Dorset Farm Systems B.V.
Dorset Biological Combi-Aircleaner

Test report

Version 3-0

Document information

Document title	Test report for Dorset Biological Combi-Aircleaner
Project	ETV Test Center and Test Organization
Responsible	Amparo Gomez Cortina
Distribution	DANETV website
Version	3-0
Status	Approved for publication

1 TABLE OF CONTENTS

2 INTRODUCTION

This test report describes the results from test under the test plan developed for verification of a biological air cleaner following the AgroTech DANETV Test Centre Quality Manual.

2.1 Verification protocol reference

The test plan was prepared to meet the requirements defined in the verification protocol for 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/test responsible

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

Test responsible: Amparo Cortina Gomez, e-mail aco@agrotech.dk, phone +45 8743 8470.

2.4 Technical experts

The technical experts assigned to this test and responsible for review of test plan and test report includes:

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

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

3 TEST DESIGN

3.1 Test site

The Dorset Biological Combi-Aircleaner was tested in full-scale on a commercial pig farm during a 6 months period covering both summer and winter temperatures.

3.1.1 Characterization of the test site

A fattening pig housing system was used for the test. The capacity of the housing system was about 250 – 260 pigs. The startweight of the pigs was aoproximately 30 kilograms. The pigs were taken from the housing system at a final weight of approximately 100 kilograms.

The flooring system of the pig house is designed with 1/3 drained floor and 2/3 firm floor. The pigs are fed using a dry feeding system. The slurry from the pigs is collected in a V-shaped slurry channel under the floors.

The ventilation system is arranged with diffuse air intake and floor extraction. In every section there are two section exhausts and one floor exhaust.

The need for ventilation in this pig house is about 28.000 m^3 per hour. The air cleaner gives 26.000 m^3 per hour. An emergency ventilation facility has been installed in case extra ventilation is needed.

Table 1 gives an overview of key characteristics of the pig house used for the test.

Table 1. Key characteristics of pig house used for test.

Parameter	Test site characteristics
Size of the livestock unit involved in the test	30 – 110 kilograms
Stock density	256 pigs
Pen design	16 double sties
Floor design	1/3 drained floor and 2/3 firmed floor
Feeding system	Dry food feeding
Manure removal system	V-shaped slurry channel
Ventilation system	Diffuse air intake and floor extraction
Ventilation requirement	28.000 m^3 per hour

3.1.2 Addresses

The test took place at Over Løjstrup pig farm, Løjstrupvej 12, 8870 Langå. The pig farm is jointly owned by Morten Simonsen and Carsten Møller. Contact person: Morten Simonsen.

3.1.3 Descriptions

The Dorset Biological Combi-Aircleaner is designed to reduce emissions of ammonia, odour and dust in ventilation air from livestock buildings through a biological air cleaning process. The air cleaner is a biotrickling filter using a counter current water and air flow.

The filter material is made of plastic and consists of a plurality of feeding pipes with 90° bends for every 10 cm. Exhaust air from an animal house enters the filter in the bottom

and leaves the filter in the top. The filter is sprinkled both from the top and bottom with water to keep the filter wet and to remove lose biofilm and dust. The filter is sprinkled with recycled water from a reservoir built in the filter.

Ammonia, odour and dust are absorbed by the liquid and made available to microorganisms. The microorganisms are immobilized in a biofilm on the surface of the filter material. This biofilm partly degrades ammonium into nitrite and nitrate and odours and dust into carbon dioxide and water.

Discharge water is replaced with fresh water according to the conductivity which is measured online and kept at a constant level. When the conductivity reaches a defined level, a small dose of filter water is discharged from the reservoir. Fresh water is added to the water reservoir whenever water is drained or a significant amount has evaporated. In table 2 the most important specifications of the tested Dorset biological air filter is presented.

Table 2. Specifications of the tested Dorset Biological Combi-Aircleaner.

Filter Dimensions	
Filter material	Plastic filter material type F-LKP 25-312-1200
Life of filter material	Unknown
Length x width x height	3,9 m x 1,8 m x 0,9 m
Area / volume[1]	7,02 m^2 / 6,32 m^3
Max. installation ventilation	26.000 m^3/h (+ emergency ventilation)
Residence time max. ventilation	1,21 seconds
Max. air flow	2.991 m^3/m^2
Volume water reservoir	8 m^3
Operational parameters	
pH waste water	6,5-7,5
Conductivity waste water	14 mS
Pressure through the air cleaner (Max. ventilation)	30 Pa
Pressure trough the air cleaner and the stable (max. ventilation)	90 Pa
Specific water flow (the bottom nozzles)	0,6 m^3/m^2·hour
Number of nozzles	6
Specific water flow (the top nozzles)	0,8 m^3/m^2·hour
Number of nozzles per area unit	1/m^2

[1] The air cleaner used for test has an extra filter area (3.48 m^2) that functions as drop collector.

Figure 1 and 2 below are technical drawings of the tested Dorset Biological Combi-Aircleaner.

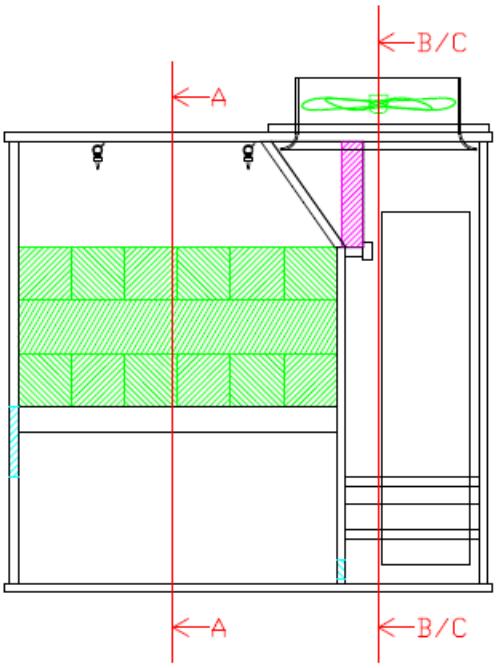

Figure 1. Dorset Biological Combi-Aircleaner. Vertical section.

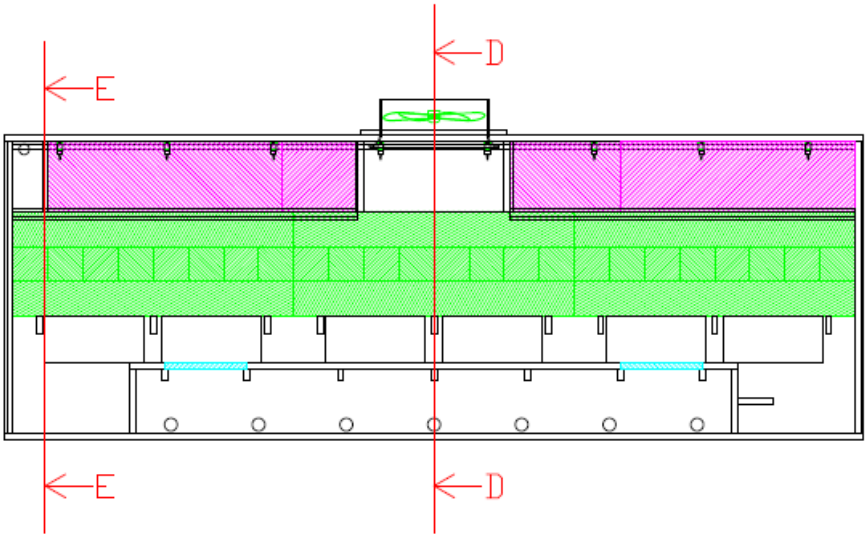

Figure 2. Dorset Biological Combi-Aircleaner. Horizontal section.

3.2 Tests

3.2.1 Test methods

The overall principle for testing the performance of the Dorset Biological Combi-Aircleaner is to take samples inlet air and samples of the air outlet air. These sets of samples were analyzed with respect to concentrations of the primary performance parameters, odour, ammonia and dust (described in more detail in section 4.3). By comparing the concentrations of inlet air and outlet air it is possible to calculate the removal performance of the air cleaner. The removal performance is expressed as:

- The removal performance over the basis of 6 months covering measurements done during summer period and measurements during winter period.
- The removal performance during the summer period.

In addition to the primary performance parameters a number of operational parameters are measured throughout the test. A list of the operational parameters is found in section 4.3.

3.2.2 Test staff

The test staffs involved in the test of Dorset Biological Combi-Aircleaner were:

- Amparo Gomez Cortina, AgroTech, Udkærsvej 15, Skejby, 8200 Århus N.
  - Phone: +45 3091 0324. E-mail: aco@agrotech.dk
- Peter Hansen, AgroTech, Udkærsvej 15, Skejby, 8200 Århus N.
  - Phone: +45 2172 7942. E-mail: pth@agrotech.dk
- Merete Maahn, AgroTech, Udkærsvej 15, Skejby, 8200 Århus N.
  - Phone: +45 3091 1184. E-mail: mzm@agrotech.dk

3.2.3 Test schedule

The test schedule is presented in table 3.

Table 3. Test schedule.

Task	**2009**								**2010**		
Month	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
Test plan	X										
Installation and pre-testing	X										
Start test period (08.06.2009)		X									
Sampling summer period		X	X	X	X						
Sampling winter period						X	X	X			
End of test period (10.12.2009)								X			
Test report draft									X		
Test report quality assurance										X	
Test report final version											X

Here is the list of measuring dates:

- 09.07.2009: Odour, ammonia, dust
- 16.07.2009: Odour, ammonia, dust
- 23.07.2009: Odour
- 30.07.2009: Odour
- 06.08.2009: Odour, ammonia, dust
- 13.08.2009: Odour
- 20.08.2009: Odour, ammonia, dust
- 27.08.2009: Odour
- 23.09.2009: Odour
- 01.10.2009: Odour, ammonia, dust
- 22.10.2009: Odour, ammonia, dust
- 26.11.2009: Odour, ammonia, dust
- 10.12.2009: Odour, ammonia, dust

3.2.4 Test equipment

Equipment used for the test is described in section 4.3 Analytical methods and in Appendix 4 In-house test methods.

3.2.5 Type and number of samples

The sample types and the number of samples that was taken are described in section 4.3.

3.2.6 Operation conditions

Operational parameters like temperature, ventilation rate, air humidity were recorded during the test. A description of the measurement of operational parameters is found in section 4.3.

3.2.7 Operation measurements

The measurement of operational parameters and secondary parameters is described in section 4.3.

3.2.8 Product maintenance

Maintenance of the Dorset Biological Combi-Aircleaner during the test period was the responsibility of the farmer. If the farmer identified a problem with the air cleaner that the farmer could not solve himself he should contact Rotor A/S. As the company marketing the Dorset Biological Combi-Aircleaner in Denmark Rotor A/S had the responsibility of repairing the air cleaner during the test in the case of break downs.

Irregularities and break downs during the test period were recorded by AgroTech test staff.

3.2.9 Health, safety and wastes

Laboratory work during the test was done according to the Danish rules for safe occupational health and the European regulations regarding work with chemicals. Field work was done according to Danish rules for safe field work.

Chemicals used for the test are discarded according to Danish regulations for chemical waste by collection and destruction.

It is judged by the AgroTech test staff that the use of the Dorset Biological Combi-Aircleaner does not imply any special health, safety or waste issues.

4 REFERENCE ANALYSIS

4.1 Analytical laboratory

To analyze odour concentration in ventilation air to and from the Dorset Biological Combi-Aircleaner Eurofins Danmark was used as external laboratory. Address: Smedeskovvej 38, DK-8464 Galten, Denmark. Phone: +45 7022 4266. E-mail: info@eurofins.dk.

4.2 Analytical parameters

In table 4 the primary analytical parameters are presented. Table 5 presents the operational parameters (conditional measurement parameters).

4.3 Analytical methods

In table 4 the analytical methods of the primary parameters are presented. In table 5 the analytical methods of the operational parameters are presented.

Table 4. Primary analytical parameters and corresponding analytical methods.

Parameter	Analytical method	Number of samples	Sampling time
Odour	EN 13725/AC:2006	6 in summer period* 6 distributed during rest of test period	30 – 120 minutes
Ammonia	ISO 7150/2, NIOSH6015, VDI 2461/1	4 in summer period 4 distributed during rest of test period	24 hours
Dust – PM 10	EN 15259: 2007 ISO: 23210 VDI: 2066-10 EN 13284	4 in summer period 4 distributed during rest of test period	24 hours
Dust PM 2.5	EN 15259: 2007 ISO: 23210 VDI: 2066-10 EN 13284	4 in summer period 4 distributed during rest of test period	24 hours
Total dust	EN 15259: 2007 ISO: 23210 VDI: 2066-10 EN 13284	4 in summer period 4 distributed during rest of test period	24 hours

* Summer period is here defined as: 15th of May to 30th of September.

Table 5. Secondary parameters and corresponding analytical methods.

Parameter	Analytical method	Number of samples	Sampling time
CO_2	Photoacoustic multigas analyzer/Kitagawa	8	Minimum 24 hours for multigas analyzer.
H_2S	Jerome 631-X^{TM}	48	30 minutes
CH_4	Photoacoustic multigas analyzer	8	Minimum 24 hours
N_2O	Photoacoustic multigas analyzer	8	Minimum 24 hours
Ventilation rate	Fan wheel anemometer	Continuous measurements in situ	
Temperature	VE10 - Temperature sensor	Continuous measurements in situ	
Relative humidity	VE14 universal input from VENG system combined with a humidity sensor.	Continuous measurements in situ	
Pressure loss	VE18P-3 from VENG system (electronic micro manemometer)	Continuous measurements in situ	
Noise	Brüel and Kjær modular precision sound analyzer type 2260. ISO 9001:2000	8	30 minutes
Electricity consumption	VE14 universal input from VENG system combined with a power meter	Continuous measurements in situ	
Water consumption	VE universal input from VENG system combined with a water meter	Continuous measurements in situ	
Waste water production	VE universal input from VENG system combined with a water meter	Continuous measurements in situ	
Conductivity of waste water	ISA 9001 conductivity controller and transmitter	Continuous measurements in situ	
pH of waste water	Alpha pH 2000W pH meter	Continuous measurements in situ	
Ammonium in waste water	See Appendix 4 – In house test methods	8	
Nitrite in waste water	See Appendix 4 – In house test methods	8	
Nitrate in waste water	See Appendix 4 – In house test methods	8	

Odour

The olfactometry method is used for measurement of odour. The olfactometry method is based on dilution of an odour sample to the odour threshold. The numerical value of the odour concentration is equal to the dilution factor that is necessary to reach the odour threshold. Its unit is the European odour unit, OU_E.

For every measuring day two air samples are collected; one in the air inlet of the air cleaner and one in the air outlet of the air cleaner. The air samples are collected in Tedlar/Nalophan bags of 30 litres and transported directly to an authorized and accredited laboratory for Agriculture samples, Eurofins Danmark A/S, where they are analysed into the following day within 24 hours from the time of collection.

Collection of air samples and determination of odour concentration by olfactometry are made in agreement with the requirements of Danish Standard. Sampling time has to be 30-120 minutes. The air intake shall be up to 0.5 litres of air per minute. The air samples are collected between 10AM and 02PM. The tubes use to collect the samples are 8 mm made of Teflon.

Ammonia
Ammonia was measured using the Impinger method. A fraction of the exhaust air was continuously drawn through a pair of impingers (0.5 L each) containing a strong acid solution (sulphuric acid, 0.005 to 0.2 M) and connected in series. When the air cleaner was running on maximum airflow the air stream to the impingers is drawn at a fixed flow rate, which is controlled by a critical orifice (usually 1 L min^{-1}). When the air flow through the air cleaner was varying a controller adjusts the flow of air trough the impingers proportional to the flow rate through the air cleaner.

NH_3 was trapped by the acid and accumulates in the bottles until they were replaced depending on the measurement time. Fluctuations in the NH_3 concentration of the sampled air are thus time-averaged. The values of the sampling flow rate and sulphuric acid concentration were chosen so that the second impinger, which serves as a control, does not contain more than 5% of the amount of NH_3 trapped in the first impinger.

All sampling tubes are made of Teflon, insulated, and heated with a coil of resistance wire to approximately 20°C higher than ambient to prevent condensation of water and subsequent adsorption of NH_3.

Finally, the NH_3 concentration of the air was calculated from the nitrogen content of the acid solution in the bottles, which was determined using a spectrophotometer or a Hach Lange test kit, and the given air sampling flow rate. The impinger method is mainly used for measuring scrubber efficiencies for NH_3 removal, as it can deal more easily with the water-saturated air from the scrubber outlet [2].

Detection limit of the impinge method is 0.000003 mg/m³ (0.003 µg/m^3), and uncertainty is around 15% RSD.

Dust (PM10, PM 2.5 and total dust)
European standards for measurements of dust are available. For PM 10: DS/EN 12341:1999 and EN 481:1994. For PM 2.5: DS/EN 14907:2005. These standards are, however, developed for outdoor sampling. Standards for indoor sampling in a dusty environment still have to be evaluated on a national scale.

In this test the European Standard method for determining the PM 2.5 mass concentration of suspended particulate matter in ambient air will be used. Particulate matter is collected on filters and weighed. Measurements are made over a sampling period of about 24 hours, and expressed in µg/m^3, where the volume of air is the volume at ambient conditions near the inlet at the time of sampling.

For the dust measuring a TCR Tecora Multistage Stack Impactor for PM 10, PM 2.5 and total dust, model MSSI, is used. This equipment is ISO 9001 certified and are in compliance with: ISO: 23210, VDI: 2066-10 and EN 13284-1

The results for PM10, PM2.5 and total dust are calculated as the difference in mass between the loaded and unloaded filter, divided by the sample volume, determined as the flow rate multiple by the sampling time.

$$C = \frac{m(l) - m(u)}{F \times t}$$

Where C is the concentration, in µg/m^3;
$m(l)$ is the loaded filter mass, in µg;
$m(u)$ is the unloaded filter mass, in µg;
F is the volume flow rate at ambient air conditions, in m^3/h;
t is the sampling time, in h.

General
The two-stage impactor for the determination of PM_{10} and $PM_{2.5}$ concentrations in flue gas described in this document divides the particles into the following three fractions:

a) particles with aerodynamic diameters greater than 10 µm (first impactor stage);
b) particles with aerodynamic diameters between 10 µm and 2.5 µm (second impactor stage);
c) particles with aerodynamic diameters smaller than 2.5 µm (backup filter).

The PM2.5 mass is fraction c) and the PM10 mass is the sum of the fractions b) and c). The fraction with aerodynamic diameters greater than 10 µm was not used for the PM10 and PM2.5 data evaluation.

4.4 Analytical performance requirements

In table 6 the limits of detection and in some cases the uncertainty of the analytical methods are presented.

Table 6. Limits of detection for the analytical methods used.

Parameter	Analytical method	Limit of detection	Uncertainty
Odour	EN 13725/AC:2006	100 OU/m^3	---
Ammonia	ISO 7150/2	0.000003 mg/m^3	15 % RSD
Dust – PM 10	EN 15259: 2007 ISO: 23210 VDI: 2066-10 EN 13284	1,8-2.5 µg/m^3	5 % RDS
Dust PM 2.5	EN 15259: 2007 ISO: 23210 VDI: 2066-10 EN 13284	1,8-2.5 µg/m^3	5 % RDS
Total dust	EN 15259: 2007 ISO: 23210 VDI: 2066-10 EN 13284	1,8-2.5 µg/m^3	5 % RDS
CO_2	Photoacoustic multigas analyzer	1.5 mg/m^3	6 %
H_2S	Jerome 631-X^{TM}	0.003 ppm	5 % RSD
CH_4	Photoacoustic multigas analyzer	0.4 mg/m^3	6 %
N_2O	Photoacoustic multigas analyzer	0.03 mg/m^3	6 %
Ventilation rate	Fan wheel anemometer	500 m^3/h	5 %
Temperature	VE10 - Temperature	0.05 °C	0.2 °C

	sensor		
Relative humidity	VE14 universal input from VENG system combined with a humidity sensor.	1 % RH	10 %
Pressure loss	VE18P-3 from VENG system (electronic micro manemometer)	1 Pa	4 %
Noise	Brüel and Kjær modular precision sound analyzer type 2260. ISO 9001:2000	+-1.5dB	10 %
Electricity consumption	VE14 universal input from VENG system combined with a power meter	10 W	---
Water consumption	VE universal input from VENG system combined with a water meter	1 L	---
Waste water production	VE universal input from VENG system combined with a water meter	10 L	---
Conductivity of waste water	ISA 9001 conductivity controller and transmitter	0,01 mS	---
pH of waste water	Alpha pH 2000W pH meter	0,01	---
Ammonium in waste water	See Appendix 4 – In house test methods	0.015 -2 mg/l NH_4-N or 0.02 -2.5 mg/l NH_4	6 %
Nitrite in waste water	See Appendix 4 – In house test methods	0.6-6 mg/l NO_2-N or 2-20 mg/l NO_2	7 %
Nitrate in waste water	See Appendix 4 – In house test methods	5-35 mg/l NO_3-N or 22-155 mg/l NO_3	7 %

Note: RSD: Relative standard deviation.

4.5 Preservation and storage of samples

Odour
The air samples for olfactometric analysis were collected in Tedlar/Nalophan bags of 30 litres and marked with a unique bar cose, date of collection and initials of the person who collected the sample. The samples were packed in an opaque cage and transported directly to an authorized and accredited laboratory for olfactometric analysis, Eurofins Danmark A/S. Here the samples were analysed the following day and within 24 hours from the time of collection.

Ammonia
As the impinger method was used the sample had to be analyzed as soon as possible after sampling (within 3 hours). The sample should be less than 4 °C until analysis. A representative part of the sample should be kept as a backup in the freezer minimum one year.

Dust (PM 10 and PM 2.5)
The fibre plane filters had to be conditioned before and after the sampling for 48 hours under an atmosphere of 50 % humidity and 20°C temperature before weighed in a climate chamber.

5 DATA MANAGEMENT

Data management including filing and archiving procedures are described in the AgroTech Test Centre Quality Manual.

5.1 Data storage, transfer and control

Some data were collected and written down at the test site. In Appendix 6 of the test plan there is a collection of data recording sheets that were used for registration of data at the test site.

Some data were collected by electronic means at the test site and sent via internet to a PC in the AgroTech main office.

Results from external laboratories were sent electronically by email or in paper version by mail.

Table 7. Data compilation and storage summary.

Data type	Data media	Data recorder	Data record timing	Data storage
Test plan and test report	Protected pdf-files.	Test responsible	When approved	Files and archives at AgroTech
Data manually recorded at test site	Data recording forms	Technicia, AgroTech	During collection	Files and archives at AgroTech
Calculations	Excel files	Test responsible, AgroTech	During calculation	Files and archives at AgroTech
Analytical reports	Paper / pdf-files	Test responsible, AgroTech	When received	Files and archives at AgroTech

6 QUALITY ASSURANCE

The test followed the AgroTech Test Centre Quality Manual, which is ISO 9001 compliant, but not certified.

6.1 Test plan review

The test plan was subject to internal review by the verification responsible from AgroTech verifications.

External review of the test plan was done by the technical expert assigned to this verification.

6.2 Performance control – reference analysis

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 of the filter. The ammonia concentration was verified with INNOVA 1412, photoacoustic gas detector and Kitagawa Test Tubes.

6.3 Test system control

The stability of the test equipment was controlled continuously by supervision and recording of data. Procedures for ensuring that test facilities and equipment were calibrated and fit for the purposes are described in the Quality Manual for the Laboratories of AgroTech. These procedures are subject to internal audits from the AgroTech Management.

6.4 Data integrity check procedures

All transfer of data from printed media to digital form and between digital media were checked by spot check undertaken by test responsible. If errors were found in a spot check, all data transfer from the specific data collection had to be checked. In this test no errors were found during spot checks.

6.5 Test system audits

Internal audits from AgroTech were done following the procedure described in the AgroTech Test Centre Quality Manual.

6.6 Test report review

The test report was subject to internal review by the verification responsible from AgroTech verifications.

External review of the test report was done by the technical expert assigned to this verification as part of the review of the verification report. The verification report includes the full test report as an appendix.

7 TEST REPORT

The test report follows the template of the AgroTech Test Centre Quality Manual and is included as an appendix to the verification report.

7.1 Test site report

No specific test site report was made since it was not judged necessary to make this report. At the test site data were collected and registered on data reporting forms. Templates for data reporting forms were included in the test plan as Appendix 6.

7.2 Test data report

No specific test data report was made since it was not judged necessary to make this report. All data recorded during the test including results from external analytical laboratories were gathered and archived according to the AgroTech Test Centre Quality Manual.

7.3 Amendment report

In this test report there is a section on amendments to and deviations from the test plan. This section compiles all changes of the test plan occurring before testing with justification of deviations and evaluation of any consequences for the test data quality.

7.4 Deviations report

In the test report there is a section on amendments to and deviations from the test plan. This section compiles all changes of the test plan occurring during testing with justification of deviations and evaluation of any consequences for the test data quality.

8 TEST RESULTS

8.1 Test performance summary

The data recorded during the test have been subject to the following statistical modelling.

The measurements at inlet and outlet are logarithm transformed to ensure that the data are Gaussian distributed. There is performed standard model control of the assumption, that the log-transformed data are Gaussian distributed.

All estimates and tests are made on the log-transformed scale. The estimates shown are however transformed back to the original scale after calculations of means and confidence intervals.

For the inlet and outlet measurements, standard confidence intervals are calculated. For the reduction the hypothesis of zero reduction is tested by the Studen's T-test, and the resulting confidence interval for the sample mean is used.

8.2 Test measurement summary

In the 6 tables below the test measurements are summarized.

Table 8. 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 9. 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 10. 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

* Summer measurements are BDL and reduction is only appreciate in winter, therefore only winter values are considered here.

Table 11. 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 12. 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

Table 13. Results of consumption and pressure loss, estimated sample means. Comsumption og 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

8.3 Test quality assurance

A mass balance for nitrogen has been calculated 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 14a. 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 14b. 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 14c. 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 %.

8.4 Amendments to and deviations from test plan

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.

A P P E N D I X 1

Terms and definitions used in the test plan

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

References

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A P P E N D I X 3

References methods

The reference methods are presented in section 4 Reference analysis.

A P P E N D I X 4

In-house test methods

Test methods are described in section 3.2 Tests.

A P P E N D I X 5

In-house analytical methods

In the following detailed specifications (work instructions) are given for the in-house analytical methods relevant for the Dorset Biological Combi-Aircleaner.

Method for measuring nitrate in impinge bottles and wastewater with Hach Lange test kit

Principe: Nitrate ions in sulfur-/fosfor acid solution, react with 2.6-dimethylphenol, forming 4-nitro-2.6-dimethylphenol.
Apparatus: Spectrophotometer: Hach Lange DR 3800 sc VIS
Equipment: Hach Lange Test Kit for analysis of nitrate
Finnpipette 100 1000µl
Stopwatch
Preparation glass with stopper
Div Glassware
Chemicals: Sulfamic acid
Storage: The sample must be analyzed as soon as possible after sampling, preferably within 3 hours. The sample must be storage under 4 degrees Celsius until analysis. In case an analysis within 3 hours was not possible the samples must be frozen.
Neutralization: There may be necessary to neutralize acidic samples, because color is only accurate at pH 3-10. This will typically be the case if samples from detergent bottles. These will be highly acidic and can be neutralized with a weak alkaline solution.
Dilution: If the concentration in samples exceeding the assay measuring range may be necessary to dilute samples before analysis.
Interferences: High levels of oxide substances (COD) will be the color reagent and thereby lead to falsely elevated analysis. The test can be used only on samples with a COD content of less than 500mg / L. Any doubt should always be made plausibility's control of the analytical result in terms of dilution and / or recovery control.
Nitrite concentrations above 2.0 mg / L gives falsely elevated results. This interference can be eliminated by adding sulfamin acid to the sample.
High chloride concentrations can, through sulfur sulfate, precipitated with silver chloride.
High concentrations of calcium can form turbidity that may interfere with test results. This can prevent by addition of ethylene diamine tetra-acetic acid (EDTA) to the sample. Please note that the presence of certain ions in high concentrations can have an interference effect on the analytical result. For detailed list of examined interferences, see the accompanying data sheet.

Analysis: Before a Test Kit into use, it is necessary to check the expiration date is stamped on the box is not exceeded.
• Take 200µl neutralized and diluted sample to very carefully add the test tube.
• Then add carefully 1000µl solution A (2,6-dimethylphenol). It is very important to the addition of the sample solution which is very conservative, since there should be mixed before all reagents are added. If mixing premature analysis would be too low.
• Screw the lid on and mix a few times by turning the test tube until all precipitate is dissolved.
• NOTE: The test tube becomes very hot when the reagents are mixed, hold only at the stopper.
• The reaction should then proceed for 15 min.
• after reaction provides content that NO_3-N directly in the spectrophotometer using the predictive method.
Note that the analysis be performed at a temperature in samples of between 20 and 24

º C, the temperature differs greatly from this can mean incorrect analysis.

Data: Did the sample be diluted or neutralized this must be included in the final calculation of the result.
Safety: When working with Hach Lange Test Kit used gloves and coat. Work in fume hood or with adequate suction points.
Used tubes assembled in the original package and sent back to Hach Lange in appropriate labeled boxes. Hazard label for transport is included when purchasing the test kit.

Ætsende

Cuvette containing 60% sulfuric acid, 33% phosphor acid
R-phrases:
R10 Flammable
R35 Causes severe burns

S-phrases:
S26 of contact with eyes, rinse immediately with water and seek medical advice
S35 This material and its container must be disposed of in a safe manner.
S37/39 Wear suitable gloves and eye / face work

Method for measuring nitrite in impinge bottles and wastewater with Hach Lange test kit

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Principle: Nitrite reacts in acid solution with aromatic amines to form a diazonium salts. The salt reacts with aromatic compounds containing an amino group or hydroxyl group by formation of the color complex.
Apparatus: Spectrophotometer: Hach Lange DR 3800 sc VIS
Equipment: Hach Lange Test Kit for analysis of nitrate
Finnpipette 100 1000µl
Stopwatch
Preparation glass with stopper
Div Glassware
Chemicals: Sulfamic acid
Storage: The sample must be analyzed as soon as possible after sampling, preferably within 3 hours. The sample must be storage under 4 degrees Celsius until analysis. In case an analysis within 3 hours was not possible the samples must be frozen.
Neutralization: There may be necessary to neutralize acidic samples, because color is only accurate at pH 3-10. This will typically be the case if samples from detergent bottles. These will be highly acidic and can be neutralized with a weak alkaline solution.
Dilution: If the concentration in samples exceeding the assay measuring range may be necessary to dilute samples before analysis.
Interferences: Chromium (VI) ions interfere in the measurement.
Copper (II) ions interfere at a concentration lower than 1mg / L. I doubt should always be made plausibility's control of the analytical result in terms of dilution and / or recovery control.
Please note that the presence of certain ions in high concentrations can also have an interference effect on the analytical result. For detailed list of examined interferences,

see the accompanying data sheet.
Analysis: Before a Test Kit into use, it is necessary to check the expiration date is stamped on the box is not exceeded.
• Protective film over the lyophilized reagent in DosiCap lid removed, after which the lid screwed by.
• Take 200µl neutralized and diluted sample to the test tube.
• Then turn DosiCap lid and tightened so that the lyophilized reagent is now turning into the test tube.
• Test tube is shaken vigorously to ensure that all freeze-dried reagent is dissolved.
• The reaction should then proceed for 10 min.
• After reaction provides content to NO2-N directly in the spectrophotometer using the predictive method.
Note that the analysis be performed at a temperature in samples of between 15 and 25 º C, the temperature differs greatly from this can mean incorrect analysis.
Data: Did the sample be diluted or neutralized this must be included in the final calculation of the result.
Safety: When working with Hach Lange Test Kit used gloves and coat. Work in fume hood or with adequate suction points. When working at suction points are worn safety glasses.
Used tubes assembled in the original package and sent back to Hach Lange in appropriate labeled boxes. Hazard label for transport is included when purchasing the test kit.

DosiCap contains: 1-naphthylamine-sulfuric acid salt
R-phrases: R36/37/38 Irritating to eyes, respiratory system and skin.
S-phrases: S24/25 Avoid contact with skin and eyes.

Method for measuring ammonium in impinge bottles and waste water with Hach Lange test kit

This method of analysis follows the same chemical principles as ISO 7150-1, 1984, and can be applied to both wash water as sewage. Because the assay reaction is dependent on Ph, may be necessary to neutralize the sample before analysis, especially for the washing of water with low pH.
Principle: Ammonium ions react at pH 12.6 with hypochlorite ions and salicylate ions in the presence of sodium nitro preside as a catalyst, thereby forming indophenol blue
Apparatus: Spectrophotometer: Hach Lange DR 3800 sc VIS
Equipment: Hach Lange Test Kit for analysis of ammonium
Finnpipette 5000µl
Stopwatch
Preparation glass with stopper
Div glassware

Neutralization: There may be necessary to neutralize acidic samples, because color is only accurate at pH 4-9. This will typically be the case if samples from detergent bottles. These will be highly acidic and can be neutralized with a weak alkaline solution.
Dilution: If the concentration in samples exceeding the assay measuring range may be necessary to dilute samples before analysis.
Interferences: A very high levels of ammonia could lead to results which are within the range. Is there a suspicion of this should be a dilution of the sample. I doubt should always be made plausibility's control of the analytical result in terms of dilution and / or recovery control.
Please note that the presence of certain ions in high concentrations can have an interference effect on the analytical result. For detailed list of examined interferences, see the accompanying data sheet.
Analysis: Before a Test Kit into use, it is necessary to check the expiration date is stamped on the box is not exceeded.
• Protective film over the lyophilized reagent in DosiCap lid removed, after which the lid screwed by.
• Take 5000µl neutralized and diluted sample to the test tube.
• Then turn DosiCap lid and tightened so that the lyophilized reagent is now turning into the test tube.
• Test tube is shaken vigorously to ensure that all freeze-dried reagent is dissolved.
• The reaction should then proceed for 15 min, color remains stable for another 15 min.
• After reaction provides content to NH4-N directly in the spectrophotometer using the predictive method.
Note that the analysis be performed at a temperature in samples of approx. 20 º C, the temperature differs greatly from this it may mean incorrect analysis.
Data: Did the sample be diluted or neutralized this must be included in the final calculation of the result.
Storage: Before use, Hach Lange Test Kit refrigerates. The sample must be analyzed as soon as possible after sampling, preferably within 3 hours. The sample must be storage under 4 degrees Celsius until analysis. In case an analysis within 3 hours was not possible the samples must be frozen.
Safety: When working with Hach Lange Test Kit used gloves and coat. Work in fume hood or with adequate suction point.
Used tubes assembled in the original package and sent back to Hach Lange in appropriate labeled boxes. Hazard label for transport is included when purchasing the test kit.

Cuvette contains: Sodium hydroxide
DosiCap contains: Sodium nitro preside, Troclosen Sodium

R-phrases:

- R22 Harmful if swallowed
- R31 liberates toxic gas on contact with acid
- R36/37/38 Irritating to eyes, respiratory system and skin
- R51/53 Toxic to organisms living in water, can cause long term adverse effects on the aquatic environment.

S-phrases:

- S7 Keep container tightly closed
- S16 Keep away from sources of ignition - No smoking
- S26 of contact with eyes, rinse immediately with water and seek medical advice
- S37/39 Wear suitable gloves and eye / face work
  S45 In case of accident or illness are urgently needed medical care show the label where possible.

A P P E N D I X 6

Test data report

Table A1. Primary and secondary data from different sample days.

Primary parameters	09-07-2009	16-07-2009	23-07-2009	30-07-2009
Odour (OUe/s 1000kg)				
Inlet	1004	990	402	623
Outlet	763	689	153	386
Odour (OU m^{-3})				
Inlet	2500	2300	1000	2100
Outlet	1900	1600	380	1300
Ammonia (mg/m^3)				
Inlet	5.1	5.1	-	-
Outlet	2.7	2.7		
Dust ($\mu g/m^3$)			-	-
Inlet PM 2.5	BDL	BDL	-	-
Outlet PM 2.5	BDL	BDL	-	-
Inlet PM 10	97	128	-	-
Outlet PM 10	71	53	-	-
Inlet Total dust	181	246		
Outlet Total dust	96	72		
Secondary parameters				
Hydrogen sulfide (mg/m3)				
Inlet	0	0	-	-
Outlet	0	0	-	-
Carbon dioxide (mg/m^3)				
Inlet	1979	1439	2159	1979
Outlet	1799	1439	2159	1979
Specific ventilation rate[1] (m^3/h)	20200	17212	20602	28129
Ventilation rate (m^3/h) daily mean	15600	13100	11900	11400
Environment temperature (°C)	19.5	24.93	21.27	20
Temperature, daily mean (°C)				
Inlet	19.4	23.0	21.5	21.3
Outlet	15.2	18.3	19.2	18.1
Relative humidity (%)	65	66	78.14	80
Inlet	65	66	78.14	80
Outlet	99	99	99	99
Pressure loss (Pa) daily mean	33	26	21	16
Noise (dB)	60	56		
Electricity consumption (kWh/d)	67	61	55	50.5
Water consumption (L/d)			858	918
Waste water production (L/d)	310	330	490	480
Characteristics of discharge liquid from the air cleaner				
Conductivity (mS/cm)	13.9	13.9	14	14
pH	8.0	7.7	7.5	7.5
Ammonium (NH_4-N mg/L)	1200	1259		
Nitrite (NO_2-N mg/L)	1120	422		
Nitrate (NO_3-N mg/L)	355	875		
Log book				
Number of animals	259	259	259	259
Animals incorporation	27-05-2009	27-05-2009	27-05-2009	27-05-2009
Average weight (kg)	50	50	55	60
Comments		Slurry channel emptied 14/07/09		

[1] Ventilation rate through the air cleaner when odour samples were done. When max. ventilation is necessary (>26.000 m3/h) the air cleaner is supplied with diffuse ventilation from Skov A/S. Dust and ammonium are measured during 24 hours.

Table A2 Primary and secondary data from different sample days.

Date	06-08-2009	13-08-2009	20-08-2009	27-08-2009
Odour (OUe/s 1000kg)				
Inlet	2542	918	339	350
Outlet	359	667	363	95
Odour (OU m^{-3})				
Inlet	8500	3300	1400	1700
Outlet	1200	2400	1500	460
Ammonia (mg/m^3)				
Inlet	4.3	-	3.1	-
Outlet	1.6	-	0.7	-
Dust (µg/m^3)				
Inlet PM 2.5	-	-	2.2	-
Outlet PM 2.5	-	-	2.1	-
Inlet PM 10	29	-	72	-
Outlet PM 10	2	-	26	-
Inlet Total dust	37		126	
Outlet Total dust	3		34	
Hydrogen sulfide (mg/m3)				
Inlet	0	-	0	-
Outlet	0	-	0	-
Carbon dioxide (mg/m^3)				
Inlet	1799	1799	-	-
Outlet	1799	1799	-	-
Specific ventilation rate[1] (m^3/h)	19.357	20.579	19.041	20.452
Ventilation rate (m^3/h) daily mean	18900	12100	17900	
Environment temperature (°C)	24.40	19	23.99	22.56
Temperature (°C)				
Inlet	23.6	19.7	23.3	22.8
Outlet	19	16.8	19.4	18.6
Relative humidity (%)				
Inlet	51.5	80	50	70
Outlet	99	99	99	99
Pressure loss (Pa) daily mean	43	21.7	42	
Noise (dB)	59		62	
Electricity consumption (kWh/d)	79	51	84	
Water consumption (L/d)	1828	1608	1650	
Waste water production (L/d)	560	1070	360	
Characteristic of discharge liquid from the air cleaner				
Conductivity (mS/cm)	14	14	14	
pH	7.4	7.5	7.2	
Ammonium	1404		1334	
Nitrite	432		466	
Nitrate	1057		976	
Log book				
Number of animals	259	257	257	257
Animals incorporation	27-05-2009	27-05-2009	27-05-2009	27-05-2009
Average weight (kg)	70	80	85	110
Comments	Slurry channel empty 31/07/09	Slurry channel empty 7/08/09		

Table A3. Primary and secondary data from different sample days.

Date	23-09-09	01-10-09	22-10-09	01-12-09	10-12-09
Odour (OUe/s 1000kg)					
Inlet	220	340	239	165	113
Outlet	68	259	284	130	177
Odour (OU m^{-3})					
Inlet	580	2100	1600	1400	1400
Outlet	180	1600	1900	1100	2200
Ammonia (mg/m^3)					
Inlet	-	7.8	7.8	15.3	15.3
Outlet	-	2.5	2.5	1.3	1.3
Dust (µg/m^3)					
Inlet PM 2.5	-	134	25.8	-	
Outlet PM 2.5	-	6.6	5.8	-	
Inlet PM 10	-	262	86	-	49
Outlet PM 10	-	84	44	-	30
Inlet Total dust		369	150	-	70
Outlet Total dust		161	64	-	48
Hydrogen sulphide (mg/m^3)					
Inlet	-	0	0	0	0
Outlet	-	0.149	0.129	0.037	0.024
Nitrous oxide mg/m^3					
Inlet				0.44	
Outlet				1.35	
Carbon dioxide (mg/m^3)					
Inlet	-	3058	-	3238	-
Outlet	-	3058	-	3238	-
Specific ventilation rate[1] (m^3/h)	13988	6708	8244	5167	7105
Ventilation rate (m^3/h) daily mean	9500	6380	8250	5200	6740
Environment temperature (°C)	16	11.25	8.5	-1.6	7.38
Temperature inlet (°C)					
Inlet	18.0	16.9	16.9	14.5	16.4
Outlet	15.2	14.3	14.6	13.4	15.7
Relative humidity (%)					
Inlet	-	88.9	94.2	76	94.7
Outlet		99	99	99	99
Pressure loss (Pa) daily mean	13	5	10.1	4.1	6.8
Noise (dB)		52	64	62	60
Electricity consumption (kWh/d)	50.5	57	64	44	
Water consumption (L/d)	778	820	1047	808	1286
Waste water production (L/d)	300	470	530	470	700
Characteristic of discharge liquid from the air cleaner					
Conductivity (mS/cm)	14	14	14	14	14
pH	7.15	7.38	8.0	7.8	7.9
Ammonium		1494		1389	1443
Nitrite		355		838	711
Nitrate		957		890	927
Number of animals	255	235	235	235	235
Animals incorporation	18-09-2009	18-09-2009	18-09-2009	18-09-2009	18-09-2009
Average weight (kg)	40	45	60	105	110
Comments	Slurry channel empty 18/10/09			Slurry channel empty 26/11/09	

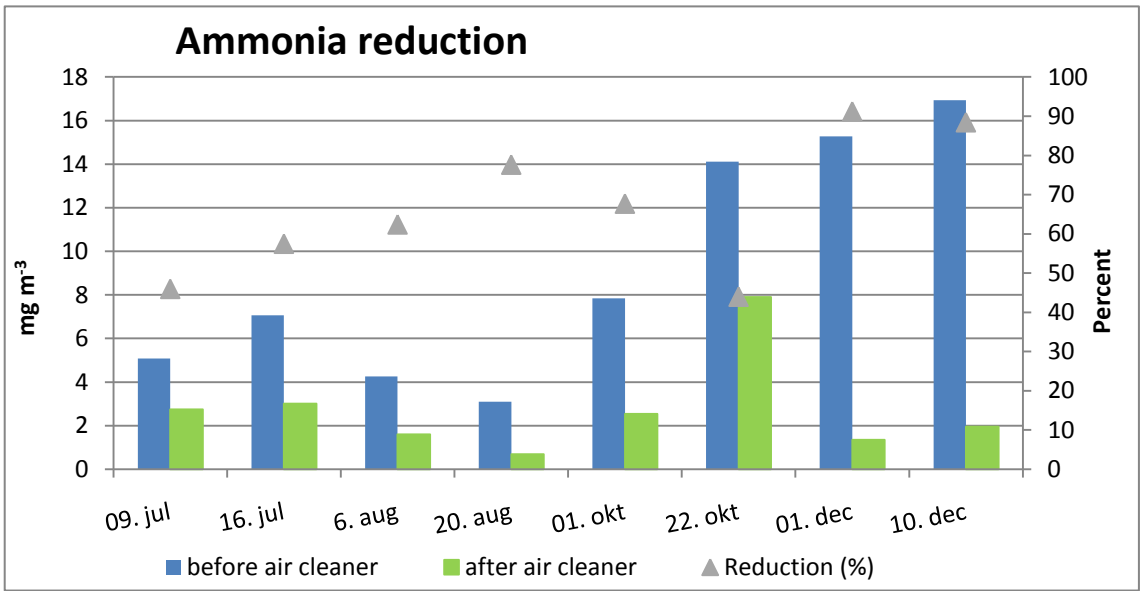

Figure A1 Concentration of ammonia before and after the air cleaner and reduction in %

As expected the ammonia reduction is higher in the winter period than in the summer period where ventilation is running at higher ventilation rates.

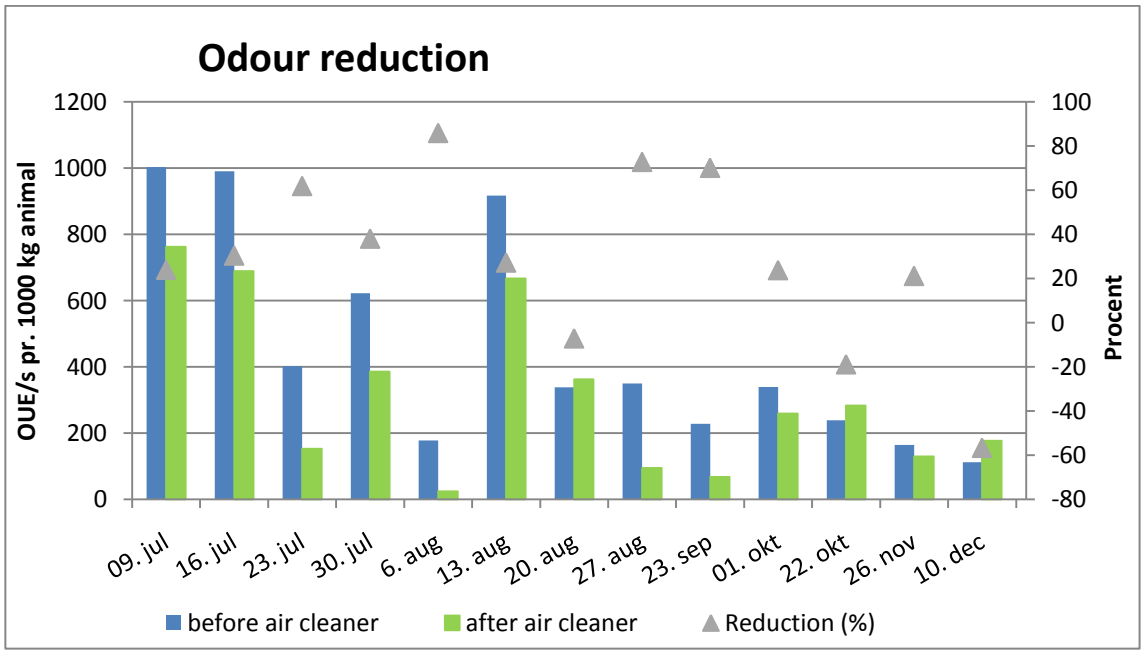

Figure A2 Concentration of odour before and after the air cleaner and reduction in %

During the test period there has been a stable reduction of odour due to the air cleaner. However, there are exceptions: One in October and one in December, where the odour concentration was higher before the air cleaner.

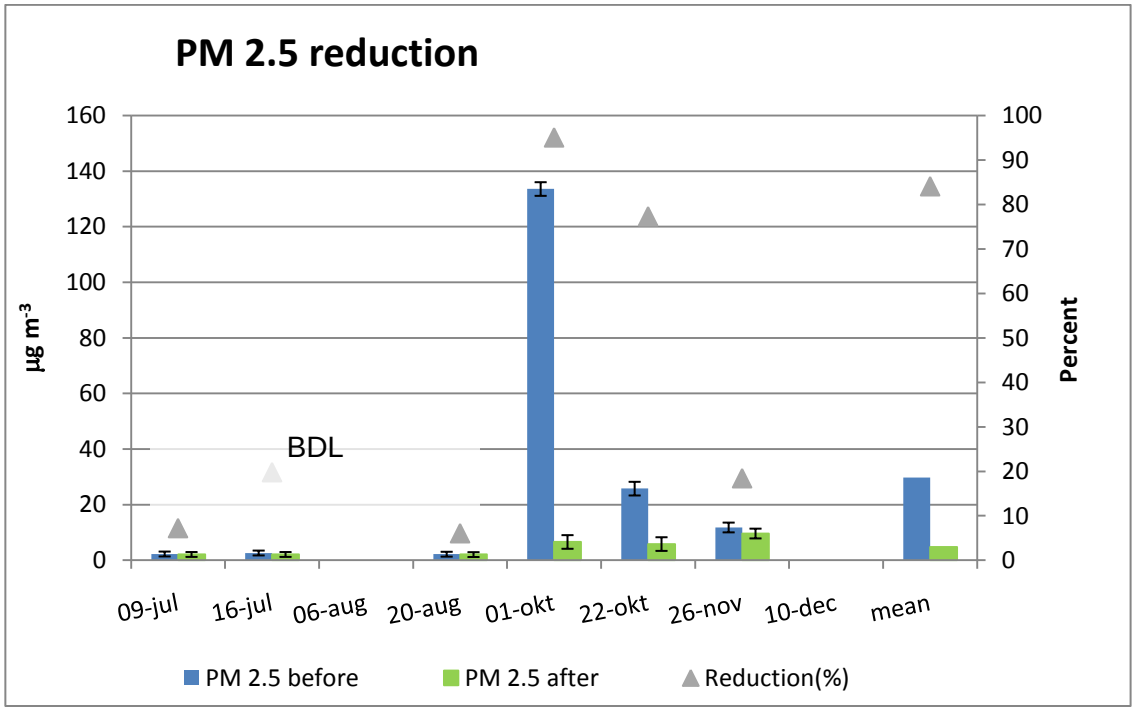

Figure A3 Concentration of PM2.5 before and after the air cleaner and reduction in %

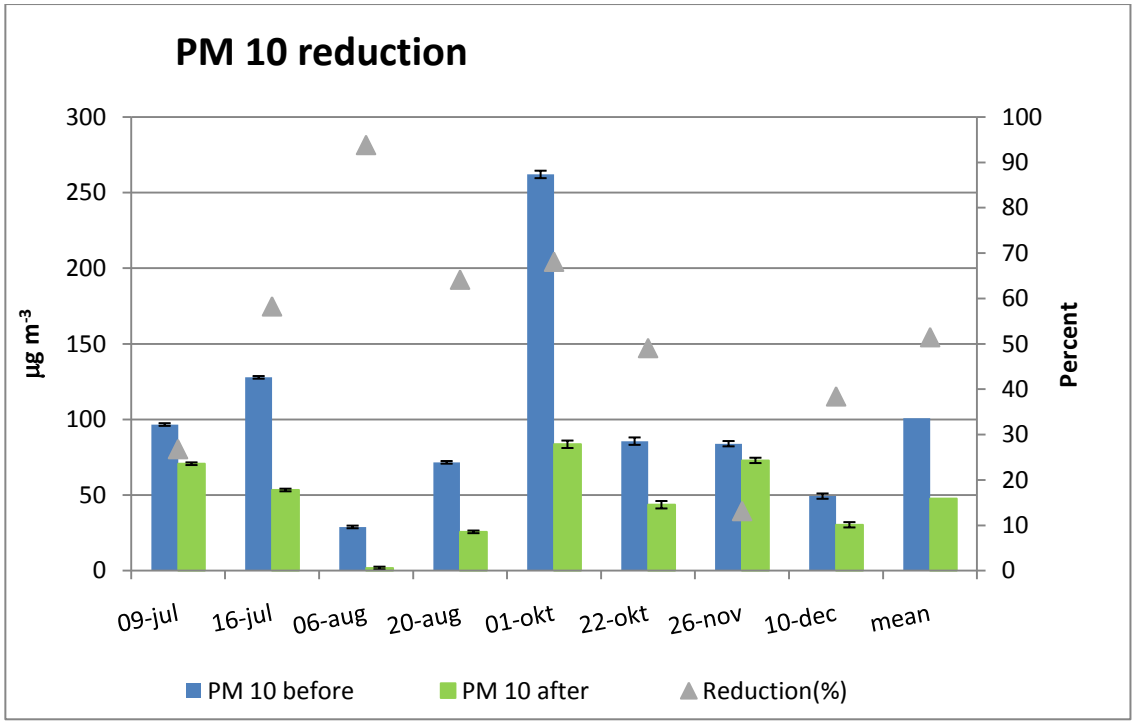

Figure A4 Concentration of PM10 before and after the air cleaner and reduction in %

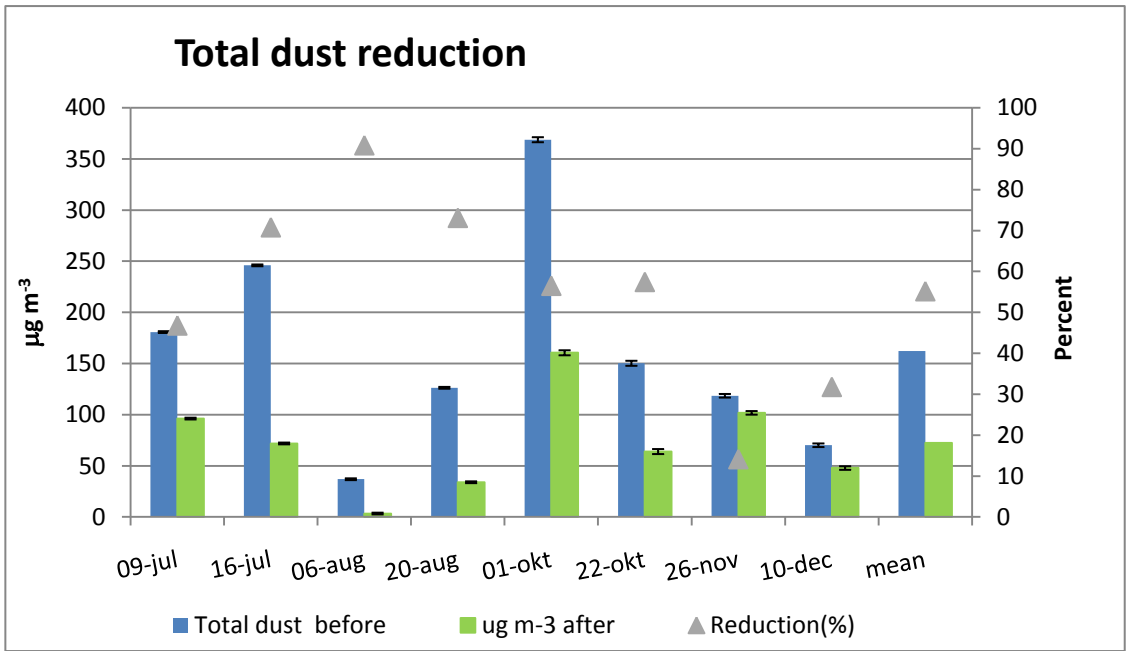

Figure A5 Concentration of total dust before and after the air cleaner and reduction in %

During the test period a significant dust reduction has been measured. The sample from the 6 th of Agust and the 10th of December could not be reported for PM 2.5 since the filters were broken.

A P P E N D I X 7

Amendment and deviation reports for test

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.