Dorset Farm Systems B.V.
Dorset biological Combi-aircleaner

Verification Report

Version 2-0

Document information

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1 TABLE OF CONTENTS

2 INTRODUCTION

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and quality assurance.

This document is the verification report resulting from the test and verification of a specific product, Dorset biological Combi-aircleaner, used for cleaning of ventilation air from pig houses.

2.1 Name of product

The product to be verified is Dorset biological Combi-aircleaner.

2.2 Name and contact of vendor

The Dorset biological Combi-aircleaner is developed and produced by Dorset Farm Systems B.V. Weverij 26, 7122 MS Alten, the Netherlands. Contact person of Dorset Farm Systems is Gerjan Groot Wassink. Phone: +31 (0) 543 475596. E-mail: g.grootwassink@dorset.nu.

The Dorset biological Combi-aircleaner is marketed and sold in Denmark by Rotor A/S, Industrivej 8, 6800 Varde, Denmark. Contact person of Rotor A/S is Søren Langsig. Phone: +45 7522 1000. Email: rotor@rotor.dk.

2.3 Name of centre and verification responsible

Verification Centre: DANETV verification Centre, AgroTech, Udkaersvej 15, DK-8200 Aarhus N, Denmark.

Verification responsible: Mathias Andersen, e-mail mxa@agrotech.dk, phone +45 8743 8463.

2.4 Verification and test organization

The verification was conducted by Danish Centre for Verification of Climate and Environmental Technologies, DANETV, which performs independent tests of technologies and products for the reduction of climate changes and pollution.

The verification was planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).

An internal and an external technical expert have provided independent review of the planning, conducting and reporting of the verification and tests.

An overview of the organisation associated with test and verification is given in figure 1.

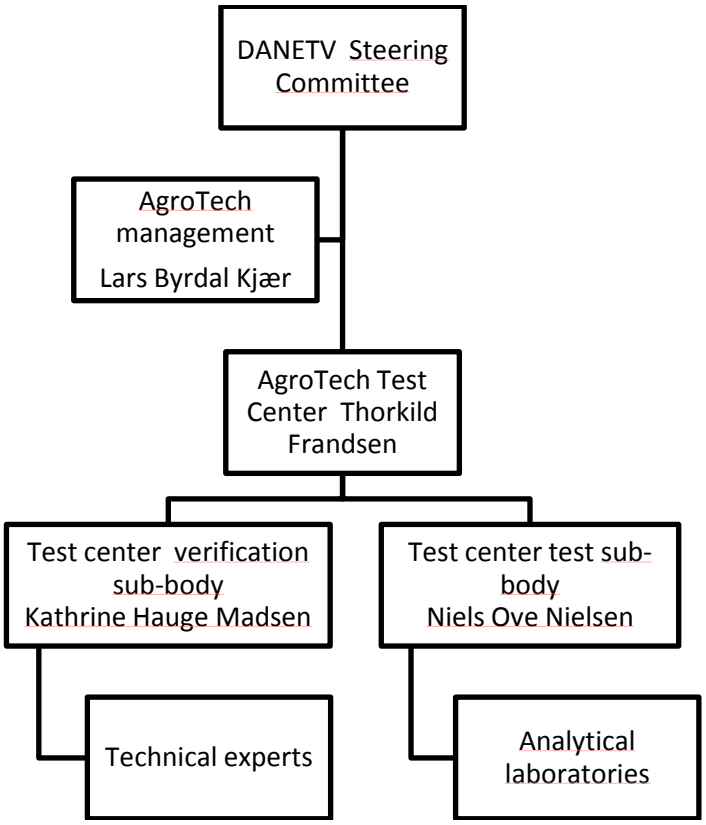

Figure 1. Organisation of test and verification

2.5 Technical experts

The technical experts assigned to this verification and responsible for review of the verification plan and report documents include:

Internal expert: Hans Jørgen Tellerup, AgroTech, Udkærsvej 15, DK-8200 Århus N, Denmark. Phone: +45 8743 8406, e-mail: hjt@agrotech.dk.

External expert: Arne Grønkjær Hansen, Danish Technological Institute, Kongsvang Allé 29, 8000 Århus C, Denmark. Phone: +45 7220 2142. E-mail: arne-gronkjaer.hansen@teknologisk.dk.

2.6 Verification process

Verification and tests were conducted in two separate steps, as required by the EU ETV. The steps in the verification are shown in Figure 2.

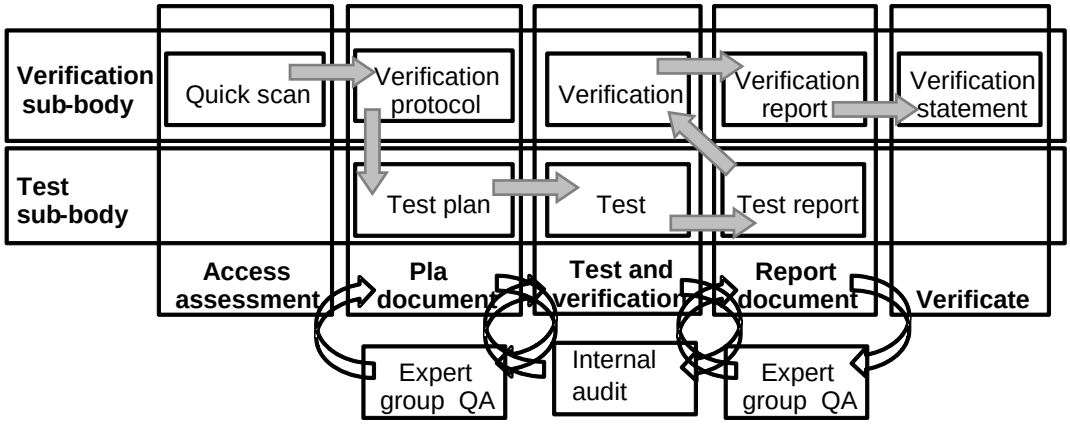

Figure 2. Verification steps

The verification process is described in the AgroTech Test Centre Quality Manual [12].

This verification protocol, the test plan and the AgroTech Test Centre Quality Manual shall be seen as one consolidated verification description.

3 DESCRIPTION OF THE TECHNOLOGY

Biological air filters are used to reduce odour and ammonia emissions from animal houses [6] [7]. Previous tests show that the efficiency of the biological filter depends on the animal house air concentration of ammonia and dust, humidity of the filters, pH of the waste water, the surface structure of the biological filter and the pressure through the filter [8] [9]. Studies have also shown that odour reduction is higher during winter than during summer time, and that water consumption is largest during the summer due to higher water evaporation [10].

A biotrickling filter is one type of biological air filters. A biotrickling filter is an 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.

It is important for the proper operation of a biotrickling filter 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 re-circulated; another fraction is discharged and replaced by fresh water. The 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.

4 DESCRIPTION OF THE PRODUCT

The Dorset biological Combi-aircleaner is a biotrickling filter. The filter material is made of a matrix consisting of cubic plastic units that serves as support for microorganisms. Exhaust air enters the cleaner from the bottom of the filter bed, whereas recycled liquid is distributed counter currently from the top. The system has a water reservoir, that starts to empty when the electrical conductivity (EC) has reached 14 mS. Fresh water is added to the reservoir in order to keep the water level. To prevent dust from clogging the filter bed an extra set of sprayers are installed in the bottom of the filter where dusty air enters the filter.

The Dorset biological Combi-aircleaner is integrated in a double layered plastic container. It has a maximum air flow capacity of 26.000 m^3 per hour. The Combi-aircleaner is connected to the ventilation system in one section of a pig facility that produces finishing pigs. The exhaust air leading to the filter is collected from the floor exhaustion and supplemented by two Ø-820 pipes in the wall of the animal house. In case of overheating of the stable or breakdown of the filter, two extra floor ventilators will be activated.

Table 1. Characteristics of the Dorset biological Combi-aircleaner.

Parameters	Unit	Values
Max ventilation rate	m^3/hour	26.000
Specific flow rate	$m^3/m^2/h$	3.000
Inflow surface	m^2	8.7
Height of filter material	m	0.90
Volume of filter material	m^3	7.8
Pressure drop trough filter	Pa	~40
Specific wash water flow	$m^3/m^2/h$	0.8
Sprayers	pieces/m^2	1
Specific dust-water flow	$m^3/m^2/h$	0.6
Number of Sprayers	pieces	6
Control setting for EC	mS/cm	14
Volume of water reservoir	m^3	~5

Note: The values are reported by the manufacturer.

5 APPLICATION AND PERFORMANCE PARAMETERS

The Dorset biological Combi-aircleaner produced by Dorset Farm Systems B.V. is verified for treatment of ventilation air from pig houses. The intended application is defined in terms of the matrix, the target and the effect of the air cleaner.

The matrix is the type of material that the air cleaner is intended for. Targets are the measurable properties that are affected by the air cleaner. The effects describe how the targets are affected by the air cleaner.

A detailed description of the application can be seen in Appendix 3 – Application and performance parameter definitions.

5.1 Matrix

The matrix of the application is ventilation air from forced-ventilated pig housing systems in Denmark, Germany, the Netherlands and other countries with similar temperature regimes and housing systems. The field of application is removal of ammonia, odour and dust (PM10 and PM 2.5) from the ventilation air.

5.2 Targets

The measurable properties (targets) of the Dorset biological Combi-aircleaner are concentrations of ammonia, odour and dust (PM 10, PM2.5 and total dust) in the ventilation air leaving the air cleaner.

5.3 Effects

The effects of the Dorset biological Combi-aircleaner are reduction in the concentrations of ammonia, odour and dust in the ventilation air leaving the air cleaner compared to concentrations of the ventilation air entering the air cleaner.

5.4 Performance parameters for verification

The claims put forward by the technology producer, Dorset Farm Systems B.V. were:

- Ammonia: Minimum 70 % reduction
- Odour: Minimum 80 % reduction
- Dust, PM 2.5: Minimum 60 % reduction
- Dust, PM 10: Minimum 60 % reduction
- Dust, total: Minimum 60 % reduction

Table 2 shows the performance parameters relevant for the verification of the Dorset biological Combi-aircleaner.

Table 2. Performance parameters.

Parameter [Unit]	**Sample conditions** (where, how and how often)	**Measuring method** (reference to the method)
Odour [OU/m³]	• Minimum one sample per sampling day • Minimum eight samplings in summer period and four samplings equally distributed over the rest of the year. • Sampling between 10 am and 2 pm. • Sampling time: Between 30 and 120 minutes. • Sampling equipment: Nalophan bags.	EN 13725/AC:2006 Air quality – Determination of odour concentration by dynamic olfactometry. Methods that are in compliance with this CEN standard.
Ammonia [mg/m³]	• Minimum four samplings in summer period, and four samplings equally distributed over the rest of the year • Sampling time: 24 hours.	ISO 7150/2, impinger system. Impingers can only be used when the ventilation rate is fixed and this is the case in this test.

Dust - PM 10 - PM 2.5 - Total [mg/m³]	• Minimum one sample per sampling day. • Minimum four samplings in summer period, and four samplings equally distributed over the rest of the year. • Sampling time: 24 hours for PM10/2.5	PM10: • EN 15259: 2007, ISO: 23210, VDI: 2066-10, EN 13284 PM2.5: • EN 15259: 2007, ISO: 23210, VDI: 2066-10, EN 13284 Total dust: • EN 15259: 2007, ISO: 23210, VDI: 2066-10, EN 13284 Methods that are in compliance with these EN-standards shall be used. These standards are, however, developed for outdoor sampling only. For the present standards for indoor sampling in a dusty environment have to be evaluated on a national scale.

The test has been completed following these general recommendations for measurements:

- Avoid absorption, diffusion, condensation, leakages, and blockages during sampling.
- Consider potential cross sensitivities of measuring instruments.
- Measuring range of instruments or methods should fit to effective range of expected values; avoid measuring close to the lower or upper detection limit.

5.5 Additional parameters

5.5.1 Operational parameters

Table 3 below shows the operational parameters (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. Conditional measurement parameters also include other (secondary) environmental pollutants.

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

Table 3. Operational parameters (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. 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.
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
CO_2 (O) [mg/m³]	cf. Table 2 "Ammonia" and "General recommendations" above	
CH_4 (O) [mg/m³]	cf. Table 2 "Ammonia" and "General recommendations" above, or combined with odour sampling	
H_2S (O) [mg/m³]	Combine with odour sampling	Jerome (Measurement principle)
N_2O (M for biological systems only) [mg/m³]	Combine with odour sampling	GC-ECD, Photo-acoustic infrared monitor.
Temperature (M) [°C]	• Minimum Sampling time: 24 hours (sampling days). • Continuous measuring methods: based on hourly values (24 samples). • Sampling location: Air inlet and air outlet.	Adequate measuring range, sensitivity, detection limit. Consider undesired effects on measuring device through e.g. contaminations, wind or direct sunshine.
Humidity (M) Relative humidity [%]	• Minimum sampling time: 24 hours (sampling days) together with particles else simultaneously with odour measurements. • Sampling location: Air inlet and air outlet.	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.	Manemometer, electronic micro manemometer (difference pressure across membrane).
Noise (O)	Outdoor 1-2 m from ventilation outlet.	Brüel and Kjær modular precision sound analyzer type 2260.
Consumption of electricity (M) [kWh]	Continuous measurement of electricity consumption by ventilation in general and by the pumps in the air cleaning system.	VE14 universal input from VENG system combined with a power meter
Consumption of water (M) [l] [m³]	Continuous measurement.	VE universal input from VENG system combined with a water meter

Related to time		
Consumption of chemicals (e.g. acid) (M) [mg or kg] mass [l or m³] volume	Continuous measurement	
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)	Six samples of discharge liquid spread over the year. Samplers must be inactivated chemically and biologically. (Immediately after sampling the samples must be stored in a cooled box and within five hours placed in a freezer).	Radiometer, GLM
Registration of the dates of emptying the pits or manure channels (M)		Registration based on interviews with the farmer or his employees
Cleaning of animal house and dunging behaviour	Description of cleaning procedure. Registration of dunging behaviour in each pen on days with odour sampling.	Registration based on interviews with the farmer or his employees
Feeding parameters	During the testing period the dietary protein contents should be within specific ranges for different pig categories.	
Operational function and stability (M)	Continuous measurements of key parameters for functioning.	

5.5.2 Occupational health and safety

In general, biological air cleaners- 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 1) suitable for the intended use, 2) safe for use, 3) maintained in a safe condition and, 4)

in certain circumstances, inspected to ensure this remains the case, 5) used only by people who have received adequate information, instruction and training and 6) accompanied by suitable safety measures, e.g. protective devices, markings, warnings.

5.5.3 Animal health and welfare

The air cleaner used for test was 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 speaking, 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.

In the case of Dorset biological Combi-aircleaner it was judged by the test unit that the vendor (Rotor A/S) has demonstrated theoretical and practical knowledge of:

- thermal comfort for animals;
- climate control in animal housing units;
- design of the ventilation 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.

5.5.4 User manual

An evaluation of the user manual for the Dorset biological combi-aircleaner was undertaken as part of this verification task.

6 EXISTING DATA

The Dorset biological Combi-aircleaner was previously tested by DLG Test Center in Germany, see reference [4]. Furthermore, during a demonstration of the Dorset biological Combi-aircleaner in Denmark measurements have been undertaken to evaluate the potential effects of this technology, see reference [5].

6.1 Summary of existing data

DLG Test Center concluded in their test report that the Dorset biological Combi-aircleaner had the following effects on ammonia and odour:

- Reduced ammonia concentration in ventilation air leaving the cleaner: >90 %
- Reduced concentration of odour units in ventilation air leaving the cleaner: 80%

The Danish Agricultural Advisory Service, National Centre concluded in the report from the demonstration [5] that the Dorset biological Combi-aircleaner had the following effect on ammonia:

- Reduced ammonia concentration in ventilation air leaving the cleaner: 80 %

6.2 Quality of existing data

The documentation from the previous tests in Germany and Denmark is based on test protocols that differ significantly from the present DANETV verification protocol. Consequently, existing data do not qualify for a DANETV verification of the Dorset biological Combi-aircleaner.

6.3 Accepted existing data

Data generated in previous tests [4], [5] have not been included in this verification of the Dorset biological Combi-aircleaner.

7 TEST PLAN REQUIREMENTS

Based upon the application and performance parameters identification above the requirements for the test design have been set. A detailed test plan was prepared separately based upon the specification of the test requirements presented below.

7.1 Test design

The test should be designed in a way so that the removal performance of the pollutants could be assessed as:

- The removal performance over the time basis of one year.
- The removal performance during the summer period (with outdoor temperatures above 16˚C) at specified high ventilation rates.

In addition, the test design should include a monitoring of the system and a continuous logging of key parameters over the period of 6 months.

7.1.1 Requirements for the test site

The test facilities used for testing the air cleaning system should represent farm characteristics that are considered representative for standard practices in the geographical region in question. The following items were considered:

- Size of the livestock units involved in the test
- Stock density
- Pen design
- Feeding system
- Applicability to other housing systems and animal categories
- Manure removal system
- Ventilation system: lay-out and dimensioning in relation to number of animals
- Management strategy

The air cleaning system should be tested under farm conditions that were representative for the standard practices of pig production facilities in the geographical region in question. This implied that requirements were defined to ensure that both the lay-out of the test facility and the management conditions during the test period were representative for a typical pig production.

7.1.2 Sampling strategy for test of Dorset biological Combi-aircleaner

The sampling requirements during the test are shown in table 4 below.

Table 4. Sampling strategy during test of Dorset biological Combi-aircleaner.

Parameter	Requirement
Minimum size of housing units for sampling	The unit size shall be representative for farms in the geographical region in question.
Measurement periods	Ammonia: Eight days randomly distributed within 6 months. Maximum one half of the measurements shall be located during the first half of the growth cycle. Minimum four samplings equally distributed over the rest of the measuring period. Sampling time: 24 hours. Odour: Six days during the summer period (here defined as 15th May to 30th of September) with outdoor temperature above 16˚C (during sampling) and six days randomly distributed over the rest of the measuring period. Minimum one sample per sampling day. Dust: Minimum four samplings in summer period (here defined as 15th May to 30th of September) and four samplings equally distributed over the rest of the sampling period. Sampling time: 24 hours for PM 10, PM 2.5 and total dust.
Sampling sites	Simultaneously sampling of inlet and outlet air.

7.2 Reference analysis

All measurements and the analytical methods had to be documented satisfactory.

To verify the removal performance with respect to ammonia a mass balance on nitrogen was made. The purpose was to compare the amount of nitrogen removed from the exhaust air with the amount of nitrogen found in the waste water from the filter.

7.3 Data management

Data storage, transfer and control had to be done in accordance with the requirements of the AgroTech Test Centre Quality Manual [12]. Similarly, the filing and archiving requirements are described in the AgroTech Test Centre Quality Manual.

7.4 Quality assurance

The test plan and the test report had to be subject to review by an internal and an external expert.

The quality assurance of the tests should include control of the test system and control of the data quality and integrity.

7.5 Test report

The test report should be based on the template of the AgroTech Test Centre Quality Manual [12].

8 EVALUATION

8.1 Calculation of performance parameters

In table 6, 7, 8, 9 and 10 below the results of the calculation of performance parameters are summarized.

Table 6. Results of ammonia measurements including the estimated sample means and 95% confidence intervals (shown in square brackets).Measurements are made at the inlet and the outlet of the filter, and the reduction is calculated as the reduction over the filter, relative to the inlet level.

Ammonia	Inlet-concentration mg NH_3/m^3	Outlet-concentration mg NH_3/m^3	Reduction % of inlet-conc.
Summer measurements	4.5 [3.2; 6.4]	1.5 [0.8; 2.9]	67.1
Summer and winter measurements	7.8 [5.0; 12.1]	2.2 [1.3; 3.5]	72,2

Table 7. Results of odour measurements including the estimated sample means and 95% confidence intervals (shown in square brackets).Measurements are made at the inlet and the outlet of the filter, and the reduction is calculated as the reduction over the filter, relative to the inlet level.

Odour	Inlet-concentration OU_E / (s x ton)*	Outlet-concentration OU_E / (s x ton)*	Reduction % of inlet-conc.
Summer measurements	469 [132; 1670]	220 [21; 2330]	53 [23; 71]
Summer and winter measurements	359 [89; 1450]	215 [30; 1520]	40 [10; 60]

* Results of odour measurements are expressed per ton of animals.

Table 8. Results of PM 2.5 measurements including the estimated sample means and 95% confidence intervals (shown in square brackets). Measurements are made at the inlet and the outlet of the filter, and the reduction is calculated as the reduction over the filter, relative to the inlet level. BLD: below detection limits.

Dust – PM 2.5	Inlet-concentration µg/m^3	Outlet-concentration µg/m^3	Reduction % of inlet-conc.
Summer measurements	BDL	BDL	-
Summer and winter Measurements*	57.1 [0; 132.5]	7.4 [5.1; 9.6]	87.1

* Results from summer measurements are below detection limits and calculation of reduction is based on winter measurements, therefore only winter values are considered here.

Table 9. Results of PM 10 measurements including the estimated sample means and 95% confidence intervals (shown in square brackets). Measurements are made at the inlet and the outlet of the filter, and the reduction is calculated as the reduction over the filter, relative to the inlet level.

Dust – PM 10	Inlet-concentration µg/m^3	Outlet-concentration µg/m^3	Reduction % of inlet-conc.
Summer measurements	81.3 [40.3; 122.2]	37.9 [8.1; 67.7]	53.4
Summer and winter measurements	100.8 [51.1; 150.4]	47.8 [28.5; 67.0]	52.6

Table 40. Results of Total dust measurements including the estimated sample means and 95% confidence intervals (shown in square brackets). Measurements are made at the inlet and the outlet of the filter, and the reduction is calculated as the reduction over the filter, relative to the inlet level.

Dust – Total	Inlet-concentration µg/m^3	Outlet-concentration µg/m^3	Reduction % of inlet-conc.
Summer measurements	147.5 [60.8; 234.3]	51.4 [11.2; 91.6]	70.4
Summer and winter measurements	162.3 [89.3; 235.2]	72.5 [39.2; 105.7]	55.3

In figure 3 and figure 4 the effect of the Dorset Combi-aircleaner with respect to ammonia and odour reduction is illustrated graphically.

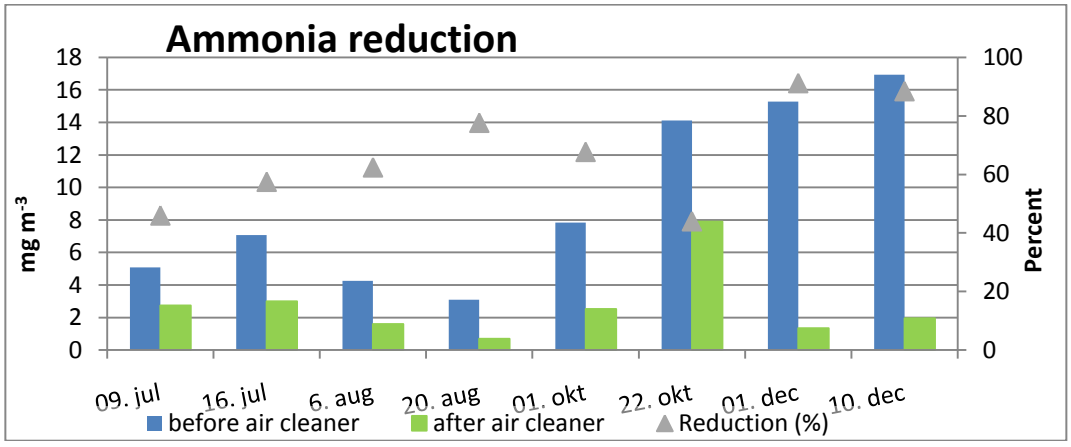

Figure 3. Concentration of ammonia before and after the air cleaner and reduction in %.

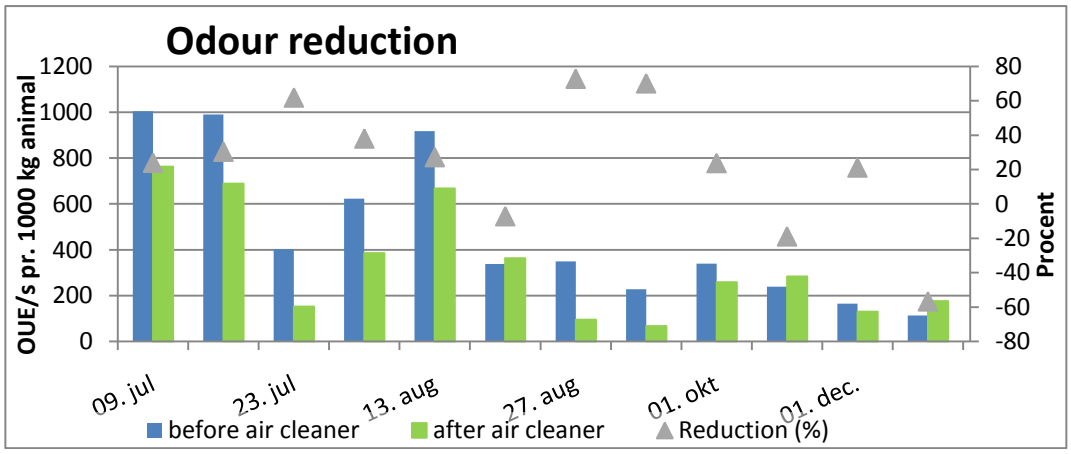

Figure 4. Concentration of odour before and after the air cleaner and reduction in %.

8.2 Performance parameter summary

In table 11 the verified performance is compared with the performance claimed by the technology producer.

Performance parameter	Claimed performance	Verified performance
Ammonia, % reduction	Min. 70	72
Odour, % reduction	Min. 80	40
Dust, PM 2.5, % reduction	Min. 60	87.1
Dust, PM 10, % reduction	Min. 60	52.6
Dust, Total, % reduction	Min. 60	55.3
Pressure loss, Pa through filter	Max. 40	47
Electricity consumption (kWh/produced pig)	Max. 25	18
Water consumption (L/produced pig)	350 – 700	408

On the basis of this test the claims for ammonia, PM2.5, electricity consumption and water consumption have been confirmed. The claim for removal efficiency of odour could not be confirmed based on the results from this test and the verified performance is only half of the expected performance. The claims for PM10, total dust and pressure loss could not be confirmed but the verified performance is close to the expected values.

8.3 Evaluation of test quality

8.3.1 Control data

A mass balance has been conducted in order to verify the reduction of ammonia emission calculated from the inlet and outlet concentration of ammonia and the corresponding air flow. In the table below the amount of nitrogen removed from the exhaust air is compared with the amount of nitrogen found in the waste water leaving the filter.

Table 12a. Mass balance for nitrogen. Results from measuring day 1 – 4.

Date	09-07-2009	16-07-2009	06-08-2009	20-08-2009
Mass of reduced N from ventilation air (Kg N d^{-1})	0,87	1,28	1,20	1,04
Mass of absorbed N in waste water (Kg N d^{-1})	0,83	0,84	1,62	1,00
Deviation in mass balance (%)	5	33	25	4

Table 12b. Mass balance for nitrogen. Results from measuring day 5 - 8.

Date	01-10-2009	22-10-2009	26-11-2009	10-12-2009
Mass of reduced N from ventilation air (Kg N d^{-1})	0,81	1,23	1,73	2,15
Mass of absorbed N in waste water (Kg N d^{-1})	1,22	1,42	1,47	2,42
Deviation in mass balance (%)	34	14	15	11

Table 12c. Mass balance for nitrogen. Average results from measuring day 1 - 8.

	Mean
Mass of reduced N from air (Kg N d^{-1})	1,29
Mass of absorbed N in waste water (Kg N d^{-1})	1,35
Deviation in mass balance (%)	18

The bass balance shows good compliance between nitrogen removed from the exhaust air and the amount of nitrogen found in the waste water leaving the filter. Only 2 sample days has more than 25 % deviation, which is considered to be acceptable.

The ammonia concentration was furthermore double checked with INNOVA 1412, photoacoustic gas detector. There was good compliance between ammonia concentrations measured with the impinger principle and Innova measurements during 4 sample days. The difference in the reduction of ammonia concentration was only 5 %.

8.3.2 Audits

No audits have been undertaken for this verification task.

8.3.3 Deviations

The test was undertaken according to the test plan except one sample day for ammonia and dust which was moved from the 26.11.2009 to the 01.12.2009.

8.4 Additional parameter summary

8.4.1 User manual

A 30 pages user manual for the Dorset Biological Combi-aircleaner has been made available for the verification. The user manual is in German and it is recommended to translate this to English or Danish since many farmers and employees are not familiar with the German language.

8.4.2 Occupational health and wastes

Issues related to health, safety and wastes have not been evaluated as part of this test.

8.5 Operational parameters

In table 13 the results of the evaluation of operational parameters are presented.

Table 13. Results of consumption and pressure loss, estimated sample means. Consumption of electricity, water and waste water production are given per produced pig. Pressure loss is given as the mean of the total pressure loss trough the ventilation system and the air cleaner.

Operational parameters	Electrical consumption kWh/pig	Water consumption L/pig	Waste water production L/pig	Pressure loss Pa
Summer and winter measurements	18	408	186	40.1

8.6 Recommendations for verification statement

It is recommended to issue a verification statement based on the verified performance described in section 8.1, 8.2, 8.3 and 8.5.

8.7 Liability exclusion

DANETV verifications are based on test and evaluation of technology performance under specific, predetermined operational conditions and parameters and the appropriate quality assurance procedures. AgroTech makes no expressed or implied warranties as to the performance of the technology and do not certify that the technology will always operate as verified. The end user is solely responsible for complying with any applicable regulatory requirements.

9 VERIFICATION SCHEDULE

The verification was planned and carried out in 2009-2010. The overall schedule is presented in table 14.

Table 14. Schedule for verification of Dorset biological Combi-aircleaner.

Task	Timing
Quick scan and contract negotiation	April - May 2009
Verification protocol and test plan	May – June 2009
Test	June – December 2009
Test reporting	January 2010
Verification report	February 2010
Report document review	March 2010
Verification statement	March 2010

10 QUALITY ASSURANCE

The quality assurance of the verification is described in table 7 and figure 2. The quality assurance of the test is described in the test report.

Table 7. Quality assurance plan for the verification of Dorset biological Combi-aircleaner.

Task	AgroTech	Technical experts
Plan document including verification protocol and test plan	Review (HJT)	Arne Grønkjær Hansen, Danish Technological Institute
Report document including test report and verification reports	Review (HJT)	Arne Grønkjær Hansen, Danish Technological Institute

Internal review of plan and report documents is done by Hans Jørgen Tellerup (HJT).

A P P E N D I X 1

Terms and definitions used in the verification protocol

Word	DANETV
Analytical laboratory	Independent analytical laboratory used to analyse test samples
Application	The use of a product specified with respect to matrix, target, effect and limitations
DANETV	Danish center for verification of environmental technologies
(DANETV) test center	Preliminary name for the verification bodies in DANETV with a verification and a test sub-body
Effect	The way the target is affected
(Environmen-tal) product	Ready to market or prototype stage product, process, system or service based upon an environmental technology
Environmental technology	The practical application of knowledge in the environmental area
Evaluation	Evaluation of test data for a technology product for performance and data quality
Experts	Independent persons qualified on a technology in verification
Matrix	The type of material that the product is intended for
Method	Generic document that provides rules, guidelines or characteris-tics for tests or analysis
NOWATECH	Nordic Water Technology Verification Centers
Performance claim	The effects foreseen by the vendor on the target (s) in the matrix of intended use
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance of an environmental technology product
Procedure	Detailed description of the use of a standard or a method within one body
Producer	The party producing the product
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Target	The property that is affected by the product
Test center,	Sub-body of the test center that plans and performs test

Word	DANETV
test sub-body	
Test center, verification sub-body	Sub-body of the test center that plans and performs the verification
Test/testing	Determination of the performance of a product for parameters defined for the application
Vendor	The party delivering the product to the customer
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance

A P P E N D I X 2

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A P P E N D I X 3

Application and performance parameter definitions

This appendix defines the application and the relevant performance parameters application as input for the verification and test of Dorset biological Combi-aircleaner following the DANETV method.

1. Applications
The intended application of the Dorset biological Combi-aircleaner is defined in terms of the matrix, the target and the effect of the air cleaner.

1.1 Matrix
The matrix of the application is ventilation air from forced-ventilated pig housing systems in Denmark, Germany, the Netherlands and other countries with similar temperature regimes and housing systems.

1.2 Targets
The targets of the application are concentrations of ammonia, odour and dust (PM10, PM 2.5 and total dust) in the ventilation air leaving the air cleaner. These are the primary performance parameters.

1.3 Effects
The effects of the application are removal performance with respect to the targets, ammonia, odour and dust. The removal performance is expressed as reduction in concentrations in ventilation air leaving the air cleaner compared to ventilation air entering the air cleaner.

The effects for application are set in terms of average, standard deviation and 95% confidence interval.

The claims put forward by the technology producer, Dorset Farm Systems B.V. are:

- Ammonia: Minimum 70 % reduction (yearly basis)
- Odour: Minimum 80 % reduction (yearly basis)
- Dust, PM 2.5: Minimum 60 % reduction (yearly basis)
- Dust, PM 10: Minimum 60 % reduction (yearly basis)
- Total dust: Minimum 60 % reduction (yearly basis)

In addition to the claimed effects on the primary performance parameters there are some claims regarding the effects on additional parameters:

- Pressure drop through the air cleaner: Maximum 40 Pa
- Electricity consumption: Maximum 25 kWh/produced pig
- Water consumption: 350 - 700 L/produced pig

1.4 Exclusions
The test is designed to document the performance of the Dorset biological Combi-aircleaner installed in housing systems for pig production only. In this test there is no intention to document the effect of the Dorset biological Combi-aircleaner installed in housing systems for poultry, cattle or other animal types.

The test is not intended to produce results that necessarily are valid if the Dorset biological Combi-aircleaner is installed in pig housing systems that vary significantly from the state-of-the-art pig housing systems in Denmark, Germany and the Netherlands.

Similarly, the test is not taking into account the impact on performance if the Dorset biological Combi-aircleaner is installed in a pig housing system located in a region with climate conditions that vary significantly from the climate conditions in Denmark, Germany and the Netherlands.

2. General performance requirements

2.1 Regulatory requirements

In Denmark there are no standards that define minimum effects of biological Combi-aircleaners in order to be approved by the authorities.

The farmer has to live up to some specific requirements for the emission of ammonia and odour in order to achieve an environmental permission for his livestock production. These requirements differ from farm to farm depending on the size of the livestock production and the geographical location of the livestock production.

However, specifically for ammonia some general requirements have been formulated. From 1st of January 2009 farms with more than 75 animal units have to reduce ammonia emissions by 25 % compared to a specifically defined reference animal housing system . The 25% ammonia reduction applies to all farms that have applied for environmental permission to expand or change the livestock production.

A biological air cleaner can be relevant for some farmers as a tool to meet the requirements regarding emission of ammonia and odour. In order to be accepted as a tool to reduce emissions to a certain level the effect of the biological air cleaner has to be evaluated by a third party. Environmental technologies for the Danish agricultural sector that have achieved such third party documentation are considered approved for installation on farms with that effect. These technologies are put on the so called “Technology list”, which is regularly updated by the Danish Environmental Protection Agency.

2.2 Application based needs

In Denmark there is a growing interest in measuring dust emissions from livestock production farms. And there is an interest to identify technologies that can be used to reduce emissions of dust because dust can cause respiratory diseases.

3. State of the art performance

A draft version of a description of Best Available Technologies for agricultural sector biological air cleaners have been made by the Danish Environmental Protection Agency. The draft version is available on www.mst.dk.

4. Performance parameter definitions

The primary performance parameters of the test are:

Ammonia: Reduced concentration in outlet air compared to inlet air (yearly basis)
Odour: Reduced concentration in outlet air compared to inlet air (yearly basis)
Dust, PM 2.5: Reduced concentration in outlet air compared to inlet air (yearly basis)
Dust, PM 10: Reduced concentration in outlet air compared to inlet air (yearly basis)
Total dust: Reduced concentration in outlet air compared to inlet air (yearly basis)

A P P E N D I X 4

Test report

The test report is attached to this verification report as a separate file.

A P P E N D I X 5

Review reports

Comments, questions and proposals for improvements of plan documents and report documents have been communicated from internal and external reviewers both by e-mail and by telephone and at meetings.

These comments, questions and proposals for improvements are stored according to the archiving procedures described in the AgroTech Test Centre Quality Manual.

A P P E N D I X 6

Amendment and deviation report for verification

The test was undertaken according to the test plan except one sample day for ammonia and dust which was moved from the 26.11.2009 to the 01.12.2009.