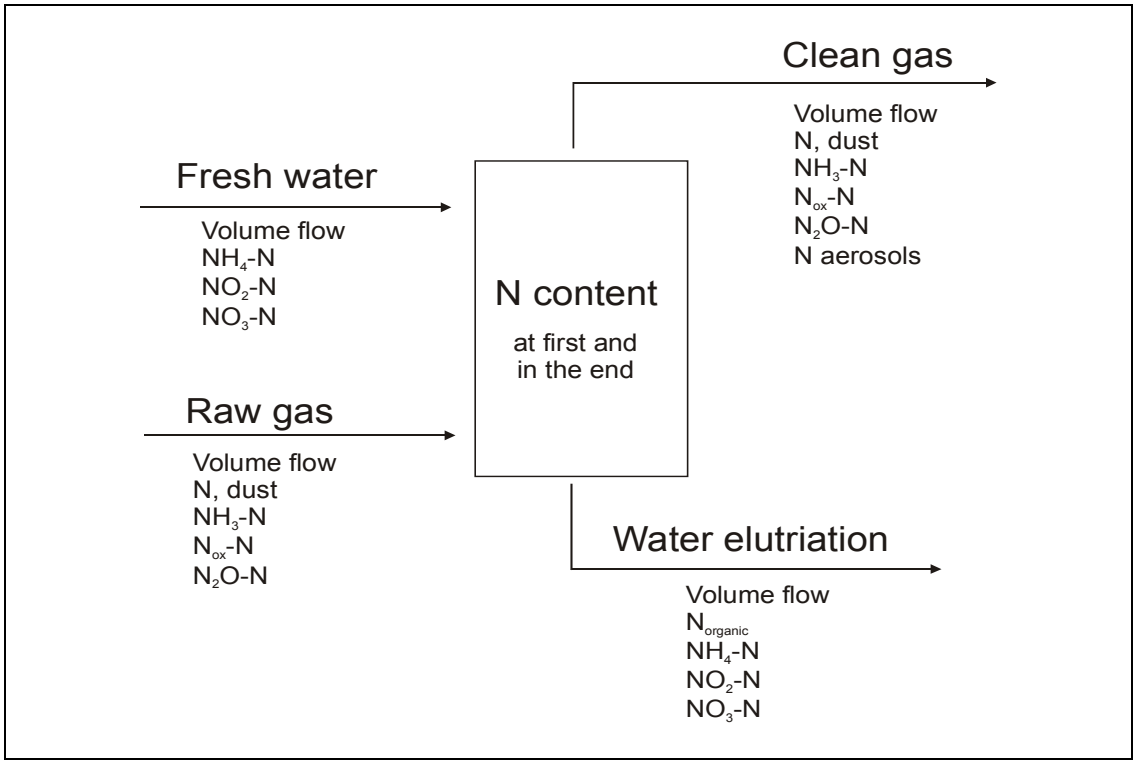

Figure 1. *Overview of required data for a nitrogen balance of an air cleaning system*

The question, whether a nitrogen balance is required, depends on the kind of technology used for air cleaning. It is not necessary for mechanical dust separation systems, for instance.

For chemical scrubbers with low pH values in the washing liquid it is reasonable to get information on aerosol discharge and precipitation processes (filling material, droplet separator) within the system. Normally only reduced nitrogen compounds as NH_3 and NH_4^+ have to be considered for balancing chemical scrubbers. One example of a nitrogen balance

of a chemical scrubber is published in the DLG-Bericht 5629 Uniqfill Air b.v., zweistufige Abluftreinigungsanlage “Chemowäscher (+)” [1].

In contrast to that a nitrogen balance for biological operating air cleaning systems is more complex and should comprise the data mentioned in Figure 1. Bio trickling filters and conventional bio filters with an organic filter material can significantly contribute to secondary trace gas emissions, if there is no sufficient water elutriation (bio trickling filters) or change of material (bio filters).

In the latter cases operation parameters as elutriation rate, pH or other parameters as the oxygen concentration in the washing liquid by varying the irrigation density have to be changed to reduce environmental impacts. This is done in close cooperation of the expert team and the accredited laboratory.

The extent of required measurements, number of samples, sampling points, measuring period, analytical devices and measuring methods will be fixed by an expert team and an accredited laboratory (ISO 17025). It will be concretised in particular cases prior and during the test period (one year in Germany).

The measurements should start after realization of a stable operation of the system as a stable operation of the system is a prerequisite for obtaining a reasonable N-balance.

Literature:

[1] DLG e.V.: Testzentrum Technik & Betriebsmittel: DLG-Bericht 5629 Uniqfill Air b.v., zweistufige Abluftreinigungsanlage “Chemowäscher (+)”, see www.dlg-test.de/pbdocs/5629.pdf.

Annex E (informative) Template for a test plan

NAME OF TEST INSTITUTE

TEST PLAN FOR [name of air cleaner]

[name of air cleaner] **integrated in ventilation system from** [name of manufacturer/applicant]

CONTACT DATA ETC.:

Herd owner / Chr. No.:	
Address of housing unit (if different from the address of the herd owner)**:**	
Health status:	
Visiting rules:	
Start of test of test (dd/mm/yy):	
End of test (dd/mm/yy):	
Responsible technician:	
Technician(s):	
Consultant(s) from the test institute:	
Local advisor/veterinarian:	
Contact person from the company financing the test:	
Service technician(s) from the air cleaning company and ventilation company:	
File:	

BACKGROUND AND AIM [maximum of one page]

A description of the air cleaning system including the ventilation system can be seen in Annex X. The development process of the air cleaner and any previous tests shall be specified (references shall be mentioned in the reference list at the end of the test plan).

The section shall include a precise description of the aim of the test and a specification of the primary test parameters.

TEST PROCEDURE

The description of the test procedure shall include the following items:

- Description of the herd, its management, and of the air cleaning system where the test is conducted. (Previous description of the individual components in the air cleaner shall be specified in an appendix to the test plan. The verification authorities can then check that the applied air cleaning system is identical to the tested system).
- Specification of the primary measurement parameters, e.g. odour and ammonia: concentration before, in the middle and after the air cleaner (see Table 3) and the methods applied.
- Specification of the secondary measurement parameters and methods applied (see Table 4).
- Description of the location of measurement points, the sampling gas tubes, the instruments and how they are calibrated with consideration of EN 15259:2007: *Air quality - Measurement of stationary source emissions - Requirements for measurement sections and sites and for the measurement objective, plan and report*.
- Description of the work procedures in the housing unit and how the animal production parameters shall be recorded (see Table 4).
- Timetable for the entire test period.
- Logbook (location of logbook and description of parameters that shall be recorded).

DATA RECORDING

The tables to be used shall be stated.

ALLOCATION OF RESPONSIBILITY

The allocation of responsibility shall include all work processes, so the technician can use the list when instructing the stockmen.

A list should be drawn up for each section and for each air cleaner.

What needs to be done	When	By who

PROCESSING OF RESULTS

Raw data shall be presented in tables, which shall be included in appendices in the final test report. The raw data shall also be presented in graphs, which shall be included in the results section in the final test report.

The primary measurement parameters shall then be analysed in order to determine whether the concentration and emission after the air cleaner are statistically significantly different from the levels before the air cleaner.

For example, the ammonia concentration and the logarithmically transformed odour concentration can be processed with an analysis of variance in the MIXED Procedure in SAS (SAS Inst. Inc., Cary, NC). Both the median and the 95 percentiles shall be calculated for odour concentration, odour emission and percentage differences before and after the air cleaner. For the other primary parameters, the average shall be calculated instead of the median.

The average and the standard deviation shall be calculated for the secondary parameters.

COMPENSATION

The herd owner is provided with compensation in connection with the test. The herd owner is paid DKK/Euro XXX per hour for any extra work.

APPENDICES

The appendices shall include all data recording tables, e.g. tables for

- Odour recordings.
- Ammonia recordings.
- Dunging behaviour.
- Production data.

UPDATINGS OF THE TEST PLAN

The test plan shall be up dated every time changes are made. It is not enough to list the changes in the logbook. For each update, the date for the changes shall be noted and the test plan shall be given a new version no.

Example:
1st version: DD/MM/YY initials 1 / initials 2
2nd version: DD/MM/YY initials 1 / initials 2

Annex F (informative) Example of a contract

CONTRACT

BETWEEN [name of the company financing the test]

AND [name of the test organisation]

AND [name of the farmer(s)]

ABOUT Test of the air cleaner called [name of air cleaner] delivered from [name of manufacturer/applicant]

****

1 AIM

1.1 The aim is to test the air cleaner called [name of air cleaner] according to the test protocol called [name of test protocol].

2 SCOPE AND TEST PROCEDURE

2.1 The test includes the air cleaner and the connected ventilation system in a unit for sows/weaners/finishers weighing between xx and yy kg or poultry…...

2.2 The enclosed test protocol states how the test shall be conducted and specifies which data recordings and analyses shall be performed.

2.3 The animals included in the trial shall be housed in accordance with EU and national legislation.

2.4 The herd owner, the company financing the test and the manufacturer/applicant shall agree that all results shall remain confidential during the test period and until the final test report is published.

2.5 Data recordings and analyses can be conducted by other institutes, provided that this is specified in the contract.

2.6 The generation of data and the realisation of analyses shall be performed by accredited laboratories following ISO 17025. If analyses are carried out through other institutes the accredited test institute have the responsibility for the generated data.

2.7 The service contracts shall be drawn up before the test starts and shall not be changed during the test period.

3 REQUIREMENTS

3.1 Requirements for checking feed and production specified in the working plan shall be met by the herd owner.

3.2 All production-related data shall be available, including receipts for purchases and sales of animals and receipts for feed.

3.3. Animals shall only be moved in accordance with the guidelines laid down by the test institute.

3.4 Changes to the housing unit and/or the production shall not be made without an agreement with the test institute.

3.5. During the contract period, the herd owner shall not conduct tests together with other parties other than the test institute.

3.6. The herd owner shall agree to inform the herd veterinarian and production consultant that the test is being conducted.

4 HERD VISITS / INFORMATION / ANALYSIS

4.1 As required, a technician from the test institute shall conduct an inspection of the herd and the air cleaning system. The technician collects data and provides the herd owner with data recording tables. Further details of the visits are described in the enclosed test protocol.

4.2. The results of the test shall remain confidential until the results have been published.

4.3. Analyses of the feed content shall be performed in accordance with the test plan.

5 TERMINATION OF THE CONTRACT

5.1 The contract runs until DD/MM/YY.

5.2 The contract is irrevocable for the farmer, the test institute and the manufacturer/applicant until DD/MM/YY.

5.3 In case of unforeseen problems with the animal production or air cleaner, the contract and test protocol can be reconsidered. If it is not possible to find a solution, the farmer, the test institute and/or the manufacturer/applicant may terminate the test with one month’s notice.

6 VISITING RULES

6.1 When the herd owner signs the contract, he shall declare that the health status of the herd is _____. The test institute shall be informed immediately of any disease outbreaks where the health status of the herd is at risk.

6.2 In order to disseminate the knowledge of the new technology, the herd owner shall agree to receive visits when contacted by the test institute.

6.3 During herd visits, the herd owner shall agree to observe the general visiting rules, i.e. quarantine period of at least 12 hours after contact with livestock with a lower health status than that of the herd owner's livestock. Quarantine is not required after visits on farms with livestock with a higher health status or the same health status.

If the herd owner has established his own visiting rules, these rules shall also be complied with.

7 COMPENSATION

7.1 Compensation is paid for extra work carried out during the test period. The herd owner is paid DKK/Euro XXX,- per hour for extra work.

This point shall include any agreements made by the three parties regarding the amount of compensation and what the compensation covers.

8 RESPONSIBILITY

8.1

8.2

9 RECONSTRUCTION COSTS

9.1 Costs relating to changes or installations that can be attributed to a specific test are covered by the test institute or the manufacturer/applicant.

9.2 Equipment and material purchased by the test institute or the manufacturer/applicant belong to these parties, unless otherwise agreed.

9.3 Ownership after completion of the test shall be specified.

9.4 If the herd owner terminates the present contract during the test period (see point 5.3), the test institute and manufacturer/applicant reserve the right to decide what to do with the equipment installed on the farm. The herd owner can, by agreement with the test institute, acquire the entire installation at a fixed price.

9.5 If the test institute or the manufacturer/applicant terminate the present contract during the test period (see 5.3), the ownership of the installation and equipment is as

specified in point 9.3. Furthermore, if the manufacturer/applicant terminates the contract during the test period, they shall pay for the measurements taken so far.

9.6 If the herd owner goes bankrupt or the farm is put up for sale, the test institute is entitled to reclaim the equipment purchased by the test institute. The same applies to the manufacturer/applicant if the company goes bankrupt or closes down.

9.7 The herd owner is responsible for maintaining the equipment and covering the costs of fire insurance for the equipment installed in connection with the test. The herd owner is also responsible for ensuring that the equipment is in compliance with the environmental approval.

9.8 With regard to test facilities established on the farm in connection with the test, the test institute and the manufacturer/applicant are subject to the legislation of the country in which the test is performed. The test institute is therefore not liable for any operating loss and cannot be held responsible for any indirect loss arising from the test facilities.

Date and place

_____

Herd owner

Date and place

_____

Applicant/Manufacturer

Date and place

_____

Test organisation

Annex G (informative) Animal welfare and the air cleaning system

Section 5.7 *Animal health and welfare* includes a number of examples of how connecting the air cleaner to the ventilation system in the housing unit could have a negative effect on the welfare of the animals. These examples will be described in greater detail in the following sections, so that companies that connect air cleaners to the ventilation system can learn from previous mistakes. The test organisation can also use the descriptions when they assess the entire air cleaning system.

The following points will be described in detail:

- Different air qualities in the individual pens.
- Air exchange in the housing unit in general.
- Fluctuations in the ventilation flow and temperature level.
- Problems with the air inlet in housing units with diffuse air intake through the ceiling.
- Emergency ventilation in the housing unit in connection with power failures.
- Tail biting.
- Increased respiratory problems among the animals.
- Reduced thermal comfort.
- Reduced productivity and, in extreme cases, death among the animals.

Different air qualities in the individual pens
The housing units have previously been ventilated by a number of fans placed at regular distances from each other throughout the housing unit. When connecting the air cleaner to the ventilation system, some companies reduced the number of outlets either due to lack of knowledge or in order to reduce the installation costs.

This has resulted in an inconsistent air quality in the individual section. The animals placed farthest away from the outlet had a reduced air quality with greater ammonia and carbon dioxide concentrations.

Air exchange in the housing unit in general
One of the general problems for the housing unit is that the air exchange in the individual section is reduced as a result of gradual clogging of the filter.

Gradual clogging can occur due to an accumulation of dust particles in the filter. However, clogging can also occur during a shorter period (e.g. a few days) due to rapid growth of microorganisms in the filter.

All previous tests have demonstrated that clogging of the filters will happen. As a consequence, the companies must have a plan for how clogging problems must be handled. For example automatic systems for systematic cleaning of the filters could be a solution. Alternatively manual washing supplemented with an alarm system could be a solution. The alarm could be controlled by the pressure drop across the filter depending of the air flow through the filter.

Problems with the air inlet in housing units with diffuse air intake through the ceiling
The air cleaner can be connected directly to the individual section, or there can be a larger air cleaner which treats the air from several sections. If the air cleaner treats the exhaust air from several sections, a central duct connecting the air cleaner and the outlets in the section must be installed.

In Denmark most of the facilities for weaners and finishers are installed with diffuse ventilation with air intake through the ceiling. The central duct is often located in the attic, and it is very important that the distance between the diffuse air intake and the duct is sufficiently large to allow a uniform flow of fresh air through the ceiling.

Emergency ventilation in the housing unit in connection with power failures
The legislation stipulates that an alarm system must be installed in cases of power failure or other types of ventilation failure. In traditional housing units without air cleaners, a damper in the outlet automatically opens to provide natural ventilation. If an air cleaner is installed, the pressure loss will be increased, which will prevent natural ventilation. In housing units with air cleaners, other types of emergency opening must be installed.

Filters in air cleaners can become clogged with dust, fungal growth or other microfilm. It would be an advantage to automatically record the ventilation rate and the pressure loss over the filter. A control box could use these data to give an alarm when the filters start to become clogged.

Reduced productivity, tail biting, thermal comfort and, in extreme cases, respiratory problems and death among the animals
If the air cleaner is not correctly connected to the individual section, there will be a risk of reduced productivity and thermal comfort. In extreme cases, draughts in the pens and reduced air exchange could result in stress, tail biting and increased respiratory problems. There are also some examples of where the animals in the entire housing unit died because of ventilation failure. Normally, ventilation failure will only affect the animals in one section. However, in housing units with central ventilation connected to the same air cleaner, all the animals in the entire unit could be affected.

Annex H (informative) Feeding parameters

Ranges of dietary protein contents in different pig categories in NL, DK and DE

Fatteners:	Up to 50 kg live weight	15-18% crude protein
	> 50 kg live weight	14-16.5% crude protein
Piglets:	< 20 kg	18-21% crude protein
	> 20 kg	17-20% crude protein
Sows:	Pregnant	11-14% crude protein
	Lactating	13-17% crude protein

Dietary protein contents in poultry feeding (approximate values)

DK

Broilers, 1.6-3.0 kg live weight, 30-45 days of age:	20-21% crude protein
Outdoor broilers, 2.4 kg live weight, 56 days of age:	15% crude protein
Turkeys, females, 10 kg live weight:	20% crude protein
Turkeys, males, 20 kg live weight:	18% crude protein
Ducks, 4 kg live weight:	17% crude protein
Geese, 7 kg live weight:	16% crude protein
Laying hens:	16-18% crude protein

DE

Laying hens:		15-20% crude protein
Broilers:	1-> 5 weeks	18-23.5% crude protein
Turkeys:	Week 1-5 (starter)	26-29.5% crude protein
	Week 6-16 (females)	18-24.5% crude protein
	Week 6-21 (males)	14-24.5% crude protein
Ducks:	Week 1-2	20-24% crude protein
	Week 3-7	16-18% crude protein

The farmer must be able to document the actual crude protein level in the feed during the test period. If the farmer is not able to deliver this documentation, three feed samples must be taken spread over the measurement period and analysed.

Annex I (informative) Examples on the contents of a user manual

Operation instructions include e.g.

- The relevant parameters to be periodically controlled by the operator (daily/weekly etc.).
- The adjustment of the parameters.
- The position and access to the relevant components of the installation.
- The operation during service times of the housing.
- The workflow for emptying, cleaning and filling of the installation (e.g. change of water, exchange of the filter material).
- The documentation of the operation (data and maintenance work).

Service and maintenance instructions include e.g.

- A maintenance schedule determining single and repetitive works and their rhythm such as the calibration of the pH-meter, the cleaning of the system components, and the exchange of components (e.g. filter elements or material).
- The limit values of decisive parameters (e.g. pH-value, water filling height, pressure drop) that causes certain maintenance work to be done.
- The position and access to the maintenance centres.
- Tools, protective devices and auxiliary materials needed.

The largest part of the maintenance and repair work necessary can be carried out by the operator of the installation. In addition, a maintenance contract should be concluded with the manufacturer/applicant.

Instructions for the prevention and dealing with incidents (environmental safety) include e.g.

- Type of possible incidents (e.g. water spilling, power failure, breakdown of ventilation), prevention and measures to be taken.
- Waste management, i.e. production, amount, composition and handling of wastes.
- Manufacturers/applicants hotline.

Note: In acid scrubbers and multi-stage systems, the ammonium sulphate solution must regularly be elutriated from the chemical stage and washing water contaminated with ammonium sulphate must be stored separately from the slurry in a special tank.

Surveillance instructions depending on the type of system operated include

1. in general, e.g.

- The control of an even air flow through the contact bed packings and filter surfaces.
- The control of crude gas breakthroughs.
- The control of a sufficient and evenly moistening of the surfaces (regular checks of sprinkling density, of the circulation pump and the liquid distributor system etc.); automatically controlled freshwater supply system with level control should be installed and checked regularly.

2. for biofilters, e.g.

- The control of the bed heights and the filter material properties such as uniformity, grain size, age and degree of decomposition of the material.
- The control and remove of emerging growth.

3. for trickling filters, single and multi-stage installations, e.g.

- The control for clogging and cleaning of wire-cloth drip separators and contact bed packings.
- The observation of the elutriation rate.
- The checks of pH-control and acid metering systems.